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**Handbook of Activation Data Calculated  
Using EASY-2007**

R.A. Forrest, A. Tabasso, C Danani, S Jakhar, A.K. Shaw

March 2009

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EURATOM/UKAEA Fusion Association  
Culham Science Centre  
Abingdon  
Oxfordshire  
OX14 3DB  
United Kingdom

Telephone: +44 1235 466433  
Fax: +44 1235 466435

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**R. A. Forrest<sup>1</sup>, A. Tabasso<sup>1</sup>, C. Danani<sup>2</sup>,  
S. Jakhar<sup>2</sup> and A. K. Shaw<sup>2</sup>**

<sup>1</sup> EURATOM/UKAEA Fusion Association, Culham Science  
Centre, Abingdon, Oxfordshire, OX14 3DB, UK.

<sup>2</sup> Institute for Plasma Research, Near Indira Bridge, Bhat,  
Gandhinagar, Gujarat-382428, India.

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# 1 INTRODUCTION

Investigation of the properties of current fusion devices such as JET, planned ones such as ITER, and conceptual power plants such as PPCS, have indicated the need for tools to predict the activation of materials. Considerable effort within the European Fusion Programme has led to the production of the European Activation System (EASY) to provide such a capability. The current version, EASY-2007, consists of an extensive library of data (EAF-2007) including neutron-, proton and deuteron-induced cross sections; decay data and biological hazard coefficients; an inventory code (FISPACT-2007); a development tool (SAFEPAQ-II) used to produce the European Activation File (EAF); and extensive documentation. EASY-2007 is widely distributed and has been used to carry out activation calculations for a large number of materials. However, it was felt that there was also a need for a comprehensive handbook of activation data that could be referred to by materials specialists and designers without the need to run codes. The present report answers this need, and updates and extends the report [1] produced about five years ago with EASY-2003 and the two reports that were produced about eleven years ago [2,3]. Since then the activation field has matured with new versions of the EAF data and FISPACT code, which improve the accuracy of the predictions. The main extension to the data is the increase of the upper energy of the energy range from 20 to 60 MeV. The ‘importance diagrams’ that allow a neutron-spectrum-independent summary of the activation properties of a material to be given, have also been extended to this higher energy. Using these new tools the activation properties of all the naturally occurring elements from Hydrogen to Bismuth are presented.

## 2 EASY-2007

An overview of EASY-2007 is available [4], which describes the various parts that make up the package, and shows how they fit together. Each of these is briefly described below.

### 2.1 SAFEPAQ-II

SAFEPAQ-II is the software tool used for the maintenance and development of the EAF nuclear data library by UKAEA. Maintenance of the EAF library is a complex procedure: the cross section files need to be evaluated (including choosing which of several data sources to use and adjustment of data), processed (conversion to a common format), compiled into a library, validated (against experimental data and systematics), and documented. Similarly, the decay data files need to be compiled and documented, and all the subsidiary files required as input to the inventory code FISPACT need to be generated in a consistent manner.

Several radical decisions were made when SAFEPAQ-II was designed; these include the use of relational databases rather than text files to store the data and a user-friendly application written in Visual Basic, as well as the choice to run under Windows. Full details are given in the User manual [5].

### 2.2 EAF-2007

The EAF-2007 data library is the result of a considerable effort over the last twenty-one years by UKAEA and collaborators. The term EAF originally described only the neutron-induced cross section library, but is now used to cover all the nuclear data libraries required for inventory calculations. The libraries contained in EAF-2007 cover:

- Cross section data for neutron-induced reactions
- Cross section data for proton-induced reactions
- Cross section data for deuteron-induced reactions
- Uncertainty data for neutron-induced reactions
- Decay data
- Fission yield data
- Biological hazard data
- Legal transport data
- Clearance data
- Charged particle ranges in materials
- Emitted particle spectral data (from neutron-induced reactions)
- Charged particle cross section data
- Gamma absorption data

Further details on the various EAF libraries are available in the neutron-induced cross section report [6], the decay data report [7], and the biological hazard report [8], while summaries of the rest are given in the overview [4].

### **2.3 FISPACT-2007**

FISPACT is an inventory code that has been developed for neutron-induced activation calculations for materials in fusion devices. The current version is FISPACT-2007, which is the culmination of twenty-one years of development. It uses external libraries of nuclear data for all relevant nuclides to calculate the number of atoms of each species at a specified time, which can be during an irradiation or after a decay time following shutdown. The various species (nuclides) are formed either by a direct reaction on a starting material, via a series of reactions (some of which can be on radioactive targets), by a decay, by a series of decays, or via a combination of both reactions and decays. The accuracy of the calculated inventory is dependent on the quality of the input nuclear data, i.e. the cross sections and decay properties. The European Activation File (EAF), described above, is the recommended source of data.

The main items of information that must be supplied by the user are: composition and mass of the material to be irradiated, a description of the neutron spectrum, details of the irradiation, which may be either continuous or in a series of pulses, and, for the period following shutdown, a series of decay times at which inventories are required.

The many options available, and the description of the code words used, are fully explained in the FISPACT-2007 User manual [9]. This contains many examples of input, which illustrate how the user can construct input files for any particular type of run.



### 3 NEUTRON SPECTRA

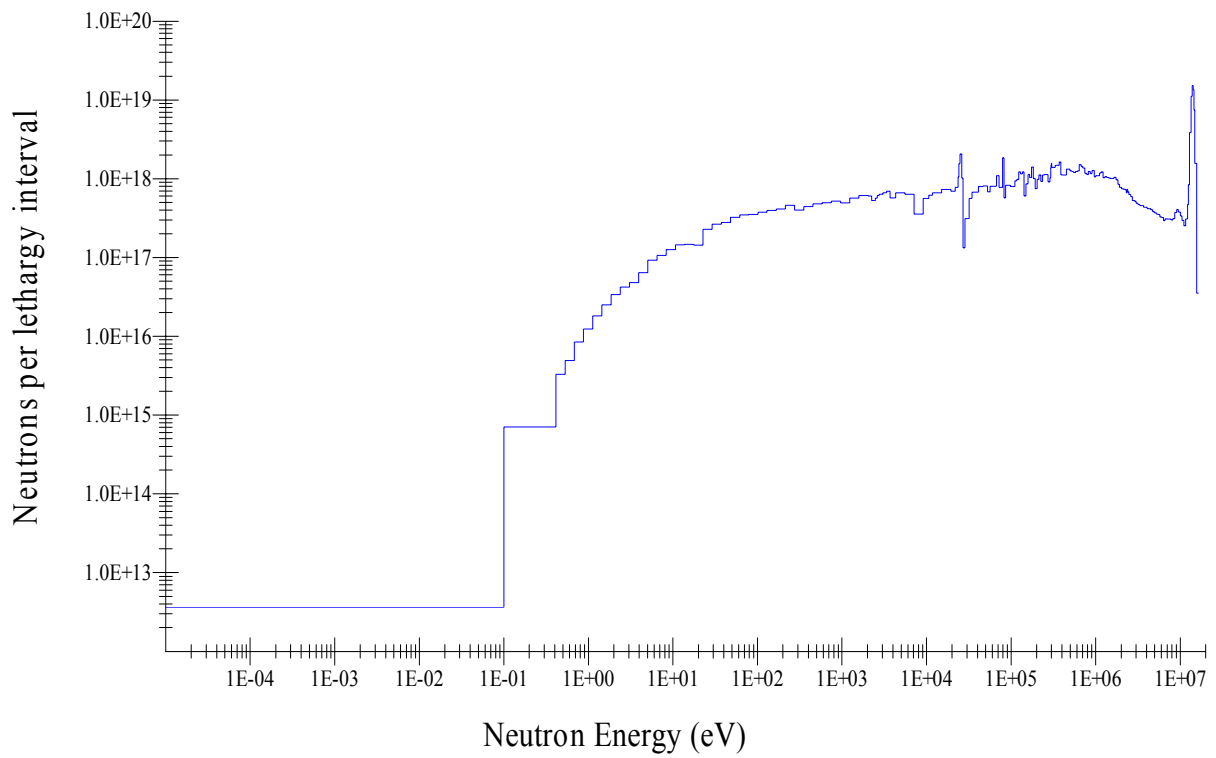
When performing calculations of material activation due to neutron irradiation in FISPACT, the user must supply a neutron spectrum for the incident particles. FISPACT combines this with cross section data in the appropriate group structure, which is determined by the form of the user-supplied spectrum, to produce a 1-group effective cross section library for all the reactions available in EAF. This library is then used directly to perform subsequent activation calculations [9].

In the calculations performed to produce the activation data presented in this handbook, various neutron spectra are used. In the case of the importance diagrams (see 4.5 for a full description), a special set of spectra are used. Each spectrum has neutrons in a single energy group covering the range of energies for the 211-group structure. It is unnecessary to use 211 spectra in practical calculations; fifty are used with the responses of the missing energies determined by interpolation. Seven of these spectrum files are also used to produce the seven columns of pathway data, as discussed in 4.3.

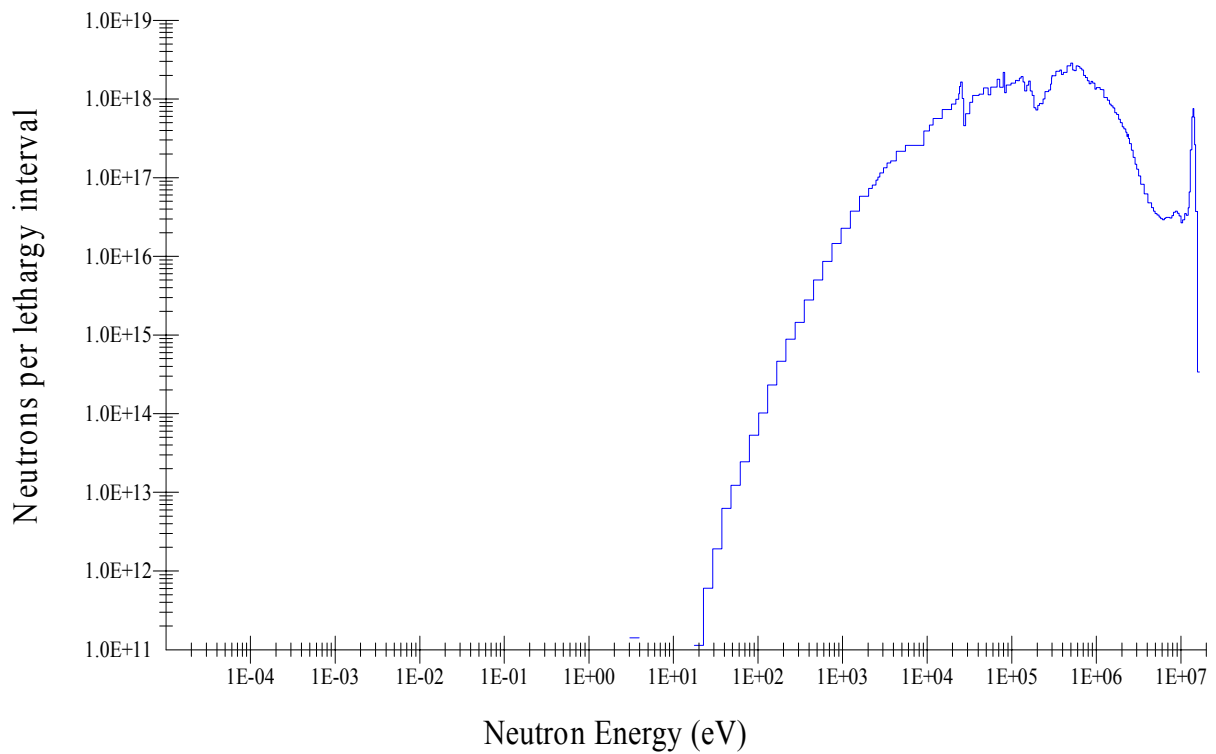
The remaining activation calculations are carried out with one of five neutron spectra appropriate to fusion research. Three are taken from the recent PPCS study on fusion power plant design studies [10,11,12]. The spectra were calculated for three regions of the plant models which use various materials for the structure, tritium generation and coolant. The most technologically relevant design was used for each region, thus the first wall spectrum is from Model B, the blanket spectrum from Model C and the shield spectrum from Model A. The three spectra have neutron fluxes of  $1.0431 \cdot 10^{15} \text{ ncm}^{-2}\text{s}^{-1}$  for the first wall,  $7.7104 \cdot 10^{14} \text{ ncm}^{-2}\text{s}^{-1}$  for the blanket, and  $25.272 \cdot 10^{11} \text{ ncm}^{-2}\text{s}^{-1}$  for the shield, with irradiation times of 5, 5, and 25 years respectively. The use of the three spectra means that the activation responses of materials in a range of neutron spectra typical of DT fusion power plants are available. Figure 1, Figure 2, and Figure 3 are graphs of the three spectra, plotted as neutron flux per lethargy interval against energy.

Figure 4 shows the fourth spectra used. In this case a calculated spectrum from an actual fusion device was used, namely the JET (Joint European Torus) experiment. Specifically, it is the spectrum representing the average flux over the vacuum vessel wall on the inboard side of JET [13]. It is for a DD plasma source rather than the DT sources described above and so may be of more interest to fusion experimentalists. It should be noted that this spectrum has much lower fluxes than any of the other three. The details for this spectrum are:  $3.46 \cdot 10^{-6} \text{ ncm}^{-2}\text{s}^{-1}$ , with an irradiation time of 1 year.

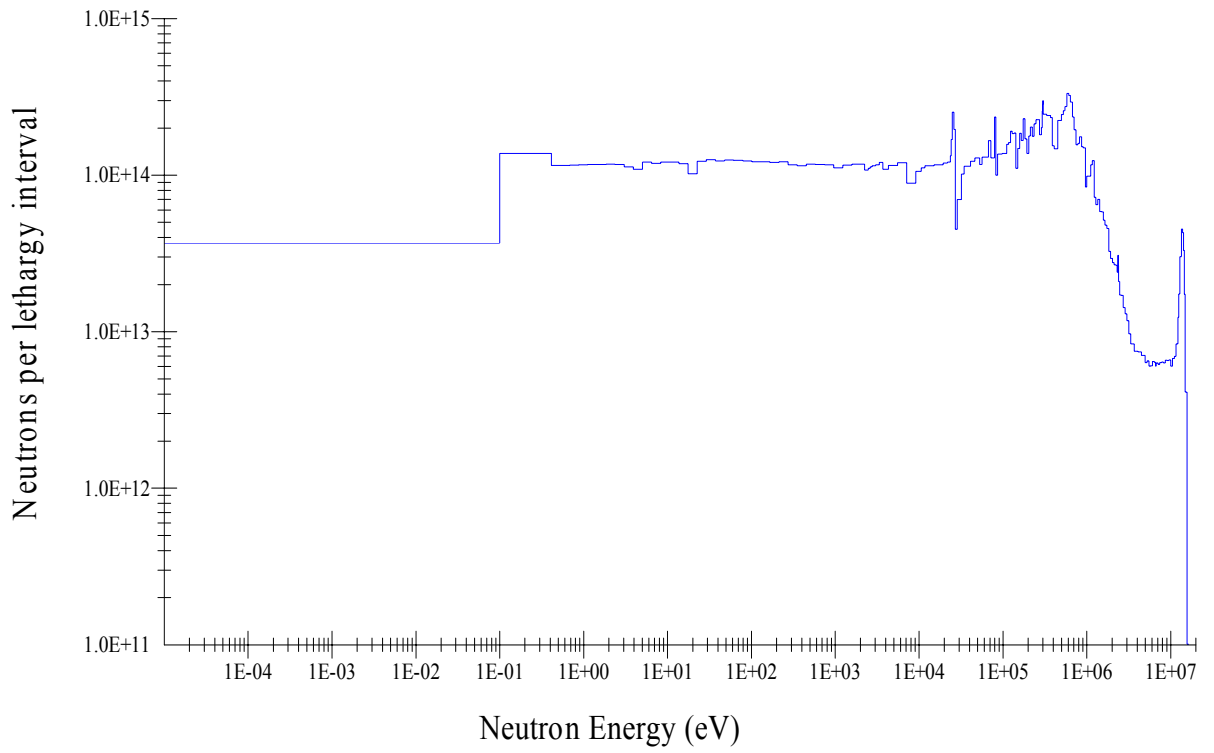
Figure 5 shows the fifth spectra used. In this case a calculated spectrum [14] for the high flux test module of IFMIF fusion device is used. IFMIF [15] is the planned materials test facility; it will produce an intense neutron field by the impact of 40 MeV deuterons on a flowing lithium target. Although producing a fusion relevant spectrum, there is a high energy tail extending up to about 55 MeV. It was the need to be able to calculate activation by such high energy neutrons that motivated the extension of EAF data to 60 MeV. The details for this spectrum are:  $7.3219 \cdot 10^{14} \text{ ncm}^{-2}\text{s}^{-1}$ , with an irradiation time of 1 year (the irradiation history is 180 days on, 30 days off, 150 days on with the specified flux).



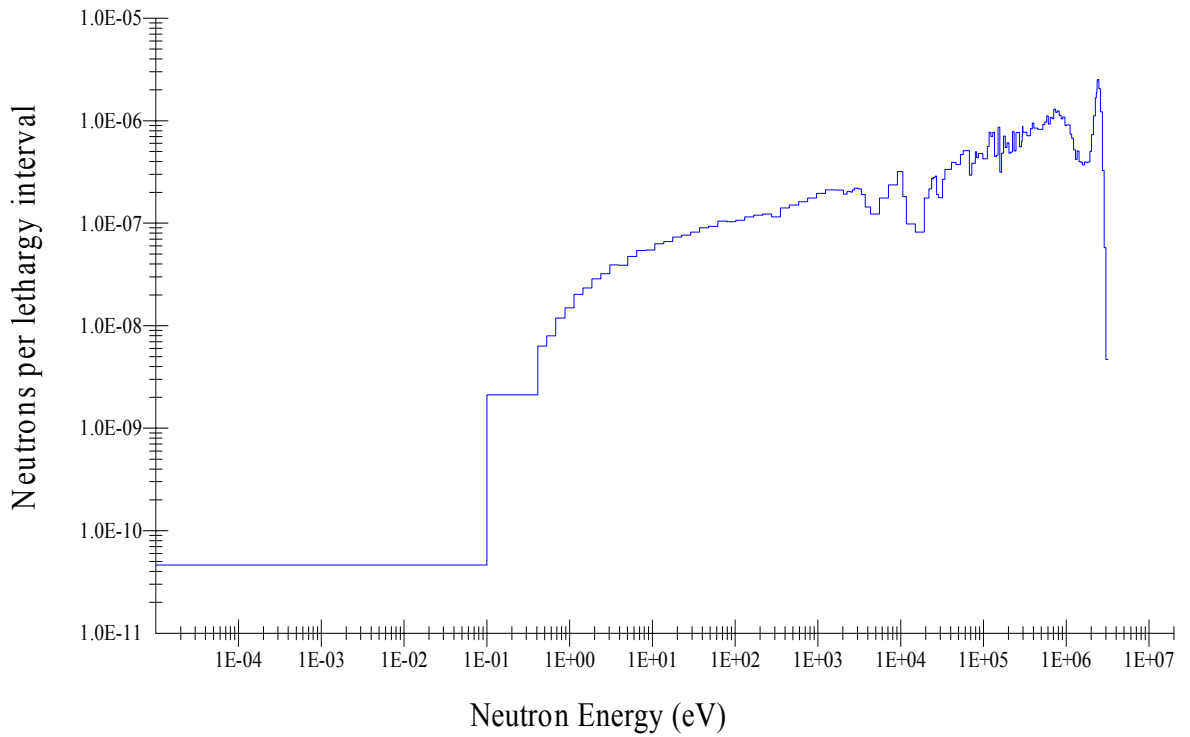
**Figure 1.** Neutron spectrum for the first wall of a conceptual power plant



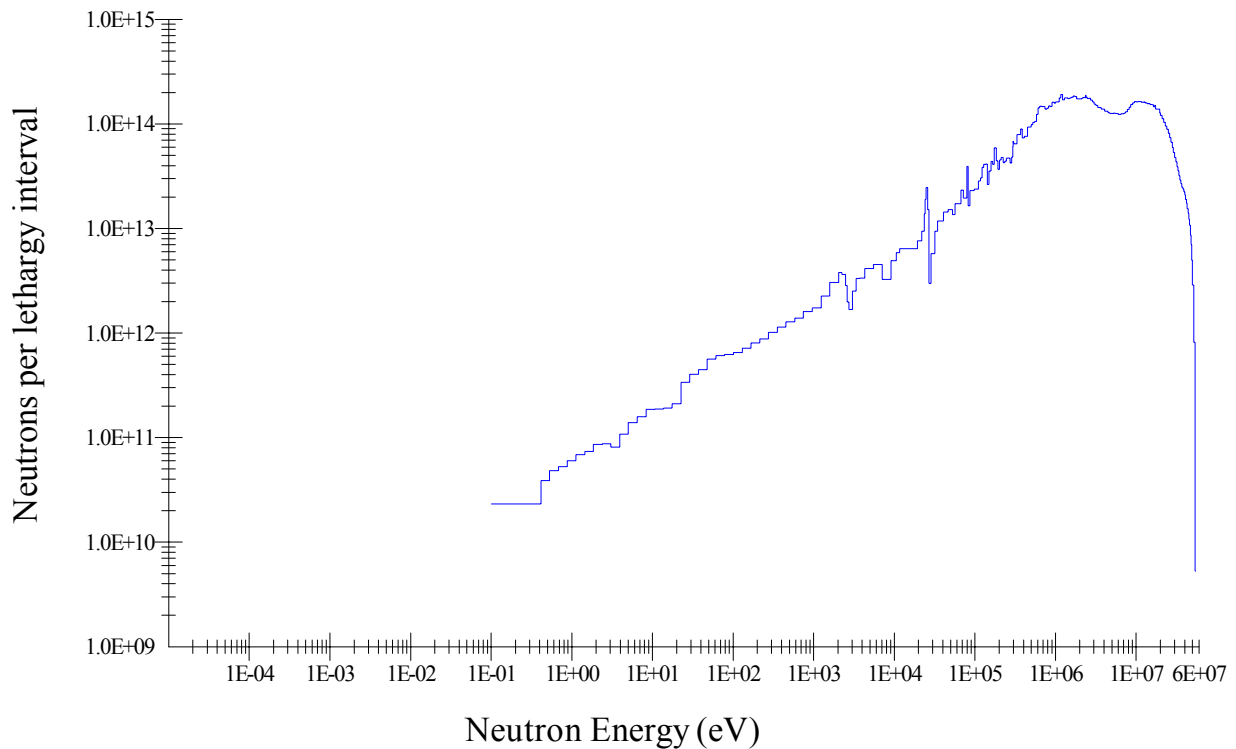
**Figure 2.** Neutron spectrum for the blanket of a conceptual power plant



**Figure 3.** Neutron spectrum for the shield of a conceptual power plant



**Figure 4.** Neutron spectrum for the vacuum vessel wall on the inboard side of JET



**Figure 5.** Neutron spectrum for the high flux target region of IFMIF.

## 4 EXPLANATION OF TABLES AND GRAPHS

The data for each element are split up into a number of sections. These are briefly described below.

### 4.1 GENERAL PROPERTIES

Basic properties of each element are given, including a list of all the naturally occurring isotopes, both stable and radioactive, with the half-lives of the radioactive ones being given in brackets. The properties included in the table are:

- Atomic number
- Crustal abundance in weight parts per million (wppm)
- Melting point in Kelvin at 101.3 kPa (1 atm)
- Boiling point in Kelvin at 101.3 kPa (1 atm)
- Density in  $\text{kgm}^{-3}$
- Thermal Conductivity in  $\text{Wm}^{-1}\text{K}^{-1}$  at 300 K
- Electrical Resistivity in  $\Omega\text{m}$
- Coefficient of linear expansion in  $\text{K}^{-1}$  at 298 K
- Crystal Structure
- Number of stable isotopes
- Mean atomic weight

Note: For the number of stable isotopes, figures in brackets indicate the number of isotopes of that particular element that occur naturally, but are also radioactive with long half-lives (as shown in the fourth column of the table).

The bulk of these data were obtained from the CRC handbook of chemistry and physics [16], together with Nuclear Wallet Cards from the National Nuclear Data Centre (USA) [17], which in the main also takes its data on elemental properties from [16]. Data on the thermal conductivity, electrical resistivity, and crystal structure have mostly been taken directly from the previous version of this handbook [1]. Notes relevant for the particular element follow below the table.

## 4.2 ACTIVATION PROPERTIES

The activation table presents the important radionuclides produced by the irradiation of a 1 kg pure sample of an element for 5 years in the first wall neutron spectrum (Figure 1). Data are presented for six activation quantities (the abbreviations used in the tables are shown in brackets, and the units used for these quantities are given):

- |   |  |
|---|--|
| 1 Specific Activity ( <b>Act</b> ) – Bqkg <sup>-1</sup>             | 2 Decay Power/Heat Output ( <b>Heat</b> ) – kWkg <sup>-1</sup> |
| 3 Gamma ( $\gamma$ ) Dose rate ( <b>Dose</b> ) – Sv h <sup>-1</sup> | 4 Inhalation dose ( <b>Inh</b> ) – Svkg <sup>-1</sup>          |
| 5 Ingestion dose ( <b>Ing</b> ) – Svkg <sup>-1</sup>                | 6 Clearance Index ( <b>Clear</b> ) – no units                  |

The specific activity is the activity induced in 1 kg of the material by the neutrons; the Decay Power is the rate of heat production in 1 kg of the material due to the various decay processes. The Gamma Dose rate is the contact dose rate due to a semi-infinite slab of the material [9], the Ingestion and Inhalation doses refer to the dose received by an average person over a 50 year period from the intake of 1 kg of the material [8]. The Clearance Index of a material determines if the material can be disposed of with no special precautions according to IAEA guidelines. If less than 1 then the material can be disposed of or ‘cleared’ as if it were non-radioactive [8].

For each of these six properties data are presented at six different decay times following irradiation. These are: 0 years (immediately after shutdown following the irradiation); 10<sup>-5</sup> years (5.26 minutes); 10<sup>-2</sup> years (3.65 days); 1 year; 100 years; and 10<sup>5</sup> years. Within the section of the table for each activation property, important radionuclides are listed along with their percentage contribution to the total for the given activation property at each cooling time. The nuclides are listed in descending order of contribution for the decay time where they first appear. For example, in Table 1 below, which shows the activation properties of Magnesium, in the specific activity section (Act) there are 6 nuclides listed in descending order of contribution at shutdown, with <sup>24</sup>Na contributing about 71% and <sup>24m</sup>Na contributing about 22%. <sup>24</sup>Na continues to dominate again up to 10<sup>-2</sup> years, while after a decay time of 1 year, <sup>3</sup>H contributes 97% with most of the remainder coming from <sup>22</sup>Na (~3%). In the next time step <sup>3</sup>H continues to dominate (85%). In the last column, which displays the data for a decay time of 10<sup>5</sup> years, 2 new nuclides, <sup>26</sup>Al and <sup>14</sup>C, produce all of the activity contributing about 60% and 40% respectively.

In most cases, nuclides are listed in these tables if their contribution to the total is greater than 1% at any time. However, there are cases where extra nuclides have been included to create symmetry with the adjacent table for any given activation property, as in the case of the Dose portion for Magnesium in Table 1, where <sup>26</sup>Na has been included to match the Ingestion dose section.

At the top of each column of percentages for each decay time, the total value of the activation property is given for that time, with units as described earlier. For instance, in the Magnesium example, at shutdown after the 5 years of first wall irradiation, the specific activity is 9.89 10<sup>14</sup> Bqkg<sup>-1</sup>. This falls as the decay times increase until, after 10<sup>5</sup> years, the activity is just 1.06 10<sup>3</sup> Bqkg<sup>-1</sup>.

**Note:** In the case of the Gamma Dose Rate percentages, an asterisk (\*) next to the percentage contribution for a given radionuclide indicates that the high-energy  $\beta^-$  bremsstrahlung radiation correction makes a significant contribution to the percentage. In such cases, the total dose rates (in  $\text{Sv h}^{-1}$ ) are adjusted to include the dose contribution from the bremsstrahlung correction. Further details of this effect and its calculation are given in reference 9.

**Table 1.** Activation properties of Magnesium

Act	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Heat	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Bq $\text{kg}^{-1}$	9.89E14	7.04E14	1.23E13	1.25E11	5.42E8	1.06E3	$\text{kW kg}^{-1}$	5.72E-1	5.27E-1	9.09E-3	1.52E-6	1.05E-9	3.18E-13
Na24	71.28	99.77	98.92				Na24	92.39	99.92	99.98			
Na24m	22.14						Na24m	2.97					
Na25	2.73	0.09					Na25	1.46	0.04				
Ne23	2.38						Ne23	1.37					
Na26	0.81						Na26	1.25					
H3	0.01	0.02	1.04	97.00	85.50		Na22			0.02	92.65		
Na22			0.04	2.94			H3				7.31	40.47	
C14				0.06	14.50	39.18	C14					59.49	1.03
Al26						59.99	Al26					0.03	98.85
Dose	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Ing	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
$\text{Sv h}^{-1}$	9.29E5	8.95E5	1.55E4	1.97E0	5.10E-7	4.63E-7	$\text{Sv kg}^{-1}$	3.24E5	3.02E5	5.24E3	1.69E1	6.51E-2	2.48E-6
Na24	96.64	99.97	99.98				Na24	93.50	99.97	99.60			
Na24m	2.18						Na22			0.29	69.60		
Na26	0.58						H3			0.10	30.13	29.92	
Na22			0.02	100.0			C14					70.07	9.72
Al26					100.0	100.0	Al26						89.88
Inh	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Clear	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
$\text{Sv kg}^{-1}$	2.01E5	1.90E5	3.32E3	3.67E1	5.76E-1	1.55E-5		8.62E11	7.04E11	1.22E10	3.80E7	8.32E4	2.14E0
Na24	94.80	99.96	98.80				Na24	81.77	99.83	99.60			
H3	0.02	0.02	1.00	85.74	20.91		Na24m	12.10					
Na22			0.19	13.00			Na26	2.34					
C14				1.26	79.09	15.61	Na22			0.39	96.60		
Al26						82.40	H3			0.01	3.18	5.57	
Be10						1.99	C14				0.21	94.43	19.46
							Al26						80.53

### 4.3 PATHWAY ANALYSES

For each element the production pathways for the dominant radionuclides from the element's naturally occurring isotopes are listed. A nuclide's production pathways are presented if it is a 'primary nuclide', and hence appears on one of the importance diagrams (see description in Section 4.5) for the particular element. The meaning of primary nuclide will be discussed later. For each daughter radionuclide the important pathways of production are given, together with their percentage contribution to the total amount of the nuclide produced, at each of seven different neutron energies. The columns are actually labelled by the group numbers (210, 186, 151, 42, 30, 21, 6) with corresponding mid-point energies of 0.2570 eV, 148.548 eV, 37.587 keV, 14.734 MeV, 25.5 MeV, 34.5 MeV, 49.5 MeV. Clearly, some pathways have contributions at more than one energy, and in such cases the pathway is listed only once with multiple percentages input on the same row of the table. As a general rule, where many pathways contribute to the production of a particular daughter nuclide, only those contributing more than about 1% for at least one of the seven different energies are included. For many nuclides with a large amount of pathway data the minimum percentage has been raised to about 5%. Along with the pathways, the half-lives of each primary nuclide are also given. For example, in the case of Boron we have the pathway analysis shown in Table 2. For  $^{11}\text{B}$  it can be seen that this radionuclide has a half-life of 13.81 seconds, and that at the three lowest energies the dominant pathway is  $\text{B10}(n,p)\text{Be10}(n,\gamma)\text{Be11}$ , while at the four highest energies the dominant pathway is  $\text{B11}(n,p)\text{Be11}$ . In the case of  $^6\text{He}$ , this nuclide is only important at high energies and for these energies there are many parallel contributing pathways.

**Table 2.** Pathway analysis for Boron

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
He6	0.808s	B11(n,n $\alpha$ )Li7(n,d)He6				48.3	13.8	8.2	7.2
		B11(n,d)Be10(n,n $\alpha$ )He6				13.0	6.7	4.8	4.2
		B10(n,n $\alpha$ )Li6(n,p)He6				10.5	0.7	2.8	1.8
		B10(n, $\alpha$ )Li7(n,d)He6				8.1	0.5		
		B11(n,t)Be9(n, $\alpha$ )He6				7.8	0.8		
		B10(n,p)Be10(n,n $\alpha$ )He6				7.0			
		B10(n,d)Be9(n, $\alpha$ )He6				4.5			
		B11(n, $\alpha$ )He6					76.9	81.9	85.2
		B11(n,2n $\alpha$ )Li6(n,p)He6						1.6	1.2
Li8	0.838 s	B10(n, $\alpha$ )Li7(n, $\gamma$ )Li8	100.0	100.0	100.0				
		B11(n, $\alpha$ )Li8				99.9	43.3	23.2	8.5
		B10(n,h)Li8					38.7	52.4	66.8
		B11(n,t)Be9(n,d)Li8					9.0	19.5	20.5
		B11(n,d)Be10(n,t)Li8					6.4	2.7	2.5
		B11(n,2n)B10(n,h)Li8					1.5	1.2	0.7
B10(n,d)Be9(n,d)Li8					0.8	0.9	0.8		
Be11	13.81 s	B10(n,p)Be10(n, $\gamma$ )Be11	100.0	100.0	100.0				
		B11(n,p)Be11				100.0	100.0	100.0	100.0
C11	20.37 m	B11(n, $\gamma$ )B12( $\beta^-$ )C12(n,2n)C11					100.0	100.0	100.0
H3	12.33 y	B10(n,2 $\alpha$ )H3	65.4	80.3	97.6	53.0	33.0	34.3	29.1
		B10(n,2 $\alpha$ )H3( $\beta^-$ )He3(n,p)H3	21.0	19.7	2.4				
		B11(n,2 $\alpha$ )H3				42.1	59.0	57.4	64.0
		B11(n,n $\alpha$ )Li7(n,n $\alpha$ )H3				3.6	3.9	2.2	0.9
		B10(n, $\alpha$ )Li7(n,n $\alpha$ )H3				0.6			
		B11(n,d)Be10(n,n $\alpha$ )H3					2.0	0.9	0.8
		B11(n,t)Be9(n,t $\alpha$ )H3					0.8	2.7	3.4
		B11(n,2n)B10(n,2 $\alpha$ )H3					0.7		
		B10(n,n $\alpha$ )Li6(n, $\alpha$ )H3							1.1
B11(n,2n $\alpha$ )Li6(n, $\alpha$ )H3							0.6	0.5	
Be10	1.6 10 <sup>6</sup> y	B10(n,p)Be10	100.0	100.0	100.0	34.9	3.6	3.2	2.7
		B11(n,d)Be10				64.7	96.3	96.8	97.3

There are a large number of possible types of reactions and decays that may occur along the production pathway from the parent isotope to the daughter radionuclide. The most common ones in this handbook, with typical examples, are listed below.

### Reactions

- (n, $\gamma$ ) – neutron absorbed, gamma photon emitted, e.g. Li7(n, $\gamma$ )Li8
- (n,2n) – neutron absorbed, two neutrons emitted, e.g. N14(n,2n)N13
- (n, $\alpha$ ) – neutron absorbed, alpha particle emitted, e.g. Mg25(n, $\alpha$ )Ne22
- (n,p) – neutron absorbed, proton emitted, e.g. Si28(n,p)Al28
- (n,n')
- (n,n') – neutron absorbed and emitted (inelastic scattering), e.g. Sc45(n,n')Sc45m
- (n,t) – neutron absorbed, triton emitted (or combination of 2 neutrons and a proton), e.g. Ti46(n,t)Sc44
- (n,n $\alpha$ ) – neutron absorbed, alpha particle and neutron emitted, e.g. Cl35(n,n $\alpha$ )P31
- (n,3n) – neutron absorbed, three neutrons emitted, e.g. V51(n,3n)V49
- (n,d) – neutron absorbed, deuteron emitted (or a neutron and a proton), e.g. Co59(n,d)Fe58
- (n,h) – neutron absorbed, <sup>3</sup>He nucleus (helion) emitted e.g. B10(n,h)Li8
- (n,2p) – neutron absorbed, two protons emitted, e.g. Ca40(n,2p)Ar39

(n,4n) – neutron absorbed, four neutrons emitted, e.g. Ag107(n,4n)Ag104. Note that other multiple neutron emission reactions such as (n,5n) and (n,6n) are also common.

(n,2n $\alpha$ ) – neutron absorbed, alpha particle and two neutrons emitted, e.g. Cu63(n,2n $\alpha$ )Co58

(n,X) – neutron absorbed, heavy nucleus recoiled (important in the production of  $^3\text{H}$ ), e.g. Be9(n,X)H3

### Decays

( $\beta^-$ ) – beta decay, e.g. C14( $\beta^-$ )N14

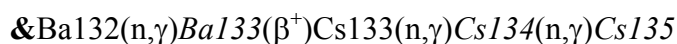
( $\beta^+$ ) – positron decay (including electron capture), e.g. Ar37( $\beta^+$ )Cl37

( $\alpha$ ) – alpha decay, e.g. Dy152( $\alpha$ )Gd148

( $\beta^- \alpha$ ) – beta decay followed by alpha emission, e.g. Be11( $\beta^- \alpha$ )Li7

(IT) – isomeric transition resulting in gamma ray emission, e.g. Na24m(IT)Na24

These reactions and decays can combine to form very long pathways, some of which take up several lines in the pathway analysis tables, so it was important to find ways of limiting the amount of information presented, while still providing a full picture of the production of each radionuclide. Note that in cases where a pathway occupies more than one line the symbol ‘\_’ indicates a continuation. Many of the long chain pathways include short-lived isomeric transition nuclides that simply rejoin the main pathway by decaying back to their ground state, e.g. Na24m(IT)Na24. It was decided that pathways that only differed from one another in these isomeric transition (IT) steps, should be summed together, with only the simplest or ‘generic’ pathway, i.e. the one that has no IT steps, displayed in the handbook. In such cases the generic pathway displayed is preceded by an ampersand in bold (&), with all the ground state nuclides that have an isomeric (or metastable) state, which is important in the production of the particular radionuclide daughter, printed in italics. Thus, for example, in the case of the production of  $^{135}\text{Cs}$  from  $^{132}\text{Ba}$ , we have the generic pathway:



which contributes 94.2% of the total  $^{135}\text{Cs}$  production for Barium at low energies. It is displayed in this form in the pathway analysis for Barium, and it can be seen that Ba133, Cs134 and Cs135 are in italics, indicating that the 94.2% is actually the sum of the contributions from these 8 pathways which include the isomeric transitions:

1. Ba132(n, $\gamma$ )Ba133( $\beta^+$ )Cs133(n, $\gamma$ )Cs134(n, $\gamma$ )Cs135 (the basic pathway)
2. Ba132(n, $\gamma$ )Ba133( $\beta^+$ )Cs133(n, $\gamma$ )Cs134(n, $\gamma$ )Cs135m(IT)Cs135
3. Ba132(n, $\gamma$ )Ba133( $\beta^+$ )Cs133(n, $\gamma$ )Cs134m(IT)Cs134(n, $\gamma$ )Cs135
4. Ba132(n, $\gamma$ )Ba133( $\beta^+$ )Cs133(n, $\gamma$ )Cs134m(IT)Cs134(n, $\gamma$ )Cs135m(IT)Cs135
5. Ba132(n, $\gamma$ )Ba133m(IT)Ba133( $\beta^+$ )Cs133(n, $\gamma$ )Cs134(n, $\gamma$ )Cs135
6. Ba132(n, $\gamma$ )Ba133m(IT)Ba133( $\beta^+$ )Cs133(n, $\gamma$ )Cs134(n, $\gamma$ )Cs135m(IT)Cs135
7. Ba132(n, $\gamma$ )Ba133m(IT)Ba133( $\beta^+$ )Cs133(n, $\gamma$ )Cs134m(IT)Cs134(n, $\gamma$ )Cs135
8. Ba132(n, $\gamma$ )Ba133m(IT)Ba133( $\beta^+$ )Cs133(n, $\gamma$ )Cs134m(IT)Cs134(n, $\gamma$ )Cs135m(IT)Cs135

It should be noted that where a metastable nuclide undergoes a reaction or decay, other than an isomeric transition to the ground state, then the pathway involved is displayed separately, and is not included in a generic pathway.

Note that in cases where the pathways for a particular nuclide span two pages, then this is shown by the symbol ‘▶’ at the bottom of the first page and ‘◀’ at the top of the second.



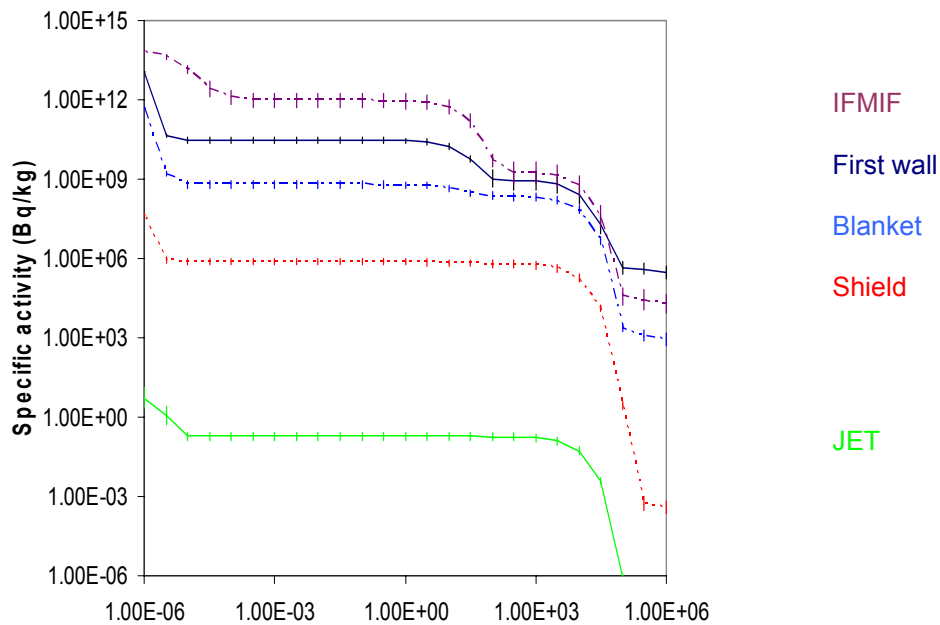
The pathway data were obtained by employing the ability of FISPACT to calculate pathways, full details of which can be found in the User manual [9]. They result from the irradiation of pure samples of the elements for 5 years with the seven relevant single-energy neutron spectra described earlier, followed by a series of decay times adding up to about  $10^6$  years. The seven energies, listed above, were chosen to give a broad picture of the reaction behaviour of the elements when irradiated with neutrons. It should be noted that not all of the primary nuclides are produced at all seven of the energies, as can be seen in the cases of  $^6\text{He}$  and  $^{11}\text{C}$  for Boron in Table 2.

In some cases it has not been possible to find the pathways for given daughter nuclides because the pathways are so long that they exceed the limits of FISPACT (see reference 9 for details). In the standard outputs there may be no pathway data for a nuclide, or there may be only a few of the pathways presented, which do not sum to the total production (100%) for the nuclide. Wherever possible special FISPACT runs with different parameters have been made to find pathways so that the total percentage is at least 90%, but in cases where this has not been achieved, notes have been placed within the appropriate part of the table. There are also instances where no pathways have been given because the threshold for the production of a particular radionuclide falls outside the range of energies employed in the pathway analysis, even though it may still appear on the importance diagrams. This is also referred to appropriately within the main body of the handbook. Another complication arises when some of the naturally occurring isotopes are radioactive, in such cases the radionuclides are typically one of the dominant nuclides (at long times) and much of their amount is not formed but is initially present. Such cases are noted in the tables.

#### **4.4 ACTIVATION GRAPHS**

Activation calculations performed using the three neutron spectra for conceptual power plant designs, the spectrum calculated for the JET experimental device and the IFMIF high flux region (see Section 3), are presented in graphical form. For each element, there is a separate graph for all six of the activation properties presented in the activation properties table (see 4.2), with the same units as before. The graphs are colour coded (in the colour version of this report) to enable distinction between the results from the five different spectra. In each graph the solid dark blue curve represents the data produced from irradiation of the element with the first wall spectra. The dash-dotted blue curve and the dotted red curve represent results for the blanket and shield spectra, respectively. The purple dash-dot curve represents the results for the IFMIF irradiation. Finally, the solid green curve (always the lowest of the five curves, in case the graphs are being viewed in black-and-white) represents the results of calculations with the JET DD spectrum. Each graph is a log-log plot of the activation property as a function of decay time following irradiation. The decay time ranges from  $10^{-6}$  to  $10^6$  years. The irradiation times used for each spectrum are as stated in Section 3. As with the activation properties, an asterisk, in this case in the title of the dose rate graph, indicates that the contribution from bremsstrahlung is significant.

Figure 6 shows, as an example graph, the plot of the specific activity of Oxygen. It shows that the five curves have a similar pattern of variation with the highest activity in the IFMIF curve, followed by the first wall, blanket, shield, and JET DD curves. Note also that error bars have been included for the data on each curve; these represent the uncertainty in the quantity due to uncertainties in the cross section and half-life data in the EAF library calculated in the standard FISPACT runs.



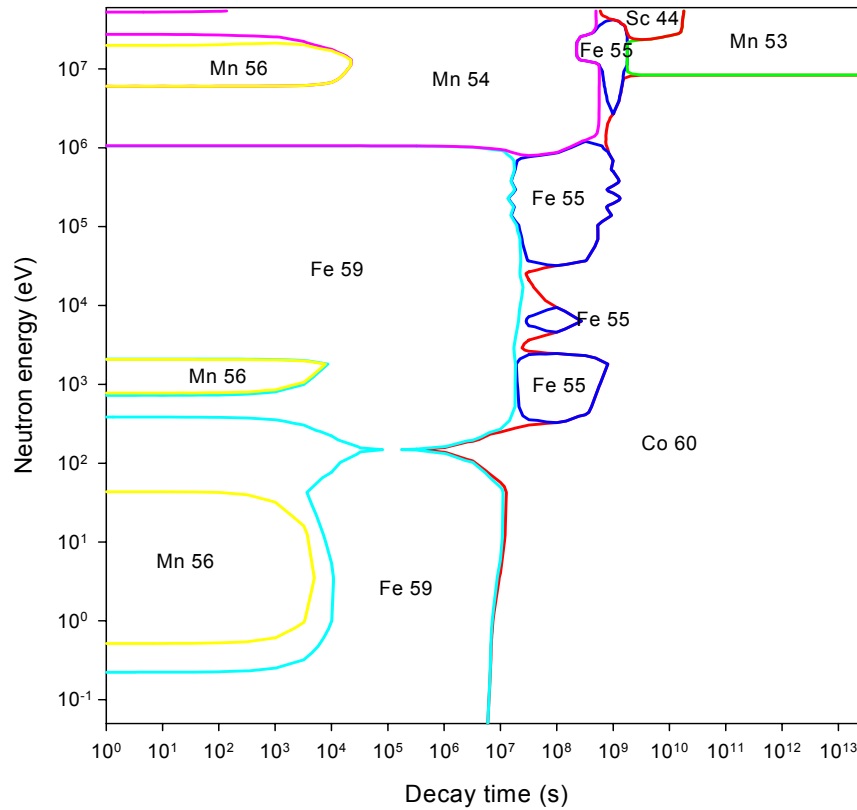
**Figure 6.** The activation graph for the specific activity of Oxygen, showing five curves for the neutron spectra indicated at the right

**Note:** In the case of the Clearance Index graph, a line indicating a Clearance Index of 1 is provided (brown line).

#### 4.5 IMPORTANCE DIAGRAMS

In Section 3 the neutron spectra used for the above calculations are discussed. Neutron spectra are necessary to give results for a particular irradiation, but the motivation for the importance diagrams is to present activation results that do not require the definition of a neutron spectrum. To do this the response of a material to mono-energetic neutrons is considered. Results produced by such calculations allow the most important radionuclides to be identified for each neutron energy. Plotting the regions where a nuclide contributes 50% or more of the total response, at various decay times, gives an importance diagram. A full description of these diagrams is given in [18] and examples for various materials can be found in [19,20]. Figure 7 shows the dose rate importance diagram for pure iron. In this the various regions shown are labelled by a nuclide, e.g. for decay times  $< 1 \times 10^4$  s and for energies  $> 0.5$  eV and  $< 40$  eV the nuclide  $^{56}\text{Mn}$  is dominant (i.e. it contributes more than 50% of the total dose rate). Note that there are three distinct regions labelled by  $^{56}\text{Mn}$  at these short decay times, at various energies. At other energies  $^{54}\text{Mn}$  or  $^{59}\text{Fe}$  dominate, while at energies  $> 40$  eV and  $< 400$  eV no single nuclide contributes more than 50% for these short decay times. In the latter case it is usual for three nuclides to dominate. It is typical that nuclides dominate at particular decay times giving a vertical band in the diagram (e.g.  $^{55}\text{Fe}$  dominates at about  $1 \times 10^8$  s) although in many cases these bands are split into several distinct regions by a region for another nuclide. Also there is generally a different set of nuclides that dominant at MeV energies from those that dominate at low energy, because of the importance of threshold reactions rather than capture reactions. The importance diagram gives no information on the magnitude of the dose rate (a neutron spectrum is needed for such data), but instead summarises which nuclides will be important at particular decay times, when neutrons of various energies are present. Thus for iron in a hard spectrum, at times  $> 30$  y ( $\sim 10^9$  s), Figure 7 shows that  $^{53}\text{Mn}$  would dominate the dose rate, while in a soft spectrum  $^{60}\text{Co}$  would be more important. If the importance diagram is compared with the earlier one in reference 1 calculated with EASY-2003, it can be seen that there is an

additional region due to  $^{44}\text{Sc}$  at high energies at times around  $10^{10}$  s cooling. The appearance of new dominant nuclides at high energies is commonly seen for the various elements.



**Figure 7.** Dose rate importance diagram for pure iron

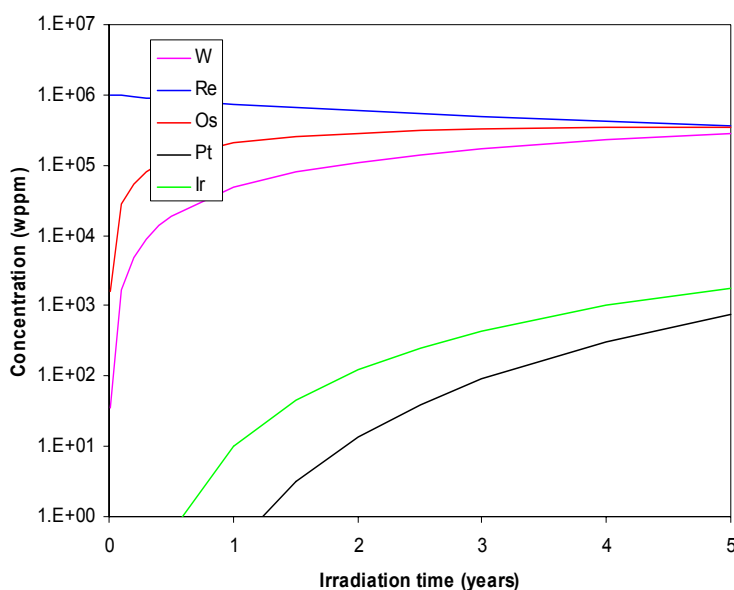
The nuclides shown in the importance diagrams, which appear because they contribute 50% or more of the total quantity in at least one region of the Decay time-Neutron energy plane, are termed ‘primary nuclides’. These are the nuclides which have their production pathways presented in the pathways analysis tables described in 4.3. Of course, other radionuclides are produced during irradiations by mono-energetic neutrons, and those that contribute between 1% and 50% are termed ‘secondary nuclides’. The pathways for these are not listed, but the nuclides themselves are listed in Table 1 of the Summary section (see Section 4.7 for a full description).

#### 4.6 TRANSMUTATION GRAPHS

The rates of production of the most important transmutation elements, together with the burn-up of the element under consideration, are plotted as a function of time. These results are produced by irradiating the given element with the first wall spectrum described in Section 3. The curve for a particular element is generally only shown if it is produced in concentrations greater than 1 wppm (weight part per million). Exceptions include Hydrogen and Helium, where the boundary was lowered so that the graph had something other than just the starting material on it. Concentrations below this 1 wppm are not included because elements in such small amounts will generally not have any significant effect on material properties.

An example of the type of transmutation graph presented in this handbook is shown in Figure 8, which shows the results for the transmutation of Rhenium (Re). It can be seen that there is considerable burn-up of the starting material, with the major transmutation product being Osmium (Os). In fact the rate of burn-up is so great that, after around 5.0 years, the concentration of Osmium (orange line) becomes approximately equal to that of Rhenium

itself (blue line). The other important products are Tungsten (W), Iridium (Ir), and Platinum (Pt).



**Figure 8.** Transmutation graph for Rhenium

#### 4.7 SUMMARY TABLES

In this section of the handbook three tables are presented, which summarise some of the important information in a more easily accessible format. The first of these is a table displaying both the primary and secondary nuclides (see definition of these in 4.5) of all elements considered in the handbook. The table takes the form of a list of all the radionuclides that are a primary or secondary nuclide for at least one of the elements in the main body of the handbook. For each of these radionuclides, which are displayed in increasing atomic number for easy location, their half-life is given. Two subsequent columns in the table then list the elements for which this nuclide is primary and secondary, respectively. These elements are listed in order of increasing atomic number. For example, the entry for the nuclide  $^{94}\text{Nb}$  has the format shown in Table 3, with appropriate column headings. It shows that there are eleven elements for which  $^{94}\text{Nb}$  is a primary nuclide, with a single other element having this radionuclide as a secondary nuclide. The information on the primary nuclides is the same as that shown in the importance diagrams and pathways analysis for each element, but this table displays it in a more concise form, with the added information on those nuclides that form the next level of importance in the activation of the elements. Some nuclides have a symbol (\*, +, >, <) on the left of the first column. This shows changes compared to the previous table [1] based on EASY-2003. ‘\*’ indicates that the nuclide is a new primary nuclide, ‘+’ indicates a new secondary nuclide, ‘>’ indicates a nuclide that is now primary but was previously secondary and ‘<’ indicates a nuclide that is now secondary but was previously primary. A total of 923 nuclides, out of a total of 2,231 present in EAF-2007, are listed in the table.

**Table 3.** Entry for  $^{94}\text{Nb}$  in the Primary and Secondary nuclides table

Nuclide	$T_{1/2}$	Contributing elements	
		Primary	Secondary
Nb94	$2.00 \cdot 10^4$ y	Zr, Nb, Mo, Ru, Rh, Pd, Ag, Cd, In, Sn, Sb	Y

The second summary table displays some of the information from the pathway analysis data, which is large and extensive. It presents the major reactions (those with importance of 5 or 4) found within the pathway tables, and gives the nuclides that have these reactions as steps in their important production chains. Every primary nuclide listed in the pathway analysis of at least one element has the major reactions from its main pathways of production listed. The format of this table is shown in Table 4.

**Table 4.** The initial part of the Summary of Major reactions table

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>H1</b> (n, $\gamma$ ) <b>H2</b>	H3	5	4*	•	
<b>H2</b> (n, $\gamma$ ) <b>H3</b>	H3	5	4*	•	
<b>He3</b> (n,p) <b>H3</b>	H3	5	4	•	
<b>He4</b> (n,2n) <b>He3</b>	H3	5	0		
<b>Li6</b> (n, $\alpha$ ) <b>H3</b>	H3	5	4	•	
<b>Li7</b> (n, $n\alpha$ ) <b>H3</b>	H3	5	5 <sub>3</sub>	•	•
<b>Li7</b> (n, $\gamma$ ) <b>Li8</b>	Li8	5	4	•	
<b>Li7</b> (n,d) <b>He6</b>	He6	5	2	•	
<b>Be9</b> (n, $\gamma$ ) <b>Be10</b>	H3, Li8, Be10, Be11	5	2	•	
<b>Be9</b> (n,d) <b>Li8</b>	Li8	5	4	•	
<b>Be9</b> (n,t) <b>Li7</b>	H3, He6, Li8	5	5 <sub>2</sub>	•	
<b>Be9</b> (n, $\alpha$ ) <b>He6</b>	He6	5	4	•	
<b>Be10</b> (n, $\gamma$ ) <b>Be11</b>	Li8, Be11	5	2*	•	
<b>B10</b> (n,p) <b>Be10</b>	He6, Li8, Be10, Be11	5	2	•	
<b>B10</b> (n,h) <b>Li8</b>	Li8	5	0		
<b>B10</b> (n, $\alpha$ ) <b>Li7</b>	H3, He6, Li8	5	4	•	
<b>B10</b> (n,2 $\alpha$ ) <b>H3</b>	H3	5	6	•	•

The definition of the importance values are: if the reaction is on a pathway that contributes  $\geq 50\%$ ,  $20\%$ ,  $10\%$ ,  $5\%$ ,  $1\%$  to the production of the nuclide then the importance values are 5, 4, 3, 2, 1 respectively. So, for example, in Table 2, the pathway data for the production of  $^8\text{Li}$  from the naturally occurring isotopes of Boron, lists a single pathway (B10(n, $\alpha$ )Li7(n, $\gamma$ )Li8) that contributes to the production at 0.2570 eV. It contributes 100.0%, and so the two reactions in the pathway are included in the summary table with  $^8\text{Li}$  shown in the ‘Daughter nuclide’ column. However, the pathway B11(n,2n)B10(n,h)Li8 contributes only 1.5% at 25.5 MeV, and so its two reactions are not included in the table (actually the second reaction is present because it contributes more than 50% at 34.5 MeV), unless they are important in the production of other radionuclides, or indeed in the production of  $^8\text{Li}$  from an element other than Boron. The table displays, as one group, all the major reactions with a single element’s isotopes as the parents, displayed in increasing atomic number of the element. Within the group the reactions are listed in order of increasing mass number of the target nuclide. In the case of generic pathways, only the reactions for the basic pathway, i.e. excluding any isomeric transitions (IT), have been included in the summary table. Thus reactions involving metastable nuclides (e.g.  $^{193\text{m}}\text{Pt}$ ) are only included in the table if they are involved in pathways where they do not decay to the ground state nuclide via an isomeric transition. This can happen if the metastable isomer has a half-life that is long enough to allow time for reactions to occur, or if the isomer has a decay mode that is not an isomeric transition. An example of this can be seen in the production of  $^{77}\text{As}$  from  $^{76}\text{Ge}$ . Both  $^{77}\text{Ge}$  and  $^{77\text{m}}\text{Ge}$  are produced via an (n, $\gamma$ ) reaction from  $^{76}\text{Ge}$ , but while in some cases the  $^{77\text{m}}\text{Ge}$  decays to  $^{77}\text{Ge}$  via an IT reaction, followed by beta decay to  $^{77}\text{As}$ , in other cases the metastable nuclide beta decays directly to  $^{77}\text{As}$ , with both pathways contributing more than 20%. Thus, in the summary table, Ge76(n, $\gamma$ )Ge77m is included, along with Ge76(n, $\gamma$ )Ge77.

Target nuclides that are stable or naturally occurring are printed in bold. Similarly the product nuclides that are stable are printed in bold. This is an aid to identify reactions that could be measured experimentally. Although some data on radioactive targets are available these can only be obtained at particular energies typically in a fission reactor environment. Similarly data for stable products are available, but only by employing particle counting techniques rather than the more common activation methods.

The first column of the table lists the major reactions in the order as described above. The second column has a list of all the nuclides whose major production pathways contain the reaction. Column 3 shows the importance value described above, note that since only the major reactions are listed these are always 5 or 4. Column 4 presents the ‘quality score’ for the reaction. The scores are listed in reference 6, and indicate the agreement of the library data with the experimental database. The meaning of the values are: 0 – no experimental data, 1 – weak disagreement with the differential data, 2 – weak agreement with the differential data, 3 – strong disagreement with the differential data, 4 – strong agreement with the differential data, 5 – discrepant integral and differential data, 6 - agreement between the library and the integral and differential data (validated reaction). The scores for discrepant reactions are subdivided to show the various combinations of integral and differential data.  $5_0$  – differential data are missing and there is unsatisfactory agreement with integral data,  $5_1$  – there is unsatisfactory agreement with differential and integral data,  $5_2$  – there is satisfactory agreement with differential and unsatisfactory agreement with integral data,  $5_3$  – differential data are missing and there is satisfactory agreement with integral data,  $5_4$  – there is unsatisfactory agreement with differential data and satisfactory agreement with integral data. The integral data and the results of the validation exercise on EAF-2007 are reported in reference 21. Columns five and six in the table indicate, with a bullet point, whether differential (Diff) and/or integral (Int) experimental data are available to support the data in EAF-2007 for the cross sections of each reaction listed. In cases where a single reaction rather than reactions to the two or three isomeric states is given, if the scores are not the same for all states then all the values are given; thus ‘2/4’ means that the score is 2 for the ground state and 4 for the isomer. In cases where the scores differ from reference 6 (usually as a result of the validation exercise reported in reference 21) this is shown by an asterisk (\*).

The third table shows how many reactions there are of the various types for each importance value. The reactions are shown in column 1, column 2 shows other reactions that produce the same daughter; all results from FISPACT actually refer to the sum of the reactions in the first two columns, columns 3-7 show the numbers of each reaction and column 8 shows the total number of each reaction for importance value  $> 0$ . Reactions shown in **bold** are the types included in EAF-2003, the remaining reactions are termed ‘exotic’. At the bottom of columns 3-8 the number of standard and exotic reactions and the total number of reactions are shown. It can be seen from the table that for each importance value most of the reactions are of standard type; the most significant of the exotic reaction types of major importance are:  $(n,5n)$ , 69;  $(n,6n)$ , 41;  $(n,2nt)$ , 25;  $(n,d\alpha)$ , 25;  $(n,t\alpha)$ , 14 and  $(n,4n\alpha)$ , 9.

## 5 ACKNOWLEDGEMENT

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**PART 1:**  
**Activation Analysis of the Naturally Occurring**  
**Elements (H - Bi)**

# Alphabetical list of elements

Element (Z)	Page	Element (Z)	Page	Element (Z)	Page
Aluminium (13)	77	Helium (2)	27	Praseodymium (59)	389
Antimony (51)	327	Holmium (67)	459	Rhenium (75)	529
Argon (18)	107	Hydrogen (1)	23	Rhodium (45)	285
Arsenic (33)	209	Indium (49)	313	Rubidium (37)	237
Barium (56)	365	Iodine (53)	343	Ruthenium (44)	277
Beryllium (4)	35	Iridium (77)	545	Samarium (62)	411
Bismuth (83)	591	Iron (26)	165	Scandium (21)	127
Boron (5)	39	Krypton (36)	229	Selenium (34)	217
Bromine (35)	223	Lanthanum (57)	373	Silicon (14)	83
Cadmium (48)	305	Lead (82)	583	Silver (47)	297
Calcium (20)	119	Lithium (3)	31	Sodium (11)	65
Carbon (6)	43	Lutetium (71)	497	Strontium (38)	243
Cerium (58)	381	Magnesium (12)	71	Sulphur (16)	95
Caesium (55)	359	Manganese (25)	157	Tantalum (73)	513
Chlorine (17)	101	Mercury (80)	569	Tellurium (52)	335
Chromium (24)	149	Molybdenum (42)	269	Terbium (65)	439
Cobalt (27)	171	Neodymium (60)	397	Thallium (81)	577
Copper (29)	183	Neon (10)	59	Thulium (69)	477
Dysprosium (66)	447	Nickel (28)	177	Tin (50)	319
Erbium (68)	467	Niobium (41)	263	Titanium (22)	133
Europium (63)	421	Nitrogen (7)	47	Tungsten (74)	521
Fluorine (9)	55	Osmium (76)	535	Vanadium (23)	141
Gadolinium (64)	429	Oxygen (8)	51	Xenon (54)	351
Gallium (31)	195	Palladium (46)	291	Ytterbium (70)	487
Germanium (32)	201	Phosphorus (15)	89	Yttrium (39)	249
Gold (79)	561	Platinum (78)	553	Zinc (30)	189
Hafnium (72)	505	Potassium (19)	113	Zirconium (40)	255



## Elements ordered by atomic number

Element (Z)	Page	Element (Z)	Page	Element (Z)	Page
Hydrogen (1)	23	Nickel (28)	177	Barium (56)	365
Helium (2)	27	Copper (29)	183	Lanthanum (57)	373
Lithium (3)	31	Zinc (30)	189	Cerium (58)	381
Beryllium (4)	35	Gallium (31)	195	Praseodymium (59)	389
Boron (5)	39	Germanium (32)	201	Neodymium (60)	397
Carbon (6)	43	Arsenic (33)	209	Samarium (62)	411
Nitrogen (7)	47	Selenium (34)	217	Europium (63)	421
Oxygen (8)	51	Bromine (35)	223	Gadolinium (64)	429
Fluorine (9)	55	Krypton (36)	229	Terbium (65)	439
Neon (10)	59	Rubidium (37)	237	Dysprosium (66)	447
Sodium (11)	65	Strontium (38)	243	Holmium (67)	459
Magnesium (12)	71	Yttrium (39)	249	Erbium (68)	467
Aluminium (13)	77	Zirconium (40)	255	Thulium (69)	477
Silicon (14)	83	Niobium (41)	263	Ytterbium (70)	487
Phosphorus (15)	89	Molybdenum (42)	269	Lutetium (71)	497
Sulphur (16)	95	Ruthenium (44)	277	Hafnium (72)	505
Chlorine (17)	101	Rhodium (45)	285	Tantalum (73)	513
Argon (18)	107	Palladium (46)	291	Tungsten (74)	521
Potassium (19)	113	Silver (47)	297	Rhenium (75)	529
Calcium (20)	119	Cadmium (48)	305	Osmium (76)	535
Scandium (21)	127	Indium (49)	313	Iridium (77)	545
Titanium (22)	133	Tin (50)	319	Platinum (78)	553
Vanadium (23)	141	Antimony (51)	327	Gold (79)	561
Chromium (24)	149	Tellurium (52)	335	Mercury (80)	569
Manganese (25)	157	Iodine (53)	343	Thallium (81)	577
Iron (26)	165	Xenon (54)	351	Lead (82)	583
Cobalt (27)	171	Caesium (55)	359	Bismuth (83)	591

# Hydrogen

## General properties

Atomic number	1	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	152	H1	99.985
Melting point / K	14.01	H2	0.015
Boiling point / K	20.28		
Density / kgm <sup>-3</sup>	8.988 10 <sup>-2</sup>		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	1.82 10 <sup>-1</sup>		
Electrical resistivity / Ωm	-		
Coefficient of thermal expansion / K <sup>-1</sup>	-		
Crystal structure	HCP		
Number of stable isotopes	2		
Mean atomic weight	1.0079		

## Activation properties

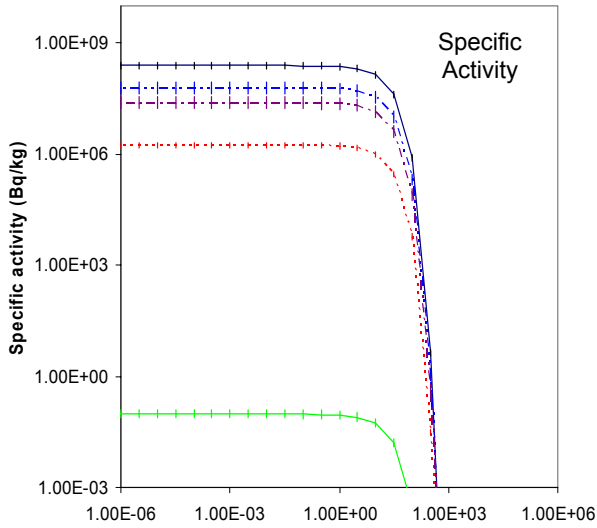
Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	2.43E8	2.43E8	2.43E8	2.30E8	8.80E5	0.00E0	kW kg <sup>-1</sup>	2.22E-10	2.22E-10	2.22E-10	2.10E-10	8.04E-13	0.00E0
H3	100.0	100.0	100.0	100.0	100.0		H3	100.0	100.0	100.0	100.0	100.0	
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	0.00E0	0.00E0	0.00E0	0.00E0	0.00E0	0.00E0	Sv kg <sup>-1</sup>	1.02E-2	1.02E-2	1.02E-2	9.65E-3	3.69E-5	0.00E0
							H3	100.0	100.0	100.0	100.0	100.0	
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	6.32E-2	6.32E-2	6.32E-2	5.97E-2	2.29E-4	0.00E0		2.43E3	2.43E3	2.43E3	2.30E3	8.80E0	0.00E0
H3	100.0	100.0	100.0	100.0	100.0		H3	100.0	100.0	100.0	100.0	100.0	

# Hydrogen

## Pathway analysis

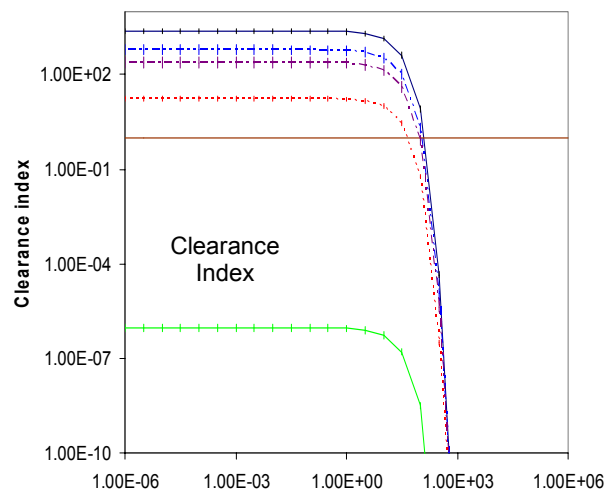
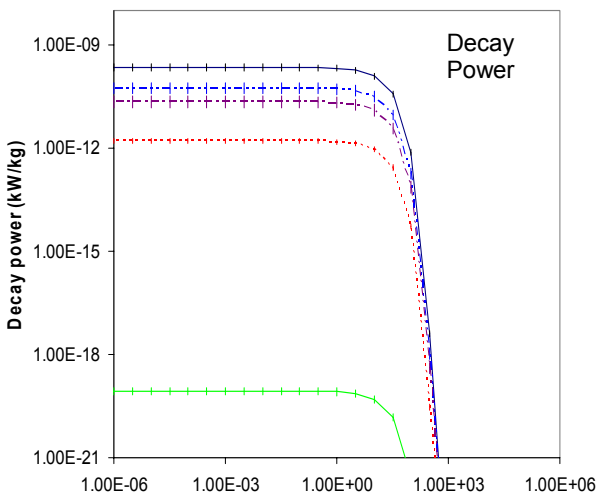
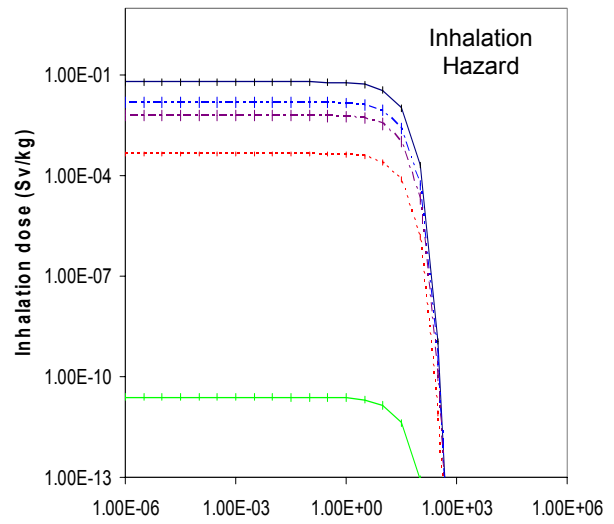
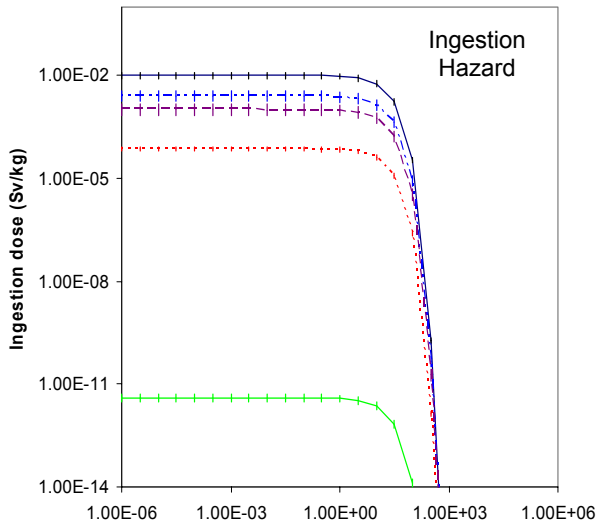
<b>Nuclide</b>	<b>T<sub>1/2</sub></b>	<b>Pathway</b>	<b>210</b>	<b>186</b>	<b>151</b>	<b>42</b>	<b>30</b>	<b>21</b>	<b>6</b>
H3	12.33 y	H1(n,γ)H2(n,γ)H3	89.7	64.8	10.3	1.6	1.3	1.2	1.0
		H2(n,γ)H3	1.5	27.2	87.7	98.3	98.7	98.8	99.0

# Hydrogen activation characteristics



Gamma  
Dose rate

*There is no  $\gamma$ -dose from tritium*

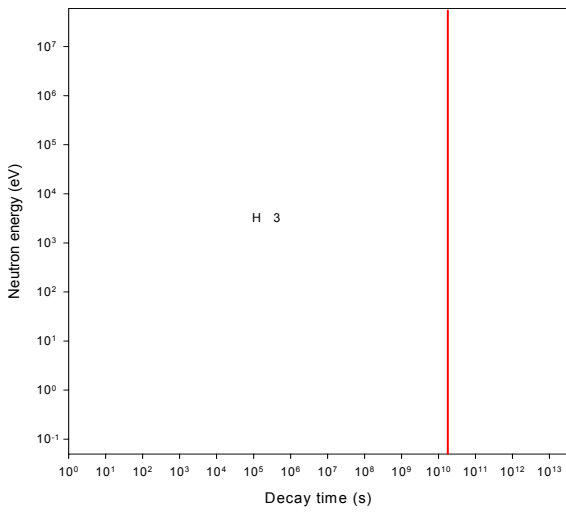


Decay time (years)

Decay time (years)

# Hydrogen importance diagrams & transmutation

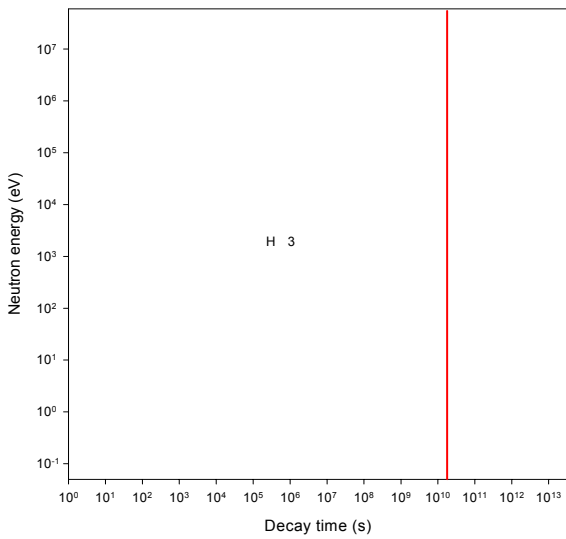
## Activity



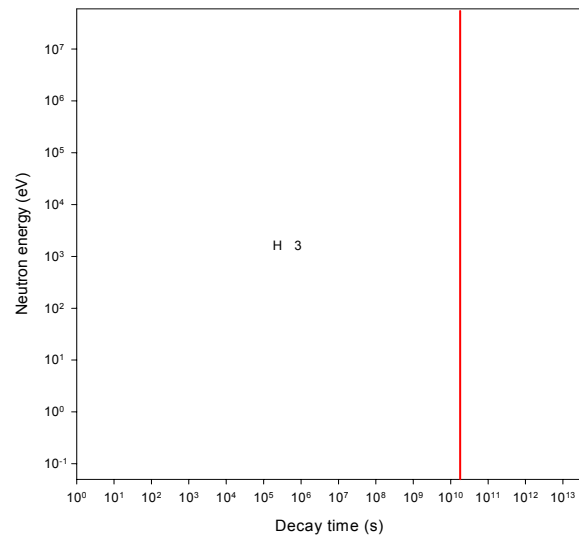
## Dose rate

*There is no  $\gamma$ -dose from tritium*

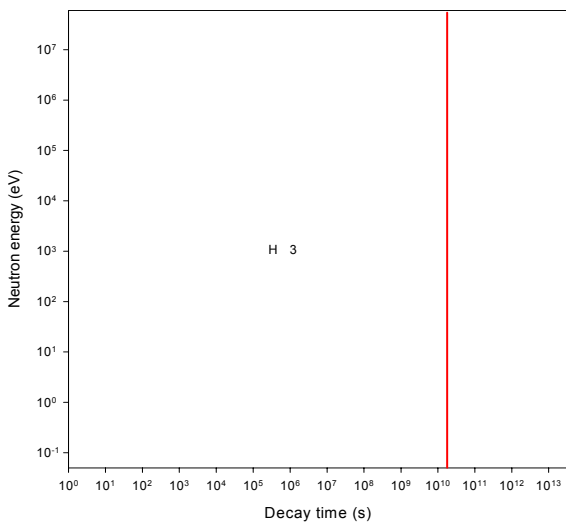
## Heat output



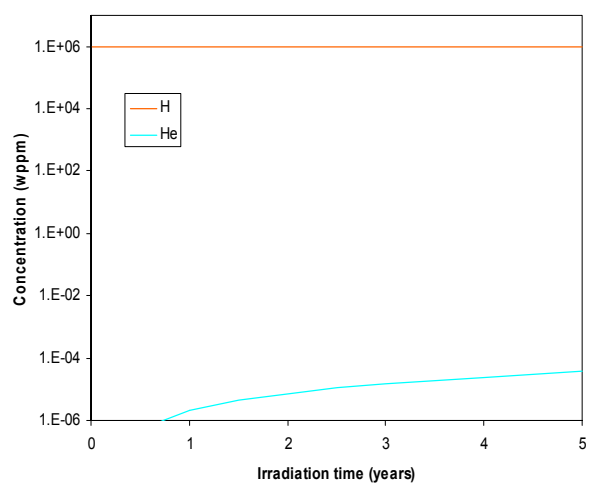
## Ingestion dose



## Inhalation dose



## First wall transmutation





# Helium

## General properties

Atomic number	2	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	$8.0 \cdot 10^{-3}$	He3	0.000137
Melting point / K	0.95*	He4	99.999863
Boiling point / K	4.216		
Density / $\text{kgm}^{-3}$	$1.785 \cdot 10^{-1}$		
Thermal conductivity / $\text{Wm}^{-1}\text{K}^{-1}$	$1.52 \cdot 10^{-1}$		
Electrical resistivity / $\Omega\text{m}$	-		
Coefficient of thermal expansion / $\text{K}^{-1}$	-		
Crystal structure	HCP		
Number of stable isotopes	2		
Mean atomic weight	4.0026		

\* under pressure

## Activation properties

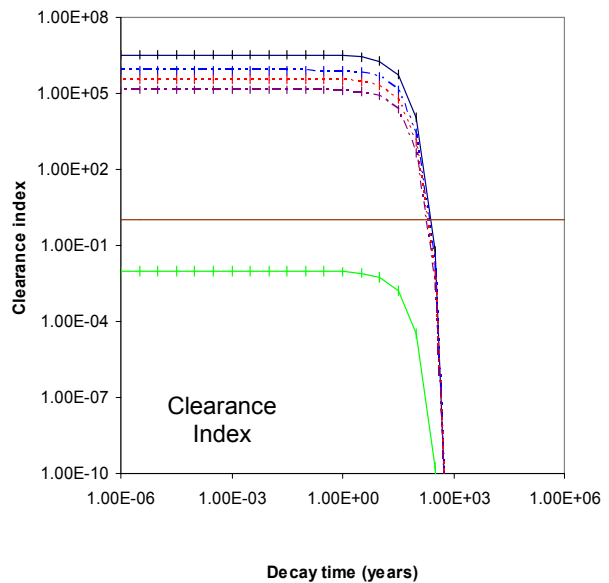
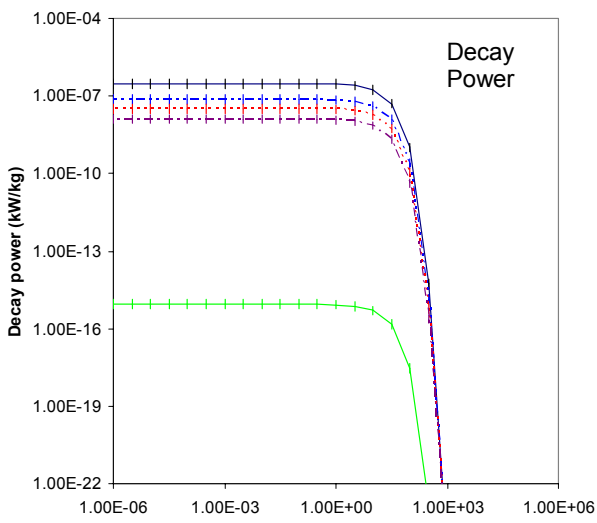
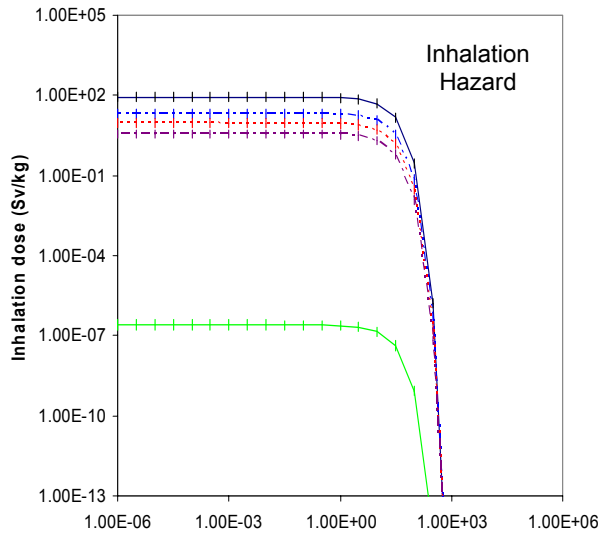
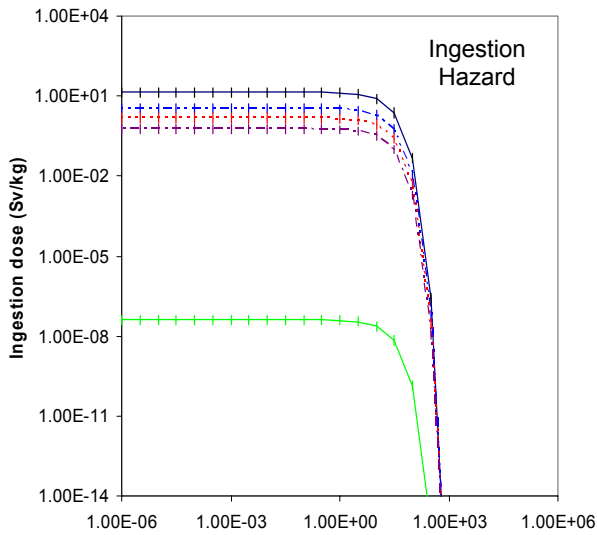
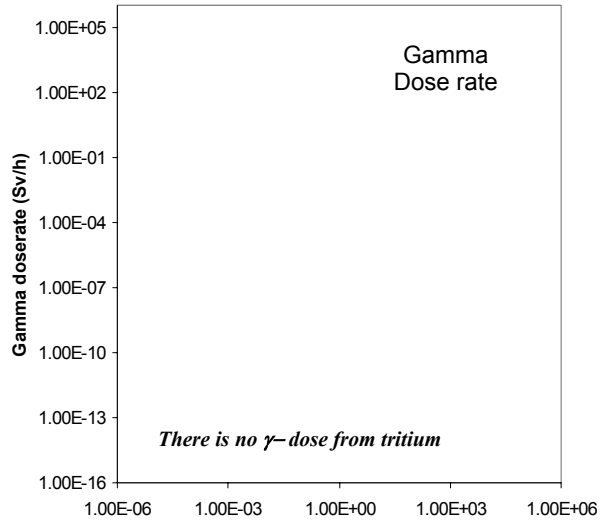
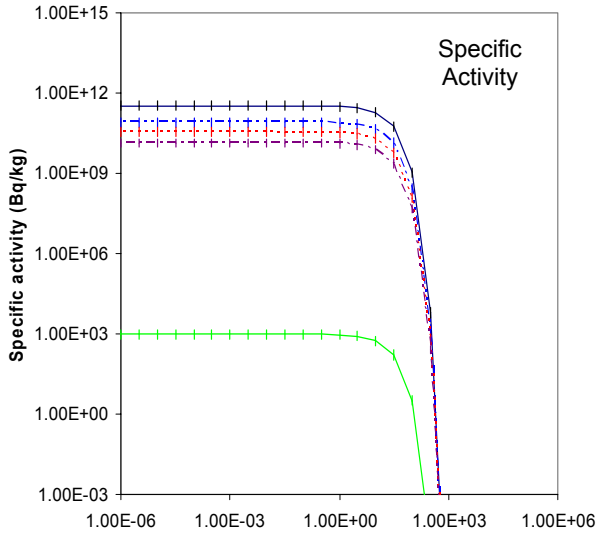
Act	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Heat	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Bq $\text{kg}^{-1}$	3.31E11	3.31E11	3.31E11	3.13E11	1.20E9	0.00E0	kW $\text{kg}^{-1}$	3.03E-7	3.03E-7	3.03E-7	2.86E-7	1.10E-9	0.00E0
H3	100.0	100.0	100.0	100.0	100.0		H3	100.0	100.0	100.0	100.0	100.0	
Dose	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Ing	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{h}^{-1}$	0.0E0	0.0E0	0.0E0	0.0E0	0.0E0	0.0E0	Sv $\text{kg}^{-1}$	1.39E1	1.39E1	1.39E1	1.31E1	5.03E-2	0.00E0
							H3	100.0	100.0	100.0	100.0	100.0	
Inh	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Clear	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{kg}^{-1}$	8.61E1	8.61E1	8.61E1	8.14E1	3.12E-1	0.00E0		3.31E6	3.31E6	3.31E6	3.13E6	1.20E4	0.00E0
H3	100.0	100.0	100.0	100.0	100.0		H3	100.0	100.0	100.0	100.0	100.0	

# Helium

## Pathway analysis

<b>Nuclide</b>	<b>T<sub>1/2</sub></b>	<b>Pathway</b>	<b>210</b>	<b>186</b>	<b>151</b>	<b>42</b>	<b>30</b>	<b>21</b>	<b>6</b>
H3	12.33 y	He3(n,p)H3 He4(n,2n)He3(n,p)H3	100.0	100.0	100.0	100.0	96.6 3.4	0.9 99.1	99.5

# Helium activation characteristics

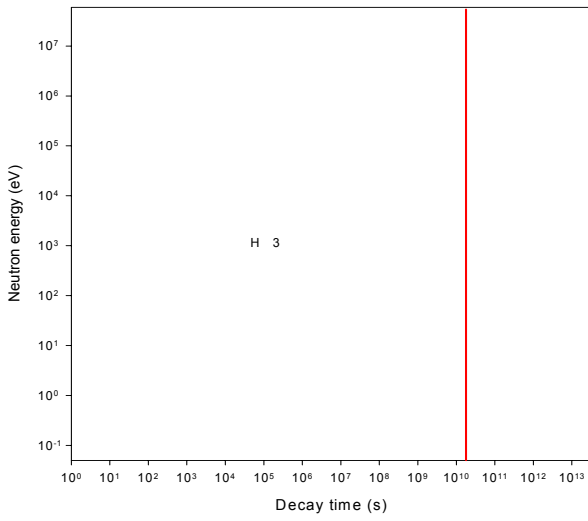


Decay time (years)

Decay time (years)

# Helium importance diagrams & transmutation

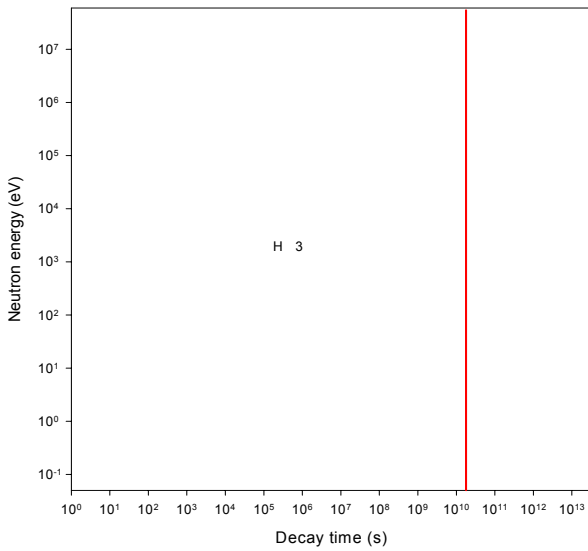
## Activity



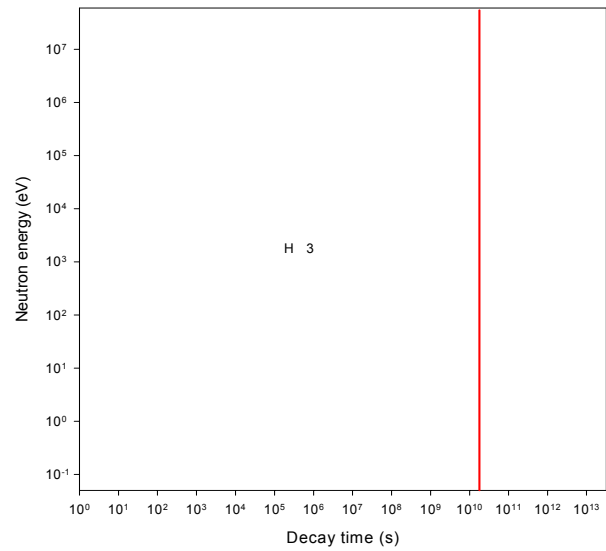
## Dose rate

*There is no  $\gamma$ -dose from tritium*

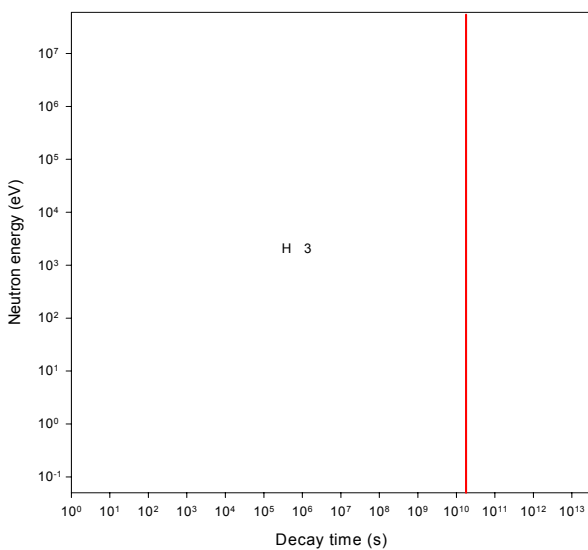
## Heat output



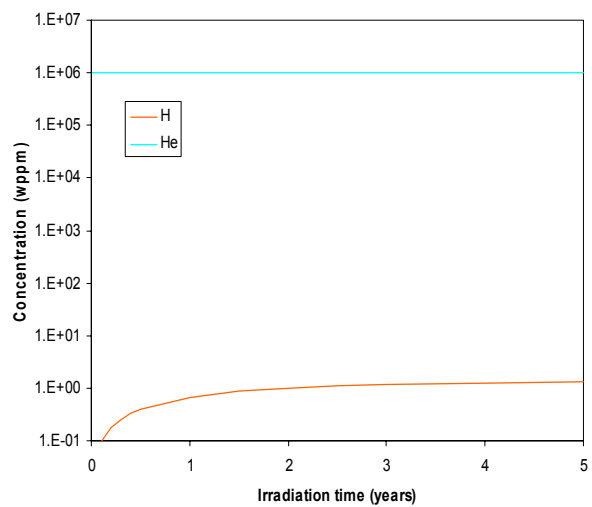
## Ingestion dose



## Inhalation dose



## First wall transmutation



# Lithium

## General properties

Atomic number	3	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	20.0	Li6	7.59
Melting point / K	453.7	Li7	92.41
Boiling point / K	1620		
Density / kgm <sup>-3</sup>	534.0		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	84.7		
Electrical resistivity /Ωm	8.55 10 <sup>-8</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	5.6 10 <sup>-5</sup>		
Crystal structure	BCC		
Number of stable isotopes	2		
Mean atomic weight	6.939		

## Activation properties

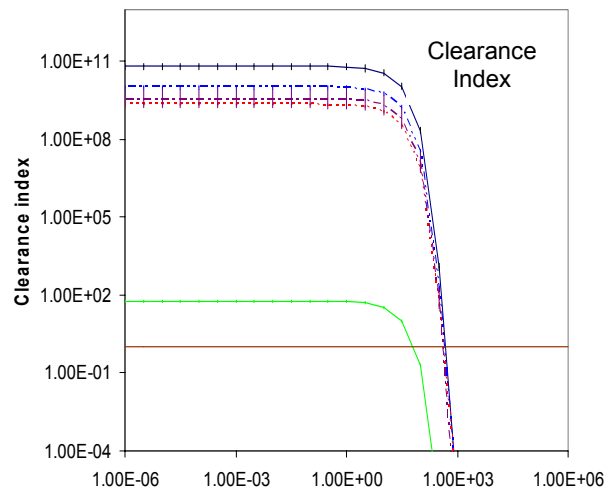
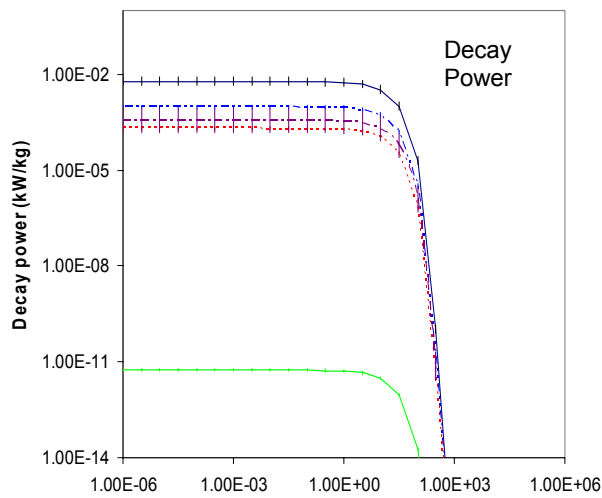
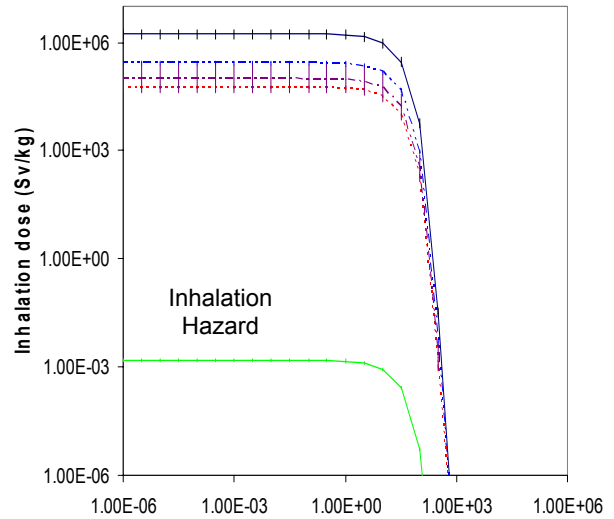
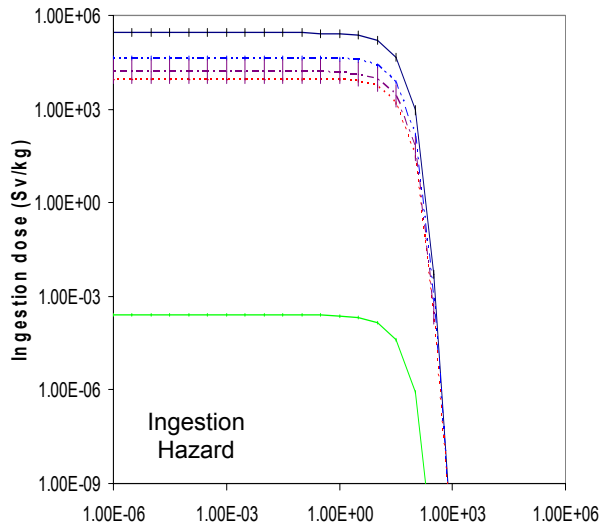
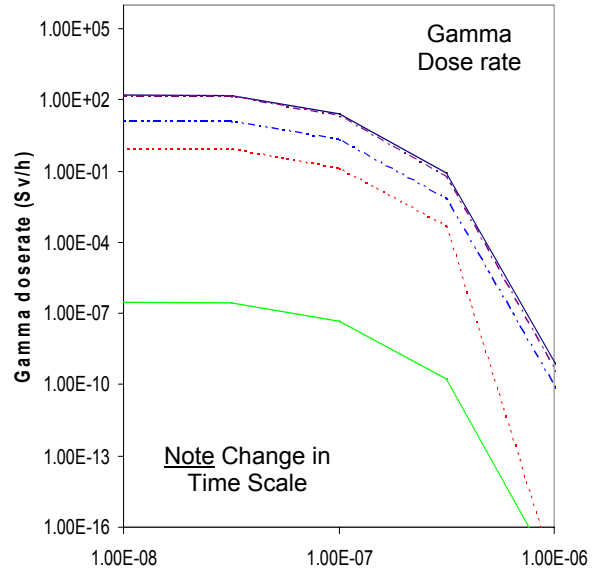
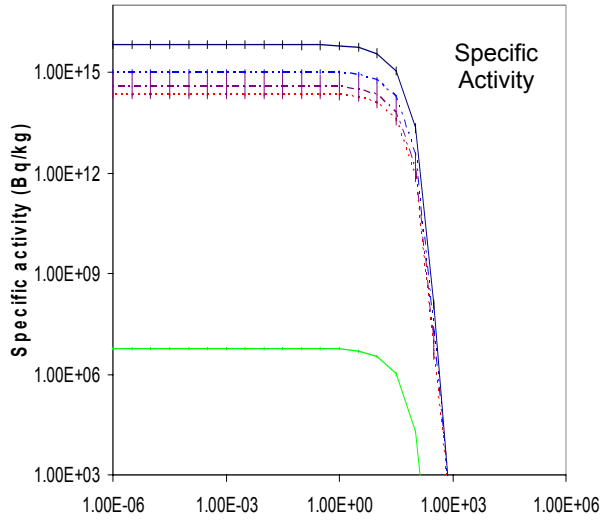
Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	6.70E15	6.53E15	6.53E15	6.17E15	2.36E13	0.00E0	kW kg <sup>-1</sup>	6.74E-2	5.97E-3	5.97E-3	5.65E-3	2.16E-5	0.00E0
H3	97.50	100.0	100.0	100.0	100.0		Li8	34.43					
He6	0.23						He6	56.73					
Li8	0.02						H3	00.89	100.0	100.0	100.0	100.0	
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	3.68E2	0.00E0	0.00E0	0.00E0	0.00E0	0.00E0	Sv kg <sup>-1</sup>	2.77E5	2.74E5	2.74E5	2.59E5	9.93E2	0.00E0
Li8	45.36						H3	100.0	100.0	100.0	100.0	100.0	
He6	54.64												
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	1.70E6	1.70E6	1.70E6	1.61E6	6.15E3	0.00E0		1.00E11	6.53E10	6.53E10	6.17E10	2.36E8	0.00E0
H3	100.0	100.0	100.0	100.0	100.0		H3	65.19	100.0	100.0	100.0	100.0	
							He6	24.51					
							Li8	10.29					

# Lithium

## Pathway analysis

Nuclide	$T_{1/2}$	Pathway	210	186	151	42	30	21	6
He6	0.808 s	Li7(n,d)He6 Li6(n,p)He6 Li7(n,2n)Li6(n,p)He6				96.4 3.2 0.3	99.1 0.8	95.9 3.6	98.1 1.7
Li8	0.838 s	Li7(n, $\gamma$ )Li8	100.0	100.0	100.0	100.0	100.0	100.0	100.0
H3	12.33 y	Li6(n, $\alpha$ )H3 Li6(n, $\alpha$ )H3( $\beta^-$ )He3(n,p)H3 Li7(n,n $\alpha$ )H3	76.0 24.0	85.6 14.4	97.8 2.2	0.7 99.2	0.5 99.4	5.2 94.4	5.3 94.4

# Lithium activation characteristics

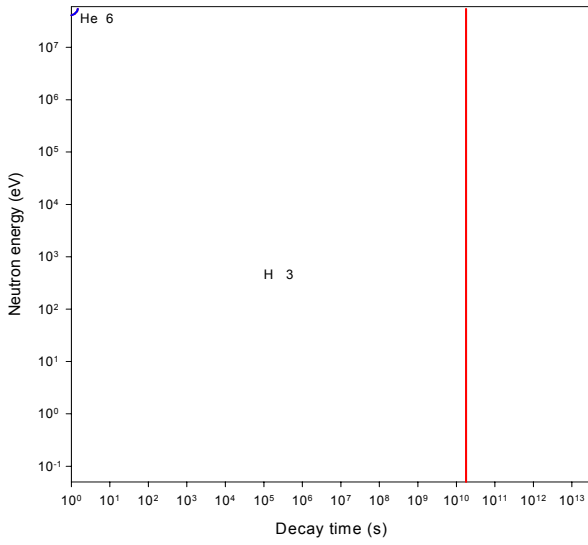


Decay time (years)

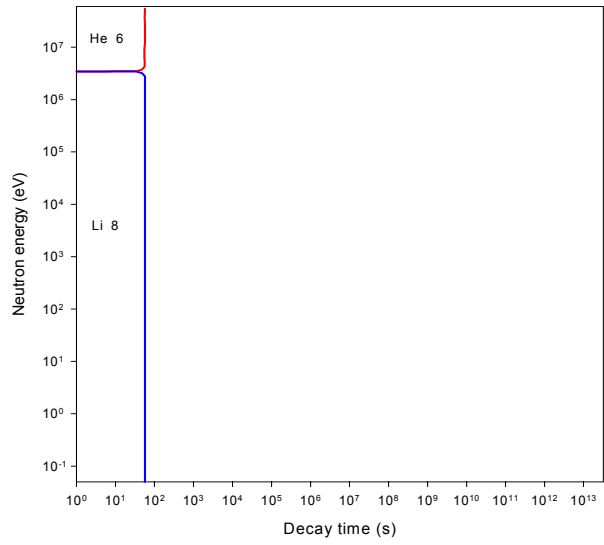
Decay time (years)

# Lithium importance diagrams & transmutation

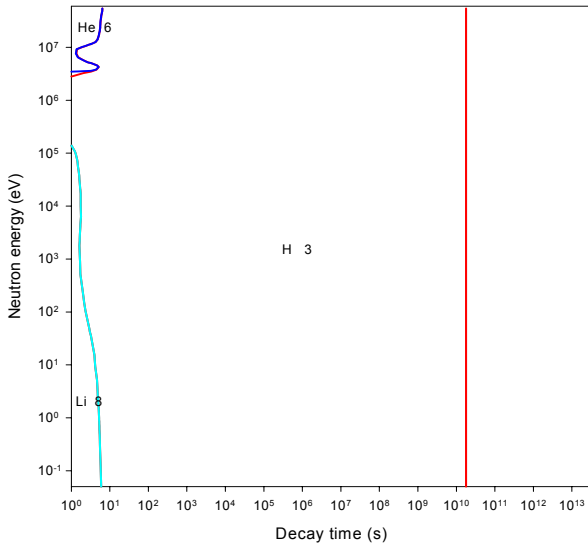
**Activity**



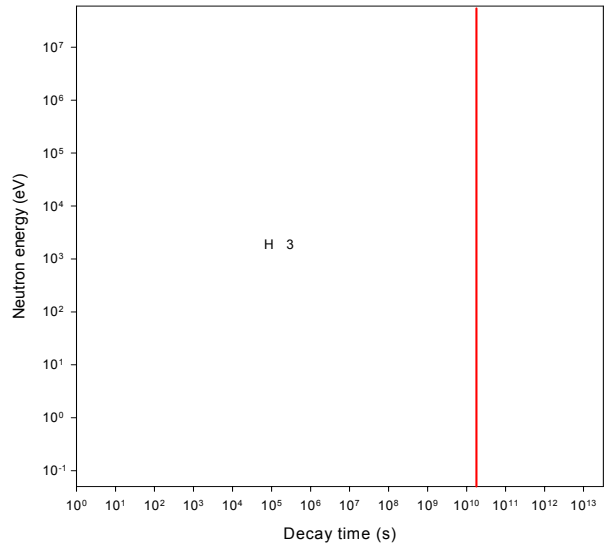
**Dose rate**



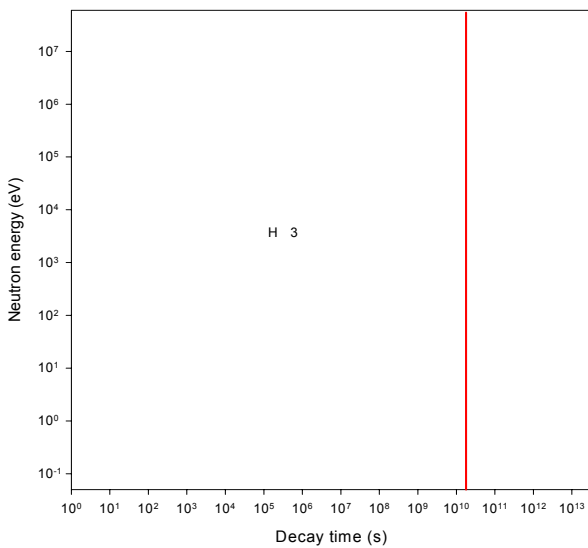
**Heat output**



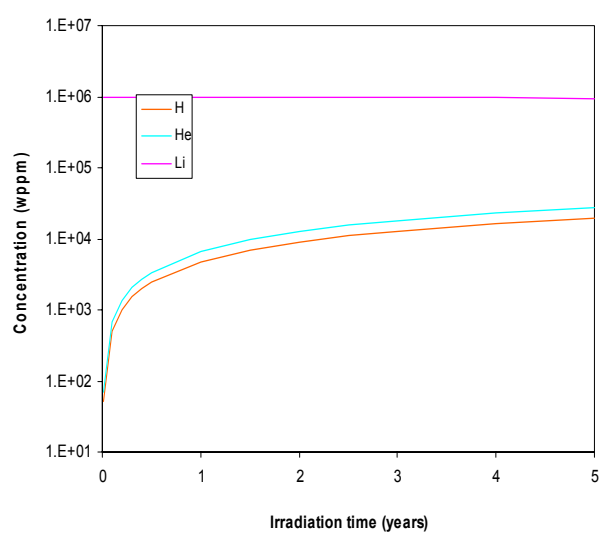
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**





# Beryllium

## General properties

Atomic number	4	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	2.6	Be9	100.0
Melting point / K	1551		
Boiling point / K	3243*		
Density / kgm <sup>-3</sup>	1848		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	200		
Electrical resistivity /Ωm	4.0 10 <sup>-8</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	1.15 10 <sup>-5</sup>		
Crystal structure	HCP		
Number of stable isotopes	1		
Mean atomic weight	9.0122		

\* under pressure

## Activation properties

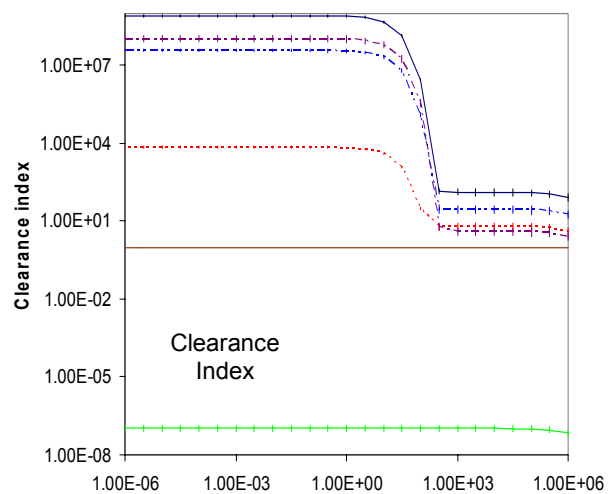
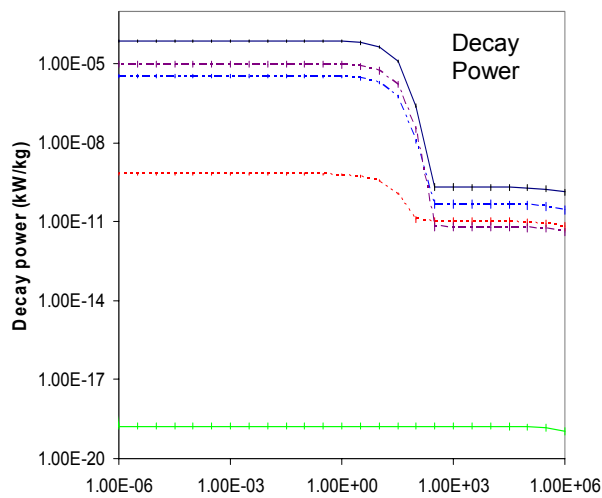
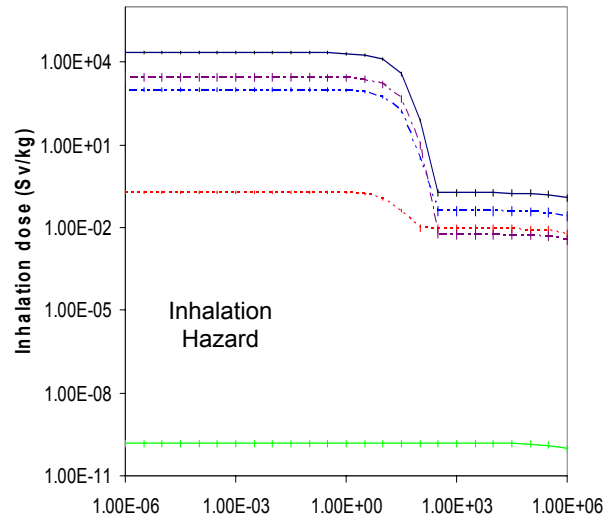
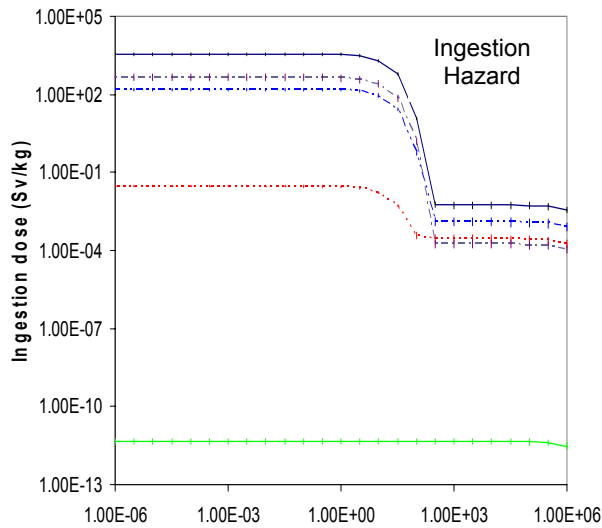
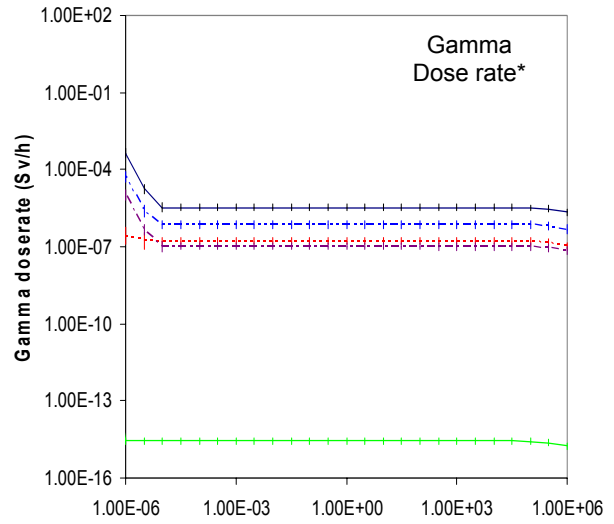
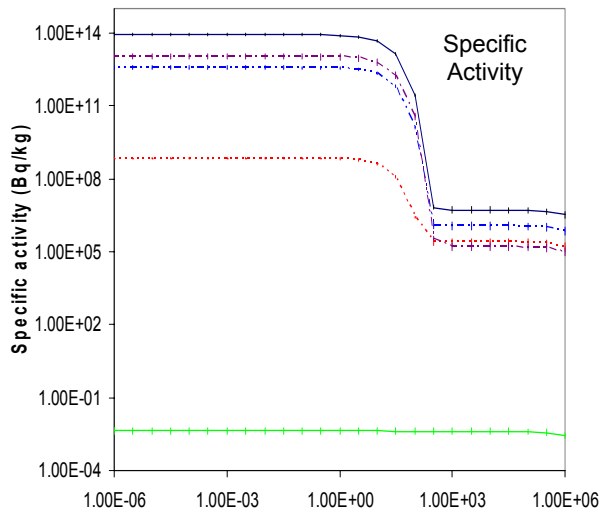
Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	5.54E14	8.37E13	8.37E13	7.91E13	3.03E11	4.92E6	kW kg <sup>-1</sup>	1.19E-1	7.65E-5	7.65E-5	7.24E-5	2.77E-7	1.99E-10
He6	84.80						He6	99.58					
H3	15.12	100.0	100.0	100.0	100.0		H3	0.07	100.0	100.0	100.0	99.92	
Be10						100.0	Be10					0.07	100.0
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	5.77E2	3.38E-6	3.38E-6	3.38E-6	3.38E-6	3.24E-6	Sv kg <sup>-1</sup>	1.06E4	3.52E3	3.51E3	3.32E3	1.27E1	5.42E-3
He6	99.27						H3	66.73	100.0	100.0	100.0	99.95	
Li9	0.72						He6	33.27					
Be10		100.0*	100.0*	100.0*	100.0*	100.0*	Be10					0.04	100.0
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	2.52E4	2.18E4	2.18E4	2.06E4	7.89E1	1.72E-1		7.69E10	8.37E8	8.37E8	7.91E8	3.03E6	1.23E2
H3	99.90	100.0	100.0	100.0	99.77		He6	99.61					
He6	0.10						H3	0.04	100.0	100.0	100.0	99.87	
Be10					0.23	100.0	Be10					0.13	100.0

# Beryllium

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
He6	0.808 s	Be9(n,α)He6				99.3	90.8	37.3	39.0
		Be9(n,t)Li7(n,d)He6					9.1	55.9	57.9
		Be9(n,nt)Li6(n,p)He6						6.6	3.0
Li8	0.838 s	Be9(n,γ)Be10(β <sup>-</sup> )B10(n,α)Li7(n,γ)Li8	57.2	96.9					
		Be9(n,γ)Be10(n,γ)Be11(β <sup>-</sup> α)Li7(n,γ)Li8	43.3	3.1					
		Be9(n,t)Li7(n,γ)Li8				100.0			
		Be9(n,d)Li8					100.0	100.0	100.0
Be11	13.81 s	Be9(n,γ)Be10(n,γ)Be11	100.0	100.0	100.0	100.0	100.0	100.0	100.0
H3	12.33 y	Be9(n,γ)Be10(β <sup>-</sup> )B10(n,2α)H3	92.3	94.0	99.3				
		Be9(n,γ)Be10(β <sup>-</sup> )B10(n,2α)H3(β <sup>-</sup> )He3(n,p)H3	8.6	6.0	0.7				
		Be9(n,X)H3				97.5	98.6	99.1	99.7
		Be9(n,t)Li7(n,nα)H3				2.3	1.4	0.7	
Be10	1.6 10 <sup>6</sup> y	Be9(n,γ)Be10	100.0	100.0	100.0	100.0	100.0	100.0	100.0

# Beryllium activation characteristics

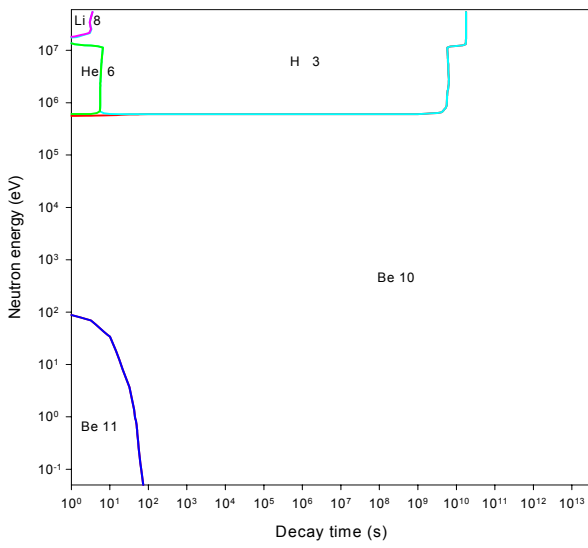


Decay time (years)

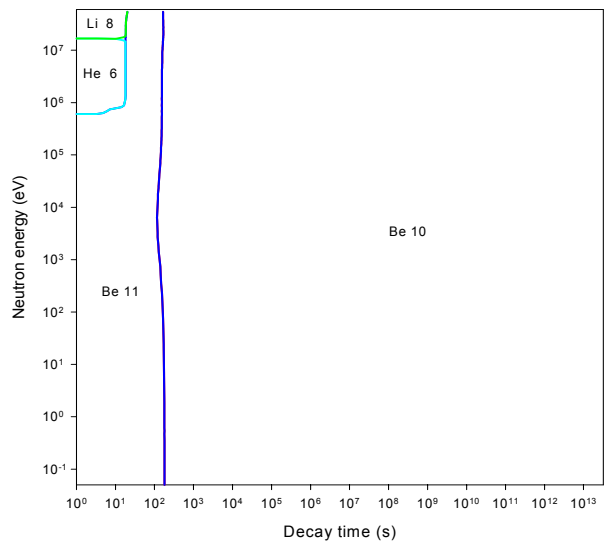
Decay time (years)

# Beryllium importance diagrams & transmutation

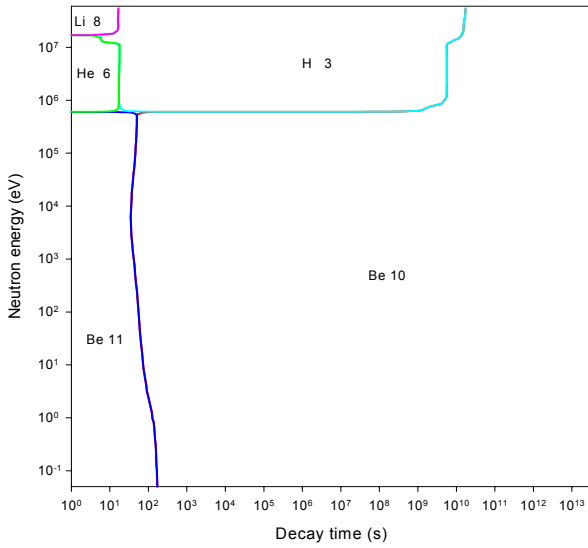
**Activity**



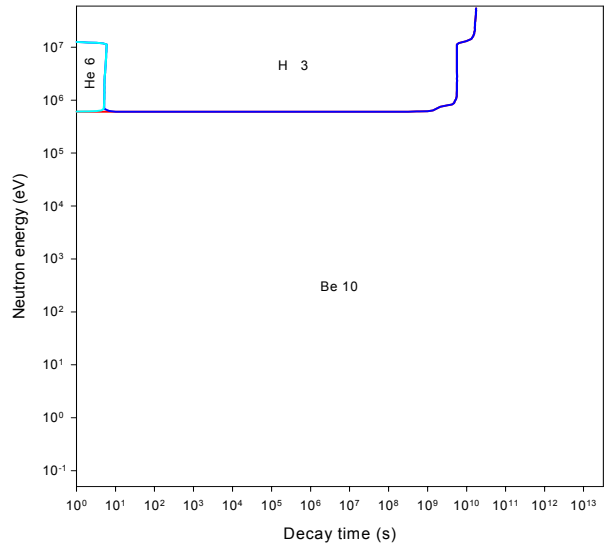
**Dose rate**



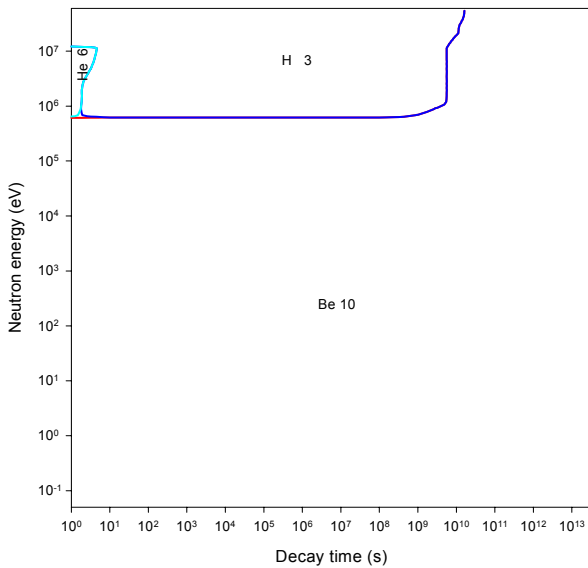
**Heat output**



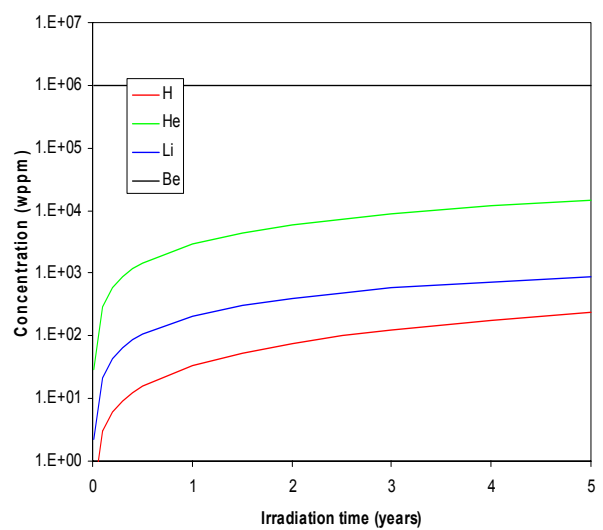
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**



# Boron

## General properties

Atomic number	5	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	10	B10	19.8
Melting point / K	2573	B11	80.2
Boiling point / K	3931		
Density / kgm <sup>-3</sup>	2340		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	27.0		
Electrical resistivity / Ωm	1.80 10 <sup>4</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	5.0 10 <sup>-5</sup>		
Crystal structure	tetragonal		
Number of stable isotopes	2		
Mean atomic weight	10.811		

## Activation properties

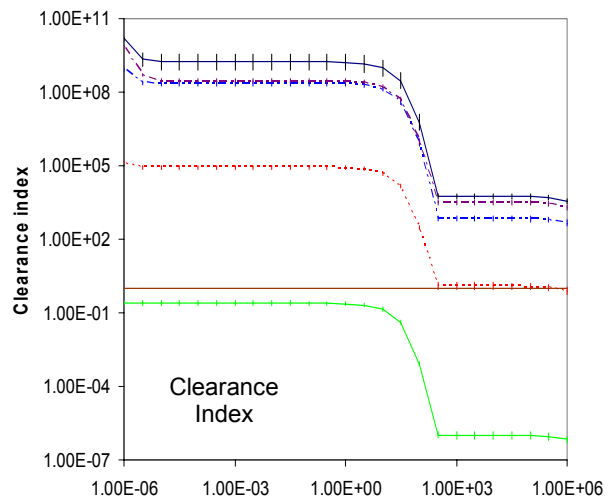
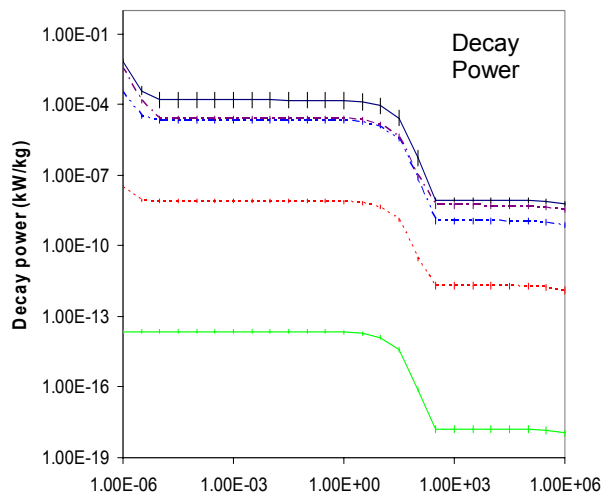
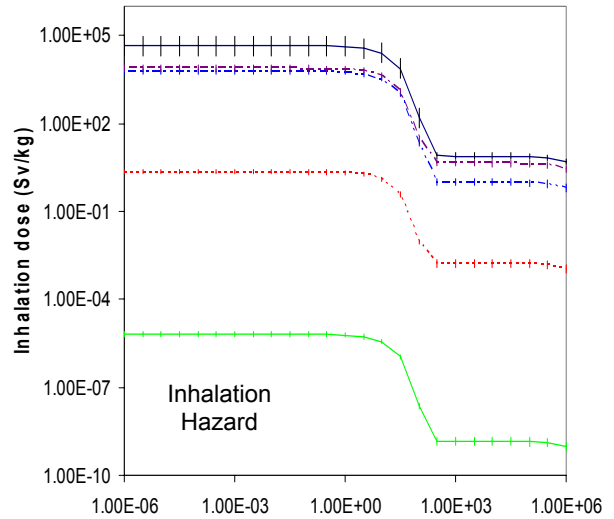
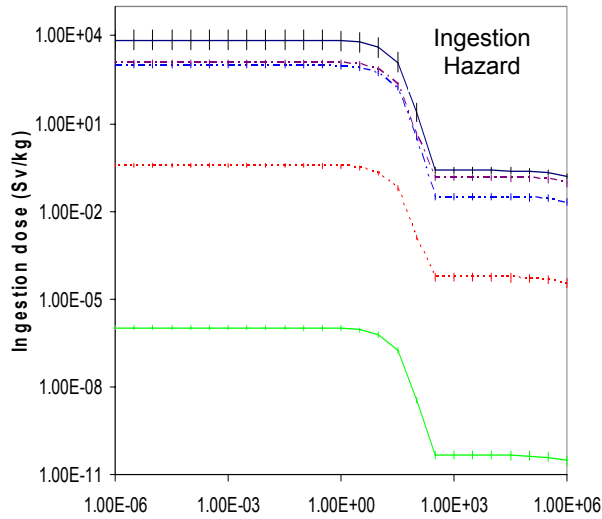
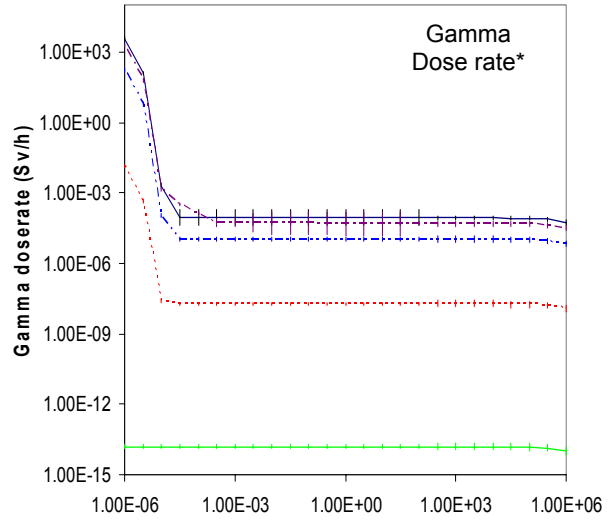
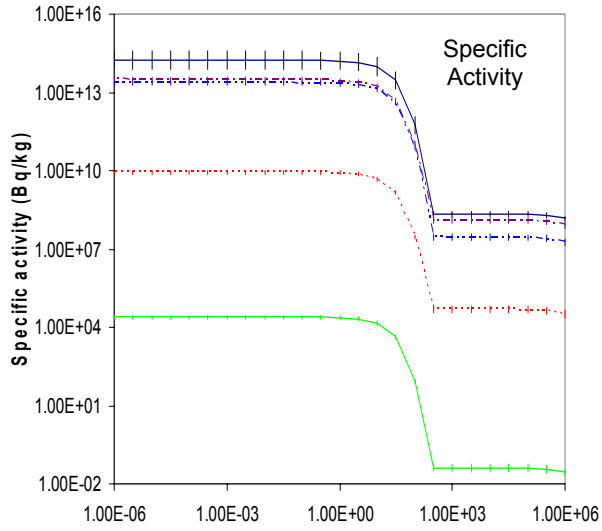
Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	4.48E14	1.71E14	1.71E14	1.62E14	6.21E11	2.16E8	kW kg <sup>-1</sup>	3.72E-1	1.57E-4	1.57E-4	1.48E-4	5.76E-7	8.72E-9
Li8	49.29						Li8	88.95					
H3	38.26	100.0	100.0	100.0	99.96		Be11	9.21					
Be11	7.82						B12	0.53					
He6	4.20						H3	0.04	99.99	99.99	99.99	98.39	
Be10						100.0	Be10		0.01	0.01	0.01	1.61	100.0
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	2.10E4	2.56E-3	8.44E-5	8.44E-5	8.44E-5	8.08E-5	Sv kg <sup>-1</sup>	7.52E3	7.20E3	7.20E3	6.81E3	2.63E1	2.37E-1
Be11	89.21	96.62					H3	95.80	100.0	100.0	100.0	99.04	
Li8	10.49						He6	3.76					
Be10		3.38*	100.0*	100.0*	100.0*	100.0*	Be10					0.96	100.0
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	4.47E4	4.46E4	4.46E4	4.21E4	1.69E2	7.55E0		2.20E11	1.71E9	1.71E9	1.62E9	6.21E6	5.40E3
H3	99.62	99.98	99.98	99.98	95.24		Li8	67.07					
He6	0.3						Be11	30.15	0.02				
Be11	0.02						H3	0.08	99.98	99.99	99.99	97.29	
Be10	0.02	0.02	0.02	0.02	4.76	100.0	Be10		0.01	0.01	0.01	2.71	100.0

# Boron

## Pathway analysis

Nuclide	$T_{1/2}$	Pathway	210	186	151	42	30	21	6
He6	0.808s	B11(n,n $\alpha$ )Li7(n,d)He6				48.3	13.8	8.2	7.2
		B11(n,d)Be10(n,n $\alpha$ )He6				13.0	6.7	4.8	4.2
		B10(n,n $\alpha$ )Li6(n,p)He6				10.5	0.7	2.8	1.8
		B10(n, $\alpha$ )Li7(n,d)He6				8.1	0.5		
		B11(n,t)Be9(n, $\alpha$ )He6				7.8	0.8		
		B10(n,p)Be10(n,n $\alpha$ )He6				7.0			
		B10(n,d)Be9(n, $\alpha$ )He6				4.5			
		B11(n,d $\alpha$ )He6					76.9	81.9	85.2
		B11(n,2n $\alpha$ )Li6(n,p)He6						1.6	1.2
Li8	0.838 s	B10(n, $\alpha$ )Li7(n, $\gamma$ )Li8	100.0	100.0	100.0				
		B11(n, $\alpha$ )Li8				99.9	43.3	23.2	8.5
		B10(n,h)Li8					38.7	52.4	66.8
		B11(n,t)Be9(n,d)Li8					9.0	19.5	20.5
		B11(n,d)Be10(n,t)Li8					6.4	2.7	2.5
		B11(n,2n)B10(n,h)Li8					1.5	1.2	0.7
		B10(n,d)Be9(n,d)Li8					0.8	0.9	0.8
Be11	13.81 s	B10(n,p)Be10(n, $\gamma$ )Be11	100.0	100.0	100.0				
		B11(n,p)Be11				100.0	100.0	100.0	100.0
C11	20.37 m	B11(n, $\gamma$ )B12( $\beta^-$ )C12(n,2n)C11					100.0	100.0	100.0
H3	12.33 y	B10(n,2 $\alpha$ )H3	65.4	80.3	97.6	53.0	33.0	34.3	29.1
		B10(n,2 $\alpha$ )H3( $\beta^-$ )He3(n,p)H3	21.0	19.7	2.4				
		B11(n,n2 $\alpha$ )H3				42.1	59.0	57.4	64.0
		B11(n,n $\alpha$ )Li7(n,n $\alpha$ )H3				3.6	3.9	2.2	0.9
		B10(n, $\alpha$ )Li7(n,n $\alpha$ )H3				0.6			
		B11(n,d)Be10(n,n $\alpha$ )H3					2.0	0.9	0.8
		B11(n,t)Be9(n,t $\alpha$ )H3					0.8	2.7	3.4
		B11(n,2n)B10(n,2 $\alpha$ )H3					0.7		
		B10(n,n $\alpha$ )Li6(n, $\alpha$ )H3						1.1	0.7
B11(n,2n $\alpha$ )Li6(n, $\alpha$ )H3						0.6	0.5		
Be10	1.6 10 <sup>6</sup> y	B10(n,p)Be10	100.0	100.0	100.0	34.9	3.6	3.2	2.7
		B11(n,d)Be10				64.7	96.3	96.8	97.3

# Boron activation characteristics

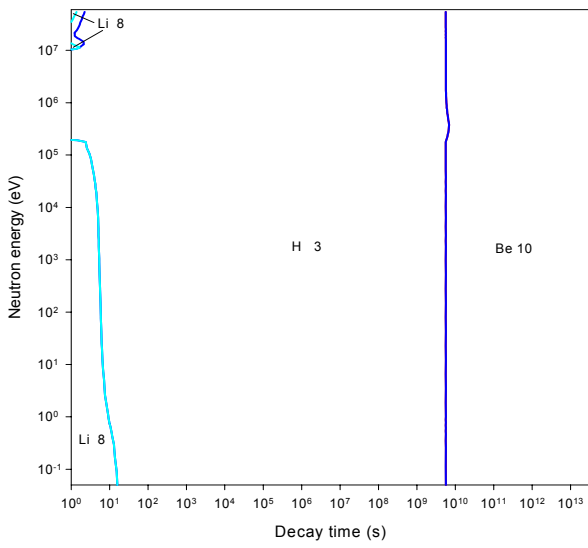


Decay time (years)

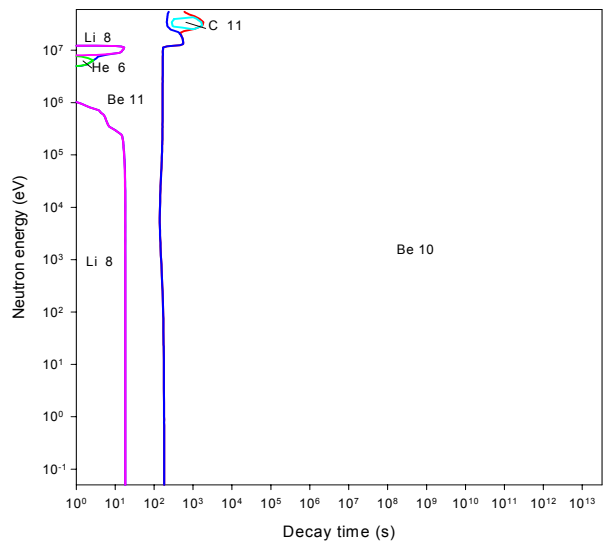
Decay time (years)

# Boron importance diagrams & transmutation

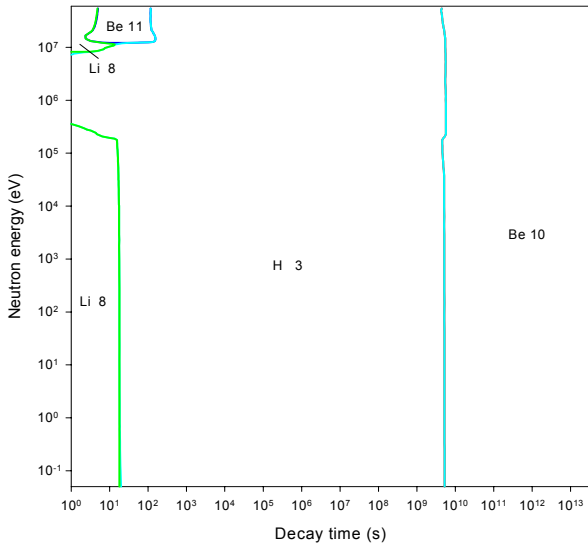
**Activity**



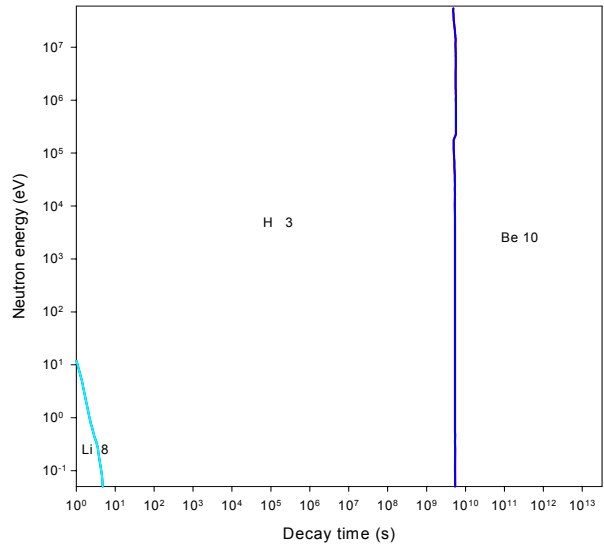
**Dose rate**



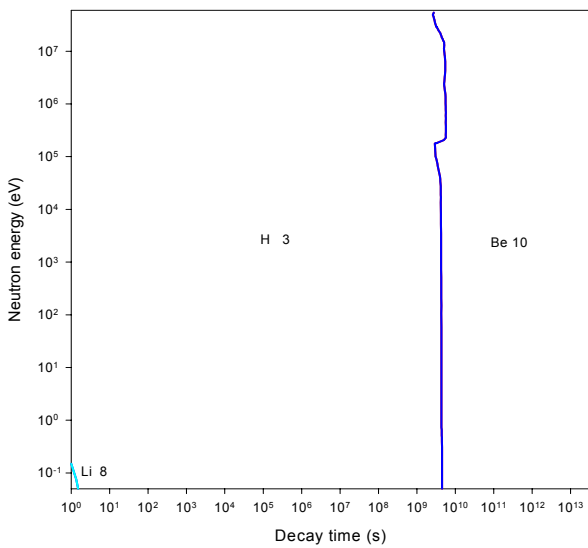
**Heat output**



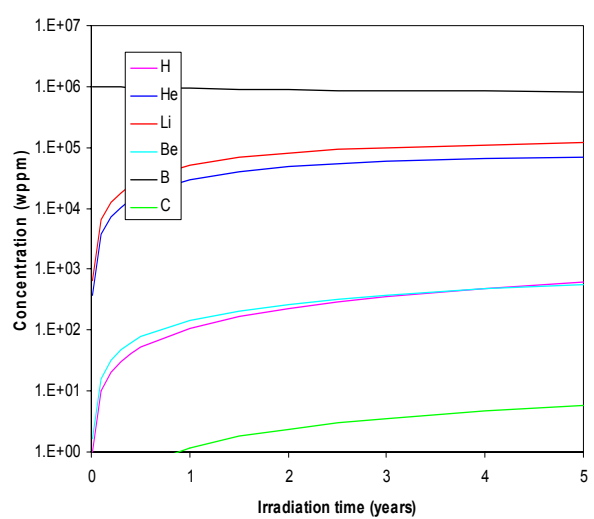
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**





# Carbon

## General properties

Atomic number	6	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	480	C12	98.89
Melting point / K	3820 (d)	C13	1.11
Boiling point / K	5100 (subl)	C14	Trace ( $T_{1/2} = 5700$ y)
Density / $\text{kgm}^{-3}$	1400 (a) 2260 (g) 3513 (d)		
Thermal conductivity / $\text{Wm}^{-1}\text{K}^{-1}$	4.2 (a) 5.7-1960 (g) 990-2320 (d)		
Electrical resistivity / $\Omega\text{m}$	$1.357 \cdot 10^{-5}$ (g) $1.0 \cdot 10^{11}$ (d)		
Coefficient of thermal expansion / $\text{K}^{-1}$	$1.19 \cdot 10^{-6}$ (d)		
Crystal structure	Hexagonal (g) Cubic (d)		
Number of stable isotopes	2 (3)		
Mean atomic weight	12.011		

(d) = diamond, (g) = graphite, (a) = amorphous, (subl) = sublimes

## Activation properties

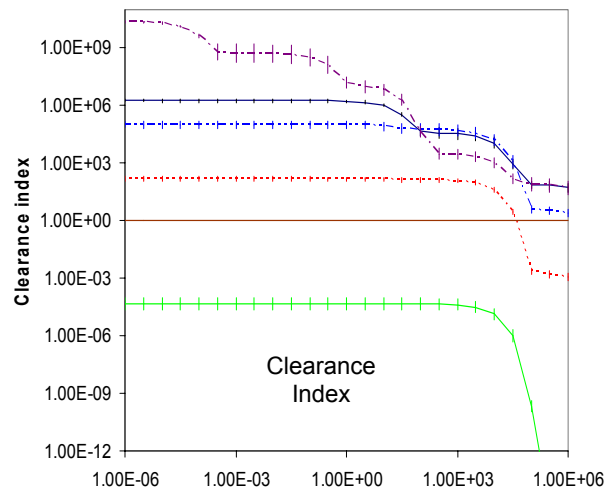
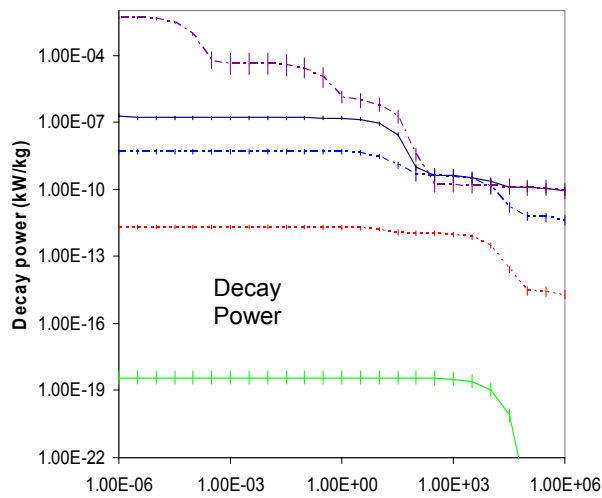
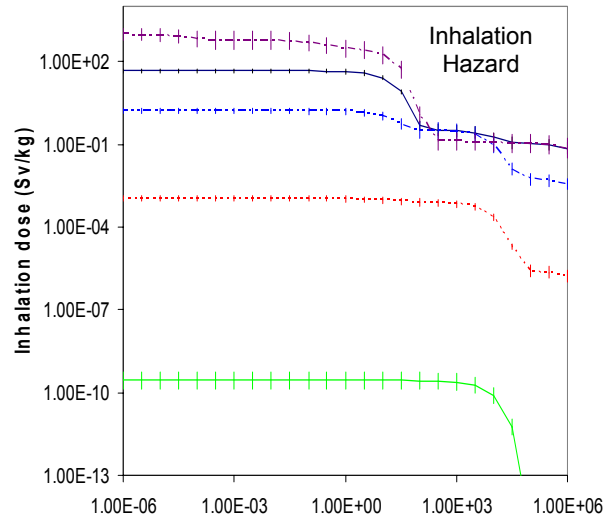
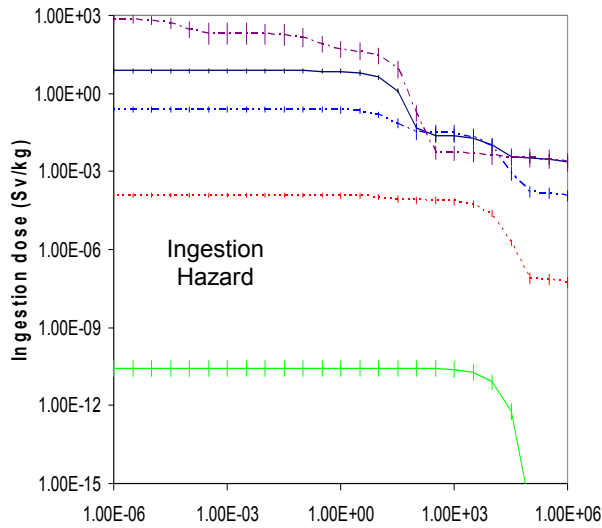
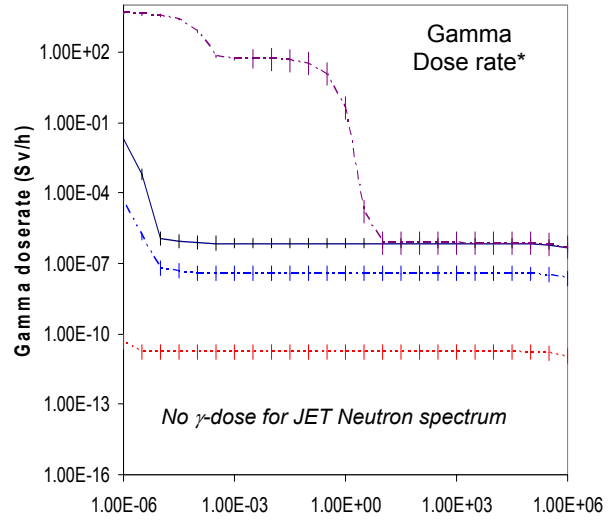
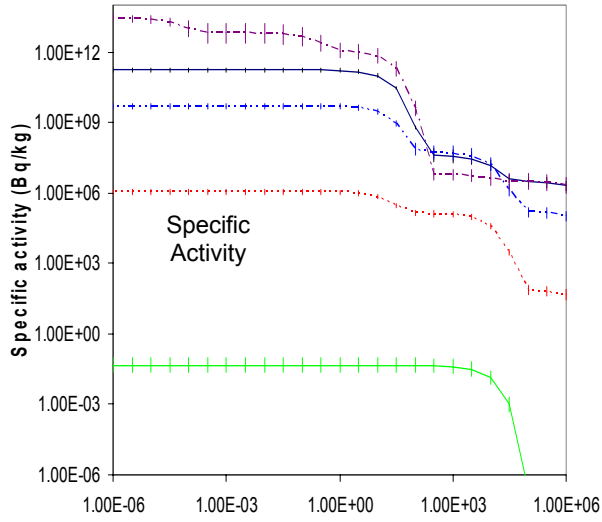
Act	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Heat	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Bq $\text{kg}^{-1}$	4.93E12	1.75E11	1.74E11	1.65E11	6.73E8	3.03E6	kW $\text{kg}^{-1}$	4.35E-3	1.60E-7	1.60E-7	1.51E-7	1.01E-9	1.22E-10
B12	49.81						B12	57.90					
B13	31.51						B13	37.75					
He6	15.09						He6	4.29					
H3	3.54	99.98	99.98	99.97	93.87		H3		99.73	99.73	99.71	57.35	
C14		0.02	0.02	0.02	5.66		C14		0.19	0.19	0.20	29.97	
Be10		0.01	0.01	0.01	0.46	100.0	Be10		0.08	0.08	0.08	12.68	100.0
Dose	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Ing	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{h}^{-1}$	2.00E2	1.10E-6	7.24E-7	7.24E-7	7.24E-7	6.93E-7	Sv $\text{kg}^{-1}$	1.85E1	7.35E0	7.35E0	6.95E0	5.21E-2	3.33E-3
B13	74.63						He6	60.21					
B12	24.93						H3	39.57	99.65	99.65	99.63	50.92	
Be11	0.05	0.36					C14	0.12	0.30	0.30	0.32	42.40	
Be10		89.90*	100.0*	100.0*	100.0*	100.0*	B12	0.09					
N13		9.75					Be10	0.04	0.05	0.05	0.05	6.67	100.0
Inh	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Clear	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{kg}^{-1}$	5.11E1	4.57E1	4.57E1	4.32E1	4.96E-1	1.06E-1		1.78E6	1.78E6	1.69E6	4.45E4	7.58E1	3.56E2
H3	88.72	99.27	99.27	99.23	33.13		B12	53.32					
He6	10.61						B13	42.93					
C14	0.44	0.49	0.49	0.52	44.56		He6	3.67					
Be10	0.22	0.24	0.24	0.26	22.31	100.0	H3	0.05	97.83	97.83	97.71	14.20	
							C14		2.16	2.16	2.28	85.62	0.27
							Be10					0.18	99.73

# Carbon

## Pathway analysis

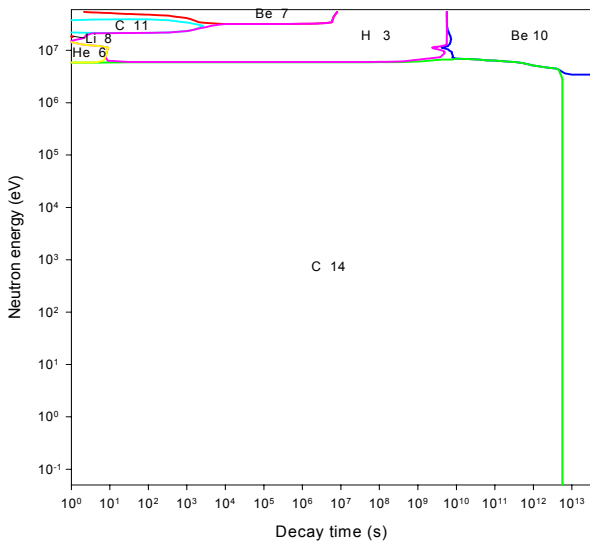
Nuclide	$T_{1/2}$	Pathway	210	186	151	42	30	21	6	
He6	0.808 s	C12(n, $\alpha$ )Be9(n, $\alpha$ )He6				98.8	2.4		0.1	
		C13(n, $\alpha$ )Be10(n, $n\alpha$ )He6				0.5				
		C12(n,d)B11(n,d $\alpha$ )He6					59.4	10.6	2.7	
		C13(n,2 $\alpha$ )He6					12.1	1.4	0.3	
		C12(n,d $\alpha$ )Li7(n,d)He6					7.8	42.3	38.9	
		C12(n,h)Be10(n, $n\alpha$ )He6					5.3	3.6	6.1	
		C12(n,d)B11(n, $n\alpha$ )Li7(n,d)He6					5.3	0.5	0.1	
		C12(n,2n)C11( $\beta^+$ )B11(n,d $\alpha$ )He6					2.8	1.2	0.4	
		C12(n,d)B11(n,d)Be10(n, $n\alpha$ )He6					2.6	0.3		
		C12(n,h $\alpha$ )He6							30.3	36.2
		C12(n,2 $n\alpha$ )Be7( $\beta^+$ )Li7(n,d)He6							5.5	10.6
C12(n,t $\alpha$ )Li6(n,p)He6							3.2	3.5		
Li8	0.838 s	C13(n,t)B11(n, $\alpha$ )Li8				84.0				
		C12(n,d)B11(n, $\alpha$ )Li8				15.6	36.5	1.2	0.2	
		C12(n, $\alpha$ )Be9(n,d)Li8					29.7	3.7	15.3	
		C12(n,t)B10(n,h)Li8					9.4	3.7	4.6	
		C12(n,h)Be10(n,t)Li8					5.6	0.8	2.6	
		C13(n, $n\alpha$ )Be9(n,d)Li8					5.3	0.4	0.3	
		C12(n,d)B11(n,t)Be9(n,d)Li8					3.8	0.5	0.2	
		C12(n,p $\alpha$ )Li8					3.6	89.1	74.9	
		C12(n,d)B11(n,d)Be10(n,t)Li8					2.8			
		C12(n,2n)C11( $\beta^+$ )B11(n, $\alpha$ )Li8					1.7	0.1		
		C12(n,d)B11(n,2n)B10(n,h)Li8					0.6			
		C12(n,d)B11(n, $\alpha$ )Li8							1.2	
		C13(n,d $\alpha$ )Li8								1.6
C15	2.449 s	C13(n, $\gamma$ )C14(n, $\gamma$ )C15	99.2	100.0	100.0	99.4	98.4	99.3	99.7	
		C12(n, $\gamma$ )C13(n, $\gamma$ )C14(n, $\gamma$ )C15	0.8				0.2	0.1		
Be11	13.81 s	C13(n,t)B11(n,p)Be11				83.5	0.2			
		C12(n,d)B11(n,p)Be11				15.5	95.3	3.5	0.4	
		C13(n, $\alpha$ )Be10(n, $\gamma$ )Be11				0.5				
		C12(n,2n)C11( $\beta^+$ )B11(n,p)Be11					4.4	0.4		
		C12(n,2p)Be11						95.7	97.7	
C13(n,h)Be11							0.3	1.8		
C11	20.37 m	C12(n,2n)C11					99.9	99.3	98.4	
		C13(n,3n)C11						0.7	1.6	
Be7	53.22 d	C12(n,2 $n\alpha$ )Be7						99.7	99.5	
H3	12.33 y	C13(n, $\gamma$ )C14( $\beta^-$ )N14(n,X)H1(n, $\gamma$ )H2(n, $\gamma$ )H3	95.3	97.2						
		C12(n, $\alpha$ )Be9(n,X)H3				63.8	0.2	0.3	0.4	
		C13(n,t2 $\alpha$ )H3				34.7	0.6	0.8	0.7	
		C12(n, $\alpha$ )Be9(n,t)Li7(n, $n\alpha$ )H3				1.0				
		C12(n,d2 $\alpha$ )H3					95.8	93.6	97.6	
		C12(n,d)B11(n,n2 $\alpha$ )H3					2.2	0.9	0.1	
C12(n,d $\alpha$ )Li7(n, $n\alpha$ )H3						0.2	2.5	0.5		
C14	5700 y	C13(n, $\gamma$ )C14	99.2	100.0	100.0	99.5	98.4	99.3	99.7	
		C12(n, $\gamma$ )C13(n, $\gamma$ )C14	0.8				0.2	0.1		
Be10	1.6 10 <sup>6</sup> y	C13(n, $\alpha$ )Be10				99.5	1.2	0.3	0.6	
		C12(n,h)Be10					64.9	90.6	98.0	
		C12(n,d)B11(n,d)Be10					31.9	7.7	1.1	
		C12(n,2n)C11( $\beta^+$ )B11(n,d)Be10					1.5	0.9	0.2	

# Carbon activation characteristics

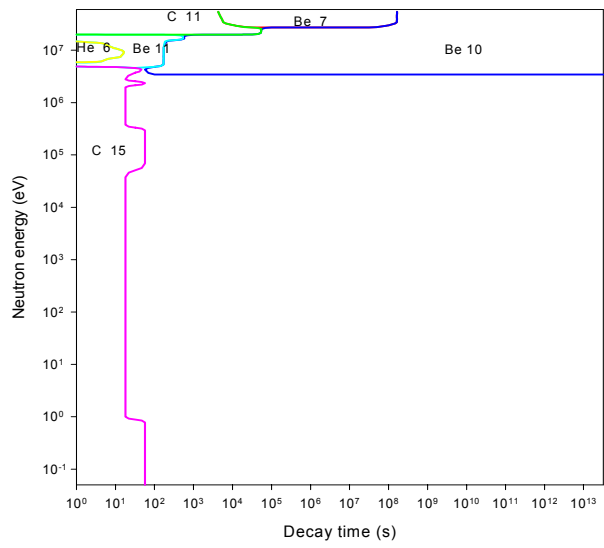


# Carbon importance diagrams & transmutation

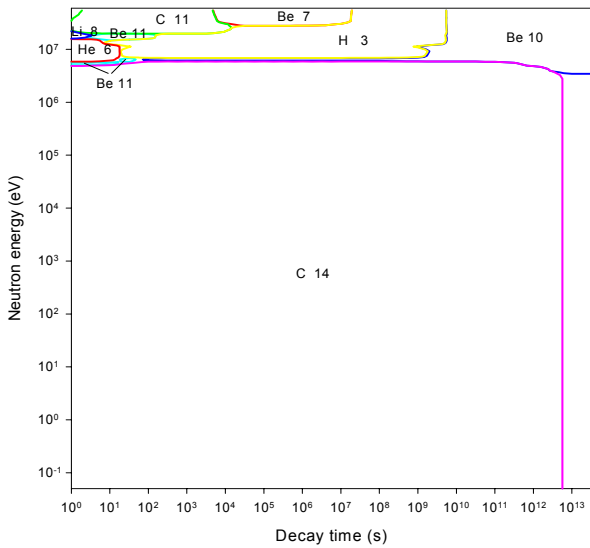
Activity



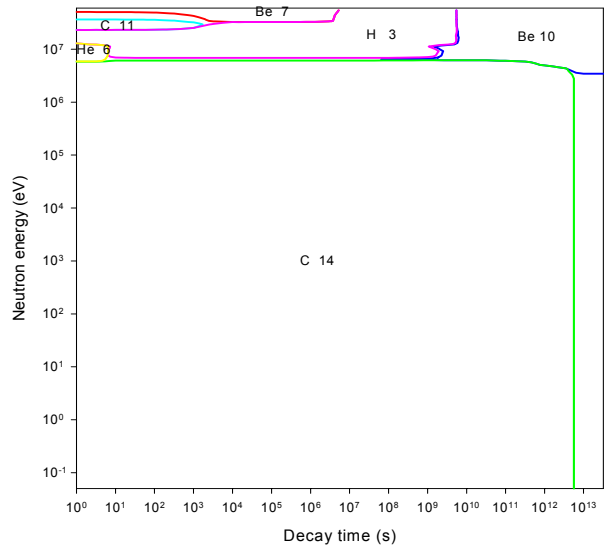
Dose rate



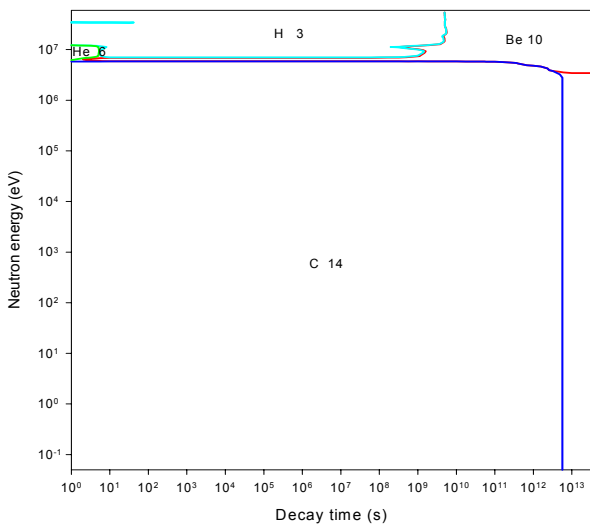
Heat output



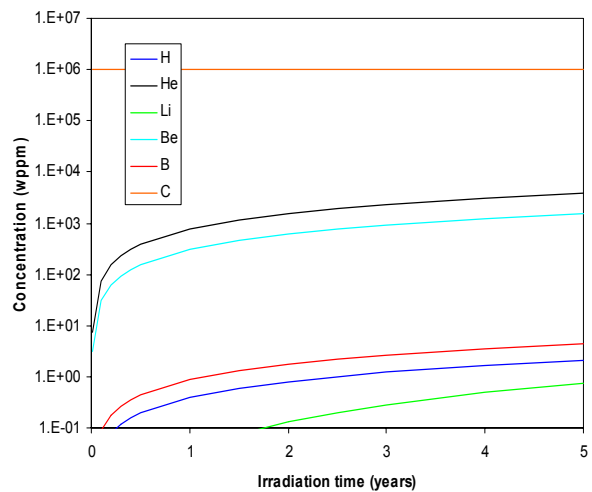
Ingestion dose



Inhalation dose



First wall transmutation



# Nitrogen

## General properties

Atomic number	7	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	25	N14	99.634
Melting point / K	63.29	N15	0.366
Boiling point / K	77.4		
Density / kgm <sup>-3</sup>	1.251		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	2.60 10 <sup>-2</sup>		
Electrical resistivity /Ωm	-		
Coefficient of thermal expansion / K <sup>-1</sup>	-		
Crystal structure	Cubic		
Number of stable isotopes	2		
Mean atomic weight	14.00674		

## Activation properties

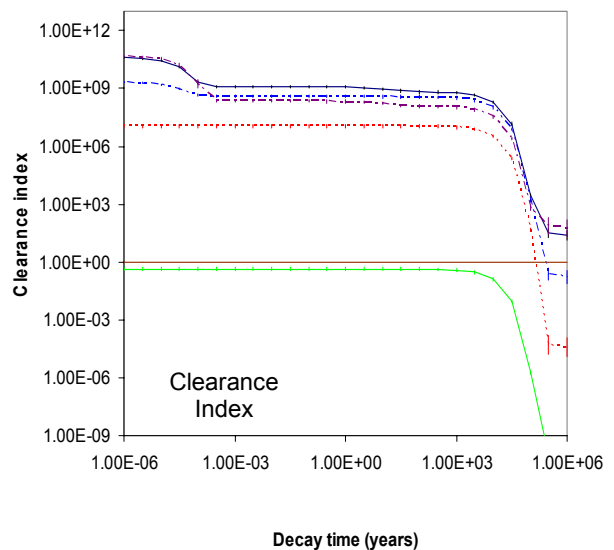
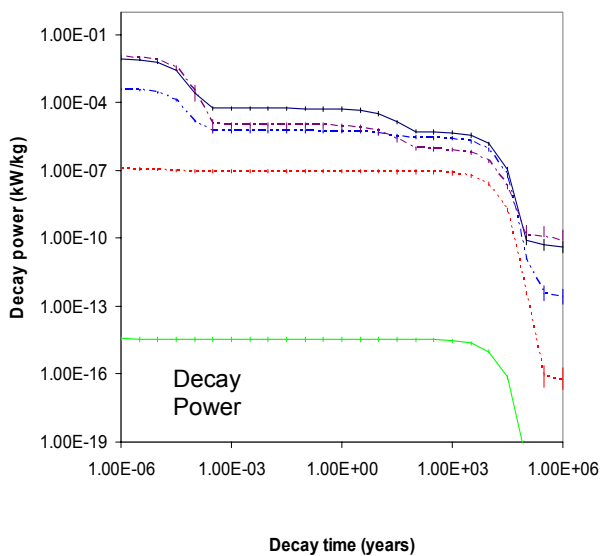
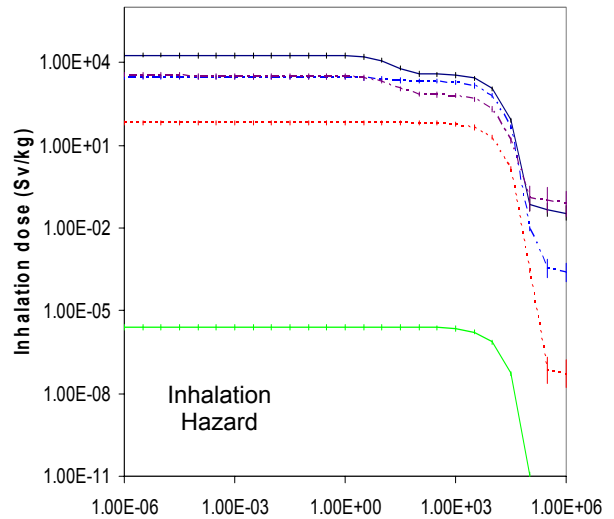
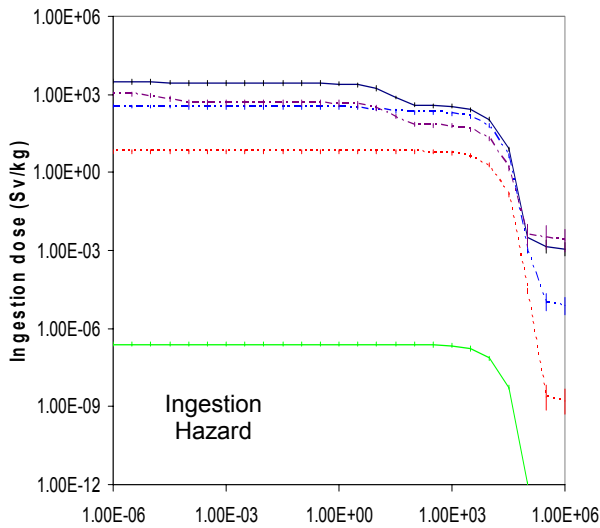
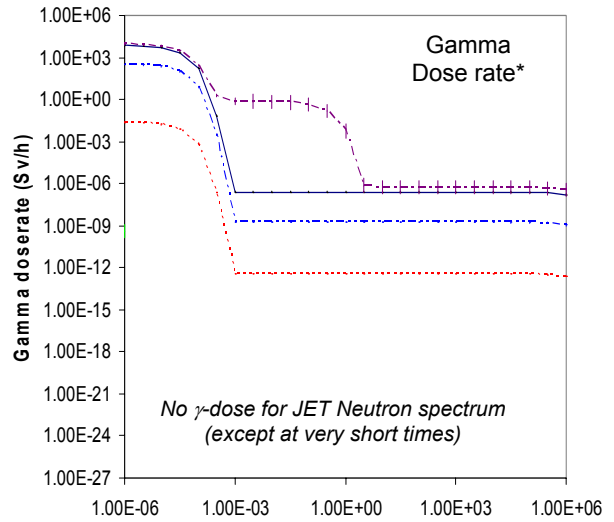
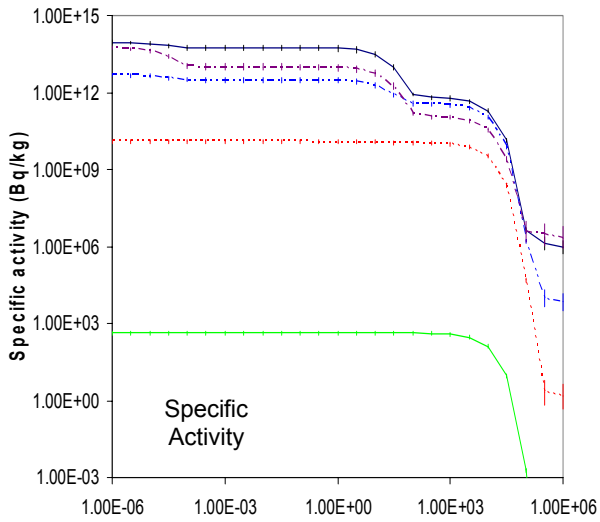
Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	9.50E13	8.06E13	5.53E13	5.24E13	8.58E11	4.95E6	kW kg <sup>-1</sup>	1.25E-2	6.17E-3	5.53E-5	5.26E-5	5.41E-6	8.63E-11
H3	57.59	67.83	98.79	98.72	23.06		N13	70.31	99.10				
N13	38.35	31.34					Li8	10.63					
B13	1.03						B13	8.29					
Li8	0.93						B12	5.01					
C14	0.70	0.83	1.20	1.28	76.94	70.69	C15	3.81					
B12	0.64						H3	0.39	0.81	90.42	89.93	3.34	
C15	0.48						C14	0.04	0.09	9.58	10.07	96.66	32.12
Be10						29.31	Be10						67.88
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	8.08E3	5.04E3	2.47E-7	2.47E-7	2.47E-7	2.36E-7	Sv kg <sup>-1</sup>	3.16E3	3.01E3	2.68E3	2.56E3	3.91E2	3.62E-3
N13	89.92	100.0					H3	72.70	76.23	85.56	84.86	2.13	
C15	7.59						N13	14.99	10.9				
Be11	1.04						C14	12.77	12.86	14.44	15.14	97.87	55.99
Be10			100.0*	100.0*	100.0*	100.0*	Be10						44.01
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	1.84E4	1.83E4	1.81E4	1.73E4	3.88E3	7.10E-2		4.40E10	2.81E10	1.21E9	1.19E9	6.62E8	3.53E3
H3	77.10	77.55	78.57	77.62	1.33		N13	88.06	95.67				
C14	21.02	21.14	21.27	22.38	98.67	28.56	C15	4.03					
N13	1.88	1.31					B13	2.03					
Be10						71.44	C14	1.52	2.38	55.01	56.38	99.79	98.97
							Li8	1.35					
							H3	1.24	1.95	44.99	43.62	0.29	
							Be11	0.74					
							Be10						1.03

# Nitrogen

## Pathway analysis

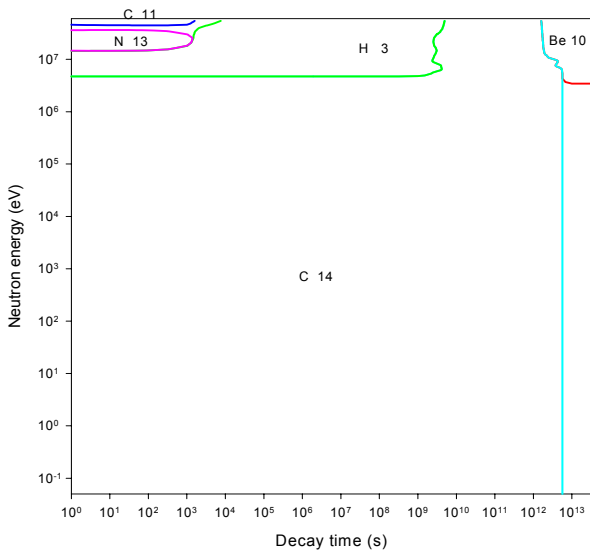
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
Li8	0.838 s	N14(n,α)B11(n,α)Li8				99.5	4.4	0.6	0.3	
		N14(n,nα)B10(n,h)Li8					51.5	19.2	7.0	
		N14(n,dα)Be9(n,d)Li8					17.4	57.1	55.6	
		N14(n,pα)Be10(n,t)Li8					12.3	3.7	2.4	
		N14(n,d)C13(n,nα)Be9(n,d)Li8					10.2	2.4	0.5	
		N14(n,t)C12(n,pα)Li8							12.2	5.2
		N14(n,d)C13(n,dα)Li8							1.2	6.3
		N14(n,hα)Li8							0.6	19.9
C15	2.449 s	N14(n,p)C14(n,γ)C15	100.0	100.0	100.0		0.6	0.5	0.1	
		N15(n,p)C15				99.9	99.4	99.5	99.9	
N16	7.13 s	N14(n,γ)N15(n,γ)N16	50.4	4.0	0.3					
		N15(n,γ)N16	49.6	96.0	99.7	99.1	99.9	100.0	100.0	
Be11	13.81 s	N14(n,α)B11(n,p)Be11				77.5	19.0	6.7	1.1	
		N14(n,p)C14(n,α)Be11				22.0	76.5	10.2	0.5	
		N15(n,d)C14(n,α)Be11				0.2	1.7	0.3		
		N14(n,d)C13(n,t)B11(n,p)Be11				0.2	0.5	0.8		
		N14(n,t)C12(n,d)B11(n,p)Be11					1.5	0.9		
		N14(n,t)C12(n,2p)Be11						50.3	12.2	
		N14(n,d)C13(n,h)Be11						15.2	13.1	
		N15(n,pα)Be11						10.3	1.6	
		N14(n,h)B12(β <sup>-</sup> )C12(n,2p)Be11						2.2	0.9	
		N14(n,nt)C11(β <sup>+</sup> )B11(n,p)Be11						1.1	0.3	
		N14(n,2n)N13(β <sup>+</sup> )C13(n,h)Be11						0.7	0.6	
N14(n,ph)Be11								69.2		
N13	9.967 m	N14(n,2n)N13				100.0	100.0	99.3	98.1	
		N15(n,3n)N13						0.7	1.9	
C11	20.37 m	N14(n,t)C12(n,2n)C11					82.4	14.3	2.2	
		N14(n,nt)C11					7.3	75.1	95.5	
		N14(n,h)B12(β <sup>-</sup> )C12(n,2n)C11					4.7	0.6	0.2	
		N14(n,d)C13(n,2n)C12(n,2n)C11					2.9	0.1		
		N14(n,d)C13(n,3n)C11					1.7	9.2	2.0	
Be7	53.22 d	N14(n,t)C12(n,2nα)Be7						93.9	22.3	
		N14(n,h)B12(β <sup>-</sup> )C12(n,2nα)Be7						4.2	1.6	
		N14(n,ntα)Be7						0.7	72.6	
		N14(n,d)C13(n,2n)C12(n,2nα)Be7						0.7		
		N14(n,d)C13(n,3nα)Be7							2.8	
H3	12.33 y	N14(n,X)H1(n,γ)H2(n,γ)H3	93.4	95.2	99.3					
		N14(n,3α)H3				94.0	79.9	91.7	94.4	
		N14(n,2α)Li7(n,nα)H3				4.4	9.9	1.5	0.1	
		N14(n,d)C13(n,t2α)H3				0.7	2.0	1.2	1.0	
		N15(n,n3α)H3				0.2	1.3	0.9	0.6	
		N14(n,nα)B10(n,2α)H3				0.1	3.1	0.8	0.1	
		N14(n,t)C12(n,d2α)H3					1.5	1.6	2.2	
		N14(n,dα)Be9(n,tα)H3					0.2	1.0	0.9	
C14	5700 y	N14(n,p)C14	100.0	100.0	100.0	99.3	97.8	97.2	96.6	
		N15(n,d)C14				0.7	2.2	2.7	3.3	
Be10	1.6 10 <sup>6</sup> y	N14(n,d)C13(n,α)Be10				76.4	1.5	0.5	1.1	
		N14(n,α)B11(n,d)Be10				14.7	2.5	0.9	1.6	
		N14(n,pα)Be10				5.1	92.8	95.4	91.7	
		N14(n,nα)B10(n,p)Be10				1.7	1.2	0.4	0.1	
		N14(n,2n)N13(β <sup>+</sup> )C13(n,α)Be10				1.7				
		N14(n,p)C14(n,nα)Be10					1.2	0.5	0.1	
		N14(n,t)C12(n,h)Be10					0.4	1.5	3.3	
		N15(n,dα)Be10						0.3	1.1	

# Nitrogen activation characteristics

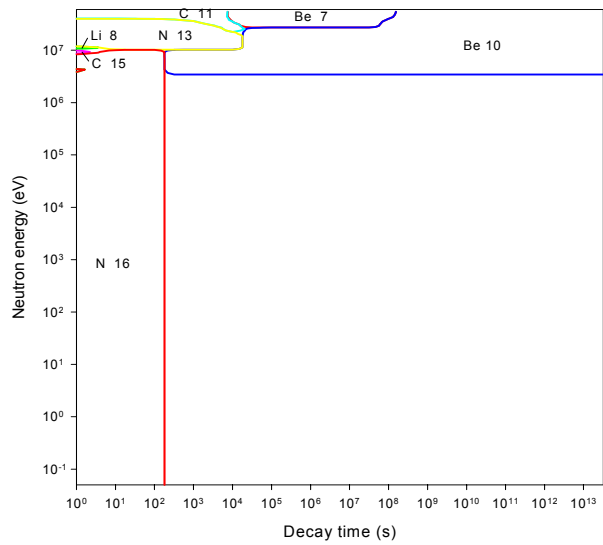


# Nitrogen importance diagrams & transmutation

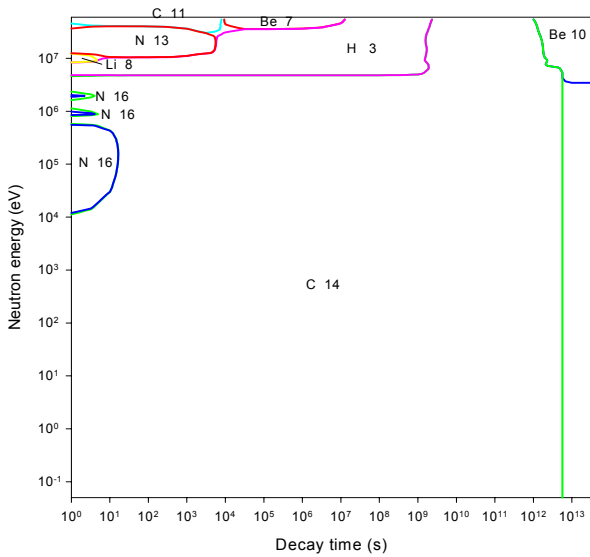
Activity



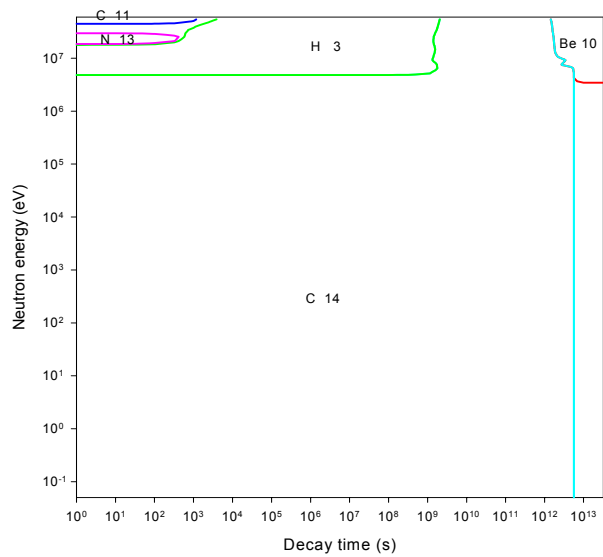
Dose rate



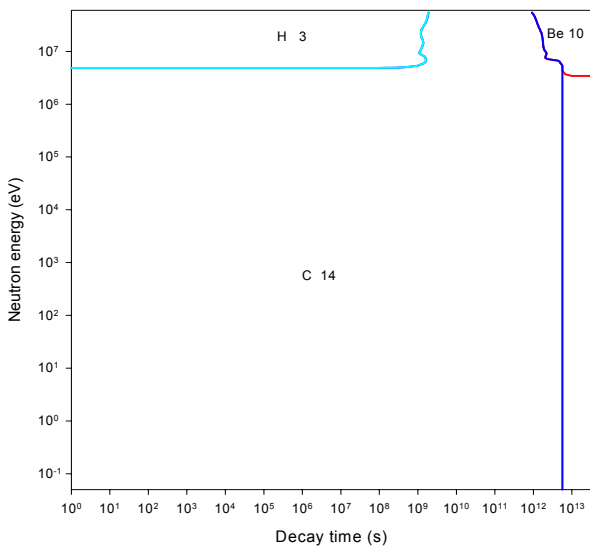
Heat output



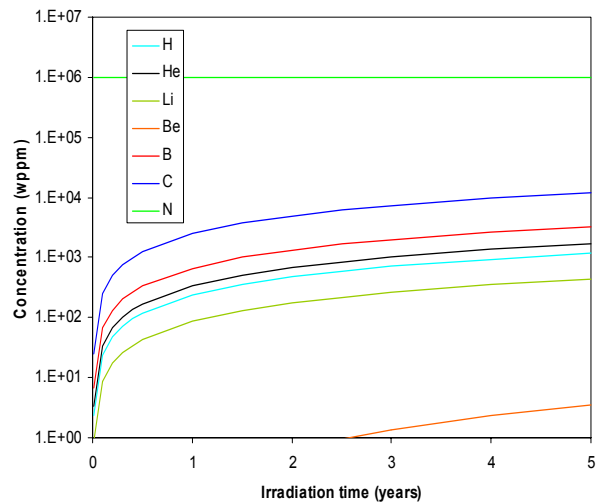
Ingestion dose



Inhalation dose



First wall transmutation





# Oxygen

## General properties

Atomic number	8	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	4.74 10 <sup>5</sup>	O16	99.762
Melting point / K	54.8	O17	0.038
Boiling point / K	90.19	O18	0.20
Density / kgm <sup>-3</sup>	1.429		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	2.67 10 <sup>-1</sup>		
Electrical resistivity /Ωm	-		
Coefficient of thermal expansion / K <sup>-1</sup>	-		
Crystal structure	Rhombic		
Number of stable isotopes	3		
Mean atomic weight	15.9994		

## Activation properties

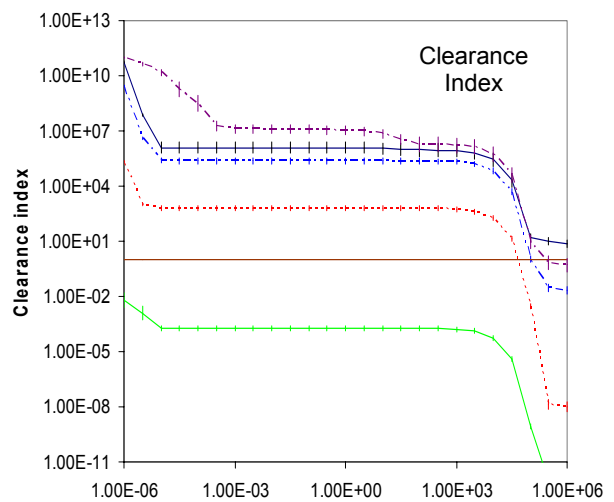
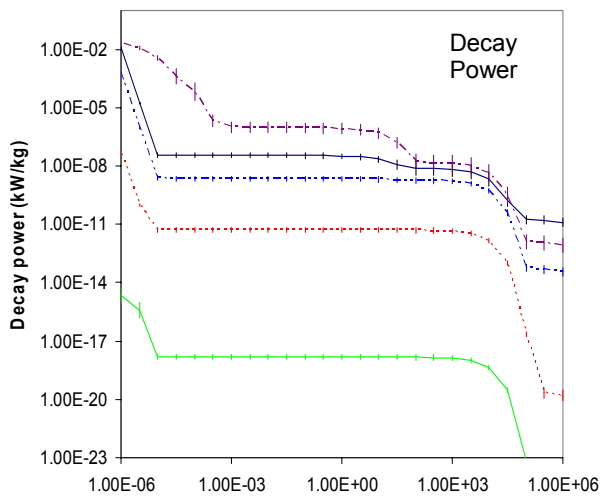
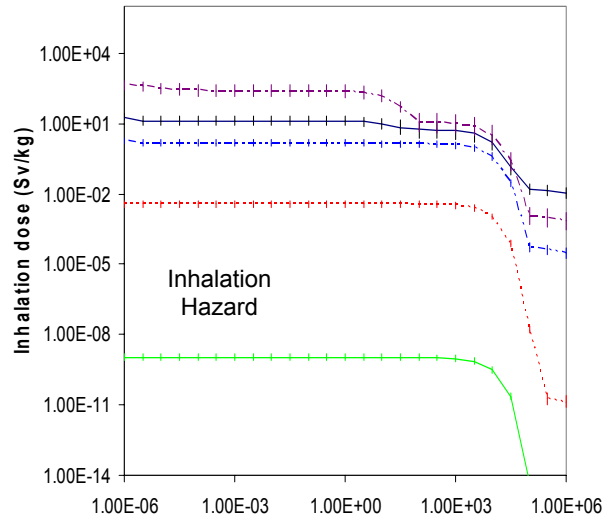
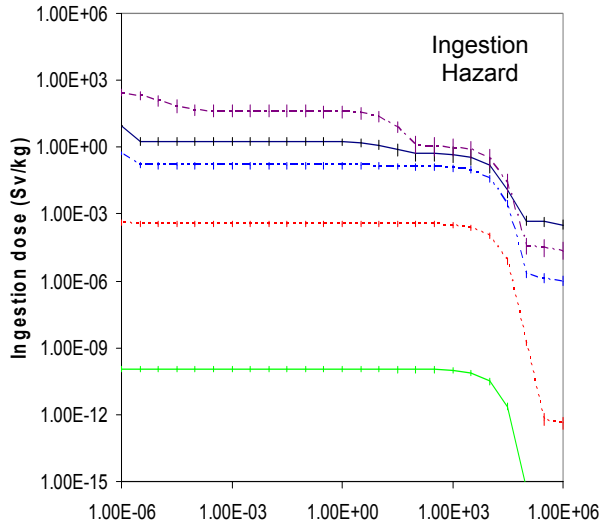
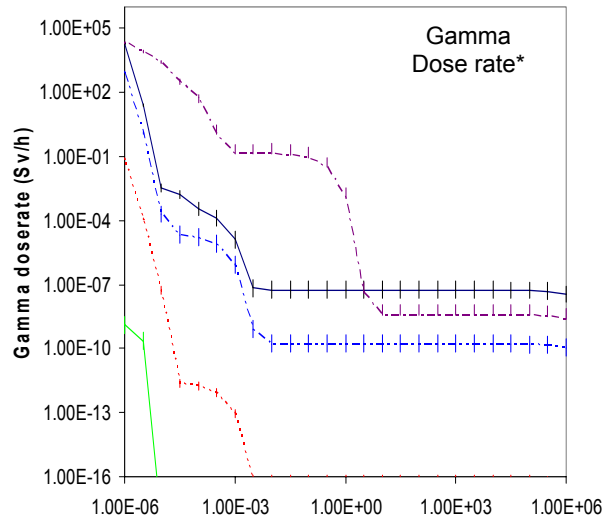
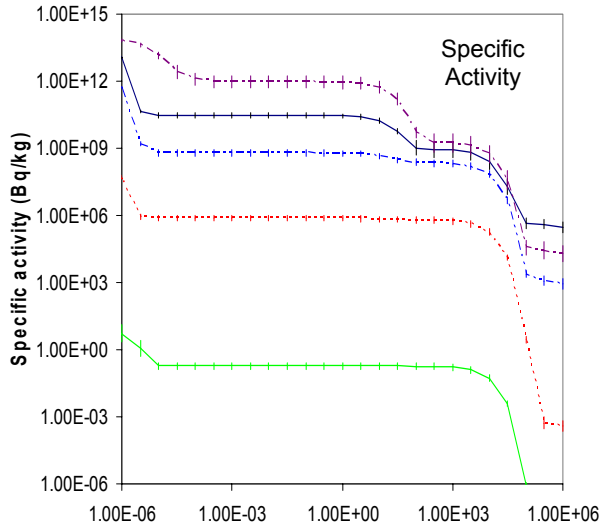
Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	2.41E14	3.01E10	3.01E10	2.85E10	1.04E9	4.49E5	kW kg <sup>-1</sup>	2.82E-1	3.83E-8	3.42E-8	3.27E-8	7.51E-9	1.80E-11
N16	99.68						N16	99.76					
B13	0.19						H3		69.59	78.03	77.06	1.29	
H3	0.01	96.81	96.86	96.69	89.80		C14		19.53	21.91	22.88	98.47	0.22
C14		3.14	3.14	3.31	10.16	1.10	N13		9.20				
Be10					0.05	98.90	Be10		0.05	0.05	0.06	0.25	99.78
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	4.04E5	3.40E-3	5.68E-8	5.68E-8	5.68E-8	5.43E-8	Sv kg <sup>-1</sup>	1.78E2	1.77E0	1.77E0	1.71E0	5.46E-1	4.92E-4
N16	99.94						N16	98.92					
N13		85.28					H3	0.69	99.59	69.07	68.87	0.81	
O19		4.41					C14	0.31	0.39	30.90	32.10	99.09	0.58
Be10			100.0*	100.0*	100.0*	100.0*	Be10			0.03	0.03	0.09	99.42
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	1.46E2	1.31E1	1.31E1	1.27E1	5.45E0	1.56E-2		1.20E12	1.25E6	1.24E6	1.22E6	9.34E5	1.60E1
N16	90.94						N16	99.91					
H3	5.20	57.99	57.98	56.62	0.50		C14		75.40	76.41	77.40	99.89	30.78
C14	3.76	41.89	41.90	43.25	99.20	0.18	H3		23.29	23.59	22.60	0.11	
N17	0.06						N13		0.12				
Be10	0.01	0.12	0.12	0.13	0.30	99.82	Be10						69.22

# Oxygen

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
C15	2.449 s	O17(n,α)C14(n,γ)C15	98.6	99.9	99.5				
		O16(n,γ)O17(n,α)C14(n,γ)C15	1.4		0.5				
		O16(n,d)N15(n,p)C15				76.0	25.6	0.7	0.3
		O18(n,α)C15				23.6	2.1	0.1	0.8
		O16(n,2p)C15					53.8	98.3	98.3
		O16(n,2n)O15(β <sup>+</sup> )N15(n,p)C15					18.2	0.8	0.4
N16	7.13 s	O17(n,α)C14(β <sup>-</sup> )N14(n,γ)N15(n,γ)N16	93.0						
		O17(n,α)C14(n,γ)C15(β <sup>-</sup> )N15(n,γ)N16	6.3						
		O16(n,p)N16				100.0	98.4	77.3	55.8
		O18(n,t)N16					0.6	17.9	38.8
		O17(n,d)N16					0.5	3.3	4.6
O19	26.91 s	O18(n,γ)O19	100.0	100.0	100.0	99.7	99.9	99.9	100.0
O15	2.041 m	O16(n,2n)O15					99.9	100.0	100.0
N13	9.967 m	O16(n,d)N15(n,2n)N14(n,2n)N13				99.6	4.4		
		O16(n,t)N14(n,2n)N13					67.3	3.1	0.5
		O16(n,d)N15(n,3n)N13					14.6	3.2	0.6
		O16(n,2n)O15(β <sup>+</sup> )N15(n,3n)N13					10.4	3.7	0.7
		O16(n,2n)O15(β <sup>+</sup> )N15(n,2n)N14(n,2n)N13					3.2		
		O16(n,nt)N13						89.9	98.1
C11	20.37 m	O16(n,nα)C12(n,2n)C11					99.4	13.7	0.8
		O16(n,2nα)C11						81.6	95.6
		O16(n,t)N14(n,nt)C11						1.6	1.6
		O16(n,α)C13(n,3n)C11						1.4	1.4
F18	1.829 h	O18(n,γ)O19(β <sup>-</sup> )F19(n,2n)F18				100.0	100.0	100.0	100.0
Na24	14.957 h	&O18(n,γ)O19(β <sup>-</sup> )F19(n,γ)F20(β <sup>-</sup> )Ne20(n,γ) Ne21(n,γ)Ne22(n,γ)Ne23(β <sup>-</sup> )Na23(n,γ)Na24	100.0						
Be7	53.22 d	O16(n,nα)C12(n,2nα)Be7						92.7	17.7
		O16(n,pα)B12(β <sup>-</sup> )C12(n,2nα)Be7						5.5	0.8
		O16(n,2n2α)Be7							72.9
		O16(n,α)C13(n,3nα)Be7							4.2
		O16(n,t)N14(n,ntα)Be7							2.4
H3	12.33 y	O17(n,α)C14(β <sup>-</sup> )N14(n,X)H1(n,γ)H2(n,γ)H3	95.1	97.1					
		O16(n,α)C13(n,t2α)H3				75.7			0.4
		O16(n,d)N15(n,n3α)H3				17.6	1.5	0.5	0.2
		O17(n,X)H3				4.1	0.3	0.2	0.3
		O16(n,X)H3					93.4	96.5	97.1
		O16(n,nα)C12(n,d2α)H3					2.1	0.6	0.5
		O16(n,2n)O15(β <sup>+</sup> )N15(n,n3α)H3					1.1	0.6	0.2
C14	5700 y	O17(n,α)C14	98.6	99.9	99.5	5.7			
		O16(n,γ)O17(n,α)C14	1.4		0.5	0.3			
		O18(n,nα)C14				58.3	3.0	0.4	0.2
		O16(n,d)N15(n,d)C14				34.0	7.7	1.0	0.3
		O16(n,h)C14					83.3	97.1	99.0
		O16(n,2n)O15(β <sup>+</sup> )N15(n,d)C14					5.5	1.2	0.3
Be10	1.6 10 <sup>6</sup> y	O16(n,α)C13(n,α)Be10				99.4	4.3	0.8	3.5
		O16(n,nα)C12(n,h)Be10					37.9	16.6	5.7
		O16(n,h)C14(n,nα)Be10					23.9	23.1	3.9
		O16(n,nα)C12(n,d)B11(n,d)Be10					12.4	0.9	
		O16(n,t)N14(n,pα)Be10					6.7	11.6	3.5
		O16(n,d)N15(n,nα)B11(n,d)Be10					3.0	0.2	
		O16(n,2n)O15(β <sup>+</sup> )N15(n,nα)B11(n,d)Be10					2.2	0.2	
		O16(n,dα)B11(n,d)Be10					1.1	24.1	8.4
		O16(n,d)N15(n,dα)Be10					0.8	4.9	2.7
		O16(n,2n)O15(β <sup>+</sup> )N15(n,dα)Be10					0.5	5.7	3.1
		O16(n,hα)Be10						6.0	64.7
		O16(n,2nα)C11(β <sup>+</sup> )B11(n,d)Be10						1.8	2.2

# Oxygen activation characteristics

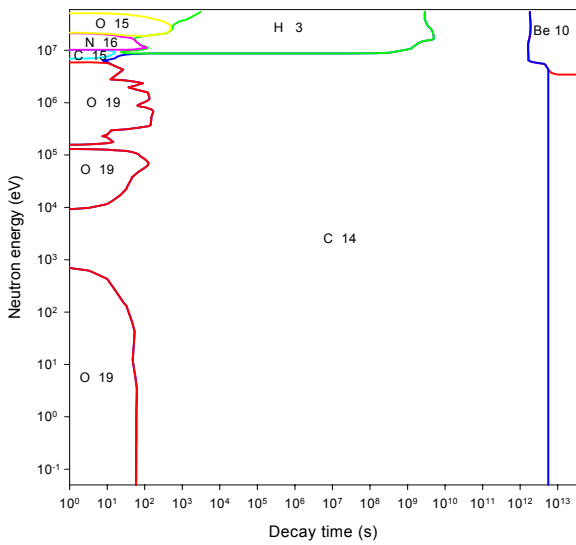


Decay time (years)

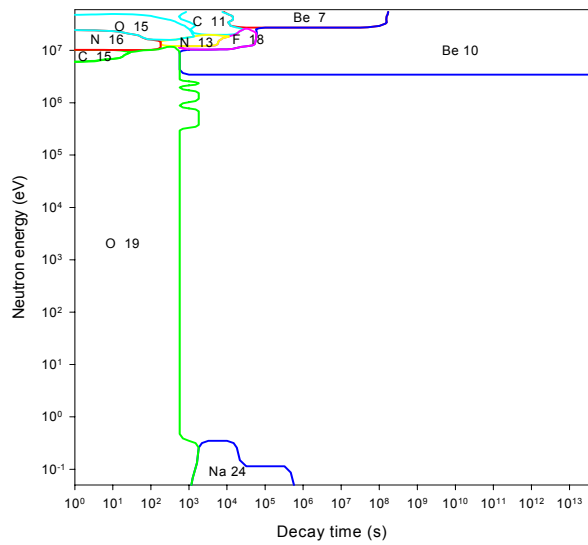
Decay time (years)

# Oxygen importance diagrams & transmutation

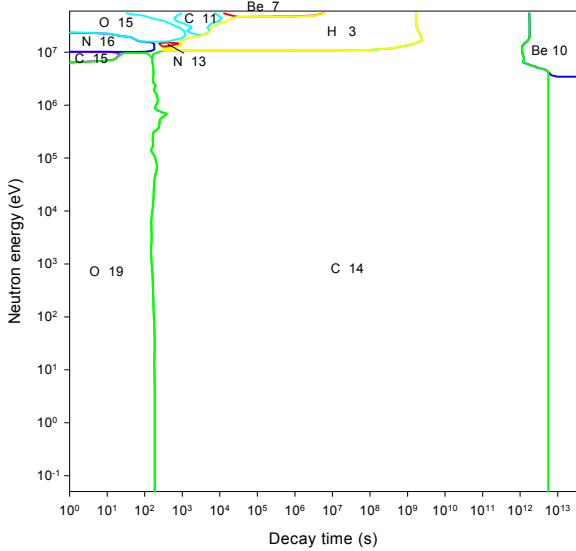
**Activity**



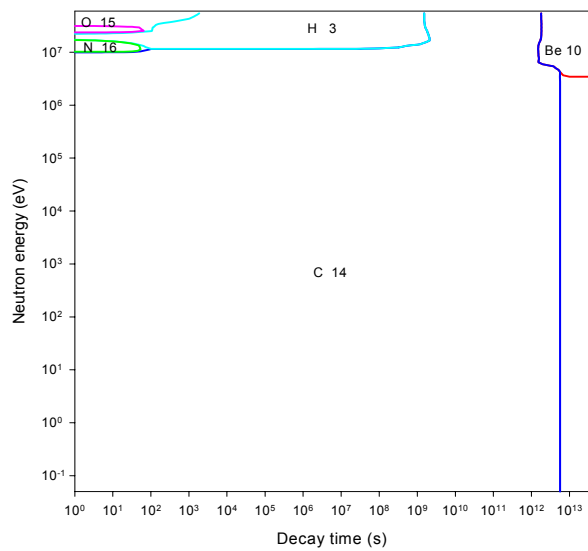
**Dose rate**



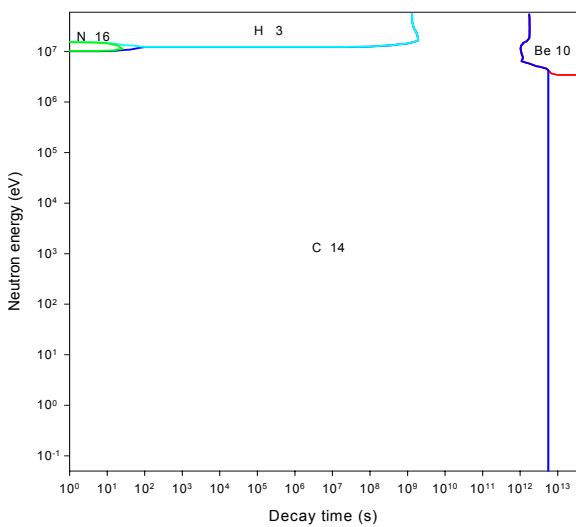
**Heat output**



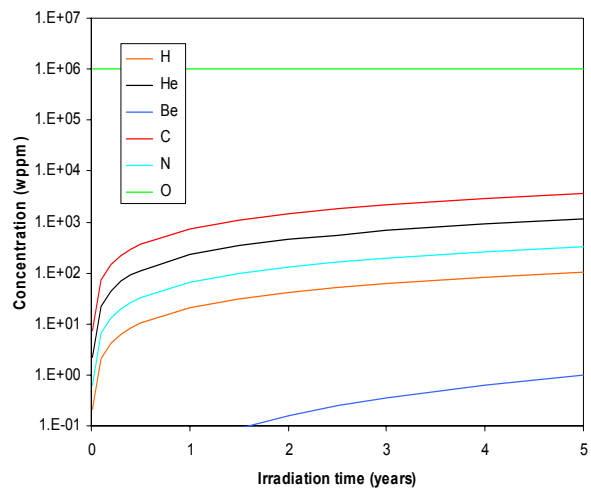
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**



# Fluorine

## General properties

Atomic number	9	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	950	F19	100.0
Melting point / K	53.53		
Boiling point / K	85.01		
Density / kgm <sup>-3</sup>	1.696		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	2.79 10 <sup>-2</sup>		
Electrical resistivity /Ωm	-		
Coefficient of thermal expansion / K <sup>-1</sup>	-		
Crystal structure	Rhombic		
Number of stable isotopes	1		
Mean atomic weight	18.9984032		

## Activation properties

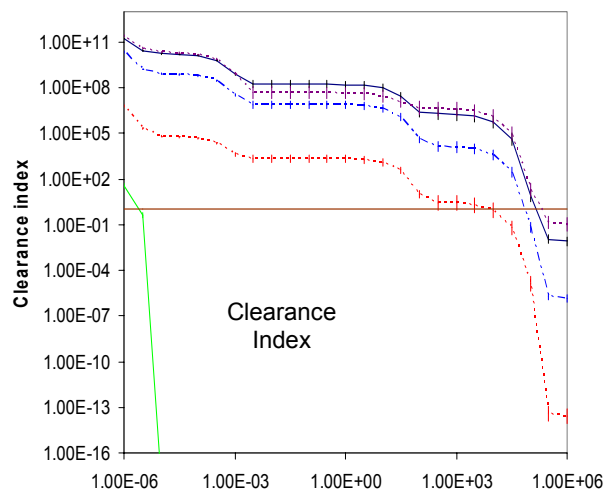
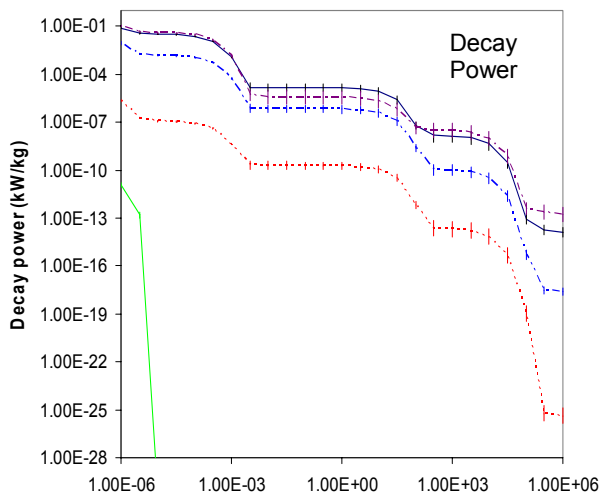
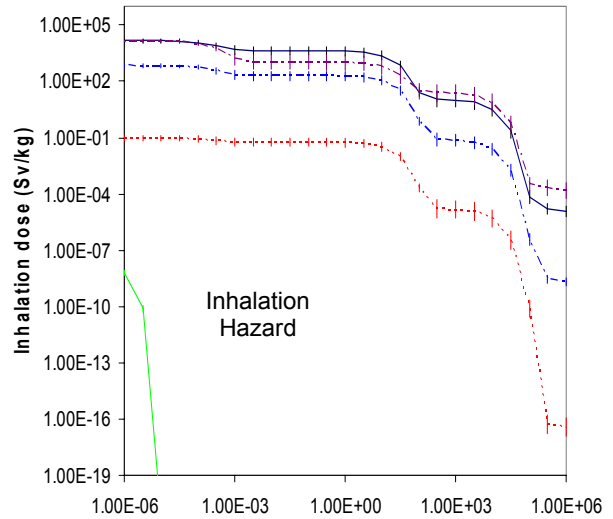
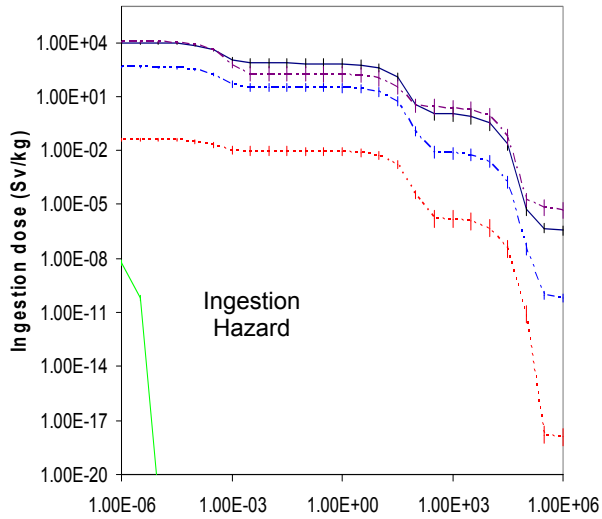
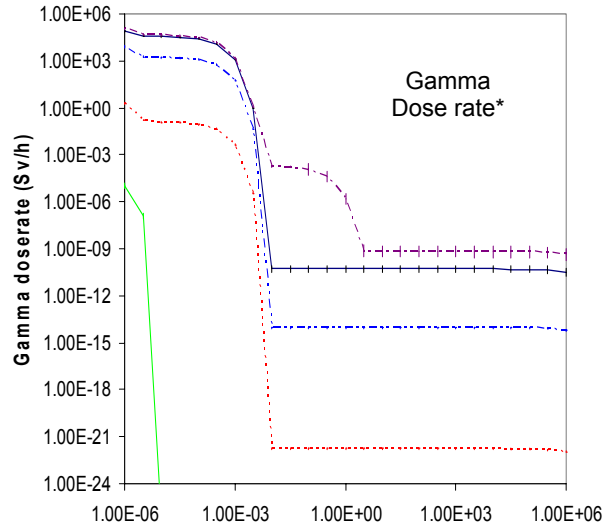
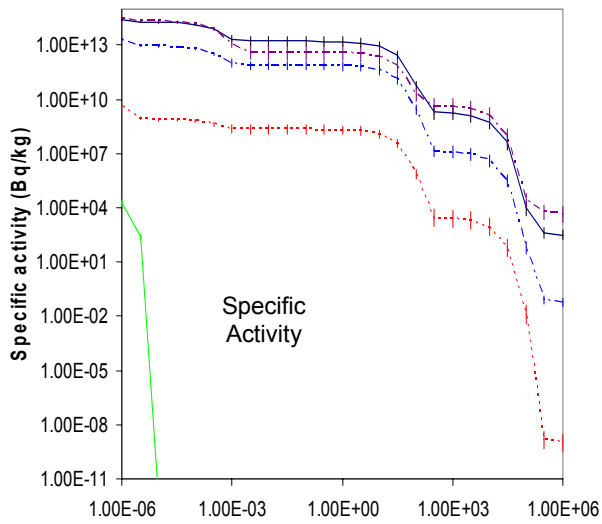
Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	6.54E14	1.88E14	1.65E13	1.57E13	6.19E10	1.10E4	kW kg <sup>-1</sup>	4.68E-1	3.39E-2	1.51E-5	1.43E-5	7.06E-8	1.03E-13
N16	46.37						N16	75.77					
F18	27.12	91.18					O19	10.78	0.04				
O19	17.75	0.02					F18	7.47	99.91				
F20	5.78						F20	5.32					
H3	2.53	8.79	99.99	99.99	96.78		H3		0.04	99.89	99.89	77.62	
C14			0.01	0.01	3.21	95.66	C14			0.11	0.11	22.38	81.21
Be10						4.34	Be10						18.79
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	6.16E5	3.50E4	5.06E-11	5.06E-11	5.06E-11	4.85E-11	Sv kg <sup>-1</sup>	9.73E3	9.10E3	6.96E2	6.58E2	3.67E0	6.65E-6
N16	85.94						F18	89.27	92.35				
F18	5.88	99.97					H3	7.14	7.63	99.83	99.82	68.53	
O19	4.84	0.03					N16	2.27					
F20	3.04						C14	0.01	0.01	0.17	0.18	31.47	92.08
Be10			100.0*	100.0*	100.0*	100.0*	Be10						7.92
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	1.50E4	1.44E4	4.31E3	4.08E3	2.71E1	7.79E-5		1.75E12	1.74E10	1.67E8	1.58E8	2.59E6	1.06E1
F18	69.54	70.11					N16	86.724					
H3	28.60	29.81	99.73	99.71	57.41		O19	7.81	0.23				
N16	1.10						F20	4.08					
O19	0.59						F18	1.01	98.80				
F20	0.08						H3		0.95	98.80	98.73	23.12	
C14			0.27	0.29	42.59	78.50	C14		0.01	1.20	1.27	76.88	99.89
Be10						21.50	Be10						0.11

# Fluorine

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
N16	7.13 s	F19(n,α)N16				99.1	78.6	59.5	86.9
		F19(n,t)O17(n,d)N16					14.1	19.3	5.5
		F19(n,d)O18(n,t)N16					4.1	13.6	4.8
		F19(n,2n)F18(β <sup>+</sup> )O18(n,t)N16					1.9	5.7	2.0
		F19(n,3n)F17(β <sup>+</sup> )O17(n,d)N16					0.3	1.6	0.6
		F19(n,nt)O16(n,p)N16					0.3		
F20	11.03 s	F19(n,γ)F20	100.0	100.0	100.0	94.8	99.2	99.6	99.8
O19	26.91 s	F19(n,γ)F20(β <sup>-</sup> )Ne20(n,γ)Ne21(n,α)O18_	100.0	100.0					
		(n,γ)O19 F19(n,p)O19				100.0	100.0	100.0	100.0
F18	1.829 h	F19(n,2n)F18				99.7	99.9	99.9	100.0
Na24	14.957 h	&F19(n,γ)F20(β <sup>-</sup> )Ne20(n,γ)Ne21(n,γ)_ Ne22(n,γ)Ne23(β <sup>-</sup> )Na23(n,γ)Na24	100.0	100.0					
Be7	53.22 d	F19(n,ntα)C12(n,2nα)Be7						27.5	23.3
		F19(n,2α)B12(β <sup>-</sup> )C12(n,2nα)Be7						21.7	1.4
		F19(n,2nα)N14(n,t)C12(n,2nα)Be7						11.8	1.7
		F19(n,t)O17(n,2nα)C12(n,2nα)Be7						10.8	1.6
		F19(n,nt)O16(n,nα)C12(n,2nα)Be7						7.6	1.4
		F19(n,dα)C14(n,3n)C12(n,2nα)Be7						6.1	0.7
		F19(n,nα)N15(n,nt)C12(n,2nα)Be7						4.2	1.4
		F19(n,tα)C13(n,2n)C12(n,2nα)Be7						1.8	0.6
		F19(n,dα)C14(n,t)B12(β <sup>-</sup> )C12(n,2nα)Be7						1.2	0.4
		F19(n,d)O18(n,3nα)C12(n,2nα)Be7						1.0	0.5
		F19(n,2nα)N14(n,ntα)Be7						0.2	11.3
		F19(n,tα)C13(n,3nα)Be7						0.1	34.3
		F19(n,nt)O16(n,2n2α)Be7							11.3
		F19(n,3nα)N13(β <sup>+</sup> )C13(n,3nα)Be7							3.8
H3	12.33 y	F19(n,X)H3				95.5	94.6	93.2	93.0
		F19(n,nα)N15(n,3nα)H3				4.0	1.6	0.8	0.4
		F19(n,t)O17(n,X)H3					2.2	3.8	4.3
		F19(n,d)O18(n,X)H3					0.7	0.6	0.4
C14	5700 y	F19(n,nα)N15(n,d)C14				68.1	5.2	1.6	0.7
		F19(n,d)O18(n,nα)C14				17.9	3.4	0.9	0.4
		F19(n,2n)F18(β <sup>+</sup> )O18(n,nα)C14				7.7	1.6	0.5	0.2
		F19(n,dα)C14				4.4	89.3	96.4	97.4
		F19(n,t)O17(n,α)C14				1.0	0.2	0.2	0.5
Be10	1.6 10 <sup>6</sup> y	F19(n,nα)N15(n,nα)B11(n,d)Be10				41.9	4.5	0.6	
		F19(n,nα)N15(n,t)C13(n,α)Be10				23.0	0.2		
		F19(n,α)N16(β <sup>-</sup> )O16(n,α)C13(n,α)Be10				15.8			
		F19(n,t)O17(n,nα)C13(n,α)Be10				8.3	0.2		
		F19(n,nα)N15(n,2n)N14(n,d)C13(n,α)Be10				4.2			
		F19(n,d)O18(n,2n)O17(n,nα)C13(n,α)Be10				1.5			
		F19(n,nt)O16(n,α)C13(n,α)Be10				0.9			
		F19(n,nα)N15(n,d)C14(n,nα)Be10				0.4	2.2	0.5	
		F19(n,t)O17(n,2α)Be10				0.3	10.2	8.1	1.4
		F19(n,d)O18(n,nα)C14(n,nα)Be10				0.1	1.5	0.3	
		F19(n,dα)C14(n,nα)Be10					57.6	43.2	8.3
		F19(n,2nα)N14(n,pα)Be10					9.7	9.6	2.9
		F19(n,2n)B11(n,d)Be10					8.7	11.0	2.0
		F19(n,nα)N15(n,dα)Be10					1.1	14.6	14.5
		F19(n,tα)C13(n,α)Be10					0.6	0.9	5.2
		F19(n,d)O18(n,2nα)Be10					0.2	3.9	1.8
		F19(n,d2α)Be10						2.0	57.6
		F19(n,2n)F18(β <sup>+</sup> )O18(n,2nα)Be10						1.6	0.8
		F19(n,ntα)C12(n,h)Be10						0.3	1.4

# Fluorine activation characteristics

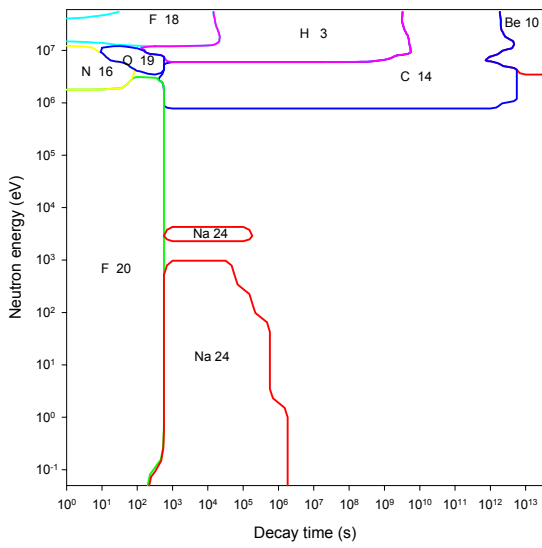


Decay time (years)

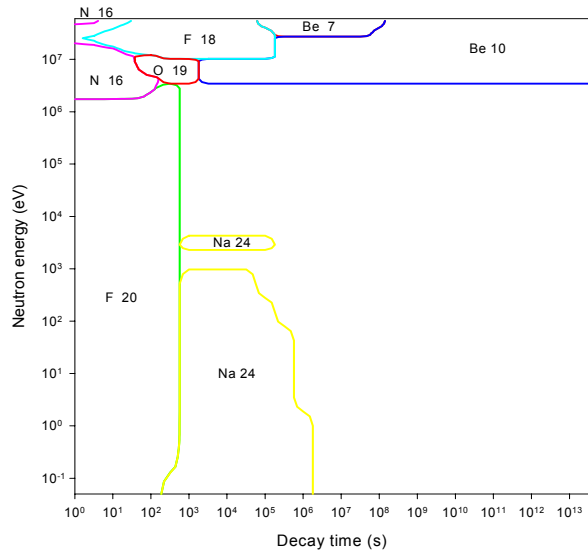
Decay time (years)

# Fluorine importance diagrams & transmutation

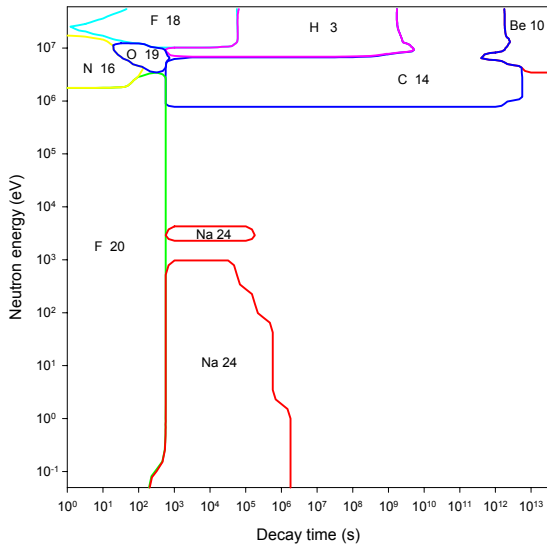
Activity



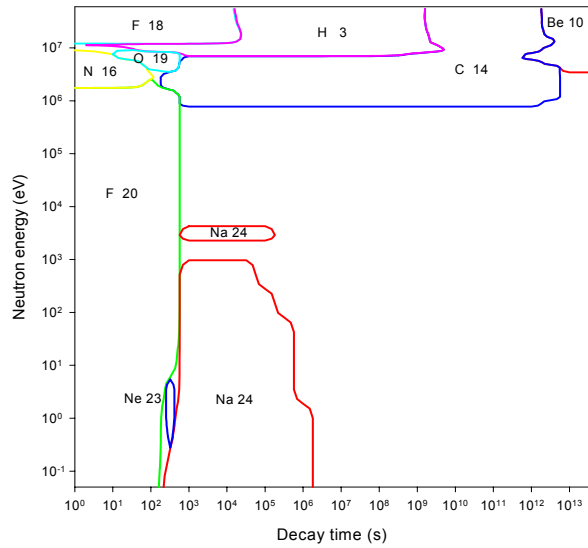
Dose rate



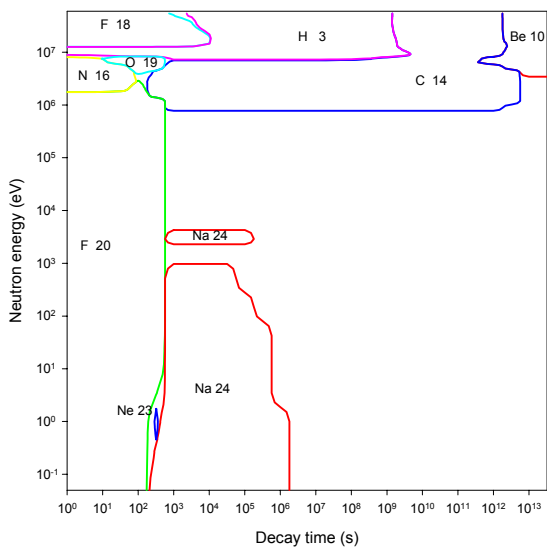
Heat output



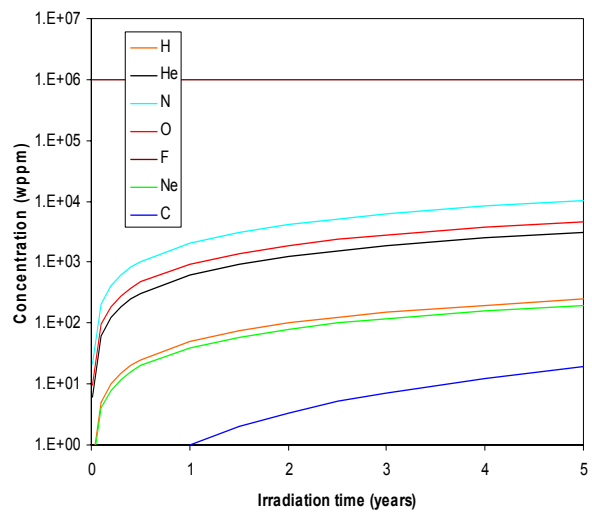
Ingestion dose



Inhalation dose



First wall transmutation





# Neon

## General properties

Atomic number	10	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	7.0 10 <sup>-5</sup>	Ne20	90.48
Melting point / K	24.48	Ne21	0.27
Boiling point / K	27.10	Ne22	9.25
Density / kgm <sup>-3</sup>	8.999 10 <sup>-1</sup>		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	4.93 10 <sup>-1</sup>		
Electrical resistivity /Ωm	-		
Coefficient of thermal expansion / K <sup>-1</sup>	-		
Crystal structure	FCC		
Number of stable isotopes	3		
Mean atomic weight	20.1797		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	1.38E15	1.17E11	4.25E10	4.02E10	1.58E9	2.60E4	kW kg <sup>-1</sup>	9.18E-1	1.57E-5	6.12E-8	5.07E-8	1.15E-8	8.04E-13
F20	98.21						F20	97.47					
F22	0.95						F22	1.86					
O19	0.47	1.66					O19	0.31	5.34				
F21	0.13						Ne23	0.02	3.99				
N16	0.11						F18		87.61				
Ne23	0.05	1.65					Na24		2.70	11.99			
F18		59.83					H3		0.23	61.22	69.19	1.18	
H3		35.14	96.54	96.38	9.39		C14		0.07	1.86	22.63	98.81	7.47
C14		1.24	3.41	3.60	90.60	70.84	Na22		0.03	8.03	7.50		
Be10						29.16	Be10						92.53
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	6.70E5	1.49E1	1.94E-2	5.29E-3	1.51E-9	1.44E-9	Sv kg <sup>-1</sup>	9.89E2	7.96E0	2.61E0	2.50E0	8.36E-1	2.46E-5
F20	95.81						Ne23	61.13	21.23				
F22	3.52						F20	37.06					
N16	0.38						O19	0.66	0.02				
O19	0.24	3.19					F18	0.36	42.98				
F21	0.03						H3	0.17	21.64	66.04	65.14	0.75	
F18		91.46					C14	0.08	10.55	32.22	33.59	99.25	17.84
Na24		4.86	64.47				Na24	0.02	3.06	0.16			
Na22		0.05	35.53	100.0			Na22		0.52	1.58	1.27		
Be10					100.0*	100.0*	Be10						82.16
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	7.81E2	2.42E1	1.91E1	1.85E1	8.34E0	6.88E-4		2.66E12	1.25E7	2.00E6	1.93E6	1.43E6	8.04E0
F20	57.41						F20	96.43					
Ne23	38.30	3.5					F22	2.91					
H3	1.37	44.08	55.87	54.51	0.46		O19	0.29	18.20				
C14	1.07	34.72	44.03	45.41	99.53	6.38	F18		55.58				
O19	0.65						Na24		4.54	0.49			
F18	0.56	17.03					H3		3.28	20.53	20.04	0.10	
F22	0.42						Na22		1.03	6.44	5.11		
N16	0.11						C14			72.53	74.85	99.90	94.27
Be10						93.61	Be10						5.73

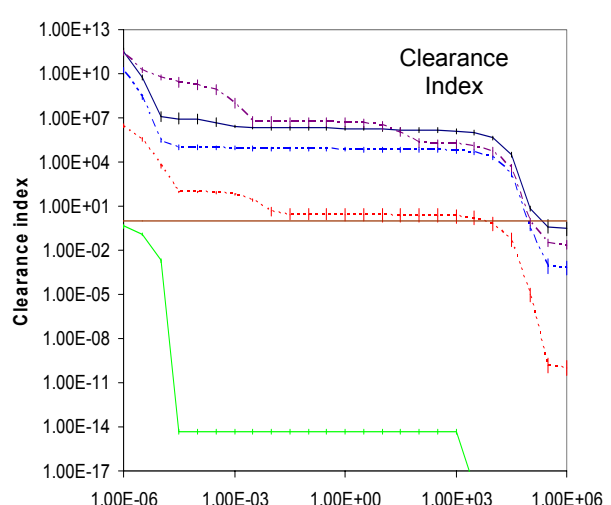
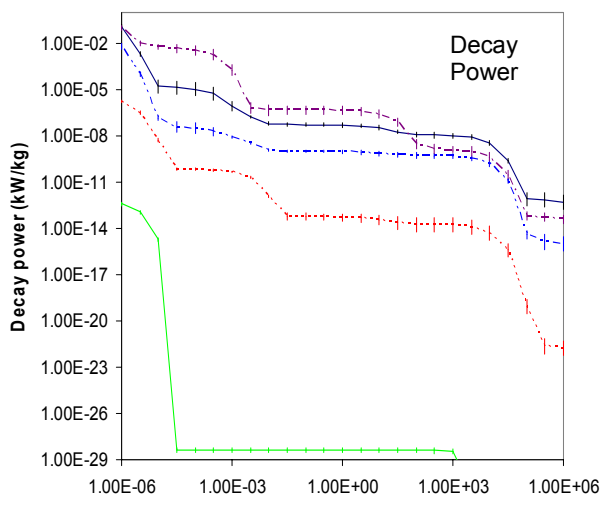
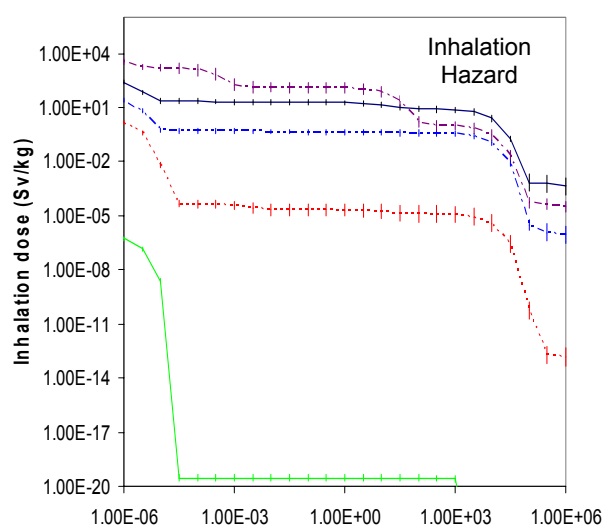
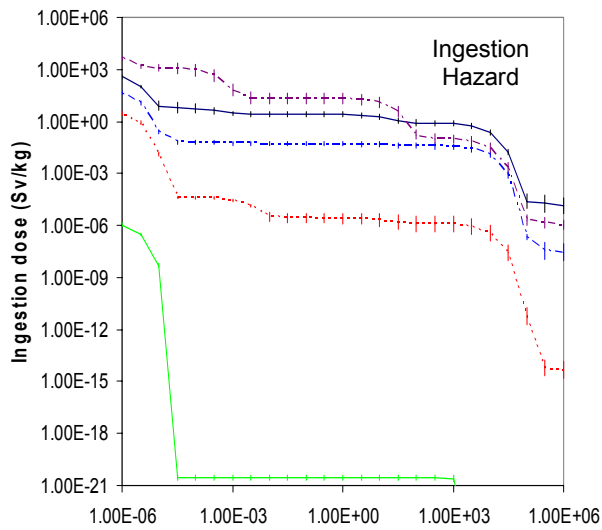
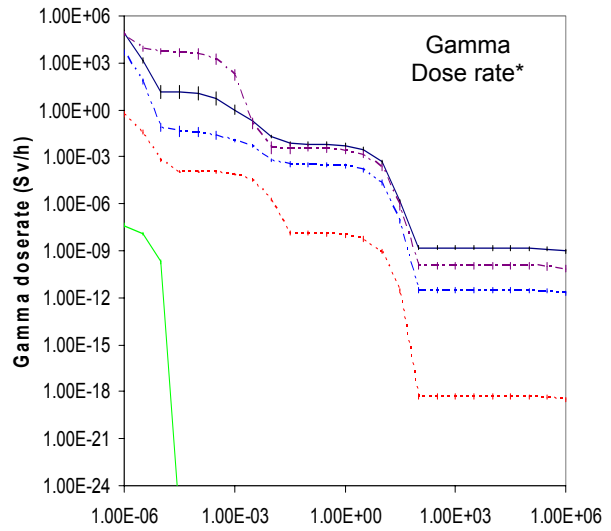
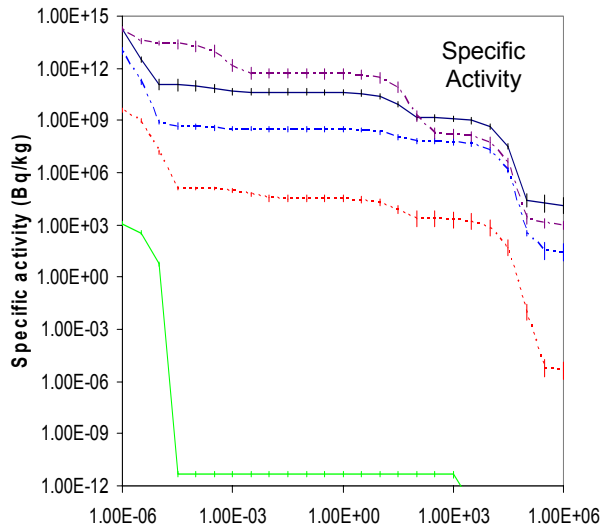
# Neon

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
F21	4.158 s	Ne22(n,2n)Ne21(n,p)F21				69.7	2.9	0.8	0.2
		Ne21(n,p)F21				27.8	1.7	0.9	0.5
		Ne22(n,d)F21				1.8	94.2	97.6	98.9
F20	11.03 s	Ne21(n,α)O18(n,γ)O19(β <sup>-</sup> )F19(n,γ)F20	82.1	99.2	100.0				
		Ne20(n,γ)Ne21(n,α)O18(n,γ)O19(β <sup>-</sup> )_	17.9	0.8					
		F19(n,γ)F20				100.0	96.1	76.9	55.8
		Ne20(n,p)F20					1.4	20.3	41.3
		Ne22(n,t)F20					1.2	0.8	0.5
		Ne22(n,2n)Ne21(n,d)F20					0.7	0.9	1.1
Ne19	17.22 s	Ne20(n,2n)Ne19					99.0	99.2	98.3
		Ne22(n,4n)Ne19							1.1
O19	26.91 s	Ne21(n,α)O18(n,γ)O19	75.2	98.7	100.0				
		Ne20(n,γ)Ne21(n,α)O18(n,γ)O19	24.8	1.3					
		Ne22(n,α)O19				93.9	5.1	4.4	34.6
		Ne20(n,d)F19(n,p)O19				5.2	9.6	3.6	1.9
		Ne20(n,2p)O19					83.0	90.1	61.4
		Ne20(n,2n)Ne19(β <sup>+</sup> )F19(n,p)O19					1.1	0.5	0.2
Ne21(n,h)O19							0.3	0.8	
Ne23	37.2 s	Ne22(n,γ)Ne23	99.9	100.0	100.0	98.8	99.3	99.6	99.8
F18	1.829 h	Ne20(n,d)F19(n,2n)F18				92.8	21.5	1.5	0.5
		Ne22(n,α)O19(β <sup>-</sup> )F19(n,2n)F18				4.6			
		Ne20(n,t)F18					74.9	97.4	97.3
		Ne20(n,2n)Ne19(β <sup>+</sup> )F19(n,2n)F18					2.5	0.2	
		Ne20(n,3n)Ne18(β <sup>+</sup> )F18							1.3
Na24	14.957 h	&Ne22(n,γ)Ne23(β <sup>-</sup> )Na23(n,γ)Na24	95.6	91.2	91.2	92.6	94.3	94.3	94.3
Be7	53.22 d	Ne20(n,2α)C12(n,2nα)Be7						91.2	58.4
		Ne20(n,nα)O16(n,nα)C12(n,2nα)Be7						4.4	1.5
		Ne20(n,dα)N15(n,nt)C12(n,2nα)Be7						1.4	2.7
		Ne20(n,tα)N14(n,t)C12(n,2nα)Be7						0.2	1.5
		Ne20(n,nα)O16(n,2n2α)Be7							12.6
		Ne20(n,tα)N14(n,ntα)Be7							9.9
		Ne20(n,2α)C13(n,3nα)Be7							1.4
		Ne20(n,dα)N15(n,t)C13(n,3nα)Be7							1.2
Na22	2.603 y	Ne22(n,γ)Ne23(β <sup>-</sup> )Na23(n,2n)Na22				99.8	99.8	99.9	100.0
H3	12.33 y	Ne20(n,α)O17(n,X)H3				62.7	0.6	0.7	2.9
		Ne20(n,d)F19(n,X)H3				19.0	5.0	2.3	1.0
		Ne20(n,2α)C13(n,t2α)H3				5.2	0.1		
		Ne22(n,2n)Ne21(n,X)H3				4.2	0.1		
		Ne21(n,X)H3				3.2	0.1	0.2	0.2
		Ne20(n,nα)O16(n,α)C13(n,t2α)H3				1.1			
		Ne22(n,α)O19(β <sup>-</sup> )F19(n,X)H3				0.9			
		Ne20(n,X)H3					81.5	78.8	82.8
		Ne22(n,X)H3					6.3	10.0	7.8
		Ne20(n,nα)O16(n,X)H3					2.1	1.6	0.8
		Ne20(n,dα)N15(n,n3α)H3					1.6	2.4	1.1
C14	5700 y	Ne20(n,α)O17(n,α)C14				75.2	0.2	0.2	2.8
		Ne22(n,2n)Ne21(n,2α)C14				9.5	0.7	0.1	
		Ne21(n,2α)C14				7.7	0.8	0.9	
		Ne22(n,nα)O18(n,nα)C14				2.8	3.5	0.5	0.2
		Ne20(n,d)F19(n,nα)N15(n,d)C14				0.9	0.8	0.1	
		Ne20(n,nα)O16(n,d)N15(n,d)C14				0.4	0.3		
		Ne21(n,α)O18(n,nα)C14				0.3			
		Ne20(n,d)F19(n,d)O18(n,nα)C14				0.2	0.5		
		Ne22(n,n2α)C14					28.2	23.0	17.7
		Ne20(n,dα)N15(n,d)C14					24.2	24.1	14.1

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	Ne20(n,d)F19(n,dα)C14					21.1	11.7	8.3
		Ne20(n,nα)O16(n,h)C14					5.3	8.3	8.2
		Ne20(n,hα)C14					4.4	14.5	31.6
		Ne20(n,t)F18(β <sup>+</sup> )O18(n,nα)C14					2.6	5.9	5.7
		Ne20(n,2n)Ne19(β <sup>+</sup> )F19(n,dα)C14					2.5	1.6	1.0
		Ne20(n,2nα)O15(β <sup>+</sup> )N15(n,d)C14					1.5	5.7	4.4
		Ne20(n,h)O18(n,nα)C14					1.3	2.2	2.1
Be10	1.6 10 <sup>6</sup> y	Ne20(n,2α)C13(n,α)Be10				76.7	26.0	1.0	0.4
		Ne20(n,nα)O16(n,α)C13(n,α)Be10				15.3	0.2		
		Ne20(n,α)O17(n,nα)C13(n,α)Be10				5.8			
		Ne20(n,α)O17(n,2α)Be10				0.2	6.2	1.7	1.3
		Ne20(n,dα)N15(n,nα)B11(n,d)Be10					11.0	2.1	0.2
		Ne22(n,n2α)C14(n,nα)Be10					9.4	2.2	0.3
		Ne20(n,n2α)C12(n,h)Be10					9.2	11.4	6.5
		Ne20(n,dα)N15(n,d)C14(n,nα)Be10					5.4	1.5	0.1
		Ne20(n,d)F19(n,dα)C14(n,nα)Be10					5.4	0.8	
		Ne20(n,n2α)C12(n,d)B11(n,d)Be10					3.0	0.7	
		Ne20(n,dα)N15(n,dα)Be10					2.7	47.4	52.1
		Ne22(n,2nα)O17(n,2α)Be10					2.3	1.3	0.1
		Ne20(n,nα)O16(n,nα)C12(n,h)Be10					1.9	0.4	0.1
		Ne20(n,hα)C14(n,nα)Be10					1.5	1.4	0.5
		Ne20(n,tα)N14(n,pα)Be10					1.3	1.9	4.9
		Ne20(n,nα)O16(n,h)C14(n,nα)Be10					1.3	0.5	
		Ne20(n,dα)N15(n,2n)N14(n,pα)Be10					1.2	0.3	
		Ne20(n,d)F19(n,t)O17(n,2α)Be10					1.1		
		Ne20(n,2nα)O15(β <sup>+</sup> )N15(n,dα)Be10					0.2	11.2	16.3
		Ne20(n,t)F18(β <sup>+</sup> )O18(n,n2α)Be10						5.5	4.9
		Ne20(n,h)O18(n,n2α)Be10						2.0	1.8
		Ne20(n,dα)N15(n,d)C14(n,nα)Be10						1.5	
		Ne20(n,nα)O16(n,hα)Be10						0.2	2.0
		Ne22(n,n3α)Be10							1.0

# Neon activation characteristics

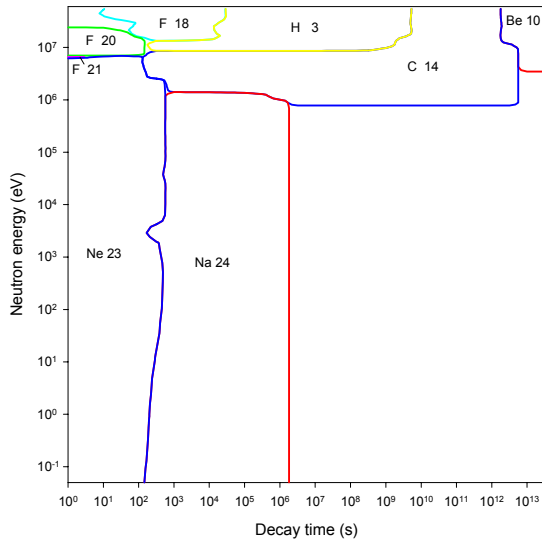


Decay time (years)

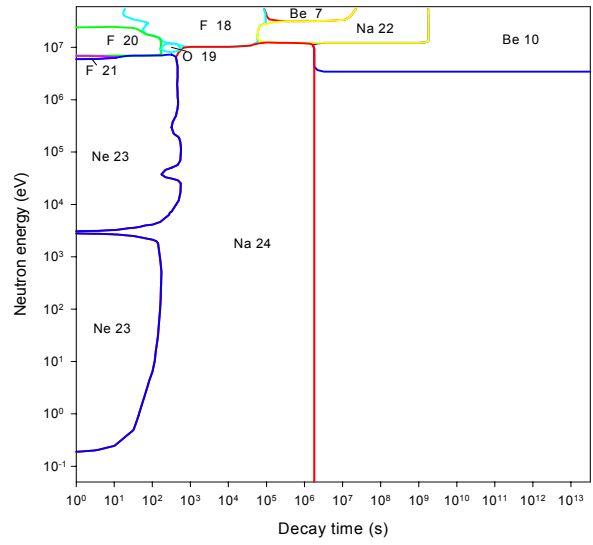
Decay time (years)

# Neon importance diagrams & transmutation

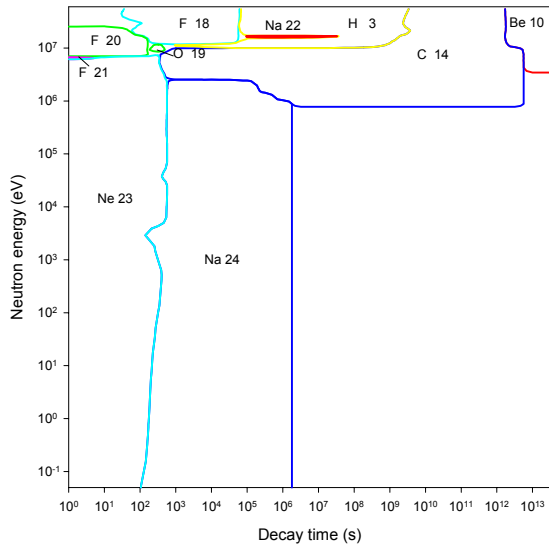
**Activity**



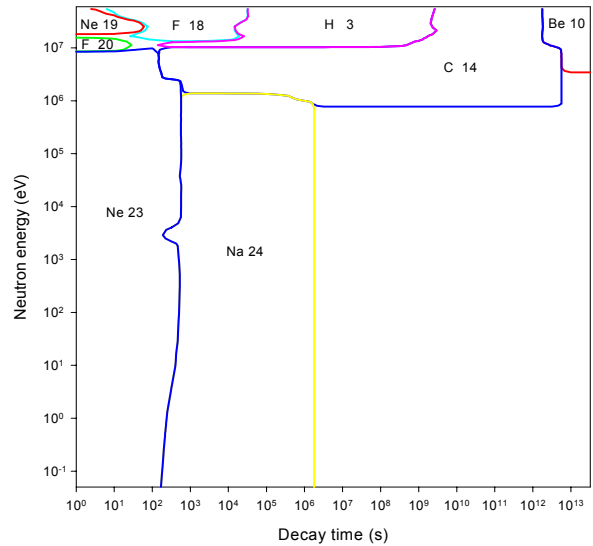
**Dose rate**



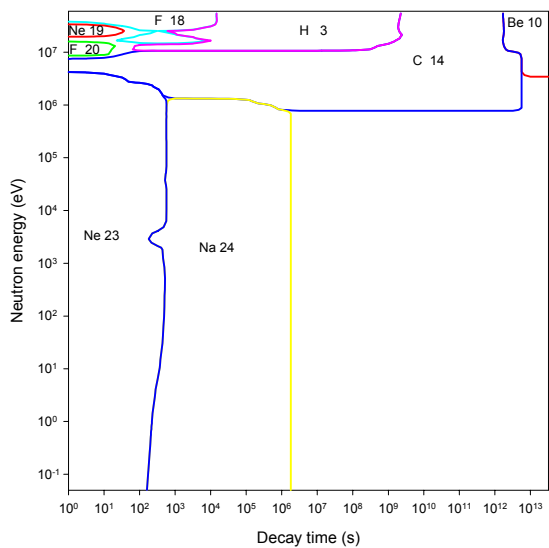
**Heat output**



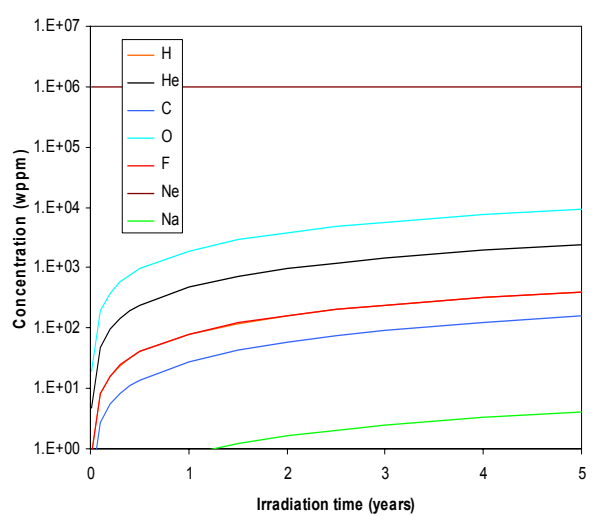
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**



*Graphs for He, F are indistinguishable*



# Sodium

## General properties

Atomic number	11	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	2.3 10 <sup>4</sup>	Na23	100.0
Melting point / K	371.0		
Boiling point / K	1156		
Density / kgm <sup>-3</sup>	971		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	141		
Electrical resistivity /Ωm	4.2 10 <sup>-8</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	7.06 10 <sup>-5</sup>		
Crystal structure	hexagonal		
Number of stable isotopes	1		
Mean atomic weight	22.989768		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	1.09E15	1.46E14	1.02E13	6.86E12	1.68E10	4.28E1	kW kg <sup>-1</sup>	6.03E-1	1.05E-1	3.02E-3	9.53E-4	1.53E-8	1.07E-15
F20	58.27						F20	69.57					
Ne23	19.33	0.40					Na24	17.16	98.62	58.97			
Na24	12.64	94.18	23.23				Ne23	11.58	0.19				
Na24m	8.90						Na24m	1.25					
H3	0.42	3.17	45.20	63.81	99.98		Na22	0.21	1.19	40.89	99.58		
Na22	0.30	2.22	31.57	36.19			H3			0.14	0.42	99.80	
C14					0.02	47.38	C14					0.20	15.01
Be10						52.62	Be10						84.99
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	5.15E5	1.83E5	4.92E3	1.38E3	1.59E-12	1.52E-12	Sv kg <sup>-1</sup>	2.58E5	7.03E4	1.16E4	8.13E3	7.06E-1	3.65E-8
F20	60.64						Ne23	72.83					
Na24	35.38	99.00	63.64				Na24	23.01	84.22	8.85			
Na24m	1.81						Na22	4.01	14.75	89.47	97.74		
Ne23	1.47	0.01					H3	0.08	0.28	1.68	2.26	99.69	
Na22	0.35	0.98	36.36	100.0			C14					0.31	32.19
Be10					100.0*	100.0*	Be10						67.81
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	1.36E5	4.28E4	6.05E3	4.36E3	4.38E0	9.06E-7		1.50E12	1.70E11	3.47E10	2.49E10	1.71E5	2.08E-2
Ne23	68.40						F20	80.11					
Na24	27.45	86.75	10.62				Na24	9.21	80.24	6.85			
Na22	3.01	9.83	69.48	73.93			Ne23	5.03	0.12				
H3	0.89	2.81	19.90	26.07	99.49		Na24m	3.09					
C14					0.51	12.98	Na22	2.16	19.03	93.02	99.82		
Be10						87.02	H3			0.13	0.18	97.77	
							C14					2.23	97.30
							Be10						2.70

# Sodium

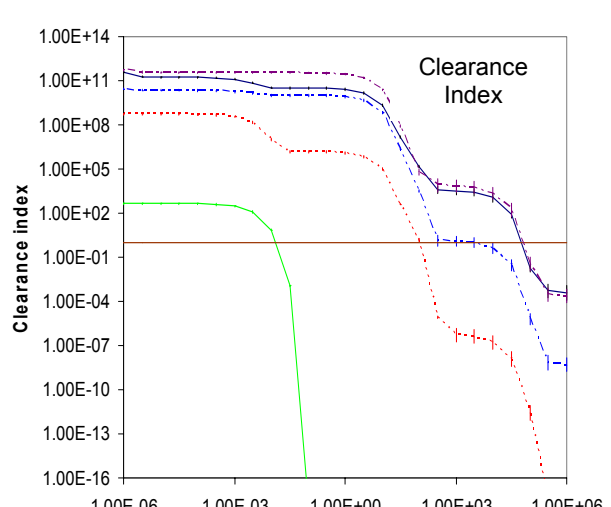
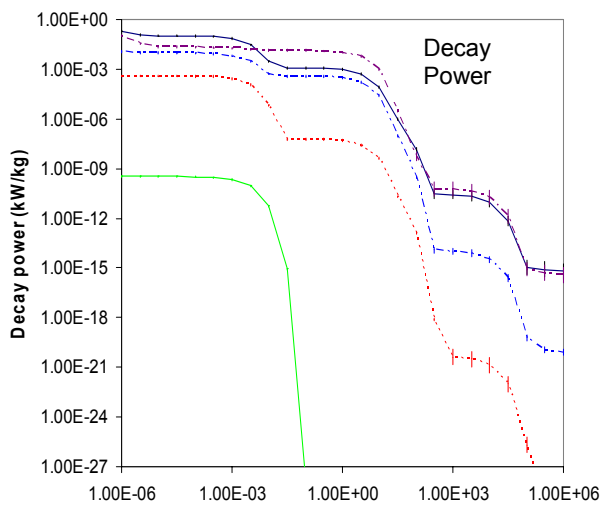
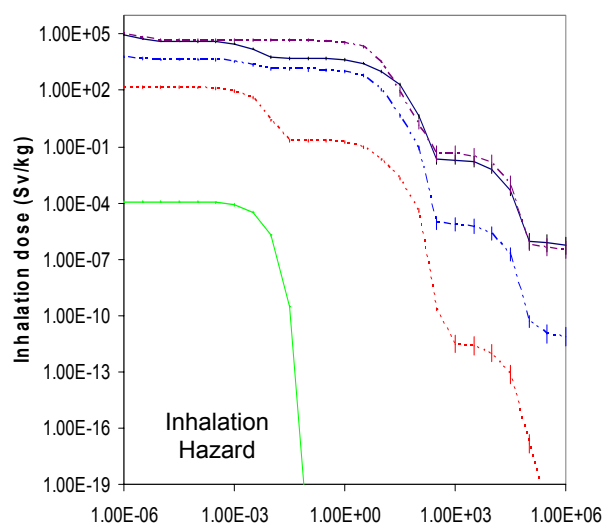
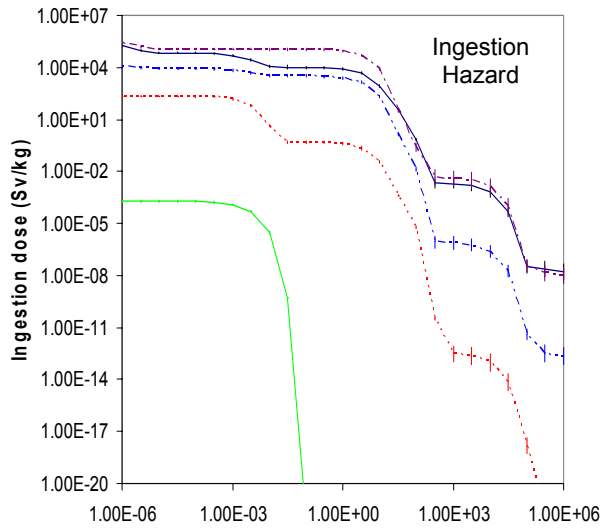
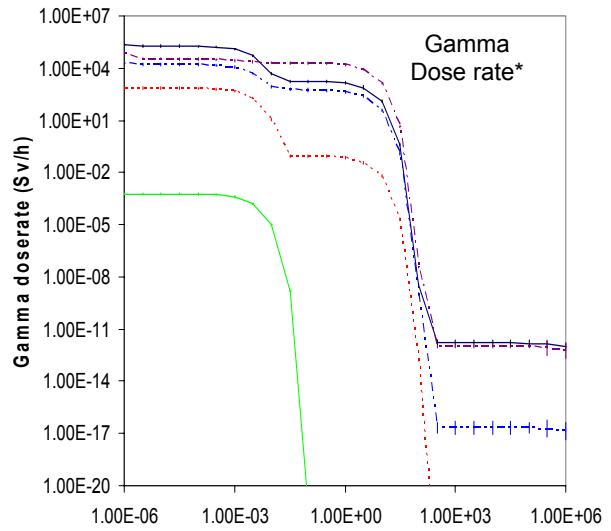
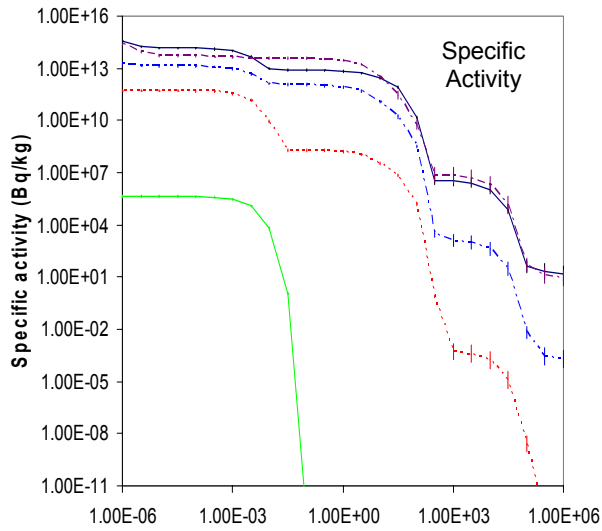
## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
F20	11.03 s	Na23(n,α)F20 Na23(n,t)Ne21(n,d)F20 Na23(n,d)Ne22(n,t)F20 Na23(n,3n)Na21(β <sup>+</sup> )Ne21(n,d)F20 Na23(n,2n)Na22(β <sup>+</sup> )Ne22(n,t)F20				94.5	84.6	48.8	77.3
Ne23	37.2 s	&Na23(n,γ)Na24(β <sup>-</sup> )Mg24(n,γ)Mg25(n,α)_ Ne22(n,γ)Ne23	99.5						
		Na23(n,γ)Na24m(β <sup>-</sup> )Mg24(n,γ)Mg25(n,α)_ Ne22(n,γ)Ne23	0.4						
		Na23(n,p)Ne23				100.0	99.7	99.9	99.9
Na24	14.957 h	&Na23(n,γ)Na24	100.0	100.0	100.0	96.8	100.0	100.0	100.0
P32	14.27 d	&Na23(n,γ)Na24(β <sup>-</sup> )Mg24(n,γ)Mg25(n,γ)_ Mg26(n,γ)Mg27(β <sup>-</sup> )Al27(n,γ)Al28(β <sup>-</sup> )Si28_ (n,γ)Si29(n,γ)Si30(n,γ)Si31(β <sup>-</sup> )P31(n,γ)P32	99.3						
Na22	2.603 y	Na23(n,2n)Na22				99.6	99.9	100.0	100.0
H3	12.33 y	Na23(n,X)H3				98.6	96.8	96.6	94.6
		Na23(n,nα)F19(n,X)H3				0.4	1.4	0.6	0.3
		Na23(n,tα)O17(n,X)H3						0.2	2.0
Si32	132.0 y	&Na23(n,γ)Na24(β <sup>-</sup> )Mg24(n,γ)_ Mg25(n,γ)Mg26(n,γ)Mg27(β <sup>-</sup> )Al27(n,γ)_ Al28(β <sup>-</sup> )Si28(n,γ)Si29(n,γ)Si30(n,γ)Si31_ (n,γ)Si32	100.0						
C14	5700 y	Na23(n,t)Ne21(n,2α)C14				27.3	5.8	5.3	0.9
		Na23(n,d)Ne22(n,2n)Ne21(n,2α)C14				26.8	0.3		
		Na23(n,nα)F19(n,nα)N15(n,d)C14				12.3	1.5	0.2	
		Na23(n,α)F20(β <sup>-</sup> )Ne20(n,α)O17(n,α)C14				11.7			
		Na23(n,d)Ne22(n,nα)O18(n,nα)C14				7.7	1.5	0.2	
		Na23(n,nα)F19(n,d)O18(n,nα)C14				3.3	1.0	0.1	
		Na23(n,2n)Na22(n,2α)N15(n,d)C14				3.3			
		Na23(n,2n)Na22(n,d)Ne21(n,2α)C14				2.1			
		Na23(n,nα)F19(n,2n)F18(β <sup>+</sup> )O18(n,nα)C14				1.4	0.5		
		Na23(n,nα)F19(n,dα)C14				1.2	38.7	19.9	8.3
		Na23(n,2n)Na22(n,nα)F18(β <sup>+</sup> )O18(n,nα)C14				0.9	0.2		
		Na23(n,t)Ne21(n,α)O18(n,nα)C14				0.6			
		Na23(n,d)Ne22(n,2n)Ne21(n,α)O18(n,nα)C14				0.5			
		Na23(n,nα)F19(n,t)O17(n,α)C14				0.2			
		Na23(n,n2α)N15(n,d)C14					27.5	22.5	5.4
		Na23(n,d)Ne22(n,n2α)C14					18.1	12.5	3.9
		Na23(n,2n)Na22(β <sup>+</sup> )Ne22(n,n2α)C14					1.8	1.1	0.4
		Na23(n,d)Ne22(n,nα)O18(n,nα)C14					1.5		
		Na23(n,dα)O18(n,nα)C14					0.9	7.1	4.2
		Na23(n,d2α)C14						18.2	60.3
Na23(n,2nα)F18(β <sup>+</sup> )O18(n,nα)C14						8.6	4.4		
Na23(n,nα)O16(n,h)C14						0.3	2.3		
Na23(n,tα)O17(n,α)C14						0.3	6.0		
Be10	1.6 10 <sup>6</sup> y	Na23(n,α)F20(β <sup>-</sup> )Ne20(n,2α)C13(n,α)Be10				80.9	0.1		
		Na23(n,α)F20(β <sup>-</sup> )Ne20(n,nα)O16(n,α)_ C13(n,α)Be10				12.1			
		Na23(n,α)F20(β <sup>-</sup> )Ne20(n,α)O17(n,nα)_ C13(n,α)Be10				4.5			
		Na23(n,nα)F19(n,nα)N15(n,nα)B11(n,d)Be10				0.4	1.0		
		Na23(n,n2α)N15(n,nα)B11(n,d)Be10					25.4	2.5	0.2
		Na23(n,nα)F19(n,dα)C14(n,nα)Be10					17.4	1.6	0.2
		Na23(n,n2α)N15(n,d)C14(n,nα)Be10					12.4	1.9	0.1
		Na23(n,d)Ne22(n,n2α)C14(n,nα)Be10					8.1	1.0	



Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	Na23(n,n2α)N15(n,dα)Be10					6.2	57.3	47.0
		Na23(n,nα)F19(n,t)O17(n,2α)Be10					3.1	0.3	
		Na23(n,nα)F19(n,2nα)N14(n,pα)Be10					2.9	0.4	
		Na23(n,nα)F19(n,n2α)B11(n,d)Be10					2.6	0.4	
		Na23(n,t)Ne21(n,2α)C14(n,nα)Be10					2.6	0.4	
		Na23(n,t)Ne21(n,nα)O17(n,2α)Be10					2.5	0.5	
		Na23(n,n2α)N15(n,2n)N14(n,pα)Be10					2.5	0.4	
		Na23(n,tα)O17(n,2α)Be10					2.1	3.3	6.4
		Na23(n,d)Ne22(n,2nα)O17(n,2α)Be10					2.0	0.6	
		Na23(n,n2α)N15(n,t)C13(n,α)Be10					1.0	0.3	0.2
		Na23(n,2nα)F18(β <sup>+</sup> )O18(n,n2α)Be10						10.4	8.8
		Na23(n,dα)O18(n,n2α)Be10						8.5	8.3
		Na23(n,d2α)C14(n,nα)Be10						2.3	2.1
		Na23(n,t)Ne21(n,3α)Be10						0.9	2.4
		Na23(n,2n2α)N14(n,pα)Be10						0.5	5.1
		Na23(n,t)Ne21(n,tα)N15(n,dα)Be10						0.4	1.8
		Na23(n,nt)Ne20(n,dα)N15(n,dα)Be10						0.3	1.4
		Na23(n,nα)F19(n,d2α)Be10						0.1	2.0
		Na23(n,ntα)O16(n,hα)Be10							1.3
		Na23(n,n3α)B11(n,d)Be10							1.2

# Sodium activation characteristics

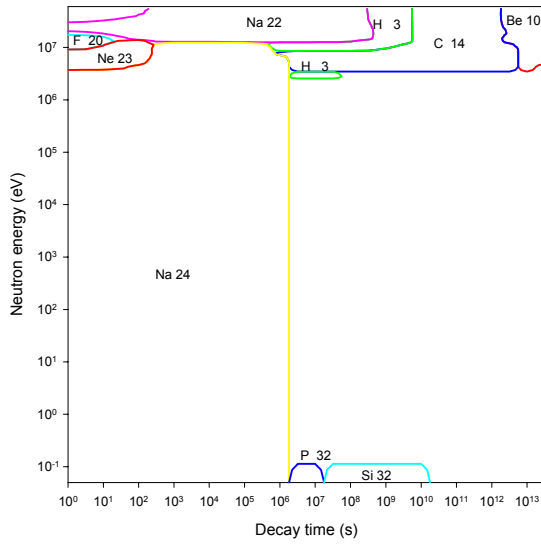


Decay time (years)

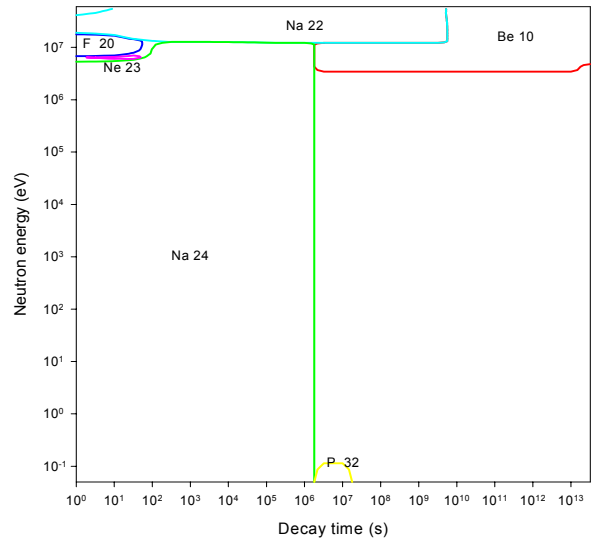
Decay time (years)

# Sodium importance diagrams & transmutation

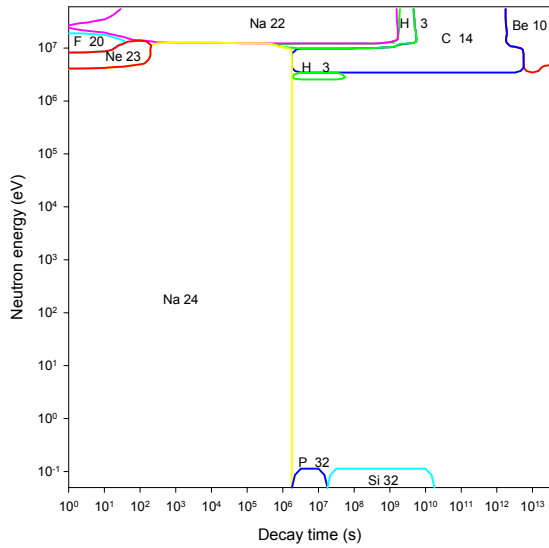
Activity



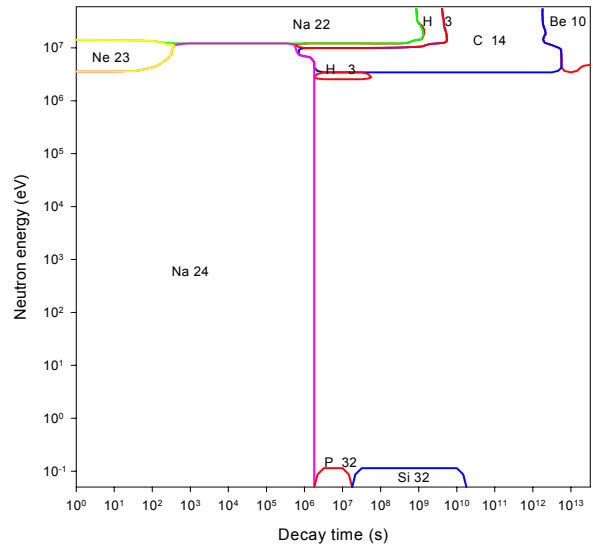
Dose rate



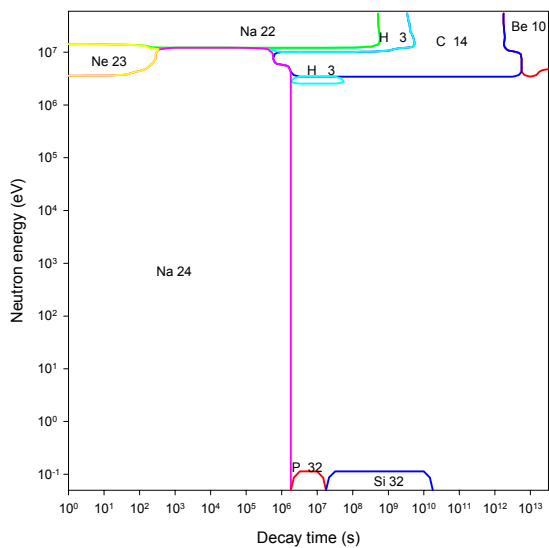
Heat output



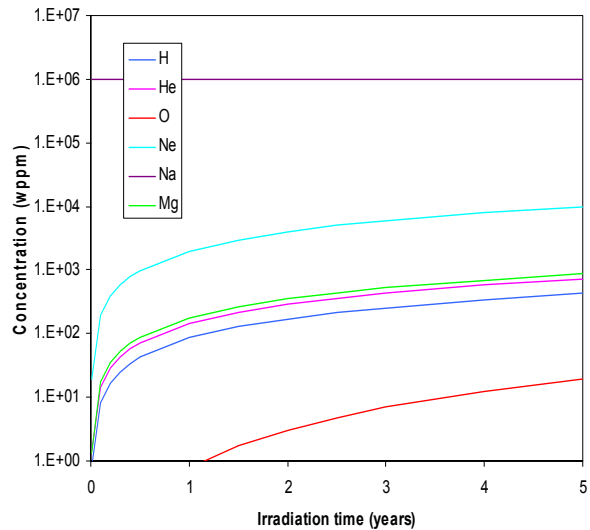
Ingestion dose



Inhalation dose



First wall transmutation





# Magnesium

## General properties

Atomic number	12	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	2.30 10 <sup>4</sup>	Mg24	78.99
Melting point / K	922.0	Mg25	10.00
Boiling point / K	1363	Mg26	11.01
Density / kgm <sup>-3</sup>	1738		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	156		
Electrical resistivity /Ωm	4.38 10 <sup>-8</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	2.61 10 <sup>-5</sup>		
Crystal structure	HCP		
Number of stable isotopes	3		
Mean atomic weight	24.3050		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	9.89E14	7.04E14	1.23E13	1.25E11	5.42E8	1.06E3	kW kg <sup>-1</sup>	5.72E-1	5.27E-1	9.09E-3	1.52E-6	1.05E-9	3.18E-13
Na24	71.28	99.77	98.92				Na24	92.39	99.92	99.98			
Na24m	22.14						Na24m	2.97					
Na25	2.73	0.09					Na25	1.46	0.04				
Ne23	2.38						Ne23	1.37					
Na26	0.81						Na26	1.25					
H3	0.01	0.02	1.04	97.00	85.50		Na22			0.02	92.65		
Na22			0.04	2.94			H3				7.31	40.47	
C14				0.06	14.50	39.18	C14					59.49	1.03
Al26						59.99	Al26					0.03	98.85
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	9.29E5	8.95E5	1.55E4	1.97E0	5.10E-7	4.63E-7	Sv kg <sup>-1</sup>	3.24E5	3.02E5	5.24E3	1.69E1	6.51E-2	2.48E-6
Na24	96.64	99.97	99.98				Na24	93.50	99.97	99.60			
Na24m	2.18						Na22			0.29	69.60		
Na26	0.58						H3			0.10	30.13	29.92	
Na22			0.02	100.0			C14					70.07	9.72
Al26					100.0	100.0	Al26						89.88
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	2.01E5	1.90E5	3.32E3	3.67E1	5.76E-1	1.55E-5		8.62E11	7.04E11	1.22E10	3.80E7	8.32E4	2.14E0
Na24	94.80	99.96	98.80				Na24	81.77	99.83	99.60			
H3	0.02	0.02	1.00	85.74	20.91		Na24m	12.10					
Na22			0.19	13.00			Na26	2.34					
C14				1.26	79.09	15.61	Na22			0.39	96.60		
Al26						82.40	H3			0.01	3.18	5.57	
Be10						1.99	C14				0.21	94.43	19.46
							Al26						80.53

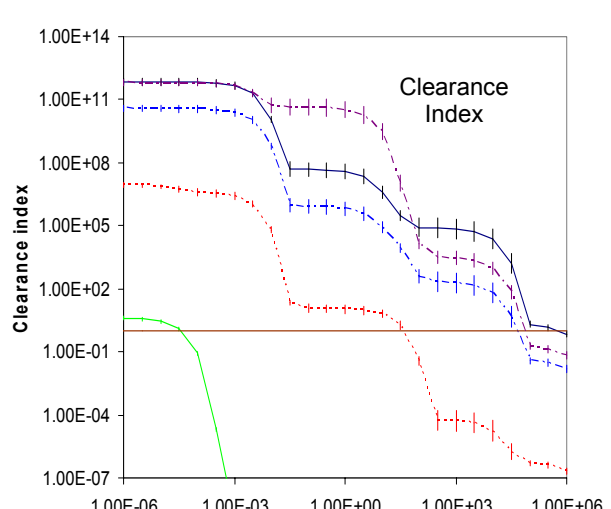
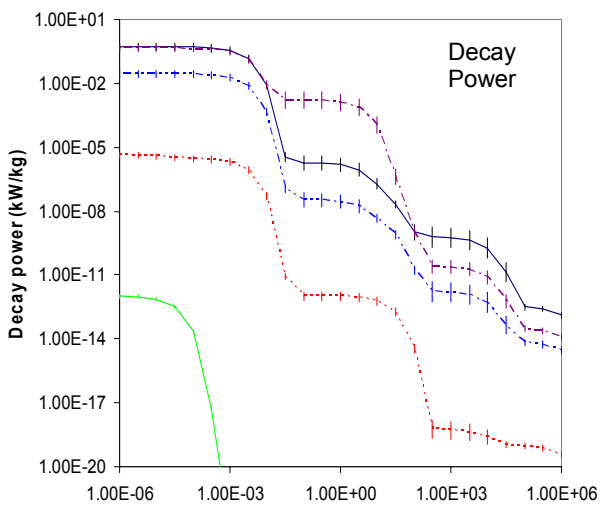
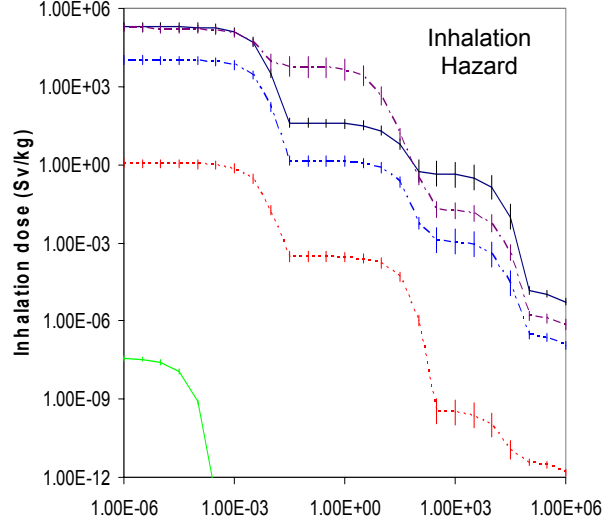
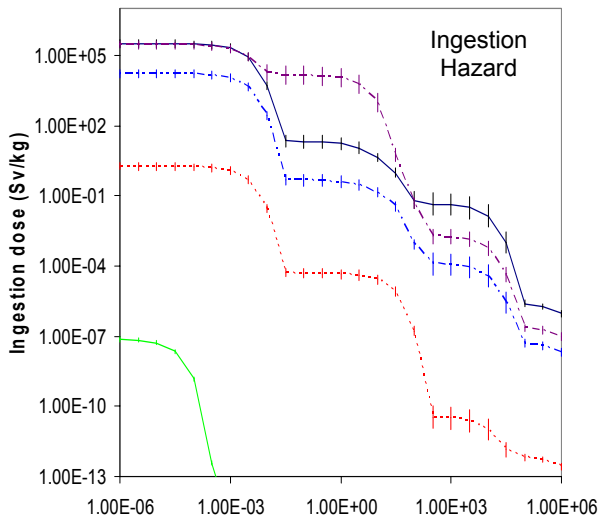
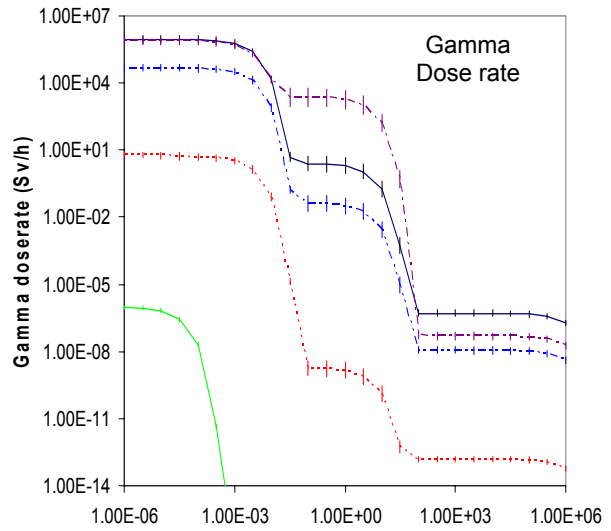
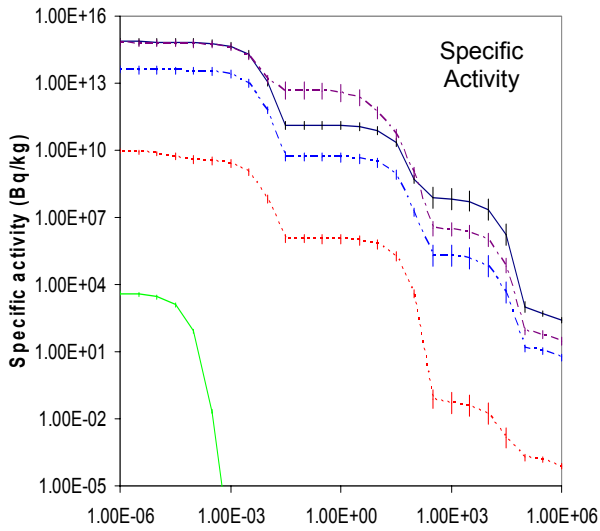
# Magnesium

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Na25	59.6 s	Mg25(n,p)Na25 Mg26(n,2n)Mg25(n,p)Na25 Mg26(n,d)Na25				89.2 6.9 3.8	14.1 0.9 84.5	9.9 0.3 89.4	7.3 0.1 92.4
Mg27	9.46 m	Mg26(n,γ)Mg27 Mg25(n,γ)Mg26(n,γ)Mg27	99.1 0.9	100.0	100.0	98.6	99.6	99.7	99.9
Si31	2.62 h	Mg26(n,γ)Mg27(β <sup>-</sup> )Al27(n,γ)Al28(β <sup>-</sup> ) Si28(n,γ)Si29(n,γ)Si30(n,γ)Si31	99.8	100.0					
Na24	14.96 h	&Mg25(n,α)Ne22(n,γ)Ne23(β <sup>-</sup> )Na23_ (n,γ)Na24 &Mg24(n,p)Na24 &Mg25(n,2n)Mg24(n,p)Na24 &Mg25(n,d)Na24 &Mg26(n,2n)Mg25(n,d)Na24 &Mg26(n,t)Na24 Mg26(n,h)Ne24(β <sup>-</sup> )Na24	99.3	100.0	100.0				
P32	14.27 d	Mg26(n,γ)Mg27(β <sup>-</sup> )Al27(n,γ)Al28(β <sup>-</sup> )Si28_ (n,γ)Si29(n,γ)Si30(n,γ)Si31(β <sup>-</sup> )P31(n,γ)P32	99.9						
Na22	2.60 y	Mg24(n,d)Na23(n,2n)Na22 Mg26(n,α)Ne23(β <sup>-</sup> )Na23(n,2n)Na22 Mg25(n,2n)Mg24(n,d)Na23(n,2n)Na22 Mg25(n,t)Na23(n,2n)Na22 Mg24(n,t)Na22 Mg24(n,2n)Mg23(β <sup>+</sup> )Na23(n,2n)Na22 Mg24(n,2p)Ne23(β <sup>-</sup> )Na23(n,2n)Na22 Mg25(n,nt)Na22 Mg24(n,3n)Mg22(β <sup>+</sup> )Na22				92.3 5.8 0.4 0.2	39.0 0.9 54.5 4.1 0.7	1.6 0.1 96.5 0.2	0.5 94.0 3.8 0.8
H3	12.33 y	Mg25(n,X)H3 Mg24(n,d)Na23(n,X)H3 Mg24(n,α)Ne21(n,X)H3 Mg26(n,2n)Mg25(n,X)H3 Mg26(n,α)Ne23(β <sup>-</sup> )Na23(n,X)H3 Mg24(n,X)H3 Mg26(n,X)H3 Mg24(n,α)Ne20(n,X)H3 Mg24(n,2α)O17(n,X)H3 Mg24(n,2n)Mg23(β <sup>+</sup> )Na23(n,X)H3				64.5 19.9 9.4 2.6 1.3	18.5 9.1 0.6 56.7 9.5 1.2 1.2 1.0	14.9 3.2 0.3 0.3 64.2 12.6 0.4 0.3 0.5	13.1 1.2 0.3 0.1 68.5 13.1 0.3 0.2
Si32	132.0 y	Mg26(n,γ)Mg27(β <sup>-</sup> )Al27(n,γ)Al28(β <sup>-</sup> ) Si28(n,γ)Si29(n,γ)Si30(n,γ)Si31(n,γ)Si32	100.0						
C14	5700 y	Mg24(n,α)Ne21(n,2α)C14 Mg24(n,α)Ne21(n,α)O17(n,α)C14 Mg24(n,α)Ne21(n,α)O18(n,α)C14 Mg24(n,α)Ne20(n,α)O17(n,α)C14 Mg25(n,α)Ne21(n,2α)C14 Mg24(n,2α)O17(n,α)C14 Mg24(n,h)Ne22(n,2α)C14 Mg24(n,d)Na23(n,α)F19(n,α)C14 Mg24(n,2α)O16(n,h)C14 Mg26(n,α)Ne22(n,2α)C14 Mg24(n,d)Na23(n,2α)N15(n,d)C14 Mg24(n,α)Ne20(n,α)N15(n,d)C14 Mg25(n,2α)O18(n,α)C14 Mg24(n,α)Ne20(n,d)F19(n,α)C14 Mg24(n,d)Na23(n,d)Ne22(n,2α)C14 Mg25(n,3α)C14 Mg24(n,α)Ne20(n,hα)C14 Mg24(n,d)Na23(n,t)Ne21(n,2α)C14 Mg24(n,α)Ne20(n,α)O16(n,h)C14				90.1 3.6 2.1 0.8 1.0	6.5 8.8 10.5 8.3 7.7 7.6 6.5 5.5 5.2 4.8 4.5 3.6 1.8 1.4 1.2 1.1	0.8 0.5 0.9 18.2 0.8 28.1 1.2 0.9 1.2 0.5 0.6 0.5 5.5 1.1 0.2 0.4	1.2 0.5 0.5 18.0 0.3 0.1 0.3 0.2 4.8 0.9 0.2

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	Mg24(n,t)Na22(β <sup>+</sup> )Ne22(n,n2α)C14 Mg24(n,dα)F19(n,dα)C14 Mg24(n,d)Na23(n,d2α)C14 Mg24(n,2nα)Ne19(β <sup>+</sup> )F19(n,dα)C14 Mg24(n,tα)F18(β <sup>+</sup> )O18(n,nα)C14 Mg24(n,d2α)N15(n,d)C14 Mg25(n,2n2α)O16(n,h)C14 Mg25(n,tα)F19(n,dα)C14 Mg24(n,2n2α)O15(β <sup>+</sup> )N15(n,d)C14 Mg26(n,n3α)C14					0.9 0.1	5.1 22.1 1.1 0.5 0.4 0.4 0.2 0.1	3.7 23.7 2.3 4.3 5.6 2.8 1.3 1.6 3.5 6.0
Cl36	3.0 10 <sup>5</sup> y	Mg26(n,γ)Mg27(β <sup>-</sup> )Al27(n,γ)Al28(β <sup>-</sup> )Si28_ (n,γ)Si29(n,γ)Si30(n,γ)Si31(β <sup>-</sup> )P31(n,γ)P32_ (β <sup>-</sup> )S32(n,γ)S33(n,γ)S34(n,γ)S35(β <sup>-</sup> )Cl35_ (n,γ)Cl36	94.5						
Al26	7.2 10 <sup>5</sup> y	Mg26(n,γ)Mg27(β <sup>-</sup> )Al27(n,2n)Al26				99.9	99.9	100.0	100.0
Be10	1.6 10 <sup>6</sup> y	Mg24(n,nα)Ne20(n,2α)C13(n,α)Be10 Mg24(n,α)Ne21(n,nα)O17(n,nα)C13(n,α)Be10 Mg24(n,nα)Ne20(n,nα)O16(n,α)C13(n,α)Be10 Mg24(n,nα)Ne20(n,α)O17(n,nα)C13(n,α)Be10 Mg24(n,α)Ne21(n,2n)Ne20(n,2α)C13(n,α)Be10 Mg24(n,2α)O17(n,2α)Be10 Mg24(n,2α)O17(n,nα)C13(n,α)Be10 Mg24(n,n2α)O16(n,nα)C12(n,h)Be10 Mg24(n,h)Ne22(n,2nα)C14(n,nα)Be10 Mg24(n,nα)Ne20(n,n2α)C12(n,h)Be10 Mg24(n,n2α)O16(n,h)C14(n,nα)Be10 Mg24(n,nα)Ne20(n,dα)N15(n,dα)Be10 Mg24(n,d)Na23(n,n2α)N15(n,dα)Be10 Mg25(n,n2α)O17(n,2α)Be10 Mg25(n,3α)C14(n,nα)Be10 Mg24(n,n2α)O16(n,t)N14(n,pα)Be10 Mg24(n,h)Ne22(n,2nα)O17(n,2α)Be10 Mg24(n,n2α)O16(n,dα)B11(n,d)Be10 Mg24(n,dα)F19(n,dα)C14(n,nα)Be10 Mg24(n,d2α)N15(n,dα)Be10 Mg24(n,3α)C13(n,α)Be10 Mg24(n,n2α)O16(n,hα)Be10 Mg24(n,nα)Ne20(n,2nα)O15(β <sup>+</sup> )N15_ (n,dα)Be10 Mg24(n,dα)F19(n,nα)N15(n,dα)Be10 Mg25(n,2α)O18(n,n2α)Be10 Mg24(n,n2α)O16(n,2n)O15(β <sup>+</sup> )N15(n,dα)Be10 Mg24(n,n2α)O16(n,d)N15(n,dα)Be10 Mg24(n,tα)F18(β <sup>+</sup> )O18(n,n2α)Be10 Mg24(n,α)Ne21(n,3α)Be10 Mg24(n,dα)F19(n,d2α)Be10 Mg24(n,α)Ne21(n,tα)N15(n,dα)Be10 Mg24(n,2n2α)O15(β <sup>+</sup> )N15(n,dα)Be10 Mg24(n,n3α)C12(n,h)Be10 Mg25(n,t2α)N15(n,dα)Be10				64.5 15.4 9.7 3.6 1.2	1.7 82.1 1.4 0.8 0.6 0.6 0.5 0.2 0.2 0.2 0.1 0.1	0.1 20.2 0.1 3.3 3.0 1.4 4.6 6.0 4.6 4.0 1.4 2.3 1.8 4.8 3.6 2.1 2.0 1.8 1.4 1.2 1.1 1.1 1.0 0.8 0.3 0.2 0.1	0.4 0.5 0.1 0.2 0.3 0.7 0.4 18.1 1.4 7.7 0.6 0.7 0.2 8.4 2.3 4.3 1.7 22.7 6.5 1.3

# Magnesium activation characteristics



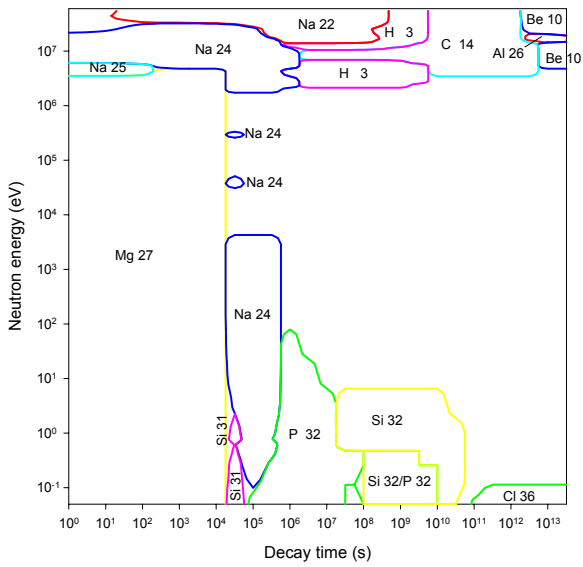
Decay time (years)

Decay time (years)

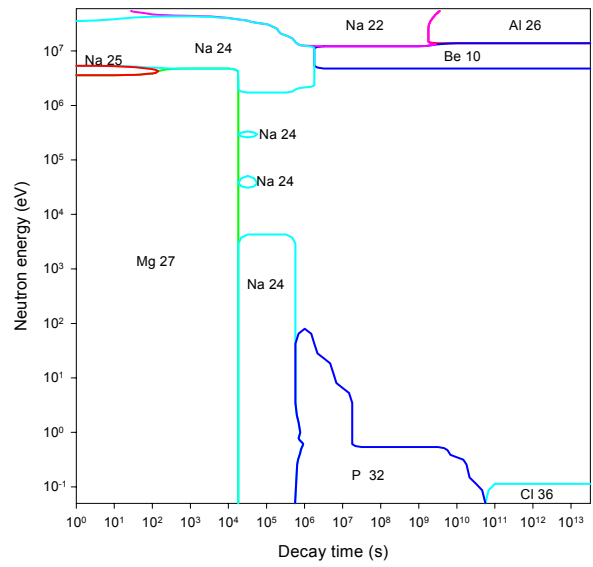


# Magnesium importance diagrams & transmutation

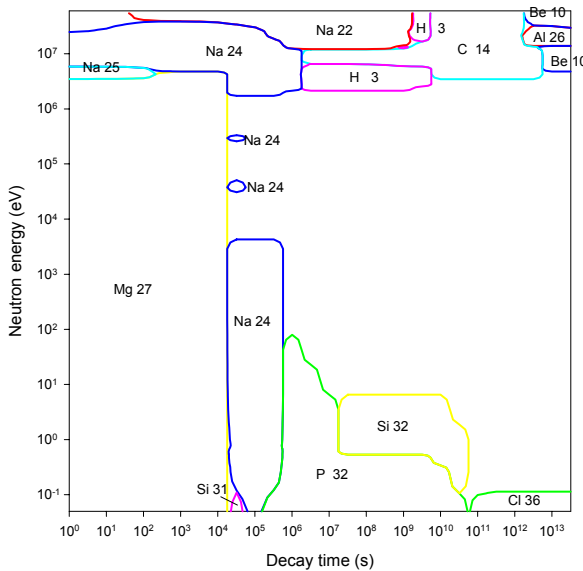
Activity



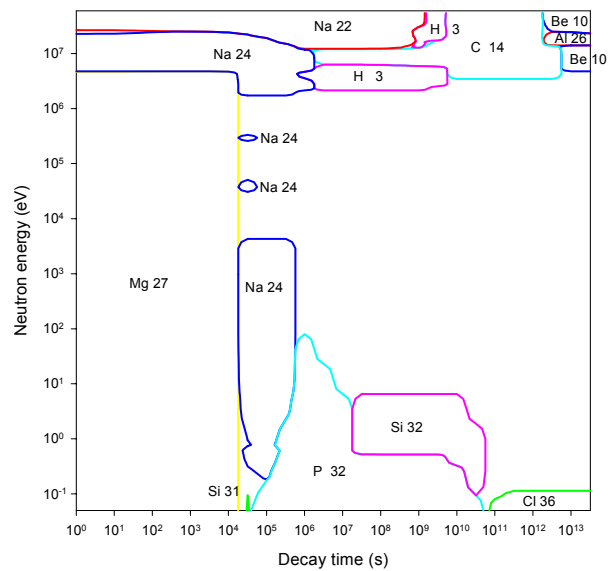
Dose rate



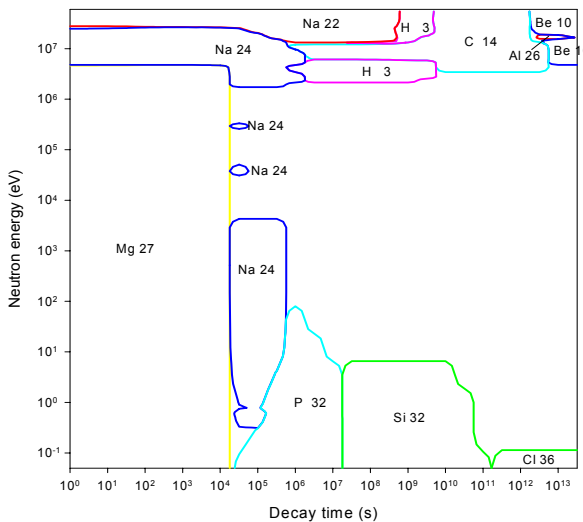
Heat output



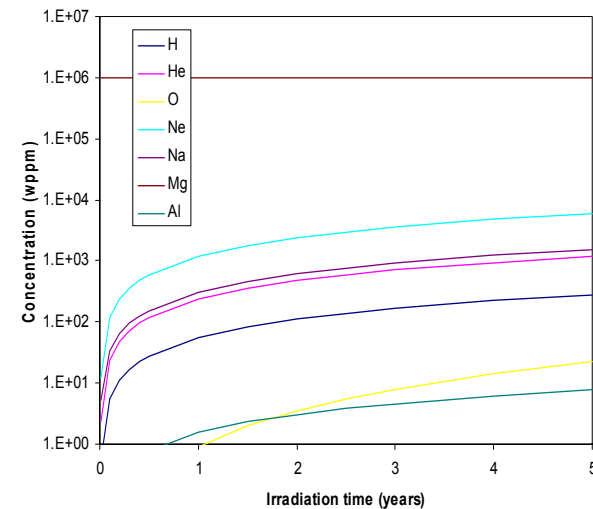
Ingestion dose



Inhalation dose



First wall transmutation





# Aluminium

## General properties

Atomic number	13	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	8.20 10 <sup>4</sup>	Al27	100.0
Melting point / K	933.5		
Boiling point / K	2740		
Density / kgm <sup>-3</sup>	2698		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	237		
Electrical resistivity /Ωm	2.655 10 <sup>2</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	2.303 10 <sup>-5</sup>		
Crystal structure	FCC		
Number of stable isotopes	1		
Mean atomic weight	26.98154		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	9.11E14	6.33E14	9.22E12	1.78E12	6.97E9	1.64E8	kW kg <sup>-1</sup>	4.34E-1	3.74E-1	5.50E-3	1.96E-6	9.51E-8	8.07E-8
Na24	46.79	67.04	79.63				Na24	73.62	85.11	99.96			
Mg27	31.40	30.72					Mg27	16.85	13.30				
Na24m	14.53						Al28	6.99	1.60				
Al28	6.88	1.95					Na24m	2.37					
H3	0.21	0.30	20.36	99.95	97.41		Al26m	0.07					
Al26m	0.09						H3				82.73		
Na22				0.04			Na22				12.74		
Al26				0.01	2.59	100.0	Al26				4.53	100.0	100.0
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	6.69E5	6.05E5	9.56E3	4.93E-1	1.34E-1	1.22E-1	Sv kg <sup>-1</sup>	1.90E5	1.86E5	3.24E3	7.73E1	9.17E-1	5.73E-1
Na24	82.96	91.43	99.99				Na24	96.66	98.01	97.46			
Mg27	9.88	7.44					Mg27	2.72	1.88				
Al28	5.22	1.14					Al28	0.30	0.06				
Na24m	1.88						H3	0.04		2.43	96.48	31.12	
Na22				72.78			Na22			0.08	2.71		
Al26				27.22	100.0	100.0	Al26			0.02	0.82	68.88	100.0
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	1.19E5	1.17E5	2.47E3	4.66E2	5.38E0	3.28E0		8.98E11	6.43E11	7.37E9	2.48E7	5.56E5	4.43E5
Na24	96.80	97.98	80.09				Na24	47.48	66.05	99.62			
Mg27	2.21	1.53					Mg27	31.86	30.26				
H3	0.41	0.42	19.72	99.04	32.86		Al28	13.42	3.69				
Al28	0.35	0.07					Na24m	7.02					
Al26			0.15	0.77	67.13	100.0	H3			0.25	71.65	12.22	
Na22			0.05	0.18			Na22			0.11	26.38		
							Al26				1.97	87.76	100.0

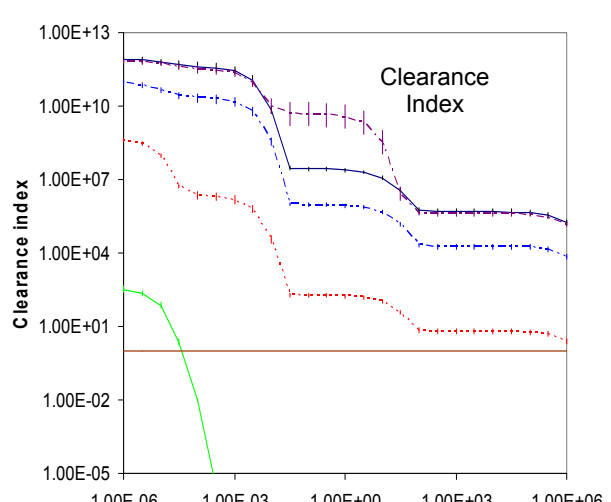
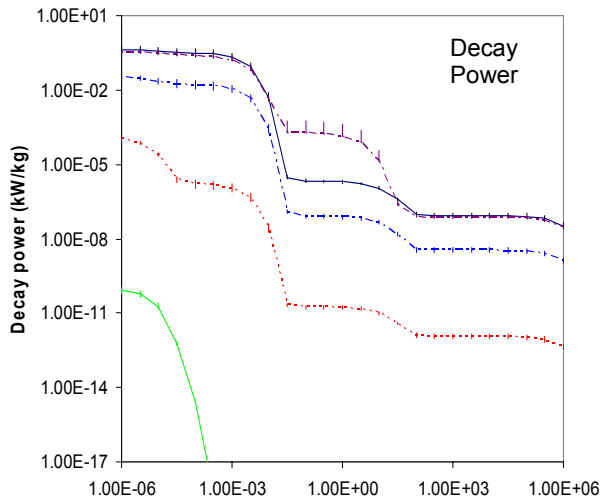
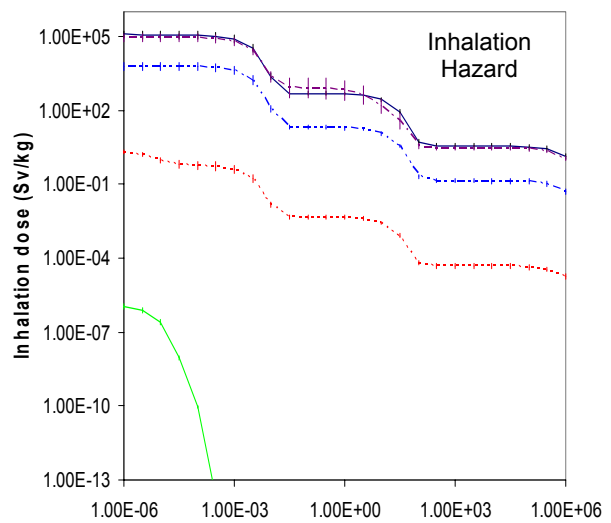
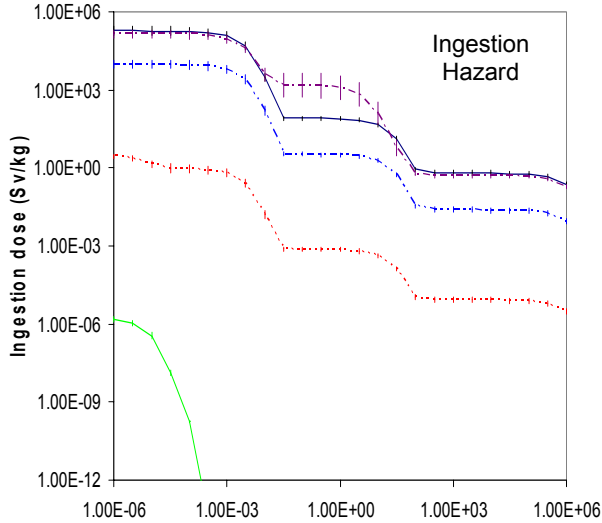
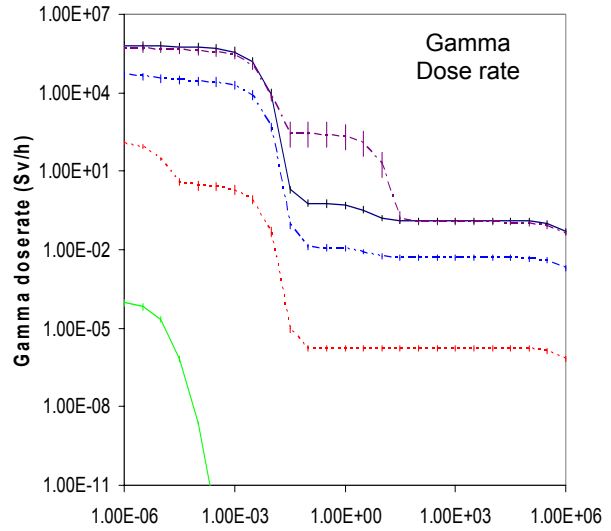
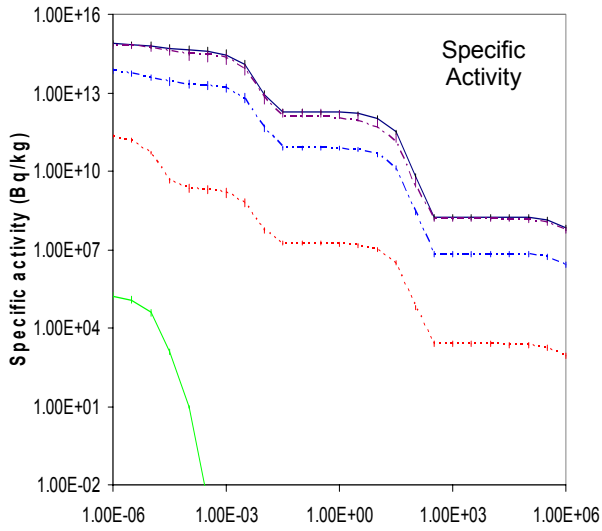
# Aluminium

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	46	30	21	6
Al28	2.241 m	Al27(n,γ)Al28	100.0	100.0	100.0	95.4	99.2	99.6	99.8
Mg27	9.46 m	Al27(n,p)Mg27				100.0	100.0	100.0	100.0
Si31	2.62 h	Al27(n,γ)Al28(β <sup>-</sup> )Si28(n,γ)Si29(n,γ)_ Si30(n,γ)Si31	100.0	100.0	100.0	98.7	99.6	99.7	
Na24	14.96 h	&Al27(n,α)Na24 &Al27(n,t)Mg25(n,d)Na24 &Al27(n,d)Mg26(n,t)Na24 &Al27(n,2n)Al26(n,h)Na24 &Al27(n,2n)Al26m(β <sup>+</sup> )Mg26(n,t)Na24				96.2	82.3 13.2 0.8 0.4 0.1	48.7 32.2 9.2 1.5 1.6	85.0 8.5 2.9 0.5 0.5
P32	14.27 d	Al27(n,γ)Al28(β <sup>-</sup> )Si28(n,γ)Si29(n,γ)_ Si30(n,γ)Si31(β <sup>-</sup> )P31(n,γ)P32	100.0	100.0	100.0	98.6			
Na22	2.60 y	Al27(n,nα)Na23(n,2n)Na22 Al27(n,2n)Al26(n,nα)Na22 &Al27(n,α)Na24(β <sup>-</sup> )Mg24(n,d)Na23_ (n,2n)Na22 Al27(n,d)Mg26(n,α)Ne23(β <sup>-</sup> )Na23(n,2n)Na22   Al27(n,2n)Al26(n,α)Na23(n,2n)Na22 Al27(n,pα)Ne23(β <sup>-</sup> )Na23(n,2n)Na22 Al27(n,2nα)Na22 Al27(n,nt)Mg24(n,t)Na22 Al27(n,t)Mg25(n,nt)Na22				66.5 26.7 3.2  1.7 1.4   1.7  0.7	54.7 42.4 0.1    1.7    0.1	2.5 2.2     91.7 1.7 0.7	0.6 0.4     88.5 5.5 3.1
H3	12.33 y	Al27(n,X)H3 Al27(n,2n)Al26(n,X)H3 Al27(n,nα)Na23(n,X)H3 Al27(n,t)Mg25(n,X)H3				97.7 1.3 0.3  0.6	95.5 1.6 1.4  1.5	96.3 0.6 0.5  1.5	96.8 0.3 0.2  1.2
Si32	132.0 y	Al27(n,γ)Al28(β <sup>-</sup> )Si28(n,γ)Si29(n,γ)_ Si30(n,γ)Si31(n,γ)Si32	84.4	99.3	100.0				
C14	5700 y	&Al27(n,α)Na24(β <sup>-</sup> )Mg24(n,α)Ne21_ (n,2α)C14 &Al27(n,α)Na24(β <sup>-</sup> )Mg24(n,α)_ Ne21(n,nα)O17(n,α)C14 &Al27(n,α)Na24(β <sup>-</sup> )Mg24(n,α)Ne21_ (n,α)O18(n,nα)C14 &Al27(n,α)Na24(β <sup>-</sup> )Mg24(n,nα)_ Ne20(n,α)O17(n,α)C14 Al27(n,nα)Na23(n,t)Ne21(n,2α)C14 Al27(n,t)Mg25(n,nα)Ne21(n,2α)C14 Al27(n,nα)Na23(n,nα)F19(n,nα)N15(n,d)C14   Al27(n,nα)Na23(n,nα)F19(n,dα)C14 Al27(n,nα)Na23(n,2α)N15(n,d)C14 Al27(n,nα)Na23(n,d)Ne22(n,n2α)C14 Al27(n,dα)Ne22(n,n2α)C14 Al27(n,d)Mg26(n,nα)Ne22(n,n2α)C14 Al27(n,t)Mg25(n,2α)O18(n,nα)C14 Al27(n,t)Mg25(n,3α)C14 Al27(n,nα)Na23(n,nα)F19(n,d)O18(n,nα)C14   Al27(n,2n)Al26(n,nα)Na22(n,nα)F18(β <sup>+</sup> )_ O18(n,nα)C14 Al27(n,2α)F19(n,dα)C14 Al27(n,2nα)Na22(β <sup>+</sup> )Ne22(n,n2α)C14 Al27(n,nα)Na23(n,d2α)C14 Al27(n,tα)Ne21(n,2α)C14 Al27(n,3α)N15(n,d)C14 Al27(n,2n2α)F18(β <sup>+</sup> )O18(n,nα)C14				91.6  2.7  1.6  0.7  0.4 0.2 0.2  26.8 19.0 12.5 7.7 4.1 2.1 1.2  0.5 0.1   21.4 5.7 2.1 0.6  12.0 3.2	4.0 3.9 0.8  1.5 1.7 0.9 47.6 0.3 0.4 6.6   24.0 4.7 3.9 3.6  24.0 3.2		

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	46	30	21	6											
Cl36	3.0 10 <sup>3</sup> y	Al27(n,γ)Al28(β <sup>-</sup> )Si28(n,γ)Si29(n,γ)Si30_(n,γ)Si31(β <sup>-</sup> )P31(n,γ)P32(β <sup>-</sup> )S32(n,γ)S33_(n,γ)S34(n,γ)S35(β <sup>-</sup> )Cl35(n,γ)Cl36	95.1																	
Al26	7.2 10 <sup>5</sup> y	Al27(n,2n)Al26				99.5	99.9	99.9	100.0											
Be10	1.6 10 <sup>6</sup> y	&Al27(n,α)Na24(β <sup>-</sup> )Mg24(n,α)Ne20_(n,2α)C13(n,α)Be10 Al27(n,α)Na23(n,α)F20(β <sup>-</sup> )Ne20(n,2α)_C13(n,α)Be10 &Al27(n,α)Na24(β <sup>-</sup> )Mg24(n,α)Ne21_(n,α)O17(n,α)C13(n,α)Be10 &Al27(n,α)Na24(β <sup>-</sup> )Mg24(n,α)Ne20_(n,α)O16(n,α)C13(n,α)Be10 Al27(n,α)Na23(n,α)F20(β <sup>-</sup> )Ne20(n,α)_O16(n,α)C13(n,α)Be10 &Al27(n,α)Na24(β <sup>-</sup> )Mg24(n,α)Ne20_(n,α)O17(n,α)C13(n,α)Be10 Al27(n,α)Na23(n,2α)N15(n,α)B11_(n,d)Be10 Al27(n,α)Na23(n,α)F19(n,dα)C14_(n,α)Be10 Al27(n,α)Na23(n,2α)N15(n,d)C14_(n,α)Be10 &Al27(n,α)Na24(β <sup>-</sup> )Mg24(n,2α)O17_(n,2α)Be10 Al27(n,α)Na23(n,2α)N15(n,dα)Be10 Al27(n,α)Na23(n,d)Ne22(n,2α)C14_(n,α)Be10 Al27(n,dα)Ne22(n,2α)C14(n,α)Be10 Al27(n,α)Na23(n,α)F19(n,t)O17(n,2α)Be10   Al27(n,dα)Ne22(n,2α)O17(n,2α)Be10   Al27(n,t)Mg25(n,2α)O17(n,2α)Be10   Al27(n,2α)F20(β <sup>-</sup> )Ne20(n,dα)N15(n,dα)Be10   Al27(n,2α)F19(n,dα)C14(n,α)Be10   Al27(n,α)Na23(n,2α)F18(β <sup>+</sup> )O18_(n,2α)Be10   Al27(n,dα)Ne22(n,α)O18(n,2α)Be10   Al27(n,α)Na23(n,dα)O18(n,2α)Be10   Al27(n,2α)F19(n,α)N15(n,dα)Be10   Al27(n,tα)Ne21(n,3α)Be10   Al27(n,2α)F19(n,d2α)Be10   Al27(n,3α)N15(n,dα)Be10   Al27(n,tα)Ne21(n,tα)N15(n,dα)Be10   Al27(n,2n2α)F18(β <sup>+</sup> )O18(n,2α)Be10				57.6	14.1	11.0	6.9	1.7	2.6									
								16.0	0.5											
								11.0	0.3											
								7.8	0.4											
								5.9												
								5.3	15.2	1.2										
								5.2	0.2											
								4.2	13.9	0.3										
								2.0												
								1.0	8.2	0.2										
								0.6	5.7	0.1										
								0.1	2.6	0.1										
									6.3	0.3										
									2.8	0.2										
									2.8	0.2										
									2.2	0.2										
									2.1	0.6										
									0.4	5.3										
									0.4	3.3										
									0.2	60.7										
									0.2	4.0										
										3.7										

# Aluminium activation characteristics

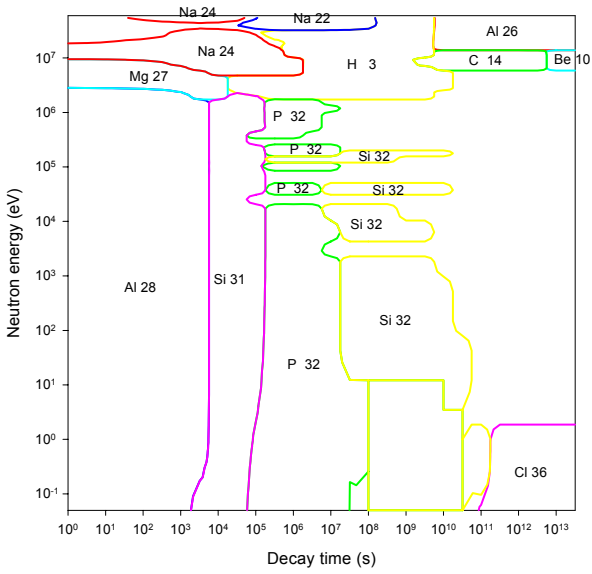


Decay time (years)

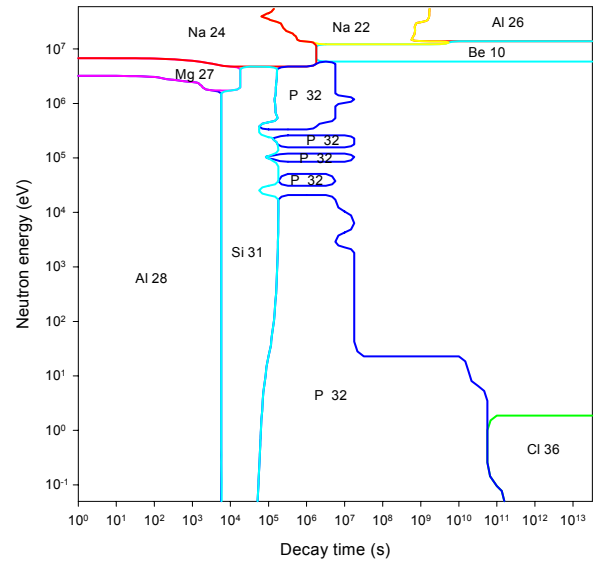
Decay time (years)

# Aluminium importance diagrams & transmutation

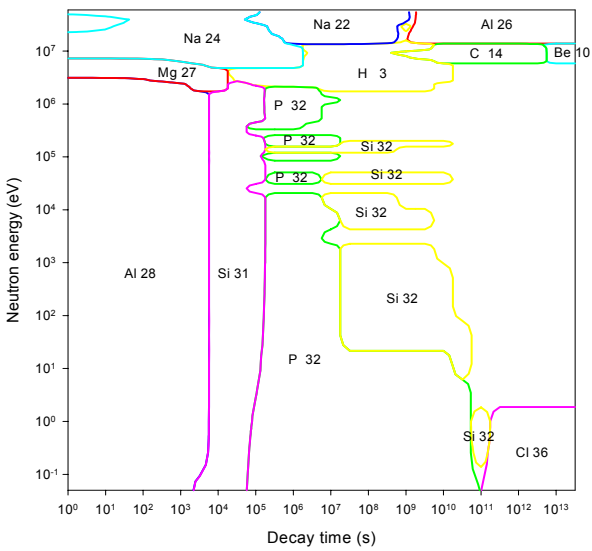
**Activity**



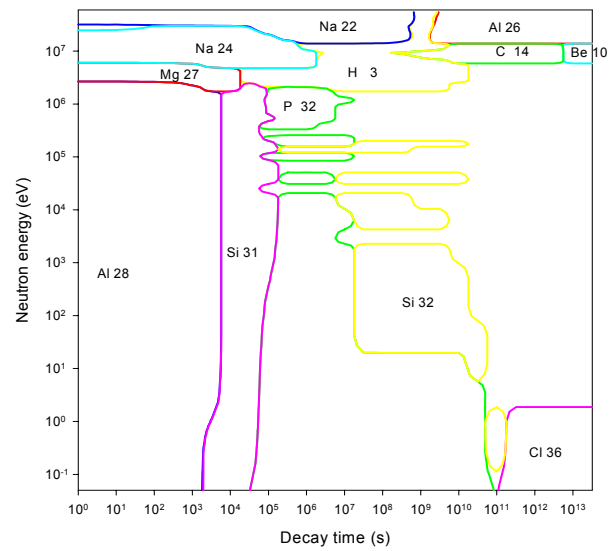
**Dose rate**



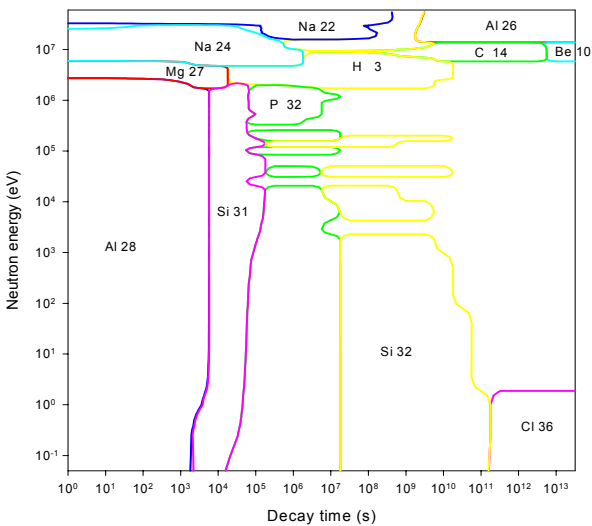
**Heat output**



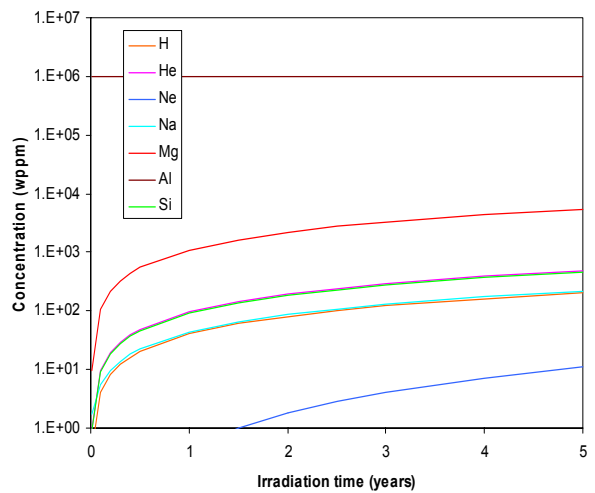
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**







# Silicon

## General properties

Atomic number	14	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	2.77 10 <sup>5</sup>	Si28	92.23
Melting point / K	1683	Si29	4.683
Boiling point / K	2628	Si30	3.087
Density / kgm <sup>-3</sup>	2329		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	148		
Electrical resistivity /Ωm	1.0 10 <sup>-3</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	4.2 10 <sup>-6</sup>		
Crystal structure	cubic		
Number of stable isotopes	3		
Mean atomic weight	28.0855		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	9.28E14	2.14E14	4.65E10	1.69E10	6.48E7	1.76E5	kW kg <sup>-1</sup>	4.37E-1	9.17E-2	1.83E-5	1.62E-8	1.55E-10	8.67E-11
Al28	93.21	79.28					Al28	95.76	89.77				
Si31	2.86	12.07					Al29	1.85	5.06				
Al29	2.31	5.74					Al30	1.07					
Mg27	0.76	2.25					Si31	0.58	2.70				
Al30	0.54						Mg27	0.41	1.34				
Na24	0.15	0.64	50.90				Na24	0.24	1.12	96.87			
Na25	0.12	0.01					P32			3.03	0.02	0.41	
H3			38.36	99.99	99.66		H3			0.09	95.18	38.03	
P32			10.73				Na22				4.22		
Al26					0.30	100.0	Al26				0.59	61.44	100.0
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	4.83E5	9.92E4	2.97E1	1.09E-3	1.39E-4	1.26E-4	Sv kg <sup>-1</sup>	1.34E4	6.66E3	2.29E1	7.15E-1	3.42E-3	6.16E-4
Al28	96.41	92.36					Al28	59.30	23.50				
Al29	1.72	4.81					Si31	31.60	62.24				
Al30	1.15						Na24	4.41	8.85	44.42			
Na24	0.36	1.85	99.99				Al29	3.36	3.83				
Mg27	0.33	1.09					Mg27	0.95	1.30				
Na25	0.02						P32	0.11	0.22	52.27			
Na22			0.01	87.21			H3		0.01	3.27	99.10	79.39	
Al26				12.79	100.0	100.0	Al26					19.84	100.0
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	8.61E3	3.79E3	2.80E1	4.40E0	2.14E-2	3.52E-3		1.72E12	3.51E11	2.39E7	1.87E5	1.19E3	4.76E2
Al28	66.35	29.60					Al28	96.54	93.07				
Si31	24.33	53.95					Al29	1.83	5.15				
Na24	4.32	9.76	22.82				Al30	1.09					
Al29	3.74	4.87					Mg27	0.41	1.37				
Mg27	0.76	1.17					Na24	0.08	0.39	99.13			
P32	0.24	0.53	60.59		0.09		Si31		0.01				
H3	0.06	0.12	16.56	99.83	78.44		H3			0.75	90.15	54.48	
Al26			0.01	0.09	18.10	100.0	Na22			0.10	9.56		
Si32				0.02	2.93		Al26				0.28	44.16	100.0

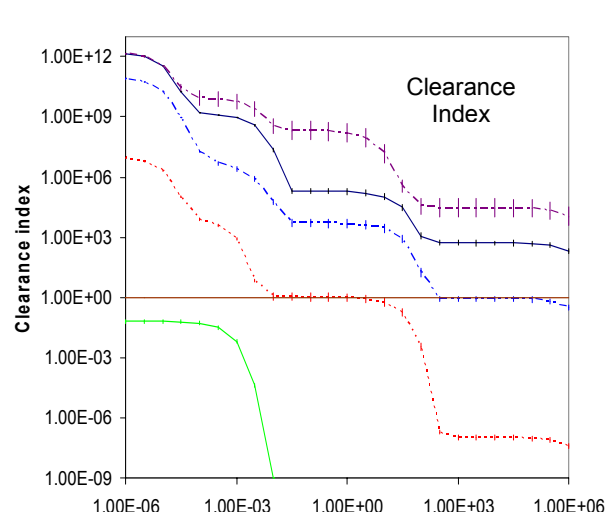
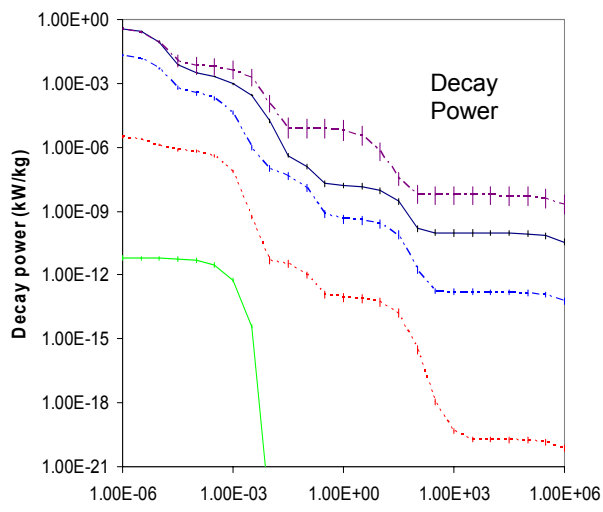
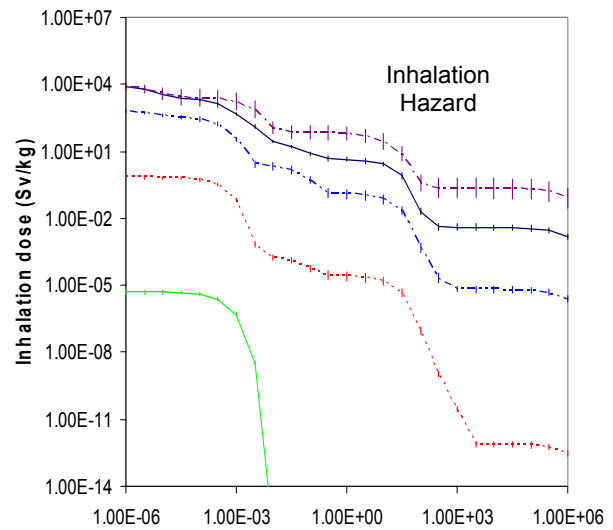
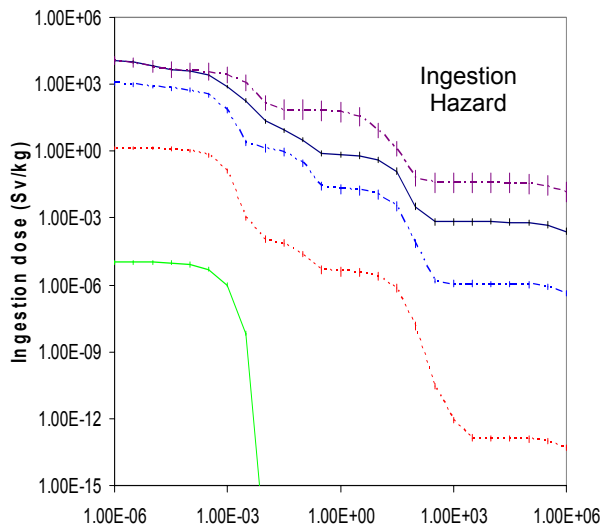
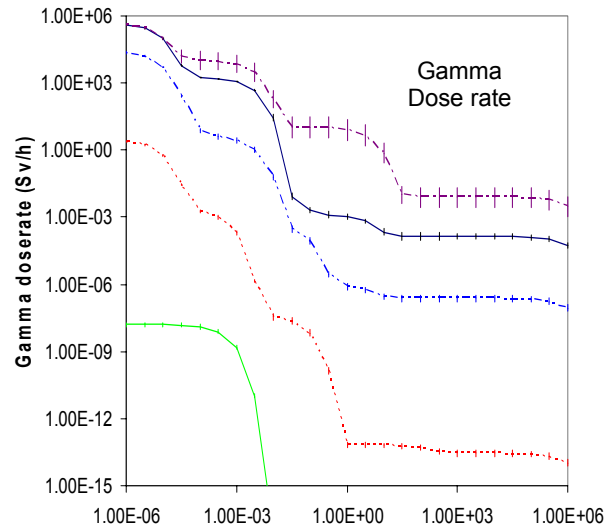
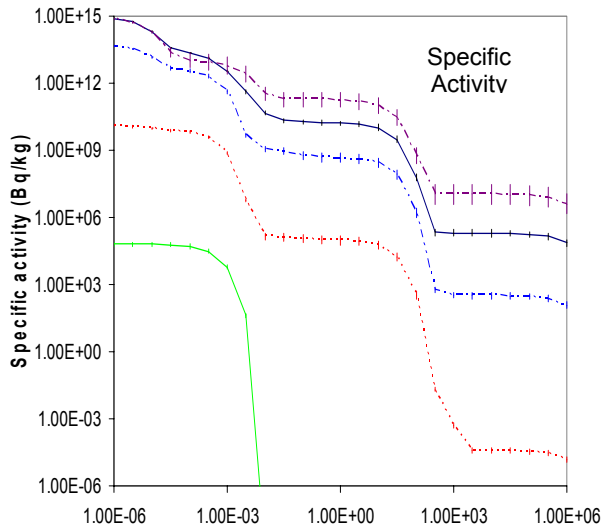
# Silicon

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Al28	2.241 m	Si28(n,p)Al28				99.2	70.6	58.4	47.0
		Si29(n,2n)Si28(n,p)Al28				0.5	0.2		
		Si29(n,d)Al28				0.3	26.5	27.2	30.4
		Si30(n,2n)Si29(n,d)Al28					1.2	0.6	0.4
		Si30(n,t)Al28					0.6	12.6	21.0
Al29	6.56 m	Si29(n,p)Al29				93.3	23.4	18.5	13.4
		Si30(n,2n)Si29(n,p)Al29				5.0	1.0	0.4	0.2
		Si30(n,d)Al29				1.4	74.8	80.4	86.1
Si31	2.62 h	Si30(n,γ)Si31	99.1	100.0	98.9	97.7	99.0	99.4	99.7
		Si29(n,γ)Si30(n,γ)Si31	0.8		1.1				
Na24	14.96 h	&Si28(n,d)Al27(n,α)Na24				55.2	4.9	1.1	4.8
		&Si28(n,nα)Mg24(n,p)Na24				18.3	2.8	0.8	0.4
		&Si28(n,α)Mg25(n,d)Na24				9.6	2.0	1.1	11.7
		&Si28(n,α)Mg25(n,2n)Mg24(n,p)Na24				5.4			
		&Si30(n,α)Mg27(β <sup>-</sup> )Al27(n,α)Na24				0.8			
		&Si28(n,pα)Na24					86.4	80.5	42.2
		&Si28(n,h)Mg26(n,t)Na24					0.1	10.0	16.6
		&Si29(n,dα)Na24						1.0	7.9
		&Si28(n,t)Al26m(β <sup>+</sup> )Mg26(n,t)Na24						1.0	3.9
		&Si28(n,t)Al26(n,h)Na24						0.8	2.6
&Si30(n,tα)Na24							1.7		
P32	14.27 d	Si30(n,γ)Si31(β <sup>-</sup> )P31(n,γ)P32	100.0	100.0	100.0	98.9	100.0	100.0	100.0
Na22	2.60 y	Si28(n,nα)Mg24(n,d)Na23(n,2n)Na22				39.1	17.8	0.4	
		Si28(n,d)Al27(n,nα)Na23(n,2n)Na22				29.5	12.3	0.3	
		Si28(n,d)Al27(n,2n)Al26(n,nα)Na22				11.9	9.6	0.2	
		Si28(n,α)Mg25(n,2n)Mg24(n,d)Na23(n,2n)Na22				6.4			
		Si29(n,α)Mg26(n,α)Ne23(β <sup>-</sup> )Na23(n,2n)Na22				5.0			
		Si28(n,α)Mg25(n,t)Na23(n,2n)Na22				3.5	0.2		
		Si28(n,nα)Mg24(n,t)Na22					41.2	44.4	6.8
		Si28(n,t)Al26(n,nα)Na22					7.2	12.4	1.7
		&Si28(n,pα)Na24(β <sup>-</sup> )Mg24(n,t)Na22					3.6	7.4	0.6
		Si28(n,nα)Mg24(n,2n)Mg23(β <sup>+</sup> )Na23(n,2n)Na22					1.9		
		Si28(n,pα)Na24(β <sup>-</sup> )Mg24(n,d)Na23(n,2n)Na22					1.1		
		Si28(n,dα)Na23(n,2n)Na22					0.3	10.1	2.0
		Si29(n,2nα)Mg24(n,t)Na22					0.1	1.4	0.3
		Si28(n,d)Al27(n,2nα)Na22						15.0	2.9
		Si28(n,tα)Na22						2.4	78.6
		Si28(n,2n)Si27(β <sup>+</sup> )Al27(n,2nα)Na22						1.2	0.3
Si28(n,α)Mg25(n,nt)Na22						0.2	3.8		
H3	12.33 y	Si28(n,d)Al27(n,X)H3				36.1	9.3	3.3	1.4
		Si29(n,X)H3				33.8	11.3	7.2	5.9
		Si28(n,α)Mg25(n,X)H3				26.3	0.3	0.1	0.7
		Si28(n,X)H3					70.0	80.4	84.5
		Si30(n,X)H3					4.6	4.1	3.8
		Si28(n,nα)Mg24(n,X)H3					1.3	0.6	0.3
Si28(n,h)Mg26(n,X)H3					0.2	1.3	0.9		
Si32	132.0 y	Si30(n,γ)Si31(n,γ)Si32	67.4	98.2	99.4	69.7	77.9	83.2	92.7
		Si30(n,γ)Si31(β <sup>-</sup> )P31(n,γ)P32(n,p)Si32	32.9	1.8		29.7	22.0	16.8	7.3
		Si29(n,γ)Si30(n,γ)Si31(n,γ)Si32	0.3		0.6				
C14	5700 y	Si28(n,nα)Mg24(n,α)Ne21(n,2α)C14				51.1	1.1	0.2	
		Si28(n,α)Mg25(n,nα)Ne21(n,2α)C14				30.5	1.0		
		Si28(n,α)Mg25(n,2n)Mg24(n,α)Ne21(n,α)C14				7.8			
		Si28(n,nα)Mg24(n,α)Ne21(n,nα)O17(n,α)C14				1.5			
		Si28(n,nα)Mg24(n,α)Ne21(n,α)O18(n,nα)C14				0.9			
		Si28(n,α)Mg25(n,nα)Ne21(n,nα)O17(n,α)C14				0.9			

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Si28(n,2α)Ne21(n,2α)C14 Si28(n,nα)Mg24(n,h)Ne22(n,n2α)C14 Si28(n,nα)Mg24(n,n2α)O16(n,h)C14 Si28(n,h)Mg26(n,nα)Ne22(n,n2α)C14 Si28(n,d)Al27(n,dα)Ne22(n,n2α)C14 Si28(n,α)Mg25(n,3α)C14 Si28(n,n2α)Ne20(n,dα)N15(n,d)C14 Si28(n,dα)Na23(n,d2α)C14 Si28(n,n2α)Ne20(n,hα)C14 Si28(n,dα)Na23(n,n2α)N15(n,d)C14 Si28(n,nα)Mg24(n,dα)F19(n,dα)C14 Si28(n,dα)Na23(n,nα)F19(n,dα)C14 Si28(n,n2α)Ne20(n,d)F19(n,dα)C14 Si28(n,dα)Na23(n,d)Ne22(n,n2α)C14 Si28(n,3α)O17(n,α)C14 Si28(n,n3α)O16(n,h)C14 Si28(n,h)Mg26(n,n3α)C14 Si28(n,tα)Na22(β <sup>+</sup> )Ne22(n,n2α)C14 Si28(n,d2α)F19(n,dα)C14 Si28(n,t)Al26m(β <sup>+</sup> )Mg26(n,n3α)C14						75.5 1.4 1.3 1.1 0.3 0.3	16.0 3.6 5.5 2.7 2.8 1.5 5.5 5.4 5.0 4.5 4.3 4.0 2.7 2.5 0.3	0.3 0.5 1.0 0.3 0.4 5.4 1.1 13.7 3.7 0.8 1.3 1.3 0.6 0.6 3.1 23.8 8.5 4.3 2.8 2.0
Cl36	3.0 10 <sup>5</sup> y	Si30(n,γ)Si31(β <sup>-</sup> )P31(n,γ)P32(β <sup>-</sup> )S32(n,γ)_ S33(n,γ)S34(n,γ)S35(β <sup>-</sup> )Cl35(n,γ)Cl36 Si30(n,γ)Si31(β <sup>-</sup> )P31(n,γ)P32(n,γ)P33(β <sup>-</sup> )_ S33(n,γ)S34(n,γ)S35(β <sup>-</sup> )Cl35(n,γ)Cl36	96.5 3.2	96.4 3.4						
Al26	7.2 10 <sup>5</sup> y	Si28(n,d)Al27(n,2n)Al26 Si30(n,α)Mg27(β <sup>-</sup> )Al27(n,2n)Al26 Si28(n,t)Al26 Si29(n,nt)Al26 Si28(n,2n)Si27(β <sup>+</sup> )Al27(n,2n)Al26 Si28(n,2p)Mg27(β <sup>-</sup> )Al27(n,2n)Al26				96.8 1.5	60.4 33.4	2.3 96.9 0.1 0.2	0.6 97.7 1.3	
Be10	1.6 10 <sup>6</sup> y	Si28(n,nα)Mg24(n,nα)Ne20(n,2α)C13_ (n,α)Be10 Si28(n,nα)Mg24(n,α)Ne21(n,nα)O17_ (n,nα)C13(n,α)Be10 Si28(n,α)Mg25(n,2n)Mg24(n,nα)Ne20_ (n,2α)C13(n,α)Be10 Si28(n,nα)Mg24(n,nα)Ne20(n,nα)O16_ (n,α)C13(n,α)Be10 Si28(n,α)Mg25(n,nα)Ne21(n,nα)O17_ (n,nα)C13(n,α)Be10 Si28(n,nα)Mg24(n,nα)Ne20(n,α)O17_ (n,nα)C13(n,α)Be10 Si28(n,nα)Mg24(n,2α)O17(n,2α)Be10 Si28(n,2α)Ne21(n,2α)C14(n,nα)Be10 Si28(n,2α)Ne21(n,nα)O17(n,2α)Be10 &Si28(n,pα)Na24(β <sup>-</sup> )Mg24(n,2α)O17_ (n,2α)Be10 Si28(n,n2α)Ne20(n,dα)N15(n,dα)Be10 Si28(n,dα)Na23(n,n2α)N15(n,dα)Be10 Si28(n,n2α)Ne20(n,n2α)C12(n,h)Be10 Si28(n,n3α)O16(n,hα)Be10 Si28(n,n2α)Ne20(n,2nα)O15(β <sup>+</sup> )N15_ (n,dα)Be10 Si28(n,3α)O17(n,2α)Be10 Si28(n,d)Al27(n,n3α)N15(n,dα)Be10 Si28(n,2α)Ne21(n,3α)Be10 Si28(n,dα)Na23(n,2nα)F18(β <sup>+</sup> )O18_ (n,n2α)Be10 Si28(n,dα)Na23(n,dα)O18(n,n2α)Be10 Si28(n,n2α)Ne20(n,t)F18(β <sup>+</sup> )O18(n,n2α)Be10				55.4 10.6 6.8 6.6 6.3 2.5	0.7 49.4 17.3 16.3 4.2	2.7 1.8 2.2 0.4	19.0 15.4 4.6 16.0 4.5 3.8 2.3 1.0 1.6 1.5 1.1	

# Silicon activation characteristics

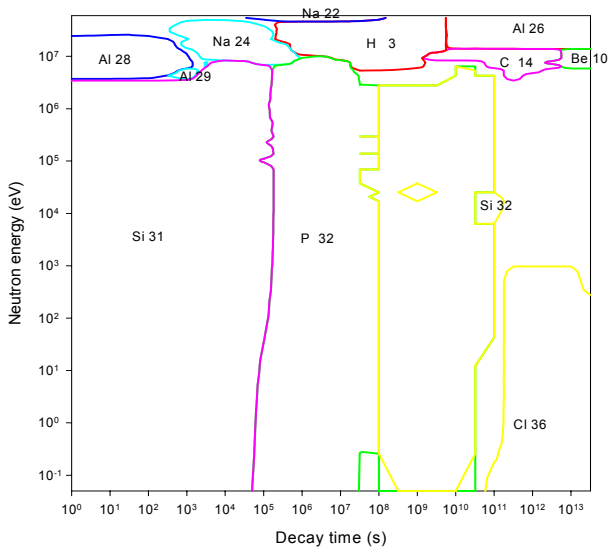


Decay time (years)

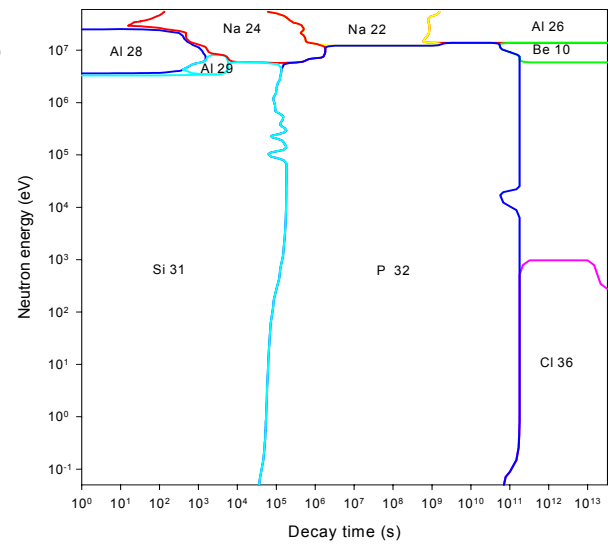
Decay time (years)

# Silicon importance diagrams & transmutation

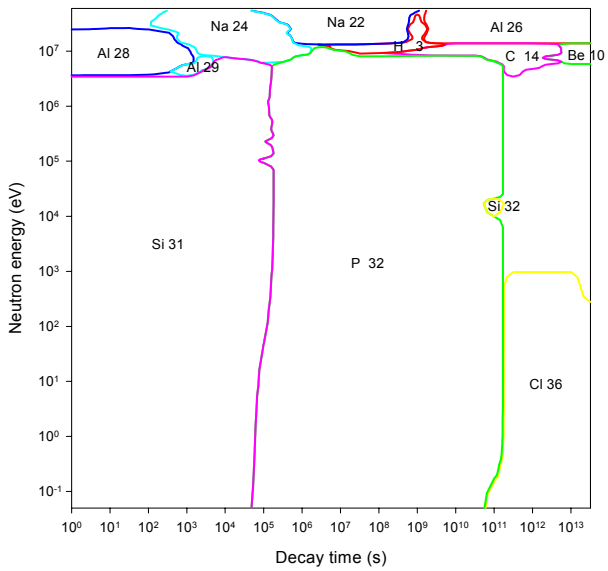
**Activity**



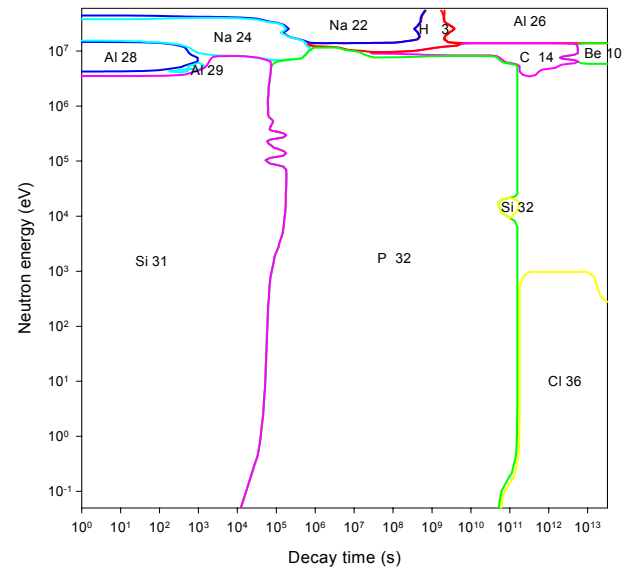
**Dose rate**



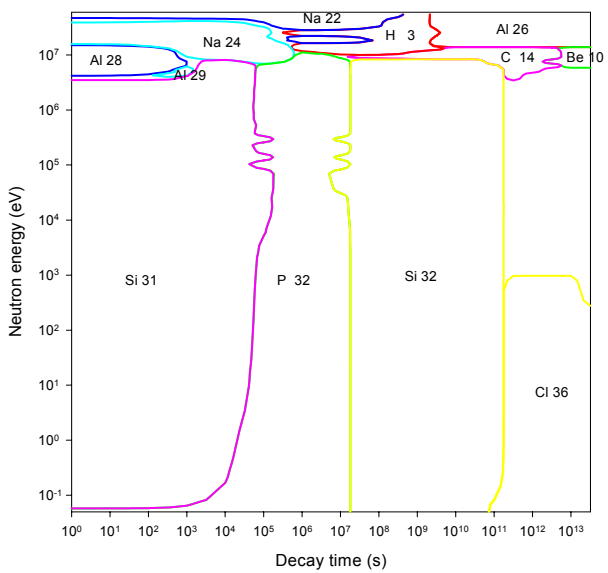
**Heat output**



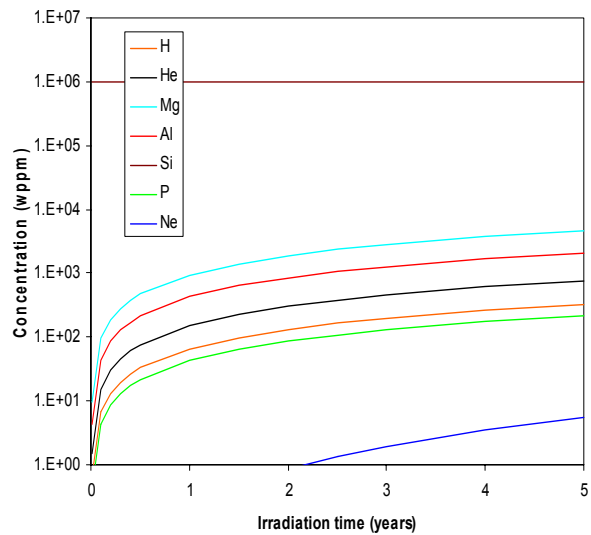
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**





# Phosphorus

## General properties

Atomic number	15	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	1.00 10 <sup>3</sup>	P31	100.0
Melting point / K	317.3		
Boiling point / K	553		
Density / kgm <sup>-3</sup>	1820		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	2.35 10 <sup>-1</sup>		
Electrical resistivity /Ωm	1.0 10 <sup>9</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	1.245 10 <sup>-4</sup>		
Crystal structure	cubic		
Number of stable isotopes	1		
Mean atomic weight	30.973761		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	8.76E14	5.15E14	2.48E13	1.48E12	5.71E9	1.86E4	kW kg <sup>-1</sup>	2.54E-1	8.30E-2	2.59E-3	1.36E-6	7.36E-9	9.16E-12
Al28	47.46	77.17					Al28	79.37	47.70				
Si31	46.43	15.87					Si31	15.32	45.77				
P32	3.16	5.38	93.67		0.31		P30	2.88	3.72				
P30	2.12	0.84					P32	1.22	2.05	99.90	0.25	26.92	
Mg27	0.35	0.40					H3			0.06	99.72	70.43	
H3	0.18	0.30	6.32	100.0	99.38		Si32				0.02	2.50	
Al26						100.0	Al26					0.14	100.0
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	2.37E5	4.68E4	1.87E1	7.58E-5	2.78E-5	1.37E-5	Sv kg <sup>-1</sup>	1.36E5	1.31E5	5.58E4	6.23E1	2.91E-1	6.51E-5
Al28	96.88	96.54					P32	49.00	50.75	99.88	0.12	14.69	
P30	1.60	1.89					Si31	47.95	48.54				
Na24	0.05	0.27	31.21				Al28	2.82	0.57				
P32			68.78*	10.41*	19.56*		H3	0.05	0.05	0.12	99.86	81.86	
Na22				64.57			Si32				0.03	3.43	
Al26				25.01	80.44	100.0	Al26						100.0
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	1.30E5	1.27E5	7.93E4	3.89E2	3.49E0	3.72E-4		8.34E11	1.65E11	4.06E7	1.48E7	5.69E4	5.03E1
P32	72.52	74.36	99.48	0.03	1.73		Al28	95.92	95.31	57.22			
Si31	24.74	24.79					P30	2.59	3.04				
Al28	2.11	0.43					Si31	0.05	0.24				
H3	0.31	0.32	0.51	99.13	42.20		Na24	0.01	0.06	4.16			
P30	0.27	0.06					P32		0.02				
Na24	0.03	0.02					H3			38.61	99.99	99.66	
Si32				0.85	56.06		Si32					0.21	
Al26						100.0	Al26						100.0

# Phosphorus

## Pathway analysis

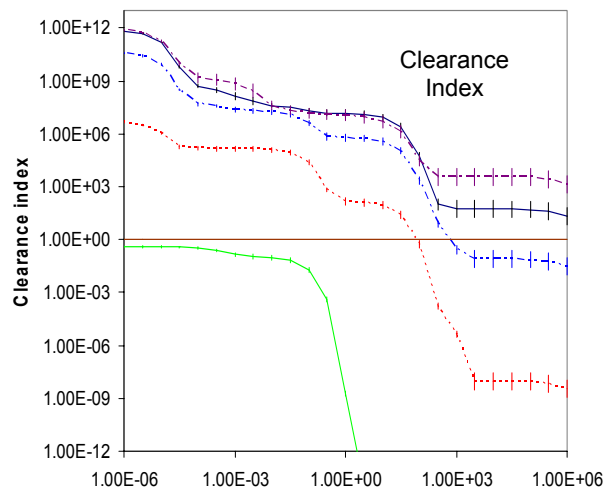
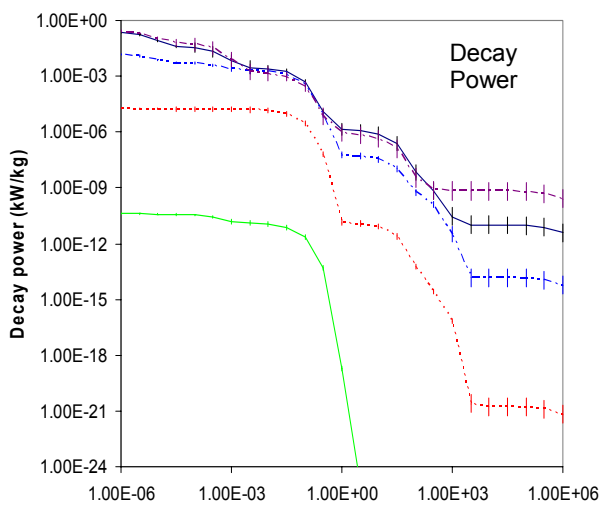
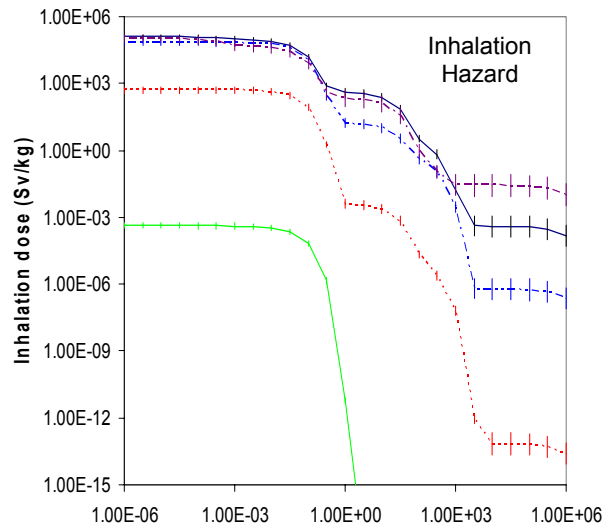
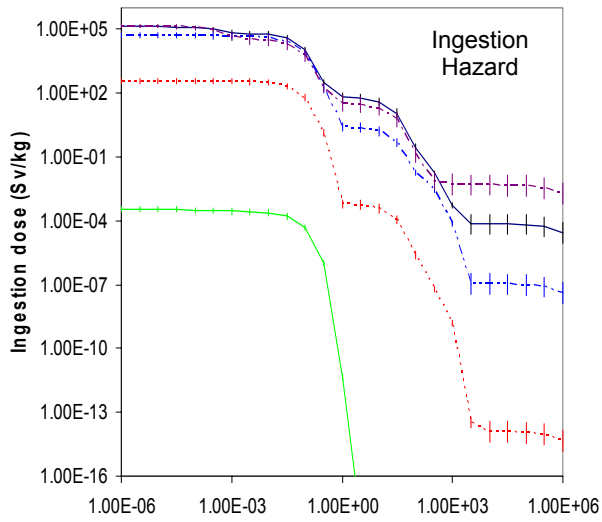
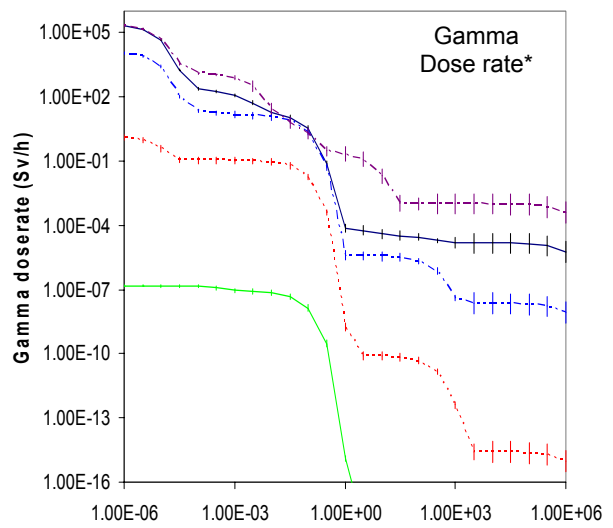
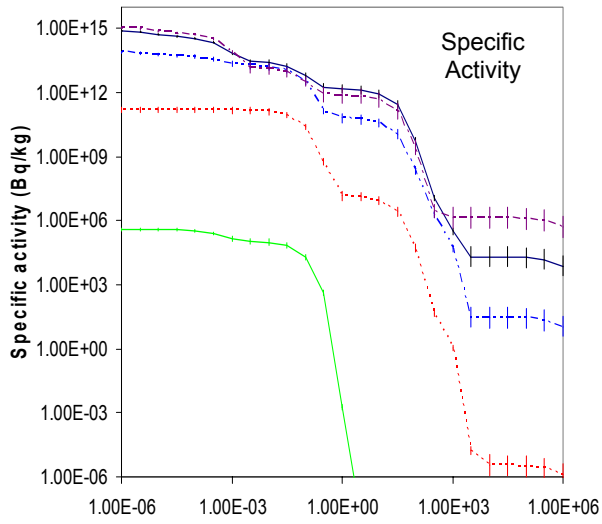
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Al28	2.241 m	P31(n,α)Al28 P31(n,t)Si29(n,d)Al28 P31(n,d)Si30(n,2n)Si29(n,d)Al28 P31(n,d)Si30(n,t)Al28 P31(n,d)Si30(n,d)Al29(β <sup>-</sup> )Si29(n,d)Al28 P31(n,2n)P30(β <sup>+</sup> )Si30(n,t)Al28 P31(n,h)Al29(β <sup>-</sup> )Si29(n,d)Al28				94.9	51.4 35.5 4.1 3.9 1.4 0.6 0.3	28.0 35.7 0.6 26.9 0.4 4.1 1.7	79.7 8.7 7.9 1.3 0.7
P30	2.50 m	P31(n,2n)P30				98.7	99.5	99.7	99.8
Si31	2.62 h	P31(n,γ)P32(β <sup>-</sup> )S32(n,γ)S33(n,α)Si30(n,γ)_Si31 P31(n,γ)P32(n,γ)P33(β <sup>-</sup> )S33(n,α)Si30(n,γ)_Si31 P31(n,p)Si31 P31(n,γ)P32(β <sup>-</sup> )S32(n,α)Si29(n,γ)Si30_(n,γ)Si31	97.5 1.7 0.7	97.6 1.6 0.8	1.8 0.1 98.1				
Na24	14.96 h	&P31(n,α)Al27(n,α)Na24 &P31(n,d)Si30(n,α)Mg27(β <sup>-</sup> )Al27(n,α)Na24 &P31(n,α)Al28(β <sup>-</sup> )Si28(n,d)Al27(n,α)Na24 &P31(n,α)Al28(β <sup>-</sup> )Si28(n,α)Mg25(n,d)Na24 &P31(n,2α)Na24 &P31(n,t)Si29(n,α)Mg25(n,d)Na24 &P31(n,nt)Si28(n,pα)Na24 &P31(n,dα)Mg26(n,t)Na24 &P31(n,t)Si29(n,dα)Na24 &P31(n,2nα)Al26m(β <sup>+</sup> )Mg26(n,t)Na24 &P31(n,2nα)Al26(n,h)Na24 &P31(n,tα)Mg25(n,d)Na24 &P31(n,h)Al29(β <sup>-</sup> )Si29(n,dα)Na24 &P31(n,d)Si30(n,tα)Na24				81.3 11.6 4.4 0.8	14.3 75.7 1.8 0.4	1.8 62.4 0.8 1.8 17.0 5.3 0.8 0.7 0.4 0.2	4.8 17.5 0.4 2.3 18.5 18.6 2.8 1.4 12.3 1.5 5.3
P32	14.27 d	P31(n,γ)P32	100.0	100.0	100.0	95.3	98.6	99.2	99.5
S35	87.32 d	P31(n,γ)P32(β <sup>-</sup> )S32(n,γ)S33(n,γ)S34(n,γ)_S35 P31(n,γ)P32(n,γ)P33(β <sup>-</sup> )S33(n,γ)S34(n,γ)_S35 P31(n,γ)P32(n,γ)P33(n,γ)P34(β <sup>-</sup> )S34(n,γ)S35	97.8 1.8	98.1 1.9	92.6 5.9	95.1 3.2	97.4 2.1	97.8 1.9	97.5 2.2 0.1
Na22	2.60 y	P31(n,α)Al27(n,α)Na23(n,2n)Na22 P31(n,α)Al27(n,2n)Al26(n,α)Na22 P31(n,d)Si30(n,α)Mg27(β <sup>-</sup> )Al27(n,α)_Na23(n,2n)Na22 P31(n,α)Al28(β <sup>-</sup> )Si28(n,α)Mg24(n,d)_Na23(n,2n)Na22 P31(n,d)Si30(n,α)Mg27(β <sup>-</sup> )Al27(n,2n)_Al26(n,α)Na22 P31(n,α)Al28(β <sup>-</sup> )Si28(n,d)Al27(n,α)_Na23(n,2n)Na22 P31(n,α)Al27(n,α)Na24(β <sup>-</sup> )Mg24(n,d)_Na23(n,2n)Na22 P31(n,α)Al27(n,pα)Ne23(β <sup>-</sup> )Na23_(n,2n)Na22 P31(n,α)Al27(n,d)Mg26(n,α)Ne23(β <sup>-</sup> )_Na23(n,2n)Na22 P31(n,α)Al28(β <sup>-</sup> )Si28(n,d)Al27(n,2n)_Al26(n,α)Na22 &P31(n,2α)Na24(β <sup>-</sup> )Mg24(n,t)Na22 P31(n,pα)Mg27(β <sup>-</sup> )Al27(n,α)Na23(n,2n)Na22 P31(n,pα)Mg27(β <sup>-</sup> )Al27(n,2n)Al26(n,α)Na22				57.4 23.2 5.1 2.6 2.1 2.0 1.4 1.4 1.1 0.8	47.2 36.7 0.6 2.6 2.1 2.0 1.4 1.4 1.1 0.8	0.7 0.6 0.7 0.6 0.7 0.7 0.7 0.7 0.7 0.7	



Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&P31(n,2α)Na24(β <sup>-</sup> )Mg24(n,d)Na23_ (n,2n)Na22 P31(n,nα)Al27(n,pα)Ne23(β <sup>-</sup> )Na23(n,2n)Na22   P31(n,t)Si29(n,2nα)Mg24(n,t)Na22 P31(n,nα)Al27(n,2nα)Na22 P31(n,2nα)Al26(n,nα)Na22 P31(n,n2α)Na23(n,2n)Na22 P31(n,pα)Mg27(β <sup>-</sup> )Al27(n,2nα)Na22 P31(n,t)Si29(n,t)Al27(n,2nα)Na22 P31(n,dα)Mg26(n,3n)Mg24(n,t)Na22 P31(n,tα)Mg25(n,nt)Na22 P31(n,2n2α)Na22 P31(n,nt)Si28(n,tα)Na22 P31(n,α)Al28(β <sup>-</sup> )Si28(n,tα)Na22 P31(n,ntα)Mg24(n,t)Na22 P31(n,dα)Mg26(n,2nt)Na22					1.8		
							1.4		
							0.2	4.6	1.0
								41.5	10.1
								19.8	3.2
								7.5	2.3
								2.4	0.4
								2.3	0.6
								2.0	0.4
								0.2	13.6
									41.4
									9.8
									3.4
									2.5
									1.2
H3	12.33 y	P31(n,X)H3 P31(n,nα)Al27(n,X)H3 P31(n,d)Si30(n,X)H3 P31(n,t)Si29(n,X)H3				99.0	96.6	95.9	96.0
						0.2	0.7	0.4	0.2
							1.3	1.3	1.0
							0.6	1.4	1.2
Si32	132.0 y	P31(n,γ)P32(n,p)Si32 P31(n,p)Si31(n,γ)Si32	100.0	100.0	100.0	97.0	99.3	99.7	99.8
						1.5	0.8	0.8	1.0
C14	5700 y	P31(n,α)Al28(β <sup>-</sup> )Si28(n,nα)Mg24(n,α)_ Ne21(n,2α)C14 &P31(n,nα)Al27(n,α)Na24(β <sup>-</sup> )Mg24_ (n,α)Ne21(n,2α)C14 P31(n,α)Al28(β <sup>-</sup> )Si28(n,α)Mg25(n,nα)_ Ne21(n,2α)C14 P31(n,α)Al28(β <sup>-</sup> )Si28(n,α)Mg25(n,2n)_ Mg24(n,α)Ne21(n,2α)C14 P31(n,α)Al28(β <sup>-</sup> )Si28(n,nα)Mg24(n,α)_ Ne21(n,α)O18(n,nα)C14 P31(n,nα)Al27(n,α)Na24(β <sup>-</sup> )Mg24(n,α)_ Ne21(n,nα)O17(n,α)C14 &P31(n,nα)Al27(n,α)Na24(β <sup>-</sup> )Mg24_ (n,α)Ne21(n,α)O18(n,nα)C14 P31(n,α)Al28(β <sup>-</sup> )Si28(n,α)Mg25(n,nα)_ Ne21(n,α)O18(n,nα)C14 P31(n,α)Al28(β <sup>-</sup> )Si28(n,nα)Mg24(n,nα)_ Ne20(n,α)O17(n,α)C14 P31(n,nα)Al27(n,nα)Na23(n,t)Ne21(n,2α)C14   P31(n,nα)Al27(n,nα)Na23(n,nα)F19_ (n,dα)C14 P31(n,t)Si29(n,2α)Ne22(n,n2α)C14 P31(n,nα)Al27(n,nα)Na23(n,n2α)N15(n,d)C14   P31(n,dα)Mg26(n,nα)Ne22(n,n2α)C14 P31(n,nα)Al27(n,nα)Na23(n,d)Ne22_ (n,n2α)C14 P31(n,d)Si30(n,nα)Mg26(n,nα)Ne22_ (n,n2α)C14 P31(n,nα)Al27(n,dα)Ne22(n,n2α)C14 P31(n,t)Si29(n,nα)Mg25(n,nα)Ne21(n,2α)C14   P31(n,nα)Al27(n,d)Mg26(n,nα)Ne22_ (n,n2α)C14 P31(n,nα)Al27(n,t)Mg25(n,nα)Ne21(n,2α)C14   P31(n,n2α)Na23(n,d2α)C14 P31(n,nα)Al27(n,n2α)F19(n,dα)C14 P31(n,n2α)Na23(n,n2α)N15(n,d)C14 P31(n,dα)Mg26(n,2nα)Ne21(n,2α)C14 P31(n,n2α)Na23(n,nα)F19(n,dα)C14 P31(n,n2α)Na23(n,d)Ne22(n,n2α)C14				36.4			
							27.5		
							21.7		
							4.5		
							0.5		
							0.5		
							0.4		
							0.3		
							0.2		
							0.1	2.0	
							13.6	0.3	
							9.7	4.5	0.2
							9.6	0.3	
							6.4	11.2	0.8
							6.3	0.2	
							5.9	0.2	
							5.2	11.0	1.0
							3.0		
							2.1		
							2.0		
								5.7	11.8
								4.9	1.1
								4.7	0.7
								4.7	0.2
								4.1	1.1
								2.6	0.5

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	P31(n,α)Mg25(n,3α)C14 P31(n,dα)Mg26(n,n3α)C14 P31(n,2nα)Al26m(β <sup>+</sup> )Mg26(n,n3α)C14 P31(n,α)Mg25(n,α)F19(n,dα)C14 P31(n,α)Mg25(n,2n2α)O16(n,h)C14						1.4	14.0
Cl36	3.0 10 <sup>5</sup> y	P31(n,γ)P32(β <sup>-</sup> )S32(n,γ)S33(n,γ)S34(n,γ)_ S35(β <sup>-</sup> )Cl35(n,γ)Cl36 P31(n,γ)P32(n,γ)P33(β <sup>-</sup> )S33(n,γ)S34(n,γ)_ S35(β <sup>-</sup> )Cl35(n,γ)Cl36	97.2	97.0		93.7	96.1		
Al26	7.2 10 <sup>5</sup> y	P31(n,nα)Al27(n,2n)Al26 P31(n,d)Si30(n,α)Mg27(β <sup>-</sup> )Al27(n,2n)Al26 P31(n,α)Al28(β <sup>-</sup> )Si28(n,d)Al27(n,2n)Al26 P31(n,pα)Mg27(β <sup>-</sup> )Al27(n,2n)Al26 P31(n,α)Al28(β <sup>-</sup> )Si28(n,t)Al26 P31(n,2nα)Al26 P31(n,nt)Si28(n,t)Al26 P31(n,t)Si29(n,nt)Al26				85.7	93.2	3.8	1.0
						9.6	0.2		
						3.7	0.1		
							5.4	0.2	
							0.1	0.3	1.7
								93.1	88.7
								1.2	4.9
								0.4	2.7
Be10	1.6 10 <sup>6</sup> y	P31(n,α)Al28(β <sup>-</sup> )Si28(n,nα)Mg24(n,nα)_ Ne20(n,2α)C13(n,α)Be10 &P31(n,nα)Al27(n,α)Na24(β <sup>-</sup> )Mg24_ (n,nα)Ne20(n,2α)C13(n,α)Be10 P31(n,nα)Al27(n,nα)Na23(n,α)F20(β <sup>-</sup> )_ Ne20(n,2α)C13(n,α)Be10 P31(n,α)Al28(β <sup>-</sup> )Si28(n,nα)Mg24(n,α)_ Ne21(n,nα)O17(n,nα)C13(n,α)Be10 &P31(n,nα)Al27(n,α)Na24(β <sup>-</sup> )Mg24_ (n,α)Ne21(n,nα)O17(n,nα)C13(n,α)Be10 P31(n,α)Al28(β <sup>-</sup> )Si28(n,α)Mg25(n,2n)_ Mg24(n,nα)Ne20(n,2α)C13(n,α)Be10 P31(n,α)Al28(β <sup>-</sup> )Si28(n,nα)Mg24(n,nα)_ Ne20(n,nα)O16(n,α)C13(n,α)Be10 P31(n,α)Al28(β <sup>-</sup> )Si28(n,α)Mg25(n,nα)_ Ne21(n,nα)O17(n,nα)C13(n,α)Be10 &P31(n,nα)Al27(n,α)Na24(β <sup>-</sup> )Mg24_ (n,nα)Ne20(n,nα)O16(n,α)C13(n,α)Be10 P31(n,α)Al28(β <sup>-</sup> )Si28(n,nα)Mg24(n,nα)_ Ne20(n,α)O17(n,nα)C13(n,α)Be10 &P31(n,nα)Al27(n,α)Na24(β <sup>-</sup> )Mg24_ (n,nα)Ne20(n,α)O17(n,nα)C13(n,α)Be10 P31(n,nα)Al27(n,nα)Na23(n,α)F20(β <sup>-</sup> )_ Ne20(n,nα)O16(n,α)C13(n,α)Be10 &P31(n,2α)Na24(β <sup>-</sup> )Mg24(n,2α)O17_ (n,2α)Be10 P31(n,nα)Al27(n,nα)Na23(n,n2α)N15_ (n,nα)B11(n,d)Be10 P31(n,nα)Al27(n,nα)Na23(n,nα)F19_ (n,dα)C14(n,nα)Be10 P31(n,t)Si29(n,2α)Ne22(n,n2α)C14(n,nα)Be10 P31(n,nα)Al27(n,nα)Na23(n,n2α)N15_ (n,d)C14(n,nα)Be10 P31(n,n2α)Na23(n,n2α)N15(n,dα)Be10 P31(n,2nα)Al26(n,3α)N15(n,dα)Be10 P31(n,n2α)Na23(n,2nα)F18(β <sup>+</sup> )O18_ (n,n2α)Be10 P31(n,dα)Mg26(n,n2α)O18(n,n2α)Be10 P31(n,n2α)Na23(n,dα)O18(n,n2α)Be10 P31(n,nα)Al27(n,n3α)N15(n,dα)Be10 P31(n,α)Mg25(n,t2α)N15(n,dα)Be10 P31(n,α)Mg25(n,2n2α)O16(n,hα)Be10				33.5			
						25.3			
						6.2			
						5.3			
						4.0			
						3.4			
						3.3			
						3.2			
						2.5			
						1.3			
						1.0			
						0.6			
							41.8	1.4	
							4.5		
							3.1		
							2.8	0.6	
							2.2		
								26.2	10.8
								5.1	1.4
								4.8	2.0
								4.7	2.3
								3.9	1.9
									8.4
									5.8
									2.6

# Phosphorus activation characteristics

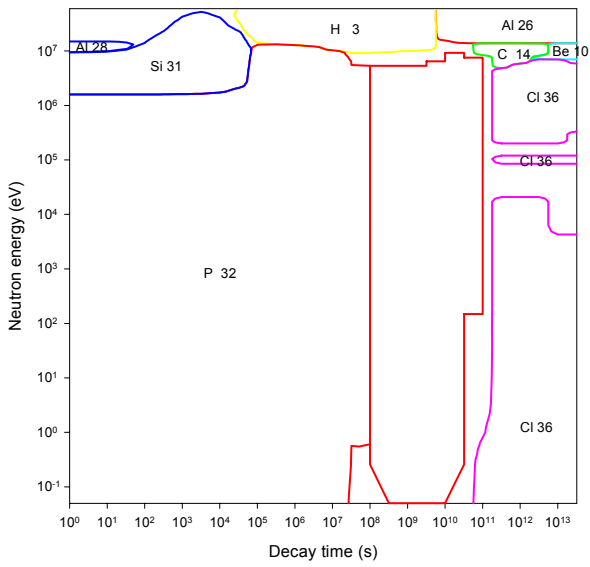


Decay time (years)

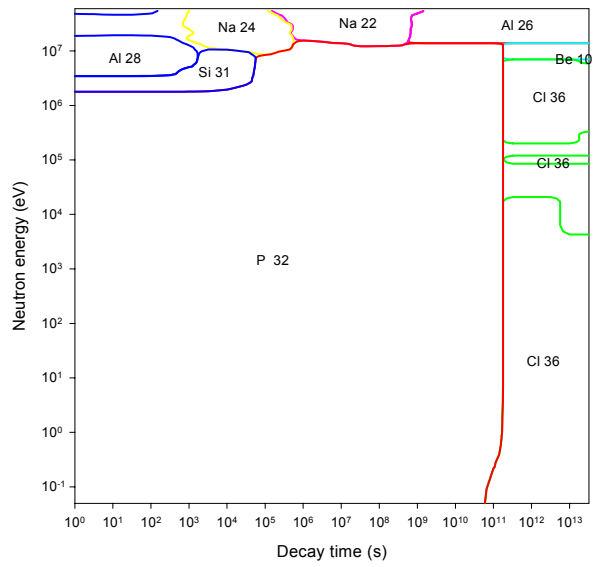
Decay time (years)

# Phosphorus importance diagrams & transmutation

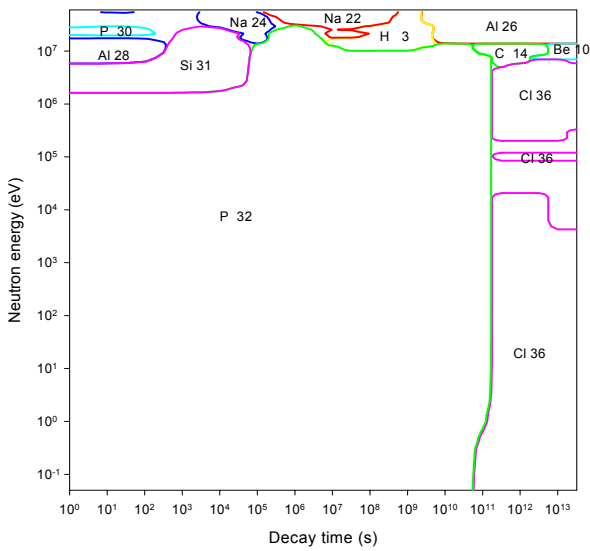
**Activity**



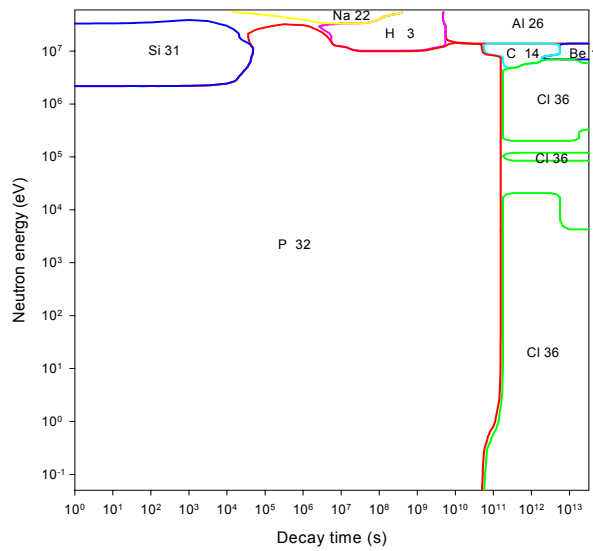
**Dose rate**



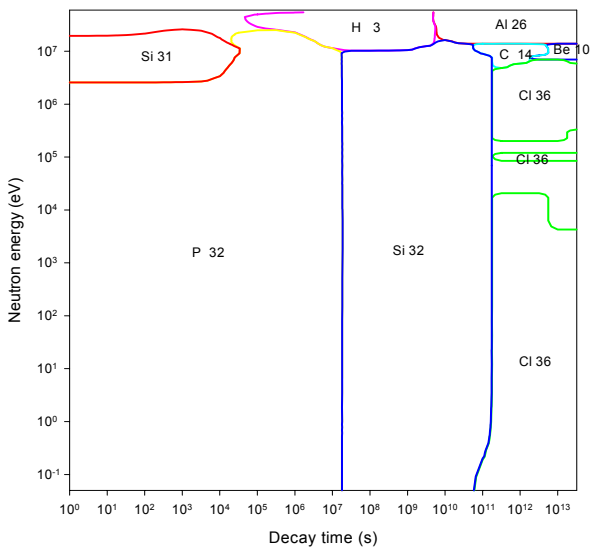
**Heat output**



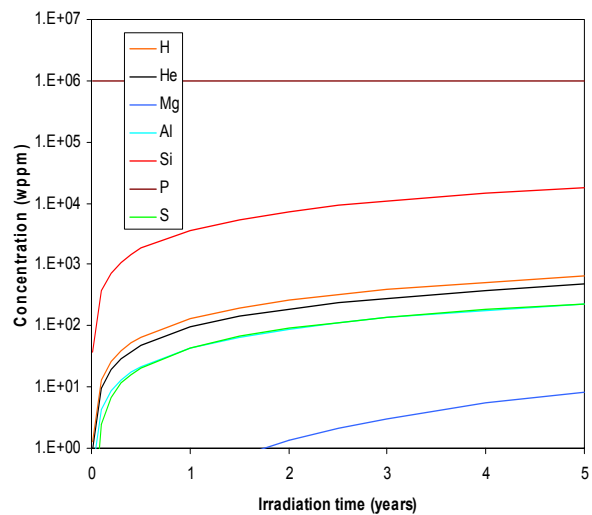
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**



# Sulphur

## General properties

Atomic number	16	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	260	S32	95.02
Melting point / K	386.0	S33	0.75
Boiling point / K	717.8	S34	4.21
Density / kgm <sup>-3</sup>	2070	S36	0.02
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	2.69 10 <sup>-1</sup>		
Electrical resistivity /Ωm	2.0 10 <sup>15</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	7.433 10 <sup>-5</sup>		
Crystal structure	orthorhombic		
Number of stable isotopes	4		
Mean atomic weight	32.066		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	1.02E15	1.00E15	8.13E14	1.87E11	2.05E9	1.17E5	kW kg <sup>-1</sup>	1.18E-1	1.11E-1	8.95E-2	8.31E-7	9.92E-8	5.22E-12
P32	94.40	95.98	98.85	0.74	39.52		P32	90.61	96.45	99.88	18.53	91.12	
Si31	2.72	2.70					P34	3.57					
P34	0.98						Al28	2.42	0.51				
P33	0.87	0.88	0.98				Si31	2.24	2.33				
Al28	0.58						S35			0.01	66.80		
S35	0.13	0.13	0.15	38.10			H3				12.37	0.39	
H3	0.01	0.02	0.01	60.21	20.96		Si32				1.70	8.48	
Si32				0.73	39.51		Cl36						97.50
Cl36						99.77	Al26						2.50
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	6.10E3	1.93E3	5.15E2	8.95E-4	5.21E-4	1.95E-7	Sv kg <sup>-1</sup>	2.31E6	2.31E6	1.93E6	6.37E1	2.42E0	1.09E-4
Al28	55.70	44.35					P32	99.67	99.68	99.85	5.21	80.48	
Al29	20.45	41.40					Si31	0.19	0.19				
P34	18.48						S35	0.04	0.04	0.05	86.01		
P32	3.30*	12.49*	99.96*	97.28*	99.87*		H3				7.42	0.74	
Na22				2.64			Si32				1.20	18.77	
Al26				0.75	0.14	99.81	Cl36						99.15
Cl36						0.19*	Al26						0.85
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	3.28E6	3.28E6	2.75E6	3.20E2	9.21E1	8.54E-4		2.31E10	5.84E9	8.25E8	1.85E6	1.07E4	1.17E2
P32	99.45	99.45	99.47	1.47	3.0		Al28	49.09	38.09				
P33	0.42	0.40	0.44	0.19			P34	25.45					
S35	0.07	0.07	0.09	42.26			Al29	19.10	43.35				
Si31	0.07	0.07					P32	4.16	16.42	97.36	0.07	7.60	
Si32				46.94	96.88		Si31	0.12	0.46				
H3				9.14	0.12		S35	0.06	0.22	1.52	38.52		
Cl36						99.38	P33	0.04	0.15	0.97	0.02		
Al26						0.62	H3			0.14	60.85	40.33	
							Si32				0.49	50.69	
							Cl36						99.39
							Al26						0.61

# Sulphur

## Pathway analysis

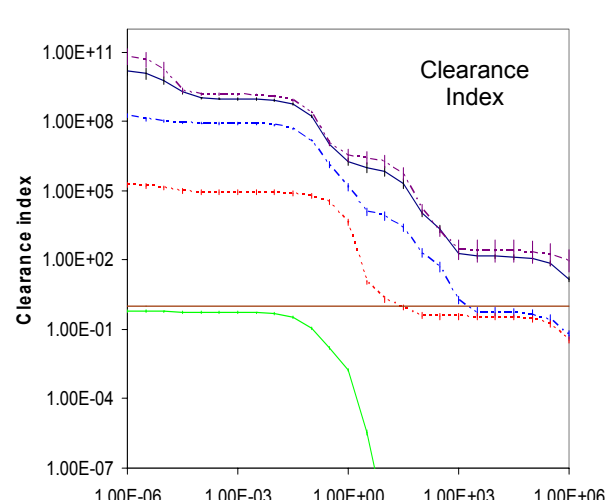
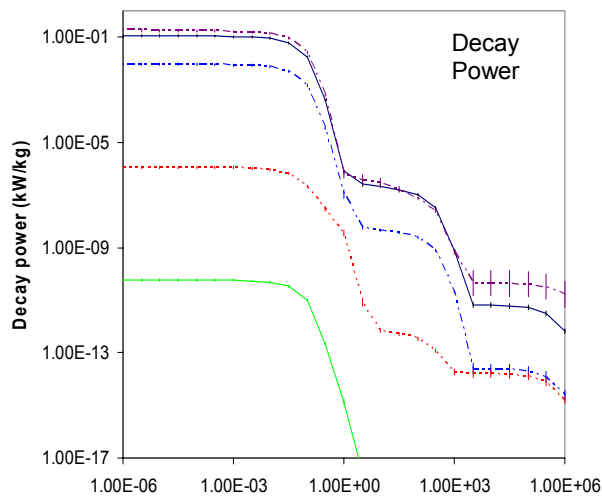
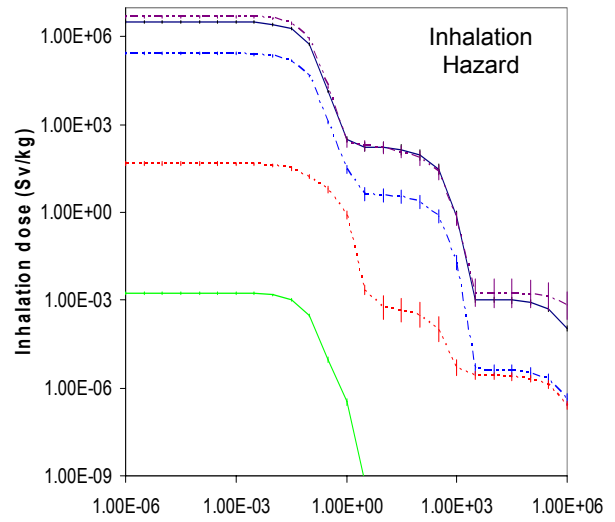
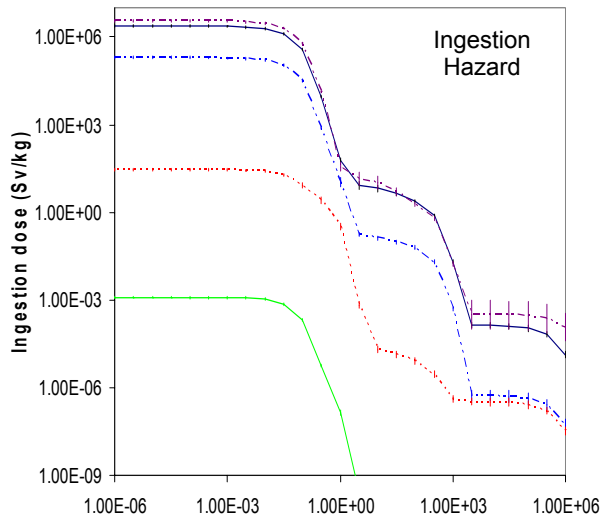
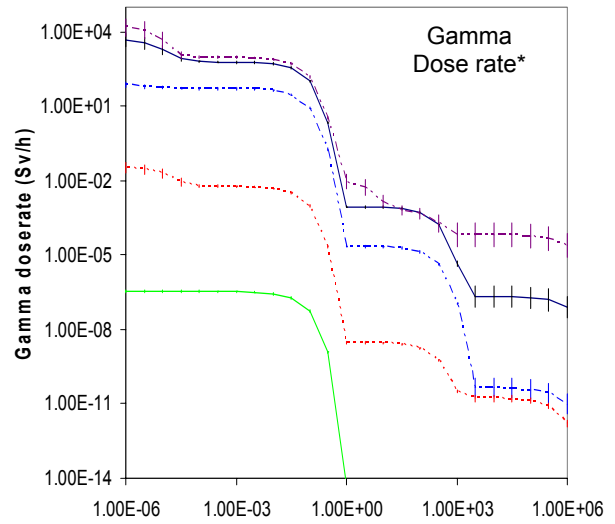
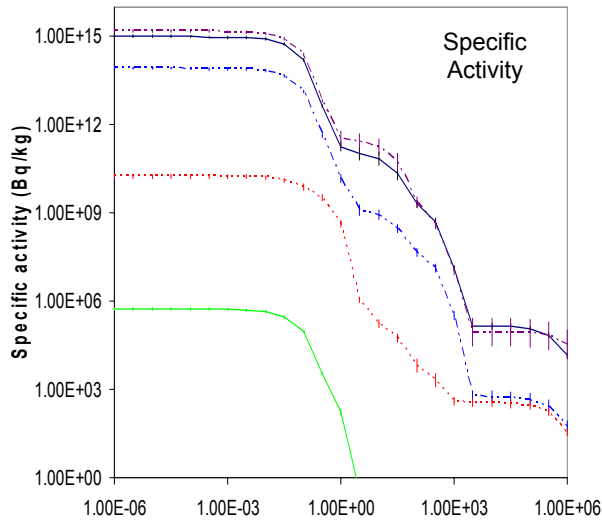
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Al28	2.241 m	S32(n,n $\alpha$ )Si28(n,p)Al28				53.7	2.7	1.2	0.6
		S32(n,d)P31(n, $\alpha$ )Al28				36.0	1.2	0.8	4.3
		S32(n, $\alpha$ )Si29(n,d)Al28				3.6	2.6	2.9	13.6
		S32(n, $\alpha$ )Si29(n,2n)Si28(n,p)Al28				2.5			
		S32(n,p $\alpha$ )Al28					90.0	67.4	44.3
		S32(n,h)Si30(n,t)Al28					0.5	16.1	17.7
		S32(n,t)P30( $\beta^+$ )Si30(n,t)Al28						7.0	11.1
P30	2.50 m	S32(n,d)P31(n,2n)P30				90.2	25.0	1.5	0.6
		S32(n,t)P30				4.1	72.0	97.6	98.3
		S34(n, $\alpha$ )Si31( $\beta^-$ )P31(n,2n)P30				1.8			
		S32(n,2p)Si31( $\beta^-$ )P31(n,2n)P30				1.4	1.7		
S37	4.99 m	S36(n, $\gamma$ )S37	99.7	100.0	100.0	99.1	98.9	99.3	99.7
Al29	6.56 m	S32(n, $\alpha$ )Si29(n,p)Al29				96.7	2.6	1.1	2.6
		S32(n,d)P31(n,d)Si30(n,d)Al29				0.2	7.0	1.3	0.4
		S32(n,h)Si30(n,d)Al29					72.5	58.4	31.0
		S32(n,t)P30( $\beta^+$ )Si30(n,d)Al29					6.4	25.3	19.5
		S34(n,n $\alpha$ )Si30(n,d)Al29					3.5	0.8	0.4
		S32(n,d)P31(n,h)Al29					1.5	6.1	5.4
		S34(n,d $\alpha$ )Al29						2.2	6.5
		S32(n,ph)Al29						1.5	31.9
Cl38	37.2 m	&S34(n, $\gamma$ )S35( $\beta^-$ )Cl35(n, $\gamma$ )Cl36(n, $\gamma$ )Cl37_ (n, $\gamma$ )Cl38	94.4	0.4					
		&S36(n, $\gamma$ )S37( $\beta^-$ )Cl37(n, $\gamma$ )Cl38	4.2	98.1	98.5	87.9	87.9	87.8	88.1
Si31	2.62 h	S32(n, $\gamma$ )S33(n, $\alpha$ )Si30(n, $\gamma$ )Si31	63.3	6.3	0.3				
		S33(n, $\alpha$ )Si30(n, $\gamma$ )Si31	36.3	93.6	83.9				
		S32(n, $\alpha$ )Si29(n, $\gamma$ )Si30(n, $\gamma$ )Si31	0.5		15.8				
		S34(n, $\alpha$ )Si31				40.1	0.6	1.8	17.0
		S32(n,2p)Si31				30.0	90.8	87.1	74.4
		S32(n,d)P31(n,p)Si31				26.5	6.8	7.0	3.9
		S33(n,h)Si31					0.1	2.0	3.0
Na24	14.96 h	&S32(n,n $\alpha$ )Si28(n,d)Al27(n, $\alpha$ )Na24				45.8	1.3	0.2	0.2
		&S32(n,n $\alpha$ )Si28(n,n $\alpha$ )Mg24(n,p)Na24				15.3	0.8	0.1	
		&S32(n,d)P31(n,n $\alpha$ )Al27(n, $\alpha$ )Na24				9.2	0.8		
		&S32(n,n $\alpha$ )Si28(n, $\alpha$ )Mg25(n,d)Na24				8.1	0.5	0.2	0.6
		&S32(n,n $\alpha$ )Si28(n, $\alpha$ )Mg25(n,2n)Mg24_ (n,p)Na24				3.1			
		&S32(n, $\alpha$ )Si29(n,2n)Si28(n,d)Al27(n, $\alpha$ )Na24				1.4			
		&S34(n,n $\alpha$ )Si30(n, $\alpha$ )Mg27( $\beta^-$ )Al27(n, $\alpha$ )Na24				0.5			
		&S32(n, $\alpha$ )Si29(n,t)Al27(n, $\alpha$ )Na24				0.2			0.5
		&S32(n,n $\alpha$ )Si28(n,p $\alpha$ )Na24					46.6	34.7	4.2
		&S32(n,2 $\alpha$ )Mg25(n,d)Na24					20.8	11.2	1.5
		&S32(n,d)P31(n,2 $\alpha$ )Na24					8.4	8.2	0.8
		&S32(n,p $\alpha$ )Al28( $\beta^-$ )Si28(n,p $\alpha$ )Na24					8.4	5.5	0.4
		&S32(n,d $\alpha$ )Al27(n, $\alpha$ )Na24					0.4	7.0	16.7
		&S32(n, $\alpha$ )Si29(n,d $\alpha$ )Na24						2.3	27.2
&S32(n,h)Si30(n,t $\alpha$ )Na24						0.1	11.1		
&S32(n,t)P30( $\beta^+$ )Si30(n,t $\alpha$ )Na24							6.9		
P32	14.27 d	S32(n, $\gamma$ )S33(n, $\alpha$ )Si30(n, $\gamma$ )Si31( $\beta^-$ )P31_ (n, $\gamma$ )P32	44.4	0.6					
		S33(n, $\alpha$ )Si30(n, $\gamma$ )Si31( $\beta^-$ )P31(n, $\gamma$ )P32	39.4	12.2	25.1				
		S34(n, $\gamma$ )S35( $\beta^-$ )Cl35(n, $\alpha$ )P32	16.5	87.5	72.3				
		S32(n, $\alpha$ )Si29(n, $\gamma$ )Si30(n, $\gamma$ )Si31( $\beta^-$ )P31_ (n, $\gamma$ )P32	0.3		3.2				
		S32(n,p)P32				98.9	90.4	73.1	63.3
		S33(n,d)P32				0.7	4.6	4.3	4.9
		S34(n,2n)S33(n,d)P32				0.2	1.5	0.7	0.5

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	S34(n,t)P32					2.2	20.9	30.5
P33	25.38 d	S34(n,γ)S35(β <sup>-</sup> )Cl35(n,γ)Cl36(n,α)P33 S32(n,γ)S33(n,p)P33 S33(n,p)P33 S34(n,d)P33 S34(n,2n)S33(n,p)P33	55.2 35.5 10.1	0.5 11.9 87.9	0.7 99.3	0.3 29.4 59.2 8.9	1.8 96.6 0.6	1.6 97.3 0.3	1.1 97.8 0.1
S35	87.32 d	S34(n,γ)S35 S32(n,γ)S33(n,γ)S34(n,γ)S35 S36(n,2n)S35 S36(n,d)P35(β <sup>-</sup> )S35	98.3 0.5	100.0	100.0	10.9 86.7 0.2	12.2 74.0 12.5	11.6 64.6 23.0	8.9 62.4 28.2
Na22	2.60 y	S32(n,α)Si29(n,α)Mg26(n,α)Ne23(β <sup>-</sup> ) Na23(n,2n)Na22 S32(n,nα)Si28(n,nα)Mg24(n,d)Na23_ (n,2n)Na22 S32(n,nα)Si28(n,d)Al27(n,nα)Na23(n,2n)Na22 S32(n,nα)Si28(n,d)Al27(n,2n)Al26(n,nα)Na22 S32(n,d)P31(n,nα)Al27(n,nα)Na23(n,2n)Na22 S32(n,nα)Si28(n,α)Mg25(n,2n)Mg24_ (n,d)Na23(n,2n)Na22 S32(n,d)P31(n,nα)Al27(n,2n)Al26(n,nα)Na22 S32(n,nα)Si28(n,nα)Mg24(n,t)Na22 S32(n,2α)Mg25(n,t)Na23(n,2n)Na22 S32(n,nα)Si28(n,t)Al26(n,nα)Na22 S32(n,pα)Al28(β <sup>-</sup> )Si28(n,nα)Mg24(n,t)Na22 S32(n,dα)Al27(n,nα)Na23(n,2n)Na22 S32(n,dα)Al27(n,2n)Al26(n,nα)Na22 S32(n,2α)Mg25(n,2n)Mg24(n,t)Na22 S32(n,n2α)Mg24(n,t)Na22 S32(n,dα)Al27(n,2nα)Na22 S32(n,nα)Si28(n,tα)Na22 S32(n,tα)Al26(n,nα)Na22				47.6 19.1 14.4 5.8 2.9 2.4 1.2 27.8 8.1 4.9 4.9 3.7 2.8 2.2 1.0 44.6 0.3 0.2	8.6 6.0 4.7 3.6 2.8 3.6 0.2 1.0 0.6 0.7 0.6 0.3 36.4 44.6 0.3 0.2	0.8 0.2 0.2 0.1	
H3	12.33 y	S34(n,γ)S35(β <sup>-</sup> )Cl35(n,X)H1(n,γ)H2(n,γ)H3 S33(n,X)H1(n,γ)H2(n,γ)H3 S32(n,γ)S33(n,X)H1(n,γ)H2(n,γ)H3 S34(n,γ)S35(β <sup>-</sup> )Cl35(n,γ)Cl36(n,X)H1_ (n,γ)H2(n,γ)H3 S32(n,d)P31(n,X)H3 S32(n,X)H3 S33(n,X)H3 S32(n,α)Si29(n,X)H3 S32(n,p)P32(n,X)H3 S32(n,X)He3(n,p)H3 S34(n,2n)S33(n,X)H3 S34(n,X)H3 S34(n,α)Si31(β <sup>-</sup> )P31(n,X)H3 S32(n,h)Si30(n,X)H3	49.4 22.8 20.1 2.0	2.6 89.6 3.1	99.1 0.2	49.7 18.8 11.5 8.2 2.2 1.8 1.8 1.5 1.0	4.7 86.6 1.4 0.2 0.2 0.2 0.2 3.9 4.3	2.1 88.4 1.0 0.2 0.2 0.2 0.2 4.3	1.2 89.3 0.9 0.8 0.1 4.4
Si32	132.0 y	S32(n,γ)S33(n,α)Si30(n,γ)Si31(n,γ)Si32 S33(n,α)Si30(n,γ)Si31(n,γ)Si32 S33(n,α)Si30(n,γ)Si31(β <sup>-</sup> )P31(n,γ)P32_ (n,p)Si32 S32(n,γ)S33(n,α)Si30(n,γ)Si31(β <sup>-</sup> )P31_ (n,γ)P32(n,p)Si32 S34(n,γ)S35(β <sup>-</sup> )Cl35(n,α)P32(n,p)Si32 S32(n,α)Si29(n,γ)Si30(n,γ)Si31(n,γ)Si32 S34(n,γ)S35(n,α)Si32 S32(n,p)P32(n,p)Si32 S33(n,2p)Si32 S36(n,nα)Si32 S34(n,2n)S33(n,2p)Si32 S34(n,d)P33(n,d)Si32 S34(n,d)P33(β <sup>-</sup> )S33(n,2p)Si32 S34(n,h)Si32	38.6 33.2 10.4 9.0 8.3 0.3 0.1	3.6 79.0 0.9 9.6 6.8	36.9 4.7 58.3	77.8 14.1 3.4 2.2 0.8 0.3	2.5 37.4 6.0 6.0 3.0 3.6 40.9	0.3 7.1 1.0 0.6 0.6 0.5 89.6	3.3 0.5 0.2 0.2 0.1 95.4

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Ar39	269.0 y	&S34(n,γ)S35(β <sup>-</sup> )Cl35(n,γ)Cl36(n,γ)_ Cl37(n,γ)Cl38(β <sup>-</sup> )Ar38(n,γ)Ar39	91.7	0.1					
		&S36(n,γ)S37(β <sup>-</sup> )Cl37(n,γ)Cl38(β <sup>-</sup> )_ Ar38(n,γ)Ar39	8.2	99.9	100.0	99.4	99.5	99.8	99.9
C14	5700 y	S32(n,nα)Si28(n,nα)Mg24(n,α)Ne21(n,2α)C14				51.1	0.4		
		S32(n,nα)Si28(n,α)Mg25(n,nα)Ne21(n,2α)C14				30.5	0.3		
		S32(n,nα)Si28(n,α)Mg25(n,2n)Mg24_				6.3			
		(n,α)Ne21(n,2α)C14							
		S32(n,nα)Si28(n,2α)Ne21(n,2α)C14					33.0	2.2	
		S32(n,2α)Mg25(n,nα)Ne21(n,2α)C14					22.8	0.9	
		S32(n,2α)Mg25(n,2α)O18(n,nα)C14					12.4	0.8	
		S32(n,2α)Mg25(n,3α)C14					7.1	14.6	2.3
		S32(n,pα)Al28(β <sup>-</sup> )Si28(n,2α)Ne21(n,2α)C14					5.9	0.4	
		S32(n,dα)Al27(n,dα)Ne22(n,n2α)C14						15.7	4.9
		S32(n,n2α)Mg24(n,n2α)O16(n,h)C14						8.5	4.2
		S32(n,dα)Al27(n,n2α)F19(n,dα)C14						7.1	5.4
		S32(n,n2α)Mg24(n,dα)F19(n,dα)C14						6.7	5.5
		S32(n,n2α)Mg24(n,h)Ne22(n,n2α)C14						5.5	1.9
		S32(n,dα)Al27(n,t)Mg25(n,3α)C14						2.2	1.0
		S32(n,3α)Ne21(n,2α)C14						0.2	2.0
		S32(n,tα)Al26m(β <sup>+</sup> )Mg26(n,n3α)C14							4.4
		S32(n,nα)Si28(n,n3α)O16(n,h)C14							2.9
S32(n,dα)Al27(n,n3α)N15(n,d)C14							2.7		
S32(n,hα)Mg26(n,n3α)C14							2.5		
S32(n,n3α)Ne20(n,hα)C14							2.3		
Cl36	3.0 10 <sup>5</sup> y	S34(n,γ)S35(β <sup>-</sup> )Cl35(n,γ)Cl36	99.7	100.0	100.0	6.6	4.2	4.6	3.8
		S36(n,2n)S35(β <sup>-</sup> )Cl35(n,γ)Cl36				52.7	25.6	26.1	26.4
		S36(n,γ)S37(β <sup>-</sup> )Cl37(n,2n)Cl36				40.3	65.6	59.8	57.8
Al26	7.2 10 <sup>5</sup> y	S32(n,nα)Si28(n,d)Al27(n,2n)Al26				76.8	28.4	0.7	
		S32(n,d)P31(n,nα)Al27(n,2n)Al26				15.5	16.9	0.3	
		S32(n,α)Si29(n,2n)Si28(n,d)Al27(n,2n)Al26				1.8			
		S34(n,nα)Si30(n,α)Mg27(β <sup>-</sup> )Al27(n,2n)Al26				0.9			
		S32(n,α)Si29(n,t)Al27(n,2n)Al26				0.3	0.6	0.1	
		S32(n,nα)Si28(n,t)Al26					23.6	41.9	6.2
		S32(n,dα)Al27(n,2n)Al26					13.8	26.3	2.4
		S32(n,pα)Al28(β <sup>-</sup> )Si28(n,d)Al27(n,2n)Al26					5.1	0.1	
		S32(n,pα)Al28(β <sup>-</sup> )Si28(n,t)Al26					4.2	6.6	0.6
		S32(n,d)P31(n,2nα)Al26						11.8	1.6
S32(n,tα)Al26						7.2	84.2		
S32(n,α)Si29(n,nt)Al26						0.3	2.9		



# Sulphur activation characteristics

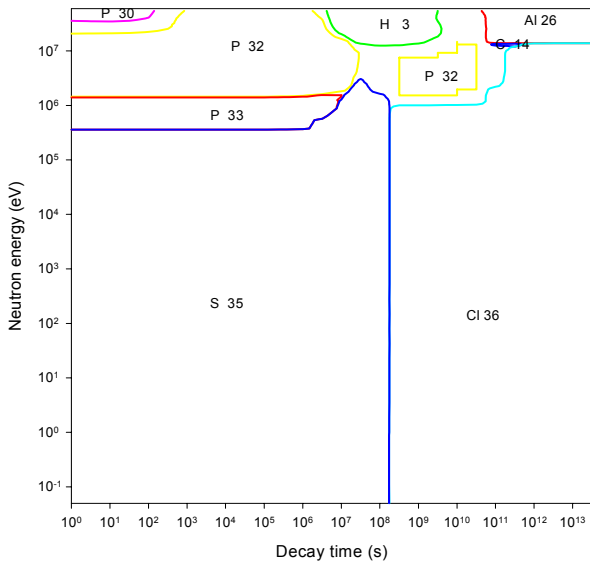


Decay time (years)

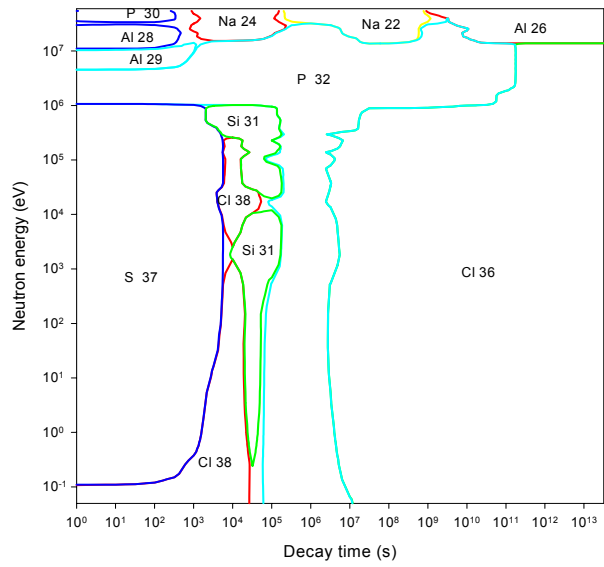
Decay time (years)

# Sulphur importance diagrams & transmutation

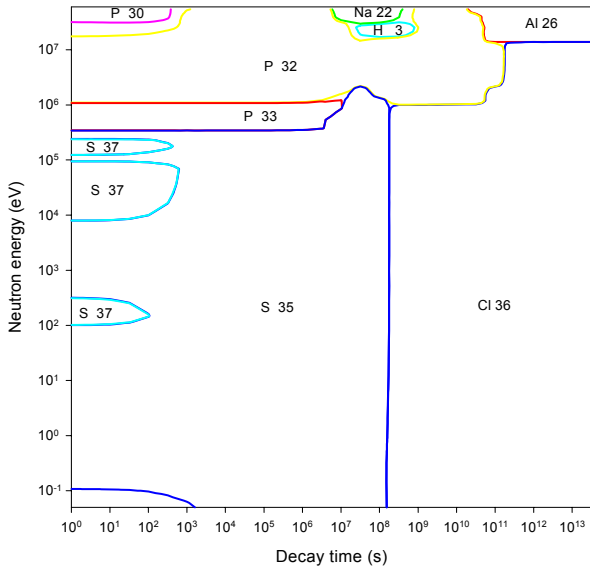
Activity



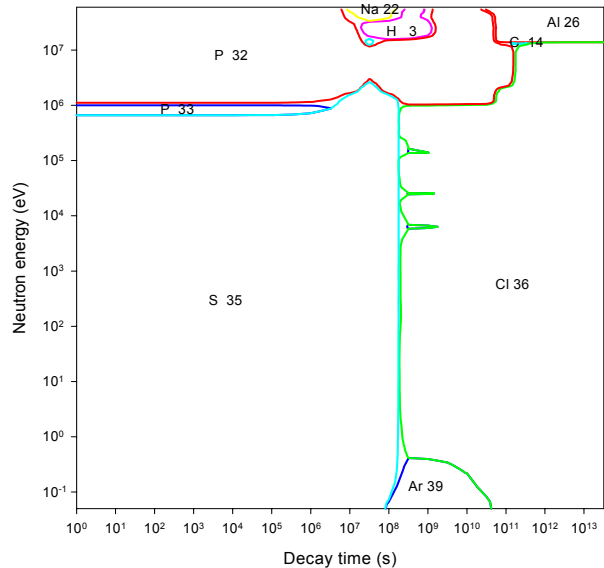
Dose rate



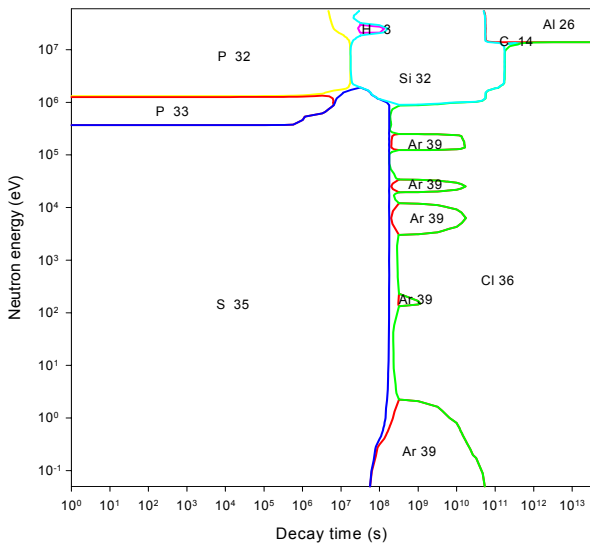
Heat output



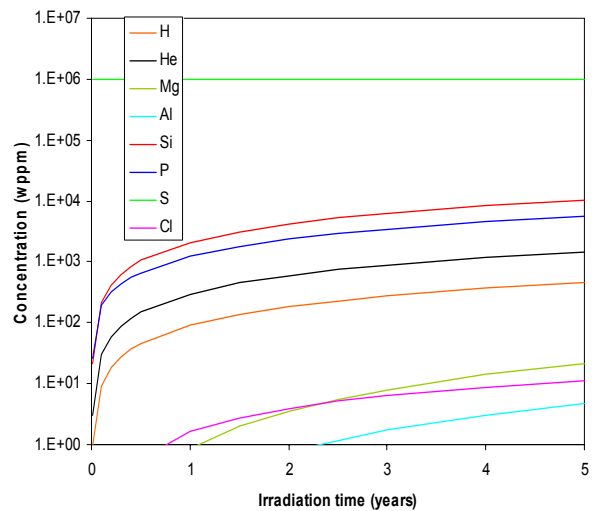
Ingestion dose



Inhalation dose



First wall transmutation



# Chlorine

## General properties

Atomic number	17	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	130	Cl35	75.77
Melting point / K	172.2	Cl37	24.23
Boiling point / K	239.2		
Density / kgm <sup>-3</sup>	3.214		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	8.9 10 <sup>-3</sup>		
Electrical resistivity /Ωm	-		
Coefficient of thermal expansion / K <sup>-1</sup>	-		
Crystal structure	tetragonal		
Number of stable isotopes	2		
Mean atomic weight	35.4527		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	1.12E15	1.08E15	9.68E14	3.87E13	2.85E10	1.94E10	kW kg <sup>-1</sup>	7.64E-2	5.83E-2	3.68E-2	2.99E-4	1.16E-6	8.51E-7
S35	61.75	64.02	69.36	98.25			P32	49.04	64.30	85.30	0.05	7.05	
P32	30.09	31.19	29.14		2.59		S37	13.61	8.60				
P34	2.07						P34	12.78					
S37	1.56						S35	7.06	9.26	14.24	99.39		
P33	1.37	1.42	1.43				Cl38	6.61	7.86				
H3	0.06	0.06	0.07	1.68	8.75		Cl34	4.71					
Cl36				0.06	85.98	100.0	Cl34m	4.58	5.36				
Si32					2.59		Cl36				0.36	92.02	100.0
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	3.19E4	1.82E4	1.76E2	1.89E-3	1.57E-3	8.78E-4	Sv kg <sup>-1</sup>	1.35E6	1.35E6	1.20E6	2.94E4	5.10E1	1.81E1
S37	54.03	45.67					P32	59.97	59.98	56.52		3.47	
Cl34m	15.84	24.81					S35	39.48	39.49	43.17	99.70		
Cl38	15.35	24.44					P33	2.72	2.72	0.27			
P34	7.95						Ar39				0.11	50.94	
Cl34	4.75	4.40					H3				0.09	0.21	
P32	0.21*	0.37*	100.0*	75.49*	64.67*		Cl36					44.58	100.0
Cl36				24.40*	35.33*	100.0*	Si32					0.81	
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	2.49E6	2.48E6	2.26E6	7.39E4	1.16E3	1.42E2		1.04E11	5.50E10	7.04E9	4.11E8	2.45E7	1.94E7
S35	52.82	52.83	56.49	97.77			S37	50.52	46.16				
P32	46.06	46.06	42.47		0.22		Cl34m	17.63	29.84				
P33	9.23	9.30	0.92				P34	13.05					
Cl38	0.02	0.02					Cl34	8.65	8.67				
Ar39			0.05	1.57	77.36		S35	6.62	12.55	95.35	92.47		
Cl36				0.24	15.38	100.0	Cl38		1.72				
H3				0.23	0.06		P32		0.61	4.01			
Si32				0.18	6.99		Cl36		0.04	0.35	5.95	99.87	100.0
							H3		0.01	0.09	1.58	0.10	
							Si32					0.02	

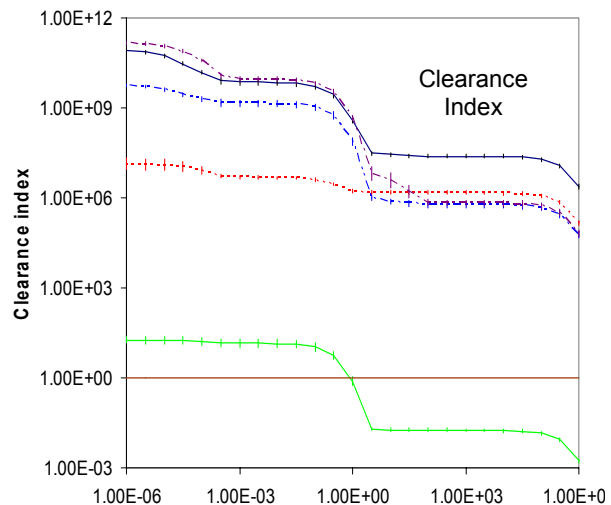
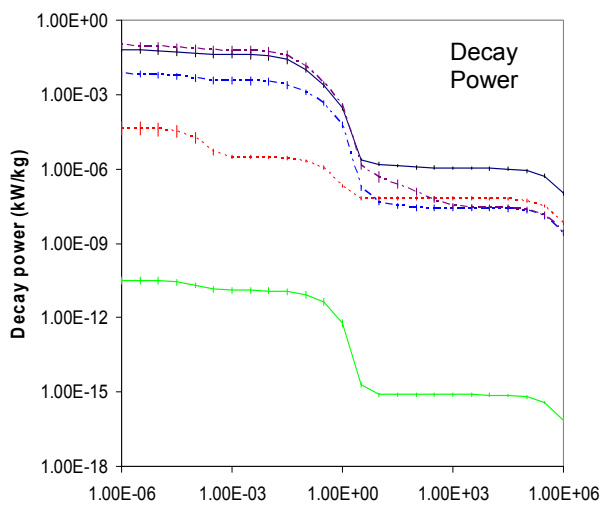
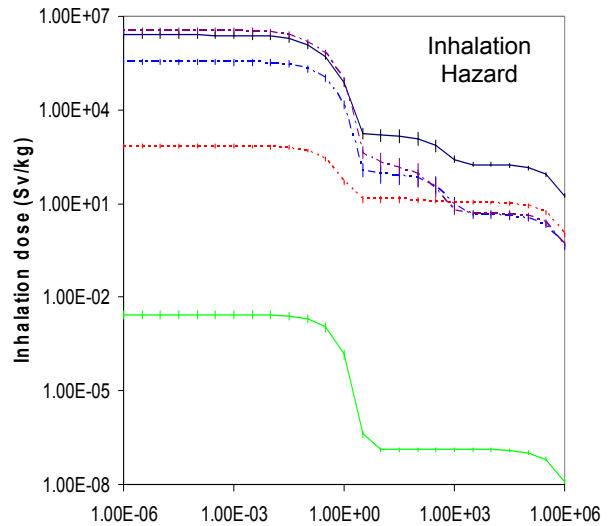
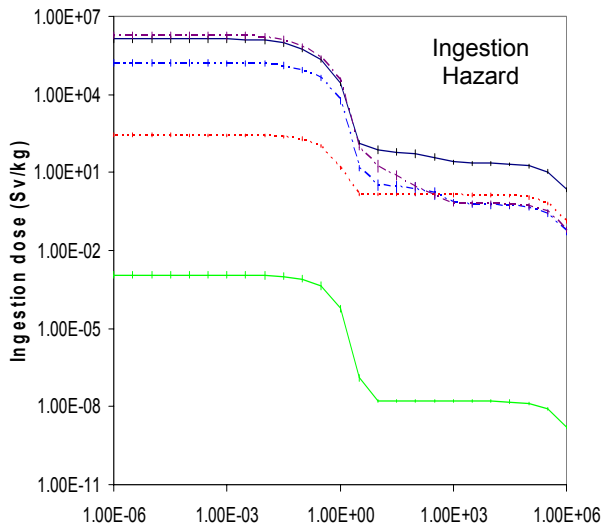
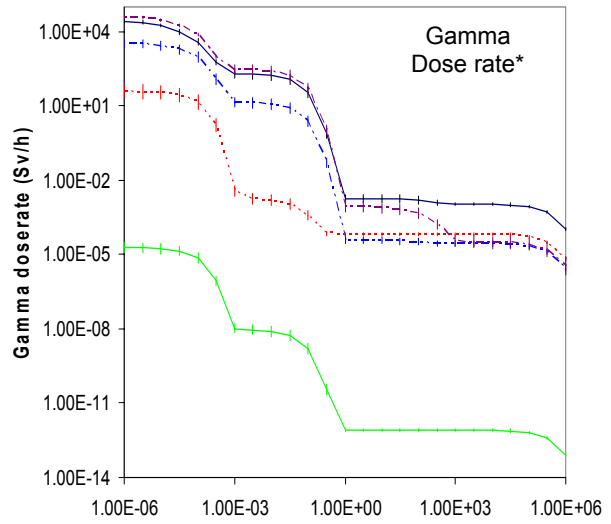
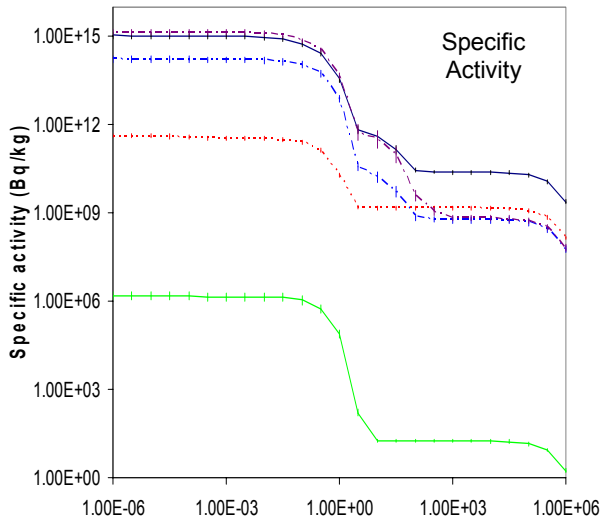
# Chlorine

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6		
S37	4.99 m	Cl35(n,γ)Cl36(n,p)S36(n,γ)S37 Cl35(n,p)S35(n,γ)S36(n,γ)S37 Cl37(n,p)S37	97.8 0.6	99.0 0.4	3.7 96.1	100.0	99.9	99.9	100.0		
Cl34m	32.1 m	Cl35(n,2n)Cl34m Cl37(n,4n)Cl34m				98.1	98.3	97.6	91.8 6.8		
Cl38	37.2 m	Cl37(n,γ)Cl38 &Cl35(n,γ)Cl36(n,γ)Cl37(n,γ)Cl38 Cl37(n,γ)Cl38m(IT)Cl38	48.4 44.7 6.6	88.0 11.9	88.1 11.9	46.9 52.4	44.3 55.7	43.7 56.3	45.4 54.6		
Ar41	1.827 h	&Cl37(n,γ)Cl38(β <sup>-</sup> )Ar38(n,γ)Ar39(n,γ) Ar40(n,γ)Ar41 &Cl35(n,γ)Cl36(n,γ)Cl37(n,γ)Cl38(β <sup>-</sup> ) Ar38(n,γ)Ar39(n,γ)Ar40(n,γ)Ar41	84.7 15.3	100.0	100.0	99.2	99.7				
K42	12.36 h	&Cl37(n,γ)Cl38(β <sup>-</sup> )Ar38(n,γ)Ar39(n,γ) Ar40(n,γ)Ar41(β <sup>-</sup> )K41(n,γ)K42 &Cl35(n,γ)Cl36(n,γ)Cl37(n,γ)Cl38(β <sup>-</sup> ) Ar38(n,γ)Ar39(n,γ)Ar40(n,γ)Ar41(β <sup>-</sup> ) K41(n,γ)K42	89.4 10.6	99.9							
Na24	14.96 h	&Cl35(n,nα)P31(n,nα)Al27(n,α)Na24 Cl35(n,d)S34(n,nα)Si30(n,α)Mg27(β <sup>-</sup> ) Al27(n,α)Na24 Cl35(n,nα)P31(n,d)Si30(n,α)Mg27(β <sup>-</sup> ) Al27(n,α)Na24 Cl35(n,α)P32(β <sup>-</sup> )S32(n,nα)Si28(n,d) Al27(n,α)Na24 &Cl35(n,nα)P31(n,2α)Na24 &Cl35(n,2α)Al28(β <sup>-</sup> )Si28(n,pα)Na24 &Cl35(n,pα)Si31(β <sup>-</sup> )P31(n,2α)Na24 &Cl35(n,t)S33(n,2nα)Si28(n,pα)Na24 &Cl35(n,dα)Si30(n,nα)Mg26(n,t)Na24 &Cl35(n,dα)Si30(n,2nα)Mg25(n,d)Na24 &Cl35(n,n2α)Al27(n,α)Na24 &Cl35(n,tα)Si29(n,dα)Na24 &Cl35(n,dα)Si30(n,tα)Na24 &Cl35(n,3α)Na24				56.0 6.0 4.8 3.9	4.8	0.2	49.6 17.3 5.7 1.2 0.6	20.8 8.1 1.9 3.4	0.8 0.1
P32	14.27 d	Cl35(n,α)P32 Cl37(n,2n)Cl36(n,nα)P32 Cl35(n,d)S34(n,2n)S33(n,d)P32 Cl37(n,nα)P33(β <sup>-</sup> )S33(n,d)P32 Cl35(n,t)S33(n,d)P32 Cl35(n,d)S34(n,t)P32 Cl37(n,2nα)P32 Cl35(n,h)P33(β <sup>-</sup> )S33(n,d)P32	97.2	99.9	100.0	92.9 1.1 0.5 0.2	40.8 9.2 2.6 4.2	22.9 1.2 0.3 0.6	70.6 0.3 0.1		
P33	25.38 d	Cl35(n,γ)Cl36(n,α)P33 Cl37(n,nα)P33 Cl35(n,d)S34(n,d)P33 Cl37(n,2n)Cl36(n,α)P33 Cl35(n,d)S34(n,2n)S33(n,p)P33 Cl35(n,h)P33 Cl37(n,nt)S34(n,d)P33	99.1	100.0	100.0	50.5 31.8 11.1 2.4 0.1	44.5 33.1 0.4 0.2 15.1	18.5 13.8 0.2 0.7	15.0 7.6 0.5 70.5 2.2		
S35	87.32 d	Cl35(n,p)S35 Cl37(n,d)S36(n,2n)S35 Cl37(n,2n)Cl36(n,d)S35 Cl37(n,t)S35 Cl37(n,h)P35(β <sup>-</sup> )S35	100.0	99.9	100.0	92.7 3.4 3.2 0.2	58.4 4.7 6.4 28.7 0.2	29.5 1.5 1.9 65.3 0.8	22.1 0.8 1.1 73.6 1.7		
Na22	2.60 y	Cl35(n,nα)P31(n,nα)Al27(n,nα)Na23 (n,2n)Na22				43.7	26.2				

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Cl35(n,α)P31(n,α)Al27(n,2n)Al26(n,α)Na22   Cl35(n,α)P32(β <sup>-</sup> )S32(n,α)Si29(n,α)_ Mg26(n,α)Ne23(β <sup>-</sup> )Na23(n,2n)Na22 Cl35(n,d)S34(n,α)Si30(n,α)Mg27(β <sup>-</sup> )_ Al27(n,α)Na23(n,2n)Na22 Cl35(n,α)P32(β <sup>-</sup> )S32(n,α)Si28(n,α)_ Mg24(n,d)Na23(n,2n)Na22 Cl35(n,α)P31(n,d)Si30(n,α)Mg27(β <sup>-</sup> )_ Al27(n,α)Na23(n,2n)Na22 Cl35(n,pα)Si31(β <sup>-</sup> )P31(n,α)Al27(n,α)_ Na23(n,2n)Na22 Cl35(n,2α)Al28(β <sup>-</sup> )Si28(n,α)Mg24(n,t)Na22   Cl35(n,2α)Al28(β <sup>-</sup> )Si28(n,α)Mg24(n,d)_ Na23(n,2n)Na22 Cl35(n,2α)Al27(n,2nα)Na22 Cl35(n,α)P31(n,α)Al27(n,2nα)Na22 Cl35(n,tα)Si29(n,2nα)Mg24(n,t)Na22 Cl35(n,tα)Si28(n,tα)Na22 Cl35(n,α)P31(n,2n2α)Na22				17.7 8.0 3.8 3.2 3.1 0.3 12.8 4.0 66.2 3.2 1.3 5.9 3.6	20.4		1.8 66.2 3.2 1.3	29.9 0.5 4.4 5.9 3.6
H3	12.33 y	Cl35(n,X)H1(n,γ)H2(n,γ)H3 Cl35(n,γ)Cl36(n,X)H1(n,γ)H2(n,γ)H3 Cl35(n,X)H3 Cl37(n,X)H3 Cl37(n,2n)Cl36(n,X)H3 Cl35(n,t)S33(n,X)H3	87.8 4.8	94.9 0.3	99.3	80.3 11.8 5.4	71.7 22.2 1.4 0.7	69.5 24.5 0.6 1.4	68.4 26.3 0.3 1.1	
Si32	132.0 y	Cl35(n,α)P32(n,p)Si32 Cl35(n,p)S35(n,α)Si32 Cl37(n,d)S36(n,α)Si32 Cl37(n,2n)Cl36(n,pα)Si32 Cl37(n,α)P33(n,d)Si32 Cl35(n,t)S33(n,2p)Si32 Cl35(n,d)S34(n,h)Si32 Cl37(n,dα)Si32 Cl35(n,ph)Si32	99.2	100.0	99.9 0.1	24.4 35.7 28.8 3.5 1.7 0.1	0.2 0.4 38.8 10.7 2.5 15.3 12.5 8.3 6.9	3.6 1.0 0.2 4.2 12.2 67.0 6.9	0.8 0.2 0.9 5.1 50.3 39.3	
Ar39	269.0 y	&Cl37(n,γ)Cl38(β <sup>-</sup> )Ar38(n,γ)Ar39 &Cl35(n,γ)Cl36(n,γ)Cl37(n,γ)Cl38(β <sup>-</sup> )_ Ar38(n,γ)Ar39	75.6 24.3	100.0	100.0	99.2	99.7	99.8	99.9	
Cl36	3.0 10 <sup>5</sup> y	Cl35(n,γ)Cl36 Cl37(n,2n)Cl36	99.1	100.0	100.0	0.3 99.5	0.1 99.8	0.1 99.8	0.1 99.9	
Al26	7.2 10 <sup>5</sup> y	Cl35(n,α)P31(n,α)Al27(n,2n)Al26 Cl35(n,d)S34(n,α)Si30(n,α)Mg27(β <sup>-</sup> )_ Al27(n,2n)Al26 Cl35(n,α)P31(n,d)Si30(n,α)Mg27(β <sup>-</sup> )_ Al27(n,2n)Al26 Cl35(n,α)P32(β <sup>-</sup> )S32(n,α)Si28(n,d)_ Al27(n,2n)Al26 Cl35(n,pα)Si31(β <sup>-</sup> )P31(n,α)Al27(n,2n)Al26   Cl35(n,2α)Al28(β <sup>-</sup> )Si28(n,d)Al27(n,2n)Al26   Cl35(n,2α)Al28(β <sup>-</sup> )Si28(n,t)Al26 Cl35(n,α)P31(n,pα)Mg27(β <sup>-</sup> )Al27(n,2n)Al26   Cl35(n,2α)Al27(n,2n)Al26 Cl35(n,t)S33(n,2nα)Si28(n,t)Al26 Cl35(n,α)P31(n,2nα)Al26 Cl35(n,pα)Si31(β <sup>-</sup> )P31(n,2nα)Al26 Cl35(n,tα)Si29(n,nt)Al26 Cl35(n,tα)Si28(n,t)Al26 Cl35(n,2n2α)Al26 Cl35(n,nt)S32(n,tα)Al26 Cl35(n,α)P32(β <sup>-</sup> )S32(n,tα)Al26				72.4 7.5 6.1 4.9 0.6 0.6 5.8 3.8 1.1 0.3 37.6 3.3 0.4 0.3	66.1 0.1 0.1 0.1 7.6 6.9 5.8 3.8 23.5 3.6 37.6 3.3 0.4 0.3	1.0 0.2 12.3 0.8 2.9 0.5 6.6 0.5 12.4 3.1 51.2 4.7 4.6		

# Chlorine activation characteristics

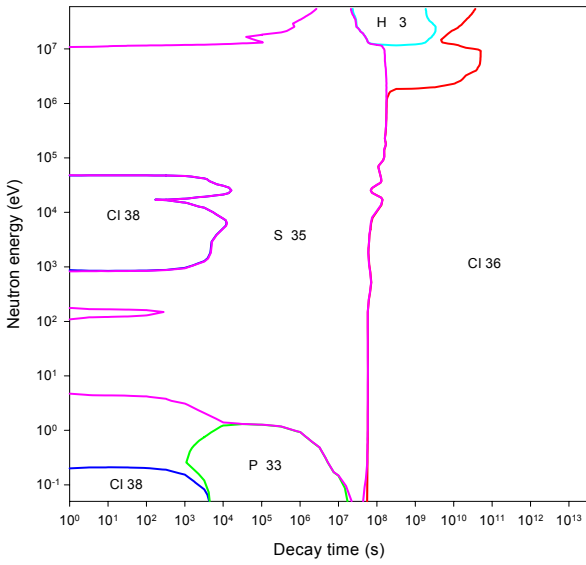


Decay time (years)

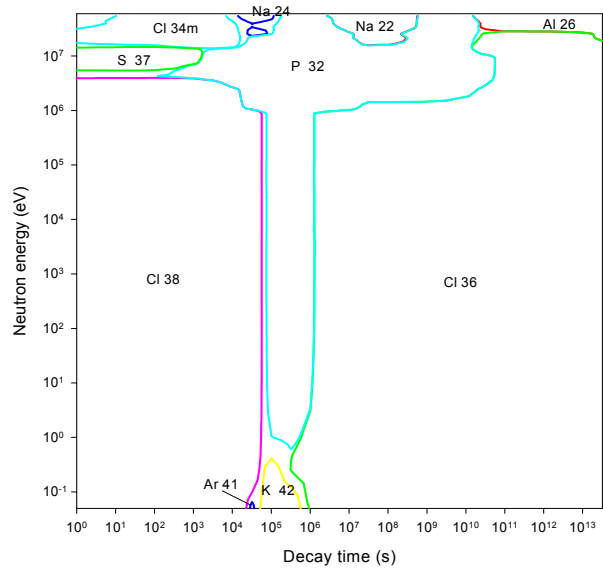
Decay time (years)

# Chlorine importance diagrams & transmutation

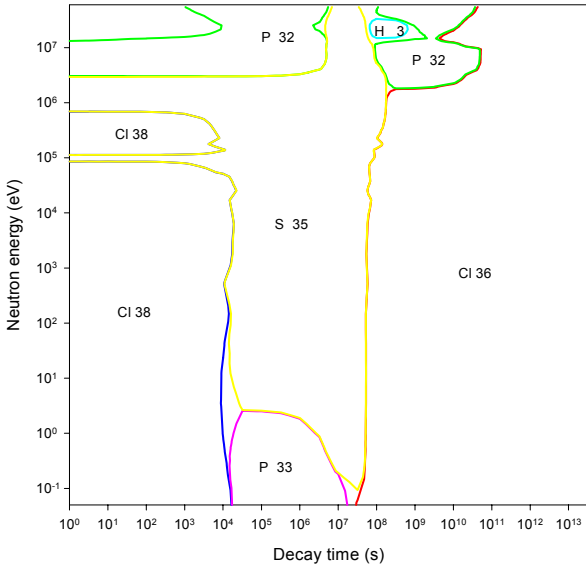
Activity



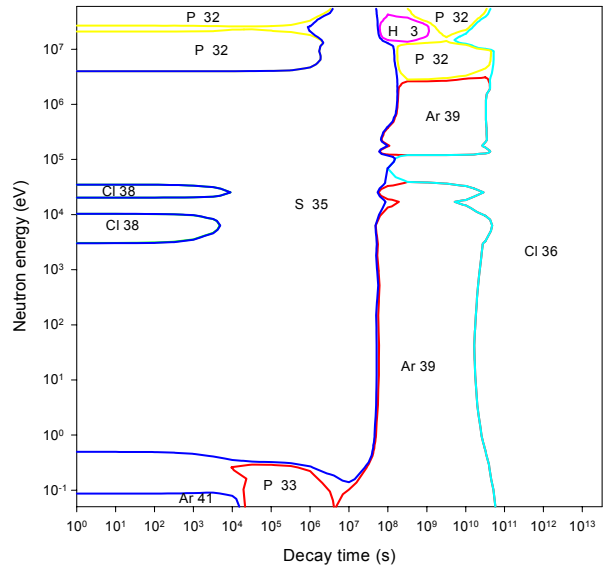
Dose rate



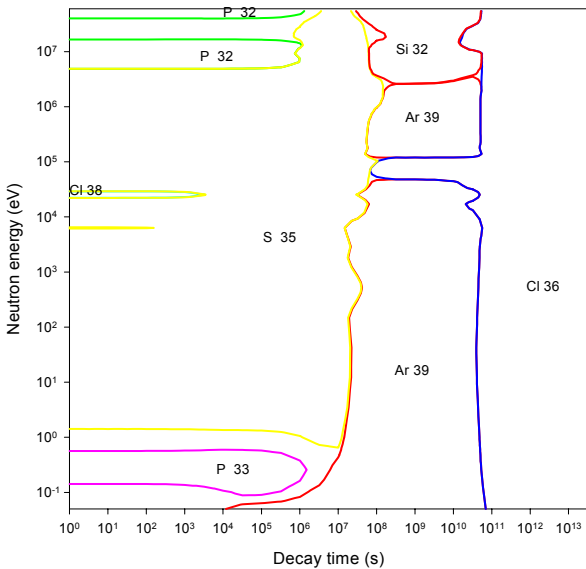
Heat output



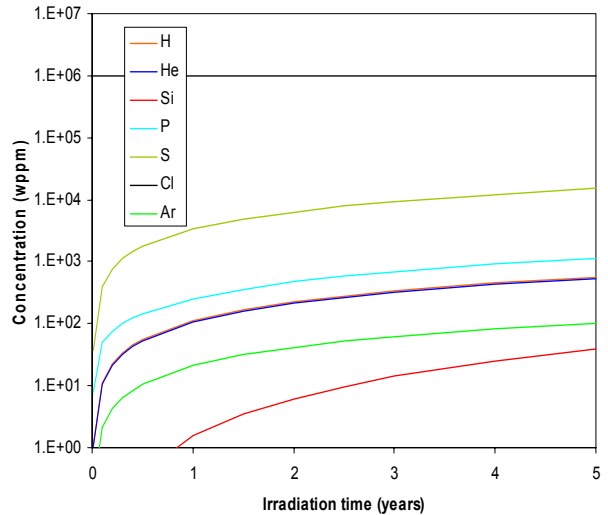
Ingestion dose



Inhalation dose



First wall transmutation



Graphs for H, He are indistinguishable





# Argon

## General properties

Atomic number	18	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	1.2	Ar36	0.3365
Melting point / K	83.78	Ar38	0.0632
Boiling point / K	87.29	Ar40	99.6003
Density / kgm <sup>-3</sup>	1.784		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	1.77 10 <sup>-2</sup>		
Electrical resistivity /Ωm	-		
Coefficient of thermal expansion / K <sup>-1</sup>	-		
Crystal structure	FCC		
Number of stable isotopes	3		
Mean atomic weight	39.948		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	1.55E14	1.03E14	1.81E13	1.46E13	1.12E13	3.85E7	kW kg <sup>-1</sup>	7.11E-2	3.16E-2	5.32E-4	5.07E-4	3.92E-4	1.69E-9
Ar41	40.11	58.37					Cl40	41.75	6.32				
S37	22.94	16.62					S37	29.93	32.45				
Cl40	21.32	2.16					Ar41	24.52	53.41				
Ar39	9.33	14.03	79.92	99.03	100.0		Cl39	2.22	4.69				
Cl39	2.79	3.93					Ar39	0.71	1.60	95.38	99.79	100.0	
S35	1.56	2.34	12.97	0.91			Cl38	0.44	0.90				
Ar37	0.82	1.24	6.59				K42	0.25	0.55	0.24			
Cl38	0.42	0.57					S35	0.03	0.06	3.45	0.20		
Cl36						99.97	Cl36						99.99
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	1.09E5	4.66E4	7.66E-1	2.97E-1	2.30E-1	1.76E-6	Sv kg <sup>-1</sup>	2.40E7	2.38E7	1.59E7	1.59E7	1.23E7	3.58E-2
Cl40	41.52	6.54					Ar39	66.26	67.00	99.91	100.0	100.0	
S37	33.99	38.37					Ar41	33.68	32.94				
Ar41	22.32	50.60					S35			0.01			
Cl39	1.71						Cl36						99.98
Cl38	0.30	0.63											
K42		0.12*	95.04*	37.34*	17.83*								
Ar37			3.27	26.85									
P32			1.69*	35.28*	80.15*								
Cl36				0.40*	1.54*	71.79*							
K40				0.13	0.47	28.09							
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	5.55E8	5.54E8	5.50E8	5.49E8	4.25E8	2.81E-1		3.37E11	1.49E11	7.87E8	7.62E8	5.89E8	3.85E4
Ar39	99.24	99.26	99.99	100.0	100.0		Cl40	40.94	6.23				
Ar41	0.75	0.72					S37	32.03	34.95				
Cl36						100.0	Ar41	24.65	54.01				
							Cl39	1.98	4.20				
							Ar39	0.22	0.51	96.85	99.81	99.99	
							Cl36			0.01	0.01	0.01	100.0

# Argon

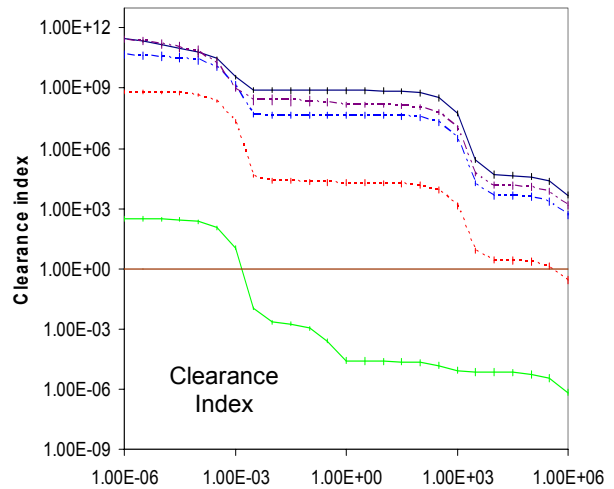
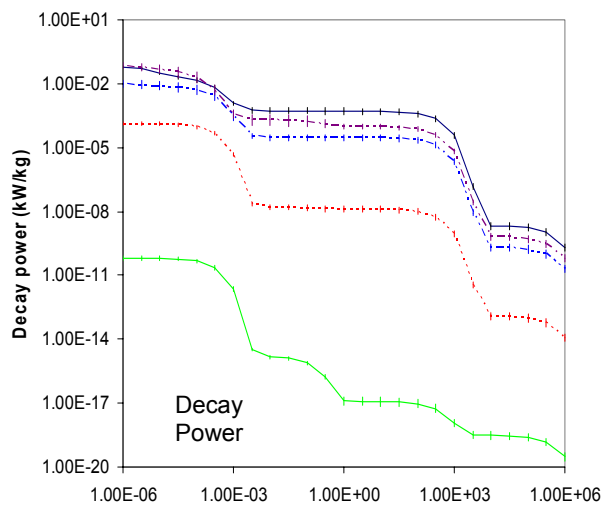
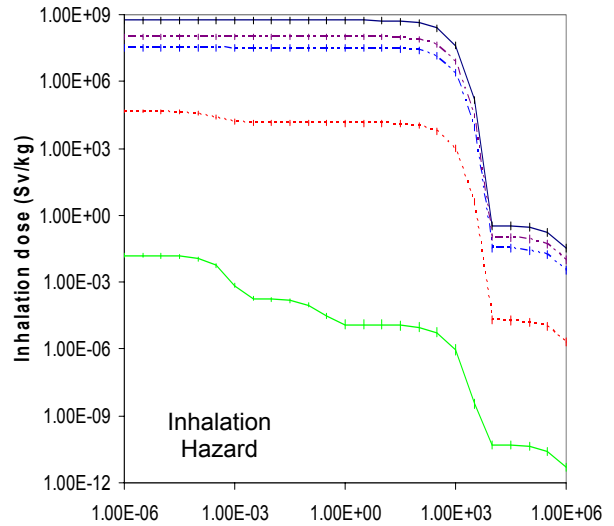
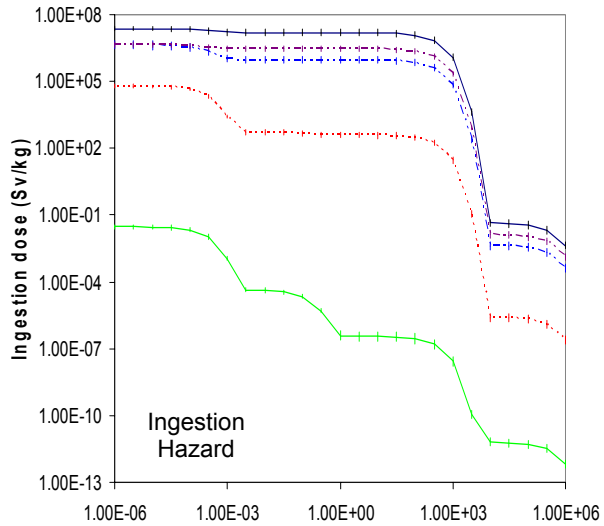
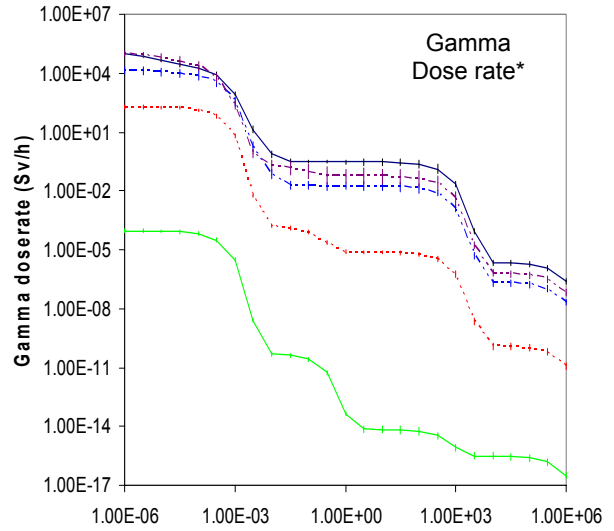
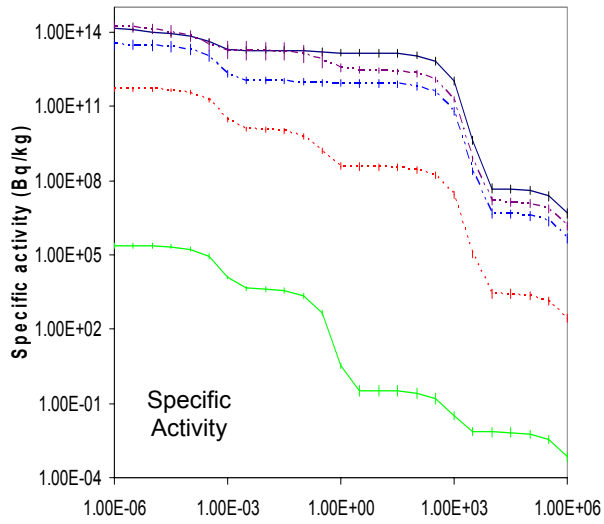
## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Cl40	1.35 m	Ar40(n,p)Cl40				100.0	100.0	100.0	100.0
S37	4.99 m	Ar38(n,γ)Ar39(n,α)S36(n,γ)S37 Ar36(n,p)Cl36(n,p)S36(n,γ)S37 Ar40(n,α)S37 Ar40(n,3n)Ar38(n,2p)S37 Ar40(n,2n)Ar39(n,h)S37 Ar40(n,d)Cl39(β <sup>-</sup> )Ar39(n,h)S37 Ar40(n,nt)Cl37(n,p)S37	99.7	100.0	98.0 1.9	99.3	95.7 1.4 1.0 0.2 0.1	92.4 1.4 2.3 1.0 1.1	96.5 0.2 0.7 0.4 1.4
Cl38	37.2 m	&Ar36(n,γ)Ar37(β <sup>+</sup> )Cl37(n,γ)Cl38 &Ar36(n,γ)Ar37(n,p)Cl37(n,γ)Cl38 &Ar40(n,2n)Ar39(n,d)Cl38 &Ar40(n,2n)Ar39(n,2n)Ar38(n,p)Cl38 &Ar38(n,p)Cl38 &Ar40(n,t)Cl38 &Ar40(n,d)Cl39(β <sup>-</sup> )Ar39(n,d)Cl38 &Ar40(n,3n)Ar38(n,p)Cl38 Ar40(n,h)S38(β <sup>-</sup> )Cl38	90.7 8.5	99.4 0.3	96.7	66.7 21.6 2.5 0.3 0.1	29.1 2.6 55.9 94.9 6.8 3.5 1.0	2.6 1.4 96.8 1.1 0.5 0.5 1.0	1.4 96.8 0.5 1.6
Cl39	55.6 m	Ar40(n,2n)Ar39(n,p)Cl39 Ar40(n,d)Cl39				77.0 22.6	2.4 96.9	0.9 98.7	0.3 99.5
Ar41	1.827 h	Ar40(n,γ)Ar41	100.0	100.0	100.0	99.0	99.7	99.8	99.9
K42	12.36 h	Ar40(n,γ)Ar41(β <sup>-</sup> )K41(n,γ)K42	100.0	100.0	100.0	98.5	99.7	99.8	99.9
P32	14.27 d	Ar36(n,γ)Ar37(n,α)S34(n,γ)S35(β <sup>-</sup> )Cl35_ (n,α)P32 Ar36(n,α)S33(n,α)Si30(n,γ)Si31(β <sup>-</sup> )P31_ (n,γ)P32 Ar40(n,2n)Ar39(n,nα)S35(β <sup>-</sup> )Cl35(n,α)P32 Ar36(n,d)Cl35(n,α)P32 Ar40(n,nα)S36(n,2n)S35(β <sup>-</sup> )Cl35(n,α)P32 Ar36(n,α)S33(n,d)P32 Ar36(n,nα)S32(n,p)P32 Ar36(n,pα)P32 Ar36(n,p)Cl36(n,nα)P32 Ar40(n,α)S37(β <sup>-</sup> )Cl37(n,2n)Cl36(n,nα)P32 Ar40(n,2nα)S35(β <sup>-</sup> )Cl35(n,α)P32 Ar40(n,3n)Ar38(n,nα)S34(n,t)P32 Ar40(n,3n)Ar38(n,t)Cl36(n,nα)P32 Ar40(n,2n)Ar39(n,2nα)S34(n,t)P32 Ar40(n,3n)Ar38(n,2nα)S33(n,d)P32 Ar40(n,nt)Cl37(n,2nα)P32 Ar40(n,3nα)S34(n,t)P32 Ar40(n,4n)Ar37(β <sup>+</sup> )Cl37(n,2nα)P32 Ar40(n,3n)Ar38(n,tα)P32 &Ar40(n,t)Cl38(β <sup>-</sup> )Ar38(n,tα)P32	98.9 1.1	99.3 0.6		26.8 22.1 16.6 8.1 6.2 5.5 4.3 2.9	0.9 0.7 0.6 0.7 0.7 50.2 0.7 0.4	0.1 0.1 0.2 1.1 6.1 3.8 3.0 3.5 3.1 16.0 18.7 3.4 1.5 0.6	0.1 0.1 0.2 1.1 5.5 0.4 0.3 0.4 0.3 18.3 29.9 6.1 11.5 6.9
P33	25.38 d	Ar36(n,γ)Ar37(n,α)S34(n,γ)S35(β <sup>-</sup> )Cl35_ (n,γ)Cl36(n,α)P33 Ar36(n,p)Cl36(n,α)P33 Ar36(n,α)S33(n,p)P33 Ar40(n,α)S37(β <sup>-</sup> )Cl37(n,nα)P33 Ar40(n,nα)S36(n,α)Si33(β <sup>-</sup> )P33 Ar40(n,α)S37(β <sup>-</sup> )Cl37(n,2n)Cl36(n,α)P33 Ar40(n,2n)Ar39(n,2n)Ar38(n,nα)S34(n,d)P33 Ar40(n,2n)Ar39(n,α)S36(n,α)Si33(β <sup>-</sup> )P33 Ar40(n,2n)Ar39(n,t)Cl37(n,nα)P33 Ar40(n,3n)Ar38(n,nα)S34(n,d)P33 Ar40(n,2n)Ar39(n,2nα)S34(n,d)P33	86.3 13.4 0.3		100.0	6.6 6.9 40.5 30.1 4.3 2.6 1.8 0.3		0.5 0.1 0.5 0.8 4.1 17.3 2.2	0.3 0.3 0.1 0.1 0.1 0.3 0.3

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	Ar40(n,3n)Ar38(n,d)Cl37(n,nα)P33 Ar40(n,3n)Ar38(n,2n)Ar37(β <sup>+</sup> )Cl37(n,nα)P33   Ar40(n,2α)Si33(β <sup>-</sup> )P33 Ar40(n,nα)S36(n,3n)S34(n,d)P33 Ar40(n,nt)Cl37(n,nα)P33 Ar40(n,2n)Ar39(n,3n)Ar37(β <sup>+</sup> )Cl37(n,nα)P33   Ar40(n,2nα)S35(β <sup>-</sup> )Cl35(n,h)P33 Ar40(n,nα)S36(n,nt)P33 Ar40(n,3n)Ar38(n,dα)P33 Ar40(n,2nα)S35(n,t)P33 Ar40(n,2n)Ar39(n,tα)P33 Ar40(n,3nα)S34(n,d)P33 &Ar40(n,t)Cl38(β <sup>-</sup> )Ar38(n,dα)P33 Ar40(n,4n)Ar37(β <sup>+</sup> )Cl37(n,nα)P33 Ar40(n,d)Cl39(β <sup>-</sup> )Ar39(n,tα)P33 Ar40(n,ntα)P33					9.6 9.4 7.3 5.6 3.5 3.2 1.6 1.3 0.9 0.8 0.1	1.1 0.9 2.4 0.7 6.4 0.5 12.8 2.5 26.9 4.5 0.9	0.1 0.3 10.2 2.6 5.8 8.3 1.0 5.9 21.1 5.0 3.4 3.2 22.5
Ar37	35.04 d	Ar36(n,γ)Ar37 Ar40(n,2n)Ar39(n,2n)Ar38(n,2n)Ar37 Ar38(n,2n)Ar37 &Ar40(n,2n)Ar39(n,d)Cl38(β <sup>-</sup> )Ar38(n,2n)Ar37   Ar40(n,3n)Ar38(n,2n)Ar37 Ar40(n,2n)Ar39(n,3n)Ar37 Ar40(n,d)Cl39(β <sup>-</sup> )Ar39(n,3n)Ar37 &Ar40(n,t)Cl38(β <sup>-</sup> )Ar38(n,2n)Ar37 Ar40(n,4n)Ar37	99.8	100.0	100.0	0.1 87.2 8.7 2.2	2.8 0.9 0.6 65.4 22.3 5.2 3.1	0.3 0.5 0.1 35.5 18.3 7.8 12.6 25.5	0.1 0.1 4.8 2.9 1.6 2.9 87.5
Sc46	83.79 d	&Ar40(n,γ)Ar41(β <sup>-</sup> )K41(n,γ)K42(β <sup>-</sup> )_ Ca42(n,γ)Ca43(n,γ)Ca44(n,γ)Ca45(β <sup>-</sup> )_ Sc45(n,γ)Sc46	99.5	99.5	99.9				
S35	87.32 d	Ar36(n,γ)Ar37(n,α)S34(n,γ)S35 Ar40(n,2n)Ar39(n,nα)S35 Ar40(n,nα)S36(n,2n)S35 Ar40(n,2n)Ar39(n,2n)Ar38(n,α)S35 Ar40(n,2n)Ar39(n,α)S36(n,2n)S35 Ar36(n,2p)S35 Ar40(n,d)Cl39(β <sup>-</sup> )Ar39(n,nα)S35 Ar40(n,2nα)S35 Ar40(n,nα)S36(n,d)P35(β <sup>-</sup> )S35 Ar40(n,nt)Cl37(n,t)S35 Ar40(n,4n)Ar37(β <sup>+</sup> )Cl37(n,t)S35	99.4	100.0	100.0	55.4 34.5 4.0 2.0 1.0 0.2	21.5 14.4 0.9 5.0 52.4 2.4	1.9 1.1 0.8 0.8 91.8 0.4 1.0 0.2	1.2 0.7 0.6 0.3 77.8 0.3 6.9 2.3
Na22	2.60 y	Ar36(n,2α)Si29(n,α)Mg26(n,α)Ne23(β <sup>-</sup> )_ Na23(n,2n)Na22 Ar36(n,nα)S32(n,α)Si29(n,α)Mg26(n,α)_ Ne23(β <sup>-</sup> )Na23(n,2n)Na22 Ar36(n,α)S33(n,nα)Si29(n,α)Mg26(n,α)_ Ne23(β <sup>-</sup> )Na23(n,2n)Na22 Ar36(n,nα)S32(n,nα)Si28(n,nα)Mg24_ (n,d)Na23(n,2n)Na22 Ar36(n,nα)S32(n,nα)Si28(n,d)Al27_ (n,nα)Na23(n,2n)Na22 Ar36(n,n2α)Si28(n,nα)Mg24(n,t)Na22 Ar36(n,dα)P31(n,nα)Al27(n,nα)Na23_ (n,2n)Na22 Ar36(n,nα)S32(n,nα)Si28(n,nα)Mg24(n,t)Na22   Ar36(n,n2α)Si28(n,nα)Mg24(n,d)Na23_ (n,2n)Na22 Ar36(n,2α)Si29(n,2nα)Mg24(n,t)Na22 Ar36(n,dα)P31(n,nα)Al27(n,2n)Al26(n,nα)Na22   Ar40(n,2nα)S35(β <sup>-</sup> )Cl35(n,nα)P31(n,nα)_ Al27(n,nα)Na23(n,2n)Na22 Ar40(n,2nα)S35(β <sup>-</sup> )Cl35(n,n2α)Al27_ (n,2nα)Na22				36.0 15.5 14.6 6.2 4.7 12.3 4.1 3.8 3.8 3.3 3.2 3.0	0.9 0.6 5.6 0.1 1.5	0.2 0.1 1.5 2.5	

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Ar36(n,α)P31(n,nα)Al27(n,2nα)Na22 Ar36(n,n2α)Si28(n,tα)Na22 Ar40(n,3nα)S34(n,3nα)Si28(n,tα)Na22 Ar40(n,2n2α)Si31(β <sup>-</sup> )P31(n,2n2α)Na22 Ar40(n,3nα)S34(n,tα)Al28(β <sup>-</sup> )Si28(n,tα)Na22 Ar40(n,3nα)S34(n,2n2α)Mg25(n,nt)Na22						3.2 0.5	0.2 4.5 10.3 7.6 4.4 3.0	
H3	12.33 y	Ar36(n,γ)Ar37(n,X)H1(n,γ)H2(n,γ)H3 Ar36(n,X)H1(n,γ)H2(n,γ)H3 Ar40(n,2n)Ar39(n,X)H3 Ar40(n,X)H3 Ar40(n,d)Cl39(β <sup>-</sup> )Ar39(n,X)H3 Ar40(n,3n)Ar38(n,X)H3	92.2 1.2	86.8 8.6	61.6 37.8					
Ar42	33.0 y	Ar40(n,γ)Ar41(n,γ)Ar42 Ar40(n,γ)Ar41(β <sup>-</sup> )K41(n,γ)K42(n,p)Ar42	100.0	100.0	100.0	97.0 2.3	97.9 1.5	98.7 0.9	99.4 0.4	
Ar39	269 y	Ar38(n,γ)Ar39 Ar40(n,2n)Ar39 Ar40(n,d)Cl39(β <sup>-</sup> )Ar39	99.6	100.0	100.0					
Cl36	3.0 10 <sup>5</sup> y	Ar36(n,γ)Ar37(n,α)S34(n,γ)S35(β <sup>-</sup> )Cl35_ (n,γ)Cl36 Ar36(n,p)Cl36 Ar40(n,α)S37(β <sup>-</sup> )Cl37(n,2n)Cl36 Ar40(n,2n)Ar39(n,t)Cl37(n,2n)Cl36 Ar40(n,3n)Ar38(n,t)Cl36 Ar40(n,3n)Ar38(n,d)Cl37(n,2n)Cl36 Ar40(n,3n)Ar38(n,2n)Ar37(β <sup>+</sup> )Cl37(n,2n)Cl36 Ar40(n,nt)Cl37(n,2n)Cl36 Ar40(n,2n)Ar39(n,nt)Cl36 Ar40(n,2n)Ar39(n,3n)Ar37(β <sup>+</sup> )Cl37(n,2n)Cl36 &Ar40(n,t)Cl38(β <sup>-</sup> )Ar38(n,t)Cl36 Ar40(n,d)Cl39(β <sup>-</sup> )Ar39(n,nt)Cl36 Ar40(n,2nt)Cl36	87.0 13.0		99.9 100.0					
Al26	7.2 10 <sup>5</sup> y	Ar36(n,nα)S32(n,nα)Si28(n,d)Al27(n,2n)Al26 Ar36(n,α)S33(n,α)Si30(n,α)Mg27(β <sup>-</sup> )_ Al27(n,2n)Al26 Ar36(n,d)Cl35(n,nα)P31(n,nα)Al27(n,2n)Al26 Ar36(n,nα)S32(n,d)P31(n,nα)Al27(n,2n)Al26 Ar40(n,2n)Ar39(n,nα)S35(β <sup>-</sup> )Cl35(n,nα)_ P31(n,nα)Al27(n,2n)Al26 Ar38(n,nα)S34(n,nα)Si30(n,α)Mg27(β <sup>-</sup> )_ Al27(n,2n)Al26 Ar40(n,nα)S36(n,2n)S35(β <sup>-</sup> )Cl35(n,nα)_ P31(n,nα)Al27(n,2n)Al26 Ar36(n,2α)Si29(n,t)Al27(n,2n)Al26 Ar36(n,dα)P31(n,nα)Al27(n,2n)Al26 Ar40(n,2nα)S35(β <sup>-</sup> )Cl35(n,nα)P31(n,nα)_ Al27(n,2n)Al26 Ar36(n,n2α)Si28(n,d)Al27(n,2n)Al26 Ar36(n,n2α)Si28(n,t)Al26 Ar40(n,3n)Ar38(n,2α)Si31(β <sup>-</sup> )P31(n,nα)_ Al27(n,2n)Al26 Ar40(n,2nα)S35(β <sup>-</sup> )Cl35(n,2α)Al28(β <sup>-</sup> )_ Si28(n,t)Al26 Ar40(n,2nα)S35(β <sup>-</sup> )Cl35(n,2nα)Al27(n,2n)Al26 Ar36(n,dα)P31(n,2nα)Al26 Ar40(n,2nα)S35(β <sup>-</sup> )Cl35(n,nα)P31(n,2nα)Al26 Ar40(n,3nα)S34(n,nt)P31(n,2nα)Al26 Ar40(n,3nα)S34(n,2nα)Si29(n,nt)Al26 Ar40(n,3nα)S34(n,3nα)Si28(n,t)Al26 Ar40(n,nt)Cl37(n,3nα)P31(n,2nα)Al26 Ar40(n,2n2α)Si31(β <sup>-</sup> )P31(n,2nα)Al26 Ar40(n,2nα)S35(β <sup>-</sup> )Cl35(n,2n2α)Al26					29.7 16.7 13.1 6.0 5.3 3.6 3.3 0.3	2.4 2.2 1.4 1.0 0.7 6.6 13.0 11.9 8.3 6.9 5.5 1.5 0.3	0.1 0.6 0.2 0.4 23.0 3.2 3.3 6.3 22.4 10.1 0.5 0.5 0.2 0.1	0.2 0.2 7.9 0.6 0.5 5.5 4.4 4.7 2.4 72.0

# Argon activation characteristics

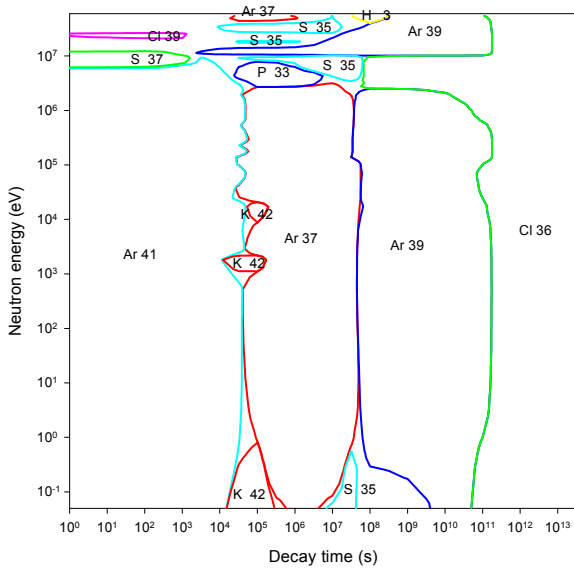


Decay time (years)

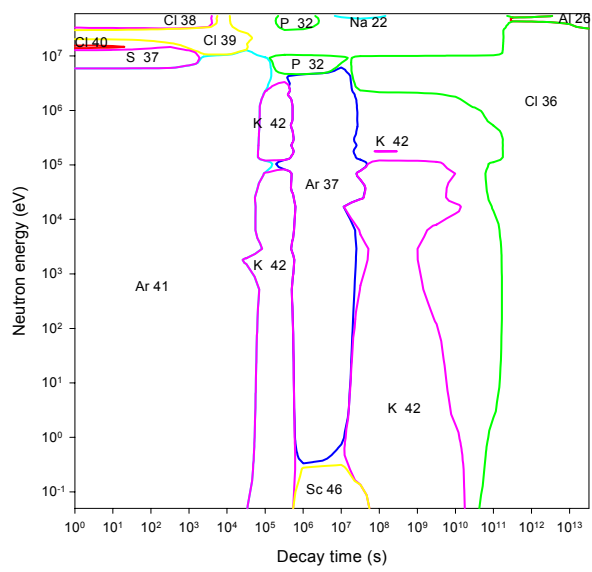
Decay time (years)

# Argon importance diagrams & transmutation

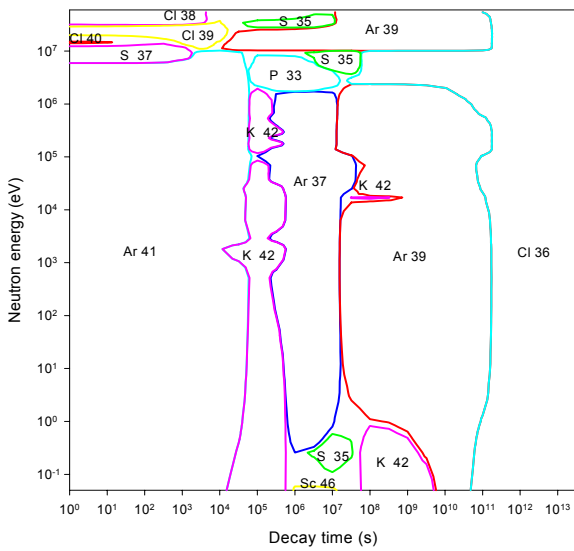
**Activity**



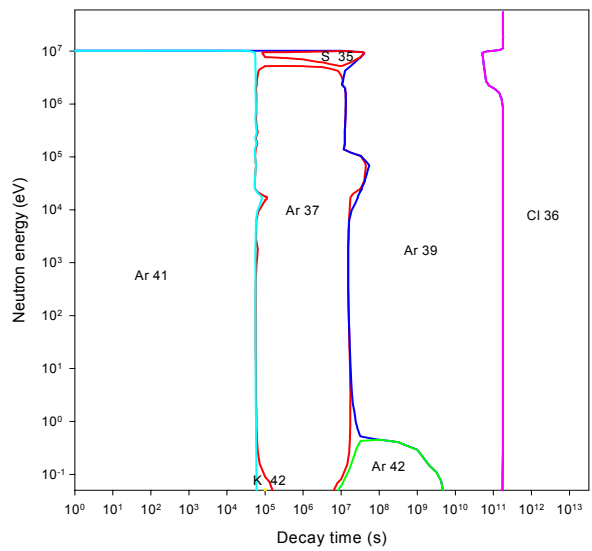
**Dose rate**



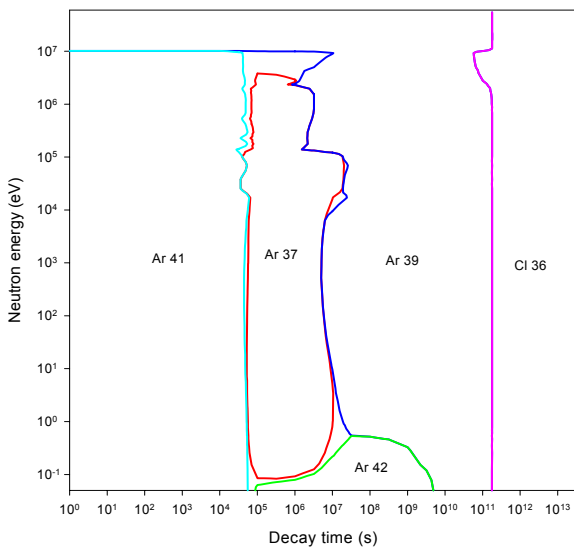
**Heat output**



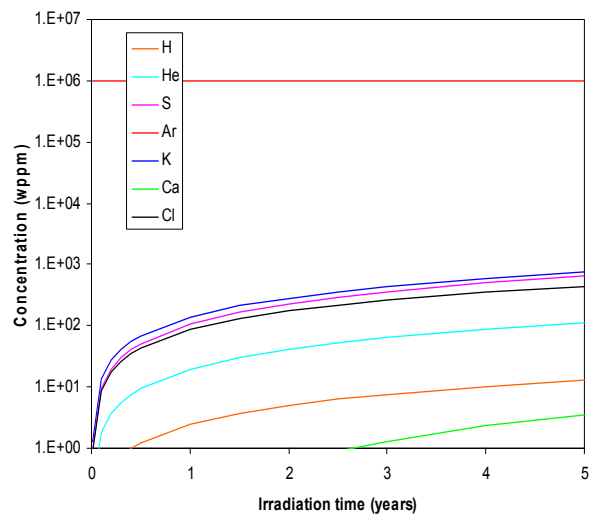
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**



# Potassium

## General properties

Atomic number	19	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	2.09 10 <sup>4</sup>	K39	93.2581
Melting point / K	336.5	K40	0.0117 (T <sub>1/2</sub> = 1.26 10 <sup>9</sup> y)
Boiling point / K	1032	K41	6.7302
Density / kgm <sup>-3</sup>	862		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	102		
Electrical resistivity /Ωm	6.15 10 <sup>-8</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	8.3 10 <sup>-5</sup>		
Crystal structure	BCC		
Number of stable isotopes	2 (3)		
Mean atomic weight	39.0983		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	1.40E14	1.30E14	3.76E13	2.18E13	1.63E13	2.92E9	kW kg <sup>-1</sup>	3.35E-2	3.00E-2	1.01E-3	7.42E-4	5.72E-4	1.28E-7
K42	48.24	51.43	1.31				K42	54.64	60.59	13.33			
Ar39	15.13	16.21	56.16	96.38	99.96		Cl38	15.91	16.08				
Cl38	7.90	7.67					K38	12.69	8.76				
S35	7.02	7.52	25.32	2.47			Ar41	7.72	8.32				
Ar41	6.61	6.85					Cl39	2.97	3.10				
K38	4.33	2.87					Ar39	2.20	2.46	73.56	99.38	99.97	
Ar37	3.89	4.17	13.45	0.01			K38m	1.37					
Cl38m	2.90						Cl38m	1.30					
Cl39	1.95	1.96					S35	0.22	0.25	7.39	0.56		
P33	0.58	0.62	1.95				P32	0.16	0.18	4.60			
P32	0.35	0.38	1.10				P33	0.03	0.03	0.89			
Cl36			0.01	0.01	0.02	99.85	Cl36			0.02	0.02	0.03	99.93
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	2.17E4	1.79E4	4.22E1	3.73E-1	2.89E-1	1.54E-4	Sv kg <sup>-1</sup>	2.45E7	2.45E7	2.33E7	2.32E7	1.79E7	2.72E0
K42	25.38*	30.64*	99.67*	72.96	36.52		Ar39	94.72	94.87	99.74	100.00	100.00	
K38	25.03	18.81					Ar41	4.89	4.74				
Cl38	23.60	25.96					K42	0.11	0.11				
Ar41	15.61	18.32					S35	0.03	0.03	0.03			
Cl39	5.06	5.75					P32	0.01	0.01				
Cl38m	2.88						Cl38	0.01	0.01				
Cl40	0.73	0.06					Cl36						99.76
K40				11.48*	45.97*	82.06*	K40						0.21
Cl36				3.13*	12.56*	17.81*							
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	8.03E8	8.03E8	8.02E8	8.00E8	6.20E8	2.13E1		5.06E10	3.75E10	1.27E9	1.12E9	8.62E8	2.92E6
Ar39	99.89	99.89	99.97	100.00	100.00		K38	39.77	33.25				
Cl36						99.99	Ar41	24.32	31.75				
							K42	13.29	17.85	3.89			
							Cl39	8.28	10.47				
							Cl38m	5.33					
							Ar39	2.19	2.96	87.79	98.97	99.57	
							Cl38	2.17	2.66				
							K38m	2.15					
							Cl36	0.01	0.01	0.29	0.32	0.42	99.99

# Potassium

## Pathway analysis

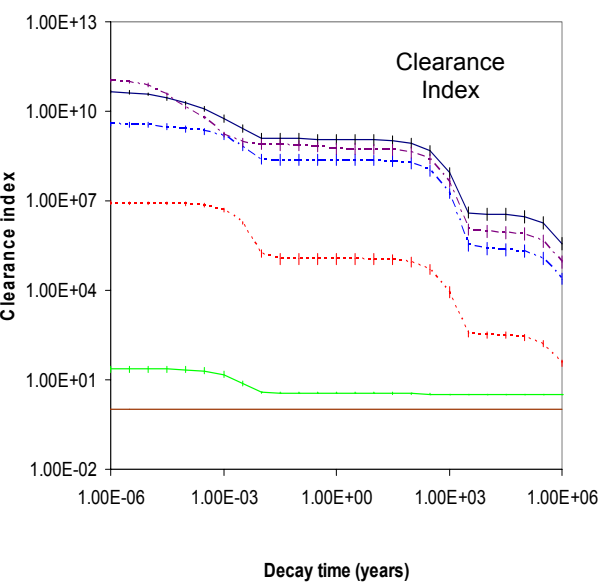
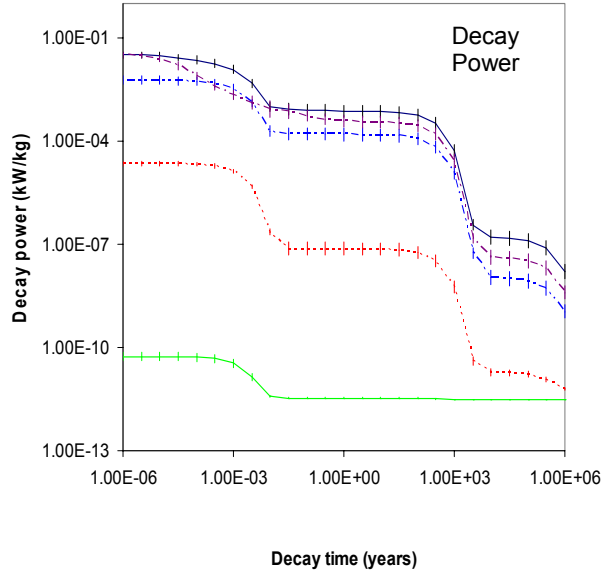
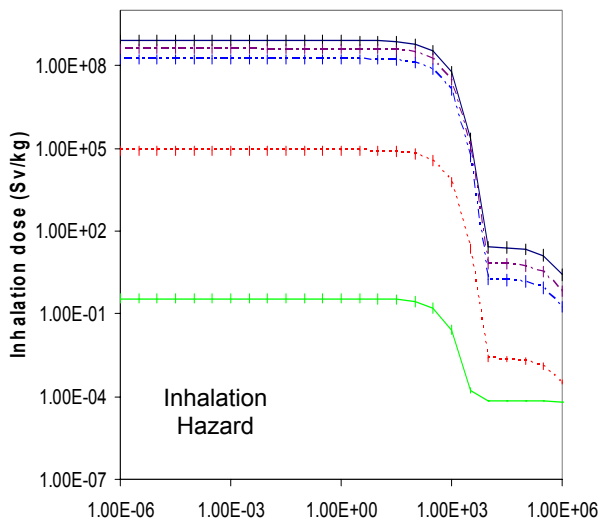
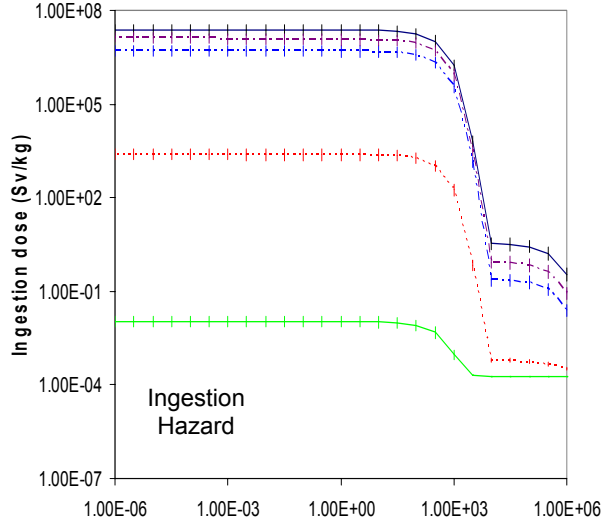
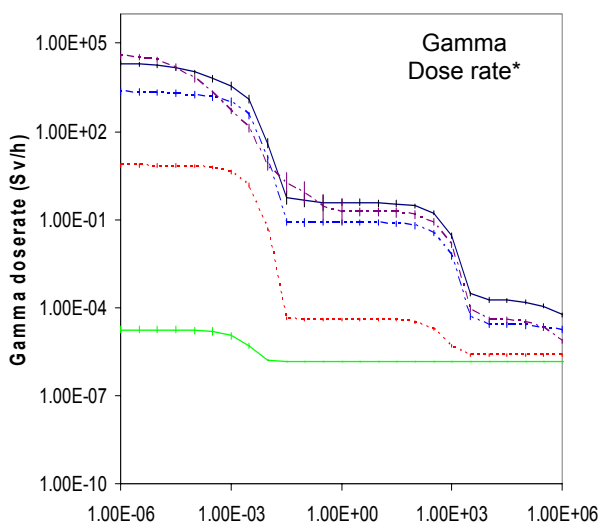
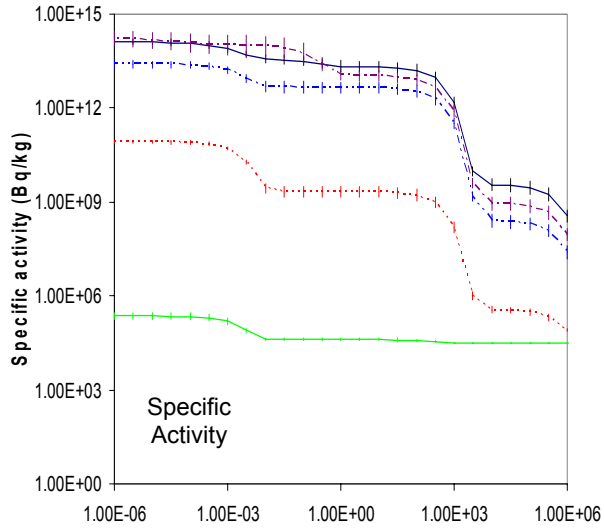
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
K38	7.61 m	K39(n,2n)K38 K41(n,4n)K38				99.9	99.8	99.7	98.1 1.7
Cl38	37.2 m	&K39(n,γ)K40(n,α)Cl37(n,γ)Cl38 &K39(n,α)Cl36(n,γ)Cl37(n,γ)Cl38 &K40(n,α)Cl37(n,γ)Cl38 &K39(n,d)Ar38(n,p)Cl38 &K41(n,α)Cl38 &K39(n,p)Ar39(n,d)Cl38 &K39(n,p)Ar39(n,2n)Ar38(n,p)Cl38 &K39(n,2p)Cl38 &K41(n,t)Ar39(n,d)Cl38 &K41(n,d)Ar40(n,t)Cl38	89.8 6.7 0.7	85.6 5.0 6.2	69.7 0.7 21.1	71.1 14.4 5.9 1.9 0.2	8.5 2.8 9.5 76.3 0.7 0.1	8.1 4.6 11.7 67.6 2.6 1.8	4.3 23.5 6.9 59.0 2.1 1.9
Cl39	55.6 m	K39(n,p)Ar39(n,p)Cl39 K41(n,d)Ar40(n,d)Cl39 K41(n,t)Ar39(n,p)Cl39 K41(n,h)Cl39				99.5	67.4 20.5 5.4 5.3	37.7 20.2 8.3 33.0	13.3 18.1 4.0 64.1
Ar41	1.827 h	K39(n,γ)K40(n,p)Ar40(n,γ)Ar41 K40(n,p)Ar40(n,γ)Ar41 K41(n,p)Ar41	99.8 0.2	94.2 5.8	75.9 24.1	100.0	99.9	100.0	100.0
K42	12.36 h	K41(n,γ)K42 K39(n,γ)K40(n,γ)K41(n,γ)K42	58.2 41.6	99.8 0.2	100.0	96.5	99.1	99.4	99.7
P32	14.27 d	K39(n,α)Cl36(n,α)P33(β <sup>-</sup> )S33(n,α)Si30_ (n,γ)Si31(β <sup>-</sup> )P31(n,γ)P32 K39(n,α)Cl36(n,nα)P32 K39(n,nα)Cl35(n,α)P32 K39(n,α)Cl36(n,2n)Cl35(n,α)P32 K39(n,pα)S35(β <sup>-</sup> )Cl35(n,α)P32 K39(n,d)Ar38(n,α)S35(β <sup>-</sup> )Cl35(n,α)P32 K39(n,p)Ar39(n,nα)S35(β <sup>-</sup> )Cl35(n,α)P32 K39(n,α)Cl36(n,d)S35(β <sup>-</sup> )Cl35(n,α)P32 K39(n,2α)P32 K39(n,dα)S34(n,t)P32 K39(n,t)Ar37(β <sup>+</sup> )Cl37(n,2nα)P32 K39(n,dα)S34(n,2n)S33(n,d)P32 K39(n,h)Cl37(n,2nα)P32 K39(n,tα)S33(n,d)P32 K39(n,d)Ar38(n,tα)P32 K41(n,2n2α)P32	99.9	100.0		44.0 39.0 4.4 3.3 3.1 1.3 1.2 0.3	2.2 0.5 0.5 0.1	1.1 0.2 0.1	6.1 2.5 0.6
P33	25.38 d	K39(n,α)Cl36(n,α)P33 K39(n,d)Ar38(n,nα)S34(n,d)P33 K39(n,d)Ar38(n,2n)Ar37(β <sup>+</sup> )Cl37(n,nα)P33 K39(n,d)Ar38(n,d)Cl37(n,nα)P33 K41(n,nα)Cl37(n,nα)P33 K39(n,t)Ar37(β <sup>+</sup> )Cl37(n,nα)P33 K39(n,dα)S34(n,d)P33 K39(n,h)Cl37(n,nα)P33 K39(n,nα)Cl35(n,h)P33 K39(n,d)Ar38(n,dα)P33 K41(n,n2α)P33 K39(n,hα)P33	100.0	100.0	100.0	78.6 7.2 3.7 3.1 2.1 0.2	0.4 5.6 3.1 3.1 1.6 23.3 48.5 6.9 0.7 0.3	0.4 0.9 0.4 0.4 0.2 19.8 46.7 5.7 1.2 10.4	9.5 0.3 0.1 0.1 0.1 12.9 28.1 3.7 2.2 11.1
Ar37	35.04 d	K39(n,α)Cl36(β <sup>-</sup> )Ar36(n,γ)Ar37 K39(n,d)Ar38(n,2n)Ar37 K39(n,p)Ar39(n,2n)Ar38(n,2n)Ar37 K39(n,t)Ar37 K39(n,2n)K38(β <sup>+</sup> )Ar38(n,2n)Ar37 K39(n,p)Ar39(n,3n)Ar37	100.0	100.0	100.0	94.1 2.8 2.6 0.9	20.7 0.1 75.7 1.1 1.0	3.5 94.7	1.8 96.0 0.1 0.2



Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Sc46	83.79 d	&K41(n,γ)K42(β <sup>-</sup> )Ca42(n,γ)Ca43(n,γ)_ Ca44(n,γ)Ca45(β <sup>-</sup> )Sc45(n,γ)Sc46	94.5	99.6	99.9	98.8			
		&K39(n,γ)K40(n,γ)K41(n,γ)K42(β <sup>-</sup> )_ Ca42(n,γ)Ca43(n,γ)Ca44(n,γ)Ca45(β <sup>-</sup> )_ Sc45(n,γ)Sc46	5.0						
		&K41(n,γ)K42(n,γ)K43(β <sup>-</sup> )Ca43(n,γ)_ Ca44(n,γ)Ca45(β <sup>-</sup> )Sc45(n,γ)Sc46	0.4	0.4		0.1			
S35	87.32 d	K39(n,α)Cl36(n,α)P33(β <sup>-</sup> )S33(n,γ)S34_ (n,γ)S35	96.5	95.1	61.2				
		K39(n,α)Cl36(n,α)P33(n,γ)P34(β <sup>-</sup> )S34_ (n,γ)S35	2.6	2.8	23.0				
		K39(n,α)Cl36(β <sup>-</sup> )Ar36(n,γ)Ar37(n,α)S34_ (n,γ)S35	0.6	2.1	15.8				
		K39(n,d)Ar38(n,α)S35				39.5	1.3	1.5	7.2
		K39(n,pα)S35				20.5	86.2	49.9	39.9
		K39(n,p)Ar39(n,nα)S35				16.0	4.1	1.9	0.7
		K39(n,α)Cl36(n,d)S35				14.6	1.0	1.6	8.0
		K39(n,nα)Cl35(n,p)S35				4.1	0.4	0.2	0.2
		K39(n,p)Ar39(n,2n)Ar38(n,α)S35				1.2			
		K39(n,t)Ar37(β <sup>+</sup> )Cl37(n,t)S35					2.6	29.1	22.5
K39(n,h)Cl37(n,t)S35					0.7	8.2	6.4		
Ca45	163.0 d	K41(n,γ)K42(β <sup>-</sup> )Ca42(n,γ)Ca43(n,γ)Ca44_ (n,γ)Ca45	92.3	99.7	99.9	99.0	99.4	99.6	99.7
		K39(n,γ)K40(n,γ)K41(n,γ)K42(β <sup>-</sup> )Ca42_ (n,γ)Ca43(n,γ)Ca44(n,γ)Ca45	7.4						
Na22	2.60 y	K39(n,nα)Cl35(n,nα)P31(n,nα)Al27_ (n,nα)Na23(n,2n)Na22				25.1	2.1		
		K39(n,d)Ar38(n,nα)S34(n,nα)Si30(n,α)_ Mg27(β <sup>-</sup> )Al27(n,nα)Na23(n,2n)Na22				10.7			
		K39(n,nα)Cl35(n,nα)P31(n,nα)Al27_ (n,2n)Al26(n,nα)Na22				10.2	1.7		
		K39(n,d)Ar38(n,nα)S34(n,nα)Si30(n,α)_ Mg27(β <sup>-</sup> )Al27(n,2n)Al26(n,nα)Na22				4.3			
		K39(n,α)Cl36(n,nα)P32(β <sup>-</sup> )S32(n,α)Si29_ (n,α)Mg26(n,α)Ne23(β <sup>-</sup> )Na23(n,2n)Na22				4.2			
		K39(n,d)Ar38(n,nα)S34(n,α)Si31(β <sup>-</sup> )P31_ (n,nα)Al27(n,nα)Na23(n,2n)Na22				3.8			
		K39(n,nα)Cl35(n,α)P32(β <sup>-</sup> )S32(n,α)Si29_ (n,α)Mg26(n,α)Ne23(β <sup>-</sup> )Na23(n,2n)Na22				3.8			
		K39(n,α)Cl36(n,α)P33(β <sup>-</sup> )S33(n,nα)Si29_ (n,α)Mg26(n,α)Ne23(β <sup>-</sup> )Na23(n,2n)Na22				3.1			
		K39(n,2α)P32(β <sup>-</sup> )S32(n,nα)Si28(n,nα)_ Mg24(n,t)Na22					16.0	0.5	
		K39(n,2α)P32(β <sup>-</sup> )S32(n,2α)Mg25(n,t)_ Na23(n,2n)Na22					4.7		
		K39(n,n2α)P31(n,nα)Al27(n,nα)Na23_ (n,2n)Na22					4.2	0.2	
		K39(n,2α)P32(β <sup>-</sup> )S32(n,nα)Si28(n,nα)_ Mg24(n,d)Na23(n,2n)Na22					3.9		
		K39(n,dα)S34(n,2α)Mg27(β <sup>-</sup> )Al27_ (n,nα)Na23(n,2n)Na22					3.9		
		K39(n,n2α)P31(n,nα)Al27(n,2n)Al26_ (n,nα)Na22					3.3	0.2	
		K39(n,dα)S34(n,2α)Mg27(β <sup>-</sup> )Al27(n,2n)_ Al26(n,nα)Na22					3.0		
		K39(n,2α)P32(β <sup>-</sup> )S32(n,n2α)Mg24(n,t)Na22					0.8	7.3	0.3
		K39(n,dα)S34(n,2nα)Si29(n,2nα)Mg24(n,t)Na22					0.4	5.8	0.3
		K39(n,n2α)P31(n,2α)Na24(β <sup>-</sup> )Mg24(n,t)Na22					0.4	3.0	
		K39(n,n2α)P31(n,nα)Al27(n,2nα)Na22						18.2	1.6
		K39(n,2α)P32(β <sup>-</sup> )S32(n,dα)Al27(n,2nα)Na22						8.9	0.4
K39(n,n2α)P31(n,2nα)Al26(n,nα)Na22						8.7	0.5		

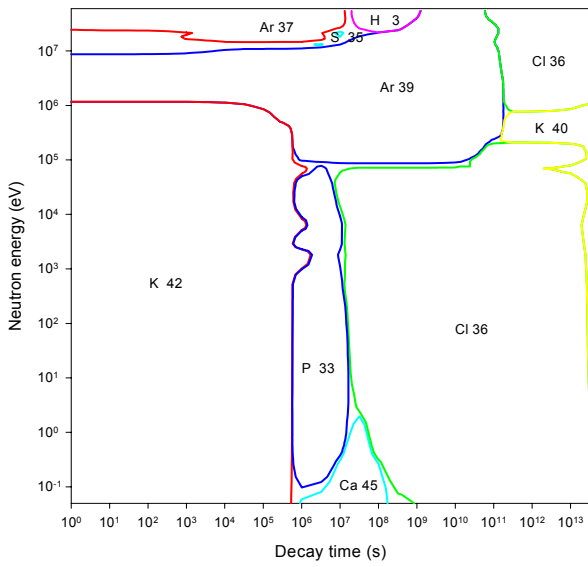
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	K39(n,n2α)P31(n,n2α)Na23(n,2n)Na22 K39(n,dα)S34(n,2α)Mg27(β <sup>-</sup> )Al27(n,2nα)Na22   K39(n,nα)Cl35(n,n2α)Al27(n,2nα)Na22 K39(n,tα)S33(n,tα)Al27(n,2nα)Na22 K39(n,n2α)P31(n,2n2α)Na22 K39(n,n3α)Al27(n,2nα)Na22 K39(n,tα)S33(n,2nα)Si28(n,tα)Na22 K39(n,tα)S33(n,2n2α)Mg24(n,t)Na22 K39(n,3α)Al28(β <sup>-</sup> )Si28(n,tα)Na22 K39(n,dα)S34(n,3nα)Si28(n,tα)Na22						3.3 3.2 2.3 0.1	0.4 0.7 7.9 10.7 7.7 5.2 4.9 4.9 4.3
H3	12.33 y	K39(n,γ)K40(n,X)H1(n,γ)H2(n,γ)H3 K40(n,X)H1(n,γ)H2(n,γ)H3 K39(n,X)H3 K41(n,X)H3 K39(n,α)Cl36(n,X)H3 K39(n,p)Ar39(n,X)H3 K41(n,2n)K40(n,X)H3 K39(n,d)Ar38(n,X)H3 K39(n,t)Ar37(β <sup>+</sup> )Cl37(n,X)H3	94.0 0.4	85.8 10.5	61.1 38.4	75.3 8.2 6.2 5.5 3.4 0.2	86.9 7.1 0.1 0.9 0.4 2.2 0.6	86.5 7.2 0.1 0.5 0.2 1.7 1.5	86.8 7.4 0.7 0.3 1.2 1.2
Ar42	33.0 y	K39(n,γ)K40(n,p)Ar40(n,γ)Ar41(n,γ)Ar42 K40(n,p)Ar40(n,γ)Ar41(n,γ)Ar42 K41(n,γ)K42(n,p)Ar42 K41(n,p)Ar41(n,γ)Ar42	99.7 0.3	91.6 8.4	67.9 32.1	85.0 13.4	90.1 9.1	89.9 9.5	89.9 9.8
Ar39	269.0 y	&K39(n,γ)K40(n,α)Cl37(n,γ)Cl38(β <sup>-</sup> )_Ar38(n,γ)Ar39 &K39(n,α)Cl36(n,γ)Cl37(n,γ)Cl38(β <sup>-</sup> )_Ar38(n,γ)Ar39 &K40(n,α)Cl37(n,γ)Cl38(β <sup>-</sup> )Ar38(n,γ)Ar39   K39(n,p)Ar39 K41(n,t)Ar39	93.3 6.4 0.3	85.1 5.0 9.9	60.7 0.7 34.0	99.0	91.3 7.3	81.1 17.8	76.1 22.7
Cl36	3.0 10 <sup>5</sup> y	K39(n,α)Cl36 K39(n,t)Ar37(β <sup>+</sup> )Cl37(n,2n)Cl36 K39(n,d)Ar38(n,t)Cl36 K41(n,2nα)Cl36 K39(n,h)Cl37(n,2n)Cl36	100.0	100.0	100.0	98.7	57.1 16.5 7.8 5.4 5.0	46.4 12.4 18.0 15.1 3.6	90.3 2.0 3.1 2.8 0.6
Al26	7.2 10 <sup>5</sup> y	K39(n,nα)Cl35(n,nα)P31(n,nα)Al27(n,2n)Al26   K39(n,d)Ar38(n,nα)S34(n,nα)Si30(n,α)_Mg27(β <sup>-</sup> )Al27(n,2n)Al26 K39(n,d)Ar38(n,nα)S34(n,α)Si31(β <sup>-</sup> )P31_(n,nα)Al27(n,2n)Al26 K39(n,nα)Cl35(n,d)S34(n,nα)Si30(n,α)_Mg27(β <sup>-</sup> )Al27(n,2n)Al26 K39(n,pα)S35(β <sup>-</sup> )Cl35(n,nα)P31(n,nα)_Al27(n,2n)Al26 K39(n,n2α)P31(n,nα)Al27(n,2n)Al26 K39(n,dα)S34(n,2α)Mg27(β <sup>-</sup> )Al27(n,2n)Al26   K39(n,2α)P32(β <sup>-</sup> )S32(n,nα)Si28(n,t)Al26 K39(n,2α)P32(β <sup>-</sup> )S32(n,nα)Si28(n,d)_Al27(n,2n)Al26 K39(n,2α)P32(β <sup>-</sup> )S32(n,dα)Al27(n,2n)Al26   K39(n,2α)P32(β <sup>-</sup> )S32(n,d)P31(n,nα)_Al27(n,2n)Al26 K39(n,n2α)P31(n,2nα)Al26 K39(n,2α)P32(β <sup>-</sup> )S32(n,tα)Al26 K39(n,3α)Al28(β <sup>-</sup> )Si28(n,t)Al26 K39(n,dα)S34(n,3nα)Si28(n,t)Al26 K39(n,tα)S33(n,ntα)Al26 K39(n,ntα)S32(n,tα)Al26				42.3 21.1 7.5 3.5 3.0	7.5 5.8	12.3 2.1 0.2 11.4 0.4 10.7 1.6 0.1 9.5 6.2 1.0 5.7	0.2 0.1 31.4 3.0 4.1 3.3 3.7 3.2
K40	1.3 10 <sup>9</sup> y	K39(n,γ)K40 K41(n,2n)K40 Nuclide also present in starting material	100.0	97.1 2.9	86.3 13.7	1.2 96.6 2.2	0.7 96.2 3.1	0.6 94.1 5.3	0.6 91.5 7.9

# Potassium activation characteristics

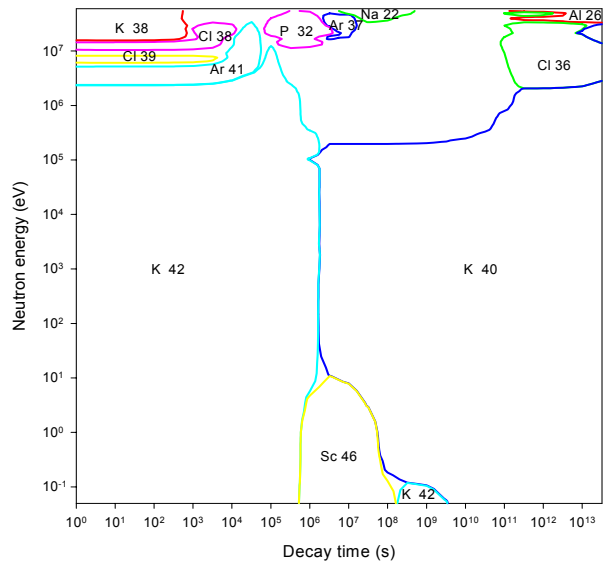


# Potassium importance diagrams & transmutation

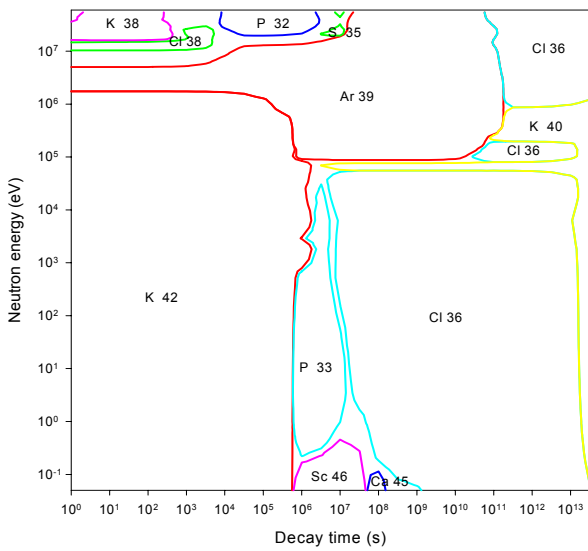
**Activity**



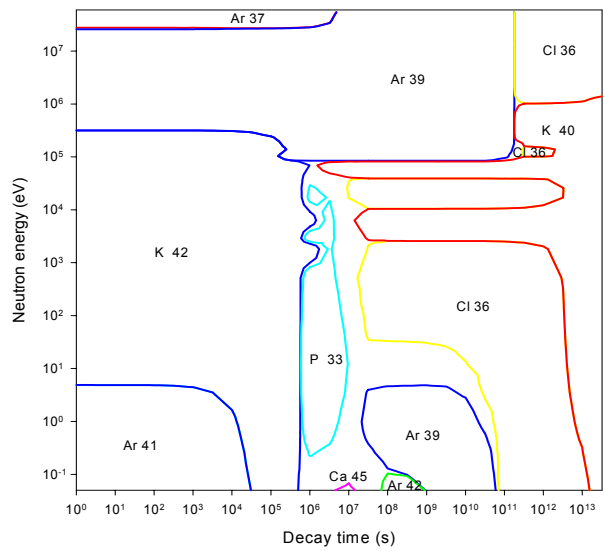
**Dose rate**



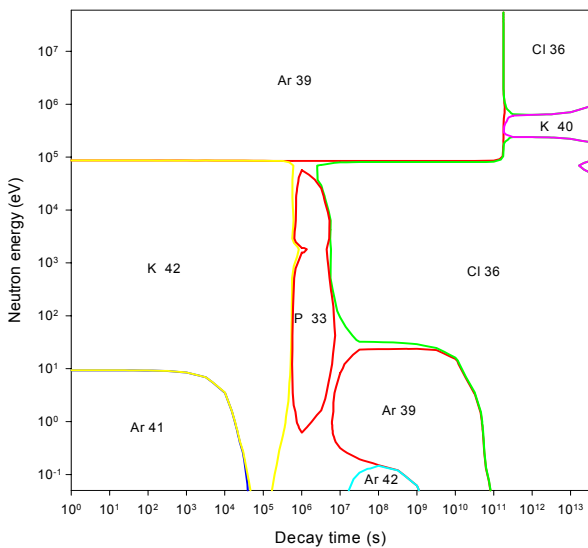
**Heat output**



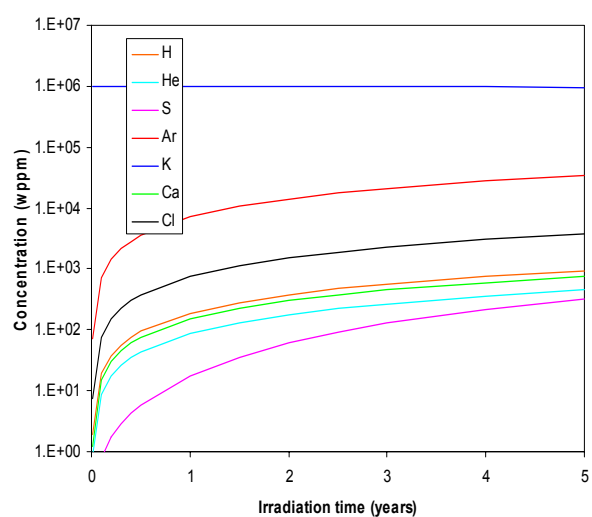
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**



# Calcium

## General properties

Atomic number	20	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	4.10 10 <sup>4</sup>	Ca40	96.941
Melting point / K	1112	Ca42	0.647
Boiling point / K	1757	Ca43	0.135
Density / kgm <sup>-3</sup>	1550	Ca44	2.086
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	200	Ca46	0.004
Electrical resistivity /Ωm	3.43 10 <sup>-8</sup>	Ca48	0.187 (T <sub>½</sub> = 5.30 10 <sup>19</sup> y)
Coefficient of thermal expansion / K <sup>-1</sup>	2.2 10 <sup>-5</sup>		
Crystal structure	FCC		
Number of stable isotopes	5 (6)		
Mean atomic weight	40.078		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	4.74E14	4.73E14	4.32E14	2.14E12	9.96E11	1.10E9	kW kg <sup>-1</sup>	4.20E-3	3.67E-3	7.94E-4	5.10E-5	3.48E-5	5.12E-9
Ar37	96.05	96.28	98.01	15.51			K44	24.51	23.78				
Sc47	0.70	0.70	0.66				K42	20.68	23.53	0.80			
Ca47	0.70	0.70	0.44				Ca47	17.65	20.18	53.40			
K42	0.67	0.67					Ar41	8.18	9.05				
Ca45	0.42	0.42	0.46	20.01			S37	4.48	2.47				
K44	0.27	0.30					P34	3.98					
Ar39	0.27	0.27		59.96	99.76		Ar37	3.78	4.32	18.57			
Ar41	0.26	0.25					Sc47	3.42	3.91	15.55			
H3	0.02	0.02	0.02	3.70	0.03		Cl38	3.12	3.23				
S35		0.05	0.06	0.65			K43	2.22	2.54	0.76			
Ca41				0.09	0.20	90.81	Ca49	1.82	1.37				
Cl36					0.01	8.93	K38	1.32	0.93				
K40						0.26	Ar39	1.07	1.23	5.67	87.99	99.98	
							Ca45	0.60	0.68	3.10	10.37		
							Sc46	0.26	0.30	1.34	1.04		
							Cl36				0.01	0.02	84.20
							Ca41						10.28
							K40						5.52
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	3.67E3	3.17E3	5.95E2	8.21E-1	1.61E-2	1.48E-4	Sv kg <sup>-1</sup>	6.09E6	6.09E6	5.61E6	1.41E6	1.09E6	3.00E-1
K44	31.46	30.84					Ar37	74.00	74.07	74.71	0.23		
Ca47	25.83	29.84	90.90				Ar39	23.21	23.23	25.18	99.74	100.0	
Ar41	11.83	13.23					Ar41	2.62	2.53				
S37	8.01	4.46					Ca47	0.09	0.08	0.05			
K42	6.58*	7.90*	0.31		25.51		Sc47	0.03	0.03	0.03			
Cl38	3.31	3.46					Ca45	0.02	0.02	0.03	0.02		
Ca49	3.24	2.47					K42	0.02	0.02				
K43	2.36	2.72	0.94				K44		44.59				
K38	1.86	1.33					S37		5.62				
Cl39	1.76	1.90					Ca41						63.47
P34	1.13						Cl36						30.54
Sc47	0.84	0.97	4.45				K40						5.99
Sc46	0.44	0.52	2.67	99.58									
K40				0.02	60.09*	89.11*							
Ca41					14.10	10.68							
Cl36					0.18*	0.21*							

<b>Inh</b>	<b>0</b>	<b>10<sup>-5</sup> y</b>	<b>10<sup>-2</sup> y</b>	<b>1 y</b>	<b>100 y</b>	<b>10<sup>5</sup> y</b>	<b>Clear</b>	<b>0</b>	<b>10<sup>-5</sup> y</b>	<b>10<sup>-2</sup> y</b>	<b>1 y</b>	<b>100 y</b>	<b>10<sup>5</sup> y</b>
Sv kg <sup>-1</sup>	6.62E7	6.62E7	6.49E7	4.87E7	3.77E7	9.06E-1		9.98E9	8.18E9	8.67E8	8.86E7	5.24E7	9.95E4
Ar39	73.72	73.73	75.19	99.97	100.0		K44	43.09	44.59				
Ar37	26.12	26.12	24.79	0.03			Ar41	16.38	19.33				
Ar41	0.12						S37	9.56	5.62				
Ca45	0.01	0.01	0.01				K43	4.57	5.56	3.41			
Ca47	0.01	0.01					Ca49	3.82	3.07				
Cl36						79.41	Ca47	3.30	4.02	21.72			
Ca41						19.92	Sc46	3.22	3.93	35.98	17.68		
K40						0.67	K42	3.20	3.88				
							K38	2.62	1.98				
							Sc47	0.33	0.40	3.28			
							Cl38	0.27	0.29				
							Cl39		2.93				
							Ar37		2.78	24.42	0.19		
							P34		2.33				
							Ar39		0.83	7.80	76.11	99.75	
							Cl36				0.14	0.23	98.99
							Ca41						0.72
							K40						0.29

# Calcium

## Pathway analysis

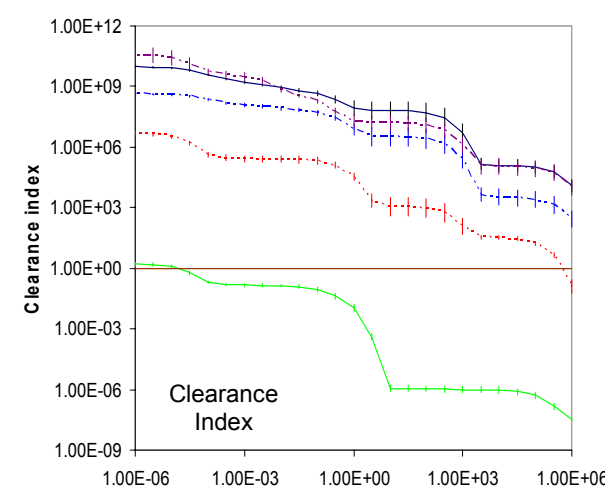
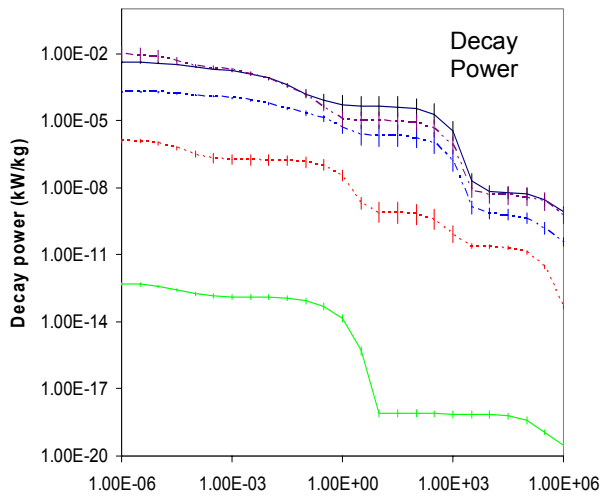
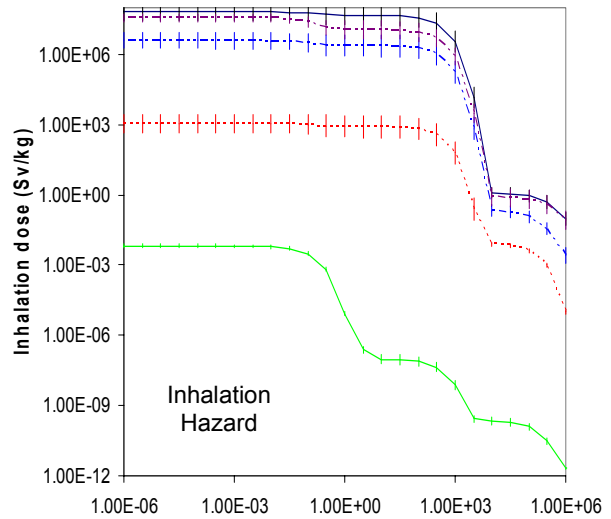
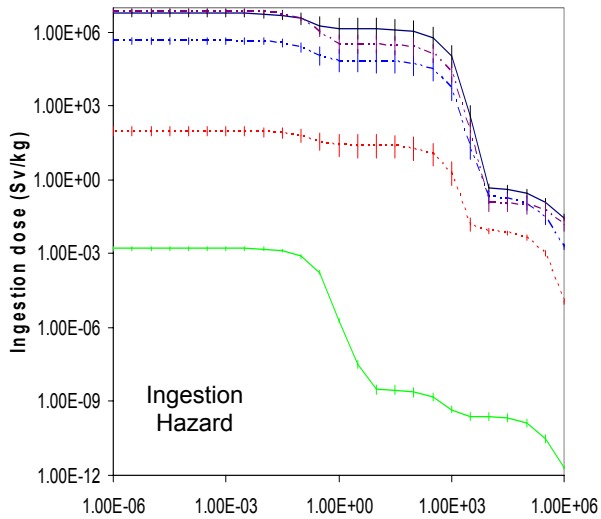
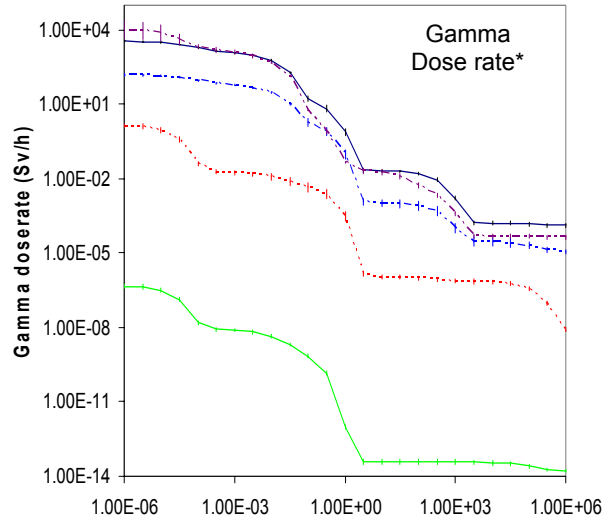
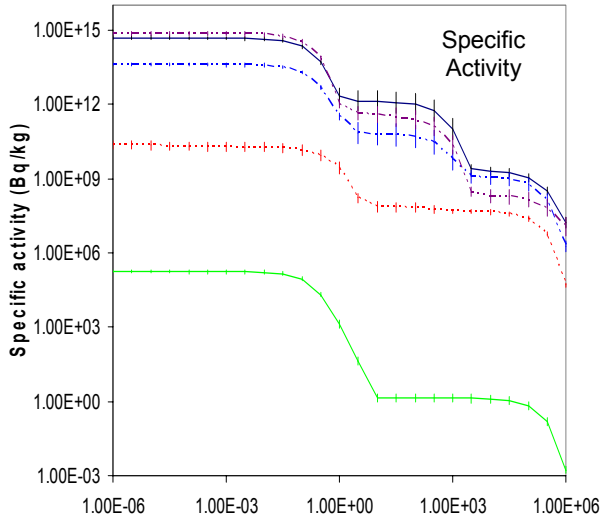
Nuclide	$T_{1/2}$	Pathway	210	186	151	42	30	21	6
Ca39	0.86 s	Ca40(n,2n)Ca39					100.0	100.0	100.0
S37	4.99 m	Ca40(n, $\gamma$ )Ca41(n, $\alpha$ )Ar38(n, $\gamma$ )Ar39(n, $\alpha$ )_S36(n, $\gamma$ )S37	86.5	82.4					
		&Ca40(n, $\alpha$ )Ar37( $\beta^+$ )Cl37(n, $\gamma$ )Cl38( $\beta^-$ )_Ar38(n, $\gamma$ )Ar39(n, $\alpha$ )S36(n, $\gamma$ )S37	5.7	12.3					
		Ca40(n, $\alpha$ )Ar37(n, $\alpha$ )S34(n, $\gamma$ )S35(n, $\gamma$ )_S36(n, $\gamma$ )S37	4.9	2.2					
		Ca40(n, $\alpha$ )Ar37(n, $\alpha$ )S34(n, $\gamma$ )S35( $\beta^-$ )Cl35_(n, $\gamma$ )Cl36(n,p)S36(n, $\gamma$ )S37	1.8						
		Ca40(n, $\alpha$ )Ar37(n, $\gamma$ )Ar38(n, $\gamma$ )Ar39(n, $\alpha$ )_S36(n, $\gamma$ )S37	0.6	2.1					
		Ca40(n, $\alpha$ )Ar37( $\beta^+$ )Cl37(n,p)S37				98.9	32.5	25.0	67.4
		Ca40(n,p)K40(n, $\alpha$ )Cl37(n,p)S37				1.1			
		Ca40(n,h)Ar38(n,2p)S37					29.1	34.9	11.2
		Ca40(n,h)Ar38(n,d)Cl37(n,p)S37					7.0	4.7	1.0
		Ca40(n,h)Ar38(n,2n)Ar37( $\beta^+$ )Cl37(n,p)S37					6.8	4.1	0.9
		Ca40(n,2p)Ar39(n,h)S37					5.7	6.0	2.9
		Ca40(n,d)K39(n,t)Ar37( $\beta^+$ )Cl37(n,p)S37					5.5	5.5	1.3
		Ca40(n,d)K39(n,d)Ar38(n,2p)S37					3.2	0.9	0.2
		Ca40(n,d)K39(n,h)Cl37(n,p)S37					1.6	1.6	0.4
		Ca44(n,2 $\alpha$ )S37					0.9	2.1	0.6
		Ca40(n,t)K38( $\beta^+$ )Ar38(n,2p)S37					0.6	4.4	2.5
		Ca40(n,t)K38m( $\beta^+$ )Ar38(n,2p)S37					0.3	1.5	0.8
		Ca40(n,d)K39(n,3p)S37						2.7	2.3
		Ca40(n,ph)Cl37(n,p)S37						1.2	6.6
K38	7.61 m	Ca40(n,d)K39(n,2n)K38				98.5	35.4	2.4	0.9
		Ca40(n,p)K40(n,2n)K39(n,2n)K38				1.4			
		Ca40(n,t)K38					61.3	97.3	98.9
		Ca40(n,2n)Ca39( $\beta^+$ )K39(n,2n)K38					2.9	0.2	
Ca49	8.72 m	Ca48(n, $\gamma$ )Ca49	100.0	100.0	100.0	100.0	99.9	99.9	99.9
Cl38	37.2 m	&Ca40(n, $\alpha$ )Ar37( $\beta^+$ )Cl37(n, $\gamma$ )Cl38	89.3	96.1	96.7	0.9			
		&Ca40(n, $\alpha$ )Ar37(n,p)Cl37(n, $\gamma$ )Cl38	8.4	0.3					
		&Ca40(n,d)K39(n,d)Ar38(n,p)Cl38				47.5	1.6	0.6	
		&Ca40(n,2p)Ar39(n,d)Cl38				19.0	35.7	11.3	5.8
		&Ca40(n,2p)Ar39(n,2n)Ar38(n,p)Cl38				6.5			
		&Ca40(n,d)K39(n,p)Ar39(n,d)Cl38				4.5	2.0	0.8	0.2
		&Ca42(n, $\alpha$ )Ar38(n,p)Cl38				1.5			
		&Ca40(n,p)K40(n,d)Ar39(n,d)Cl38				1.3	0.3	0.1	
		&Ca40(n,d)K39(n,p)Ar39(n,2n)Ar38(n,p)Cl38				1.0			
		&Ca40(n,d)K39(n,2p)Cl38				0.4	31.6	8.3	4.1
		&Ca40(n,h)Ar38(n,p)Cl38				0.4	15.7	21.5	10.8
		&Ca40(n,2n)Ca39( $\beta^+$ )K39(n,2p)Cl38					2.5	0.7	0.2
		&Ca42(n,p $\alpha$ )Cl38					1.0	0.9	0.6
		&Ca40(n,t)K38( $\beta^+$ )Ar38(n,p)Cl38					0.4	2.7	2.4
		&Ca40(n,p)K40(n,h)Cl38					0.2	1.5	1.3
		&Ca40(n,3p)Cl38						43.7	64.3
		&Ca44(n,t $\alpha$ )Cl38							4.1
K42	12.36 h	Ca40(n, $\gamma$ )Ca41(n,p)K41(n, $\gamma$ )K42	91.6	30.0	4.7				
		Ca40(n, $\gamma$ )Ca41( $\beta^+$ )K41(n, $\gamma$ )K42	8.4	70.0	95.3				
		Ca42(n,p)K42				88.8	20.2	4.9	2.7
		Ca44(n,2n)Ca43(n,d)K42				4.4	31.2	3.7	1.9
		Ca43(n,d)K42				2.7	24.0	6.0	5.1
		Ca43(n,2n)Ca42(n,p)K42				2.1	0.3		
		Ca44(n,2n)Ca43(n,2n)Ca42(n,p)K42				1.7	0.2		
		Ca44(n,t)K42					13.3	82.1	88.1
		Ca44(n,d)K43( $\beta^-$ )Ca43(n,d)K42					8.3	1.8	1.1
		Ca44(n,3n)Ca42(n,p)K42					1.7	0.7	0.2

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
K43	22.2 h	Ca40(n,γ)Ca41(n,p)K41(n,γ)K42(n,γ)K43	91.6	30.0	4.8				
		Ca40(n,γ)Ca41(β <sup>+</sup> )K41(n,γ)K42(n,γ)K43	8.4	70.0	95.2				
		Ca44(n,2n)Ca43(n,p)K43				52.2	2.5	0.9	0.3
		Ca43(n,p)K43				32.3	1.9	1.5	0.9
		Ca44(n,d)K43				14.9	94.4	96.5	97.0
Ca47	4.538 d	Ca44(n,γ)Ca45(n,γ)Ca46(n,γ)Ca47	65.8	0.5					
		Ca46(n,γ)Ca47	33.6	99.5	100.0				
		Ca48(n,2n)Ca47				100.0	94.3	79.4	70.0
		Ca48(n,d)K47(β <sup>-</sup> )Ca47					5.7	22.0	30.0
P32	14.27 d	Ca40(n,α)Ar37(n,α)S34(n,γ)S35(β <sup>-</sup> )_Cl35(n,α)P32	100.0	100.0					
		Ca40(n,α)Ar37(β <sup>+</sup> )Cl37(n,2n)Cl36(n,nα)P32				16.8	0.4	0.2	0.2
		Ca40(n,pα)Cl36(n,nα)P32				12.6	37.9	11.6	2.5
		Ca40(n,d)K39(n,α)Cl36(n,nα)P32				11.9	0.2	0.2	0.2
		Ca40(n,d)K39(n,nα)Cl35(n,α)P32				10.6			
		Ca40(n,nα)Ar36(n,d)Cl35(n,α)P32				9.5	0.1		
		Ca40(n,2α)S33(n,d)P32				7.4	17.9	9.0	1.0
		Ca40(n,nα)Ar36(n,pα)P32				4.7	16.5	5.4	1.4
		Ca40(n,nα)Ar36(n,α)S33(n,d)P32				3.5	0.1	0.1	0.2
		Ca40(n,p)K40(n,nα)Cl36(n,nα)P32				3.3	0.2		
		Ca40(n,d)K39(n,2α)P32				0.2	19.5	10.6	1.1
		Ca40(n,α)Ar37(β <sup>+</sup> )Cl37(n,2nα)P32					0.7	11.9	23.6
		Ca40(n,dα)Cl35(n,α)P32					0.7	8.3	17.2
		Ca40(n,h)Ar38(n,nα)S34(n,t)P32					0.4	3.2	0.7
		Ca40(n,d)K39(n,dα)S34(n,t)P32					0.3	3.9	0.8
		Ca40(n,h)Ar38(n,tα)P32						1.2	21.6
		Ca40(n,t)K38(β <sup>+</sup> )Ar38(n,tα)P32						0.2	4.8
Ar37	35.04 d	Ca40(n,α)Ar37	100.0	100.0	100.0	98.7	51.5	51.5	91.3
		Ca40(n,d)K39(n,d)Ar38(n,2n)Ar37				0.7	2.4	0.4	
		Ca40(n,h)Ar38(n,2n)Ar37					22.7	17.5	2.4
		Ca40(n,d)K39(n,t)Ar37					18.2	23.7	3.8
		Ca40(n,2p)Ar39(n,3n)Ar37					2.2	0.9	
		Ca40(n,2n)Ca39(β <sup>+</sup> )K39(n,t)Ar37					1.5	2.1	0.3
		Ca40(n,t)K38(β <sup>+</sup> )Ar38(n,2n)Ar37					0.5	2.2	0.5
Sc46	83.79 d	&Ca44(n,γ)Ca45(β <sup>-</sup> )Sc45(n,γ)Sc46	99.0	99.9	100.0				
		&Ca43(n,γ)Ca44(n,γ)Ca45(β <sup>-</sup> )Sc45(n,γ)Sc46	0.9						
		&Ca48(n,2n)Ca47(β <sup>-</sup> )Sc47(β <sup>-</sup> )Ti47(n,d)Sc46				77.6	92.5	78.4	70.4
		&Ca48(n,2n)Ca47(β <sup>-</sup> )Sc47(β <sup>-</sup> )Ti47_(n,2n)Ti46(n,p)Sc46				17.6	0.9	0.3	0.1
		&Ca48(n,2n)Ca47(β <sup>-</sup> )Sc47(n,2n)Sc46				3.3	0.4	0.3	0.2
&Ca48(n,d)K47(β <sup>-</sup> )Ca47(β <sup>-</sup> )Sc47(β <sup>-</sup> )_Ti47(n,d)Sc46					5.5	20.2	28.6		
Ca45	163.0 d	Ca44(n,γ)Ca45	98.3	99.9	100.0	23.7	3.7	0.8	0.2
		Ca43(n,γ)Ca44(n,γ)Ca45	1.6						
		Ca46(n,2n)Ca45				72.3	19.0	3.9	1.1
		Ca48(n,α)Ar45(β <sup>-</sup> )K45(β <sup>-</sup> )Ca45				2.7	8.5	1.7	0.6
		Ca48(n,3n)Ca46(n,2n)Ca45					58.2	12.6	1.4
		Ca48(n,3n)Ca46(n,d)K45(β <sup>-</sup> )Ca45					6.9	4.3	0.7
		Ca46(n,d)K45(β <sup>-</sup> )Ca45					2.3	1.3	0.5
		Ca48(n,4n)Ca45						71.1	80.3
		Ca48(n,nt)K45(β <sup>-</sup> )Ca45						2.7	14.3
H3	12.33 y	Ca40(n,α)Ar37(n,X)H1(n,γ)H2(n,γ)H3	56.8	79.6	74.0				
		Ca40(n,γ)Ca41(n,X)H1(n,γ)H2(n,γ)H3	36.9	16.0	24.8				
		Ca40(n,p)K40(n,X)H3				72.6	1.2	0.4	0.2
		Ca40(n,d)K39(n,X)H3				13.2	7.7	3.4	2.0
		Ca40(n,2p)Ar39(n,X)H3				4.1	1.4	0.3	0.1
		Ca40(n,α)Ar37(β <sup>+</sup> )Cl37(n,X)H3				3.4	0.3	0.2	1.3
		Ca40(n,pα)Cl36(n,X)H3				1.1	1.7	0.4	0.2
		Ca40(n,X)He3(n,p)H3				0.9	0.4	0.2	0.2
		Ca40(n,X)H3					80.3	87.0	88.2
		▶ Ca40(n,h)Ar38(n,X)H3					1.7	2.5	1.8



Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	Ca44(n,X)H3					1.7	2.0	2.6
Ar39	269.0 y	Ca40(n,γ)Ca41(n,α)Ar38(n,γ)Ar39 Ca40(n,α)Ar37(β <sup>+</sup> )Cl37(n,γ)Cl38(β <sup>-</sup> ) Ar38(n,γ)Ar39 Ca40(n,α)Ar37(n,γ)Ar38(n,γ)Ar39 Ca40(n,2p)Ar39 Ca40(n,d)K39(n,p)Ar39 Ca40(n,p)K40(n,d)Ar39 Ca42(n,α)Ar39 Ca44(n,2nα)Ar39	92.7 5.5 0.4	84.4 12.2 1.6	93.8 1.3 4.7	75.6 17.5 5.5 0.6	92.5 5.3 1.0	87.9 6.2 1.3 0.2 3.1	87.3 3.9 0.8 2.8 3.4
Ca41	1.0 10 <sup>5</sup> y	Ca40(n,γ)Ca41 Ca42(n,2n)Ca41 Ca43(n,3n)Ca41 Ca44(n,2n)Ca43(n,3n)Ca41 Ca44(n,3n)Ca42(n,2n)Ca41 Ca44(n,d)K43(β <sup>-</sup> )Ca43(n,3n)Ca41 Ca44(n,t)K42(β <sup>-</sup> )Ca42(n,2n)Ca41 Ca44(n,4n)Ca41	100.0	100.0	100.0	18.9 78.5	7.6 77.8 5.3 3.5 3.3 0.9 0.2 4.0	5.7 67.7 10.3 3.2 4.7 1.5 2.2 4.0	2.6 36.2 5.0 0.9 1.2 0.6 1.0 52.2
Cl36	3.0 10 <sup>5</sup> y	Ca40(n,α)Ar37(n,α)S34(n,γ)S35(β <sup>-</sup> ) Cl35(n,γ)Cl36 Ca40(n,α)Ar37(β <sup>+</sup> )Cl37(n,2n)Cl36 Ca40(n,pα)Cl36 Ca40(n,d)K39(n,α)Cl36 Ca40(n,p)K40(n,α)Cl36 Ca40(n,α)Ar36(n,p)Cl36 Ca40(n,α)Ar37(n,d)Cl36 Ca40(n,h)Ar38(n,t)Cl36 Ca40(n,t)K38(β <sup>+</sup> )Ar38(n,t)Cl36	100.0	100.0	100.0	36.0 26.4 25.0 7.0 3.9 1.1	1.0 95.9 0.6 0.6 0.3 0.8	1.2 76.4 1.1 0.3 0.2 16.3 2.1	6.3 66.0 6.0 0.2 0.1 0.4 13.6 3.0
Al26	7.2 10 <sup>5</sup> y	Ca40(n,2α)S33(n,α)Si30(n,α)Mg27(β <sup>-</sup> ) Al27(n,2n)Al26 Ca40(n,α)Ar37(n,2α)Si30(n,α)Mg27(β <sup>-</sup> ) Al27(n,2n)Al26 Ca40(n,nα)Ar36(n,nα)S32(n,nα)Si28 (n,d)Al27(n,2n)Al26 Ca40(n,dα)Cl35(n,nα)P31(n,nα)Al27(n,2n)Al26 Ca40(n,pα)Cl36(n,2nα)P31(n,nα)Al27 (n,2n)Al26 Ca40(n,2α)S33(n,2nα)Si28(n,t)Al26 Ca40(n,2α)S33(n,t)P31(n,nα)Al27(n,2n)Al26 Ca40(n,2α)S33(n,2nα)Si28(n,d)Al27(n,2n)Al26 Ca40(n,nα)Ar36(n,n2α)Si28(n,t)Al26 Ca40(n,n2α)S32(n,nα)Si28(n,t)Al26 Ca40(n,n2α)S32(n,dα)Al27(n,2n)Al26 Ca40(n,dα)Cl35(n,n2α)Al27(n,2n)Al26 Ca40(n,dα)Cl35(n,nα)P31(n,2nα)Al26 Ca40(n,nα)Ar36(n,dα)P31(n,2nα)Al26 Ca40(n,d)K39(n,n2α)P31(n,2nα)Al26 Ca40(n,n2α)S32(n,tα)Al26 Ca40(n,n3α)Si28(n,t)Al26 Ca40(n,dα)Cl35(n,2n2α)Al26				24.7 22.7 8.3	0.2 9.9 9.8 8.2 8.1 7.4 3.2 0.6 0.3 0.2	0.3 0.3 6.0 0.7 0.3 6.7 8.1 5.1 7.9 12.7 6.5 5.6 2.1	0.3 0.3 0.3 0.7 1.1 0.4 0.6 1.3 0.7 0.6 21.4 21.4 14.6
K40	1.3 10 <sup>9</sup> y	Ca40(n,γ)Ca41(n,α)Ar38(n,γ)Ar39(β <sup>-</sup> ) K39(n,γ)K40 &Ca40(n,α)Ar37(β <sup>+</sup> )Cl37(n,γ)Cl38(β <sup>-</sup> ) Ar38(n,γ)Ar39(β <sup>-</sup> )K39(n,γ)K40 Ca40(n,α)Ar37(n,γ)Ar38(n,γ)Ar39(β <sup>-</sup> ) K39(n,γ)K40 Ca40(n,p)K40 Ca42(n,t)K40 Ca44(n,2nt)K40 Ca43(n,nt)K40	92.6 6.0 0.7	84.1 13.2 2.7	91.3 1.4 7.3	99.9	98.7 0.8	92.7 6.2	87.6 8.1 1.7 1.2

# Calcium activation characteristics

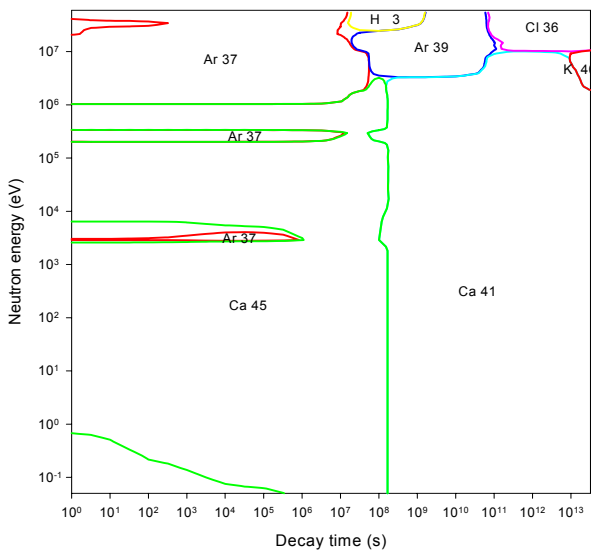


Decay time (years)

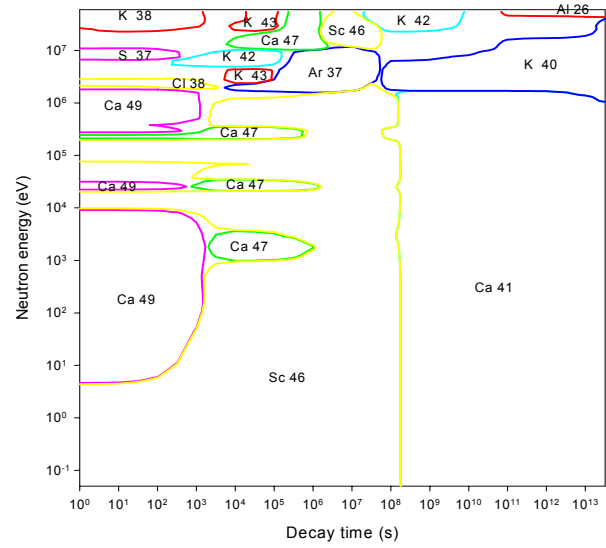
Decay time (years)

# Calcium importance diagrams & transmutation

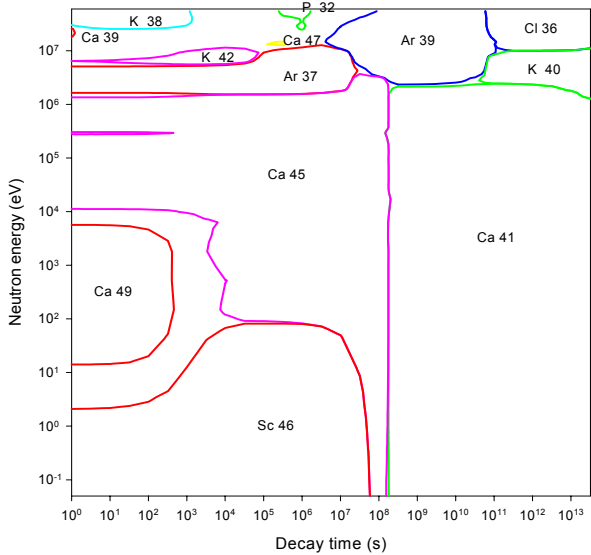
Activity



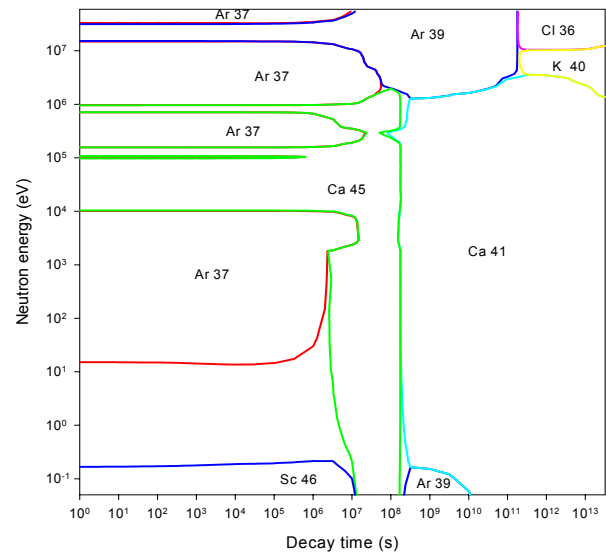
Dose rate



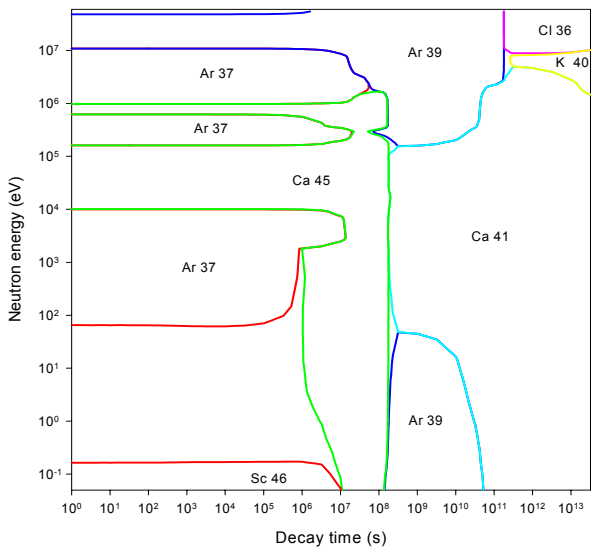
Heat output



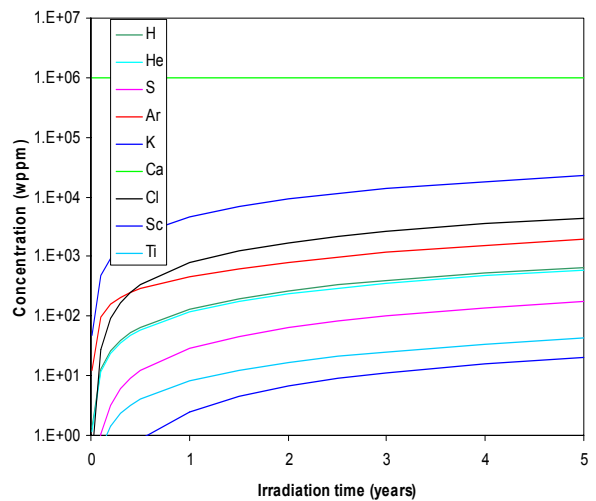
Ingestion dose



Inhalation dose



First wall transmutation





# Scandium

## General properties

Atomic number	21	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	22	Sc45	100.0
Melting point / K	1814		
Boiling point / K	3103		
Density / kgm <sup>-3</sup>	2989		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	15.8		
Electrical resistivity /Ωm	6.10 10 <sup>-7</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	1.02 10 <sup>-5</sup>		
Crystal structure	HCP		
Number of stable isotopes	1		
Mean atomic weight	44.95591		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	4.57E15	2.40E15	1.73E15	1.02E14	1.71E9	5.49E6	kW kg <sup>-1</sup>	7.76E-1	7.57E-1	5.34E-1	2.54E-2	5.41E-8	2.91E-12
Sc46	33.14	63.03	86.68	71.18			Sc46	66.29	68.01	93.48	98.62		
Sc45m	32.61						Sc44	26.08	26.50	5.56			
Sc46m	14.70						K42	3.88	3.96	0.04		22.46	
Sc44	10.12	19.08	3.91				Sc46m	1.96					
Sc44m	3.95	7.52	3.69				Sc44m	1.15	1.78	0.59			
Ca45	2.92	5.57	7.59	27.69			Sc45m	0.28					
K42	2.42	4.59	0.04		2.62		Ca45	0.21		0.30	1.37		
H3				0.11	27.42		Ar39					73.66	
Ar39					66.71		Ar42					3.08	
Ar42					2.62		H3					0.79	
Ca41					0.42	99.99	Ca41					0.01	99.13
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	1.09E6	1.08E6	8.35E5	4.00E4	3.93E-3	8.57E-8	Sv kg <sup>-1</sup>	3.11E6	3.10E6	2.48E6	1.34E5	1.43E3	1.04E-3
Sc46	75.57	76.09	95.40	100.0			Sc46	72.95	73.29	88.90	82.70		
Sc44	22.29	22.23	4.26				Sc44m	13.94	13.99	6.20			
K42	0.85	0.85			99.99*		Sc44	5.20	5.17	0.95			
Sc44m	0.72	0.72	0.33				Ca45	3.05	3.06	3.77	15.02		
Sc46m	0.45						K42	1.53	1.53	0.01			
K44	0.06	0.05					Ar39	0.05	0.05	0.06	1.20	87.50	
Ca41						94.35	Ar42	0.03	0.04	0.05	1.06	12.50	
K40						5.64	Ca41						99.91
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	1.13E7	1.13E7	1.07E7	7.19E5	5.04E4	9.91E-4		1.63E13	1.62E13	1.49E13	7.38E11	7.80E4	4.28E0
Sc46	91.06	91.11	93.41	69.73			Sc46	93.02	93.44	98.88	99.96		
Ca45	4.37	4.38	4.55	14.56			Sc44	6.17	6.14	0.99			
Sc44m	2.23	2.23	0.83				Sc46m	0.37					
Sc44	0.73	0.72	0.11				Sc44m	0.30	0.30	0.11			
Ar42	0.51	0.51	0.05	7.95	14.19		K42	0.06	0.06			5.73	
Ar39	0.49	0.49	0.06	7.75	85.81		Ar39					76.79	
Ca41						99.72	Ar42					11.46	
							Ca41						91.56
							Cl36						8.20
							K 40						0.24

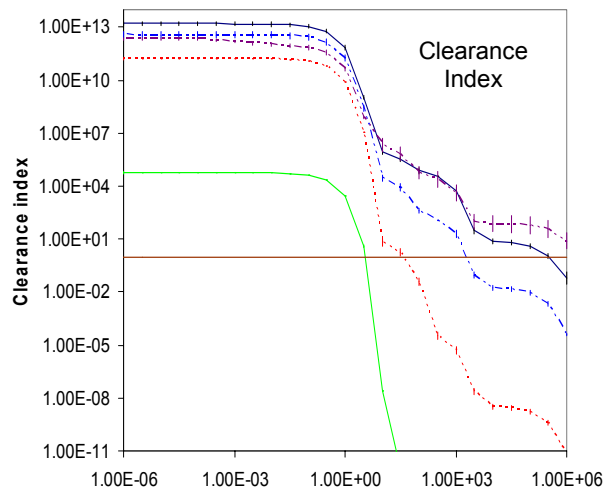
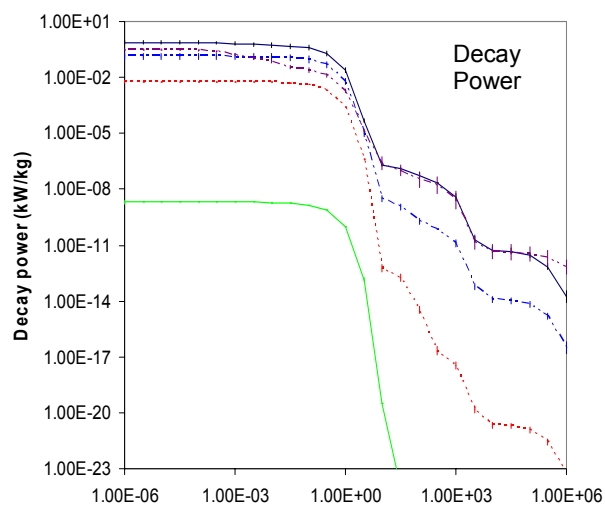
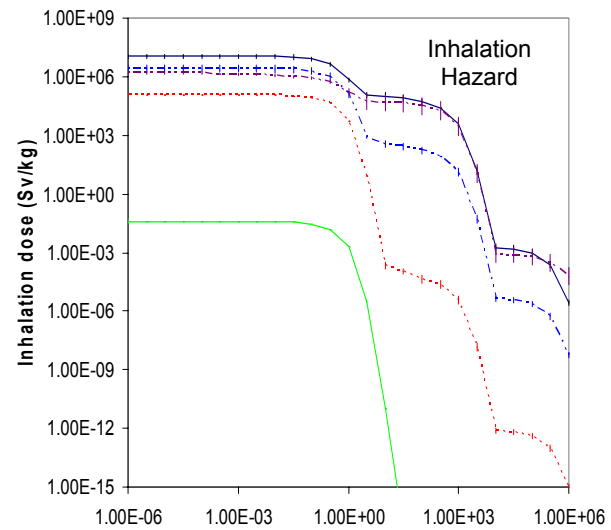
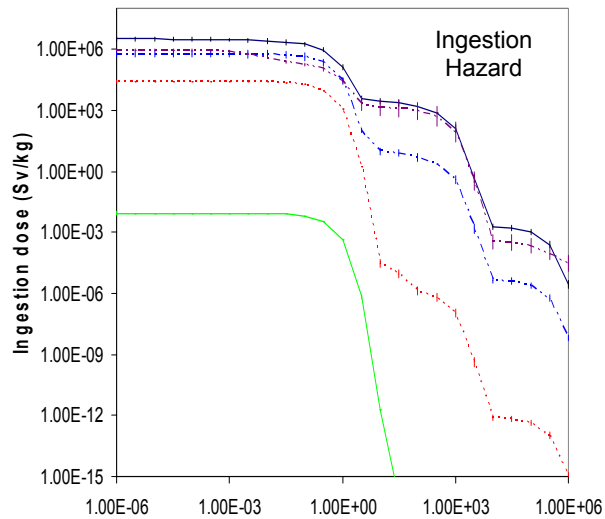
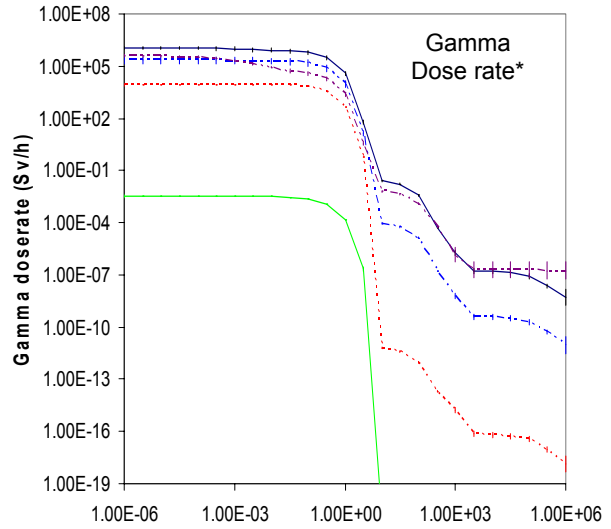
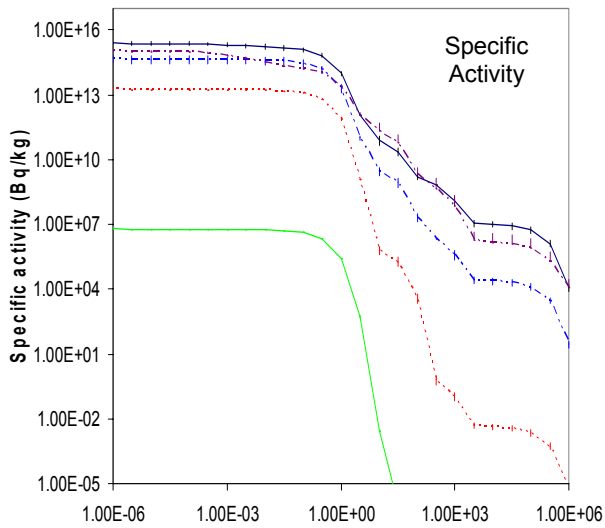
# Scandium

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Sc45m	0.316 s	Sc45(n,p)Ca45(β <sup>-</sup> )Sc45m Sc45(n,n')Sc45m	100.0	99.9	100.0	99.3	99.7	99.8	99.9
Sc44	3.97 h	&Sc45(n,2n)Sc44				99.9	100.0	100.0	100.0
K42	12.36 h	Sc45(n,α)K42 Sc45(n,d)Ca44(n,2n)Ca43(n,d)K42 Sc45(n,t)Ca43(n,d)K42 Sc45(n,3n)Sc43(β <sup>+</sup> )Ca43(n,d)K42 &Sc45(n,2n)Sc44(β <sup>+</sup> )Ca44(n,2n)Ca43(n,d)K42   &Sc45(n,2n)Sc44(β <sup>+</sup> )Ca44(n,t)K42 Sc45(n,d)Ca44(n,t)K42				96.3 0.1	55.9 2.0 28.7	28.1 0.4 28.2	76.1 7.9 1.7
Sc44m	2.442 d	Sc45(n,2n)Sc44m				99.3	99.7	99.8	99.9
Sc46	83.79 d	&Sc45(n,γ)Sc46	100.0	100.0	100.0	99.3	98.8	99.2	99.7
Ca45	163.0 d	Sc45(n,p)Ca45	100.0	99.9	100.0	99.8	99.9	99.9	100.0
Co60	5.271 y	Very long pathways of (n,γ), β <sup>-</sup>	100.0						
H3	12.33 y	&Sc45(n,γ)Sc46(n,X)H1(n,γ)H2(n,γ)H3 Sc45(n,X)H1(n,γ)H2(n,γ)H3 Sc45(n,X)H3 Sc45(n,t)Ca43(n,X)H3	51.5 41.7	7.6 87.6	25.9 73.5	99.2	95.5 1.2	94.4 2.0	94.9 1.2
Ar42	33.0 y	Sc45(n,p)Ca45(n,α)Ar42 Sc45(n,α)K42(n,p)Ar42 &Sc45(n,2n)Sc44(β <sup>+</sup> )Ca44(n,h)Ar42 Sc45(n,d)Ca44(n,h)Ar42 Sc45(n,t)Ca43(n,2p)Ar42 Sc45(n,3n)Sc43(β <sup>+</sup> )Ca43(n,2p)Ar42 Sc45(n,ph)Ar42				98.2 1.6	8.7 39.0 31.2 15.4 2.2	1.0 42.1 39.8 10.5 2.7	0.4 21.9 20.4 2.5 0.5
Ar39	269.0 y	Sc45(n,α)K42(β <sup>-</sup> )Ca42(n,α)Ar39 &Sc45(n,2n)Sc44(β <sup>+</sup> )Ca44(n,2n)Ca43_ (n,nα)Ar39 Sc45(n,d)Ca44(n,2n)Ca43(n,nα)Ar39 Sc45(n,t)Ca43(n,nα)Ar39 Sc45(n,nα)K41(n,t)Ar39 Sc45(n,3n)Sc43(β <sup>+</sup> )Ca43(n,nα)Ar39 Sc45(n,2nα)K40(n,d)Ar39 &Sc45(n,2n)Sc44(β <sup>+</sup> )Ca44(n,2nα)Ar39 Sc45(n,d)Ca44(n,2nα)Ar39 Sc45(n,tα)Ar39				87.6 3.8	0.4 2.6	0.1 0.1	0.7
Ca41	1.0 10 <sup>5</sup> y	Sc45(n,α)K42(β <sup>-</sup> )Ca42(n,2n)Ca41 Sc45(n,d)Ca44(n,2n)Ca43(n,2n)Ca42(n,2n)Ca41   Sc45(n,t)Ca43(n,3n)Ca41 Sc45(n,3n)Sc43(β <sup>+</sup> )Ca43(n,3n)Ca41 Sc45(n,t)Ca43(n,2n)Ca42(n,2n)Ca41 &Sc45(n,2n)Sc44(β <sup>+</sup> )Ca44(n,2n)Ca43_ (n,3n)Ca41 &Sc45(n,2n)Sc44(β <sup>+</sup> )Ca44(n,3n)Ca42_ (n,2n)Ca41 Sc45(n,nt)Ca42(n,2n)Ca41 Sc45(n,2nt)Ca41 &Sc45(n,2n)Sc44(β <sup>+</sup> )Ca44(n,4n)Ca41				98.6 0.6	11.3 0.1 56.9 8.3 3.7 3.4 3.2	1.9 61.5 15.9 1.0 0.5 0.8	1.5 6.4 1.4 8.1 75.4 3.2
Cl36	3.0 10 <sup>5</sup> y	Sc45(n,nα)K41(n,nα)Cl37(n,2n)Cl36 Sc45(n,nα)K41(n,2n)K40(n,nα)Cl36 Sc45(n,α)K42(β <sup>-</sup> )Ca42(n,nα)Ar38_ (n,2n)Ar37(β <sup>+</sup> )Cl37(n,2n)Cl36 Sc45(n,α)K42(β <sup>-</sup> )Ca42(n,nα)Ar38(n,d)_ Cl37(n,2n)Cl36 Sc45(n,α)K42(β <sup>-</sup> )Ca42(n,2n)Ca41_ (n,nα)Ar37(β <sup>+</sup> )Cl37(n,2n)Cl36				37.7 29.1 5.3 4.6 3.0	8.0 9.4 0.3	0.2 0.3	

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Sc45(n,α)K42(β <sup>-</sup> )Ca42(n,2n)Ca41(n,d)_ K40(n,nα)Cl36 &Sc45(n,2n)Sc44(β <sup>+</sup> )Ca44(n,α)Ar41_ (β <sup>-</sup> )K41(n,nα)Cl37(n,2n)Cl36 Sc45(n,d)Ca44(n,α)Ar41(β <sup>-</sup> )K41(n,nα)_ Cl37(n,2n)Cl36 Sc45(n,d)Ca44(n,α)Ar41(β <sup>-</sup> )K41(n,2n)_ K40(n,nα)Cl36 &Sc45(n,2n)Sc44(β <sup>+</sup> )Ca44(n,α)Ar41_ (β <sup>-</sup> )K41(n,2n)K40(n,nα)Cl36 Sc45(n,α)K42(β <sup>-</sup> )Ca42(n,d)K41(n,nα)_ Cl37(n,2n)Cl36 Sc45(n,α)K42(β <sup>-</sup> )Ca42(n,d)K41(n,2n)_ K40(n,nα)Cl36 Sc45(n,α)K42(β <sup>-</sup> )Ca42(n,2n)Ca41_ (n,pα)Cl37(n,2n)Cl36 Sc45(n,nα)K41(n,2nα)Cl36 Sc45(n,2nα)K40(n,nα)Cl36 Sc45(n,2α)Cl37(n,2n)Cl36 Sc45(n,t)Ca43(n,2nα)Ar38(n,t)Cl36 Sc45(n,t)Ca43(n,t)K41(n,2nα)Cl36 Sc45(n,2nα)K40(n,t)Ar38(n,t)Cl36 Sc45(n,ntα)Ar38(n,t)Cl36 Sc45(n,nt)Ca42(n,tα)Cl36 Sc45(n,3nα)K39(n,α)Cl36 Sc45(n,2n2α)Cl36 Sc45(n,tα)Ar39(n,nt)Cl36				2.8				
						2.6				
						2.5				
						1.9				
						1.9				
						1.8				
						1.4				
						0.9				
							57.5	29.1	1.6	
							14.0	39.5	2.0	
							2.5	6.5	0.6	
							1.0	4.3	0.2	
							0.5	3.3	0.1	
								2.6	0.1	
								0.3	2.0	
								0.2	9.1	
								0.1	3.7	
									69.2	
									4.1	
Fe60	1.5 10 <sup>6</sup> y	Very long pathways of (n,γ), β <sup>-</sup>	100.0							
K40	1.3 10 <sup>9</sup> y	Sc45(n,nα)K41(n,2n)K40 Sc45(n,α)K42(β <sup>-</sup> )Ca42(n,2n)Ca41(n,d)K40 Sc45(n,d)Ca44(n,α)Ar41(β <sup>-</sup> )K41(n,2n)K40 Sc45(n,α)K42(β <sup>-</sup> )Ca42(n,d)K41(n,2n)K40 Sc45(n,2n)Sc44(β <sup>+</sup> )Ca44(n,α)Ar41(β <sup>-</sup> )_ K41(n,2n)K40 Sc45(n,2n)Sc44m(n,nα)K40 Sc45(n,2nα)K40 Sc45(n,α)K42(β <sup>-</sup> )Ca42(n,t)K40 Sc45(n,t)Ca43(n,nt)K40 Sc45(n,nt)Ca42(n,t)K40 Sc45(n,3n)Sc43(β <sup>+</sup> )Ca43(n,nt)K40				72.1	47.5	1.0	0.7	
						9.2	0.1			
						6.4	0.1			
						4.6	0.1			
						4.0				
						0.5				
							47.1	95.4	81.7	
							1.0	0.3	1.3	
							0.3	0.8	5.7	
							0.2	1.2	7.0	
								0.2	1.2	
Ca48	5.3 10 <sup>19</sup> y	&Sc45(n,γ)Sc46(n,p)Ca46(n,γ)Ca47(n,γ)_ Ca48 Sc45(n,p)Ca45(n,γ)Ca46(n,γ)Ca47(n,γ)Ca48 Sc45(n,γ)Sc46(n,γ)Sc47(n,p)Ca47(n,γ)Ca48	94.5	95.6	99.9	55.8	62.4	62.8	63.4	
			5.5	4.4		43.1	36.7	36.4	36.0	
						0.1	0.2	0.2	0.2	

# Scandium activation characteristics



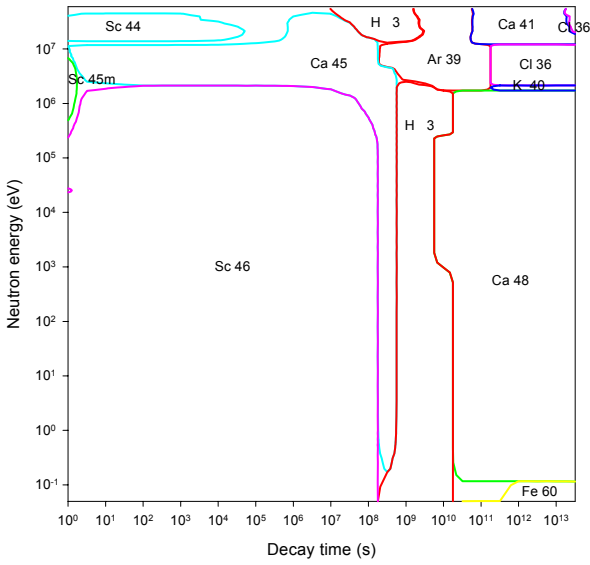
Decay time (years)

Decay time (years)

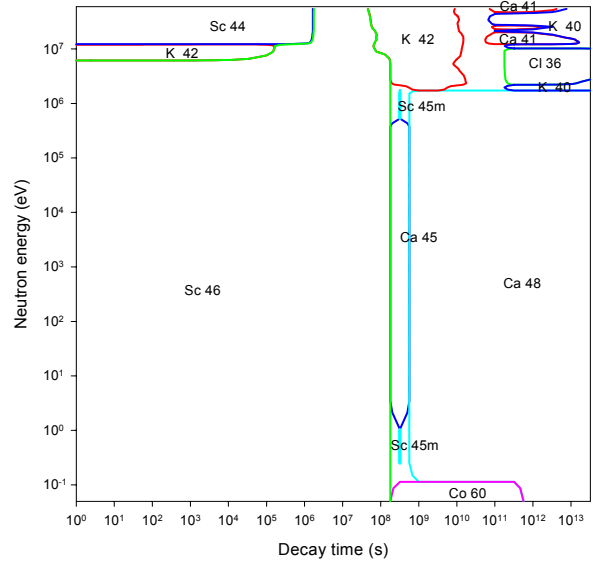


# Scandium importance diagrams & transmutation

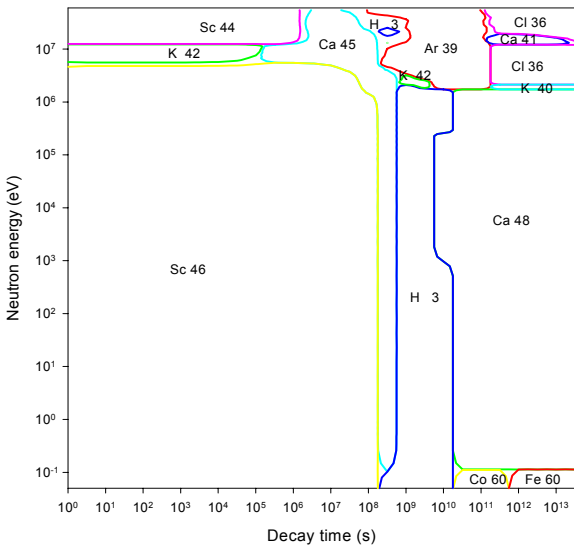
**Activity**



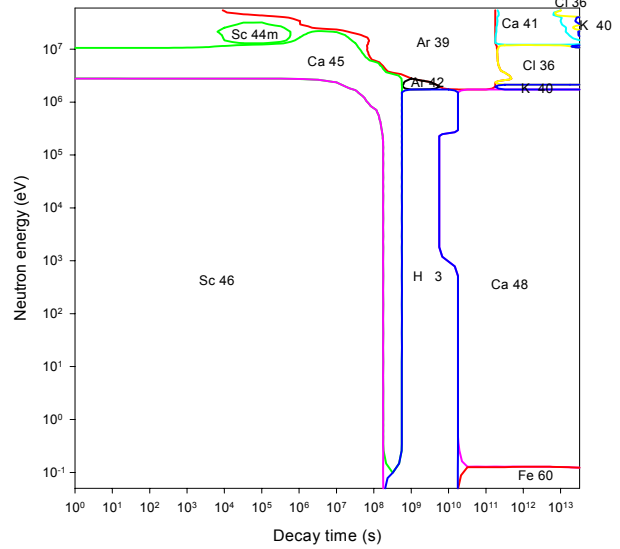
**Dose rate**



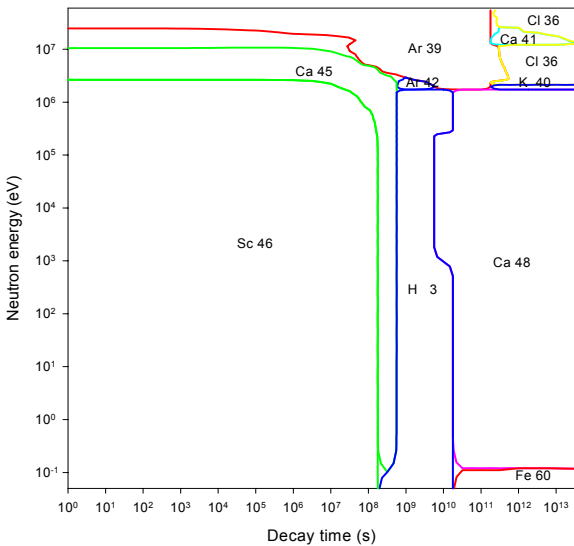
**Heat output**



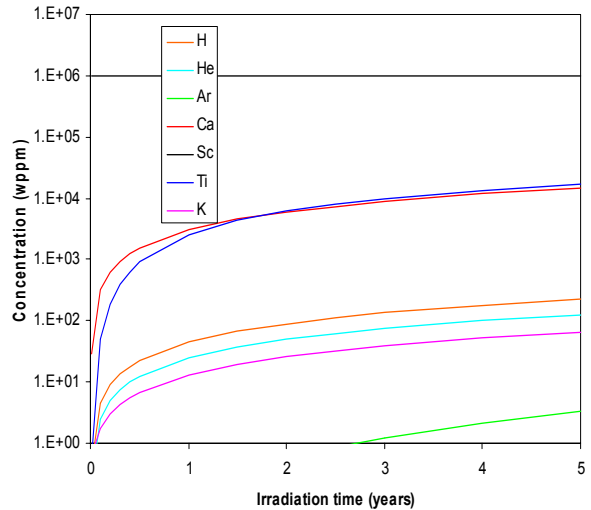
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**





# Titanium

## General properties

Atomic number	22	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	5.65 10 <sup>3</sup>	Ti46	8.25
Melting point / K	1941	Ti47	7.44
Boiling point / K	3560	Ti48	73.72
Density / kgm <sup>-3</sup>	4540	Ti49	5.41
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	21.9	Ti50	5.18
Electrical resistivity /Ωm	4.2 10 <sup>-7</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	8.60 10 <sup>-6</sup>		
Crystal structure	HCP		
Number of stable isotopes	5		
Mean atomic weight	47.867		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	2.54E14	2.28E14	1.31E14	1.09E13	5.39E7	3.72E4	kW kg <sup>-1</sup>	7.28E-2	7.15E-2	3.08E-2	9.53E-4	4.80E-9	1.96E-14
Sc48	34.51	38.40	16.72				Sc48	68.93	70.05	40.46			
Sc46	20.18	22.48	38.13	22.93			Sc46	23.95	24.38	54.85	89.10		
Sc47	15.92	17.73	14.79				Sc47	2.41	2.45	2.71			
Ca45	15.62	17.40	29.94	77.05			Sc50	1.24	0.14				
Sc45m	5.23						Ti45	0.92	0.91				
Sc46m	4.20						Sc49	0.72	0.69				
Sc49	1.57	1.64					Ca45	0.67	0.68	1.56	10.89		
Ti45	1.32	1.44					Ca47	0.23	0.23	0.31			
K42	0.04	0.03			24.10		K42	0.03	0.03			73.57	
H3				0.01	10.53		Ar39					16.17	
Ar39					41.11		Ar42					10.09	
Ar42					24.10		H3					0.10	
Ca41					0.13	100.0	Ca41						99.87
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	1.14E5	1.13E5	4.84E4	1.38E3	1.16E-3	5.09E-10	Sv kg <sup>-1</sup>	2.83E5	2.80E5	1.51E5	1.02E4	7.63E1	7.07E-6
Sc48	72.84	73.50	42.63				Sc48	52.69	53.21	24.53			
Sc46	24.81	25.07	56.65	100.0			Sc46	27.18	27.49	49.37	36.90		
Sc50	9.35	0.11					Ca45	9.95	10.07	18.35	58.70		
Ti45	0.53	0.53					Sc47	7.72	7.83	6.89			
Sc47	0.33	0.33	0.37				Ar42	0.14	0.15	0.28	4.09	68.06	
Ca47	0.20	0.20	0.27				Ar39	0.01	0.01	0.02	0.30	31.93	
Sc44	0.18	0.18	0.06		0.25		K42	0.01	0.01				
K42					99.74*		Ca41						99.99
Ca41						99.28							
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	6.44E5	6.42E5	5.40E5	6.58E4	2.92E3	6.70E-6		6.11E11	6.06E11	5.20E11	2.51E10	5.13E03	2.70E-2
Sc46	54.19	54.29	62.65	25.84			Sc46	83.92	84.59	95.66	99.66		
Ca45	22.82	22.86	26.77	47.24			Sc48	14.35	14.45	4.19			
Sc48	14.99	15.00	4.44				Sc47	0.06	0.06	0.03			
Sc47	4.59	4.59	2.60				Ar42					50.62	
Ar42	2.63	2.64	2.34	25.27	71.17		K42					25.31	
Ca47	0.24	0.24	0.16				Ar39					22.72	
Ar39	0.16	0.16	0.20	1.65	28.83		H3					1.10	
Ca41						99.95	Ca41						98.37

# Titanium

## Pathway analysis

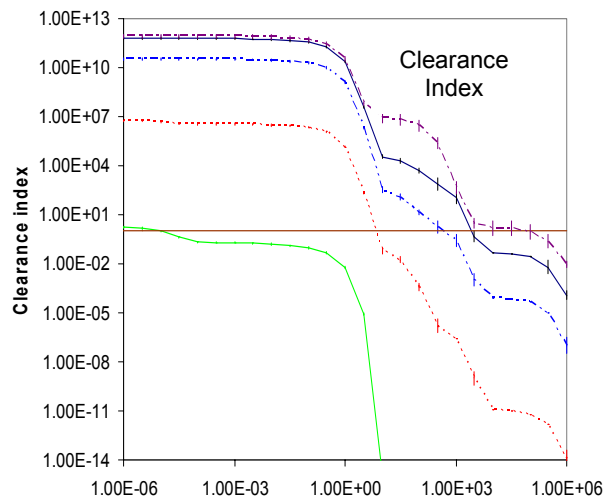
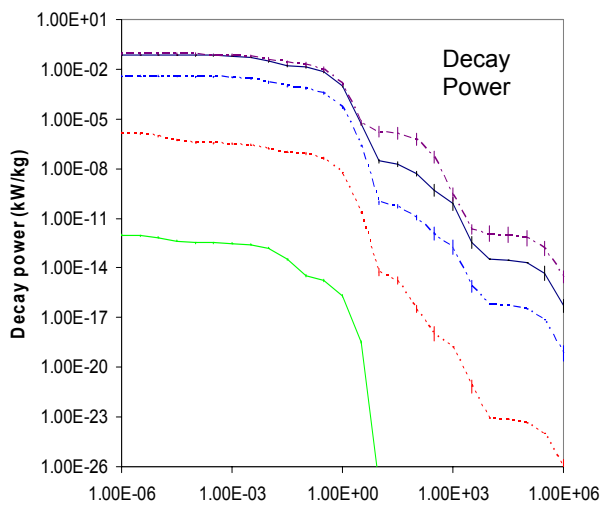
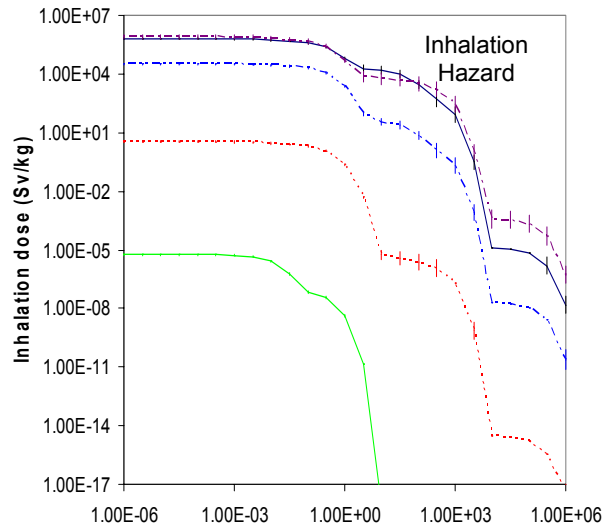
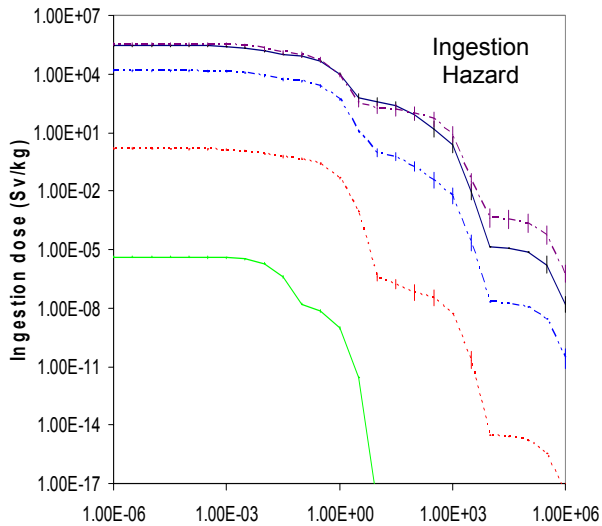
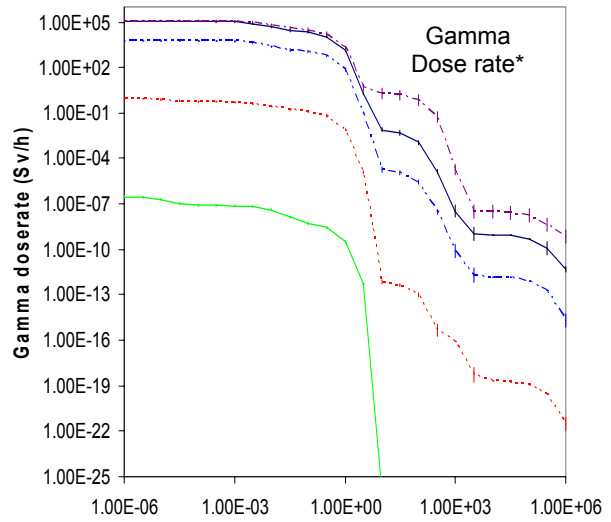
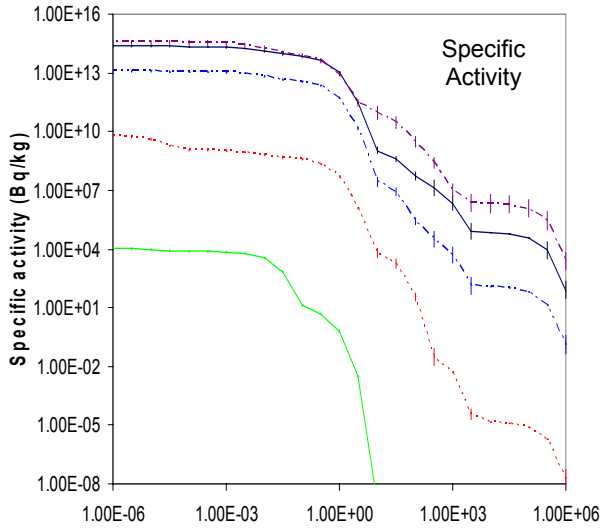
Nuclide	T <sub>1/2</sub>	Pathway	240	186	151	42	30	21	6	
V52	3.745 m	Ti50(n,γ)Ti51(β <sup>-</sup> )V51(n,γ)V52 Ti48(n,γ)Ti49(n,γ)Ti50(n,γ)Ti51(β <sup>-</sup> )V51_(n,γ)V52 Ti49(n,γ)Ti50(n,γ)Ti51(β <sup>-</sup> )V51(n,γ)V52	85.7 9.1 5.2	99.9  0.1	99.9  0.1	99.3	99.7	99.8	99.9	
Ti51	5.8 m	Ti50(n,γ)Ti51 Ti48(n,γ)Ti49(n,γ)Ti50(n,γ)Ti51 Ti49(n,γ)Ti50(n,γ)Ti51	71.2 20.5 8.2	99.7  0.3	99.8  0.2	99.3	99.6	99.7	99.9	
Mn56	2.582 h	Ti50(n,γ)Ti51(β <sup>-</sup> )V51(n,γ)V52(β <sup>-</sup> )Cr52(n,γ)_ Cr53(n,γ)Cr54(n,γ)Cr55(β <sup>-</sup> )Mn55(n,γ)Mn56 Ti49(n,γ)Ti50(n,γ)Ti51(β <sup>-</sup> )V51(n,γ)V52_(β <sup>-</sup> )Cr52(n,γ)Cr53(n,γ)Cr54(n,γ)Cr55(β <sup>-</sup> )_Mn55(n,γ)Mn56 Ti48(n,γ)Ti49(n,γ)Ti50(n,γ)Ti51(β <sup>-</sup> )V51_(n,γ)V52(β <sup>-</sup> )Cr52(n,γ)Cr53(n,γ)Cr54(n,γ)_Cr55(β <sup>-</sup> )Mn55(n,γ)Mn56	96.4  2.0  1.6	100.0						
Sc44	3.97 h	&Ti46(n,d)Sc45(n,2n)Sc44 &Ti48(n,α)Ca45(β <sup>-</sup> )Sc45(n,2n)Sc44 &Ti46(n,2n)Ti45(β <sup>+</sup> )Sc45(n,2n)Sc44 &Ti46(n,t)Sc44 &Ti47(n,t)Sc45(n,2n)Sc44 &Ti48(n,3n)Ti46(n,t)Sc44 &Ti48(n,t)Sc46(β <sup>-</sup> )Ti46(n,t)Sc44 &Ti47(n,nt)Sc44 &Ti48(n,2n)Ti47(n,nt)Sc44 &Ti48(n,nt)Sc45(n,2n)Sc44 &Ti48(n,d)Sc47(β <sup>-</sup> )Ti47(n,nt)Sc44 &Ti48(n,2nt)Sc44				45.0 37.6 7.1	34.1 5.4 13.7 18.0 5.4 2.0	1.8 0.2 0.8 56.8 1.5 16.4 8.4 1.1	0.7 0.5 0.2 38.3 0.7 5.7 5.0 20.2 3.7 5.2 3.4 7.4	
K42	12.36 h	&Ti46(n,d)Sc45(n,α)K42 Ti48(n,α)Ca45(β <sup>-</sup> )Sc45(n,α)K42 Ti46(n,2n)Ti45(β <sup>+</sup> )Sc45(n,α)K42 Ti46(n,α)Ca43(n,d)K42 Ti46(n,nα)Ca42(n,p)K42 Ti46(n,pα)K42 Ti47(n,nα)Ca43(n,d)K42 Ti48(n,3n)Ti46(n,pα)K42 Ti48(n,2n)Ti47(n,nα)Ca43(n,d)K42 Ti48(n,nα)Ca44(n,t)K42 Ti46(n,h)Ca44(n,t)K42 &Ti46(n,t)Sc44(β <sup>+</sup> )Ca44(n,t)K42 Ti48(n,2nα)Ca43(n,d)K42 Ti47(n,dα)K42 Ti48(n,tα)K42 Ti48(n,nt)Sc45(n,α)K42				41.2 33.8 6.6 5.9 2.9	5.2 0.8 2.2 3.3 2.9	0.7  0.3 0.7 0.4 18.0 1.6 5.6 0.3 11.4 3.9 12.7 12.3 6.1 0.1	1.1 0.7 0.4 2.2  3.2 0.4 0.5  3.2 1.2 4.4 4.2 10.1 38.1 5.4	
Sc48	1.820 d	&Ti47(n,α)Ca44(n,γ)Ca45(β <sup>-</sup> )Sc45(n,γ)_ Sc46(n,γ)Sc47(n,γ)Sc48 Ti47(n,α)Ca44(n,γ)Ca45(n,γ)Ca46(n,γ)_ Ca47(β <sup>-</sup> )Sc47(n,γ)Sc48 &Ti46(n,γ)Ti47(n,α)Ca44(n,γ)Ca45(β <sup>-</sup> )_ Sc45(n,γ)Sc46(n,γ)Sc47(n,γ)Sc48 Ti48(n,p)Sc48 Ti49(n,2n)Ti48(n,p)Sc48 Ti49(n,d)Sc48 Ti50(n,2n)Ti49(n,d)Sc48 Ti50(n,t)Sc48	78.3 11.5 0.9	69.3 18.9			98.2 1.0 0.7	70.0 0.4 25.5	55.3 0.2 26.0	38.8  29.4 0.7 30.3
Sc47	3.351 d ▶	&Ti47(n,α)Ca44(n,γ)Ca45(β <sup>-</sup> )Sc45(n,γ)_ Sc46(n,γ)Sc47	84.7	76.4	95.7					

Nuclide	T <sub>1/2</sub>	Pathway	240	186	151	42	30	21	6
	◀	Ti47(n,α)Ca44(n,γ)Ca45(n,γ)Ca46(n,γ)_ Ca47(β <sup>-</sup> )Sc47 Ti48(n,d)Sc47 Ti47(n,p)Sc47 Ti48(n,2n)Ti47(n,p)Sc47 Ti50(n,α)Ca47(β <sup>-</sup> )Sc47 Ti49(n,t)Sc47 Ti50(n,nt)Sc47	12.4	20.4	3.6				
						37.0	93.0	88.8	84.4
						33.1	2.1	2.0	1.3
						26.4	1.6	0.6	0.3
						1.5	0.2	0.1	0.3
							0.7	5.7	6.9
								0.2	5.3
Sc46	83.79 d	&Ti47(n,α)Ca44(n,γ)Ca45(β <sup>-</sup> )Sc45(n,γ)Sc46 Ti46(n,γ)Ti47(n,α)Ca44(n,γ)Ca45(β <sup>-</sup> )_ Sc45(n,γ)Sc46 &Ti46(n,p)Sc46 &Ti47(n,d)Sc46 &Ti48(n,2n)Ti47(n,d)Sc46 &Ti47(n,2n)Ti46(n,p)Sc46 &Ti48(n,d)Sc47(β <sup>-</sup> )Ti47(n,d)Sc46 &Ti48(n,t)Sc46 &Ti49(n,nt)Sc46	99.0 0.6	99.9	99.9				
						67.1	10.9	2.8	1.6
						12.8	36.5	9.1	7.5
						9.6	26.1	2.7	1.4
						5.9	0.6		
						0.3	12.4	2.2	1.3
							9.3	79.9	81.2
								0.2	5.0
Ca45	163.0 d	Ti47(n,α)Ca44(n,γ)Ca45 Ti46(n,γ)Ti47(n,α)Ca44(n,γ)Ca45 Ti48(n,α)Ca45 Ti49(n,2n)Ti48(n,α)Ca45 &Ti46(n,d)Sc45(n,p)Ca45 Ti49(n,nα)Ca45 Ti46(n,2p)Ca45 Ti47(n,h)Ca45 Ti48(n,2n)Ti47(n,h)Ca45 Ti48(n,d)Sc47(β <sup>-</sup> )Ti47(n,h)Ca45 Ti48(n,h)Ca46(n,2n)Ca45 Ti50(n,2nα)Ca45	98.4 1.5	99.9	99.8 0.2				
						96.1	66.3	46.1	78.9
						0.8	0.4	0.1	0.1
						0.7	1.0	0.5	
							13.9	13.2	3.9
							9.3	5.6	1.3
							0.8	10.8	5.1
							0.5	3.1	0.9
							0.3	2.4	0.8
							0.3	1.5	0.6
								7.3	4.7
Co60	5.271 y	Very long pathways of (n,γ), β <sup>-</sup>	100.0						
H3	12.33 y	&Ti47(n,α)Ca44(n,γ)Ca45(β <sup>-</sup> )Sc45(n,γ)_ Sc46(n,X)H1(n,γ)H2(n,γ)H3 Ti47(n,α)Ca44(n,γ)Ca45(β <sup>-</sup> )Sc45(n,X)H1_ (n,γ)H2(n,γ)H3 Ti47(n,X)H3 Ti48(n,2n)Ti47(n,X)H3 Ti49(n,X)H3 Ti46(n,d)Sc45(n,X)H3 Ti48(n,α)Ca45(β <sup>-</sup> )Sc45(n,X)H3 Ti46(n,p)Sc46(n,X)H3 Ti46(n,α)Ca43(n,X)H3 Ti46(n,2n)Ti45(β <sup>+</sup> )Sc45(n,X)H3 Ti48(n,d)Sc47(β <sup>-</sup> )Ti47(n,X)H3 Ti48(n,X)H3 Ti46(n,X)H3 Ti50(n,X)H3	49.5 45.9						
						42.3	11.6	9.4	7.9
						17.2	4.5	1.6	0.8
						12.3	7.9	6.6	6.1
						8.0	0.7	0.2	
						5.9	0.1		
						5.2			
						2.4			
						1.3	0.3	0.1	
						0.5	2.2	1.2	0.7
							58.7	64.3	67.7
							7.1	7.3	6.8
							3.5	4.4	4.9
Ar42	33.0 y	Ti48(n,α)Ca45(n,α)Ar42 Ti48(n,nα)Ca44(n,h)Ar42 Ti50(n,nα)Ca46(n,nα)Ar42 Ti48(n,h)Ca46(n,nα)Ar42 Ti49(n,α)Ca46(n,nα)Ar42 Ti49(n,nα)Ca45(n,α)Ar42 Ti47(n,2p)Ca46(n,nα)Ar42 Ti49(n,2α)Ar42 Ti46(n,h)Ca44(n,h)Ar42 &Ti46(n,t)Sc44(β <sup>+</sup> )Ca44(n,h)Ar42 Ti47(n,α)Ca44(n,h)Ar42 &Ti47(n,nt)Sc44(β <sup>+</sup> )Ca44(n,h)Ar42 Ti48(n,hα)Ar42 Ti50(n,2α)Ar42				97.8	18.3	1.3	3.8
							17.7	18.6	8.2
							15.7	4.0	0.7
							11.8	19.5	6.8
							9.0	1.3	0.8
							3.9	0.4	0.2
							3.5	0.6	
							1.6	7.9	3.0
							1.4	6.4	3.2
							0.7	20.8	11.3
							0.6	1.0	3.2
								0.4	6.0
									19.8
									15.5
Ar39	269.0 y ▶	Ti46(n,α)Ca43(n,nα)Ar39				54.1	4.6	0.6	1.3

Nuclide	T <sub>½</sub>	Pathway	240	186	151	42	30	21	6
	◀	Ti46(n,α)Ca42(n,α)Ar39 Ti46(n,α)Ca43(n,2n)Ca42(n,α)Ar39 Ti46(n,α)Ca43(n,α)Ar40(n,2n)Ar39 &Ti46(n,d)Sc45(n,α)K42(β <sup>-</sup> )Ca42(n,α)Ar39 Ti48(n,α)Ca45(β <sup>-</sup> )Sc45(n,α)K42(β <sup>-</sup> ) Ca42(n,α)Ar39 Ti47(n,α)Ca43(n,α)Ar39 Ti48(n,2n)Ti47(n,α)Ca43(n,α)Ar39 Ti46(n,2α)Ar39 Ti48(n,α)Ca44(n,2nα)Ar39 Ti46(n,h)Ca44(n,2nα)Ar39 &Ti46(n,t)Sc44(β <sup>+</sup> )Ca44(n,2nα)Ar39 Ti48(n,2nα)Ca43(n,α)Ar39 Ti47(n,2α)Ar39 Ti46(n,dα)K41(n,t)Ar39 Ti46(n,2nα)Ca41(n,h)Ar39 Ti48(n,2n2α)Ar39 &Ti48(n,nt)Sc45(n,tα)Ar39 Ti48(n,3nα)Ca42(n,α)Ar39				18.3 9.5 4.8 2.5 1.6 0.5 0.1 46.4 1.4 0.1 14.1 9.2 7.7 3.6 3.3 33.5 11.8 5.6	3.3 15.3 3.9 46.4 1.4 0.1 12.7 4.3 14.1 9.2 7.7 3.6 3.3	0.5 1.2 0.1 17.1 12.7 4.3 7.7 3.6 3.3	0.9 0.3 1.6 1.6 0.6 2.2 2.4 8.7 1.5 0.6 33.5 11.8 5.6
Ca41	1.0 10 <sup>5</sup> y	Ti46(n,α)Ca42(n,2n)Ca41 Ti46(n,α)Ca43(n,2n)Ca42(n,2n)Ca41 &Ti46(n,d)Sc45(n,α)K42(β <sup>-</sup> )Ca42(n,2n)Ca41 Ti48(n,α)Ca45(β <sup>-</sup> )Sc45(n,α)K42(β <sup>-</sup> ) Ca42(n,2n)Ca41 Ti46(n,2nα)Ca41 Ti47(n,α)Ca43(n,3n)Ca41 Ti46(n,pα)K42(β <sup>-</sup> )Ca42(n,2n)Ca41 Ti46(n,α)Ca43(n,3n)Ca41 Ti48(n,3n)Ti46(n,2nα)Ca41 Ti48(n,t)Sc46(β <sup>-</sup> )Ti46(n,2nα)Ca41 Ti48(n,2nα)Ca43(n,3n)Ca41 Ti47(n,3nα)Ca41 Ti48(n,3nα)Ca42(n,2n)Ca41				52.6 27.4 7.1 4.7 12.9 10.4 3.6 3.1 0.8 4.9 4.7 24.9 3.0	47.1 0.2 0.1 12.9 69.1 10.4 0.6 0.2 10.8 4.9 4.7	1.1 0.6 0.2 0.3 10.8 4.9 4.7	0.5 0.2 0.2 1.2 3.3 2.5 2.2 24.9 3.0
Cl36	3.0 10 <sup>5</sup> y	Ti46(n,α)Ca42(n,α)Ar38(n,2n)Ar37_ (β <sup>+</sup> )Cl37(n,2n)Cl36 Ti46(n,α)Ca42(n,α)Ar38(n,d)Cl37_ (n,2n)Cl36 &Ti46(n,d)Sc45(n,α)K41(n,α)Cl37_ (n,2n)Cl36 Ti46(n,α)Ca42(n,2n)Ca41(n,α)Ar37_ (β <sup>+</sup> )Cl37(n,2n)Cl36 &Ti46(n,d)Sc45(n,α)K41(n,2n)K40_ (n,α)Cl36 &Ti46(n,d)Sc45(n,α)K41(n,2n)K40_ (n,α)Cl36 Ti47(n,α)Ca44(n,α)Ar41(β <sup>-</sup> )K41(n,α) Cl37(n,2n)Cl36 Ti46(n,α)Ca42(n,2n)Ca41(n,d)K40(n,α)Cl36 Ti48(n,α)Ca45(β <sup>-</sup> )Sc45(n,α)K41(n,α) Cl37(n,2n)Cl36 Ti47(n,α)Ca44(n,α)Ar41(β <sup>-</sup> )K41(n,2n) K40(n,α)Cl36 Ti46(n,α)Ca42(n,d)K41(n,α)Cl37(n,2n)Cl36 Ti48(n,α)Ca45(β <sup>-</sup> )Sc45(n,α)K41(n,2n) K40(n,α)Cl36 Ti46(n,α)Ca42(n,d)K41(n,2n)K40(n,α)Cl36 Ti46(n,α)Ca42(n,2n)Ca41(n,pα)Cl37_ (n,2n)Cl36 Ti46(n,α)Ca43(n,2n)Ca42(n,2n)Ca41_ (n,d)K40(n,α)Cl36 Ti46(n,α)Ca42(n,t)K40(n,α)Cl36				9.4 8.3 6.8 5.4 5.3 5.3 5.3 5.0 4.1 4.1 3.2 3.2 2.5 1.7 1.6 8.7	1.0 1.0 1.0 0.7 1.2 1.2 0.9 0.1 1.2 0.9 0.1 1.0 0.2	0.5 0.2 0.2 1.2 3.3 2.5 2.2 24.9 3.0	

Nuclide	T <sub>1/2</sub>	Pathway	240	186	151	42	30	21	6
	◀	Ti46(n,nα)Ca42(n,d)K41(n,2nα)Cl36 Ti46(n,nα)Ca42(n,nα)Ar38(n,t)Cl36 Ti46(n,2α)Ar38(n,t)Cl36 Ti46(n,2nα)Ca41(n,dα)Cl36 Ti46(n,dα)K41(n,2nα)Cl36 Ti48(n,3nα)Ca42(n,tα)Cl36 Ti48(n,nt)Sc45(n,2n2α)Cl36					8.2 6.9 2.7 0.8	0.5 0.5 18.0 24.4 14.6	2.8 3.3 2.8 19.4 9.3
Fe60	1.5 10 <sup>6</sup> y	Very long pathways of (n,γ), β <sup>-</sup>	100.0						
K40	1.3 10 <sup>9</sup> y	&Ti46(n,d)Sc45(n,nα)K41(n,2n)K40 Ti46(n,nα)Ca42(n,2n)Ca41(n,d)K40 Ti47(n,α)Ca44(n,α)Ar41(β <sup>-</sup> )K41(n,2n)K40 Ti48(n,α)Ca45(β <sup>-</sup> )Sc45(n,nα)K41(n,2n)K40 Ti46(n,nα)Ca42(n,d)K41(n,2n)K40 Ti46(n,α)Ca43(n,2n)Ca42(n,2n)Ca41(n,d)K40 Ti46(n,α)Ca43(n,2n)Ca42(n,d)K41(n,2n)K40 Ti48(n,2n)Ti47(n,α)Ca44(n,α)Ar41(β <sup>-</sup> )_K41(n,2n)K40 &Ti46(n,d)Sc45(n,α)K42(β <sup>-</sup> )Ca42(n,2n)_Ca41(n,d)K40 &Ti46(n,d)Sc45(n,d)Ca44(n,α)Ar41(β <sup>-</sup> )_K41(n,2n)K40 Ti46(n,nα)Ca42(n,t)K40 &Ti46(n,d)Sc45(n,2nα)K40 Ti46(n,2n)Ti45(β <sup>+</sup> )Sc45(n,2nα)K40 Ti46(n,2nα)Ca41(n,d)K40 &Ti47(n,t)Sc45(n,2nα)K40 Ti47(n,2nα)Ca42(n,t)K40 Ti48(n,2nα)Ca43(n,nt)K40 Ti48(n,nt)Sc45(n,2nα)K40 Ti46(n,tα)K40 Ti48(n,3nα)Ca42(n,t)K40 Ti48(n,t)Sc46(β <sup>-</sup> )Ti46(n,tα)K40				17.9 16.8 13.8 11.8 8.4 6.6 3.3 2.7 1.1 0.8	6.2 4.7 0.8 5.5	10.3 12.9 5.2 8.5 11.5 9.8 3.5 1.5 1.2	1.0 0.8 0.4 0.7 0.8 0.9 4.8 4.5 50.6 6.1 3.2
Ca48	5.3 10 <sup>19</sup> y	Ti47(n,α)Ca44(n,γ)Ca45(n,γ)Ca46(n,γ)_Ca47(n,γ)Ca48 Ti48(n,p)Sc48(n,p)Ca48 Ti49(n,2p)Ca48 Ti50(n,2n)Ti49(n,2p)Ca48 Ti50(n,h)Ca48	99.2	100.0		59.2 37.5 2.4	0.3 29.4 1.4 68.4	10.7 0.2	8.3 0.1 91.4

# Titanium activation characteristics



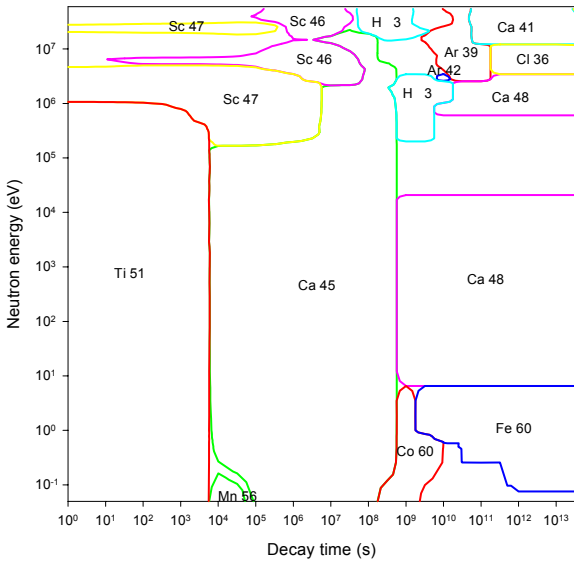
Decay time (years)

Decay time (years)

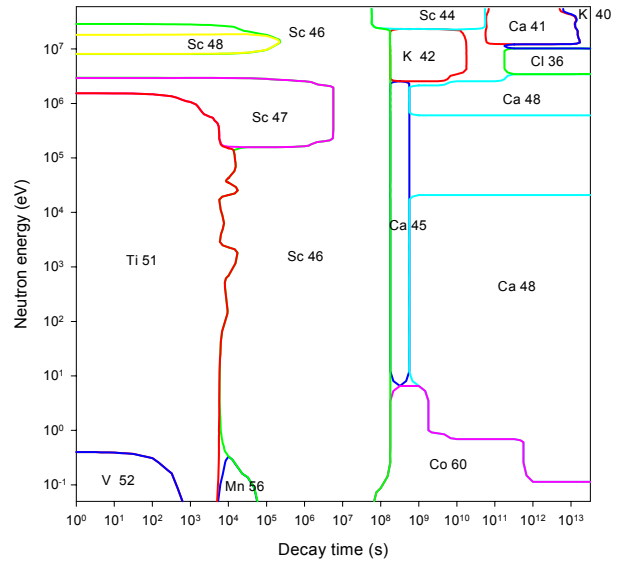


# Titanium importance diagrams & transmutation

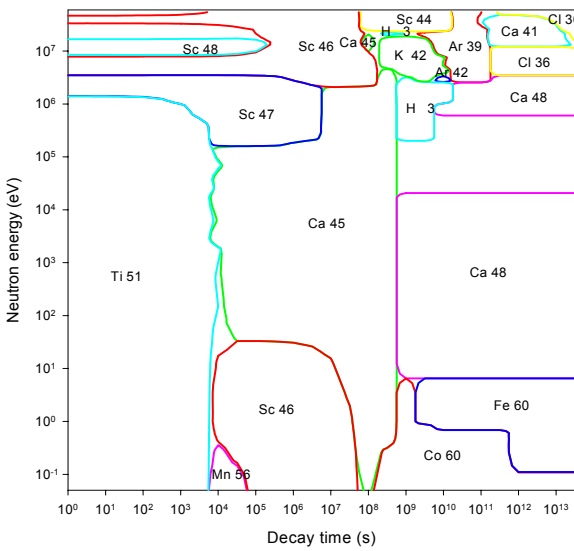
**Activity**



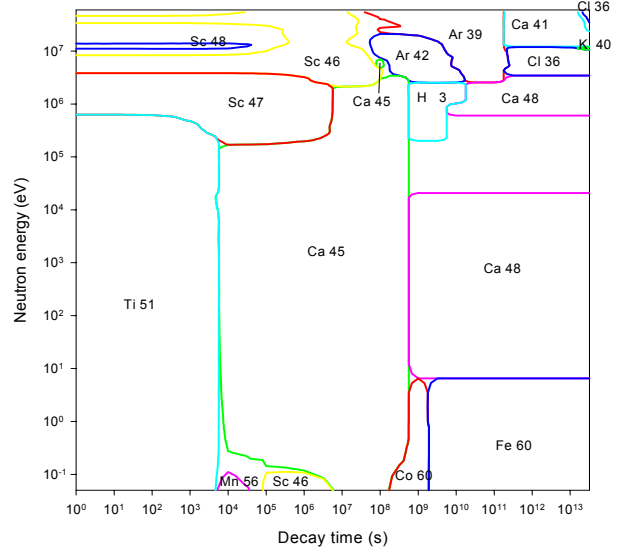
**Dose rate**



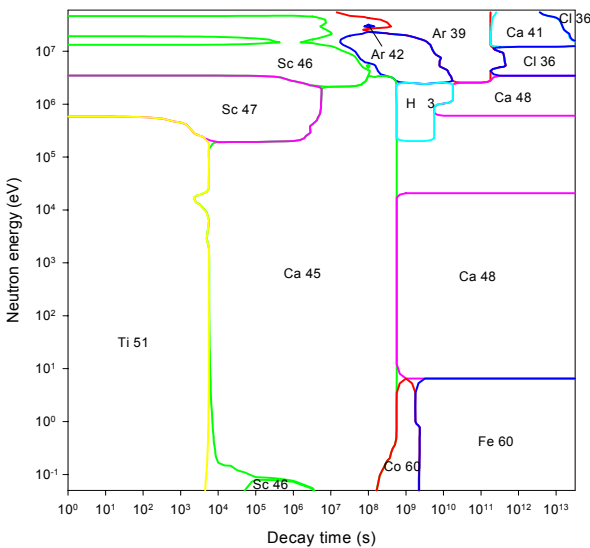
**Heat output**



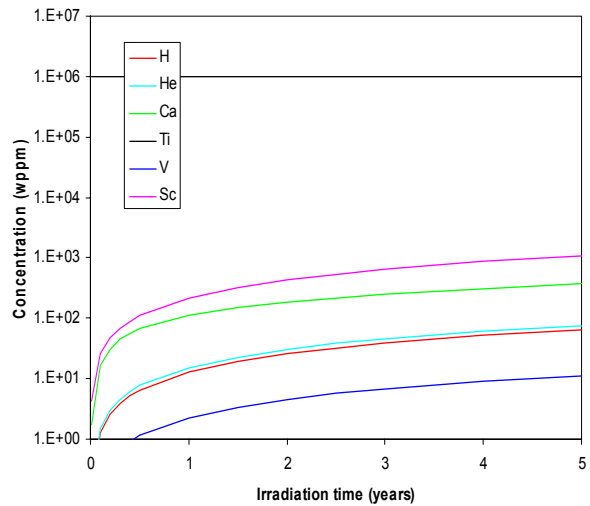
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**





# Vanadium

## General properties

Atomic number	23	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	120	V50	0.25 ( $T_{1/2} = 1.40 \cdot 10^{17}$ y)
Melting point / K	2183	V51	99.75
Boiling point / K	3680		
Density / $\text{kgm}^{-3}$	6110		
Thermal conductivity / $\text{Wm}^{-1}\text{K}^{-1}$	30.7		
Electrical resistivity / $\Omega\text{m}$	$2.48 \cdot 10^{-7}$		
Coefficient of thermal expansion / $\text{K}^{-1}$	$8.4 \cdot 10^{-6}$		
Crystal structure	BCC		
Number of stable isotopes	1 (2)		
Mean atomic weight	50.9415		

## Activation properties

Act	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Heat	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Bq $\text{kg}^{-1}$	5.92E14	2.59E14	2.22E13	5.78E12	5.49E7	9.64E-2	kW $\text{kg}^{-1}$	2.25E-1	9.61E-2	3.83E-3	4.32E-6	5.11E-11	5.74E-18
V52	83.07	71.67					V52	88.16	77.87				
Ti51	9.66	11.77					Sc48	6.75	15.67	98.49			
Sc48	4.47	10.21	29.78				Ti51	5.03	6.27				
V49	2.09	4.78	55.56	99.68			V49			0.23	96.69		
Cr51	0.50	1.15	12.29				Sc46			0.04	2.00		
Sc47	0.16	0.36	2.07				Ca45				0.96		
H3			0.06	0.24	99.99		H3				0.30	98.37	
Ca45				0.05			K42					1.43	
Ca41						74.36	V50						99.34
V50						25.63	Ca41						0.65
Dose	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Ing	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{h}^{-1}$	2.45E5	1.09E5	6.39E3	1.40E0	2.49E-7	1.08E-11	Sv $\text{kg}^{-1}$	5.39E4	4.91E4	1.19E4	1.07E2	1.31E-2	1.72E-10
V52	87.96	74.67					Sc48	83.67	91.80	94.54			
Sc48	10.40	23.55	99.32				V52	12.78	5.30				
Ti51	1.60	1.92					Ti51	1.59	0.93				
Sc50	0.01	0.01					Sc47	0.95	1.05	2.08			
Cr51			0.24	0.13			V49	0.41	0.45	1.87	96.76		
V49			0.04	89.65			Ca45	0.02	0.02	0.09	2.22		
Sc46			0.04	10.12			Sc46	0.01	0.01	0.06	0.35		
K42					99.99*		H3				0.56	17.58	
V50						99.93	Ar42				0.01	82.22	
Ca41						0.06	V50						92.06
							Ca41						7.92
Inh	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Clear	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{kg}^{-1}$	3.58E4	3.26E4	8.28E3	2.17E2	4.47E-1	2.85E-10		8.22E11	3.31E11	6.71E9	1.02E7	5.50E2	3.54E-5
Sc48	81.50	89.33	87.65				V52	93.57	87.76				
V52	12.64	5.24					Sc48	3.22	8.00	98.26			
Sc47	1.95	2.14	4.04				Ti51	3.16	4.19				
Ti51	1.75	1.03					Sc46		0.01	0.75	24.96		
V49	1.17	0.45	5.05	90.16			Cr51			0.40	0.03		
Cr51	0.21	0.33	1.21				V49			0.23	73.27		
Ca45	0.16	0.18	0.69	5.72			Sc47			0.06			
Sc46	0.09	0.10	0.41	0.79			H3				1.40	99.85	
H3	0.01	0.01	0.04	1.71	3.18		Ar42					0.09	
Ar42		0.01	0.04	1.59	96.61		K42					0.04	
V50						95.46	V50						99.84
Ca41						4.53	Ca41						0.14

# Vanadium

## Pathway analysis

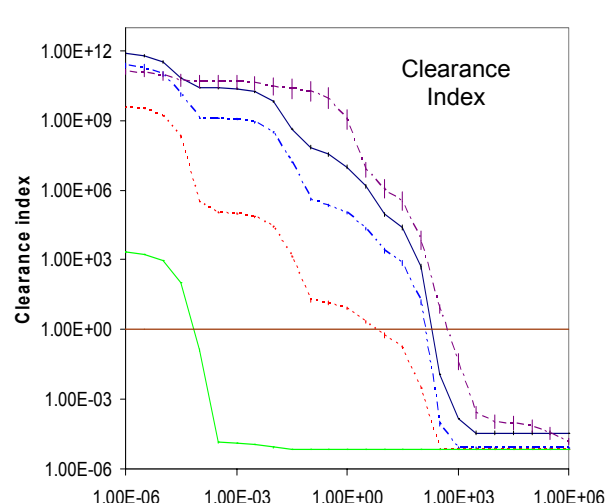
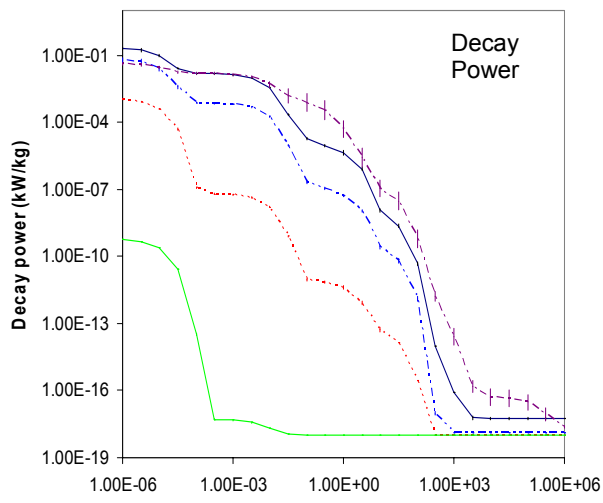
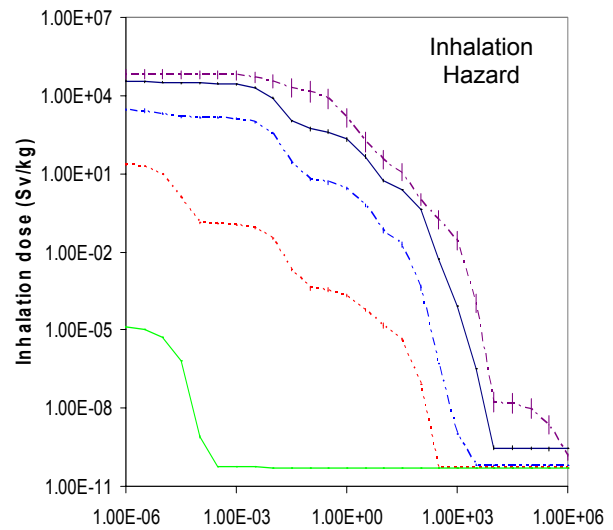
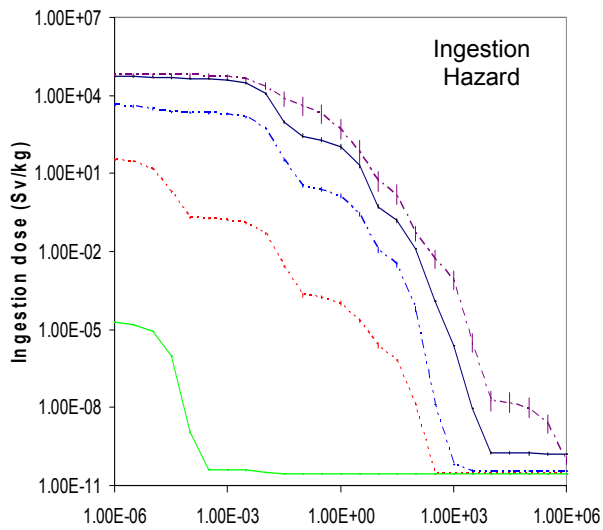
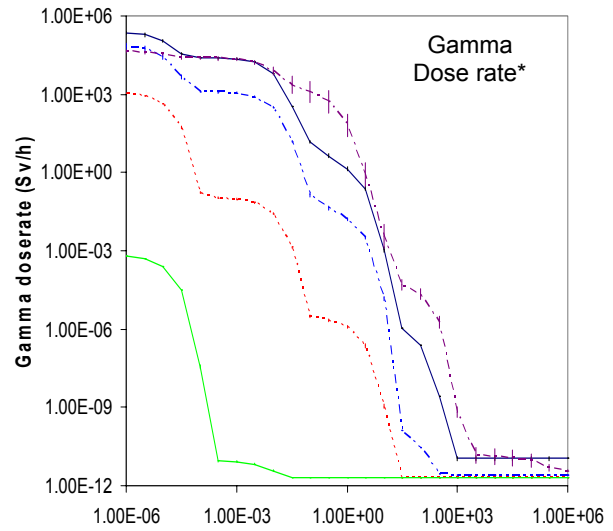
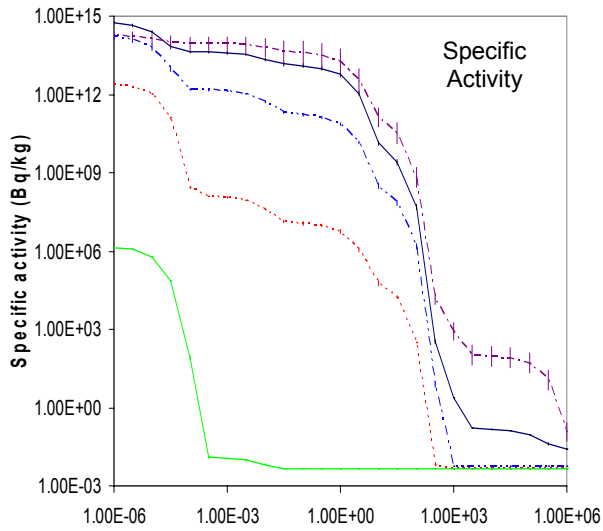
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	31	21	6
V52	3.745 m	V51(n,γ)V52 V50(n,γ)V51(n,γ)V52	99.8 0.2	99.8 0.2	100.0	98.3	99.4	99.6	99.8
Ti51	5.8 m	V50(n,p)Ti50(n,γ)Ti51 V51(n,p)Ti51	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Mn56	2.582 h	V51(n,γ)V52(β <sup>-</sup> )Cr52(n,γ)Cr53(n,γ)Cr54_ (n,γ)Cr55(β <sup>-</sup> )Mn55(n,γ)Mn56	99.9	99.8	100.0				
Sc44	3.97 h	&V51(n,3n)V49(n,α)Sc45(n,2n)Sc44 &V51(n,α)Sc47(β <sup>-</sup> )Ti47(n,t)Sc45(n,2n)Sc44   V51(n,3n)V49(β <sup>+</sup> )Ti49(n,α)Ca45(β <sup>-</sup> )_ Sc45(n,2n)Sc44 &V51(n,α)Sc47(β <sup>-</sup> )Ti47(n,2n)Ti46(n,t)Sc44   &V51(n,t)Ti49(n,α)Ca45(β <sup>-</sup> )Sc45(n,2n)Sc44   &V51(n,2n)V50(n,α)Sc46(n,3n)Sc44   &V51(n,2n)V50(n,α)Sc46(β <sup>-</sup> )Ti46(n,t)Sc44   &V51(n,2nα)Sc46(β <sup>-</sup> )Ti46(n,t)Sc44 &V51(n,3n)V49(n,2nα)Sc44 &V51(n,3nα)Sc45(n,2n)Sc44 &V51(n,2n)V50(n,3nα)Sc44 &V51(n,2nt)Ti47(n,nt)Sc44 &V51(n,nt)Ti48(n,2nt)Sc44					18.9 17.8 8.0 3.9 3.8 3.7 3.4 50.0 21.2	0.5 1.5 0.3 2.0 0.5 1.3 19.3 4.1 12.3 10.6 9.9 3.3	0.1
K42	12.36 h	V51(n,α)Sc48(β <sup>-</sup> )Ti48(n,α)Ca45(β <sup>-</sup> )Sc45_ (n,α)K42 V51(n,α)Sc47(β <sup>-</sup> )Ti47(n,α)Ca43(n,d)K42   V51(n,2n)V50(n,α)Sc46(n,α)K42 V51(n,3n)V49(n,2α)K42 V51(n,2nα)Sc46(β <sup>-</sup> )Ti46(n,α)K42 V51(n,α)Sc47(β <sup>-</sup> )Ti47(n,dα)K42 V51(n,t)Ti49(n,2nα)Ca44(n,t)K42 V51(n,3n)V49(β <sup>+</sup> )Ti49(n,2nα)Ca44(n,t)K42   V51(n,2n2α)K42 V51(n,nt)Ti48(n,tα)K42 V51(n,3nα)Sc45(n,α)K42 V51(n,2nt)Ti47(n,dα)K42				82.2	36.5 7.2 4.3	1.8 0.2 6.7 14.2 13.5 6.4 5.9	0.2 1.2 4.1 0.8 0.5 17.6 15.4 11.3 4.6
Sc48	1.82 d	V51(n,α)Sc48 V51(n,3n)V49(β <sup>+</sup> )Ti49(n,d)Sc48 V51(n,t)Ti49(n,d)Sc48 V51(n,d)Ti50(n,t)Sc48				98.2	63.6 22.2 6.0 0.7	30.6 29.1 25.7 9.5	69.6 8.3 11.6 6.8
Sc47	3.351 d	V51(n,2n)V50(n,α)Sc47 V51(n,α)Sc47 V51(n,d)Ti50(n,α)Ca47(β <sup>-</sup> )Sc47 V50(n,α)Sc47 V51(n,α)Sc48(β <sup>-</sup> )Ti48(n,d)Sc47 V51(n,3n)V49(β <sup>+</sup> )Ti49(n,t)Sc47 V51(n,t)Ti49(n,t)Sc47 V51(n,nt)Ti48(n,d)Sc47 V51(n,d)Ti50(n,nt)Sc47 V51(n,4n)V48(β <sup>+</sup> )Ti48(n,d)Sc47				70.1 20.4 2.8 1.6 1.5	1.3 93.2 0.2 0.2 0.5 1.0 0.3	0.4 74.6 0.2 0.2 0.2 10.1 8.9 1.1 0.2	2.1 58.5 0.2 0.2 0.7 7.3 10.2 10.6 4.4 2.4
V48	15.97 d	V51(n,2n)V50(n,2n)V49(n,2n)V48 V50(n,2n)V49(n,2n)V48 V51(n,2n)V50(n,3n)V48 V51(n,3n)V49(n,2n)V48 V50(n,3n)V48 V51(n,4n)V48				96.8 3.0	4.5 0.2 65.1 28.6 2.0 6.5	0.6 5.2 1.7 0.6 92.3	
Fe59	44.495 d	V51(n,γ)V52(β <sup>-</sup> )Cr52(n,γ)Cr53(n,γ)Cr54_ (n,γ)Cr55(β <sup>-</sup> )Mn55(n,γ)Mn56(β <sup>-</sup> )Fe56_ (n,γ)Fe57(n,γ)Fe58(n,γ)Fe59	99.9	99.8					

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	31	21	6
Sc46	83.79 d	&V51(n,2n)V50(n,2n)V49(n,α)Sc46 &V51(n,2n)V50(n,α)Sc47(β <sup>-</sup> )Ti47(n,d)Sc46 &V51(n,α)Sc48(β <sup>-</sup> )Ti48(n,2n)Ti47(n,d)Sc46 &V51(n,nα)Sc47(β <sup>-</sup> )Ti47(n,d)Sc46 &V50(n,2n)V49(n,α)Sc46 &V51(n,2n)V50(n,nα)Sc46 &V50(n,nα)Sc46 &V51(n,2nα)Sc46 &V51(n,nt)Ti48(n,t)Sc46 &V51(n,3n)V49(β <sup>+</sup> )Ti49(n,nt)Sc46 &V51(n,t)Ti49(n,nt)Sc46 &V51(n,4n)V48(β <sup>+</sup> )Ti48(n,t)Sc46				78.7 4.8 3.3 3.0 2.6 2.5	0.1 0.2 0.1 31.1 60.0 1.8	3.9	0.9 1.1 0.1 69.0 9.8 4.9 7.0 2.3
Ca45	163.0 d	V51(n,α)Sc48(β <sup>-</sup> )Ti48(n,α)Ca45 V51(n,2n)V50(n,2n)V49(β <sup>+</sup> )Ti49(n,2n) Ti48(n,α)Ca45 V51(n,2n)V50(n,d)Ti49(n,2n)Ti48(n,α)Ca45 V51(n,3n)V49(β <sup>+</sup> )Ti49(n,nα)Ca45 V51(n,t)Ti49(n,nα)Ca45 V51(n,2n)V50(n,2n)V49(β <sup>+</sup> )Ti49(n,nα)Ca45 V51(n,2n)V50(n,d)Ti49(n,nα)Ca45 V51(n,nα)Sc47(β <sup>-</sup> )Ti47(n,h)Ca45 V51(n,d)Ti50(n,2nα)Ca45 V51(n,2n)V50(n,dα)Ca45 V51(n,nt)Ti48(n,α)Ca45 V51(n,tα)Ca45				86.0 3.4 1.6	1.2 0.2	0.2	0.7 4.1 5.9 0.5 0.7 4.0 2.0 10.2 63.9
V49	330.0 d	V51(n,2n)V50(n,2n)V49 V50(n,2n)V49 V51(n,3n)V49				96.9 3.0	13.7 0.6 85.6	2.7 0.2 97.0	2.2 0.3 97.4
Co60	5.271 y	Very long pathways of (n,γ), β <sup>-</sup> , see Fe59	100.0						
H3	12.33 y	V50(n,X)H1(n,γ)H2(n,γ)H3 V51(n,2n)V50(n,X)H3 V51(n,X)H3 V50(n,X)H3 V51(n,3n)V49(β <sup>+</sup> )Ti49(n,X)H3 V51(n,t)Ti49(n,X)H3	92.9	93.7	99.3	60.6 36.2 2.8	8.5 87.8 0.5 0.8 0.3	2.7 92.1 0.4 1.2 1.3	1.3 94.1 0.3 0.6 0.9
Ar42	33.0 y	V51(n,α)Sc48(β <sup>-</sup> )Ti48(n,α)Ca45(n,α)Ar42 V51(n,2n)V50(n,d)Ti49(n,2n)Ti48(n,α) Ca45(n,α)Ar42 V51(n,d)Ti50(n,nα)Ca46(n,nα)Ar42 V51(n,3n)V49(β <sup>+</sup> )Ti49(n,α)Ca46(n,nα)Ar42 V51(n,3n)V49(β <sup>+</sup> )Ti49(n,nα)Ca45(n,α)Ar42 V51(n,t)Ti49(n,α)Ca46(n,nα)Ar42 V51(n,3n)V49(β <sup>+</sup> )Ti49(n,2α)Ar42 V51(n,t)Ti49(n,2α)Ar42 V51(n,dα)Ca46(n,nα)Ar42 V51(n,d)Ti50(n,n2α)Ar42 V51(n,tα)Ca45(n,α)Ar42				91.9 0.9	0.2 37.8 15.2 9.9 5.9 4.8 1.6	4.5 4.5 0.8 2.5 21.5 23.0 23.5 0.1	0.5 0.6 0.2 1.1 3.8 6.5 24.8 19.2 7.7
Ni63	100.6 y	Very long pathways of (n,γ), β <sup>-</sup> , see Fe59	100.0						
Ar39	269.0 y	V51(n,α)Sc48(β <sup>-</sup> )Ti48(n,α)Ca45(β <sup>-</sup> )Sc45 (n,α)K42(β <sup>-</sup> )Ca42(n,α)Ar39 V51(n,nα)Sc47(β <sup>-</sup> )Ti47(n,2n)Ti46(n,α) Ca43(n,nα)Ar39 &V51(n,2n)V50(n,2n)V49(n,α)Sc46(β <sup>-</sup> ) Ti46(n,α)Ca43(n,nα)Ar39 V51(n,2n)V50(n,α)Sc47(β <sup>-</sup> )Ti47(n,2n) Ti46(n,α)Ca43(n,nα)Ar39 V51(n,nα)Sc47(β <sup>-</sup> )Ti47(n,α)Ca44(n,2n) Ca43(n,nα)Ar39 V51(n,α)Sc48(β <sup>-</sup> )Ti48(n,2n)Ti47(n,2n) Ti46(n,α)Ca43(n,nα)Ar39 ▶ V51(n,nα)Sc47(β <sup>-</sup> )Ti47(n,nα)Ca43(n,nα)Ar39				22.2 8.6 8.2 5.9 4.5 4.1 3.5	0.3 0.3	1.6	

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	31	21	6	
	◀	V51(n,2n)V50(n,α)Sc47(β <sup>-</sup> )Ti47(n,α) <sub>-</sub> Ca43(n,α)Ar39 V51(n,2n)V50(n,α)Sc47(β <sup>-</sup> )Ti47(n,α) <sub>-</sub> Ca44(n,2n)Ca43(n,α)Ar39 &V51(n,2n)V50(n,2n)V49(n,α)Sc46(β <sup>-</sup> ) Ti46(n,α)Ca42(n,α)Ar39 V51(n,α)Sc48(β <sup>-</sup> )Ti48(n,2n)Ti47(n,α) <sub>-</sub> Ca44(n,2n)Ca43(n,α)Ar39 V51(n,α)Sc48(β <sup>-</sup> )Ti48(n,2n)Ti47(n,α) <sub>-</sub> Ca43(n,α)Ar39 V51(n,2n)V50(n,α)Sc47(β <sup>-</sup> )Ti47(n,2n) <sub>-</sub> Ti46(n,α)Ca42(n,α)Ar39 V51(n,α)Sc48(β <sup>-</sup> )Ti48(n,α)Ca45(n,2n) <sub>-</sub> Ca44(n,2n)Ca43(n,α)Ar39 &V51(n,2n)V50(n,α)Sc46(β <sup>-</sup> )Ti46(n,α) <sub>-</sub> Ca43(n,α)Ar39 &V51(n,2n)V50(n,α)Sc46(β <sup>-</sup> )Ti46_ (n,α)Ca42(n,α)Ar39 V51(n,α)Sc47(β <sup>-</sup> )Ti47(n,2n)Ti46(n,2α)Ar39   V51(n,2n)V50(n,α)Sc46(β <sup>-</sup> )Ti46(n,2α)Ar39   V51(n,α)Sc47(β <sup>-</sup> )Ti47(n,2α)Ar39 V51(n,2nα)Sc46(β <sup>-</sup> )Ti46(n,2α)Ar39 V51(n,t)Ti49(n,2nα)Ca44(n,2nα)Ar39 V51(n,3n)V49(β <sup>+</sup> )Ti49(n,2nα)Ca44(n,2nα)Ar39   &V51(n,3n)V49(n,2nα)Sc44(β <sup>+</sup> )Ca44_ (n,2nα)Ar39 V51(n,2nα)Sc46(β <sup>-</sup> )Ti46(n,t)Sc44(β <sup>+</sup> ) Ca44(n,2nα)Ar39 &V51(n,3nα)Sc45(n,tα)Ar39 V51(n,nt)Ti48(n,2n2α)Ar39				3.1	0.2			
						3.1				
						2.7				
						2.2				
						2.1	0.2			
						2.0				
						1.1				
						0.4	0.2			
						0.1	0.9			
							6.5	0.4		
							5.1	0.2		
								15.5	2.9	
								11.7	0.5	
								8.6	0.5	
								6.9	0.2	
								6.3	0.1	
								4.0	0.3	
									39.8	
									11.2	
Ca41	1.0 10 <sup>5</sup> y	V51(n,α)Sc48(β <sup>-</sup> )Ti48(n,α)Ca45(β <sup>-</sup> ) Sc45(n,α)K42(β <sup>-</sup> )Ca42(n,2n)Ca41 V51(n,α)Sc47(β <sup>-</sup> )Ti47(n,2n)Ti46(n,α) <sub>-</sub> Ca42(n,2n)Ca41 &V51(n,2n)V50(n,2n)V49(n,α)Sc46(β <sup>-</sup> ) Ti46(n,α)Ca42(n,2n)Ca41 V51(n,2n)V50(n,α)Sc47(β <sup>-</sup> )Ti47(n,2n) <sub>-</sub> Ti46(n,α)Ca42(n,2n)Ca41 V51(n,α)Sc48(β <sup>-</sup> )Ti48(n,2n)Ti47(n,2n) <sub>-</sub> Ti46(n,α)Ca42(n,2n)Ca41 V51(n,α)Sc47(β <sup>-</sup> )Ti47(n,2n)Ti46(n,α) <sub>-</sub> Ca43(n,2n)Ca42(n,2n)Ca41 V51(n,α)Sc47(β <sup>-</sup> )Ti47(n,α)Ca43(n,2n) <sub>-</sub> Ca42(n,2n)Ca41 V51(n,2n)V50(n,α)Sc47(β <sup>-</sup> )Ti47(n,α) <sub>-</sub> Ca43(n,2n)Ca42(n,2n)Ca41 &V51(n,2n)V50(n,α)Sc46(β <sup>-</sup> )Ti46_ (n,α)Ca42(n,2n)Ca41 V51(n,α)Sc47(β <sup>-</sup> )Ti47(n,α)Ca43(n,3n)Ca41 V51(n,α)Sc47(β <sup>-</sup> )Ti47(n,2nα)Ca42(n,2n)Ca41 V51(n,α)Sc47(β <sup>-</sup> )Ti47(n,2n)Ti46(n,2nα)Ca41   V51(n,2nα)Sc46(β <sup>-</sup> )Ti46(n,2nα)Ca41 V51(n,α)Sc47(β <sup>-</sup> )Ti47(n,3nα)Ca41 V51(n,2nt)Ti47(n,3nα)Ca41 &V51(n,3nα)Sc45(n,2nt)Ca41				54.5				
						7.1	4.3			
						6.8				
						4.9				
						3.4				
						2.2				
						1.1	2.7			
						0.8				
						0.3	3.2			
							56.7	1.2		
							7.1	2.1	0.2	
							2.4	2.4	0.2	
								66.0	18.2	
								0.2	13.1	
									14.7	
									12.6	
Cl36	3.0 10 <sup>5</sup> y	V51(n,α)Sc48(β <sup>-</sup> )Ti48(n,α)Ca45(β <sup>-</sup> )Sc45_ (n,α)K41(n,α)Cl37(n,2n)Cl36 V51(n,α)Sc48(β <sup>-</sup> )Ti48(n,α)Ca45(β <sup>-</sup> )Sc45_ (n,α)K41(n,2n)K40(n,α)Cl36 V51(n,α)Sc47(β <sup>-</sup> )Ti47(n,α)Ca44(n,α) <sub>-</sub> Ar41(β <sup>-</sup> )K41(n,α)Cl37(n,2n)Cl36				20.6				
						15.9				
						9.5				
	▶									

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	31	21	6	
	◀	V51(n,α)Sc47(β <sup>-</sup> )Ti47(n,α)Ca44(n,α)_ Ar41(β <sup>-</sup> )K41(n,2n)K40(n,α)Cl36 V51(n,α)Sc47(β <sup>-</sup> )Ti47(n,α)Ca43_ (n,2n)Ar38(n,t)Cl36 &V51(n,3n)V49(n,α)Sc45(n,α)K41_ (n,2n)Cl36 V51(n,α)Sc47(β <sup>-</sup> )Ti47(n,t)Sc45(n,α)_ K41(n,2n)Cl36 V51(n,α)Sc47(β <sup>-</sup> )Ti47(n,α)Ca43(n,t)_ K41(n,2n)Cl36 V51(n,2n)Sc46(β <sup>-</sup> )Ti46(n,2n)Ca41_ (n,d)Cl36 V51(n,2n)Sc46(β <sup>-</sup> )Ti46(n,2n)Ar38(n,t)Cl36 V51(n,2n)Sc46(β <sup>-</sup> )Ti46(n,d)K41(n,2n)Cl36 &V51(n,3n)Sc45(n,2n)Cl36 V51(n,nt)Ti48(n,3n)Ca42(n,t)Cl36 V51(n,t)Ca45(β <sup>-</sup> )Sc45(n,2n)Cl36				7.3		11.2	0.9	
Fe60	1.5 10 <sup>6</sup> y	V51(n,γ)V52(β <sup>-</sup> )Cr52(n,γ)Cr53(n,γ)Cr54_ (n,γ)Cr55(β <sup>-</sup> )Mn55(n,γ)Mn56(β <sup>-</sup> )Fe56_ (n,γ)Fe57(n,γ)Fe58(n,γ)Fe59(n,γ)Fe60	100.0							
K40	1.3 10 <sup>9</sup> y	V51(n,α)Sc48(β <sup>-</sup> )Ti48(n,α)Ca45(β <sup>-</sup> )Sc45_ (n,α)K41(n,2n)K40 V51(n,α)Sc47(β <sup>-</sup> )Ti47(n,α)Ca44(n,α)_ Ar41(β <sup>-</sup> )K41(n,2n)K40 V51(n,2n)V50(n,α)Sc47(β <sup>-</sup> )Ti47(n,α)_ Ca44(n,α)Ar41(β <sup>-</sup> )K41(n,2n)K40 V51(n,α)Sc48(β <sup>-</sup> )Ti48(n,2n)Ti47(n,α)_ Ca44(n,α)Ar41(β <sup>-</sup> )K41(n,2n)K40 V51(n,α)Sc48(β <sup>-</sup> )Ti48(n,α)Ca45(n,2n)_ Ca44(n,α)Ar41(β <sup>-</sup> )K41(n,2n)K40 &V51(n,3n)V49(n,α)Sc45(n,2n)K40 &V51(n,α)Sc47(β <sup>-</sup> )Ti47(n,t)Sc45(n,2n)K40 &V51(n,3n)V49(n,α)Sc45(n,α)K41_ (n,2n)K40 V51(n,α)Sc47(β <sup>-</sup> )Ti47(n,2n)Ca42(n,t)K40 V51(n,α)Sc47(β <sup>-</sup> )Ti47(n,α)Ca43(n,3n)_ Ca41(n,d)K40 V51(n,3n)V49(β <sup>+</sup> )Ti49(n,α)Ca45(β <sup>-</sup> )_ Sc45(n,2n)K40 V51(n,2n)V50(n,2n)Sc45(n,2n)K40 &V51(n,2n)Sc46(β <sup>-</sup> )Ti46(n,d)Sc45_ (n,2n)K40 &V51(n,2n)Sc46(β <sup>-</sup> )Ti46(n,α)Ca42(n,t)K40 &V51(n,2n)Sc46(β <sup>-</sup> )Ti46(n,t)K40 &V51(n,3n)Sc45(n,2n)K40				38.7 16.4 11.4 7.8 3.9		11.5 9.9 6.6	5.7 13.9	0.2
V50	1.4 10 <sup>17</sup> y	V51(n,2n)V50 Nuclide also present in starting material	100.0	100.0	100.0	97.5 2.5	96.9 3.1	93.7 6.3	90.0 10.0	

# Vanadium activation characteristics



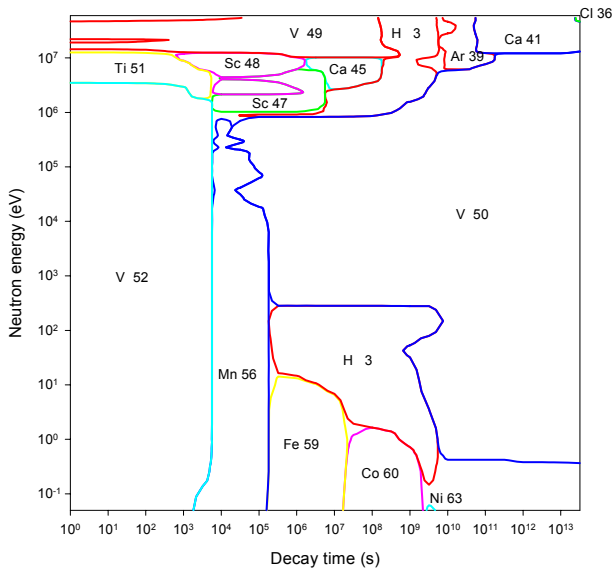
Decay time (years)

Decay time (years)

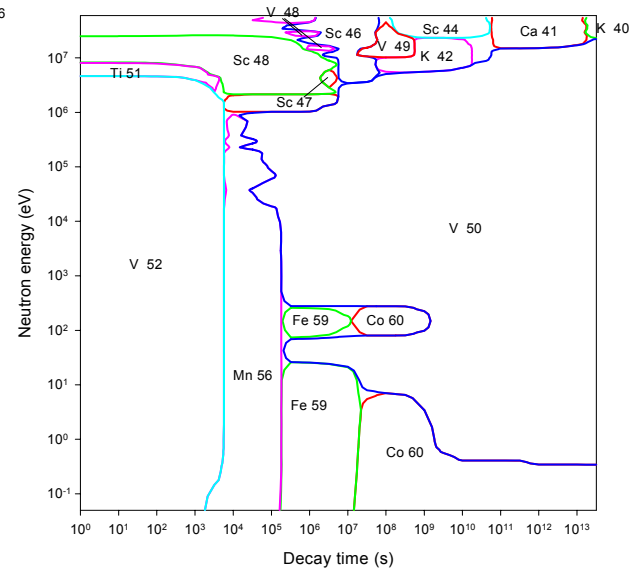


# Vanadium importance diagrams & transmutation

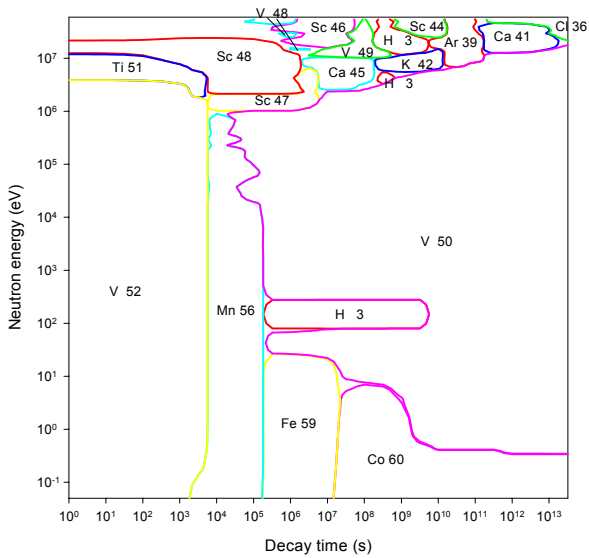
Activity



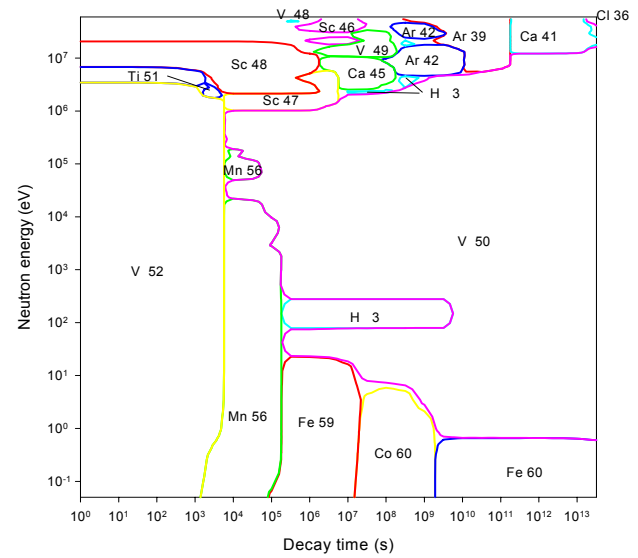
Dose rate



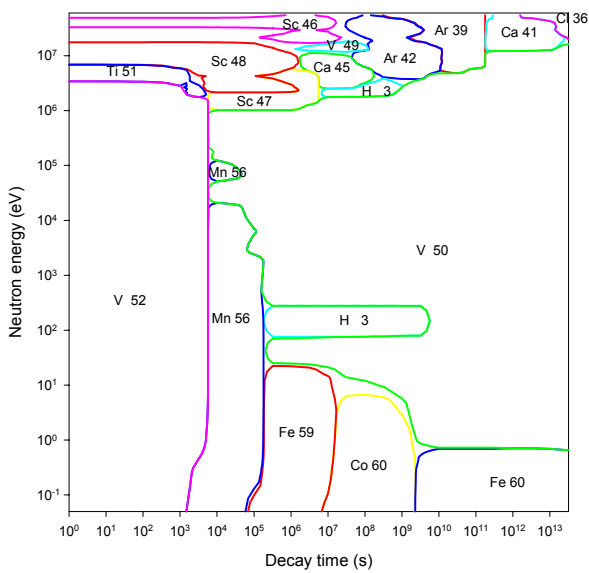
Heat output



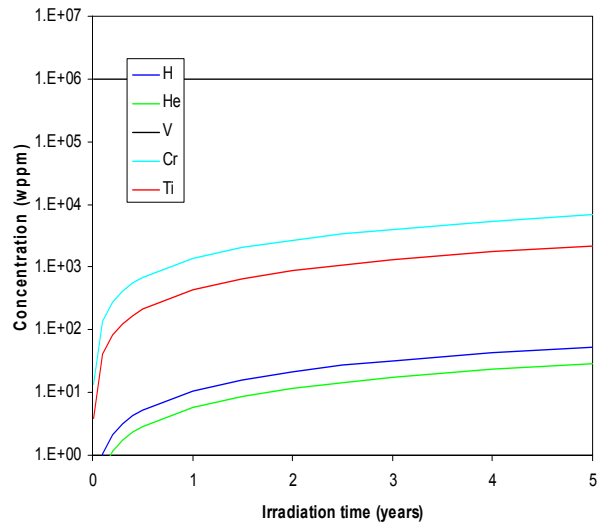
Ingestion dose



Inhalation dose



First wall transmutation





# Chromium

## General properties

Atomic number	24	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	102	Cr50	4.345 ( $T_{1/2} = 1.80 \cdot 10^{17}$ y)
Melting point / K	2180	Cr52	83.789
Boiling point / K	2944	Cr53	9.501
Density / $\text{kgm}^{-3}$	7190	Cr54	2.365
Thermal conductivity / $\text{Wm}^{-1}\text{K}^{-1}$	93.7		
Electrical resistivity / $\Omega\text{m}$	$1.27 \cdot 10^{-7}$		
Coefficient of thermal expansion / $\text{K}^{-1}$	$4.9 \cdot 10^{-6}$		
Crystal structure	BCC		
Number of stable isotopes	3 (4)		
Mean atomic weight	51.9961		

## Activation properties

Act	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Heat	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Bq $\text{kg}^{-1}$	5.70E14	4.85E14	3.99E14	7.54E12	1.29E7	2.15E1	kW $\text{kg}^{-1}$	5.58E-2	2.20E-2	2.29E-3	6.59E-6	1.18E-11	2.99E-17
Cr51	73.58	86.50	95.96	5.97			V52	89.12	85.40				
V52	21.67	9.62					Cr51	4.38	11.11	97.56	3.98		
V49	2.82	3.32	4.00	99.28			V53	4.34	1.16				
V53	1.29	0.16					Cr49	0.35	0.82				
Ti51	0.16	0.10					Sc48	0.19	0.50	1.12			
Cr55	0.16	0.07					V49		0.05	0.50	82.39		
Cr49	0.13	0.14					Sc46		0.01	0.13	2.38		
Sc48	0.03	0.04	0.01				Mn54			0.07	11.17		
H3				0.04	100.0		H3				0.04	99.78	
Mn53						99.33	Mn53						94.13
V50						0.67	V50						5.75
							Ca41						0.11
Dose	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Ing	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{h}^{-1}$	5.86E4	2.30E4	2.22E3	3.11E0	6.76E-9	6.50E-12	Sv $\text{kg}^{-1}$	1.85E4	1.74E4	1.50E4	1.41E2	9.25E-4	7.39E-10
V52	90.37	86.99					Cr51	86.10	91.70	97.00	1.21		
Cr51	4.01	10.22	96.67	8.12			V52	9.34	3.75				
V53	3.70	0.99					Sc48	1.78	1.90	0.54			
V54	1.15	0.03					V49	1.56	1.66	1.91	95.37		
Sc48	0.31	0.79	2.05				Sc46	0.07	0.08	0.09	0.49		
Sc46		0.02	0.22	8.15			Mn54	0.04	0.05	0.05	2.75		
V49		0.01	0.13	45.06			H3				0.09	58.37	
Mn54		0.01	0.12	38.67			Ar42					32.23	
K42					99.72*		Ar39					9.39	
Mn53					0.09	94.13	Mn53						86.61
V50					0.01	5.76	Cr50						10.46
Ca41						0.39	Ca41						2.12
							V50						0.76
Inh	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Clear	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{kg}^{-1}$	1.77E4	1.69E4	1.49E4	2.69E2	1.83E-2	1.25E-9		2.10E11	7.95E10	4.13E9	6.95E7	1.29E2	2.21E-4
Cr51	87.80	91.65	94.97	0.62			V52	90.02	91.67				
V52	6.43	2.53					V53	4.00	1.11				
V49	3.09	3.23	3.64	94.61			Cr51	1.99	5.27	92.61	0.64		
Sc48	1.21	1.26	0.35				V54	1.09	0.03				
Sc46	0.36	0.38	0.41	1.16			Cr49	0.39	0.95				
V48	0.34	0.35	0.34				Sc48	0.09	0.24	1.17			
Sc47	0.18	0.18	0.10				Mn54	0.05	0.15	2.95	78.69		
Mn54	0.10	0.10	0.12	3.05			Sc46	0.04	0.11	2.22	6.64		
H3				0.32	18.29		V49		0.02	0.50	13.97		
Ar42				0.03	65.28		H3				0.04	99.98	
Ar39					16.43		Mn53						96.28
Mn53						91.85	Cr50						3.12
Ca41						1.21	V50						0.56
V50						0.76	Ca41						0.02

# Chromium

## Pathway analysis

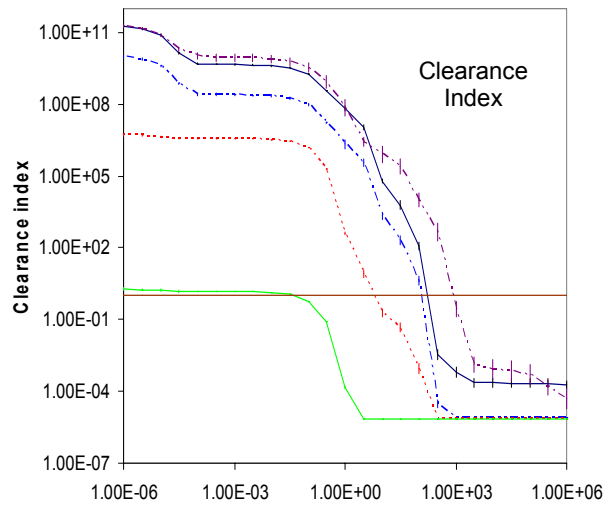
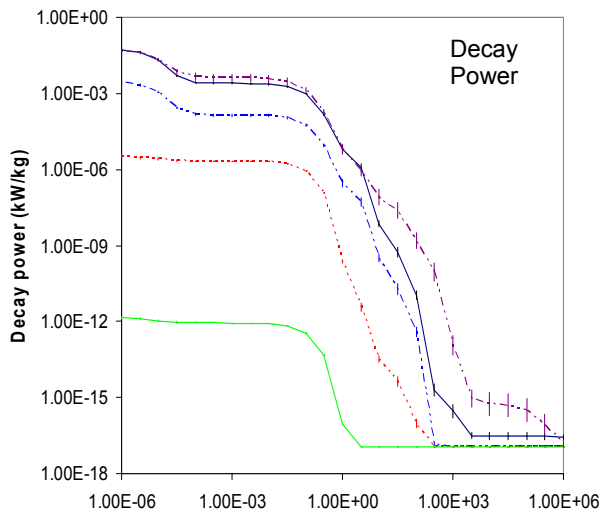
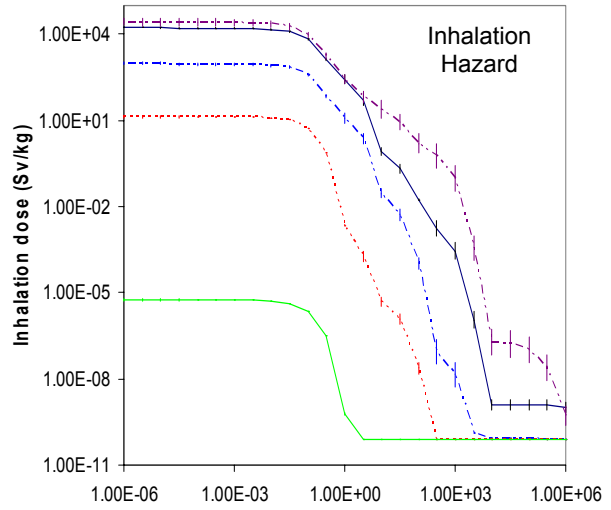
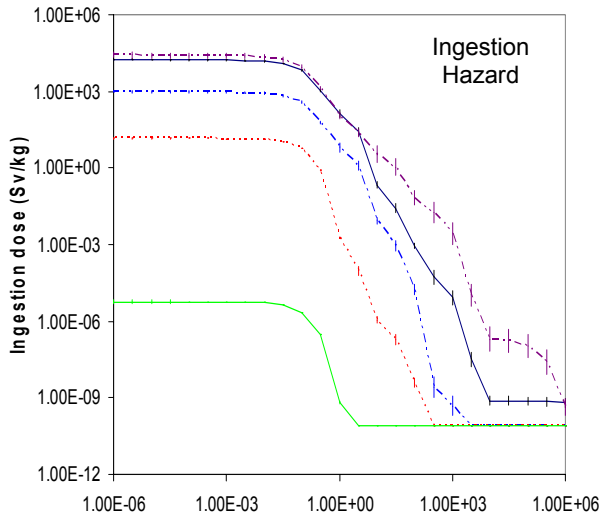
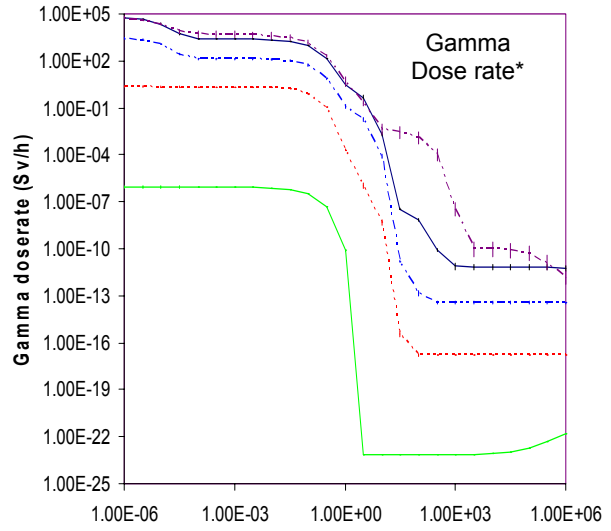
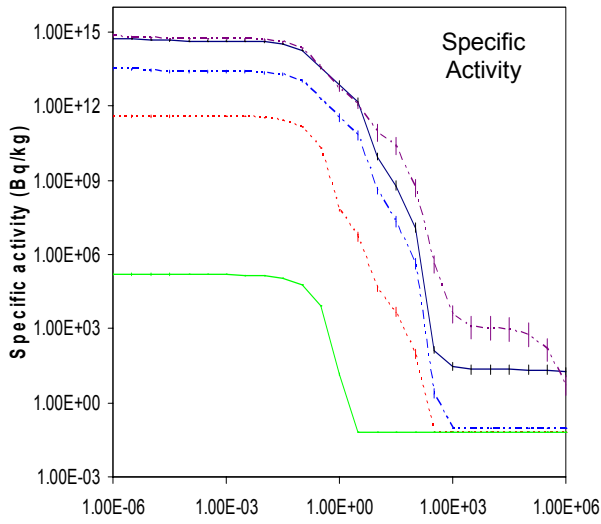
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Cr55	3.54 m	Cr53(n,γ)Cr54(n,γ)Cr55	62.4	12.3	0.7				
		Cr54(n,γ)Cr55	25.1	87.7	99.3	99.2	99.3	99.5	99.8
		Cr52(n,γ)Cr53(n,γ)Cr54(n,γ)Cr55	12.6						
V52	3.745 m	Cr50(n,γ)Cr51(β <sup>+</sup> )V51(n,γ)V52	99.7	100.0	100.0				
		Cr52(n,p)V52				97.2	59.7	50.0	38.1
		Cr53(n,2n)Cr52(n,p)V52				1.6	0.3	0.3	0.1
		Cr53(n,d)V52				1.0	37.7	40.1	48.6
		Cr54(n,t)V52					0.7	8.6	12.4
Mn56	2.582 h	Cr53(n,γ)Cr54(n,γ)Cr55(β <sup>-</sup> )Mn55(n,γ)Mn56	56.5	6.6	0.3				
		Cr54(n,γ)Cr55(β <sup>-</sup> )Mn55(n,γ)Mn56	35.9	93.4	99.7	99.0	99.6	99.7	99.9
		Cr52(n,γ)Cr53(n,γ)Cr54(n,γ)Cr55(β <sup>-</sup> )Mn55(n,γ)Mn56	7.5						
Sc44	3.97 h	&Cr50(n,α)Ti47(n,2n)Ti46(n,d)Sc45(n,2n)Sc44				21.0			
		&Cr52(n,α)Ti49(n,2n)Ti48(n,α)Ca45(β <sup>-</sup> )Sc45(n,2n)Sc44				20.1			
		&Cr52(n,α)Ti49(n,α)Ca46(n,2n)Ca45(β <sup>-</sup> )Sc45(n,2n)Sc44				9.8			
		&Cr50(n,nα)Ti46(n,d)Sc45(n,2n)Sc44				4.8	17.2	1.2	
		&Cr52(n,nα)Ti48(n,α)Ca45(β <sup>-</sup> )Sc45(n,2n)Sc44				1.7	6.6		
		&Cr50(n,nα)Ti46(n,2n)Ti45(β <sup>+</sup> )Sc45(n,2n)Sc44				0.8	7.1		
		&Cr50(n,nα)Ti46(n,t)Sc44					18.8	17.4	1.2
		&Cr52(n,nα)Ti48(n,3n)Ti46(n,t)Sc44					2.7	7.7	0.2
		&Cr52(n,3n)Cr50(n,nα)Ti46(n,t)Sc44					1.3	5.0	0.1
		&Cr52(n,2nα)Ti47(n,nt)Sc44						3.1	11.3
		&Cr52(n,nt)V49(n,2nα)Sc44						0.9	4.4
		&Cr50(n,tα)Sc44							19.5
		&Cr52(n,3nα)Ti46(n,t)Sc44							11.2
		&Cr52(n,t)V50(n,3nα)Sc44							9.7
&Cr52(n,3n)Cr50(n,tα)Sc44							6.0		
K42	12.36 h	&Cr50(n,α)Ti47(n,2n)Ti46(n,d)Sc45(n,α)K42				21.1			
		Cr52(n,α)Ti49(n,2n)Ti48(n,α)Ca45(β <sup>-</sup> )Sc45(n,α)K42				19.4			
		Cr52(n,α)Ti49(n,α)Ca46(n,2n)Ca45(β <sup>-</sup> )Sc45(n,α)K42				9.5			
		&Cr50(n,nα)Ti46(n,d)Sc45(n,α)K42				4.9	2.6		
		Cr50(n,α)Ti47(n,2n)Ti46(n,2n)Ti45(β <sup>+</sup> )Sc45(n,α)K42				3.4			
		Cr50(n,α)Ti47(n,2n)Ti46(n,α)Ca43(n,d)K42				3.0			
		Cr50(n,nα)Ti46(n,pα)K42					37.0	5.4	0.2
		Cr52(n,nα)Ti48(n,3n)Ti46(n,pα)K42					5.8	2.5	
		Cr52(n,nα)Ti48(n,2n)Ti47(n,nα)Ca43(n,d)K42					3.6		
		Cr50(n,2α)Ca43(n,d)K42					3.3	1.9	
		Cr52(n,nα)Ti48(n,nα)Ca44(n,t)K42					3.2	5.1	0.2
		Cr52(n,2nα)Ti47(n,dα)K42						16.0	11.9
		Cr52(n,nα)Ti48(n,2nα)Ca43(n,d)K42						5.5	0.3
		Cr52(n,t)V50(n,2nα)K42						1.6	7.5
		Cr52(n,2nα)Ca44(n,t)K42						0.8	5.0
		Cr50(n,α)Ti47(n,dα)K42						0.5	3.6
		Cr52(n,nα)Ti48(n,tα)K42							5.4
Sc47	3.351 d	Cr50(n,α)Ti47(n,p)Sc47				29.1			0.1
		Cr52(n,2n)Cr51(β <sup>+</sup> )V51(n,2n)V50(n,α)Sc47				20.8	0.3		
		Cr50(n,p)V50(n,α)Sc47				17.1			
		Cr52(n,2n)Cr51(β <sup>+</sup> )V51(n,nα)Sc47				12.4	37.5	16.6	2.5
		Cr52(n,d)V51(n,2n)V50(n,α)Sc47				6.2	0.1		
		Cr52(n,d)V51(n,nα)Sc47				3.6	17.6	10.5	1.7

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	Cr52(n,n $\alpha$ )Ti48(n,d)Sc47 Cr52(n, $\alpha$ )Ti49(n,t)Sc47 Cr50(n,t)V48( $\beta^+$ )Ti48(n,d)Sc47 Cr52(n,t)V50(n, $\alpha$ )Sc47 Cr52(n,d $\alpha$ )Sc47 Cr52(n,nt)V49( $\beta^+$ )Ti49(n,t)Sc47				0.1	34.4	21.7	3.5
V48	15.97 d	Cr50(n,d)V49(n,2n)V48 Cr50(n,p)V50(n,2n)V49(n,2n)V48 Cr52(n,2n)Cr51( $\beta^+$ )V51(n,2n)V50(n,2n)_ V49(n,2n)V48 Cr50(n,2n)Cr49( $\beta^+$ )V49(n,2n)V48 Cr50(n,t)V48 Cr52(n,2n)Cr51( $\beta^+$ )V51(n,2n)V50(n,3n)V48   Cr52(n,3n)Cr50(n,t)V48 Cr52(n,2n)Cr51( $\beta^+$ )V51(n,3n)V49(n,2n)V48   Cr52(n,t)V50(n,3n)V48 Cr52(n,2nt)V48				75.8 7.6 7.4  6.6	8.2  0.5  3.6	0.2    49.0	0.1    46.3
Cr51	27.703 d	Cr50(n, $\gamma$ )Cr51 Cr52(n,2n)Cr51 Cr53(n,2n)Cr52(n,2n)Cr51 Cr53(n,3n)Cr51 Cr54(n,4n)Cr51	100.0	99.9	100.0	97.0 1.6	93.8 1.0	87.1 0.5	88.7 0.3
Sc46	83.79 d	&Cr50(n,d)V49(n, $\alpha$ )Sc46 &Cr50(n, $\alpha$ )Ti47(n,d)Sc46 &Cr50(n, $\alpha$ )Ti47(n,2n)Ti46(n,p)Sc46 &Cr52(n,2n)Cr51( $\beta^+$ )V51(n,2n)V50(n,n $\alpha$ )Sc46   &Cr50(n,p $\alpha$ )Sc46 &Cr52(n,n $\alpha$ )Ti48(n,2n)Ti47(n,d)Sc46 &Cr52(n,n $\alpha$ )Ti48(n,t)Sc46 &Cr52(n,t)V50(n,n $\alpha$ )Sc46 &Cr52(n,2n)Cr51( $\beta^+$ )V51(n,2n $\alpha$ )Sc46 &Cr52(n,2n $\alpha$ )Ti47(n,d)Sc46 &Cr52(n,d)V51(n,2n $\alpha$ )Sc46 &Cr52(n,t $\alpha$ )Sc46 &Cr52(n,nt)V49( $\beta^+$ )Ti49(n,nt)Sc46				38.7 35.9 8.2 0.1	0.6 1.9  10.3	0.2 0.2  0.3	1.2   1.7
Ca45	163.0 d	Cr52(n, $\alpha$ )Ti49(n,2n)Ti48(n, $\alpha$ )Ca45 Cr52(n, $\alpha$ )Ti49(n, $\alpha$ )Ca46(n,2n)Ca45 Cr50(n,d)V49( $\beta^+$ )Ti49(n,2n)Ti48(n, $\alpha$ )Ca45   Cr52(n,2n)Cr51( $\beta^+$ )V51(n, $\alpha$ )Sc48( $\beta^-$ )_ Ti48(n, $\alpha$ )Ca45 Cr50(n,d)V49( $\beta^+$ )Ti49(n, $\alpha$ )Ca46(n,2n)Ca45   Cr52(n,n $\alpha$ )Ti48(n, $\alpha$ )Ca45 Cr52(n, $\alpha$ )Ti49(n,n $\alpha$ )Ca45 Cr50(n,d)V49( $\beta^+$ )Ti49(n,n $\alpha$ )Ca45 Cr53(n,n $\alpha$ )Ti49(n,n $\alpha$ )Ca45 Cr50(n,2n)Cr49( $\beta^+$ )V49( $\beta^+$ )Ti49(n,2n $\alpha$ )Ca45   Cr52(n,2 $\alpha$ )Ca45 Cr52(n,t)V50(n,d $\alpha$ )Ca45 Cr52(n,2n $\alpha$ )Ti47(n,h)Ca45 Cr52(n,h)Ti50(n,2n $\alpha$ )Ca45 Cr52(n,nt)V49( $\beta^+$ )Ti49(n,n $\alpha$ )Ca45 Cr53(n,2 $\alpha$ )Ca45 Cr52(n,2n)Cr51( $\beta^+$ )V51(n,t $\alpha$ )Ca45				40.2 19.6 8.8 8.4  4.3 2.2 0.3	0.2 0.2 0.1   35.1 17.6 11.5	9.5 4.5 3.4 1.9 1.0 29.7 8.6 6.6 4.8 2.1 0.2	0.1     7.7 6.0 0.7 0.3 0.2 7.1 9.1 4.2 3.0 20.9 4.4 5.3
V49	330.0 d	Cr50(n,d)V49 Cr50(n,p)V50(n,2n)V49 Cr52(n,2n)Cr51( $\beta^+$ )V51(n,2n)V50(n,2n)V49   Cr50(n,2n)Cr49( $\beta^+$ )V49 Cr52(n,2n)Cr51( $\beta^+$ )V51(n,3n)V49 Cr52(n,d)V51(n,3n)V49 Cr52(n,3n)Cr50(n,d)V49 Cr52(n,t)V50(n,2n)V49				75.5 7.7 7.6 6.6	34.8 0.1 2.1 15.2	19.8  0.3 6.0	2.8   0.7

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	Cr52(n,nt)V49 Cr52(n,4n)Cr49(β <sup>+</sup> )V49						12.2	83.6 6.1
Co60	5.271 y	&Cr54(n,γ)Cr55(β <sup>-</sup> )Mn55(n,γ)Mn56(β <sup>-</sup> ) Fe56(n,γ)Fe57(n,γ)Fe58(n,γ)Fe59(β <sup>-</sup> ) Co59(n,γ)Co60 &Cr53(n,γ)Cr54(n,γ)Cr55(β <sup>-</sup> )Mn55(n,γ) Mn56(β <sup>-</sup> )Fe56(n,γ)Fe57(n,γ)Fe58(n,γ) Fe59(β <sup>-</sup> )Co59(n,γ)Co60	65.5 33.0	97.8 2.2	99.9				
H3	12.33 y	Cr50(n,γ)Cr51(n,X)H1(n,γ)H2(n,γ)H3 Cr53(n,X)H3 Cr50(n,p)V50(n,X)H3 Cr52(n,2n)Cr51(β <sup>+</sup> )V51(n,X)H3 Cr52(n,d)V51(n,2n)V50(n,X)H3 Cr52(n,d)V51(n,X)H3 Cr52(n,X)H3 Cr50(n,X)H3 Cr54(n,X)H3 Cr52(n,t)V50(n,X)H3	93.3	95.3	99.4	69.7 8.9 6.7 2.2 2.0	16.3 4.1 0.1 2.0	12.6 1.7 0.8	11.0 1.1 0.8
Ar42	33.0 y	Cr52(n,α)Ti49(n,2n)Ti48(n,α)Ca45(n,α)Ar42 Cr52(n,α)Ti49(n,α)Ca46(n,2n)Ca45(n,α)Ar42 Cr50(n,d)V49(β <sup>+</sup> )Ti49(n,2n)Ti48(n,α) Ca45(n,α)Ar42 Cr50(n,d)V49(n,d)Ti48(n,α)Ca45(n,α)Ar42 Cr50(n,d)V49(β <sup>+</sup> )Ti49(n,α)Ca46(n,2n) Ca45(n,α)Ar42 Cr52(n,nα)Ti48(n,α)Ca45(n,α)Ar42 Cr52(n,α)Ti49(n,nα)Ca45(n,α)Ar42 Cr52(n,α)Ti49(n,α)Ca46(n,nα)Ar42 Cr52(n,nα)Ti48(n,nα)Ca44(n,h)Ar42 Cr52(n,nα)Ti48(n,h)Ca46(n,nα)Ar42 Cr50(n,d)V49(β <sup>+</sup> )Ti49(n,α)Ca46(n,nα)Ar42 Cr52(n,h)Ti50(n,nα)Ca46(n,nα)Ar42 Cr52(n,α)Ti49(n,2α)Ar42 Cr50(n,d)V49(β <sup>+</sup> )Ti49(n,2α)Ar42 Cr52(n,2α)Ca45(n,α)Ar42 Cr52(n,nt)V49(β <sup>+</sup> )Ti49(n,2α)Ar42 Cr52(n,2α)Ca44(n,h)Ar42 Cr52(n,h)Ti50(n,n2α)Ar42 &Cr50(n,tα)Sc44(β <sup>+</sup> )Ca44(n,h)Ar42				40.2 19.6 7.6 3.8 3.7 3.2 0.5 10.4 8.7 5.8 5.0 4.2 2.8 1.6 1.2 2.7 1.4 0.1	12.1 6.1 0.7 6.3 6.6 0.4 4.3 6.6 4.3 3.5 2.7 1.4 0.1	0.6 0.3 0.6 0.4 0.4 0.2 3.7 0.4 0.5 11.0 14.1 8.0	0.3 0.2 0.6 0.4 0.4 0.2 3.7 0.4 0.5 11.0 14.1 8.0
Ni63	100.6 y	Very long pathways of (n,γ), β <sup>-</sup>	100.0	100.0					
Ar39	269.0 y	Cr50(n,α)Ti47(n,2n)Ti46(n,α)Ca43(n,nα)Ar39 Cr50(n,α)Ti47(n,α)Ca44(n,2n)Ca43(n,nα)Ar39 Cr50(n,α)Ti47(n,nα)Ca43(n,nα)Ar39 Cr50(n,α)Ti47(n,2n)Ti46(n,nα)Ca42(n,α)Ar39 Cr50(n,nα)Ti46(n,α)Ca43(n,nα)Ar39 Cr50(n,nα)Ti46(n,2α)Ar39 Cr50(n,2α)Ca43(n,nα)Ar39 Cr52(n,nα)Ti48(n,nα)Ca44(n,2nα)Ar39 Cr52(n,2nα)Ti47(n,n2α)Ar39				27.0 14.3 11.1 9.1 8.3	1.5 2.7 0.1	47.8 4.7 2.6 6.9 18.5	0.1 0.1 0.1 9.5
Ca41	1.0 10 <sup>5</sup> y	Cr50(n,α)Ti47(n,2n)Ti46(n,nα)Ca42(n,2n)Ca41 Cr50(n,α)Ti47(n,2n)Ti46(n,α)Ca43(n,2n) Ca42(n,2n)Ca41 Cr50(n,nα)Ti46(n,nα)Ca42(n,2n)Ca41 Cr50(n,α)Ti47(n,α)Ca44(n,2n)Ca43 (n,2n)Ca42(n,2n)Ca41 Cr50(n,α)Ti47(n,nα)Ca43(n,2n)Ca42(n,2n)Ca41 Cr50(n,nα)Ti46(n,2nα)Ca41 Cr50(n,2α)Ca43(n,3n)Ca41 Cr52(n,nα)Ti48(n,3n)Ti46(n,2nα)Ca41 Cr52(n,3n)Cr50(n,nα)Ti46(n,2nα)Ca41 Cr52(n,2nα)Ti47(n,3nα)Ca41				35.9 11.2 11.1 5.9 5.8	34.2 0.3	14.2 30.0 6.8 2.1 1.5 9.3 0.7 6.0 0.2 0.2	1.6 0.2 0.2 17.3

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	Cr50(n,2n2α)Ca41 Cr52(n,3nα)Ti46(n,2nα)Ca41 Cr52(n,dα)Sc47(β <sup>-</sup> )Ti47(n,3nα)Ca41 Cr50(n,α)Ti47(n,3nα)Ca41							18.0 14.7 5.3 5.2
Cl36	3.0 10 <sup>5</sup> y	&Cr50(n,α)Ti46(n,d)Sc45(n,α)K41_ (n,2nα)Cl36 Cr50(n,α)Ti46(n,α)Ca42(n,t)K40(n,α)Cl36   Cr50(n,α)Ti46(n,α)Ca42(n,d)K41_ (n,2nα)Cl36 Cr50(n,α)Ti46(n,α)Ca42(n,α)Ar38_ (n,t)Cl36 Cr50(n,α)Ti46(n,2α)Ar38(n,t)Cl36 Cr50(n,α)Ti46(n,α)Ca42(n,3n)Ca40_ (n,pα)Cl36 Cr52(n,α)Ti48(n,α)Ca45(β <sup>-</sup> )Sc45(n,α)_ K41(n,2nα)Cl36 Cr50(n,α)Ti46(n,2nα)Ca41(n,dα)Cl36 Cr50(n,α)Ti46(n,dα)K41(n,2nα)Cl36 Cr50(n,dα)Sc45(n,2nα)K40(n,α)Cl36 Cr50(n,dα)Sc45(n,α)K41(n,2nα)Cl36 Cr50(n,2nα)Ti45(β <sup>+</sup> )Sc45(n,2nα)K40_ (n,α)Cl36 Cr52(n,α)Ti48(n,2nα)Ca43(n,2nα)Ar38 (n,t)Cl36 Cr52(n,2nα)Ti47(n,2nα)Ca42(n,tα)Cl36 Cr50(n,2nα)Ca42(n,tα)Cl36 Cr50(n,dα)Sc45(n,2n2α)Cl36 Cr50(n,2nα)Ti45(β <sup>+</sup> )Sc45(n,2n2α)Cl36 Cr50(n,2n2α)Ca41(n,dα)Cl36					6.8 6.3 5.9 5.0 2.6 2.3 2.0 0.7 0.7 4.0 3.2 2.4 2.4 2.4 0.7 0.3	0.1 0.1 5.0 0.1	0.1 0.2 0.1 0.1 2.4 7.4 5.6 3.8 2.5
Fe60	1.5 10 <sup>6</sup> y	Cr54(n,γ)Cr55(β <sup>-</sup> )Mn55(n,γ)Mn56(β <sup>-</sup> )_ Fe56(n,γ)Fe57(n,γ)Fe58(n,γ)Fe59(n,γ)Fe60 Cr53(n,γ)Cr54(n,γ)Cr55(β <sup>-</sup> )Mn55(n,γ)_ Mn56(β <sup>-</sup> )Fe56(n,γ)Fe57(n,γ)Fe58(n,γ)_ Fe59(n,γ)Fe60 Cr52(n,γ)Cr53(n,γ)Cr54(n,γ)Cr55(β <sup>-</sup> )_ Mn55(n,γ)Mn56(β <sup>-</sup> )Fe56(n,γ)Fe57(n,γ)_ Fe58(n,γ)Fe59(n,γ)Fe60	63.0 35.2 1.8	97.8 2.2	99.9 0.1				
Mn53	3.7 10 <sup>6</sup> y	Cr54(n,γ)Cr55(β <sup>-</sup> )Mn55(n,2n)Mn54(n,2n)Mn53   Cr54(n,γ)Cr55(β <sup>-</sup> )Mn55(n,3n)Mn53				99.9	2.0 97.9	0.6 99.3	0.5 99.5
K40	1.26 10 <sup>9</sup> y	Cr50(n,α)Ti47(n,α)Ca44(n,α)Ar41(β <sup>-</sup> )_ K41(n,2n)K40 Cr50(n,α)Ti46(n,α)Ca42(n,t)K40 Cr50(n,α)Ti46(n,d)Sc45(n,2nα)K40 &Cr50(n,dα)Sc45(n,2nα)K40 Cr50(n,2nα)Ti45(β <sup>+</sup> )Sc45(n,2nα)K40 Cr52(n,2nα)Ti47(n,2nα)Ca42(n,t)K40 Cr52(n,t)V50(n,2nα)Sc45(n,2nα)K40 Cr52(n,2nα)Ti47(n,t)Sc45(n,2nα)K40 Cr52(n,3nα)Ti46(n,tα)K40 Cr52(n,nt)V49(n,2n2α)K40 Cr52(n,tα)Sc46(β <sup>-</sup> )Ti46(n,tα)K40				80.5	28.2 5.1	0.8 0.7 24.4 13.2 6.8 6.7 5.8	3.5 1.7 0.7 0.5 0.5 30.4 5.5 5.4
V50	1.4 10 <sup>17</sup> y	Cr50(β <sup>+</sup> )V50 Cr52(n,2n)Cr51(β <sup>+</sup> )V51(n,2n)V50 Cr50(n,p)V50 Cr52(n,d)V51(n,2n)V50 Cr52(n,t)V50 Cr53(n,nt)V50	100.0	99.9	100.0	46.5 38.3 13.8	43.8 2.1 20.9 28.4	2.1 0.3 1.4 94.3 0.6	88.6 8.6
Cr50	1.8 10 <sup>17</sup> y	Cr52(n,3n)Cr50 Cr53(n,4n)Cr50 Nuclide also present in starting material	100.0	100.0	100.0	99.8	13.0 86.8	37.0 0.2 62.8	24.6 2.0 73.4

# Chromium activation characteristics



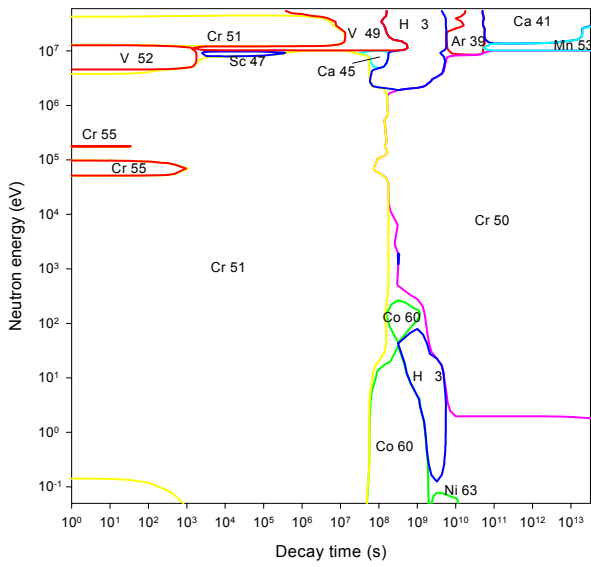
Decay time (years)

Decay time (years)

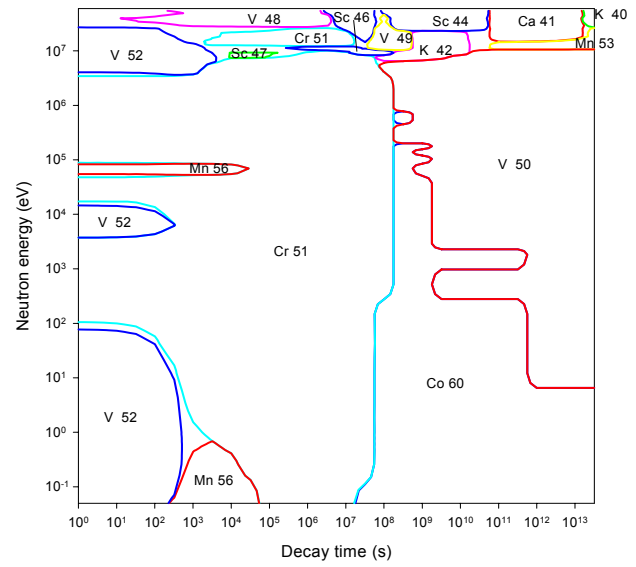


# Chromium importance diagrams & transmutation

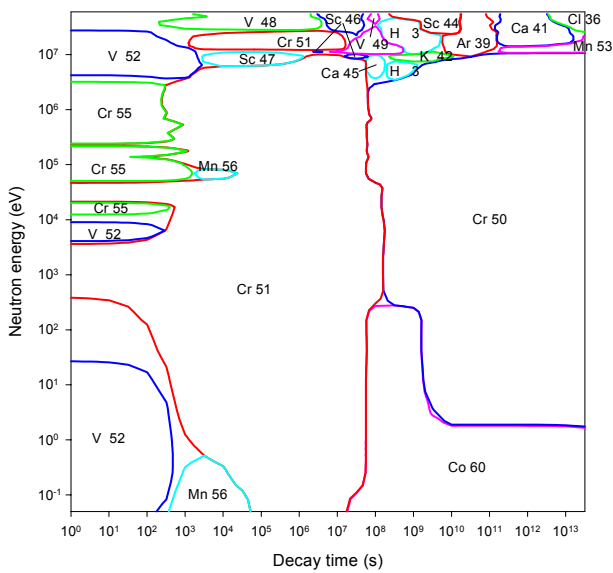
**Activity**



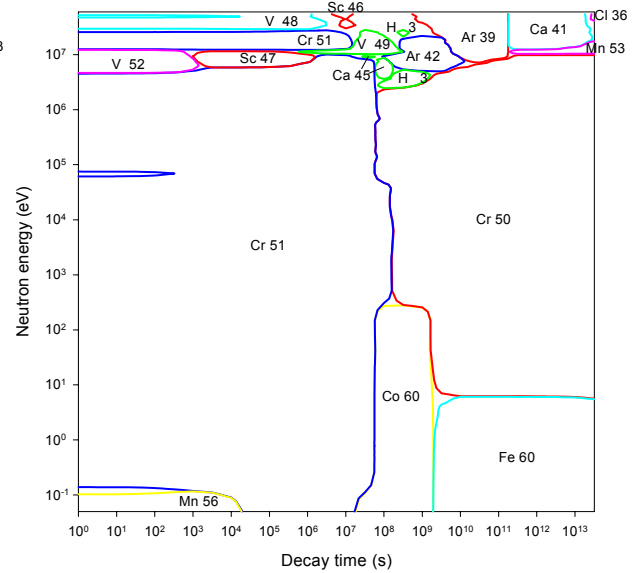
**Dose rate**



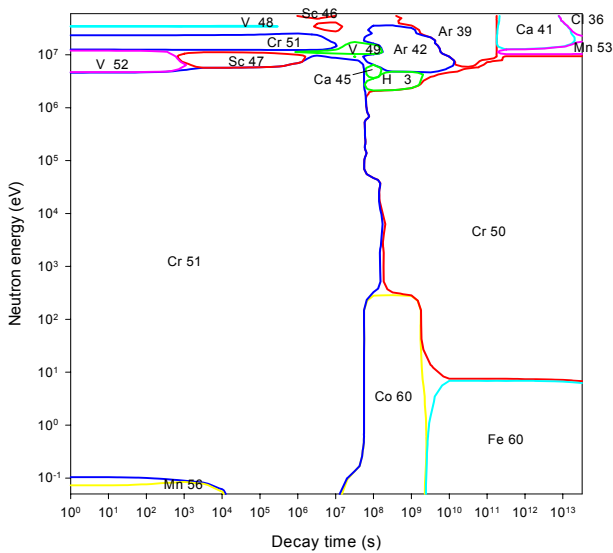
**Heat output**



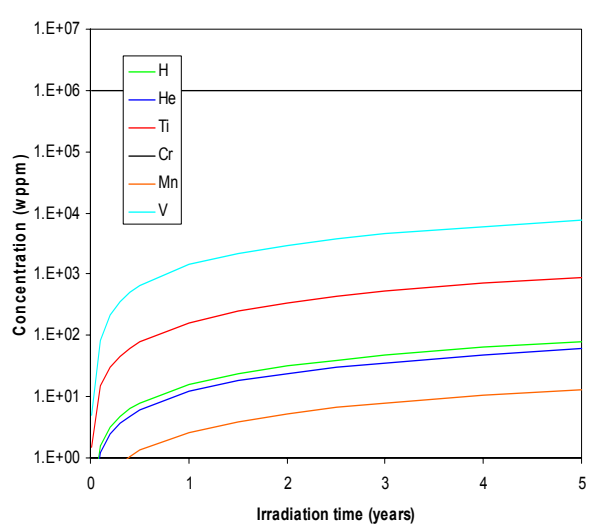
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**





# Manganese

## General properties

Atomic number	25	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	950	Mn55	100.0
Melting point / K	1519		
Boiling point / K	2234		
Density / kgm <sup>-3</sup>	7440		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	7.82		
Electrical resistivity /Ωm	1.85 10 <sup>-6</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	2.17 10 <sup>-5</sup>		
Crystal structure	BCC		
Number of stable isotopes	1		
Mean atomic weight	54.93805		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	4.35E15	4.22E15	1.16E15	5.23E14	1.28E9	3.77E6	kW kg <sup>-1</sup>	1.43E0	1.39E0	1.54E-1	6.91E-2	1.17E-9	3.28E-12
Mn56	70.91	71.46					Mn56	87.37	88.12				
Mn54	26.55	27.39	98.87	98.08			Mn54	10.68	11.21	99.99	99.99		
Cr55	1.41	0.52					V52	0.99	0.38				
Fe55	0.28	0.29	1.07	1.85			Cr55	0.75	0.27				
H3			0.03	0.06	99.70		H3					99.71	
Mn53					0.29	100.0	Mn53					0.28	100.0
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	1.85E6	1.80E6	2.55E5	1.14E5	9.85E-7	9.65E-7	Sv kg <sup>-1</sup>	1.60E6	1.58E6	8.17E5	3.68E5	5.38E-2	1.13E-4
Mn56	85.25	85.42					Mn54	51.38	51.98	99.49	99.12		
Mn54	13.90	14.26	100.0	100.0	99.90		Mn56	48.32	47.74				
V52	0.82	0.32					Fe55	0.25	0.26	0.50	0.87		
Co60					0.09		H3					99.79	
Mn53						100.0	Mn53					0.21	100.0
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	2.11E6	2.10E6	1.73E6	7.77E5	3.32E-1	2.04E-4		1.19E13	1.19E13	1.15E13	5.13E12	1.28E4	3.77E1
Mn54	82.00	82.34	99.44	99.03			Mn54	96.88	97.27	100.0	100.0		
Mn56	17.52	17.18					Mn56	2.58	2.53				
Fe55	0.45	0.45	0.55	0.96			V52	0.46	0.17				
H3				0.01	99.94		H3					99.70	
Mn53					0.06	100.0	Mn53					0.29	100.0

# Manganese

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Cr55	3.54 m	Mn55(n,γ)Mn56(β <sup>-</sup> )Fe56(n,γ)Fe57(n,α) <sub>-</sub> Cr54(n,γ)Cr55 Mn55(n,p)Cr55	100.0	100.0					
						99.8	99.8	99.9	99.9
V52	3.745 m	Mn55(n,α)V52 Mn55(n,t)Cr53(n,d)V52 Mn55(n,2n)Mn54(β <sup>+</sup> )Cr54(n,t)V52 Mn55(n,3n)Mn53(n,2p)V52 Mn55(n,d)Cr54(n,t)V52				97.9	63.8	27.2	70.8
							13.9	26.4	9.5
							6.4	25.0	9.4
							4.2	1.4	0.2
							2.7	15.2	7.0
Mn56	2.582 h	Mn55(n,γ)Mn56	100.0	100.0	100.0	97.8	99.2	99.5	99.8
Sc44	3.97 h	&Mn55(n,α)V52(β <sup>-</sup> )Cr52(n,α)Ti49_ (n,2n)Ti48(n,α)Ca45(β <sup>-</sup> )Sc45(n,2n)Sc44 &Mn55(n,nα)V51(n,α)Sc48(β <sup>-</sup> )Ti48_ (n,α)Ca45(β <sup>-</sup> )Sc45(n,2n)Sc44 &Mn55(n,α)V52(β <sup>-</sup> )Cr52(n,α)Ti49(n,α) <sub>-</sub> Ca46(n,2n)Ca45(β <sup>-</sup> )Sc45(n,2n)Sc44 &Mn55(n,2n)Mn54(n,α)V51(n,α)Sc48_ (β <sup>-</sup> )Ti48(n,α)Ca45(β <sup>-</sup> )Sc45(n,2n)Sc44 &Mn55(n,3n)Mn53(n,nα)V49(n,nα) <sub>-</sub> Sc45(n,2n)Sc44 &Mn55(n,nα)V51(n,3n)V49(n,nα)Sc45_ (n,2n)Sc44 &Mn55(n,nα)V51(n,nα)Sc47(β <sup>-</sup> )Ti47_ (n,t)Sc45(n,2n)Sc44 Mn55(n,3n)Mn53(n,nα)V49(β <sup>+</sup> )Ti49_ (n,nα)Ca45(β <sup>-</sup> )Sc45(n,2n)Sc44 &Mn55(n,2nα)V50(n,nα)Sc46(β <sup>-</sup> )Ti46_ (n,t)Sc44 &Mn55(n,2nα)V50(n,2nα)Sc45(n,2n)Sc44 &Mn55(n,3n)Mn53(n,nα)V49(n,2nα)Sc44 &Mn55(n,nα)V51(n,2nα)Sc46(β <sup>-</sup> )Ti46_ (n,t)Sc44 &Mn55(n,2nα)V50(n,2n)V49(n,2nα)Sc44 &Mn55(n,nα)V51(n,3n)V49(n,2nα)Sc44 &Mn55(n,2nα)V50(n,3nα)Sc44 &Mn55(n,3nα)V49(n,2nα)Sc44 Other pathways				24.3			
							22.5		
							11.8		
							10.6		
								23.3	
								9.4	
								7.2	
								6.3	
									11.8
									0.2
									11.4
									0.3
									7.5
									0.1
									5.7
									0.2
									5.1
									0.1
									4.4
									22.4
									9.5
							30.8	53.8	54.1
									67.2
K42	12.36 h	Mn55(n,α)V52(β <sup>-</sup> )Cr52(n,α)Ti49(n,2n) <sub>-</sub> Ti48(n,α)Ca45(β <sup>-</sup> )Sc45(n,α)K42 Mn55(n,nα)V51(n,α)Sc48(β <sup>-</sup> )Ti48(n,α) <sub>-</sub> Ca45(β <sup>-</sup> )Sc45(n,α)K42 Mn55(n,α)V52(β <sup>-</sup> )Cr52(n,α)Ti49(n,α) <sub>-</sub> Ca46(n,2n)Ca45(β <sup>-</sup> )Sc45(n,α)K42 Mn55(n,2n)Mn54(n,α)V51(n,α)Sc48(β <sup>-</sup> ) <sub>-</sub> Ti48(n,α)Ca45(β <sup>-</sup> )Sc45(n,α)K42 Mn55(n,nα)V51(n,nα)Sc47(β <sup>-</sup> )Ti47_ (n,nα)Ca43(n,d)K42 Mn55(n,3n)Mn53(n,nα)V49(n,2α)K42 Mn55(n,nα)V51(n,3n)V49(n,2α)K42 Mn55(n,nα)V51(n,nα)Sc47(β <sup>-</sup> )Ti47_ (n,2n)Ti46(n,pα)K42 Mn55(n,2nα)V50(n,n2α)K42 Mn55(n,2nα)V50(n,2nα)Sc45(n,α)K42 Mn55(n,n2α)Sc47(β <sup>-</sup> )Ti47(n,dα)K42 Other pathways				25.6			
							24.1		
							12.5		
							10.7		
								17.9	0.2
								11.8	2.5
								4.8	1.5
								4.1	
									8.6
									14.9
									3.7
									0.9
									0.8
									4.0
							27.1	61.4	82.7
									80.2
Sc48	1.820 d	Mn55(n,nα)V51(n,α)Sc48 ▶ Mn55(n,2n)Mn54(n,α)V51(n,α)Sc48				35.6	43.4	3.9	3.5
						23.5			

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	Mn55(n,α)V52(β <sup>-</sup> )Cr52(n,2n)Cr51(β <sup>+</sup> ) V51(n,α)Sc48 Mn55(n,2n)Mn54(β <sup>+</sup> )Cr54(n,α)Ti51(β <sup>-</sup> ) V51(n,α)Sc48 Mn55(n,α)V52(β <sup>-</sup> )Cr52(n,d)V51(n,α)Sc48   Mn55(n,3n)Mn53(n,α)V49(β <sup>+</sup> )Ti49(n,d)Sc48   Mn55(n,2α)Sc48   Mn55(n,α)V51(n,3n)V49(β <sup>+</sup> )Ti49(n,d)Sc48   Mn55(n,dα)Ti50(n,t)Sc48   Mn55(n,2nα)V50(n,h)Sc48   Mn55(n,t)Cr53(n,dα)Sc48   Mn55(n,3nα)V49(β <sup>+</sup> )Ti49(n,d)Sc48   Mn55(n,tα)Ti49(n,d)Sc48   Mn55(n,2nt)Cr51(β <sup>+</sup> )V51(n,α)Sc48   Other pathways				17.5 13.4 5.2 15.5 6.2 6.2 8.6 6.5 2.7 30.2 11.0 6.3 4.8	0.2   15.5 6.2 6.2 8.6 6.5 2.7  28.5	2.6 42.8 1.5 8.6 6.5 2.7  31.4	0.3 8.9 5.9 3.1 5.9 30.2 11.0 6.3 24.9
Ca47	4.538 d	Mn55(n,2n)Mn54(β <sup>+</sup> )Cr54(n,2n)Cr53_ (n,α)Ti50(n,α)Ca47   Mn55(n,2n)Mn54(β <sup>+</sup> )Cr54(n,α)Ti50(n,α)Ca47   Mn55(n,2n)Mn54(n,pα)Ti50(n,α)Ca47   Mn55(n,d)Cr54(n,2n)Cr53(n,α)Ti50(n,α)Ca47   Mn55(n,2n)Mn54(n,d)Cr53(n,α)Ti50(n,α)Ca47   Mn55(n,α)V51(n,d)Ti50(n,α)Ca47   Mn55(n,2n)Mn54(n,α)V51(n,d)Ti50(n,α)Ca47   Mn55(n,t)Cr53(n,α)Ti50(n,α)Ca47   Mn55(n,d)Cr54(n,α)Ti50(n,α)Ca47   Mn55(n,α)V51(n,pα)Ca47   Mn55(n,dα)Ti50(n,α)Ca47   Mn55(n,2n)Mn54(β <sup>+</sup> )Cr54(n,2α)Ca47   Mn55(n,3n)Mn53(n,t)Cr51(β <sup>+</sup> )V51(n,pα)Ca47   Mn55(n,d)Cr54(n,2α)Ca47   Mn55(n,3nα)V49(β <sup>+</sup> )Ti49(n,h)Ca47   Mn55(n,tα)Ti49(n,h)Ca47   Mn55(n,2nt)Cr51(β <sup>+</sup> )V51(n,pα)Ca47   Mn55(n,nt)Cr52(n,nt)V49(β <sup>+</sup> )Ti49(n,h)Ca47   Other pathways				51.3 13.0 6.4 6.1 5.6 5.5 3.0 2.6 1.3 18.7 5.3 2.1 1.5 0.9 5.2	0.4 25.5 1.5 0.2 16.6 3.0 3.0 13.3 17.8 5.3 8.5 6.7 5.2 11.0	2.0 2.0 1.6 1.1 1.5 1.6 1.1 1.5 1.7 2.2 8.5 6.7 5.2 33.2	0.5 0.5 0.5 1.0 0.5 2.6 17.7 1.6 0.4 1.2 35.5 12.9 4.6 3.3 17.7
Fe59	44.495 d	Mn55(n,γ)Mn56(β <sup>-</sup> )Fe56(n,γ)Fe57(n,γ) Fe58(n,γ)Fe59	100.0	100.0	100.0	99.4	99.7	99.8	99.9
Sc46	83.79 d	&Mn55(n,α)V51(n,2n)V50(n,2n)V49_ (n,α)Sc46 &Mn55(n,2n)Mn54(n,2n)Mn53(n,α)V50_ (n,2n)V49(n,α)Sc46 &Mn55(n,2n)Mn54(n,α)V50(n,α)Sc46 &Mn55(n,2n)Mn54(n,α)V51(n,2n)V50_ (n,2n)V49(n,α)Sc46 &Mn55(n,α)V52(β <sup>-</sup> )Cr52(n,2n)Cr51(β <sup>+</sup> ) V51(n,2n)V50(n,2n)V49(n,α)Sc46 &Mn55(n,α)V51(n,α)Sc47(β <sup>-</sup> )Ti47(n,d)Sc46   &Mn55(n,α)V51(n,2n)V50(n,α)Sc46 &Mn55(n,3n)Mn53(n,2α)Sc46 &Mn55(n,3n)Mn53(n,α)V50(n,α)Sc46 &Mn55(n,2nα)V50(n,α)Sc46 &Mn55(n,α)V51(n,2nα)Sc46 &Mn55(n,3n)Mn53(n,t)Cr51(β <sup>+</sup> )V51_ (n,2nα)Sc46 &Mn55(n,3nα)V49(β <sup>+</sup> )Ti49(n,nt)Sc46 &Mn55(n,2n2α)Sc46 &Mn55(n,nt)Cr52(n,tα)Sc46 &Mn55(n,tα)Ti49(n,nt)Sc46 &Mn55(n,2nt)Cr51(β <sup>+</sup> )V51(n,2nα)Sc46 Other pathways				25.6 25.6 14.6 12.6 6.4 1.2 0.9 9.8 5.9 1.7 17.0 6.0  13.1	0.2  16.8 32.6 9.8 5.9 1.7 17.0 6.0  33.0	0.3 0.4 7.7 0.2 4.6 4.1 0.5  22.2 12.9 8.5 8.3 7.1 34.2	0.1 0.1 4.6 4.1 0.5  22.2 12.9 8.5 8.3 7.1 31.4

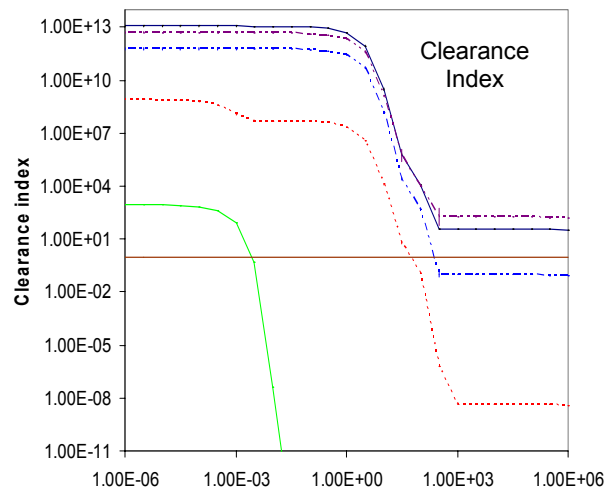
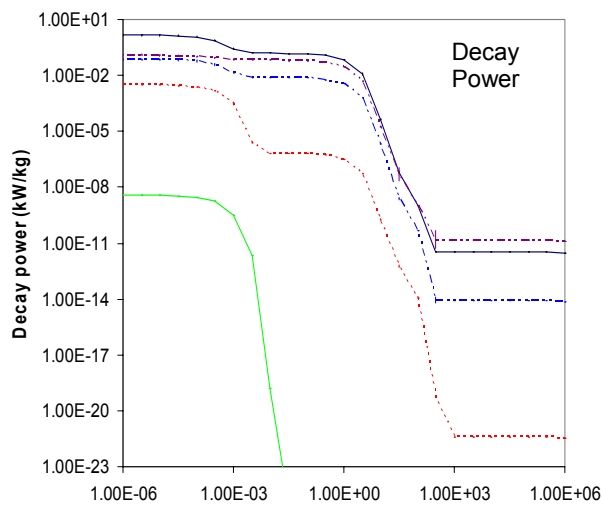
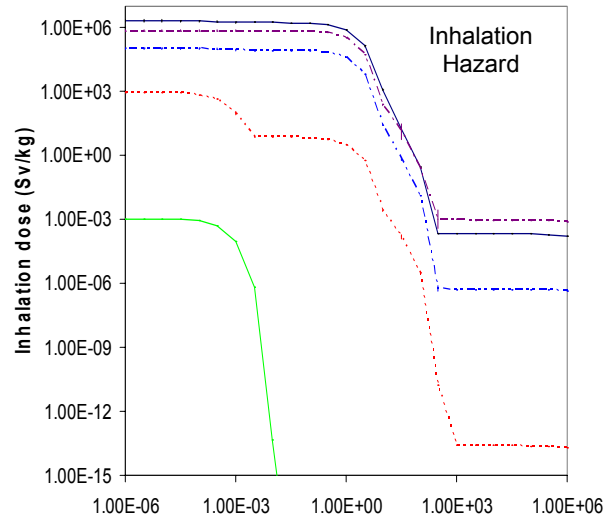
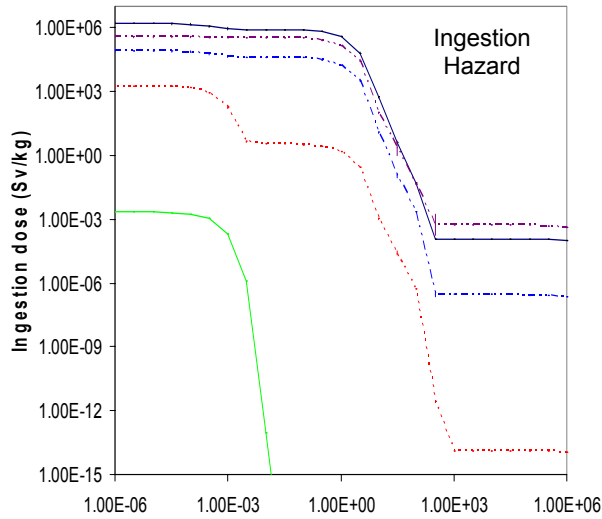
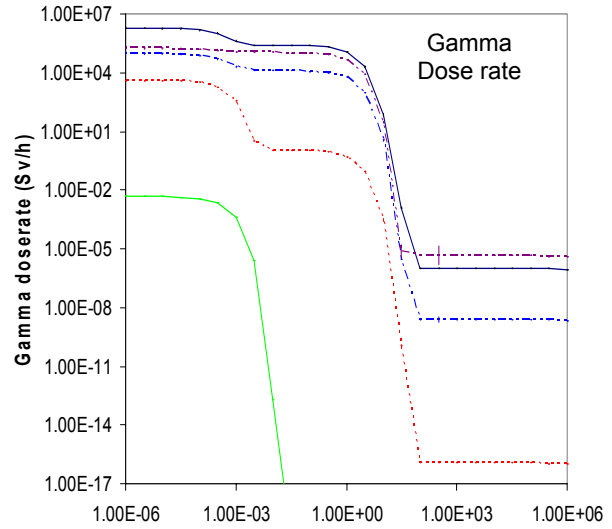
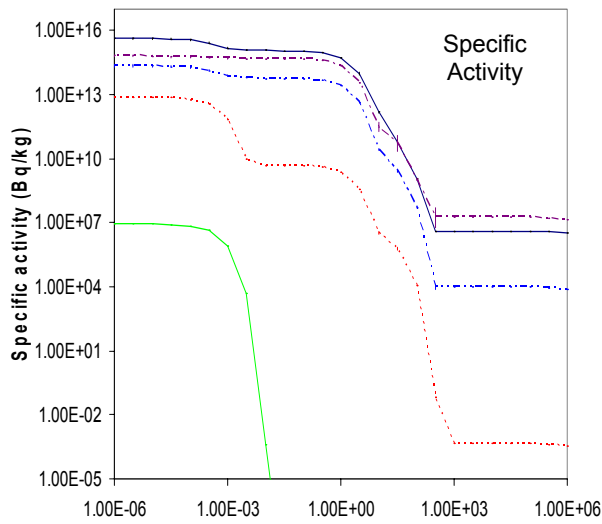
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Ca45	163.0 d	Mn55(n,α)V52(β <sup>-</sup> )Cr52(n,α)Ti49(n,2n) <sub>-</sub> Ti48(n,α)Ca45				29.1			
		Mn55(n,α)V51(n,α)Sc48(β <sup>-</sup> )Ti48(n,α)Ca45				20.8	0.4		
		Mn55(n,α)V52(β <sup>-</sup> )Cr52(n,α)Ti49(n,α) <sub>-</sub> Ca46(n,2n)Ca45				14.2			
		Mn55(n,2n)Mn54(n,α)V51(n,α)Sc48(β <sup>-</sup> ) <sub>-</sub> Ti48(n,α)Ca45				10.8			
		Mn55(n,α)V52(β <sup>-</sup> )Cr52(n,2n)Cr51(β <sup>+</sup> ) <sub>-</sub> V51(n,α)Sc48(β <sup>-</sup> )Ti48(n,α)Ca45				5.9			
		Mn55(n,3n)Mn53(n,α)V49(β <sup>+</sup> )Ti49 <sub>-</sub> (n,α)Ca45					36.9	4.6	0.2
		Mn55(n,α)V51(n,3n)V49(β <sup>+</sup> )Ti49(n,α)Ca45					14.8	2.7	0.1
		Mn55(n,t)Cr53(n,α)Ti49(n,α)Ca45					8.4	3.7	0.2
		Mn55(n,α)V51(n,t)Ti49(n,α)Ca45					5.1	3.0	0.2
		Mn55(n,2nα)V50(n,dα)Ca45						22.5	10.4
		Mn55(n,dα)Ti50(n,2nα)Ca45						15.3	5.4
		Mn55(n,3n)Mn53(n,α)Ti49(n,α)Ca45						8.0	1.5
		Mn55(n,tα)Ti49(n,α)Ca45						0.2	8.7
		Mn55(n,3nα)V49(β <sup>+</sup> )Ti49(n,α)Ca45							22.9
		Mn55(n,2nt)Cr51(β <sup>+</sup> )V51(n,tα)Ca45							7.7
		Mn55(n,α)V51(n,tα)Ca45							4.4
		Other pathways					19.2	34.4	40.0
Mn54	312.1 d	Mn55(n,2n)Mn54				99.6	99.8	99.9	99.9
Co60	5.271 y	&Mn55(n,γ)Mn56(β <sup>-</sup> )Fe56(n,γ)Fe57(n,γ) <sub>-</sub> Fe58(n,γ)Fe59(β <sup>-</sup> )Co59(n,γ)Co60	100.0	100.0	100.0	99.7	99.8		
H3	12.33 y	Mn55(n,X)H3				94.4	93.7	93.6	94.3
		Mn55(n,2n)Mn54(n,X)H3				5.2	2.0	0.9	0.5
		Mn55(n,3n)Mn53(n,X)H3					1.6	2.0	0.9
		Mn55(n,2n)Mn54(β <sup>+</sup> )Cr54(n,X)H3					1.0	0.8	0.6
		Mn55(n,t)Cr53(n,X)H3					0.4	1.2	0.8
		Mn55(n,nt)Cr52(n,X)H3						0.2	1.1
Ar42	33.0 y	Mn55(n,α)V52(β <sup>-</sup> )Cr52(n,α)Ti49(n,2n) <sub>-</sub> Ti48(n,α)Ca45(n,α)Ar42				27.3			
		Mn55(n,α)V51(n,α)Sc48(β <sup>-</sup> )Ti48(n,α) <sub>-</sub> Ca45(n,α)Ar42				25.6			
		Mn55(n,α)V52(β <sup>-</sup> )Cr52(n,α)Ti49(n,α) <sub>-</sub> Ca46(n,2n)Ca45(n,α)Ar42				13.4			
		Mn55(n,2n)Mn54(n,α)V51(n,α)Sc48(β <sup>-</sup> ) <sub>-</sub> Ti48(n,α)Ca45(n,α)Ar42				11.5			
		Mn55(n,α)V52(β <sup>-</sup> )Cr52(n,2n)Cr51(β <sup>+</sup> ) <sub>-</sub> V51(n,α)Sc48(β <sup>-</sup> )Ti48(n,α)Ca45(n,α)Ar42				5.4			
		Mn55(n,2n)Mn54(β <sup>+</sup> )Cr54(n,α)Ti50 <sub>-</sub> (n,α)Ca46(n,α)Ar42					12.0	0.5	
		Mn55(n,α)V51(n,d)Ti50(n,α)Ca46(n,α)Ar42					10.3	0.5	
		Mn55(n,3n)Mn53(n,α)V49(β <sup>+</sup> )Ti49 <sub>-</sub> (n,α)Ca46(n,α)Ar42					9.0	0.4	
		Mn55(n,d)Cr54(n,α)Ti50(n,α)Ca46 <sub>-</sub> (n,α)Ar42					8.3	0.5	
		Mn55(n,3n)Mn53(n,α)V49(β <sup>+</sup> )Ti49 <sub>-</sub> (n,α)Ca45(n,α)Ar42					6.9	0.2	
		Mn55(n,dα)Ti50(n,α)Ca46(n,α)Ar42					6.5	14.8	0.6
		Mn55(n,3n)Mn53(n,α)V49(β <sup>+</sup> )Ti49 <sub>-</sub> (n,2α)Ar42					3.7	5.0	0.1
		Mn55(n,t)Cr53(n,α)Ti49(n,2α)Ar42					0.9	4.4	0.1
		Mn55(n,2nα)V50(n,α)Ca46(n,α)Ar42					0.1	6.5	0.2
		Mn55(n,2nα)V50(n,d)Ti49(n,2α)Ar42						4.4	0.2
		Mn55(n,dα)Ti50(n,2nα)Ar42						0.4	20.7
		Mn55(n,tα)Ti49(n,2α)Ar42						0.3	7.7
		Mn55(n,3nα)V49(β <sup>+</sup> )Ti49(n,2α)Ar42							17.3
		Other pathways					16.8	42.3	62.1

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
Ni63	100.6 y	&Mn55(n,γ)Mn56(β <sup>-</sup> )Fe56(n,γ)Fe57(n,γ) <sub>-</sub> Fe58(n,γ)Fe59(β <sup>-</sup> )Co59(n,γ)Co60(n,γ) <sub>-</sub> Co61(β <sup>-</sup> )Ni61(n,γ)Ni62(n,γ)Ni63 &Mn55(n,γ)Mn56(β <sup>-</sup> )Fe56(n,γ)Fe57(n,γ) <sub>-</sub> Fe58(n,γ)Fe59(β <sup>-</sup> )Co59(n,γ)Co60(β <sup>-</sup> ) <sub>-</sub> Ni60(n,γ)Ni61(n,γ)Ni62(n,γ)Ni63 Mn55(n,γ)Mn56(β <sup>-</sup> )Fe56(n,γ)Fe57(n,γ) <sub>-</sub> Fe58(n,γ)Fe59(n,γ)Fe60(n,γ)Fe61(β <sup>-</sup> ) <sub>-</sub> Co61(β <sup>-</sup> )Ni61(n,γ)Ni62(n,γ)Ni63	86.4	93.2						
			9.4	6.7						
			4.1							
Ar39	269.0 y	Mn55(n,α)V51(n,α)Sc48(β <sup>-</sup> )Ti48(n,α) <sub>-</sub> Ca45(β <sup>-</sup> )Sc45(n,α)K42(β <sup>-</sup> )Ca42(n,α)Ar39 Mn55(n,α)V52(β <sup>-</sup> )Cr52(n,α)Ti49(n,α) <sub>-</sub> Ca46(n,α)Ar43(β <sup>-</sup> )K43(β <sup>-</sup> )Ca43(n,α)Ar39 Mn55(n,α)V51(n,α)Sc47(β <sup>-</sup> )Ti47 <sub>-</sub> (n,2n)Ti46(n,α)Ca43(n,α)Ar39 Mn55(n,α)V51(n,2n)V50(n,α)Sc47(β <sup>-</sup> ) <sub>-</sub> Ti47(n,2n)Ti46(n,α)Ca43(n,α)Ar39 Mn55(n,α)V51(n,2n)V50(n,2n)V49 <sub>-</sub> (n,α)Sc46(β <sup>-</sup> )Ti46(n,α)Ca43(n,α)Ar39 Mn55(n,α)V51(n,α)Sc47(β <sup>-</sup> )Ti47 <sub>-</sub> (n,α)Ca43(n,α)Ar39 Mn55(n,α)V51(n,α)Sc47(β <sup>-</sup> )Ti47 <sub>-</sub> (n,2n)Ti46(n,2α)Ar39 Mn55(n,α)V51(n,2n)V50(n,α)Sc46 <sub>-</sub> (β <sup>-</sup> )Ti46(n,2α)Ar39 Mn55(n,2n)Mn54(n,α)V50(n,α)Sc46 <sub>-</sub> (β <sup>-</sup> )Ti46(n,2α)Ar39 Mn55(n,3n)Mn53(n,2α)Sc46(β <sup>-</sup> )Ti46 <sub>-</sub> (n,2α)Ar39 Mn55(n,2nα)V50(n,α)Sc46(β <sup>-</sup> )Ti46 <sub>-</sub> (n,2α)Ar39 Mn55(n,nt)Cr52(n,2nα)Ti47(n,2α)Ar39 Mn55(n,α)V51(n,α)Sc47(β <sup>-</sup> )Ti47 <sub>-</sub> (n,2α)Ar39 Mn55(n,2α)Sc47(β <sup>-</sup> )Ti47(n,2α)Ar39 Mn55(n,2nα)V50(n,2nα)Sc45(n,α)Ar39 Mn55(n,2nt)Cr51(β <sup>+</sup> )V51(n,3nα)Sc45 <sub>-</sub> (n,α)Ar39 Mn55(n,3nα)V49(β <sup>+</sup> )Ti49(n,2nα)Ca44 <sub>-</sub> (n,2nα)Ar39 Other pathways				8.9				
							5.7			
							3.7	0.2		
							2.2			
							2.1			
							1.9	46.3	0.2	
								4.7		
								3.5		
								2.2		
								2.1	0.8	
								0.4	3.6	
									2.8	2.3
									2.5	0.1
									1.5	5.3
									1.2	3.0
										2.0
										2.0
							75.5	40.6	87.4	85.3
Cl36	3.0 10 <sup>5</sup> y	Mn55(n,α)V51(n,α)Sc48(β <sup>-</sup> )Ti48(n,α)Ca45 <sub>-</sub> (β <sup>-</sup> )Sc45(n,α)K41(n,α)Cl37(n,2n)Cl36 Mn55(n,α)V51(n,α)Sc48(β <sup>-</sup> )Ti48(n,α)Ca45 <sub>-</sub> (β <sup>-</sup> )Sc45(n,α)K41(n,2n)K40(n,α)Cl36 Mn55(n,α)V51(n,α)Sc47(β <sup>-</sup> )Ti47(n,α) <sub>-</sub> Ca44(n,α)Ar41(β <sup>-</sup> )K41(n,α)Cl37(n,2n)Cl36 Mn55(n,α)V51(n,α)Sc47(β <sup>-</sup> )Ti47(n,α) <sub>-</sub> Ca44(n,α)Ar41(β <sup>-</sup> )K41(n,2n)K40(n,α)Cl36 &Mn55(n,3n)Mn53(n,α)V49(n,α) <sub>-</sub> Sc45(n,α)K41(n,2nα)Cl36 Mn55(n,α)V51(n,α)Sc47(β <sup>-</sup> )Ti47 <sub>-</sub> (n,α)Ca43(n,2nα)Ar38(n,t)Cl36 Mn55(n,α)V51(n,3n)V49(n,α)Sc45 <sub>-</sub> (n,α)K41(n,2nα)Cl36 Mn55(n,α)V51(n,α)Sc47(β <sup>-</sup> )Ti47(n,t) <sub>-</sub> Sc45(n,α)K41(n,2nα)Cl36 Mn55(n,2nα)V50(n,2nα)Sc45(n,2nα) <sub>-</sub> K40(n,α)Cl36				9.1				
							7.1			
							4.5			
							3.5			
								15.5		
								5.9		
								4.5		
								3.2		
									9.6	

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Mn55(n,2nα)V50(n,2nα)Sc45(n,α)K41_ (n,2nα)Cl36 Mn55(n,2nα)V50(n,nα)Sc46(β <sup>-</sup> )Ti46_ (n,2nα)Ca41(n,dα)Cl36 Mn55(n,2nα)V50(n,nα)Sc46(β <sup>-</sup> )Ti46_ (n,n2α)Ar38(n,t)Cl36 Mn55(n,2nα)V50(n,2nα)Sc45(n,2n2α)Cl36 Mn55(n,2nt)Cr51(β <sup>+</sup> )V51(n,3nα)Sc45_ (n,2n2α)Cl36 Other pathways using (n,α), (n,nα), β <sup>-</sup>						7.1		
								4.3		
								3.2		
									4.1	
									2.7	
							75.8	70.9	75.8	91.2
Fe60	1.5 10 <sup>6</sup> y	Mn55(n,γ)Mn56(β <sup>-</sup> )Fe56(n,γ)Fe57(n,γ)_ Fe58(n,γ)Fe59(n,γ)Fe60	100.0	100.0	100.0	98.7	99.3			
Mn53	3.7 10 <sup>6</sup> y	Mn55(n,2n)Mn54(n,2n)Mn53 Mn55(n,3n)Mn53				99.8	2.4 97.5	0.7 99.2	0.6 99.4	
Ca48	5.310 <sup>19</sup> y	Mn55(n,α)V51(n,α)Sc48(n,p)Ca48 Mn55(n,α)V52(β <sup>-</sup> )Cr52(n,α)Ti49(n,2p)Ca48 Mn55(n,2n)Mn54(n,α)V51(n,α)Sc48(n,p)Ca48 Mn55(n,α)V52(β <sup>-</sup> )Cr52(n,2n)Cr51(β <sup>+</sup> )_ V51(n,α)Sc48(n,p)Ca48 Mn55(n,2n)Mn54(β <sup>+</sup> )Cr54(n,α)Ti51(β <sup>-</sup> )_ V51(n,α)Sc48(n,p)Ca48 Mn55(n,2n)Mn54(β <sup>+</sup> )Cr54(n,α)Ti50(n,h)Ca48 Mn55(n,α)V51(n,d)Ti50(n,h)Ca48 Mn55(n,d)Cr54(n,α)Ti50(n,h)Ca48 Mn55(n,3n)Mn53(n,α)V49(β <sup>+</sup> )Ti49(n,2p)Ca48 Mn55(n,dα)Ti50(n,h)Ca48 Mn55(n,α)V51(n,3n)V49(β <sup>+</sup> )Ti49(n,2p)Ca48 Mn55(n,3nα)V49(β <sup>+</sup> )Ti49(n,2p)Ca48 Mn55(n,tα)Ti49(n,2p)Ca48 Other pathways				29.5 29.0 16.1 9.4 6.3 12.8 13.6 12.8 8.1 5.1 9.7	0.2 22.4 17.0 13.6 1.0 73.6 20.8		3.8 3.5 3.3 1.0 0.6 18.2 8.1	0.8 0.9 0.8 45.8 25.4



# Manganese activation characteristics

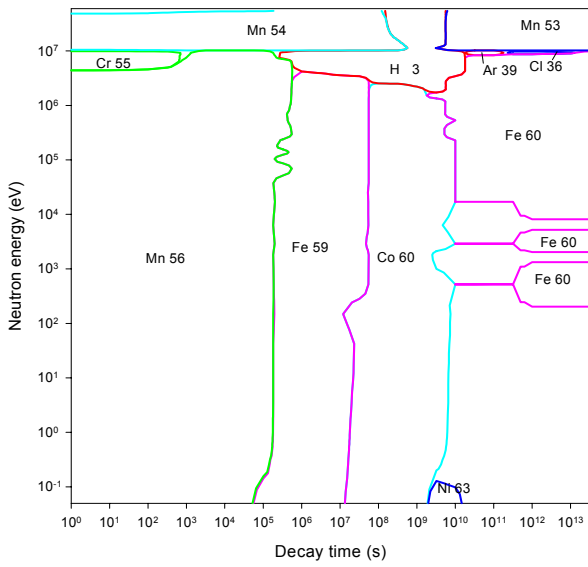


Decay time (years)

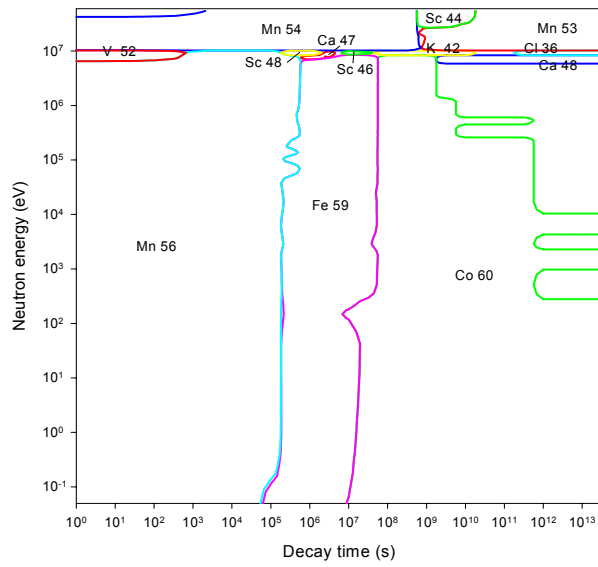
Decay time (years)

# Manganese importance diagrams & transmutation

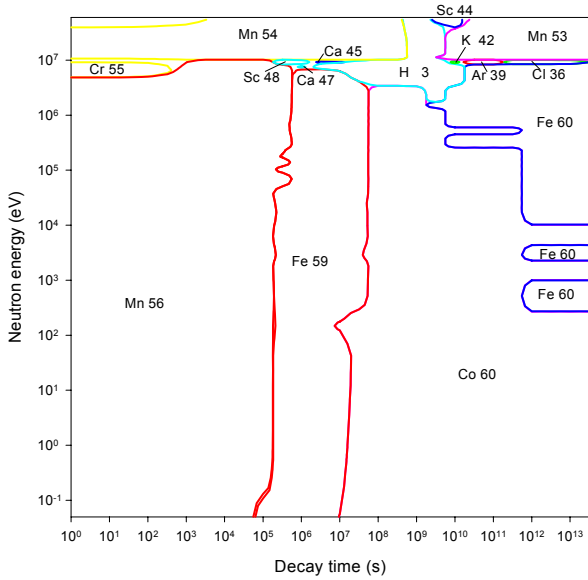
Activity



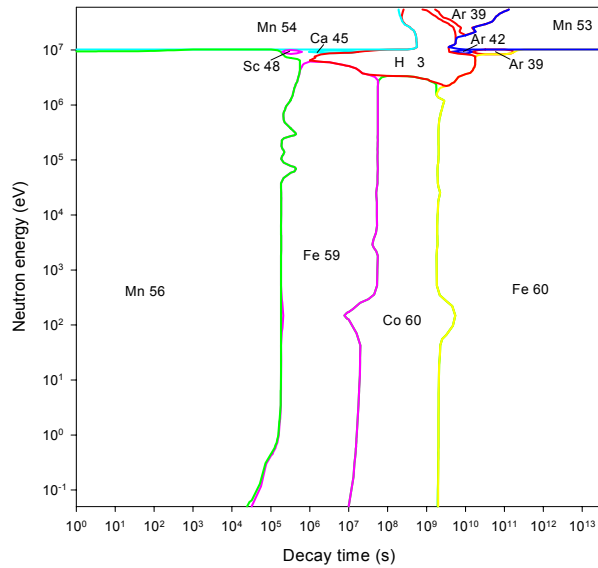
Dose rate



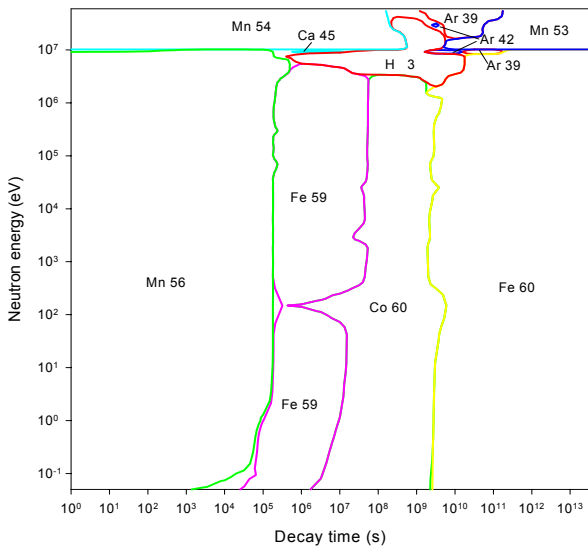
Heat output



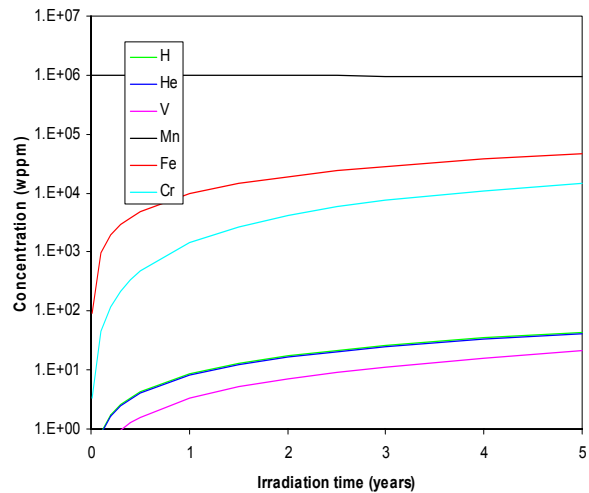
Ingestion dose



Inhalation dose



First wall transmutation



Graphs for H, He are indistinguishable

# Iron

## General properties

Atomic number	26	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	5.63 10 <sup>4</sup>	Fe54	5.845
Melting point / K	1811	Fe56	91.754
Boiling point / K	3134	Fe57	2.119
Density / kgm <sup>-3</sup>	7874	Fe58	0.282
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	80.2		
Electrical resistivity /Ωm	9.71 10 <sup>-8</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	1.18 10 <sup>-5</sup>		
Crystal structure	BCC		
Number of stable isotopes	4		
Mean atomic weight	55.845		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	6.67E14	6.60E14	4.70E14	3.41E14	6.66E7	2.06E7	kW kg <sup>-1</sup>	8.68E-2	8.43E-2	8.10E-3	3.60E-3	1.64E-10	1.85E-11
Fe55	61.02	61.71	86.50	92.83			Mn56	89.52	90.00				
Mn56	28.69	28.34					Mn54	8.47	8.72	90.09	90.70		
Mn54	8.18	8.286	11.547	7.13			Fe55	0.42	0.44	4.55	7.96		
Cr51	1.24	1.25	1.61				Fe59	0.38	0.39	3.84	0.03		
Co60	0.02	0.02	0.03	0.03	0.38	0.01	Co60	0.06	0.06	0.66	1.30	63.58	3.35
H3					68.16		H3					25.30	
Mn53					31.45	99.97	Mn53					11.09	96.45
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	1.09E5	1.06E5	1.25E4	5.44E3	1.84E-4	5.62E-6	Sv kg <sup>-1</sup>	2.25E5	2.24E5	1.76E5	1.22E5	3.56E-3	7.86E-4
Mn56	87.98	87.91					Fe55	59.79	60.09	76.17	85.55		
Mn54	10.92	11.17	93.75	96.92			Mn56	21.30	20.91				
Fe59	0.49	0.05	3.99	0.03			Mn54	17.25	17.34	21.86	14.13		
V52	0.11	0.04					Fe59	1.26	1.26	1.52	0.01		
Fe55	0.10	0.10	0.87	1.56			Co60	0.19	0.19	0.26	0.31	23.92	0.64
Co60	0.08	0.09	0.73	1.49	97.48	19.00	H3					53.56	
Mn52	0.05	0.06	0.30				Mn53					17.65	78.45
Mn53					2.52	80.95	Fe60					4.83	20.93
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	4.29E5	4.29E5	4.04E5	2.83E5	2.12E-2	1.57E-3		5.71E11	5.69E11	5.45E11	2.44E11	3.17E3	2.20E2
Fe55	73.06	73.16	77.36	85.91			Mn54	95.73	96.00	99.40	99.41		
Mn54	19.09	19.11	20.10	12.85			Mn56	3.36	3.29				
Mn56	5.35	5.24					Fe59	0.27	0.28	0.27			
Fe59	1.46	1.46	1.47	0.01			Co60	0.22	0.22	0.23	0.46	79.05	6.76
Co60	0.92	0.92	0.98	1.23	36.67	2.93	Fe55	0.07	0.07	0.07	0.13		
H3					55.76		Cr51	0.01	0.01	0.01			
Mn53					5.34	70.46	H3					14.33	
Fe60					2.07	26.57	Mn53					6.61	93.23

# Iron

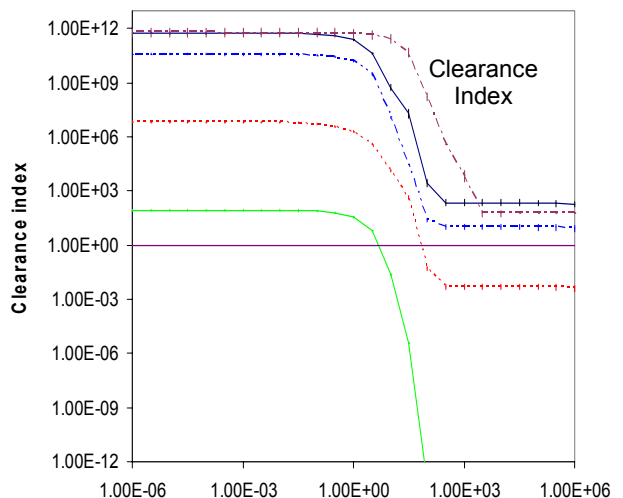
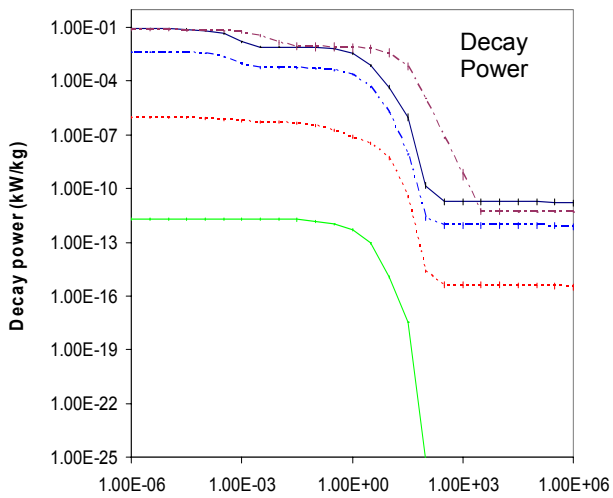
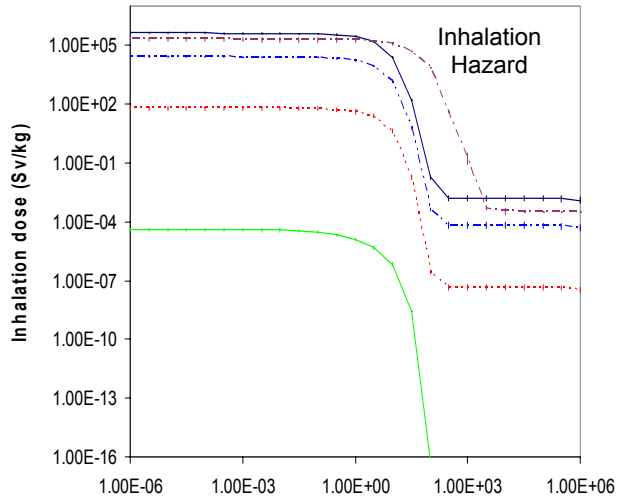
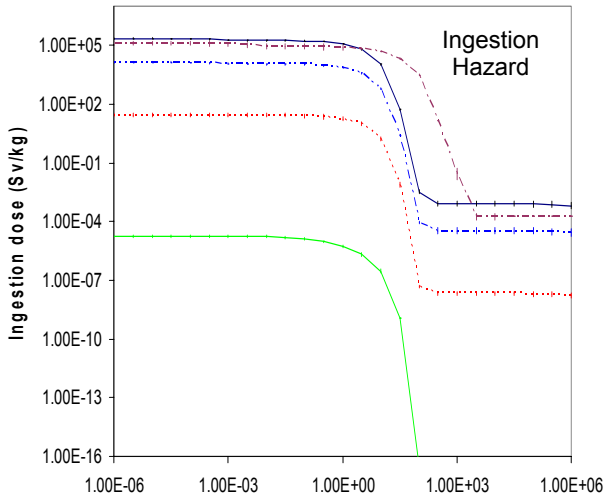
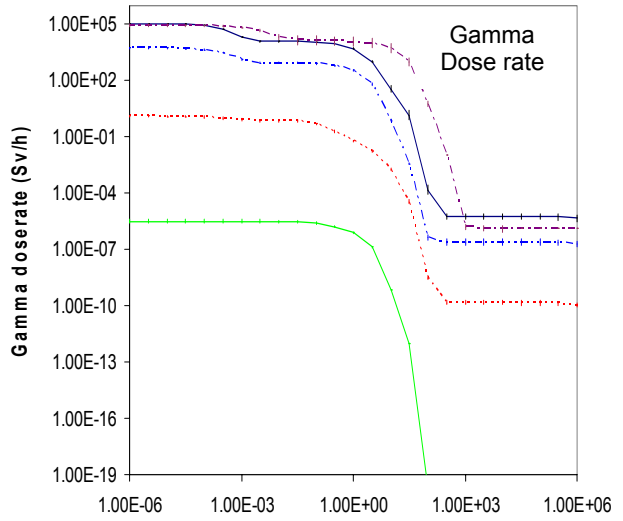
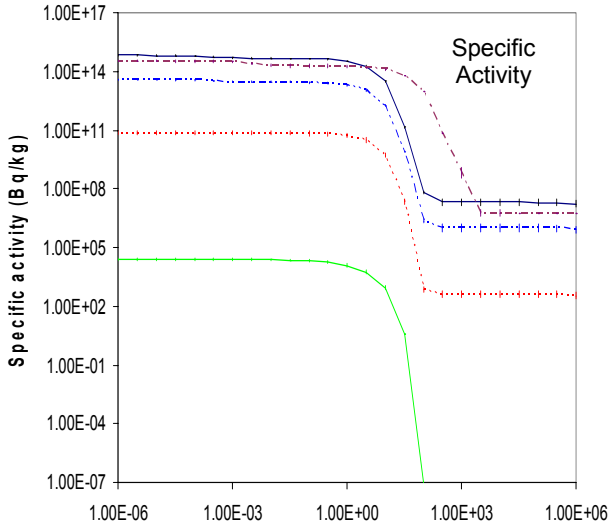
## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	60	21	6	
Mn56	2.582 h	Fe54(n,γ)Fe55(β <sup>+</sup> )Mn55(n,γ)Mn56	96.9	99.9	100.0					
		Fe56(n,γ)Fe57(n,γ)Fe58(n,γ)Fe59(n,α) <sub>-</sub>	1.6							
		Cr56(β <sup>-</sup> )Mn56								
		Fe58(n,γ)Fe59(n,α)Cr56(β <sup>-</sup> )Mn56	0.7							
		Fe57(n,γ)Fe58(n,γ)Fe59(n,α)Cr56(β <sup>-</sup> )Mn56	0.6							
		Fe56(n,p)Mn56				99.3	90.0	87.5	81.1	
		Fe57(n,d)Mn56				0.3	9.5	10.7	16.3	
		Fe57(n,2n)Fe56(n,p)Mn56				0.3	0.2			
Sc44	3.97 h	Fe58(n,t)Mn56						1.5	2.3	
		&Fe54(n,α)Cr51(β <sup>+</sup> )V51(n,α)Sc48(β <sup>-</sup> ) <sub>-</sub>				58.4				
		Ti48(n,α)Ca45(β <sup>-</sup> )Sc45(n,2n)Sc44								
		&Fe54(n,α)Cr51(n,α)Ti48(n,α)Ca45(β <sup>-</sup> ) <sub>-</sub>				15.7				
		Sc45(n,2n)Sc44								
		&Fe54(n,α)Cr50(n,α)Ti46(n,d)Sc45 <sub>-</sub>				0.3	15.2			
		(n,2n)Sc44								
		&Fe54(n,α)Cr50(n,α)Ti46(n,t)Sc44					22.6	6.1		
		&Fe54(n,α)Cr50(n,α)Ti46(n,2n)Ti45 <sub>-</sub>					6.2			
		(β <sup>+</sup> )Sc45(n,2n)Sc44							14.2	0.9
		&Fe54(n,dα)V49(n,2nα)Sc44							8.6	
		&Fe56(n,2nα)Cr51(β <sup>+</sup> )V51(n,2nα)Sc46 <sub>-</sub>								6.9
		(β <sup>-</sup> )Ti46(n,t)Sc44								3.5
		&Fe56(n,2nα)Cr51(β <sup>+</sup> )V51(n,3n)V49 <sub>-</sub>								
		(n,2nα)Sc44								
		&Fe56(n,3n)Fe54(n,dα)V49(n,2nα)Sc44								
&Fe56(n,3nα)Cr50(n,tα)Sc44								17.7		
&Fe56(n,tα)V50(n,3nα)Sc44								12.7		
&Fe56(n,nt)Mn53(n,2n2α)Sc44								3.9		
&Fe54(n,α)Cr50(n,tα)Sc44								3.6		
&Fe56(n,nt)Mn53(n,tα)Ti47(n,nt)Sc44								3.2		
Other pathways					25.6	56.0	60.7	58.0		
Fe59	44.495 d	Fe56(n,γ)Fe57(n,γ)Fe58(n,γ)Fe59	56.9	0.3						
		Fe58(n,γ)Fe59	22.8	97.0	97.4	98.6	98.9	99.1	99.4	
		Fe57(n,γ)Fe58(n,γ)Fe59	20.3	2.7	2.5					
Mn54	312.13 d	Fe54(n,p)Mn54				35.2	4.3	0.8	0.6	
		Fe56(n,2n)Fe55(β <sup>+</sup> )Mn55(n,2n)Mn54				31.3	12.0	0.9		
		Fe56(n,d)Mn55(n,2n)Mn54				16.0	16.1	1.4	0.9	
		Fe56(n,2n)Fe55(n,d)Mn54				15.5	18.4	1.5	1.0	
		Fe56(n,t)Mn54				0.1	47.6	94.5	94.5	
		Fe57(n,nt)Mn54						0.1	1.9	
Fe55	2.735 y	Fe54(n,γ)Fe55	100.0	100.0	100.0					
		Fe56(n,2n)Fe55				98.8	98.6	97.5	97.9	
		Fe57(n,2n)Fe56(n,2n)Fe55				0.2	0.1			
		Fe57(n,3n)Fe55					0.9	2.1	1.7	
Co60	5.271 y	&Fe58(n,γ)Fe59(β <sup>-</sup> )Co59(n,γ)Co60	51.4	98.4	99.1	99.8	99.8	99.8	99.9	
		&Fe56(n,γ)Fe57(n,γ)Fe58(n,γ)Fe59(β <sup>-</sup> ) <sub>-</sub>	29.7							
		Co59(n,γ)Co60								
H3	12.33 y	&Fe57(n,γ)Fe58(n,γ)Fe59(β <sup>-</sup> )Co59(n,γ) <sub>-</sub>	18.9	1.4	0.9					
		Co60								
H3	12.33 y	Fe54(n,γ)Fe55(n,X)H1(n,γ)H2(n,γ)H3	93.8	96.2	99.5					
		Fe56(n,X)H3				63.9	84.9	85.7	85.7	
		Fe56(n,2n)Fe55(β <sup>+</sup> )Mn55(n,X)H3				12.8	1.5	0.7		
		Fe56(n,d)Mn55(n,X)H3				7.7	2.4	1.2	0.8	
		Fe57(n,X)H3				6.3	2.5	2.3	2.2	
		Fe56(n,2n)Fe55(n,X)H3				4.5	2.9	1.3	0.8	
		Fe54(n,p)Mn54(n,X)H3				1.4				
		Fe54(n,X)H3					3.3	1.4	4.6	

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	60	21	6
	◀	Fe56(n,t)Mn54(n,X)H3 Fe56(n,t)Mn54(β <sup>+</sup> )Cr54(n,X)H3 Fe56(n,nt)Mn53(n,X)H3					0.2 0.1	1.1 1.0	0.6 0.8 1.4
Ar42	33.0 y	Fe54(n,α)Cr51(β <sup>+</sup> )V51(n,α)Sc48(β <sup>-</sup> ) Ti48(n,α)Ca45(n,α)Ar42 Fe54(n,α)Cr51(n,α)Ti48(n,α)Ca45(n,α)Ar42   Fe56(n,nα)Cr52(n,nα)Ti48(n,α)Ca45(n,α)Ar42   Fe56(n,nα)Cr52(n,α)Ti49(n,α)Ca46(n,nα)Ar42   Fe54(n,nα)Cr50(n,d)V49(β <sup>+</sup> )Ti49(n,α) Ca46(n,nα)Ar42 Fe56(n,t)Mn54(β <sup>+</sup> )Cr54(n,nα)Ti50(n,nα) Ca46(n,nα)Ar42 Fe56(n,2α)Ti49(n,α)Ca46(n,nα)Ar42 Fe56(n,nα)Cr52(n,nα)Ti48(n,nα)Ca44 (n,h)Ar42 Fe54(n,nα)Cr50(n,d)V49(β <sup>+</sup> )Ti49(n,nα) Ca45(n,α)Ar42 Fe56(n,nα)Cr52(n,α)Ti49(n,nα)Ca45(n,α)Ar42   Fe54(n,dα)V49(β <sup>+</sup> )Ti49(n,2α)Ar42 Fe56(n,2nα)Cr51(β <sup>+</sup> )V51(n,dα)Ca46 (n,nα)Ar42 Fe56(n,2nα)Cr51(β <sup>+</sup> )V51(n,t)Ti49(n,2α)Ar42   Fe54(n,2nα)Cr49(β <sup>+</sup> )V49(β <sup>+</sup> )Ti49(n,2α)Ar42   Fe56(n,2nα)Cr51(β <sup>+</sup> )V51(n,3n)V49(β <sup>+</sup> ) Ti49(n,2α)Ar42 Fe56(n,t)Mn54(β <sup>+</sup> )Cr54(n,2nα)Ti49(n,2α)Ar42   &Fe56(n,3nα)Cr50(n,tα)Sc44(β <sup>+</sup> )Ca44 (n,h)Ar42				66.3 17.3 0.2 4.3 4.0 3.7 3.6 3.6 3.1 3.0 22.0 5.1 5.0 4.1 3.9 3.8		0.8 0.8 0.3 3.1 3.0 5.2 2.7 0.7 1.4 6.3	
Ni63	100.6 y	&Fe58(n,γ)Fe59(β <sup>-</sup> )Co59(n,γ)Co60(n,γ) Co61(β <sup>-</sup> )Ni61(n,γ)Ni62(n,γ)Ni63 &Fe58(n,γ)Fe59(β <sup>-</sup> )Co59(n,γ)Co60(β <sup>-</sup> ) Ni60(n,γ)Ni61(n,γ)Ni62(n,γ)Ni63 &Fe57(n,γ)Fe58(n,γ)Fe59(β <sup>-</sup> )Co59(n,γ) Co60(n,γ)Co61(β <sup>-</sup> )Ni61(n,γ)Ni62(n,γ)Ni63 &Fe56(n,γ)Fe57(n,γ)Fe58(n,γ)Fe59(β <sup>-</sup> ) Co59(n,γ)Co60(n,γ)Co61(β <sup>-</sup> )Ni61(n,γ) Ni62(n,γ)Ni63 Fe58(n,γ)Fe59(n,γ)Fe60(n,γ)Fe61(β <sup>-</sup> ) Co61(β <sup>-</sup> )Ni61(n,γ)Ni62(n,γ)Ni63 &Fe57(n,γ)Fe58(n,γ)Fe59(β <sup>-</sup> )Co59(n,γ) Co60(β <sup>-</sup> )Ni60(n,γ)Ni61(n,γ)Ni62(n,γ)Ni63	63.4 10.8 10.8 9.4 2.1 1.5	89.0 10.3 0.5	84.0 11.3 0.4	76.6 11.1 11.8			
Ar39	269.0 y	Fe54(n,nα)Cr50(n,α)Ti47(n,2n)Ti46(n,α) Ca43(n,nα)Ar39 Fe54(n,nα)Cr50(n,α)Ti47(n,nα)Ca43 (n,nα)Ar39 Fe54(n,α)Cr51(n,α)Ti48(n,α)Ca45(β <sup>-</sup> ) Sc45(n,α)K42(β <sup>-</sup> )Ca42(n,α)Ar39 Fe54(n,α)Cr51(β <sup>+</sup> )V51(n,nα)Sc47(β <sup>-</sup> ) Ti47(n,2n)Ti46(n,α)Ca43(n,nα)Ar39 Fe54(n,nα)Cr50(n,nα)Ti46(n,α)Ca43 (n,nα)Ar39 Fe54(n,nα)Cr50(n,α)Ti47(n,2n)Ti46 (n,nα)Ca42(n,α)Ar39 Fe54(n,nα)Cr50(n,nα)Ti46(n,2α)Ar39 Fe54(n,nα)Cr50(n,2α)Ca43(n,nα)Ar39 Fe54(n,dα)V49(β <sup>+</sup> )Ti49(n,2nα)Ca44 (n,2nα)Ar39 Fe54(n,dα)V49(n,2nα)Sc44(β <sup>+</sup> )Ca44 (n,2nα)Ar39 Fe56(n,2nα)Cr51(β <sup>+</sup> )V51(n,nα)Sc47(β <sup>-</sup> ) Ti47(n,n2α)Ar39				9.4 4.8 4.3 4.2 3.6 3.2 49.8 9.9 6.6 4.0 3.1	1.3 2.4	1.9 1.0 6.6 4.0 3.1	

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	60	21	6
	◀	Fe56(n,α)Cr52(n,2nα)Ti47(n,n2α)Ar39 Fe56(n,n2α)Ti48(n,2n2α)Ar39 Fe54(n,α)V48(β <sup>+</sup> )Ti48(n,2n2α)Ar39 Other pathways				70.5	36.6	80.3	90.4
Fe60	1.5 10 <sup>6</sup> y	Fe58(n,γ)Fe59(n,γ)Fe60 Fe56(n,γ)Fe57(n,γ)Fe58(n,γ)Fe59(n,γ)Fe60 Fe57(n,γ)Fe58(n,γ)Fe59(n,γ)Fe60 &Fe58(n,γ)Fe59(β <sup>-</sup> )Co59(n,γ)Co60(n,p)Fe60	43.7 36.7 19.6	100.0	100.0	95.8	98.0	100.0	100.0
Mn53	3.7 10 <sup>6</sup> y	Fe54(n,d)Mn53 &Fe54(n,2n)Fe53(β <sup>+</sup> )Mn53 Fe54(n,p)Mn54(n,2n)Mn53 Fe56(n,2n)Fe55(n,2n)Fe54(n,d)Mn53 Fe56(n,d)Mn55(n,3n)Mn53 Fe56(n,2n)Fe55(n,t)Mn53 Fe56(n,2n)Fe55(β <sup>+</sup> )Mn55(n,3n)Mn53 Fe56(n,3n)Fe54(n,d)Mn53 &Fe56(n,3n)Fe54(n,2n)Fe53(β <sup>+</sup> )Mn53 Fe56(n,t)Mn54(n,2n)Mn53 Fe56(n,nt)Mn53 Fe56(n,4n)Fe53(β <sup>+</sup> )Mn53				90.1 4.2 2.4 1.0	42.3 19.1 0.1 0.3 12.2 10.3 7.6 3.4 1.5 1.3 0.3	24.1 12.7   8.0 11.8 4.4 4.3 2.3 5.6 25.0	3.0 1.9   0.5 1.1    89.0 2.3

# Iron activation characteristics

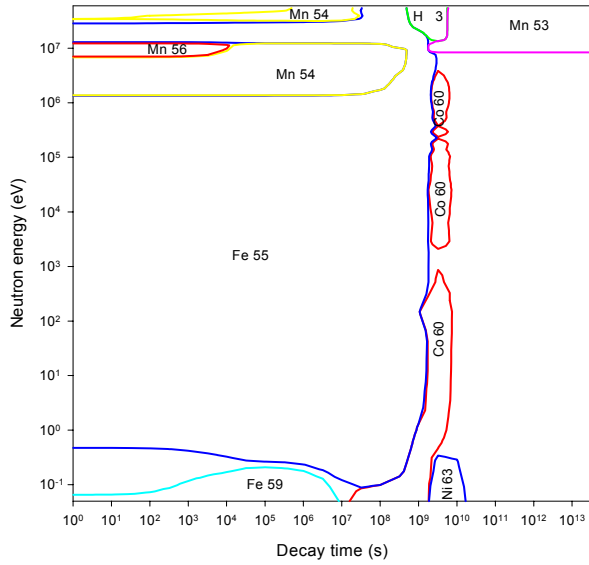


Decay time (years)

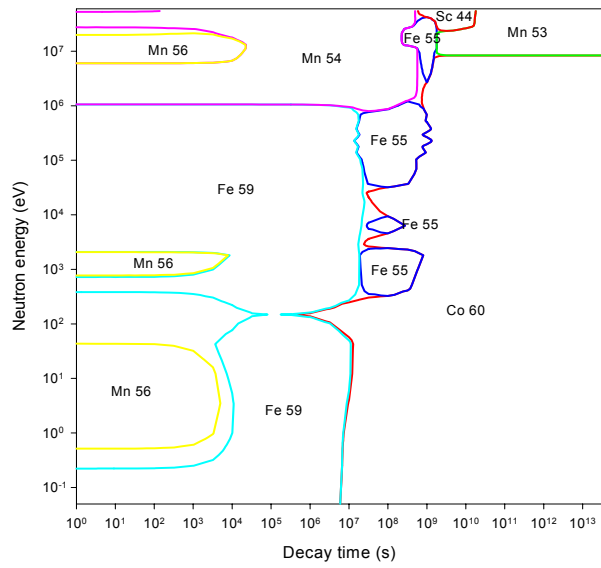
Decay time (years)

# Iron importance diagrams & transmutation

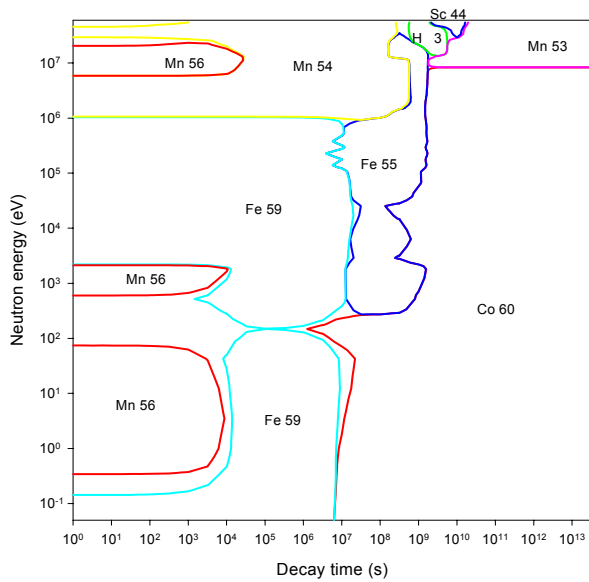
**Activity**



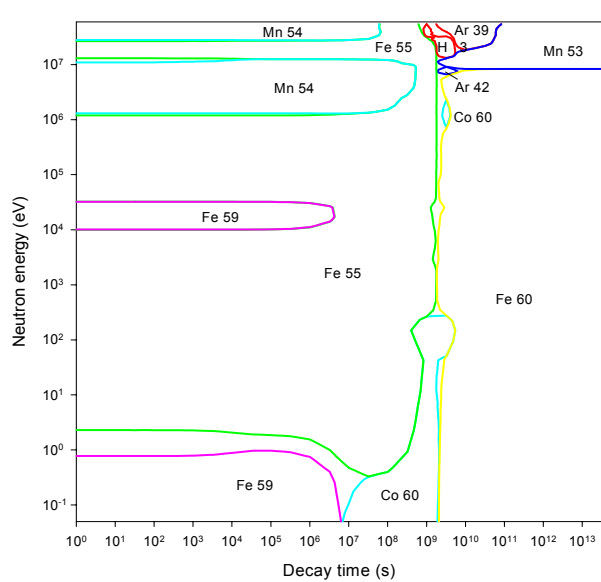
**Dose rate**



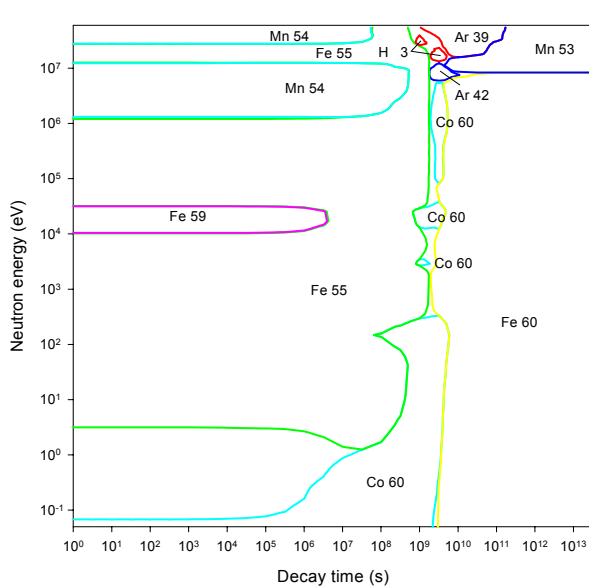
**Heat output**



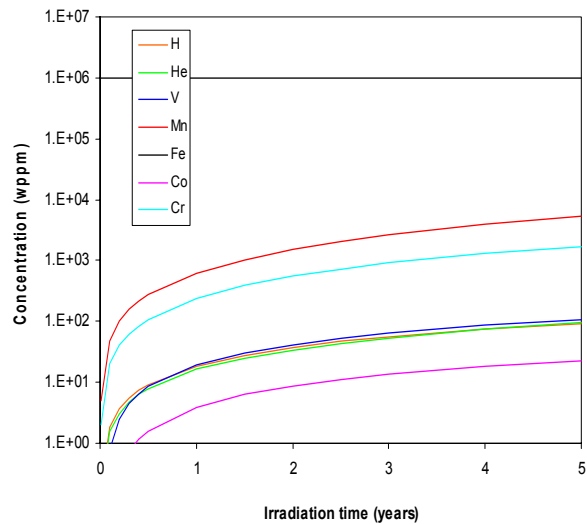
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**





# Cobalt

## General properties

Atomic number	27	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	25	Co59	100.0
Melting point / K	1768		
Boiling point / K	3200		
Density / kgm <sup>-3</sup>	8900		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	100.0		
Electrical resistivity /Ωm	6.24 10 <sup>-8</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	1.336 10 <sup>-5</sup>		
Crystal structure	BCC		
Number of stable isotopes	1		
Mean atomic weight	58.9332		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	2.02E16	1.74E16	9.77E15	8.19E15	1.98E10	3.35E8	kW kg <sup>-1</sup>	4.12E0	4.08E0	3.96E0	3.41E0	7.57E-6	1.03E-8
Co60m	47.06	38.62			0.12	6.81	Co60	94.43	95.14	98.05	99.94	99.97	91.73
Co60	46.12	53.40	95.32	99.85	91.52	6.79	Co60m	2.31	1.64				2.20
Co58m	2.22	2.57					Co58	1.57	1.58	1.59	0.05		
Co61	2.05	2.29					Co61	0.90	0.88				
Co58	1.98	2.30	3.98	0.13			Fe59	0.36	0.36	0.35			
H3					4.74		Mn56	0.33	0.32				
Ni59					3.34	79.59	Ni59					0.01	2.66
Fe60					0.12	6.81	Fe60						3.10
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	6.94E6	6.93E6	6.89E6	5.95E6	1.32E1	1.67E-2	Sv kg <sup>-1</sup>	3.22E7	3.22E7	3.21E7	2.78E7	6.45E1	2.60E0
Co60	97.70	97.77	98.26	99.95	100.0	99.26	Co60	98.48	98.49	98.72	99.97	95.79	2.97
Co58	1.43	1.43	1.40	0.04			Co58	0.92	0.92	0.89	0.03		
Fe59	0.35	0.35	0.33				Fe59	0.39	0.39	0.37			
Co60m	0.18	0.13				0.18	Fe60					4.07	96.38
Ni59						0.55	Ni59					0.06	0.64
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	2.90E8	2.90E8	2.90E8	2.54E8	5.70E2	7.21E0		9.38E13	9.38E13	9.36E13	8.18E13	1.82E8	2.30E5
Co60	99.60	99.60	99.63	99.99	98.73	9.78	Co60	99.48	99.48	99.51	99.99	99.99	98.74
Co58	0.29	0.29	0.28				Co58	0.42	0.42	0.41	0.01		
Fe60					1.17	88.59	Co60m	0.01					
Ni59					0.05	1.62	Ni59						1.15

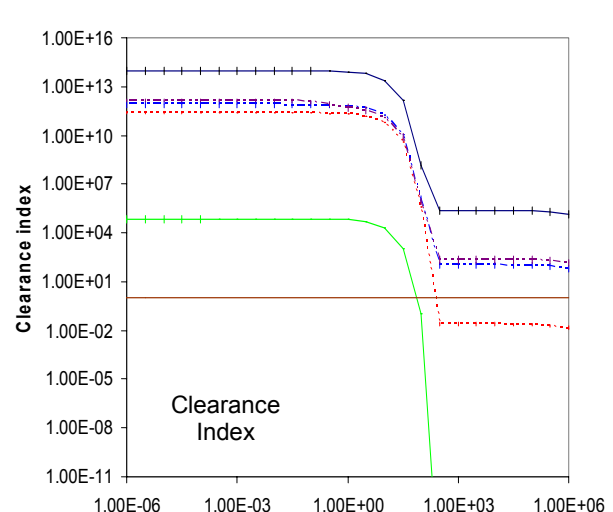
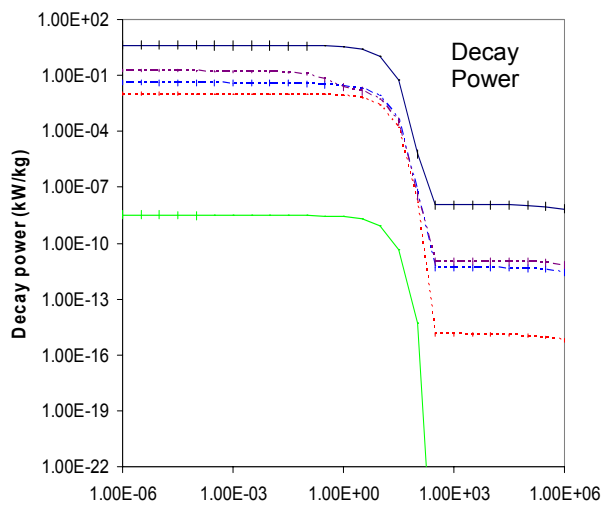
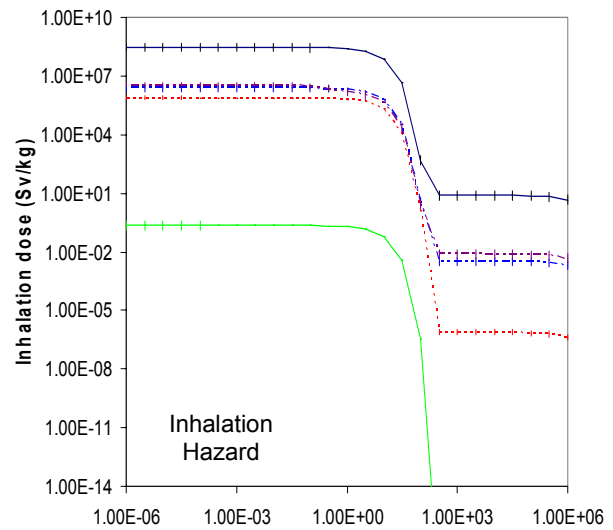
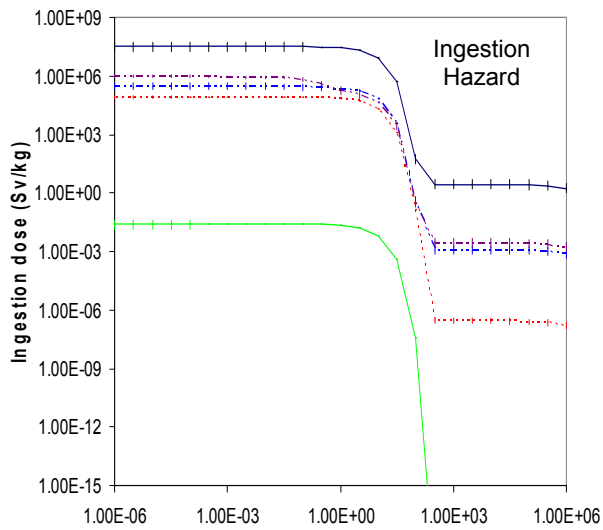
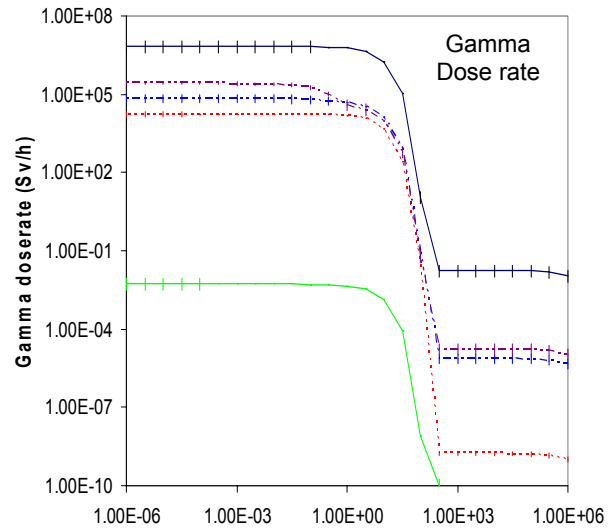
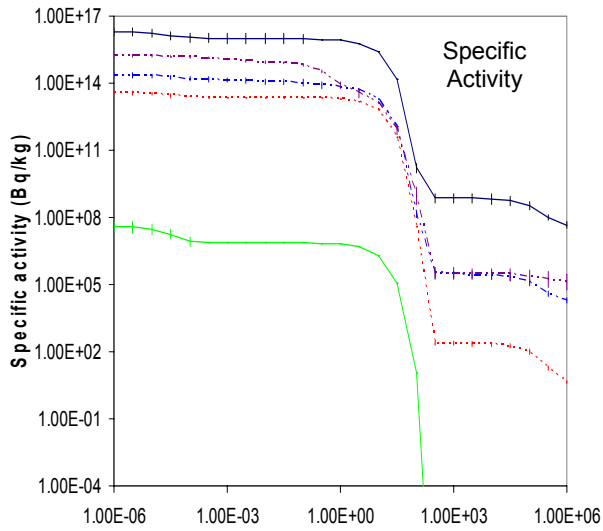
# Cobalt

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Co60m	10.47 m	Co59(n,γ)Co60m Co59(n,γ)Co60(n,n')Co60m Co59(n,γ)Co60(β <sup>-</sup> )Ni60(n,p)Co60m	100.0	100.0	100.0	96.6 1.1 0.3	98.5 0.5	99.0 0.3	99.5
Sc44	3.97 h	&Co59(n,nα)Mn55(n,nα)V51(n,α)Sc48_ (β <sup>-</sup> )Ti48(n,α)Ca45(β <sup>-</sup> )Sc45(n,2n)Sc44 &Co59(n,nα)Mn55(n,α)V52(β <sup>-</sup> )Cr52(n,α)_ Ti49(n,2n)Ti48(n,α)Ca45(β <sup>-</sup> )Sc45(n,2n)Sc44 Co59(n,α)Mn56(β <sup>-</sup> )Fe56(n,nα)Cr52(n,α)_ Ti49(n,2n)Ti48(n,α)Ca45(β <sup>-</sup> )Sc45(n,2n)Sc44 &Co59(n,nα)Mn55(n,3n)Mn53(n,nα)_ V49(n,nα)Sc45(n,2n)Sc44 &Co59(n,3n)Co57(n,nα)Mn53(n,nα)V49_ (n,nα)Sc45(n,2n)Sc44 &Co59(n,nα)Mn55(n,nα)V51(n,3n)V49_ (n,nα)Sc45(n,2n)Sc44 &Co59(n,2nα)Mn54(n,2nα)V49(n,2nα)Sc44 &Co59(n,2n2α)V50(n,3nα)Sc44 &Co59(n,3nα)Mn53(n,2n2α)Sc44 &Co59(n,3nα)Mn53(n,tα)Ti47(n,nt)Sc44 &Co59(n,3nα)Mn53(n,nt)Cr50(n,tα)Sc44 &Co59(n,nt)Fe56(n,3nα)Cr50(n,tα)Sc44 Other pathways				12.4 10.6 5.1 14.4 7.3 5.8 23.4 9.4 8.2 6.8 6.2 4.4 71.9	72.5	76.6	64.8
Fe59	44.495 d	&Co59(n,γ)Co60(n,γ)Co61(β <sup>-</sup> )Ni61(n,α)_ Fe58(n,γ)Fe59 &Co59(n,γ)Co60(β <sup>-</sup> )Ni60(n,γ)Ni61(n,α)_ Fe58(n,γ)Fe59 Co59(n,p)Fe59 Co59(n,2n)Co58m(IT)Co58(β <sup>+</sup> )Fe58(n,γ)Fe59	79.4 20.3	83.5 16.4	82.7 17.1	99.8 0.1	99.4	99.5	99.6
Co58	70.86 d	&Co59(n,2n)Co58				99.3	99.7	99.8	99.9
Co57	271.8 d	&Co59(n,2n)Co58(n,2n)Co57 Co59(n,2n)Co58m(n,2n)Co57 Co59(n,3n)Co57				99.1 0.4	0.9	0.2	99.7
Mn54	312.13 d	Co59(n,nα)Mn55(n,2n)Mn54 &Co59(n,2n)Co58(β <sup>+</sup> )Fe58(n,α)Cr55(β <sup>-</sup> )_ Mn55(n,2n)Mn54 &Co59(n,2n)Co58(n,nα)Mn54 Co59(n,α)Mn56(β <sup>-</sup> )Fe56(n,2n)Fe55(β <sup>+</sup> )_ Mn55(n,2n)Mn54 &Co59(n,2n)Co58(n,α)Mn55(n,2n)Mn54 Co59(n,α)Mn56(β <sup>-</sup> )Fe56(n,2n)Fe55(n,d)Mn54 Co59(n,α)Mn56(β <sup>-</sup> )Fe56(n,d)Mn55(n,2n)Mn54 Co59(n,d)Fe58(n,α)Cr55(β <sup>-</sup> )Mn55(n,2n)Mn54 Co59(n,2nα)Mn54 Co59(n,nt)Fe56(n,t)Mn54 Co59(n,t)Fe57(n,nt)Mn54				61.5 12.9 6.3 4.2 4.1 3.2 2.9 2.1 19.7 0.2 0.1	60.9	1.6	0.9 0.1 88.1 4.5 1.0
Fe55	2.735 y	Co59(n,α)Mn56(β <sup>-</sup> )Fe56(n,2n)Fe55 Co59(n,3n)Co57(β <sup>+</sup> )Fe57(n,3n)Fe55 Co59(n,t)Fe57(n,3n)Fe55 Co59(n,3n)Co57(n,t)Fe55 &Co59(n,2n)Co58(β <sup>+</sup> )Fe58(n,3n)Fe56_ (n,2n)Fe55 &Co59(n,2n)Co58(β <sup>+</sup> )Fe58(n,2n)Fe57_ (n,3n)Fe55 Co59(n,nt)Fe56(n,2n)Fe55 &Co59(n,2n)Co58(β <sup>+</sup> )Fe58(n,4n)Fe55 Co59(n,2nt)Fe55				94.0 35.3 21.4 12.4 6.5 3.1 1.5	3.5 25.1 33.4 16.0 0.9 0.5 10.1	0.6 2.4 4.0 1.9	0.8 2.4 4.0 1.9 9.2 4.4 71.1

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Co60	5.271 y	&Co59(n, $\gamma$ )Co60	100.0	100.0	100.0	99.4	99.8	99.8	99.9
H3	12.33 y	Co59(n,X)H3 &Co59(n,2n)Co58(n,X)H3 Co59(n,3n)Co57( $\beta^+$ )Fe57(n,X)H3 Co59(n,t)Fe57(n,X)H3 Co59(n,nt)Fe56(n,X)H3				95.7 3.5	92.5 0.9	92.7 0.3	93.5 0.5 0.9 1.5
Ni63	100.6 y	&Co59(n, $\gamma$ )Co60(n, $\gamma$ )Co61( $\beta^-$ )Ni61(n, $\gamma$ )_Ni62(n, $\gamma$ )Ni63 &Co59(n, $\gamma$ )Co60( $\beta^-$ )Ni60(n, $\gamma$ )Ni61(n, $\gamma$ )_Ni62(n, $\gamma$ )Ni63 Co59(n, $\gamma$ )Co60m( $\beta^-$ )Ni60(n, $\gamma$ )Ni61(n, $\gamma$ )_Ni62(n, $\gamma$ )Ni63	81.8 18.0 0.2	86.7 13.1 0.1	85.4 14.4 0.2	84.1 15.2 0.2	83.3 16.1 0.2	84.2 15.4 0.2	84.8 14.9 0.2
Ar39	269.0 y	Co59(n, $\alpha$ )Mn55(n, $\alpha$ )V51(n, $\alpha$ )Sc47_( $\beta^-$ )Ti47(n,2n)Ti46(n, $\alpha$ )Ca43(n, $\alpha$ )Ar39 Co59(n, $\alpha$ )Mn55(n, $\alpha$ )V51(n, $\alpha$ )Sc47_( $\beta^-$ )Ti47(n, $\alpha$ )Ca43(n, $\alpha$ )Ar39 Co59(n, $\alpha$ )Mn55(n, $\alpha$ )V51(n, $\alpha$ )Sc47_( $\beta^-$ )Ti47(n, $\alpha$ )Ca44(n,2n)Ca43(n, $\alpha$ )Ar39 Co59(n, $\alpha$ )Mn55(n, $\alpha$ )V51(n, $\alpha$ )Sc47_( $\beta^-$ )Ti47(n,2n)Ti46(n,2 $\alpha$ )Ar39 Co59(n, $\alpha$ )Mn55(n, $\alpha$ )V51(n,2n)V50_(n, $\alpha$ )Sc46( $\beta^-$ )Ti46(n,2 $\alpha$ )Ar39 Co59(n,2n $\alpha$ )Mn54( $\beta^+$ )Cr54(n,2n $\alpha$ )Ti49_(n,2n $\alpha$ )Ca44(n,2n $\alpha$ )Ar39 &Co59(n,2n $\alpha$ )Mn54(n,2n $\alpha$ )V49(n,2n $\alpha$ )_Sc44( $\beta^+$ )Ca44(n,2n $\alpha$ )Ar39 Co59(n,2n $\alpha$ )Mn54(n,2n $\alpha$ )V49( $\beta^+$ )Ti49_(n,2n $\alpha$ )Ca44(n,2n $\alpha$ )Ar39 Co59(n,2n $\alpha$ )Mn54(n,2n $\alpha$ )V49(n,d $\alpha$ )_Ca44(n,2n $\alpha$ )Ar39 Co59(n,3n $\alpha$ )Mn53(n,t $\alpha$ )Ti47(n,n2 $\alpha$ )Ar39 Co59(n,3n $\alpha$ )Mn53(n,n2 $\alpha$ )Sc45(n,t $\alpha$ )Ar39 Co59(n,3n $\alpha$ )Mn53(n,2n $\alpha$ )V48( $\beta^+$ )Ti48_(n,2n2 $\alpha$ )Ar39 Co59(n,3n $\alpha$ )Mn53(n,d $\alpha$ )Ti48(n,2n2 $\alpha$ )Ar39 &Co59(n,n2 $\alpha$ )V51(n,3n $\alpha$ )Sc45(n,t $\alpha$ )Ar39 Co59(n,t $\alpha$ )Cr53(n,3n $\alpha$ )Ti47(n,n2 $\alpha$ )Ar39 Other pathways				1.9 1.2 1.0 3.1 2.2 8.0 7.3 6.8 3.3 7.1 5.2 3.2 2.5 2.1 2.0 95.9	30.7 3.1 2.2 8.0 7.3 6.8 3.3	74.6	77.9
Ni59	7.6 10 <sup>4</sup> y	&Co59(n, $\gamma$ )Co60( $\beta^-$ )Ni60(n,2n)Ni59 Co59(n, $\gamma$ )Co60m( $\beta^-$ )Ni60(n,2n)Ni59				99.1 0.6	99.2 0.7	99.2 0.7	99.3 0.7
Fe60	1.5 10 <sup>6</sup> y	&Co59(n, $\gamma$ )Co60(n, $\gamma$ )Co61( $\beta^-$ )Ni61(n, $\alpha$ )_Fe58(n, $\gamma$ )Fe59(n, $\gamma$ )Fe60 &Co59(n, $\gamma$ )Co60( $\beta^-$ )Ni60(n, $\gamma$ )Ni61(n, $\alpha$ )_Fe58(n, $\gamma$ )Fe59(n, $\gamma$ )Fe60 &Co59(n, $\gamma$ )Co60(n,p)Fe60 Co59(n,p)Fe59(n, $\gamma$ )Fe60	82.1 16.2 1.4	87.3 12.6	100.0	93.5 6.1	88.6 11.0	89.0 10.7	89.5 10.5
Mn53	3.7 10 <sup>6</sup> y	Co59(n, $\alpha$ )Mn55(n,2n)Mn54(n,2n)Mn53 &Co59(n,2n)Co58(n, $\alpha$ )Mn54(n,2n)Mn53 &Co59(n,2n)Co58( $\beta^+$ )Fe58(n, $\alpha$ )Cr55( $\beta^-$ )_Mn55(n,2n)Mn54(n,2n)Mn53 &Co59(n,2n)Co58(n, $\alpha$ )Mn55(n,2n)Mn54_(n,2n)Mn53 Co59(n, $\alpha$ )Mn56( $\beta^-$ )Fe56(n,2n)Fe55_(n,2n)Fe54(n,d)Mn53 Co59(n, $\alpha$ )Mn55(n,3n)Mn53 Co59(n,3n)Co57(n, $\alpha$ )Mn53 &Co59(n,2n)Co58(n,2n $\alpha$ )Mn53 Co59(n,2n $\alpha$ )Mn54(n,2n)Mn53 Co59(n,3n $\alpha$ )Mn53 Co59(n,nt)Fe56(n,nt)Mn53				56.8 10.1 7.8 3.6 2.7	1.3 0.2	0.2	0.6
							66.1 24.0 1.0 0.8	31.7 12.4 4.9 18.4 6.4 2.7	82.3 9.9

# Cobalt activation characteristics

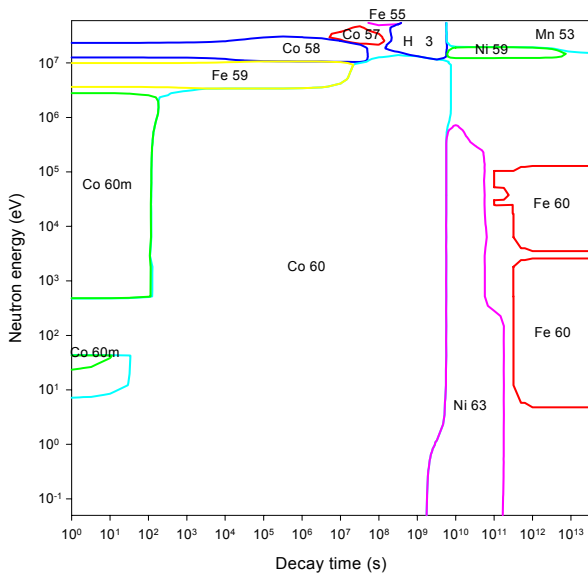


Decay time (years)

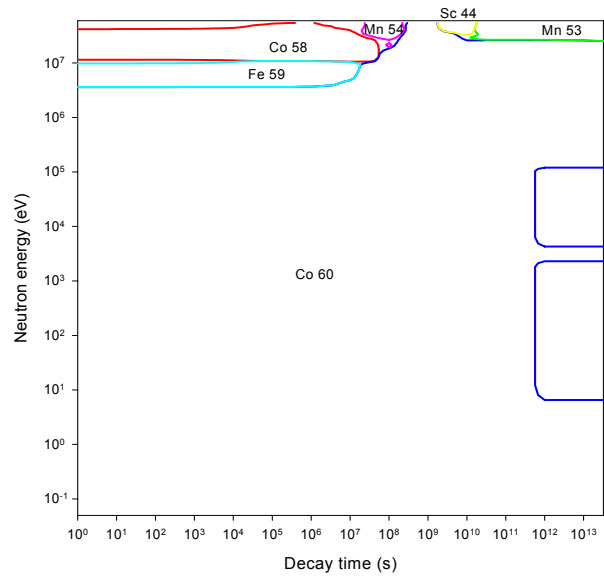
Decay time (years)

# Cobalt importance diagrams & transmutation

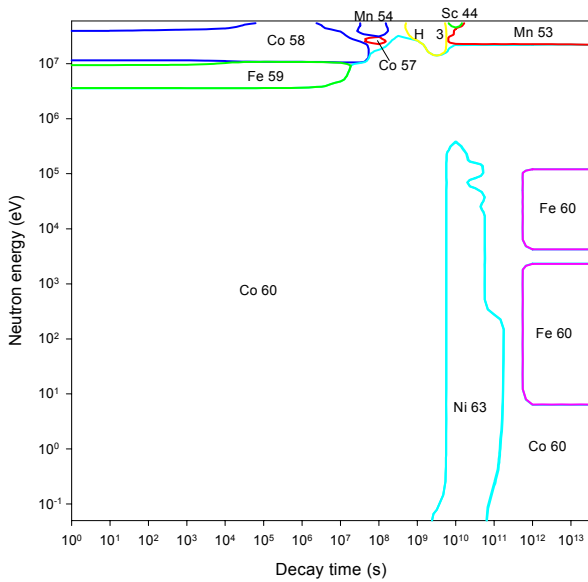
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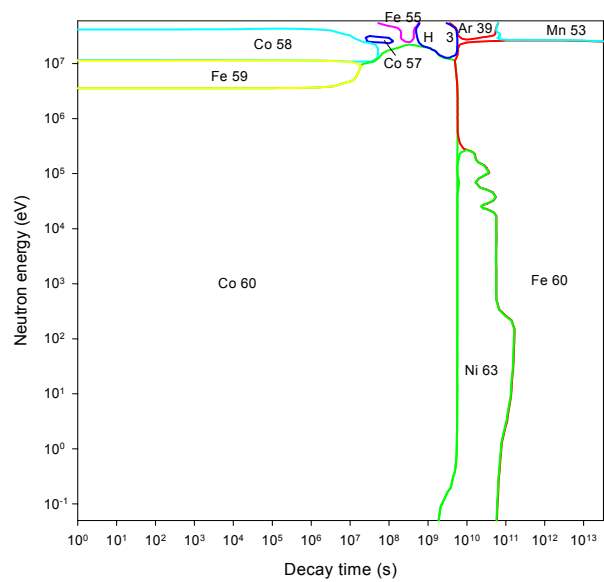
**Dose rate**



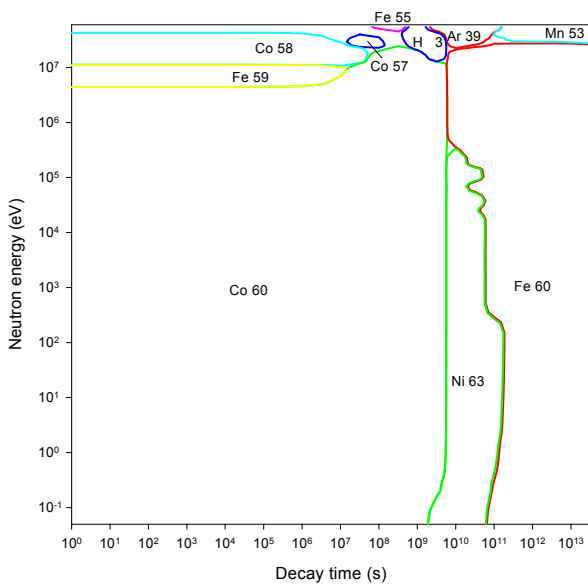
**Heat output**



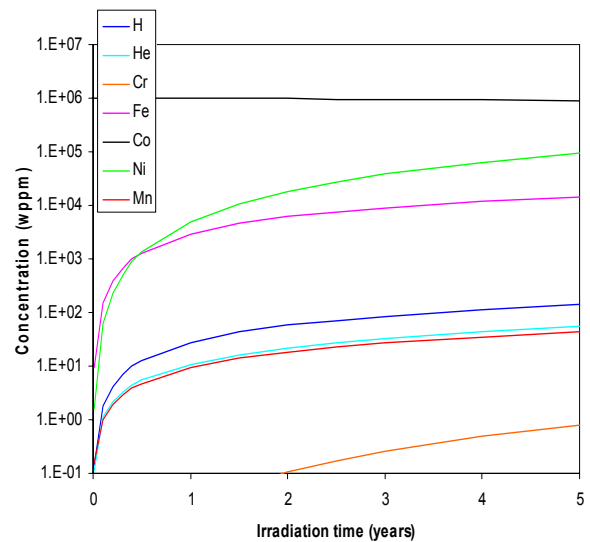
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**





# Nickel

## General properties

Atomic number	28	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	84	Ni58	68.077 (T <sub>1/2</sub> = 7.00 10 <sup>20</sup> y)
Melting point / K	1728	Ni60	26.223
Boiling point / K	3186	Ni61	1.14
Density / kgm <sup>-3</sup>	8902	Ni62	3.634
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	90.7	Ni64	0.926
Electrical resistivity /Ωm	6.84 10 <sup>-8</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	1.34 10 <sup>-5</sup>		
Crystal structure	FCC		
Number of stable isotopes	4 (5)		
Mean atomic weight	58.69		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	1.43E15	1.41E15	1.07E15	3.43E14	7.53E11	4.49E9	kW kg <sup>-1</sup>	1.02E-1	1.01E-1	8.89E-2	2.12E-2	2.11E-6	5.20E-9
Co57	41.25	41.83	54.86	67.94			Co58	56.80	57.47	63.32	7.73		
Co58	25.05	25.40	32.57	2.95			Co60	15.62	15.80	17.95	66.18	1.47	0.82
Co58m	18.49	18.63	0.02				Co57	13.28	13.44	15.15	25.29		
Fe55	5.75	5.83	7.70	18.66			Ni57	7.94	8.02	1.68			
Co60m	3.64	2.60					Fe59	1.15	1.17	1.25	0.01		
Co60	2.67	2.71	3.58	9.81			Mn56	1.03	1.10				
Ni57	1.68	1.70	0.41				Co58m	0.99	1.00				
Ni63	0.10	0.10	0.13	0.42	98.50		Ni63				0.01	97.92	
Ni59					1.48	99.99	Ni59					0.60	99.12
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	1.35E5	1.35E5	1.19E5	2.80E4	5.54E-2	1.42E-3	Sv kg <sup>-1</sup>	5.94E5	5.89E5	5.54E5	1.93E5	1.12E2	2.95E-1
Co58	63.11	63.47	69.37	8.59			Co58	44.69	45.09	46.48	3.88		
Co60	19.75	19.87	22.39	83.72	93.96	5.09	Co60	21.94	22.13	23.53	59.36	0.22	0.11
Ni57	9.26	9.30	1.93				Co57	20.88	21.07	22.22	25.39		
Co57	3.70	3.72	4.16	7.04			Fe55	4.57	4.61	4.90	10.96		
Fe59	1.37	1.37	1.46	0.02			Ni57	3.54	3.56	0.69			
Mn56	0.93	0.91					Fe59	1.71	1.72	1.73	0.01		
Co62m	0.51	0.40					Co58m	1.07	1.07				
Co56	0.37	0.37	0.41	0.06			Ni63	0.03	0.03	0.04	0.11	99.14	
Mn54	0.23	0.23	0.26	0.49			Ni59					0.62	96.00
Ni59					6.03	94.90	Fe60					0.01	3.87
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	2.65E6	2.65E6	2.60E6	1.35E6	9.72E2	2.01E0		1.41E12	1.41E12	1.35E12	5.86E11	8.28E6	4.59E4
Co60	44.87	44.94	45.71	77.28	0.23	0.15	Co57	41.93	42.00	43.38	39.73		
Co58	28.45	28.49	28.11	1.57			Co60	27.21	27.26	28.37	57.37	9.02	2.25
Co57	22.30	22.34	22.55	17.26			Co58	25.46	25.51	25.75	1.72		
Fe55	2.39	2.39	2.43	3.65			Ni57	3.36	3.36	0.64			
Fe59	0.85	0.85	0.82				Mn54	0.01	1.01	1.09	1.12		
Ni63	0.07	0.07	0.07	0.14	99.25		Mn56	0.01	0.01				
Ni59					0.50	98.39	Ni63					89.62	
Fe60						1.44	Ni59					1.34	97.74

# Nickel

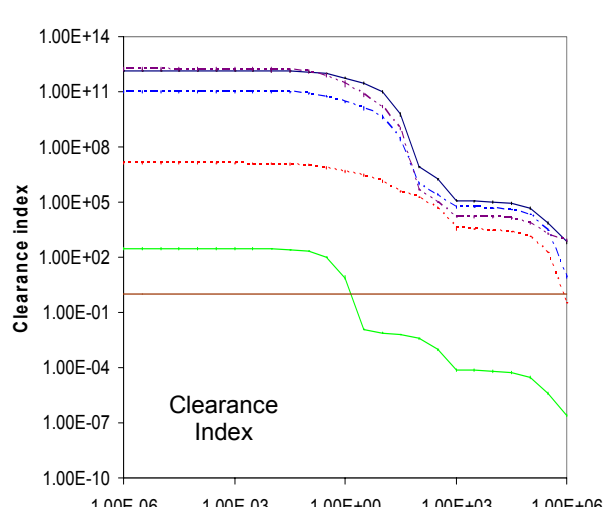
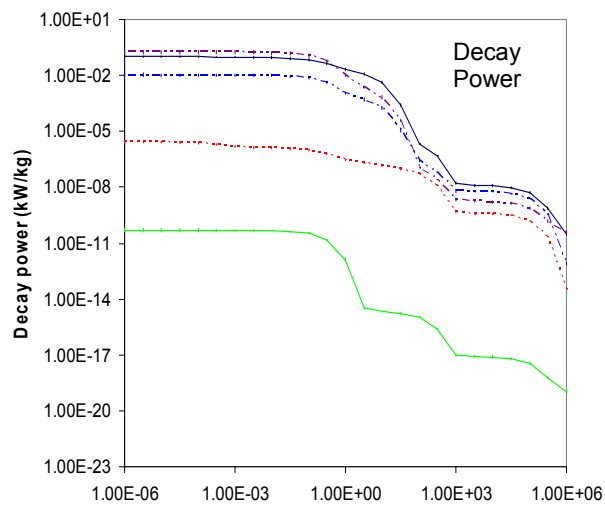
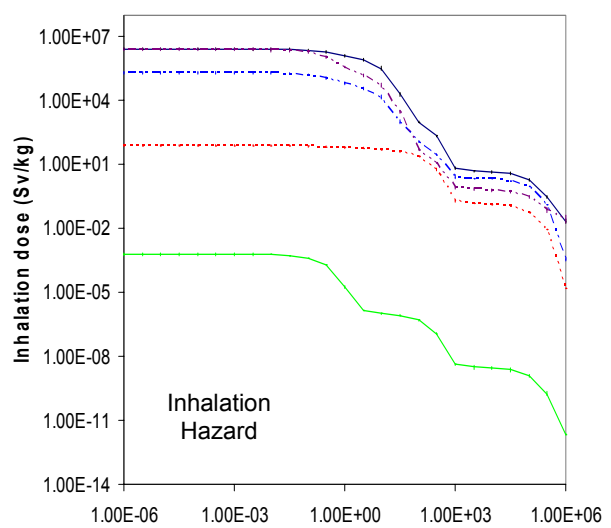
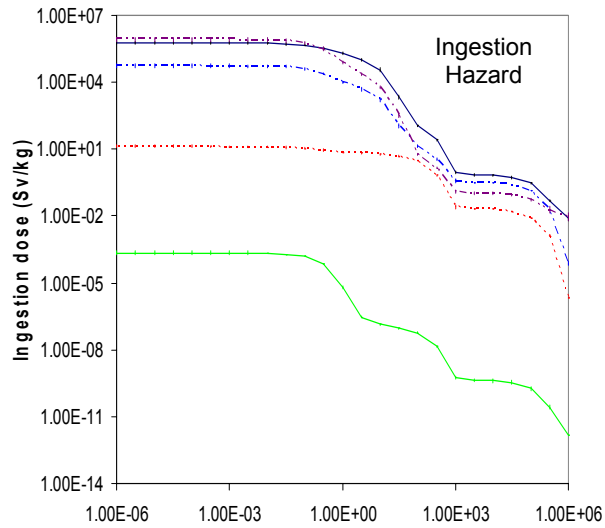
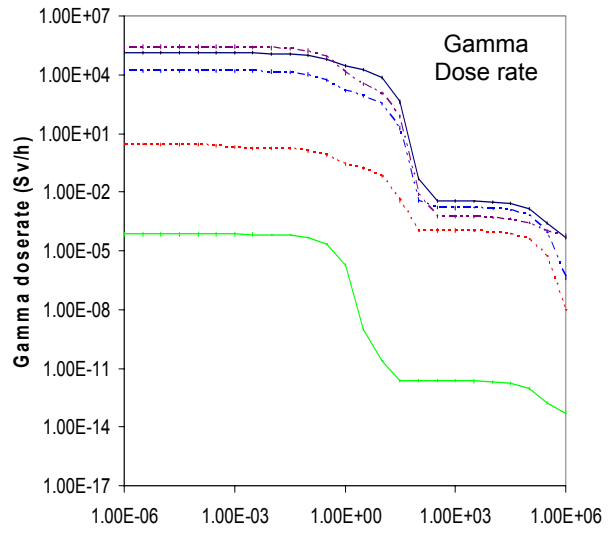
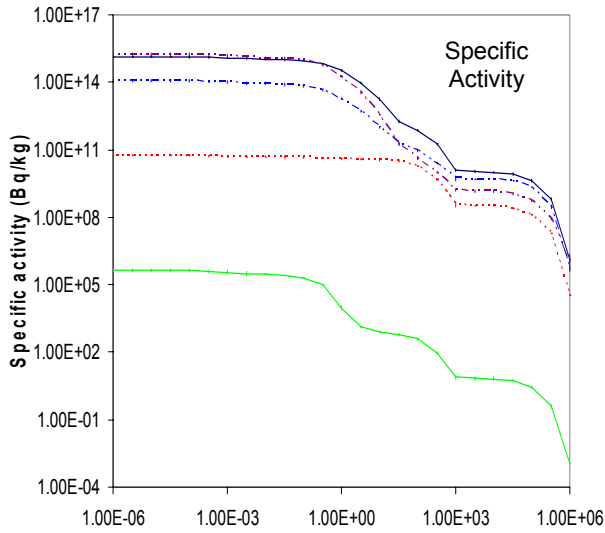
## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
Ni65	2.52 h	Ni62(n,γ)Ni63(n,γ)Ni64(n,γ)Ni65	49.4	0.6						
		Ni64(n,γ)Ni65	48.9	99.4	100.0	99.5	99.4	99.6	99.8	
		Ni61(n,γ)Ni62(n,γ)Ni63(n,γ)Ni64(n,γ)Ni65	0.8							
Cu64	12.701 h	Ni62(n,γ)Ni63(β <sup>-</sup> )Cu63(n,γ)Cu64	96.9	99.9	99.9					
		Ni61(n,γ)Ni62(n,γ)Ni63(β <sup>-</sup> )Cu63(n,γ)Cu64	1.5							
		Ni64(n,γ)Ni65(β <sup>-</sup> )Cu65(n,2n)Cu64				93.3	94.4	93.5	90.9	
		Ni64(n,2n)Ni63(β <sup>-</sup> )Cu63(n,γ)Cu64				6.1	4.8	5.2	6.9	
		Ni64(n,d)Co63(β <sup>-</sup> )Ni63(β <sup>-</sup> )Cu63(n,γ)Cu64					0.4	1.1	2.1	
Co58	70.86 d	&Ni58(n,p)Co58	99.8	100.0	100.0	93.2	45.9	17.3	14.7	
		&Ni60(n,2n)Ni59(n,d)Co58				3.8	12.5	2.0	1.4	
		&Ni60(n,d)Co59(n,2n)Co58				2.5	11.3	1.6	0.8	
		&Ni60(n,t)Co58					28.2	77.1	76.4	
		&Ni61(n,nt)Co58						0.2	2.9	
Co56	77.31 d	Ni58(n,d)Co57(n,2n)Co56				93.7	9.7	0.7		
		Ni58(n,2n)Ni57(β <sup>+</sup> )Co57(n,2n)Co56				5.4	1.3	0.1		
		Ni58(n,t)Co56				0.5	87.4	97.2	95.6	
		Ni58(n,3n)Ni56(β <sup>+</sup> )Co56					1.0	1.3	1.9	
Co57	271.78 d	Ni58(n,d)Co57				94.3	86.7	83.2	68.1	
		Ni58(n,2n)Ni57(β <sup>+</sup> )Co57				5.4	11.8	13.4	9.0	
		Ni60(n,2n)Ni59(n,t)Co57					0.6	1.0	0.5	
		Ni60(n,nt)Co57						1.2	21.1	
Fe55	2.735 y	Ni58(n,α)Fe55	100.0	100.0	100.0	97.5	34.3	33.6	78.9	
		Ni60(n,α)Fe56(n,2n)Fe55				0.3	4.5	0.8		
		Ni58(n,d)Co57(β <sup>+</sup> )Fe57(n,3n)Fe55					19.3	9.4	0.8	
		Ni58(n,h)Fe56(n,2n)Fe55					16.2	10.4	1.0	
		Ni58(n,d)Co57(n,t)Fe55					6.7	5.9	0.7	
		Ni58(n,t)Co56(β <sup>+</sup> )Fe56(n,2n)Fe55					3.8	7.4	0.9	
		Ni60(n,2nα)Fe55					0.3	21.6	4.4	
		Ni58(n,nt)Co55(β <sup>+</sup> )Fe55						2.7	10.8	
Co60	5.271 y	&Ni58(n,γ)Ni59(n,p)Co59(n,γ)Co60	100.0	99.9	97.8					
		&Ni58(n,γ)Ni59(β <sup>+</sup> )Co59(n,γ)Co60			2.2					
		&Ni60(n,p)Co60				98.4	75.3	45.1	33.6	
		&Ni62(n,2n)Ni61(n,d)Co60				1.2	1.7	0.7		
		&Ni61(n,d)Co60				0.9	16.2	9.9	12.5	
		&Ni62(n,t)Co60					4.6	42.9	49.1	
H3	12.33 y	Ni58(n,γ)Ni59(n,X)H1(n,γ)H2(n,γ)H3	94.1	96.0	99.6					
		Ni58(n,X)H3				25.6	44.6	56.1	59.5	
		Ni60(n,X)H3				12.2	29.5	25.9	25.5	
		&Ni60(n,p)Co60(n,X)H3				11.5	0.1			
		Ni58(n,d)Co57(β <sup>+</sup> )Fe57(n,X)H3				10.1	4.3	1.7	1.0	
		&Ni58(n,p)Co58(n,X)H3				8.4				
		Ni58(n,d)Co57(n,X)H3				8.0	2.4	0.9	0.5	
		Ni61(n,X)H3				5.7	2.4	1.6	1.4	
		Ni60(n,2n)Ni59(n,X)H3				5.3	2.0	0.7		
		Ni60(n,d)Co59(n,X)H3				3.3	1.3	0.2		
		Ni58(n,α)Fe55(β <sup>+</sup> )Mn55(n,X)H3				2.7				
		Ni62(n,X)H3					3.4	3.4	3.6	
Ni58(n,α)Fe54(n,X)H3					2.0	0.9				
Ni63	100.6 y	Ni62(n,γ)Ni63	93.6	99.9	99.9	0.3	0.2	0.2		
		Ni60(n,γ)Ni61(n,γ)Ni62(n,γ)Ni63	3.5							
		Ni61(n,γ)Ni62(n,γ)Ni63	2.6							
		Ni64(n,2n)Ni63				99.4	90.9	82.0	76.9	
		Ni64(n,d)Co63(β <sup>-</sup> )Ni63					8.5	17.5	22.9	
Ar39	269.0 y	Ni58(n,α)Fe54(n,α)Cr50(n,α)Ti47_ (n,2n)Ti46(n,α)Ca43(n,α)Ar39				9.1				



Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	Ni58(n,α)Fe54(n,α)Cr50(n,α)Ti47_ (n,α)Ca43(n,α)Ar39 Ni58(n,α)Fe54(n,α)Cr50(n,α)Ti47_ (n,α)Ca44(n,2n)Ca43(n,α)Ar39 Ni58(n,α)Fe54(n,α)Cr51(n,α)Ti48(n,α)_ Ca45(β <sup>-</sup> )Sc45(n,α)K42(β <sup>-</sup> )Ca42(n,α)Ar39 Ni58(n,α)Fe54(n,α)Cr50(n,α)Ti46_ (n,α)Ca43(n,α)Ar39 Ni58(n,α)Fe54(n,α)Cr51(β <sup>+</sup> )V51(n,α)_ Sc47(β <sup>-</sup> )Ti47(n,2n)Ti46(n,α)Ca43(n,α)Ar39 Ni58(n,α)Fe54(n,α)Cr50(n,α)Ti47_ (n,2n)Ti46(n,α)Ca42(n,α)Ar39 Ni58(n,α)Fe54(n,α)Cr51(β <sup>+</sup> )V51(n,α)_ Sc47(β <sup>-</sup> )Ti47(n,α)Ca43(n,α)Ar39 Ni58(n,α)Fe54(n,α)Cr50(n,α)Ti46(n,2α)Ar39   Ni58(n,α)Fe54(n,α)Cr50(n,2α)Ca43_ (n,α)Ar39 Ni58(n,α)Fe54(n,α)Cr50(n,α)Sc46_ (β <sup>-</sup> )Ti46(n,2α)Ar39 Ni58(n,α)Fe54(n,2α)Ti47(n,α)Ca43_ (n,α)Ar39 &Ni58(n,α)Fe54(n,dα)V49(n,2nα)Sc44_ (β <sup>+</sup> )Ca44(n,2nα)Ar39 Ni58(n,α)Fe54(n,dα)V49(β <sup>+</sup> )Ti49_ (n,2nα)Ca44(n,2nα)Ar39 Ni58(n,α)Fe54(n,2α)Ti47(n,2α)Ar39 Ni58(n,α)Fe54(n,dα)V49(n,dα)Ca44_ (n,2nα)Ar39 Ni58(n,dα)Mn53(n,tα)Ti47(n,2α)Ar39 Ni58(n,dα)Mn53(n,2α)Sc45(n,tα)Ar39 Ni58(n,2α)Cr50(n,3α)Ar39 Ni58(n,2α)Cr50(n,dα)Sc45(n,tα)Ar39 Ni58(n,α)Fe54(n,tα)V48(β <sup>+</sup> )Ti48(n,2n2α)Ar39   Other pathways				5.6 4.8 4.5 4.2 4.0 3.1 2.5 59.0 11.7 3.1 2.8 6.4 5.4 3.6 2.9 4.2 3.1 3.0 2.7 2.4	1.3 2.3 4.0 3.1 59.0 11.7 3.1 2.8 6.4 5.4 3.6 2.9 19.8 78.5	1.7 1.0 0.2 0.3 6.4 5.4 3.6 2.9 4.2 3.1 3.0 2.7 2.4	84.6
Ni59	7.6 10 <sup>4</sup> y	Ni58(n,γ)Ni59 Ni60(n,2n)Ni59 Ni61(n,3n)Ni59 Ni62(n,4n)Ni59	100.0	100.0	100.0	0.3 99.1	0.3 97.2 1.6	0.3 94.3 3.8 0.7	88.7 2.8 7.6
Fe60	1.5 10 <sup>6</sup> y	Ni58(n,γ)Ni59(n,α)Fe56(n,γ)Fe57(n,γ)_ Fe58(n,γ)Fe59(n,γ)Fe60 Ni61(n,α)Fe58(n,γ)Fe59(n,γ)Fe60 Ni60(n,γ)Ni61(n,α)Fe58(n,γ)Fe59(n,γ)Fe60 &Ni60(n,p)Co60(n,p)Fe60 Ni64(n,2n)Ni63(n,α)Fe60 Ni64(n,α)Fe60 Ni62(n,h)Fe60	99.7 0.1 0.1	38.8 58.8 2.1	98.5 1.2	87.9 7.6 3.1	2.3 0.3 93.4 1.4 11.2	1.2 67.0 29.6	
Mn53	3.7 10 <sup>6</sup> y	Ni58(n,α)Fe54(n,d)Mn53 Ni58(n,d)Co57(n,α)Mn53 &Ni58(n,α)Fe54(n,2n)Fe53(β <sup>+</sup> )Mn53 Ni58(n,α)Fe55(n,2n)Fe54(n,d)Mn53 Ni58(n,α)Fe55(β <sup>+</sup> )Mn55(n,2n)Mn54(n,2n)Mn53   Ni58(n,d)Co57(n,α)Mn54(n,2n)Mn53 Ni58(n,α)Fe54(n,p)Mn54(n,2n)Mn53 Ni58(n,α)Mn54(n,2n)Mn53 Ni58(n,2n)Ni57(β <sup>+</sup> )Co57(n,α)Mn53 Ni58(n,dα)Mn53 Ni58(n,α)Fe55(n,t)Mn53 &Ni58(n,2nα)Fe53(β <sup>+</sup> )Mn53 Ni58(n,h)Fe56(n,nt)Mn53 Ni58(n,t)Co56(β <sup>+</sup> )Fe56(n,nt)Mn53				71.7 9.7 3.4 3.4 3.0 2.5 1.6 0.8 0.6 3.2 0.8	52.4 7.7 23.7 2.5 0.1 7.6 1.1 0.1 79.4 0.8	4.8 0.7 2.5 0.5 0.1 0.8 0.1 68.7 0.8 6.9 0.4 0.3	1.3 0.5 4.4 9.4 4.0 3.6

# Nickel activation characteristics

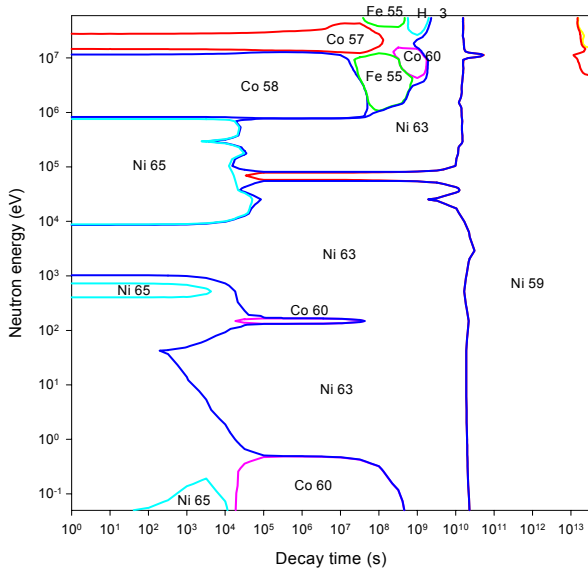


Decay time (years)

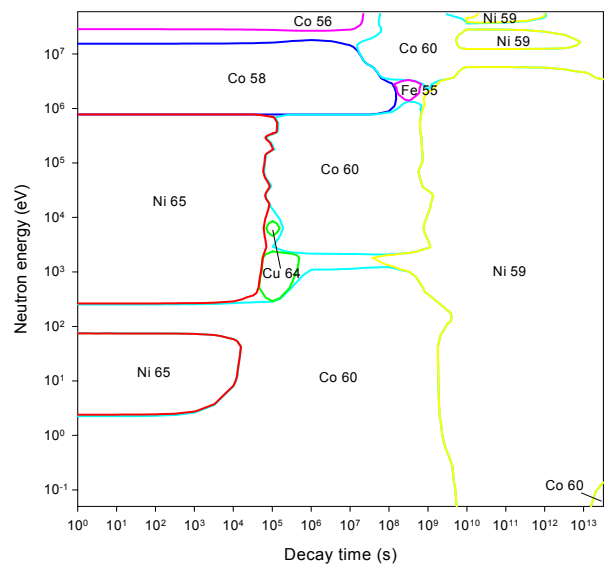
Decay time (years)

# Nickel importance diagrams & transmutation

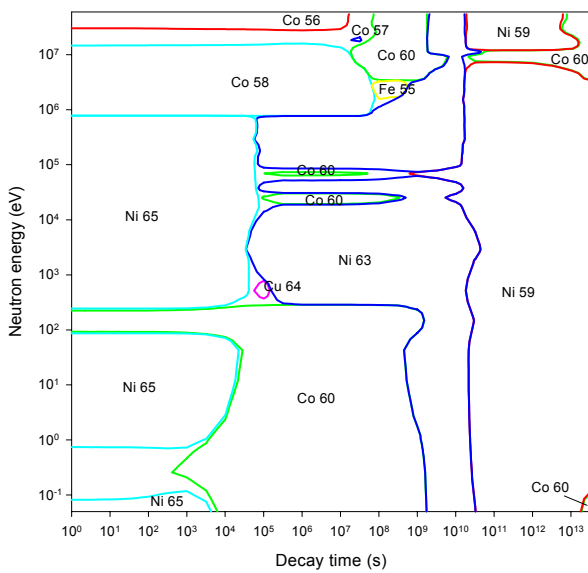
Activity



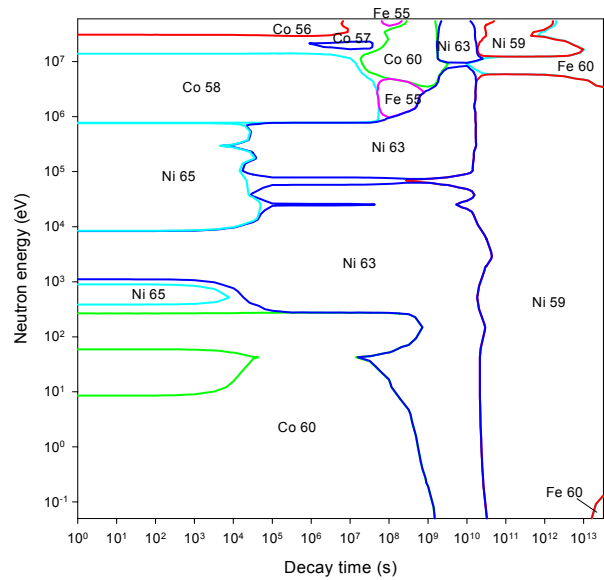
Dose rate



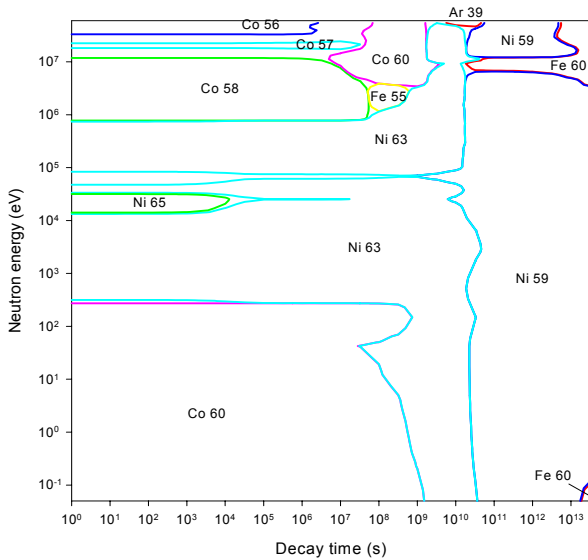
Heat output



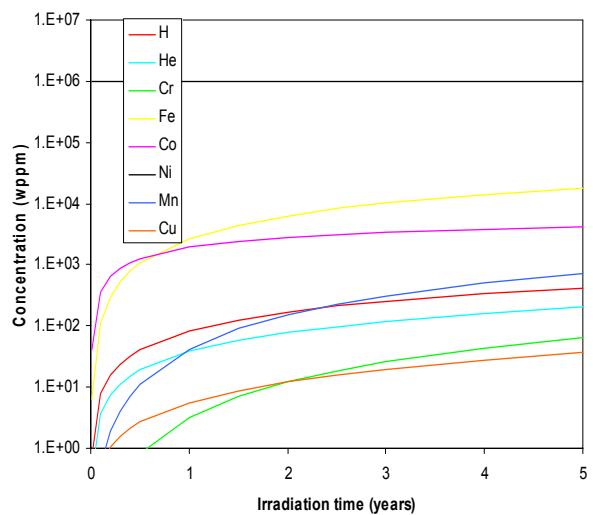
Ingestion dose



Inhalation dose



First wall transmutation





# Copper

## General properties

Atomic number	29	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	60	Cu63	69.17
Melting point / K	1357.8	Cu65	30.83
Boiling point / K	2925		
Density / kgm <sup>-3</sup>	8960		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	401		
Electrical resistivity /Ωm	1.673 10 <sup>-8</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	1.65 10 <sup>-5</sup>		
Crystal structure	FCC		
Number of stable isotopes	2		
Mean atomic weight	63.546		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	2.18E15	1.93E15	4.68E13	2.69E13	1.73E12	8.93E5	kW kg <sup>-1</sup>	2.83E-1	2.14E-1	1.13E-2	8.94E-3	4.85E-6	3.99E-11
Cu64	68.16	76.69	26.60				Cu62	53.56	48.86				
Cu62	18.91	14.71					Cu64	26.58	35.07	5.59			
Cu66	9.66	5.34					Cu66	13.75	8.92				
Co60	1.09	1.23	50.94	77.94		9.95	Co60	3.50	4.65	88.15	97.49	0.39	92.83
Co60m	0.67	0.54				9.98	Ni65	0.82	1.06				
Ni65	0.56	0.62					Zn65	0.21	0.28	5.30	2.39		
Zn65	0.29	0.33	13.54	8.45			Co60m	0.05	0.04				2.23
Ni63	0.15	0.17	7.36	12.74	99.95		Ni63			0.08	0.10	99.58	
Ni59						70.08	Fe60						3.13
Fe60						9.98	Ni59						1.80
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	1.73E5	1.42E5	1.90E4	1.56E4	3.39E-2	6.50E-5	Sv kg <sup>-1</sup>	3.32E5	3.08E5	1.09E5	8.05E4	2.60E2	1.01E-2
Cu62	49.14	41.00					Cu64	53.82	57.69	1.37			
Cu64	33.75	40.95	2.56				Co60	24.54	26.34	74.66	88.35	0.06	2.97
Co60	10.04	12.23	91.19	97.63	100.0	99.95	Cu62	7.59	5.62				
Cu66	2.69	1.60					Zn65	7.52	8.10	22.77	10.99		
Co62m	1.47	1.38					Cu66	1.01	0.53				
Ni65	1.16	1.38					Ni65	0.67	0.70				
Zn65	0.60	0.73	5.41	2.37			Ni63	0.15	0.16	0.47	0.63	99.92	
Fe59	0.08	0.09	0.69				Fe60						96.63
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	9.70E5	9.52E5	7.61E5	6.58E5	2.25E3	2.80E-2		8.36E11	6.64E11	3.02E11	2.32E11	1.78E7	8.97E2
Co60	76.27	77.69	97.14	98.55	0.06	9.84	Cu62	56.14	48.61				
Cu64	18.41	18.66	0.19				Co60	28.55	35.94	78.83	90.20	2.61	99.20
Cu62	1.61	1.13					Zn65	7.66	9.64	20.96	9.78		
Zn65	1.45	1.47	1.83	0.75			Cu66	4.76	2.93				
Ni63	0.46	0.47	0.58	0.67	99.92		Cu64	1.78	2.23	0.04			
Fe59	0.16	0.17	0.20				Ni65	0.14	0.18				
Fe60						89.17	Co62m	0.03	0.03				
Ni59						0.98	Ni63			0.01	0.01	97.33	

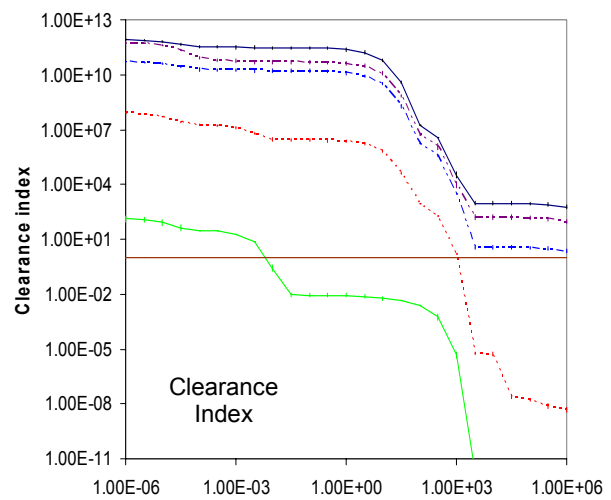
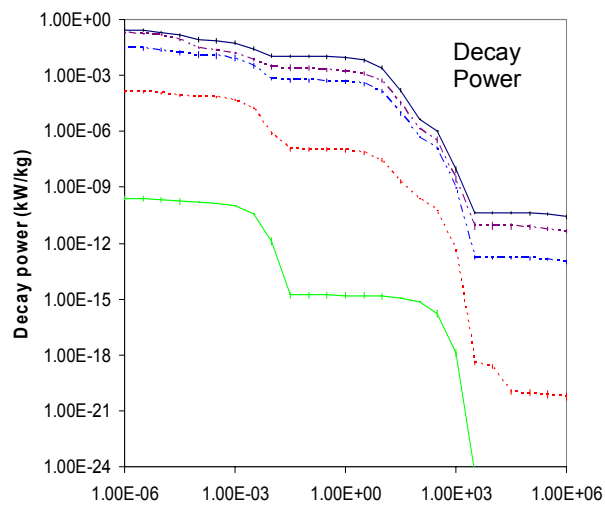
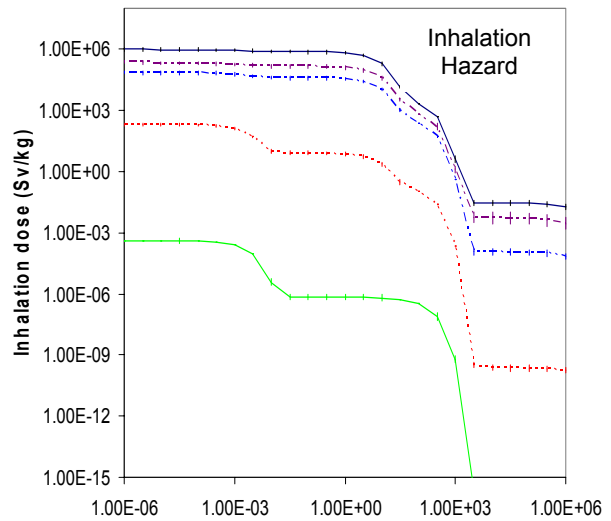
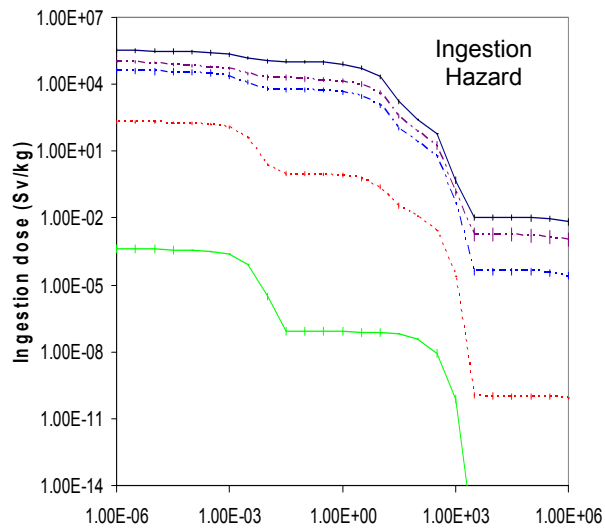
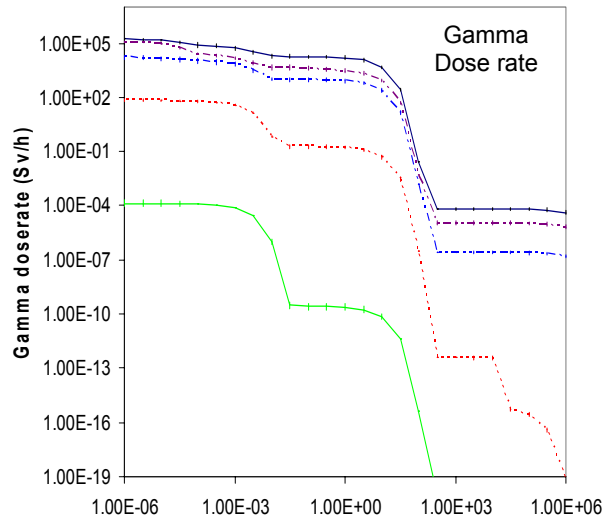
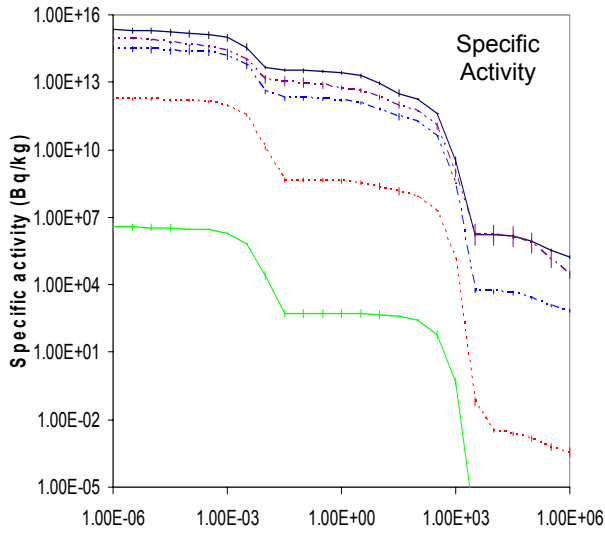
# Copper

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Cu66	5.1 m	Cu65(n,γ)Cu66	98.4	100.0	100.0	98.5	99.2	99.4	99.7
		Cu63(n,γ)Cu64(β <sup>+</sup> )Ni64(n,γ)Ni65(β <sup>-</sup> )_	1.2						
		Cu65(n,γ)Cu66							
		Cu63(n,γ)Cu64(n,γ)Cu65(n,γ)Cu66	0.3						
		Cu63(n,γ)Cu64(β <sup>-</sup> )Zn64(n,γ)Zn65(β <sup>+</sup> )_	0.1						
Cu65(n,γ)Cu66									
Cu62	9.75 m	Cu63(n,2n)Cu62				99.8	97.0	92.7	79.2
		Cu65(n,3n)Cu63(n,2n)Cu62					2.4	2.4	
		Cu65(n,2n)Cu64(β <sup>-</sup> )Zn64(n,t)Cu62					0.4	0.9	
		Cu65(n,4n)Cu62						3.9	19.4
Cu64	12.701 h	Cu63(n,γ)Cu64	100.0	100.0	100.0	0.6	0.4	0.5	
		Cu65(n,2n)Cu64				98.1	99.0	99.1	99.3
Co58	70.86 d	&Cu63(n,nα)Co59(n,2n)Co58				81.2	55.3	2.3	1.5
		&Cu63(n,α)Co60(n,2n)Co59(n,2n)Co58				11.5			
		&Cu63(n,2nα)Co58					28.6	82.1	55.7
		&Cu63(n,t)Ni61(n,nt)Co58					0.2	1.9	10.5
		&Cu63(n,nt)Ni60(n,t)Co58					0.1	5.2	13.3
		&Cu63(n,3n)Cu61(β <sup>+</sup> )Ni61(n,nt)Co58						0.7	3.0
&Cu65(n,4nα)Co58							2.4		
Zn65	244.15 d	Cu63(n,γ)Cu64(β <sup>-</sup> )Zn64(n,γ)Zn65	100.0	100.0	100.0	0.3			
		Cu65(n,γ)Cu66(β <sup>-</sup> )Zn66(n,2n)Zn65				51.9	84.7	84.7	85.0
		Cu65(n,2n)Cu64(β <sup>-</sup> )Zn64(n,γ)Zn65				47.7	15.1	15.2	14.9
Co60	5.271 y	&Cu63(n,γ)Cu64(β <sup>-</sup> )Zn64(n,α)Ni61(n,α)_	97.7	97.0	100.0				
		Fe58(n,γ)Fe59(β <sup>-</sup> )Co59(n,γ)Co60							
		&Cu63(n,γ)Cu64(n,α)Co61(β <sup>-</sup> )Ni61(n,α)_	2.2	3.0					
		Fe58(n,γ)Fe59(β <sup>-</sup> )Co59(n,γ)Co60							
		&Cu63(n,α)Co60				99.4	46.6	17.0	69.2
		&Cu63(n,t)Ni61(n,d)Co60					27.8	11.6	3.4
		&Cu63(n,3n)Cu61(β <sup>+</sup> )Ni61(n,d)Co60					6.6	3.9	0.6
		&Cu65(n,2nα)Co60					5.6	45.1	15.0
		&Cu63(n,2n)Cu62(β <sup>+</sup> )Ni62(n,t)Co60					4.2	11.8	3.7
		&Cu65(n,α)Co61(β <sup>-</sup> )Ni61(n,d)Co60					2.0	0.3	
		&Cu63(n,d)Ni62(n,t)Co60					1.8	5.4	1.7
&Cu63(n,2n)Cu62(β <sup>+</sup> )Ni62(n,2n)Ni61_					1.5				
(n,d)Co60									
&Cu65(n,nt)Ni62(n,t)Co60							1.4	1.6	
Ni63	100.6 y	Cu63(n,γ)Cu64(β <sup>-</sup> )Zn64(n,γ)Zn65(n,α)_	98.5	0.8					
		Ni62(n,γ)Ni63							
		Cu63(n,p)Ni63	1.4	99.2	99.9	70.9	46.0	22.8	16.3
		Cu65(n,2n)Cu64(β <sup>+</sup> )Ni64(n,2n)Ni63				26.5	9.7	2.0	1.2
		Cu65(n,d)Ni64(n,2n)Ni63				1.6	3.4	1.2	0.8
		Cu65(n,t)Ni63				0.2	38.3	71.9	79.3
Cu65(n,h)Co63(β <sup>-</sup> )Ni63					0.2	0.8	1.4		
Ni59	7.6 10 <sup>4</sup> y	&Cu63(n,α)Co60(β <sup>-</sup> )Ni60(n,2n)Ni59				79.3	0.7	0.1	
		Cu63(n,2n)Cu62(β <sup>+</sup> )Ni62(n,2n)Ni61_				8.1	0.2		
		(n,2n)Ni60(n,2n)Ni59							
		Cu65(n,2n)Cu64(β <sup>-</sup> )Zn64(n,α)Ni60_				6.5	0.4		
		(n,2n)Ni59							
		Cu63(n,d)Ni62(n,2n)Ni61(n,2n)Ni60_				4.4			
		(n,2n)Ni59							
		Cu63(n,t)Ni61(n,2n)Ni60(n,2n)Ni59				0.6	4.0	0.9	
		Cu63(n,t)Ni61(n,3n)Ni59					59.2	54.5	4.9
		Cu63(n,3n)Cu61(β <sup>+</sup> )Ni61(n,3n)Ni59					14.1	18.0	1.4
Cu65(n,α)Co61(β <sup>-</sup> )Ni61(n,3n)Ni59					4.2	1.5			
Cu63(n,2n)Cu62(β <sup>+</sup> )Ni62(n,3n)Ni60_					4.2	0.9			
(n,2n)Ni59									

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	Cu63(n,2n)Cu62(β <sup>+</sup> )Ni62(n,2n)Ni61(n,3n)Ni59 Cu63(n,nt)Ni60(n,2n)Ni59 Cu63(n,2n)Cu62(β <sup>+</sup> )Ni62(n,4n)Ni59 Cu63(n,2nt)Ni59					3.0 1.4	0.6 11.2 2.3 1.2	7.3 3.7 75.2
Fe60	1.5 10 <sup>6</sup> y	Cu63(n,γ)Cu64(β <sup>-</sup> )Zn64(n,α)Ni61(n,α) Fe58(n,γ)Fe59(n,γ)Fe60 Cu63(n,γ)Cu64(n,α)Co61(β <sup>-</sup> )Ni61(n,α) Fe58(n,γ)Fe59(n,γ)Fe60 Cu65(n,2n)Cu64(β <sup>+</sup> )Ni64(n,2n)Ni63(n,α)Fe60 &Cu63(n,α)Co60(n,p)Fe60 Cu63(n,p)Ni63(n,α)Fe60 Cu65(n,2n)Cu64(β <sup>+</sup> )Ni64(n,2n)Ni63(n,α)Fe60 Cu65(n,2n)Cu64(β <sup>+</sup> )Ni64(n,α)Fe60 Cu65(n,d)Ni64(n,α)Fe60 Cu63(n,2n)Cu62(β <sup>+</sup> )Ni62(n,h)Fe60 Cu65(n,t)Ni63(n,α)Fe60 Cu65(n,dα)Fe60 Cu63(n,ph)Fe60	98.1 1.9	97.0 3.0	100.0	62.7 57.7 25.8 6.4 3.9 0.2	1.0 1.0 68.8 24.0 0.8 0.8	0.8 0.5 44.8 25.3 5.0 1.7 12.4 0.2	2.9 0.6 13.8 9.5 5.5 2.8 40.4 15.4
Zn64	2.3 10 <sup>18</sup> y	Cu63(n,γ)Cu64(β <sup>-</sup> )Zn64 Cu65(n,2n)Cu64(β <sup>-</sup> )Zn64	100.0	100.0	100.0	0.6 99.2	0.4 99.4	0.5 99.4	99.5

# Copper activation characteristics



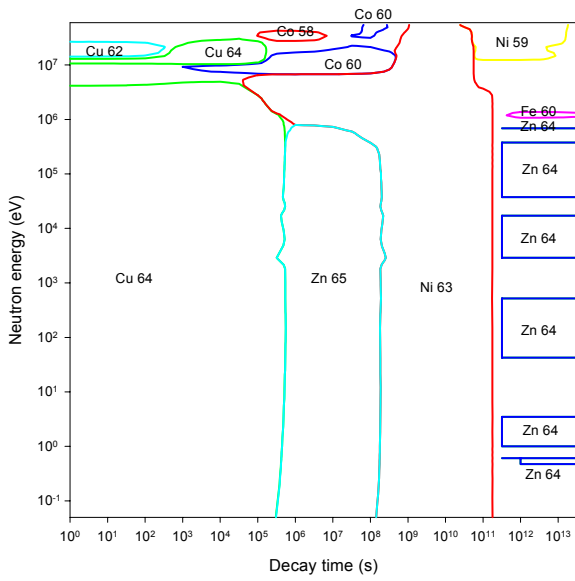
Decay time (years)

Decay time (years)

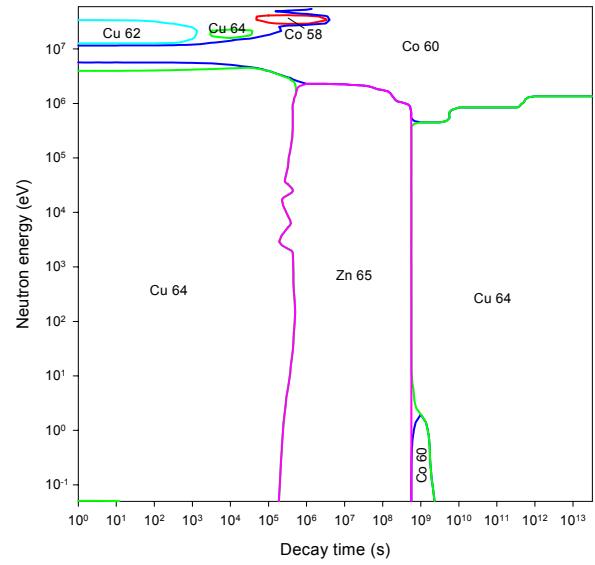


# Copper importance diagrams & transmutation

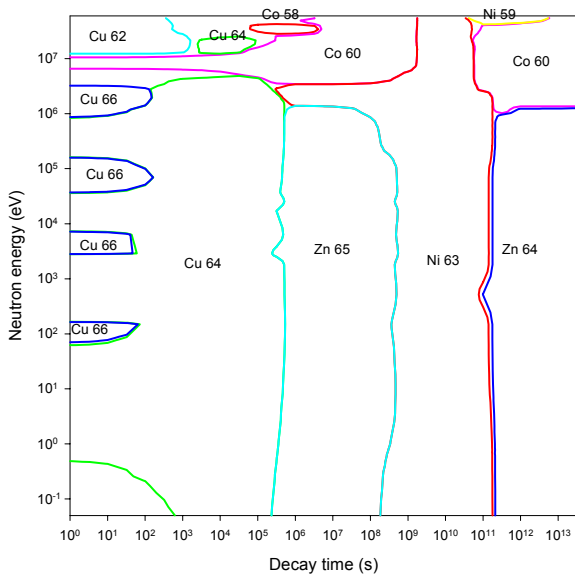
**Activity**



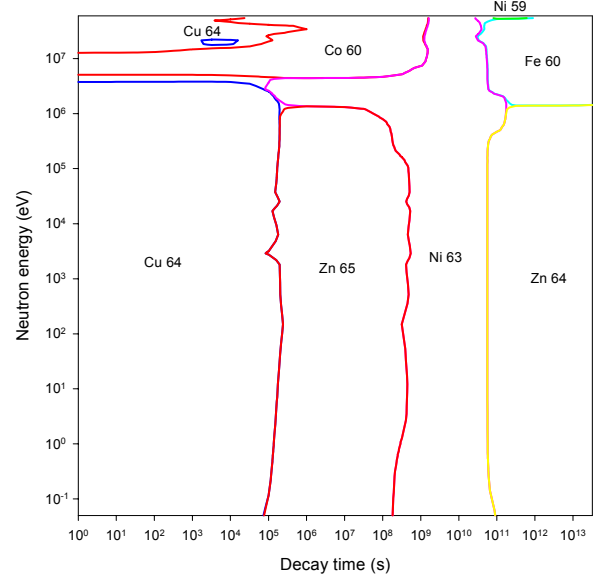
**Dose rate**



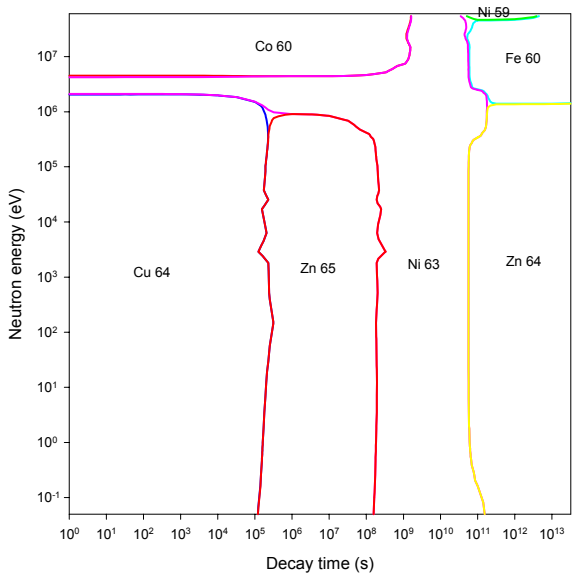
**Heat output**



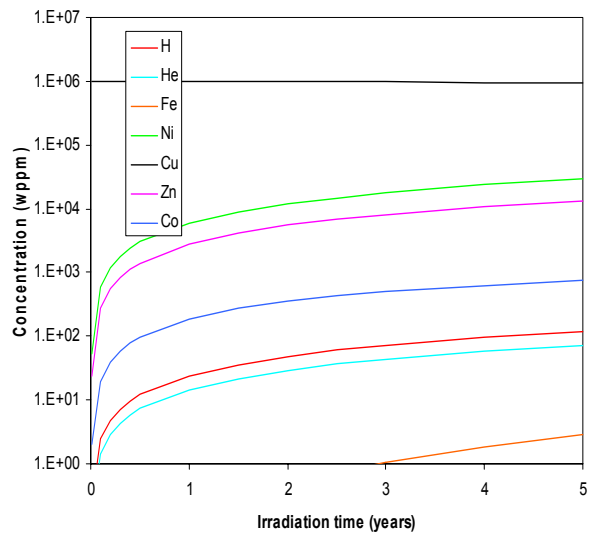
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**





# Zinc

## General properties

Atomic number	30	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	70	Zn64	48.63 ( $T_{1/2} = 2.30 \cdot 10^{18}$ y)
Melting point / K	692.7	Zn66	27.90
Boiling point / K	1180	Zn67	4.10
Density / $\text{kgm}^{-3}$	7133	Zn68	18.75
Thermal conductivity / $\text{Wm}^{-1}\text{K}^{-1}$	116	Zn70	0.62
Electrical resistivity / $\Omega\text{m}$	$5.916 \cdot 10^{-8}$		
Coefficient of thermal expansion / $\text{K}^{-1}$	$3.02 \cdot 10^{-5}$		
Crystal structure	HCP		
Number of stable isotopes	4 (5)		
Mean atomic weight	65.39		

## Activation properties

Act	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Heat	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Bq $\text{kg}^{-1}$	1.01E15	9.65E14	4.33E14	1.54E14	2.78E11	3.01E6	kW $\text{kg}^{-1}$	1.01E-1	9.26E-2	4.07E-2	1.46E-2	7.75E-7	5.98E-12
Zn65	42.69	44.84	99.00	99.52			Zn65	40.30	44.09	99.37	99.50		
Zn69	22.54	22.34	0.06				Zn63	23.24	23.12				
Cu64	17.25	18.04	0.33				Zn69	11.67	12.05	0.03			
Zn63	7.17	6.85					Cu64	8.73	9.51	0.18			
Cu66	3.61	1.85					Cu66	6.68	3.57				
Ga70	2.25	1.99					Ga70	2.35	2.16				
Zn69m	2.24	2.34	0.06				Zn69m	1.57	1.17	0.04			
Ga68	0.41	0.41					Cu68	1.32	0.21				
Cu62	0.41	0.29					Cu62	1.15	1.14				
Cu67	0.35	0.37	0.31				Ga68	1.13	1.17				
Ni65	0.35						Co60	0.07	0.08		0.48	0.02	40.17
Ni63	0.05	0.03	0.12	0.35	99.97		Ni63				0.01	99.97	
Co60	0.01	0.02	0.04	0.11		0.19	Ni59						57.50
Ni59						99.49	Fe60						1.35
Dose	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Ing	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{h}^{-1}$	1.00E5	9.68E4	6.94E4	2.49E4	2.79E-4	4.94E-6	Sv $\text{kg}^{-1}$	1.74E6	1.73E6	1.67E6	5.99E5	4.16E1	8.45E-4
Zn65	69.73	72.20	99.65	99.51			Zn65	97.15	97.39	99.91	99.89		
Zn63	16.77	15.79					Cu64	1.20	1.20	0.01			
Cu64	6.77	6.98	0.08				Zn69m	0.43	0.43				
Zn69m	1.90	1.96	0.03				Co60	0.03	0.03	0.03	0.09		2.32
Cu68	0.98	0.15					Ni63				0.01	99.99	
Co60	0.13	0.14	0.20	0.49	99.32	84.49	Fe60						75.29
Ni59					0.67	15.36	Ni59						22.34
Inh	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Clear	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{kg}^{-1}$	1.00E6	9.99E5	9.50E5	3.44E5	3.61E2	3.12E-3		4.45E12	4.43E12	4.29E12	1.54E12	2.78E6	8.77E1
Zn65	95.07	95.37	99.17	98.26			Zn65	97.63	97.76	99.95	99.89		
Cu64	2.09	2.09	0.01				Zn63	1.94	1.77				
Zn69	0.63	0.60					Zn69m	0.05	0.05				
Zn69m	0.61	0.61					Co60	0.04	0.04	0.04	0.11	0.13	65.77
Co60	0.59	0.60	0.63	1.53		5.73	Cu64	0.03	0.03				
Ni63	0.07		0.07	0.20			Zn69	0.01	0.01				
Ni59					99.99	42.29	Ni63					99.83	
Fe60						51.95	Ni59						34.16

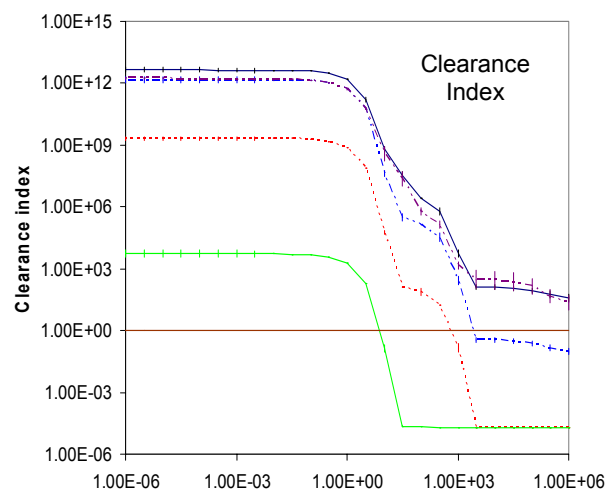
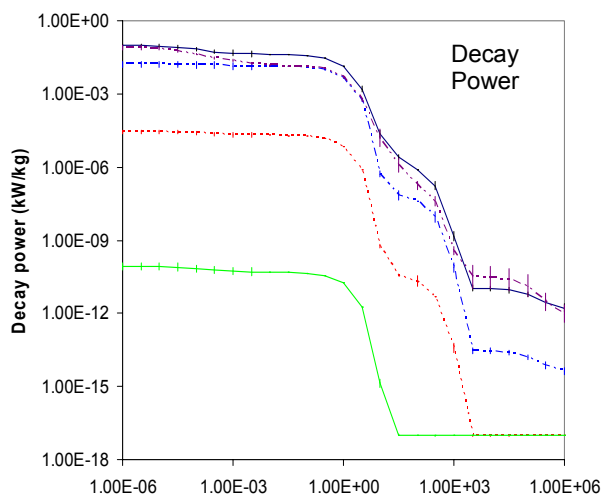
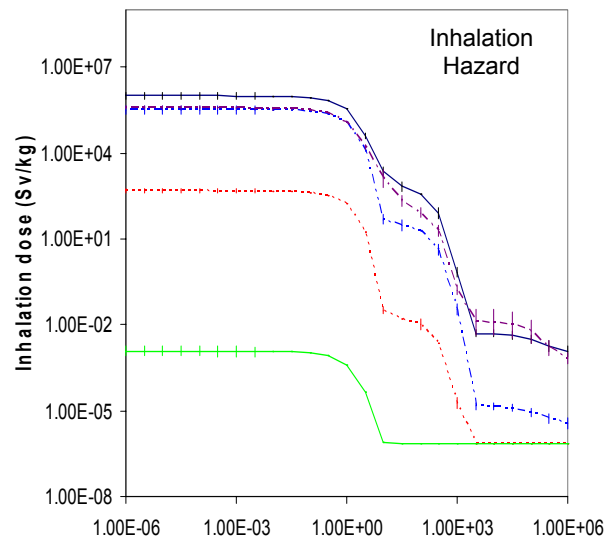
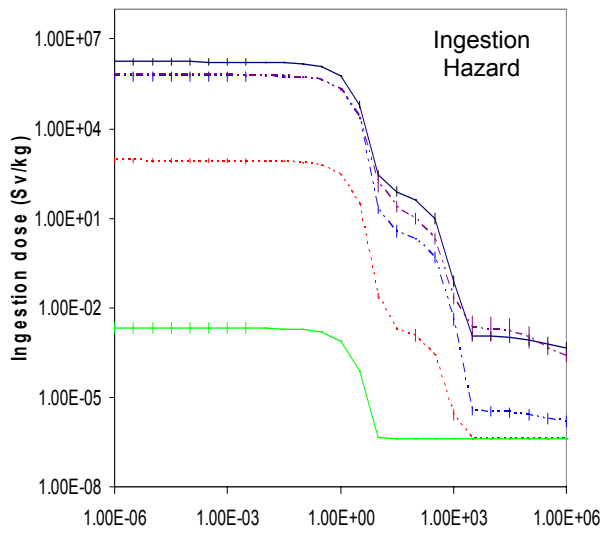
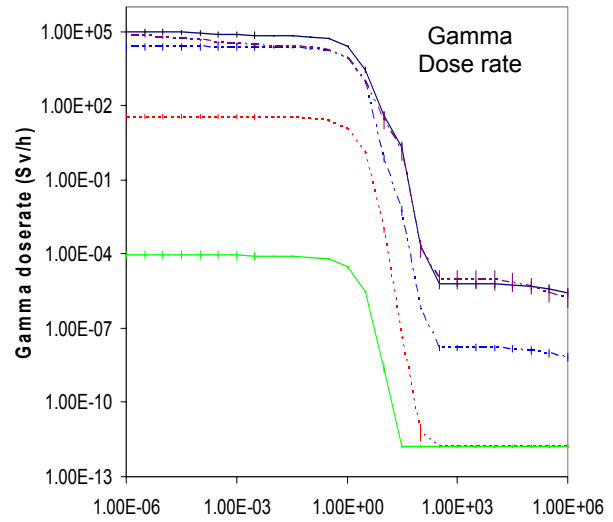
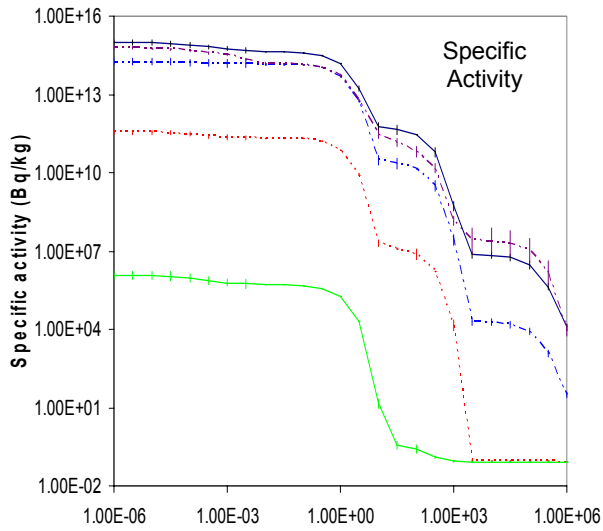
# Zinc

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Cu62	9.75 m	Zn64(n,d)Cu63(n,2n)Cu62				76.4	18.9	2.7	2.0
		Zn64(n,2n)Zn63(β <sup>+</sup> )Cu63(n,2n)Cu62				22.8	8.7	1.3	
		Zn64(n,t)Cu62				0.2	64.1	83.3	80.4
		Zn64(n,3n)Zn62(β <sup>+</sup> )Cu62					5.9	8.8	6.0
		Zn66(n,3n)Zn64(n,t)Cu62					1.1	2.0	0.9
		Zn66(n,nt)Cu63(n,2n)Cu62						0.2	1.4
		Zn66(n,2nt)Cu62							4.6
Ga70	21.14 m	&Zn68(n,γ)Zn69(β <sup>-</sup> )Ga69(n,γ)Ga70	96.2	99.5	99.7	1.0	0.7	0.7	0.6
		&Zn67(n,γ)Zn68(n,γ)Zn69(β <sup>-</sup> )Ga69(n,γ)_ Ga70	3.4	0.4	0.2				
		Zn66(n,γ)Zn67(n,γ)Zn68(n,γ)Zn69(β <sup>-</sup> )_ Ga69(n,γ)Ga70	0.3						
		&Zn70(n,2n)Zn69(β <sup>-</sup> )Ga69(n,γ)Ga70				48.1	42.2	40.9	40.1
		Zn70(n,γ)Zn71m(β <sup>-</sup> )Ga71(n,2n)Ga70				29.8	29.4	25.4	22.7
		Zn70(n,γ)Zn71(β <sup>-</sup> )Ga71(n,2n)Ga70				20.3	21.2	19.6	18.7
		Zn70(n,d)Cu69(β <sup>-</sup> )Zn69(β <sup>-</sup> )Ga69(n,γ)Ga70					6.3	13.2	17.8
Zn69	56.4 m	&Zn68(n,γ)Zn69	92.9	99.1	99.5	2.0	1.4	1.2	0.6
		&Zn67(n,γ)Zn68(n,γ)Zn69	6.2	0.8	0.4				
		Zn66(n,γ)Zn67(n,γ)Zn68(n,γ)Zn69	0.9						
		&Zn70(n,2n)Zn69				97.9	85.7	74.5	68.7
		Zn70(n,d)Cu69(β <sup>-</sup> )Zn69				0.1	12.9	24.3	30.7
Cu64	12.701 h	Zn64(n,γ)Zn65(n,α)Ni62(n,γ)Ni63(β <sup>-</sup> )_ Cu63(n,γ)Cu64	99.9	94.9	5.9				
		Zn66(n,α)Ni63(β <sup>-</sup> )Cu63(n,γ)Cu64		5.1	94.1				
		Zn64(n,p)Cu64				71.0	39.2	16.7	11.2
		Zn66(n,2n)Zn65(β <sup>+</sup> )Cu65(n,2n)Cu64				23.8	19.7	3.3	1.9
		Zn66(n,d)Cu65(n,2n)Cu64				2.9	9.9	2.1	1.4
		Zn66(n,t)Cu64					22.2	68.0	60.4
		Zn68(n,3n)Zn66(n,t)Cu64					1.1	3.4	1.2
		Zn66(n,2n)Zn65(n,d)Cu64					1.0	2.1	0.4
		Zn67(n,nt)Cu64					0.1	1.3	8.9
		Zn68(n,2nt)Cu64							8.5
Zn69m	13.78 h	Zn68(n,γ)Zn69m	92.8	99.1	99.5	2.3	1.4	1.4	1.3
		Zn67(n,γ)Zn68(n,γ)Zn69m	6.2	0.9	0.4				
		Zn66(n,γ)Zn67(n,γ)Zn68(n,γ)Zn69m	1.0						
		Zn70(n,2n)Zn69m				96.9	98.0	98.2	98.5
		Zn70(n,2n)Zn69(β <sup>-</sup> )Ga69(n,p)Zn69m				0.3	0.1		
Zn65	244.15 d	Zn64(n,γ)Zn65	100.0	100.0	100.0	0.2			
		Zn66(n,2n)Zn65				96.4	85.4	73.3	58.9
		Zn67(n,2n)Zn66(n,2n)Zn65				1.8	0.8	0.4	
		Zn67(n,3n)Zn65					6.8	10.8	6.2
		Zn68(n,3n)Zn66(n,2n)Zn65					3.4	2.9	
		Zn68(n,2n)Zn67(n,3n)Zn65					2.1	1.7	
		Zn68(n,4n)Zn65						8.8	31.9
Co60	5.271 y	&Zn64(n,α)Ni61(n,α)Fe58(n,γ)Fe59(β <sup>-</sup> )_ Co59(n,γ)Co60	100.0	100.0	100.0				
		&Zn64(n,d)Cu63(n,α)Co60				54.4	3.3	1.0	3.5
		&Zn64(n,α)Ni60(n,p)Co60				23.5	4.6	1.0	
		&Zn64(n,2n)Zn63(β <sup>+</sup> )Cu63(n,α)Co60				16.2	1.6	0.4	1.8
		&Zn64(n,α)Ni61(n,d)Co60				4.2	1.8	2.0	7.3
		&Zn64(n,pα)Co60					76.4	29.0	16.2
		&Zn64(n,t)Cu62(β <sup>+</sup> )Ni62(n,t)Co60					1.9	35.0	13.9
		&n64(n,h)Ni62(n,t)Co60					1.2	10.4	3.7
		&Zn64(n,3n)Zn62(β <sup>+</sup> )Cu62(β <sup>+</sup> )Ni62(n,t)Co60					0.1	3.6	0.6
		&Zn64(n,nt)Cu61(β <sup>+</sup> )Ni61(n,d)Co60						0.6	4.6
		&Zn66(n,tα)Co60							30.4

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
H3	12.33 y	Zn64(n,γ)Zn65(n,X)H1(n,γ)H2(n,γ)H3	93.5	94.5	95.9					
		Zn67(n,X)H1(n,γ)H2(n,γ)H3	0.2	0.9	3.5					
		Zn64(n,X)H3				28.1	58.4	52.1	46.1	
		Zn67(n,X)H3				26.6	4.9	4.5	4.5	
		Zn64(n,d)Cu63(n,X)H3				17.7	2.1	1.0	0.7	
		Zn68(n,2n)Zn67(n,X)H3				9.4	0.9	0.5		
		Zn64(n,2n)Zn63(β <sup>+</sup> )Cu63(n,X)H3				5.3	0.9	0.5		
		Zn66(n,2n)Zn65(n,X)H3				3.9	0.5	0.2		
		Zn66(n,X)H3				3.3	16.8	21.1	24.1	
		Zn66(n,2n)Zn65(β <sup>+</sup> )Cu65(n,X)H3				2.4	0.9	0.5		
		Zn68(n,X)H3				0.9	10.6	13.9	17.0	
		Ni63	100.6 y	Zn64(n,γ)Zn65(n,α)Ni62(n,γ)Ni63	100.0	96.9	9.8			
Zn66(n,α)Ni63				3.1	90.2	53.8	12.5	10.3	46.3	
Zn64(n,p)Cu64(β <sup>+</sup> )Ni64(n,2n)Ni63						22.1	4.2	1.5		
Zn64(n,d)Cu63(n,p)Ni63						7.4	3.7	1.4		
Zn64(n,2p)Ni63						5.6	41.3	14.2	7.5	
Zn67(n,nα)Ni63						3.1	14.3	7.2	5.3	
Zn64(n,2n)Zn63(β <sup>+</sup> )Cu63(n,p)Ni63						2.2	1.7	0.7		
Zn66(n,2n)Zn65(β <sup>+</sup> )Cu65(n,2n)Cu64(β <sup>+</sup> )_Ni64(n,2n)Ni63						1.9	0.5			
Zn68(n,2n)Zn67(n,nα)Ni63						1.1	2.7	0.7		
Zn68(n,2nα)Ni63							4.4	41.6	23.0	
Zn66(n,2n)Zn65(β <sup>+</sup> )Cu65(n,t)Ni63							3.5	4.6	2.3	
Zn66(n,t)Cu64(β <sup>+</sup> )Ni64(n,2n)Ni63							2.4	6.3	2.6	
Zn66(n,d)Cu65(n,t)Ni63							2.1	3.5	1.9	
Ni59	7.6 10 <sup>4</sup> y			Zn64(n,nα)Ni60(n,2n)Ni59				95.2	38.0	2.3
		Zn64(n,α)Ni61(n,2n)Ni60(n,2n)Ni59				3.9				
		Zn64(n,2nα)Ni59					54.4	91.4	77.9	
		Zn64(n,α)Ni61(n,3n)Ni59					1.2	0.9	3.2	
		Zn64(n,t)Cu62(β <sup>+</sup> )Ni62(n,4n)Ni59						0.6	4.1	
Se79	1.1 10 <sup>6</sup> y	Very long pathways of (n,γ), β <sup>-</sup>	100.0							
Fe60	1.5 10 <sup>6</sup> y	Zn64(n,α)Ni61(n,α)Fe58(n,γ)Fe59(n,γ)_Fe60	100.0	100.0	100.0					
		Zn66(n,α)Ni63(n,α)Fe60				44.8	0.4		1.7	
		Zn64(n,p)Cu64(β <sup>+</sup> )Ni64(n,2n)Ni63(n,α)Fe60				12.3				
		&Zn64(n,d)Cu63(n,α)Co60(n,p)Fe60				10.4				
		Zn64(n,p)Cu64(β <sup>+</sup> )Ni64(n,α)Fe60				7.4	38.5	13.7	5.7	
		Zn64(n,2p)Ni63(n,α)Fe60				4.7	1.2	0.1		
		&Zn64(n,nα)Ni60(n,p)Co60(n,p)Fe60				4.4				
		Zn64(n,d)Cu63(n,p)Ni63(n,α)Fe60				4.1				
		&Zn64(n,2n)Zn63(β <sup>+</sup> )Cu63(n,α)Co60_(n,p)Fe60				3.1				
		Zn67(n,nα)Ni63(n,α)Fe60				2.6	0.4			
		Zn66(n,2n)Zn65(β <sup>+</sup> )Cu65(n,2n)Cu64(β <sup>+</sup> )_Ni64(n,nα)Fe60				0.6	4.8	0.7		
		Zn66(n,t)Cu64(β <sup>+</sup> )Ni64(n,nα)Fe60					22.1	56.6	31.0	
		Zn68(n,nα)Ni64(n,nα)Fe60					14.4	4.1	2.6	
		Zn66(n,d)Cu65(n,2n)Cu64(β <sup>+</sup> )Ni64(n,nα)Fe60					3.3	0.6		
		Zn64(n,t)Cu62(β <sup>+</sup> )Ni62(n,h)Fe60					0.6	7.6	13.1	
		Zn64(n,h)Ni62(n,h)Fe60					0.4	2.3	3.5	
		Zn67(n,nt)Cu64(β <sup>+</sup> )Ni64(n,nα)Fe60					0.1	1.0	4.6	
Zn68(n,n2α)Fe60						0.5	10.4			
Zn68(n,2nt)Cu64(β <sup>+</sup> )Ni64(n,nα)Fe60							4.4			
Zn64	2.3 10 <sup>18</sup> y	Zn66(n,2n)Zn65(β <sup>+</sup> )Cu65(n,2n)Cu64(β <sup>-</sup> )Zn64				0.1				
		Zn66(n,2n)Zn65(n,2n)Zn64				0.1				
		Zn66(n,3n)Zn64					1.6	2.3	1.1	
		Zn66(n,t)Cu64(β <sup>-</sup> )Zn64					0.2	0.8	0.5	
		Zn68(n,5n)Zn64							0.2	
		Zn67(n,4n)Zn64							0.1	
Nuclide also present in starting material			100.0	100.0	100.0	99.8	98.2	96.9	98.1	

# Zinc activation characteristics

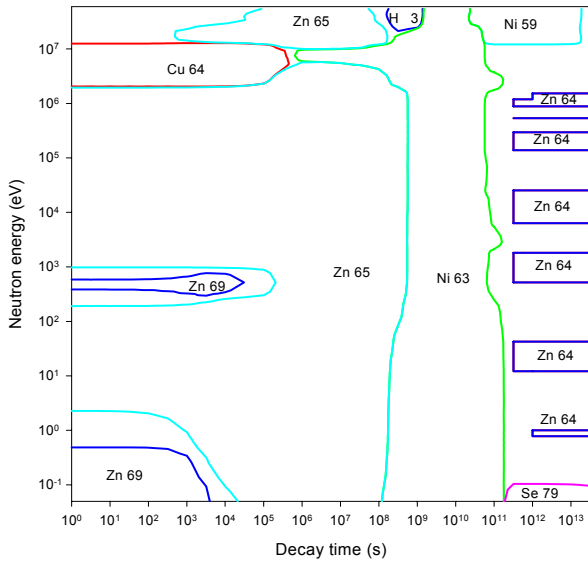


Decay time (years)

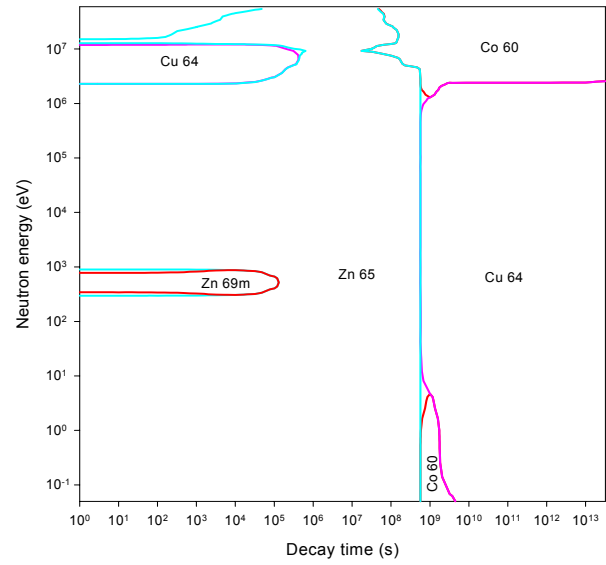
Decay time (years)

# Zinc importance diagrams & transmutation

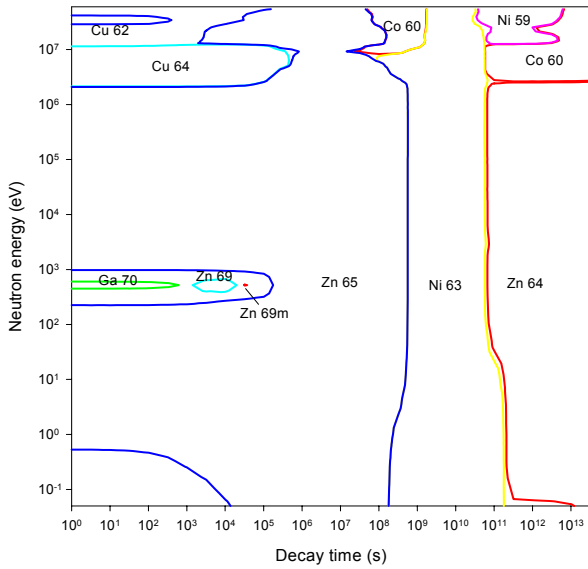
**Activity**



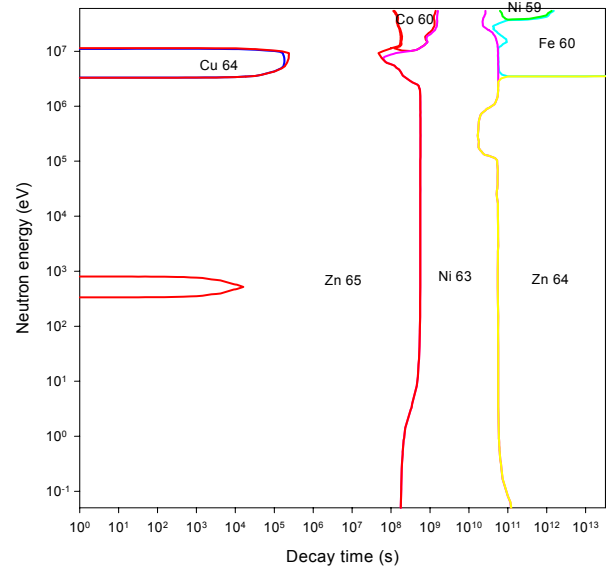
**Dose rate**



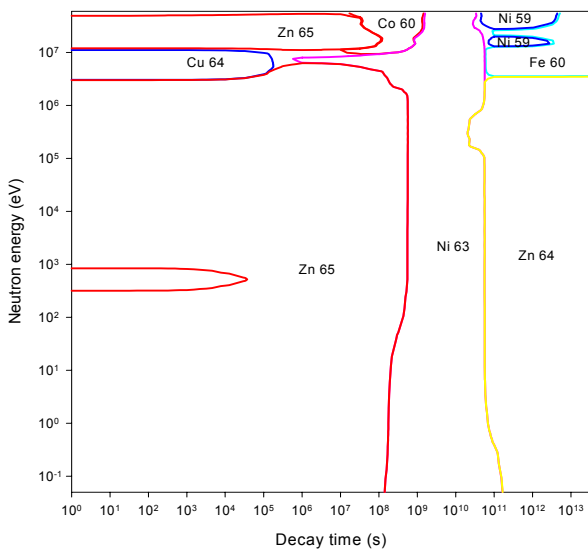
**Heat output**



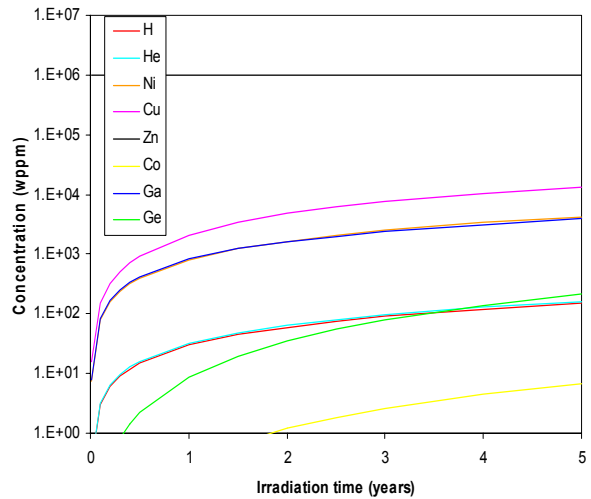
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**



*Graphs for H, He and Ga, Ni are indistinguishable*





# Gallium

## General properties

Atomic number	31	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	19	Ga69	60.108
Melting point / K	302.9	Ga71	39.892
Boiling point / K	2477		
Density / kgm <sup>-3</sup>	5904		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	40.6		
Electrical resistivity /Ωm	2.7 10 <sup>-7</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	1.2 10 <sup>-5</sup>		
Crystal structure	Orthorhombic		
Number of stable isotopes	2		
Mean atomic weight	69.723		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	7.89E15	7.26E15	1.58E14	2.02E11	6.62E8	7.32E0	kW kg <sup>-1</sup>	2.35E0	2.28E0	2.60E-2	6.99E-6	9.20E-10	9.79E-16
Ga72	44.64	48.34	29.91				Ga72	77.04	79.35	93.58			
Ga70	44.52	40.75					Ga70	15.59	13.57				
Ga68	7.23	7.46		0.09			Ga68	6.57	6.44		0.70		
Ge71	1.60	1.74	64.02				Ge69	0.30	0.31	5.63			
Ge69	0.51	0.56	5.40				Zn69	0.11	0.11	0.05			
Zn65			0.13	35.76			Ge71	0.01	0.01	0.56			
H3			0.09	63.89	74.67		Zn65			0.07	97.59		
Ni63				0.16	25.33		H3				1.69	49.13	
Co60m						30.39	Ni63					50.87	
Fe60						30.39	Co60						94.46
Co60						30.31	Fe60						3.19
Ni59						8.91	Co60m						2.28
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	3.02E6	2.99E6	4.09E4	1.21E1	1.93E-9	1.66E-9	Sv kg <sup>-1</sup>	4.10E6	4.03E6	5.63E4	2.88E2	4.59E-2	2.52E-7
Ga72	95.46	95.72	94.61				Ga72	94.61	95.66	92.49			
Ga68	3.79	3.62		0.30			Ga70	2.66	2.27				
Ge69	0.33	0.33	5.16				Ga68	1.39	1.34		0.01		
Ga70	0.23	0.20					Ge69	0.24	0.24	3.64			
Zn69m	0.06	0.06	0.05				Ge71	0.04	0.04	2.16			
Zn71m	0.06	0.06					Zn65	0.02	0.02	1.40	98.01		
Ge71			0.09				H3			0.01	1.89	45.22	
Zn65			0.08	99.69			Ni63				0.02	54.78	
Co60					99.83	99.82	Fe60						96.99
Co60m					0.15	0.17	Co60						2.99
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	2.00E6	1.96E6	2.94E4	1.96E2	3.46E-1	6.92E-7		1.25E12	1.17E12	1.54E10	7.24E8	6.62E3	2.22E-2
Ga72	93.40	94.83	85.39				Ga68	46.63	47.20		0.03		
Ga70	2.81	2.41					Ga72	28.20	29.99	30.81			
Ga68	1.40	1.35		0.01			Ga70	20.09	18.06				
Ge69	0.59	0.60	8.44				Ge69	3.24	3.46	55.63			
Ge71	0.07	0.07	3.79				Zn65	0.16	0.17	13.12	99.80		
Zn65	0.02	0.02	1.51	81.31			Ge71			0.07			
H3			0.12	17.17	37.09		H3			0.01	0.18	74.67	
Ge68			0.02	1.29			Ni63					25.33	
Ni63				0.22	62.91		Co60						99.87
Fe60						90.02	Fe60						0.09
Co60						9.94	Co60m						0.01

# Gallium

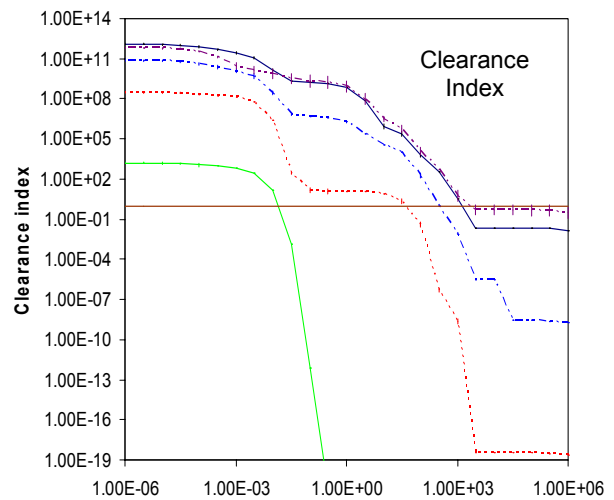
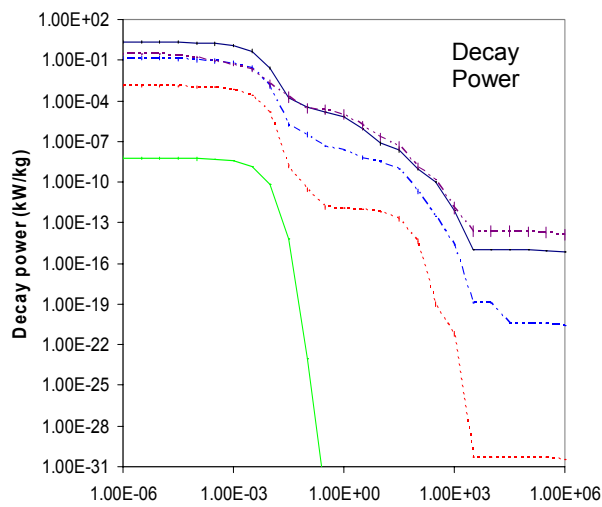
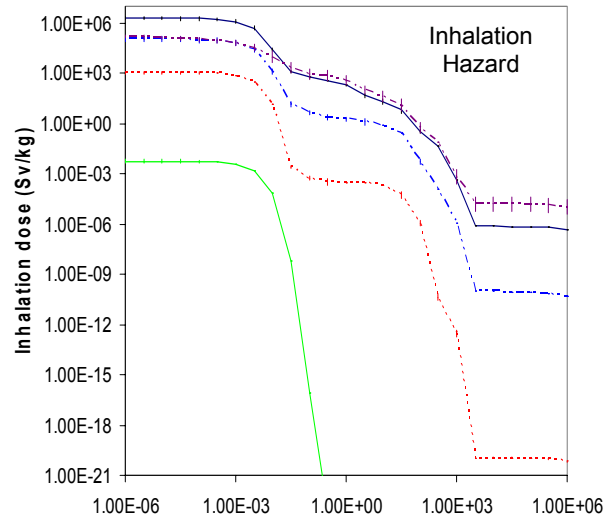
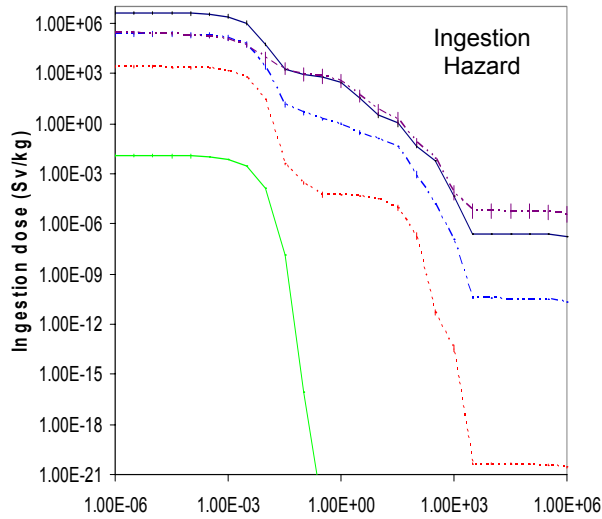
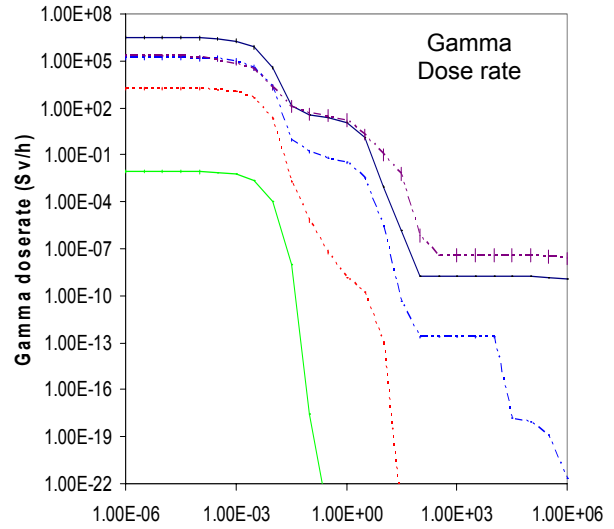
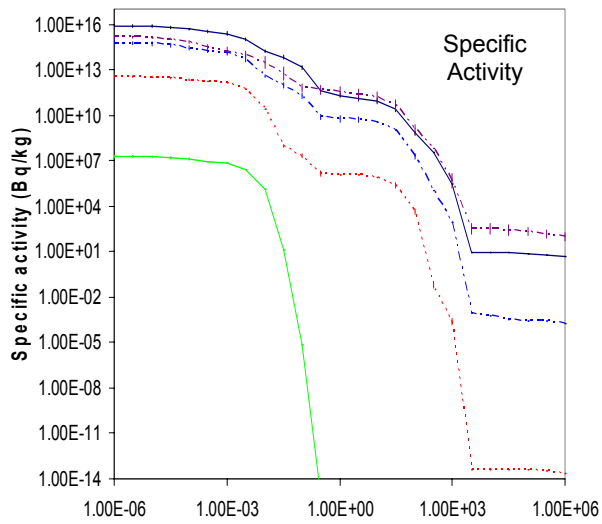
## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Zn71	2.45 m	Ga69(n,γ)Ga70(β <sup>+</sup> )Zn70(n,γ)Zn71 Ga71(n,p)Zn71	100.0	100.0	100.0	99.8	99.8	99.9	99.9
Ga70	21.14 m	Ga69(n,γ)Ga70 Ga71(n,2n)Ga70	100.0	100.0	100.0	98.4	99.4	99.6	99.7
Zn69	56.4 m	&Ga69(n,γ)Ga70(β <sup>-</sup> )Ge70(n,γ)Ge71(n,α) <sub>-</sub> Zn68(n,γ)Zn69 &Ga69(n,p)Zn69 &Ga71(n,d)Zn70(n,2n)Zn69 &Ga71(n,t)Zn69 &Ga71(n,3n)Ga69(n,p)Zn69 Ga71(n,h)Cu69(β <sup>-</sup> )Zn69	97.3	97.0	96.8	95.1 4.1 0.5	46.3 8.5 42.0 2.4 0.4	18.9 3.0 76.0 0.6 1.2	11.0 0.6 85.7 1.5
Ga68	1.128 h	Ga69(n,2n)Ga68 Ga71(n,3n)Ga69(n,2n)Ga68 Ga71(n,2n)Ga70(β <sup>-</sup> )Ge70(n,t)Ga68 Ga71(n,4n)Ga68				98.6	92.4 5.2 0.6	77.3 4.0 2.3 14.3	60.4 1.3 1.0 36.3
Ga66	9.49 h	Ga71(n,2n)Ga70(β <sup>-</sup> )Ge70(n,2n)Ge69_ (n,2n)Ge68(n,d)Ga67(n,2n)Ga66 Ga71(n,2n)Ga70(β <sup>-</sup> )Ge70(n,2n)Ge69_ (n,2n)Ge68(n,t)Ga66 Ga71(n,2n)Ga70(β <sup>-</sup> )Ge70(n,2n)Ge69(n,t) Ga67(n,2n)Ga66 Ga71(n,2n)Ga70(β <sup>-</sup> )Ge70(n,2n)Ge69(n,2n) Ge68(n,2n)Ge67(β <sup>+</sup> )Ga67(n,2n)Ga66 Ga69(n,3n)Ga67(n,2n)Ga66 Ga71(n,2n)Ga70(β <sup>-</sup> )Ge70(n,3n)Ge68(n,t)Ga66 Ga71(n,3n)Ga69(n,3n)Ga67(n,2n)Ga66 Ga69(n,4n)Ga66 Ga71(n,3n)Ga69(n,4n)Ga66				68.2 10.1 7.1 4.0	69.4 29.0 3.4	0.4 0.8	96.6 2.0
Zn69m	13.78 h	Ga69(n,γ)Ga70(β <sup>-</sup> )Ge70(n,γ)Ge71(n,α) <sub>-</sub> Zn68(n,γ)Zn69m Ga69(n,p)Zn69m Ga71(n,d)Zn70(n,2n)Zn69m Ga71(n,2n)Ga70(β <sup>+</sup> )Zn70(n,2n)Zn69m Ga71(n,t)Zn69m Ga71(n,3n)Ga69(n,p)Zn69m	100.0	100.0	99.8	93.2 3.9 1.0 0.3	45.9 9.7 0.2 40.7 2.6	19.0 3.3 76.3 1.0	11.7 2.1 85.7
Ga72	14.1 h	Ga71(n,γ)Ga72 Ga69(n,γ)Ga70(β <sup>-</sup> )Ge70(n,γ)Ge71(β <sup>+</sup> ) Ga71(n,γ)Ga72	98.8 1.2	100.0	100.0	99.0	99.5	99.7	99.8
Ge69	1.627 d	Ga71(n,2n)Ga70(β <sup>-</sup> )Ge70(n,2n)Ge69				99.7	99.8	99.8	99.8
Ga67	3.261 d	Ga71(n,2n)Ga70(β <sup>-</sup> )Ge70(n,2n)Ge69_ (n,2n)Ge68(n,d)Ga67 Ga71(n,2n)Ga70(β <sup>-</sup> )Ge70(n,2n)Ge69(n,t)Ga67 Ga69(n,3n)Ga67 Ga71(n,3n)Ga69(n,3n)Ga67 Ga71(n,2n)Ga70(β <sup>-</sup> )Ge70(n,nt)Ga67 Ga71(n,5n)Ga67				84.5 9.0	93.7 5.3	93.6 4.8 0.3	72.1 1.5 2.2 23.2
Ge71	11.43 d	Ga69(n,γ)Ga70(β <sup>-</sup> )Ge70(n,γ)Ge71 Ga71(n,2n)Ga70(β <sup>-</sup> )Ge70(n,γ)Ge71 Ga71(n,γ)Ga72(β <sup>-</sup> )Ge72(n,2n)Ge71	100.0	100.0	100.0	52.2 47.6	47.1 52.8	47.4 52.5	47.6 52.3
Fe59	44.495 d	Ga69(n,α)Cu66(β <sup>-</sup> )Zn66(n,α)Ni62(n,α)Fe59 Ga69(n,α)Cu65(n,α)Co62m(β <sup>-</sup> )Ni62(n,α)Fe59 Ga69(n,α)Cu65(n,α)Co62(β <sup>-</sup> )Ni62(n,α)Fe59 Ga69(n,2n)Ga68(β <sup>+</sup> )Zn68(n,2n)Zn67_ (n,2n)Zn66(n,α)Ni62(n,α)Fe59 Ga69(n,3n)Ga67(β <sup>+</sup> )Zn67(n,α)Ni63_ (n,α)Fe59				50.9 9.3 7.9 4.1	0.1 28.5	1.1	0.2

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Ga69(n,t)Zn67(n,nα)Ni63(n,nα)Fe59 Ga69(n,2nα)Cu64(β <sup>+</sup> )Ni64(n,nα)Fe60_ (n,2n)Fe59 Ga69(n,nα)Cu65(n,t)Ni63(n,nα)Fe59 Ga69(n,2nα)Cu64(β <sup>+</sup> )Ni64(n,2nα)Fe59 Ga69(n,tα)Ni63(n,nα)Fe59 Ga69(n,2nt)Zn65(β <sup>+</sup> )Cu65(n,tα)Fe59 Ga71(n,3nα)Cu65(n,tα)Fe59 Other pathways					9.0 8.1 5.3 1.0 0.2 0.2 27.8	0.7 3.8 0.5 59.5 0.2 34.2	0.1 0.3 0.1 14.5 5.0 8.7 4.1 67.0	
Zn65	244.15 d	Ga69(n,α)Cu66(β <sup>-</sup> )Zn66(n,α)Ni63(β <sup>-</sup> )_ Cu63(n,γ)Cu64(β <sup>-</sup> )Zn64(n,γ)Zn65 Ga69(n,α)Cu66(β <sup>-</sup> )Zn66(n,2n)Zn65 Ga69(n,2n)Ga68(β <sup>+</sup> )Zn68(n,2n)Zn67_ (n,2n)Zn66(n,2n)Zn65 Ga71(n,2n)Ga70(β <sup>-</sup> )Ge70(n,nα)Zn66_ (n,2n)Zn65 Ga69(n,3n)Ga67(β <sup>+</sup> )Zn67(n,3n)Zn65 Ga69(n,t)Zn67(n,3n)Zn65 Ga69(n,2n)Ga68(β <sup>+</sup> )Zn68(n,3n)Zn66_ (n,2n)Zn65 Ga69(n,2n)Ga68(β <sup>+</sup> )Zn68(n,2n)Zn67_ (n,3n)Zn65 Ga71(n,2n)Ga70(β <sup>-</sup> )Ge70(n,2nα)Zn65 Ga69(n,nt)Zn66(n,2n)Zn65 Ga69(n,2n)Ga68(β <sup>+</sup> )Zn68(n,4n)Zn65 Ga69(n,2nt)Zn65	100.0				80.1 10.2 6.6 51.9 16.3 6.0 3.7 2.1 0.9 6.6 1.1	1.6 0.2 0.5 37.4 22.7 1.2 0.7 4.0 10.0 6.6 1.1	0.5 0.5 3.0 2.7 0.5 6.4 5.0 64.5	
Ge68	270.95 d	Ga71(n,2n)Ga70(β <sup>-</sup> )Ge70(n,2n)Ge69_ (n,2n)Ge68 Ga71(n,2n)Ga70(β <sup>-</sup> )Ge70(n,3n)Ge68				99.8		99.7	99.8	99.9
Co60	5.271 y	&Ga69(n,nα)Cu65(n,2n)Cu64(β <sup>-</sup> )Zn64_ (n,d)Cu63(n,α)Co60 &Ga69(n,nα)Cu65(n,2n)Cu64(β <sup>-</sup> )Zn64_ (n,nα)Ni60(n,p)Co60 &Ga69(n,nα)Cu65(n,2n)Cu64(β <sup>-</sup> )Zn64_ (n,2n)Zn63(β <sup>+</sup> )Cu63(n,α)Co60 &Ga69(n,nα)Cu65(n,nα)Co61(β <sup>-</sup> )Ni61_ (n,d)Co60 &Ga69(n,nα)Cu65(n,2nα)Co60 &Ga69(n,2nα)Cu64(β <sup>-</sup> )Zn64(n,pα)Co60 &Ga69(n,3n)Ga67(β <sup>+</sup> )Zn67(n,3n)Zn65_ (β <sup>+</sup> )Cu65(n,2nα)Co60 &Ga69(n,3n)Ga67(β <sup>+</sup> )Zn67(n,2nα)Ni62_ (n,t)Co60 &Ga69(n,2nα)Cu64(β <sup>+</sup> )Ni64(n,3n)Ni62_ (n,t)Co60 &Ga69(n,3nα)Cu63(n,α)Co60 &Ga69(n,2n2α)Co60 &Ga69(n,nt)Zn66(n,tα)Co60 Other pathways				38.5 16.6 11.4 4.8 44.6 7.7 2.9 2.7 0.8 0.8 28.7	10.0 31.4 3.1 4.4 6.8 5.4 0.8	1.8 0.1 7.8 46.2 9.2 34.9		
Kr85	10.752 y	Very long pathways of (n,γ), β <sup>-</sup>	100.0							
H3	12.33 y	Ga69(n,γ)Ga70(β <sup>-</sup> )Ge70(n,γ)Ge71(n,X)_ H1(n,γ)H2(n,γ)H3 Ga69(n,X)H3 Ga71(n,X)H3 Ga69(n,3n)Ga67(β <sup>+</sup> )Zn67(n,X)H3 Ga71(n,3n)Ga69(n,X)H3 Ga69(n,2n)Ga68(β <sup>+</sup> )Zn68(n,X)H3	94.7	96.4		81.7 17.1 1.6 1.6 1.6	57.7 34.3 1.6 1.5 1.1	55.6 36.2 1.6 1.5 1.1	54.8 37.7 0.6 0.6 0.8	
Ni63	100.6 y	Ga69(n,α)Cu66(β <sup>-</sup> )Zn66(n,α)Ni63 Ga69(n,2n)Ga68(β <sup>+</sup> )Zn68(n,2n)Zn67(n,nα)Ni63 Ga69(n,nα)Cu65(n,2n)Cu64(β <sup>+</sup> )Ni64(n,2n)Ni63 Ga69(n,2n)Ga68(β <sup>+</sup> )Zn68(n,nα)Ni64(n,2n)Ni63	100.0	100.0	100.0	31.6 26.4 19.4 6.1	2.5 1.4 1.4	0.2 0.1 0.1		

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	Ga69(n,t)Zn67(n,α)Ni63 Ga69(n,α)Cu65(n,t)Ni63 Ga69(n,3n)Ga67(β <sup>+</sup> )Zn67(n,α)Ni63 Ga69(n,2n)Ga68(β <sup>+</sup> )Zn68(n,2α)Ni63 Ga69(n,2α)Cu64(β <sup>+</sup> )Ni64(n,2n)Ni63 Ga69(n,d)Zn68(n,2α)Ni63 Ga69(n,α)Ni63				0.5 0.2	14.3 8.5 45.4 6.2 6.1 1.6	9.4 6.5 15.5 19.4 16.6 7.4	1.8 1.7 2.1 2.9 2.2 1.3
Ni59	7.6 10 <sup>4</sup> y	Ga69(n,α)Cu65(n,2n)Cu64(β <sup>-</sup> )Zn64_ (n,α)Ni60(n,2n)Ni59 Ga69(n,α)Cu65(n,α)Co61(β <sup>-</sup> )Ni61_ (n,2n)Ni60(n,2n)Ni59 Ga69(n,α)Cu65(n,α)Co61(β <sup>-</sup> )Ni61_ (n,3n)Ni59 Ga69(n,2α)Cu64(β <sup>-</sup> )Zn64(n,2α)Ni59 Ga69(n,2α)Cu64(β <sup>-</sup> )Zn64(n,α)Ni60_ (n,2n)Ni59 Ga69(n,α)Cu65(n,2n)Cu64(β <sup>-</sup> )Zn64_ (n,2α)Ni59 Ga69(n,3α)Cu63(n,2nt)Ni59 Ga69(n,2nt)Zn65(n,3α)Ni59 Ga69(n,ntα)Ni62(n,4n)Ni59 Ga69(n,nt)Zn66(n,4α)Ni59 Ga69(n,4α)Cu62(β <sup>+</sup> )Ni62(n,4n)Ni59				79.4 4.1	1.6 1.2 23.3 19.2 8.9 4.5	0.4 60.0 1.0 0.4	5.7 23.1 8.8 7.0 5.5 4.5
Kr81	2.1 10 <sup>5</sup> y	Very long pathways of (n,γ), β <sup>-</sup>	100.0						
Se79	1.1 10 <sup>6</sup> y	&Ga71(n,γ)Ga72(β <sup>-</sup> )Ge72(n,γ)Ge73(n,γ)_ Ge74(n,γ)Ge75(β <sup>-</sup> )As75(n,γ)As76(β <sup>-</sup> )_ Se76(n,γ)Se77(n,γ)Se78(n,γ)Se79 &Ga71(n,γ)Ga72(n,γ)Ga73(β <sup>-</sup> )Ge73(n,γ)_ Ge74(n,γ)Ge75(β <sup>-</sup> )As75(n,γ)As76(β <sup>-</sup> )_ Se76(n,γ)Se77(n,γ)Se78(n,γ)Se79	95.7 4.0	15.7 72.1	96.7 1.2				
Fe60	1.5 10 <sup>6</sup> y	Ga69(n,α)Cu66(β <sup>-</sup> )Zn66(n,α)Ni63(n,α)Fe60 Ga69(n,2n)Ga68(β <sup>+</sup> )Zn68(n,2n)Zn67_ (n,α)Ni63(n,α)Fe60 Ga69(n,α)Cu65(n,2n)Cu64(β <sup>+</sup> )Ni64_ (n,2n)Ni63(n,α)Fe60 Ga69(n,α)Cu65(n,2n)Cu64(β <sup>+</sup> )Ni64_ (n,α)Fe60 Ga69(n,2n)Ga68(β <sup>+</sup> )Zn68(n,α)Ni64_ (n,2n)Ni63(n,α)Fe60 Ga69(n,2n)Ga68(β <sup>+</sup> )Zn68(n,α)Ni64_ (n,α)Fe60 Ga69(n,α)Cu65(n,d)Ni64(n,α)Fe60 Ga69(n,2α)Cu64(β <sup>+</sup> )Ni64(n,α)Fe60 Ga69(n,dα)Ni64(n,α)Fe60 Ga71(n,4α)Cu64(β <sup>+</sup> )Ni64(n,α)Fe60 Ga69(n,tα)Ni63(n,α)Fe60 Other pathways				31.3 19.7 14.4 11.6 4.5 3.6 0.7	12.8 0.6 12.9 4.5 83.3 4.2	0.6 0.4 0.7 0.4 0.2 44.9 4.6	0.4 0.4 0.2 4.1 38.7
Zn64	2.3 10 <sup>18</sup> y	Ga69(n,α)Cu66(β <sup>-</sup> )Zn66(n,α)Ni63(β <sup>-</sup> )_ Cu63(n,γ)Cu64(β <sup>-</sup> )Zn64 Ga69(n,α)Cu65(n,2n)Cu64(β <sup>-</sup> )Zn64 Ga69(n,2α)Cu64(β <sup>-</sup> )Zn64 Ga69(n,2n)Ga68(β <sup>+</sup> )Zn68(n,3n)Zn66_ (n,3n)Zn64 Ga69(n,nt)Zn66(n,3n)Zn64 Ga69(n,3n)Ga67(β <sup>+</sup> )Zn67(n,4n)Zn64 Ga69(n,t)Zn67(n,4n)Zn64 Ga69(n,nt)Zn66(n,t)Cu64(β <sup>-</sup> )Zn64 Ga71(n,4α)Cu64(β <sup>-</sup> )Zn64	100.0	100.0	100.0	86.5	19.5 55.3 4.7 0.9	0.8 71.0 0.6 6.6	39.7 8.5 4.4 3.9 4.1 5.9

# Gallium activation characteristics

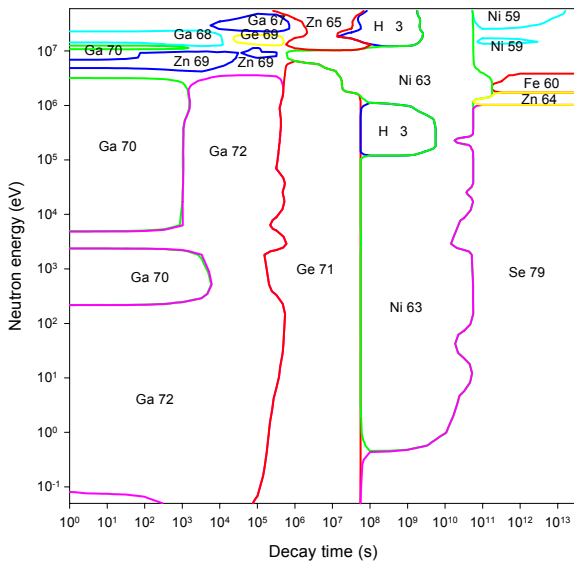


Decay time (years)

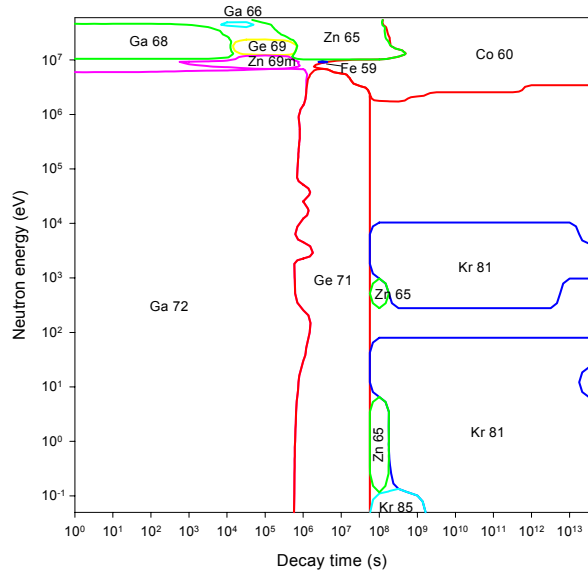
Decay time (years)

# Gallium importance diagrams & transmutation

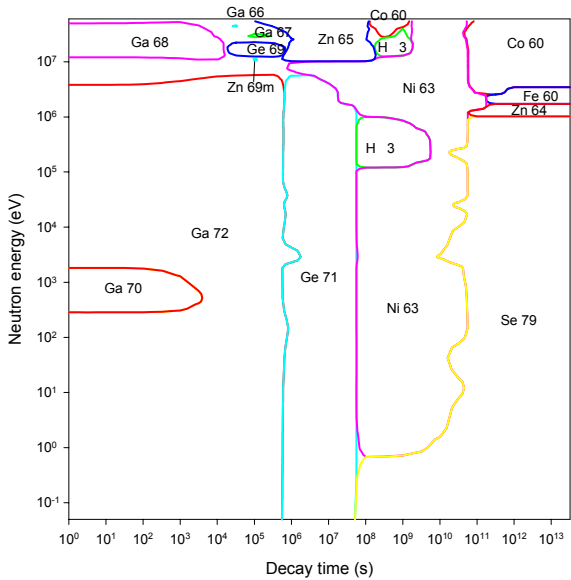
**Activity**



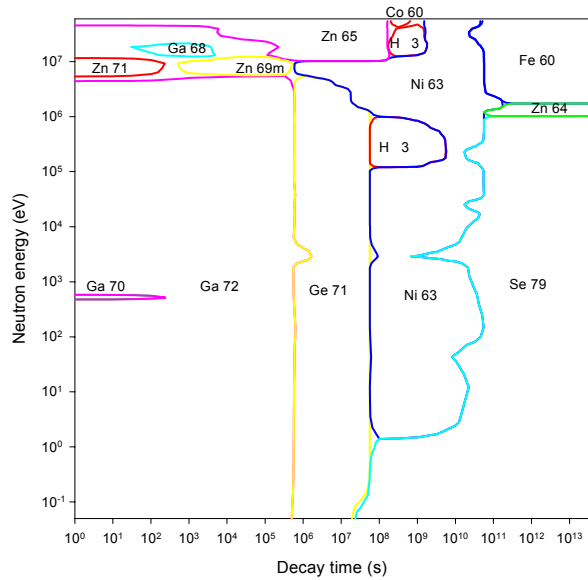
**Dose rate**



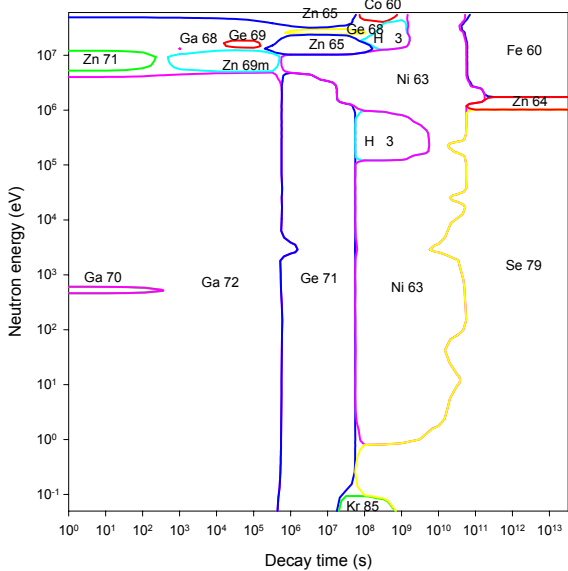
**Heat output**



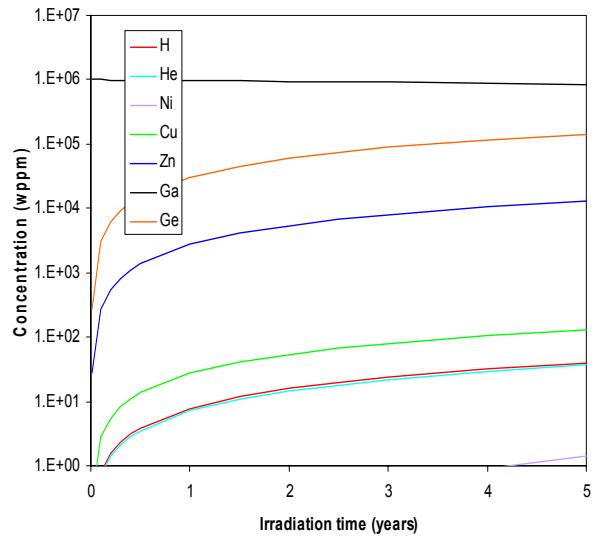
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**



# Germanium

## General properties

Atomic number	32	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	1.5	Ge70	20.37
Melting point / K	1211.4	Ge72	27.31
Boiling point / K	3106	Ge73	7.76
Density / kgm <sup>-3</sup>	5323	Ge74	36.73
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	59.9	Ge76	7.83 (T <sub>½</sub> = 1.58 10 <sup>21</sup> y)
Electrical resistivity /Ωm	4.6 10 <sup>-1</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	5.57 10 <sup>-6</sup>		
Crystal structure	Cubic		
Number of stable isotopes	4 (5)		
Mean atomic weight	72.64		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	1.40E15	9.85E14	3.85E14	1.56E11	1.19E8	1.03E5	kW kg <sup>-1</sup>	1.23E-1	1.10E-1	7.48E-3	1.08E-5	2.79E-10	9.18E-13
Ge71	30.19	43.03	88.31				Ga72	38.61	42.98	8.54			
Ge73m	19.19	0.20					Ge69	15.93	17.78	55.29			
Ge75	12.88	17.67					Ge75	10.73	11.54	16.70			
Ge69	8.14	11.59	6.26				As76	10.28	11.47				
Ge75m	7.37	0.10					Ge77	4.66	5.18	0.35			
Ga72	6.57	9.33	0.32				Ga70	4.05	3.81				
As76	3.79	5.40	1.36				Ga74	3.92	2.81				
Ga70	3.40	4.08					Ge77m	3.27	0.05				
As77	2.88	4.10	2.65				Ge73m	2.26	0.01				
Ge77m	1.72	0.03					Ge75m	1.87	0.02				
Ge77	1.48	2.10	0.02				As77	1.23	1.37	5.10			
Ga74	0.53	0.49					Ga68	0.63	0.67		1.59		
Zn69	0.34	0.47					Ge71	0.49	0.55	6.53			
As74	0.24	0.34	0.76				As74	0.45	0.50	6.50			
Se75		0.09	0.23	70.65			Se75		0.05	0.77	66.21		
Zn65			0.02	23.55			Zn65			0.12	32.10		
H3				4.72	23.78		H3				0.06	9.25	
Ni63				0.11	76.12		Ni63					90.40	
Se79					0.09	99.99	Se79					0.35	99.95
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	1.26E5	1.22E5	8.22E3	1.11E1	9.32E-10	8.35E-10	Sv kg <sup>-1</sup>	2.96E5	2.75E5	3.04E4	4.31E2	1.50E-2	2.98E-4
Ga72	60.49	62.20	12.43				Ga72	34.31	36.75	4.5			
Ge69	22.60	23.31	72.89				As76	28.83	30.93	27.75			
Ga74	5.45	3.61					Ge69	9.26	9.94	19.07			
As76	4.20	4.32	6.34				As77	5.46	5.87	13.45			
Ge77	3.93	4.04	0.27				Ge75	2.81	2.90				
Ge75	0.62	0.61					Ge77	2.31	2.48				
Ga68	0.46	0.45		1.15			Ge71	1.71	1.84	13.43			
As74	0.43	0.45	5.80				As74	1.49	1.60	12.66			
Zn71m	0.41	0.42					Se75	0.80	0.86	7.67	66.47		
Ge71	0.11	0.11	1.39				Zn65	0.13	0.14	1.31	33.23		
Se75	0.03	0.03	0.47	43.21			H3				0.07	7.87	
Zn65		0.01	0.20	55.64			Ni63					90.01	
Co60					99.79	99.79	Se79					2.10	99.92

<b>Inh</b>	<b>0</b>	<b>10<sup>-5</sup> y</b>	<b>10<sup>-2</sup> y</b>	<b>1 y</b>	<b>100 y</b>	<b>10<sup>5</sup> y</b>	<b>Clear</b>	<b>0</b>	<b>10<sup>-5</sup> y</b>	<b>10<sup>-2</sup> y</b>	<b>1 y</b>	<b>100 y</b>	<b>10<sup>5</sup> y</b>
Sv kg <sup>-1</sup>	1.90E5	1.75E5	2.69E4	2.36E2	1.25E-1	7.03E-4		2.20E11	1.93E11	2.71E10	4.79E8	1.19E3	5.82E-1
Ga72	25.83	27.89	2.44				Ge69	52.06	59.25	88.85			
As76	20.83	22.53	14.46				Ge77	10.77	12.21	0.40			
Ge69	17.49	18.93	25.96				Ga74	10.75	7.86				
As77	8.32	90.17	14.77				Ge75	6.33	6.95				
Ge77	4.06	4.38	0.13				Ga72	4.20	4.77	0.45			
As74	3.77	4.09	23.04				Ge75m	3.14	0.03				
Ge75	3.43	3.58					Ga68	1.35	1.45		0.13		
Ge71	2.46	2.66	13.87				Zn65	0.47	0.53	3.78	76.81		
Se75	0.62	0.68	4.32	60.87			Se75	0.41	0.47	3.30	23.04		
Ga70	0.40	0.36					As74	0.15		1.08			
Zn65	0.12	0.13	0.83	34.34			As76		2.76	1.94			
Ge68		0.01	0.08	3.76			Ge71		0.02	0.12			
H3				0.81	5.84		H3				0.01	23.79	
Ni63				0.09	93.56		Ni63					76.15	
Se79					0.59	99.31	Se79					0.05	98.09



# Germanium

## Pathway analysis

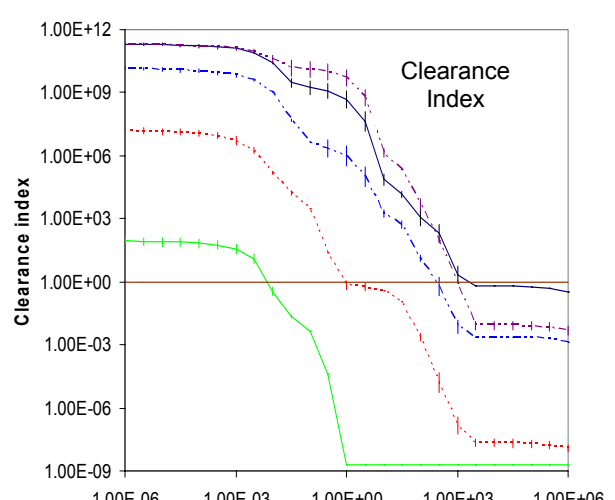
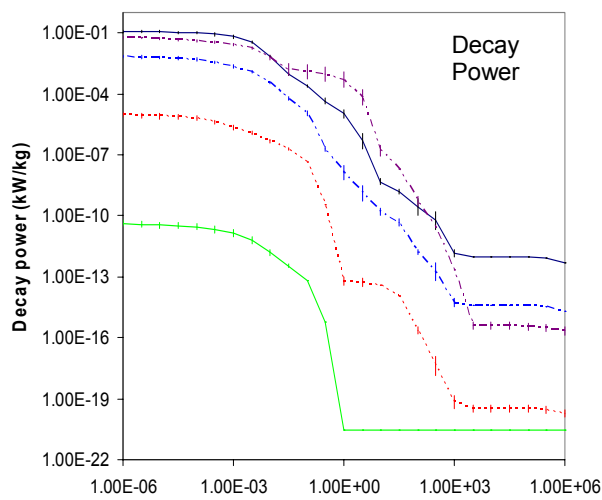
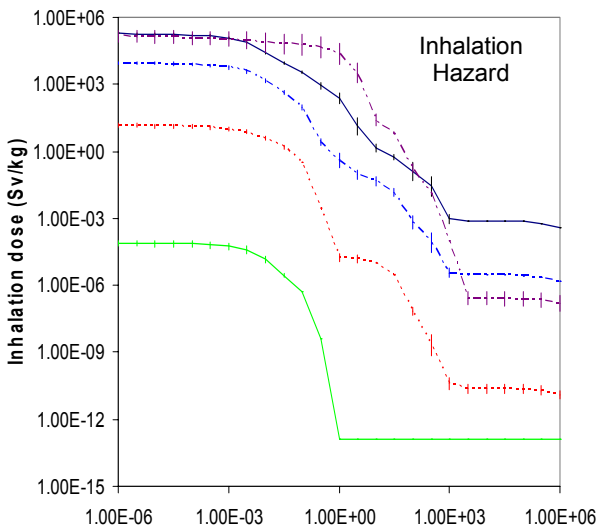
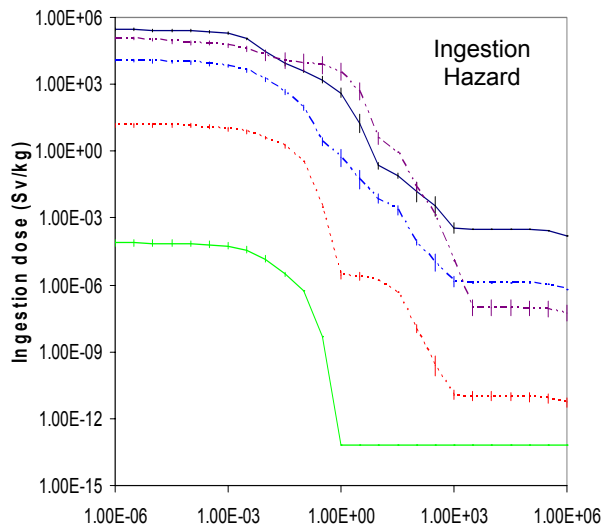
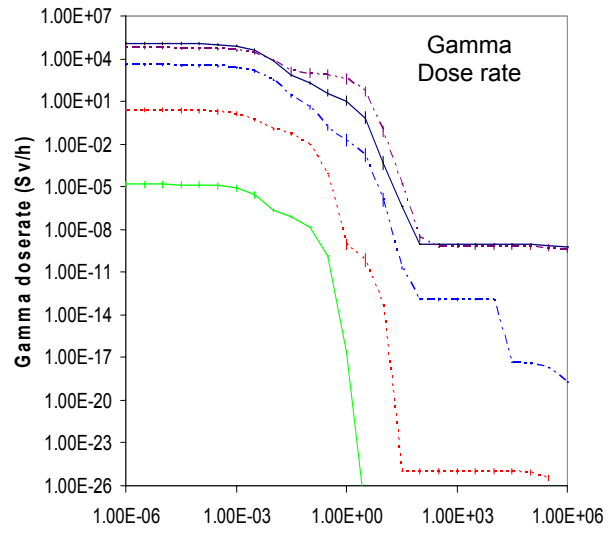
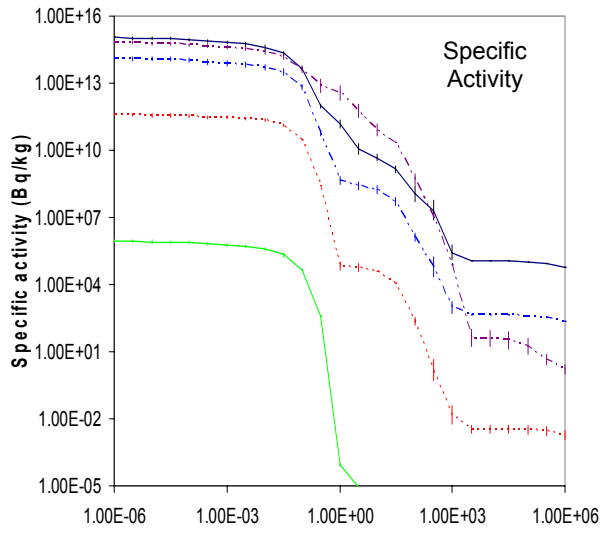
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Ga70	21.14 m	&Ge70(n,γ)Ge71(n,α)Zn68(n,γ)Zn69(β <sup>-</sup> )_	100.0	91.7	91.6				
		Ga69(n,γ)Ga70							
		Ge72(n,2n)Ge71(β <sup>+</sup> )Ga71(n,2n)Ga70				70.7	37.5	5.6	2.1
		Ge70(n,p)Ga70				24.3	13.1	4.7	2.2
		Ge72(n,d)Ga71(n,2n)Ga70				0.8	8.9	2.4	1.2
		Ge72(n,t)Ga70					17.2	64.2	47.6
		Ge73(n,2n)Ge72(n,2n)Ge71(β <sup>+</sup> )Ga71_					10.5	2.6	
		(n,2n)Ga70							
		Ge74(n,3n)Ge72(n,2n)Ge71(β <sup>+</sup> )Ga71_					2.5	0.3	
		(n,2n)Ga70							
		Ge74(n,3n)Ge72(n,t)Ga70					2.3	7.1	2.1
		Ge73(n,nt)Ga70					0.4	2.7	15.5
Ge74(n,4n)Ge71(β <sup>+</sup> )Ga71(n,2n)Ga70						4.0	3.8		
Ge74(n,2nt)Ga70							15.9		
Ga68	1.128 h	Ge70(n,2n)Ge69(β <sup>+</sup> )Ga69(n,2n)Ga68				75.5	16.9	2.3	1.4
		Ge70(n,d)Ga69(n,2n)Ga68				20.3	9.4	1.5	1.0
		Ge70(n,3n)Ge68(β <sup>+</sup> )Ga68					39.1	28.5	19.0
		Ge70(n,t)Ga68					24.5	52.2	41.7
		Ge72(n,3n)Ge70(n,t)Ga68					2.2	5.1	1.6
		Ge72(n,2nt)Ga68							10.3
Ge72(n,5n)Ge68(β <sup>+</sup> )Ga68							6.0		
Ge75	1.380 h	&Ge74(n,γ)Ge75	88.7	98.2	99.2	0.2	0.2	0.1	
		&Ge73(n,γ)Ge74(n,γ)Ge75	10.3	1.8	0.7				
		&Ge72(n,γ)Ge73(n,γ)Ge74(n,γ)Ge75	0.8						
		&Ge76(n,2n)Ge75				99.8	90.5	70.7	74.2
		Ge76(n,d)Ga75(β <sup>-</sup> )Ge75					9.3	19.2	25.8
Ge77	11.3 h	&Ge76(n,γ)Ge77	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Ga72	14.1 h	Ge70(n,γ)Ge71(β <sup>+</sup> )Ga71(n,γ)Ga72	100.0	100.0	100.0				
		Ge72(n,p)Ga72				83.0	23.0	8.4	4.0
		Ge73(n,2n)Ge72(n,p)Ga72				4.5	0.5	0.1	
		&Ge74(n,2n)Ge73(n,d)Ga72				4.3	15.3	4.6	1.7
		Ge73(n,d)Ga72				4.0	36.4	19.2	14.8
		&Ge74(n,2n)Ge73(n,2n)Ge72(n,p)Ga72				2.5			
		Ge74(n,t)Ga72					13.7	59.7	69.7
		Ge76(n,α)Zn72(β <sup>-</sup> )Ga72					4.2	1.8	1.2
		Ge74(n,3n)Ge72(n,p)Ga72					3.0	0.9	
Ge76(n,2nt)Ga72							4.2		
As76	1.093 d	&Ge74(n,γ)Ge75(β <sup>-</sup> )As75(n,γ)As76	93.3	99.0	99.6	0.2	0.1		
		&Ge73(n,γ)Ge74(n,γ)Ge75(β <sup>-</sup> )As75(n,γ)_	6.3	0.9	0.4				
		As76							
		&Ge76(n,2n)Ge75(β <sup>-</sup> )As75(n,γ)As76				97.1	64.8	52.8	46.6
		&Ge76(n,γ)Ge77(β <sup>-</sup> )As77(β <sup>-</sup> )Se77(n,d)As76					21.9	26.5	28.8
		&Ge76(n,d)Ga75(β <sup>-</sup> )Ge75(β <sup>-</sup> )As75(n,γ)As76					6.5	12.6	16.3
Ge76(n,γ)Ge77m(β <sup>-</sup> )As77(β <sup>-</sup> )Se77(n,d)As76					5.5	6.9	7.6		
As77	1.618 d	&Ge76(n,γ)Ge77(β <sup>-</sup> )As77	51.5	51.4	51.5	80.2	79.9	79.5	79.2
		Ge76(n,γ)Ge77m(β <sup>-</sup> )As77	48.6	48.6	48.6	19.8	20.1	20.5	20.8
		&Ge74(n,γ)Ge75(β <sup>-</sup> )As75(n,γ)As76(n,γ)_	0.2						
As77									
Ge69	1.627 d	Ge70(n,2n)Ge69				96.9	89.9	76.2	41.6
		Ge72(n,2n)Ge71(β <sup>+</sup> )Ga71(n,2n)Ga70(β <sup>-</sup> )_				1.8	0.4		
		Ge70(n,2n)Ge69							
		Ge72(n,3n)Ge70(n,2n)Ge69					7.9	7.4	1.6
		Ge72(n,t)Ga70(β <sup>-</sup> )Ge70(n,2n)Ge69					0.4	2.2	
		Ge72(n,4n)Ge69						10.6	44.2
		Ge74(n,3n)Ge72(n,4n)Ge69						1.2	1.9
		Ge73(n,5n)Ge69							3.9
Ge74(n,5n)Ge70(n,2n)Ge69							1.3		

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Ge71	11.43 d	Ge70(n, $\gamma$ )Ge71	100.0	100.0	100.0				
		Ge72(n,2n)Ge71				91.5	63.0	40.2	30.7
		Ge73(n,2n)Ge72(n,2n)Ge71				5.0	1.5	0.5	
		&Ge74(n,2n)Ge73(n,2n)Ge72(n,2n)Ge71				2.7	0.2		
		Ge73(n,3n)Ge71					17.5	18.2	9.1
		Ge74(n,3n)Ge72(n,2n)Ge71					8.3	4.4	1.3
		&Ge74(n,2n)Ge73(n,3n)Ge71					7.3	4.3	1.1
Ge74(n,4n)Ge71							28.3	54.2	
As74	17.78 d	&Ge76(n,2n)Ge75( $\beta^-$ )As75(n,2n)As74				99.6	90.5	80.3	74.0
		&Ge76(n,d)Ga75( $\beta^-$ )Ge75( $\beta^-$ )As75(n,2n)As74					9.2	19.3	25.8
Zn65	244.15 d	Ge70(n, $\alpha$ )Zn66(n,2n)Zn65				90.3	24.6	1.7	1.8
		Ge70(n, $\alpha$ )Zn67(n,2n)Zn66(n,2n)Zn65				4.8			
		Ge70(n,2n)Ge69( $\beta^+$ )Ga69(n, $\alpha$ )Cu66( $\beta^-$ )_Zn66(n,2n)Zn65				2.2			
		Ge70(n,2n $\alpha$ )Zn65					53.9	74.6	44.0
		Ge72(n,3n)Ge70(n,2n $\alpha$ )Zn65					3.9	5.9	1.4
		Ge70(n,2n)Ge69( $\beta^+$ )Ga69(n,3n)Ga67( $\beta^+$ )_Zn67(n,3n)Zn65					2.2	0.3	
		Ge72(n,2n $\alpha$ )Zn67(n,3n)Zn65					0.7	2.2	0.7
		Ge70(n,t)Ga68( $\beta^+$ )Zn68(n,4n)Zn65						33.0	5.5
		Ge70(n,nt)Ga67( $\beta^+$ )Zn67(n,3n)Zn65						1.7	6.2
		Ge72(n,4n $\alpha$ )Zn65							9.9
		Ge72(n,nt)Ga69(n,2nt)Zn65							2.3
		Ge72(n,4n)Ge69( $\beta^+$ )Ga69(n,2nt)Zn65							2.1
		Ge68	270.95 d	Ge70(n,2n)Ge69(n,2n)Ge68				97.8	
Ge70(n,3n)Ge68							92.0	89.4	69.5
Ge72(n,3n)Ge70(n,3n)Ge68							6.5	6.9	2.2
Ge72(n,5n)Ge68									21.8
Co60	5.271 y	&Ge70(n, $\alpha$ )Zn66(n,2n)Zn65(n, $\alpha$ )Ni61_(n,d)Co60				15.7	0.7		
		&Ge70(n, $\alpha$ )Zn66(n, $\alpha$ )Ni62(n,2n)Ni61_(n,d)Co60				22.9	1.4		
		&Ge70(n, $\alpha$ )Zn66(n, $\alpha$ )Ni63( $\beta^-$ )Cu63_(n, $\alpha$ )Co60				11.3			
		&Ge70(n, $\alpha$ )Zn66(n,2n)Zn65(n,2n)Zn64_(n,d)Cu63(n, $\alpha$ )Co60				7.6			
		&Ge70(n,2n $\alpha$ )Zn65( $\beta^+$ )Cu65(n,2n $\alpha$ )Co60					20.5	55.2	6.9
		&Ge70(n, $\alpha$ )Zn66(n,2n $\alpha$ )Ni61(n,d)Co60					7.7	0.5	
		&Ge70(n, $\alpha$ )Zn66(n,3n)Zn64(n, $\alpha$ )Co60					6.2		
		&Ge70(n, $\alpha$ )Zn66(n, $\alpha$ )Ni62(n,t)Co60					5.5	0.4	
		&Ge70(n,2n $\alpha$ )Zn65(n, $\alpha$ )Ni61(n,d)Co60					4.6	0.2	
		&Ge70(n,2n $\alpha$ )Ni62(n,t)Co60					3.0	6.4	1.5
		&Ge70(n,d $\alpha$ )Cu65(n,2n $\alpha$ )Co60					0.7	7.2	1.3
		&Ge70(n,2n $\alpha$ )Zn65(n,d $\alpha$ )Co60					0.5	5.0	
		&Ge72(n,3n $\alpha$ )Zn66(n,t $\alpha$ )Co60							7.7
		&Ge70(n, $\alpha$ )Zn66(n,t $\alpha$ )Co60							7.3
		&Ge70(n,t $\alpha$ )Cu64( $\beta^+$ )Ni64(n,2nt)Co60							4.5
Other pathways					42.5	49.2	25.1	70.8	
Kr85	10.752 y	Very long pathways of (n, $\gamma$ ), $\beta^-$	100.0	100.0	100.0				
H3	12.33 y	Ge70(n, $\gamma$ )Ge71(n,X)H1(n, $\gamma$ )H2(n, $\gamma$ )H3	92.1	95.1	99.2				
		Ge73(n,X)H3				45.1	12.9	10.2	9.1
		&Ge74(n,2n)Ge73(n,X)H3				25.0	2.8	1.2	
		Ge70(n,2n)Ge69( $\beta^+$ )Ga69(n,X)H3				11.2	1.5	0.6	
		Ge72(n,2n)Ge71( $\beta^+$ )Ga71(n,X)H3				7.9	1.8	0.7	
		Ge70(n,d)Ga69(n,X)H3				3.0	0.9	0.4	
		Ge70(n,X)H3				2.0	18.7	19.1	17.8
		Ge72(n,X)H3				1.3	24.0	25.4	25.5
		Ge74(n,X)H3				0.1	26.2	28.6	31.6
		Ge76(n,X)H3					4.3	5.7	6.6
		Ge74(n,3n)Ge72(n,X)H3					1.6	1.4	
Ni63	100.6 y	&Ge70(n, $\gamma$ )Ge71(n, $\alpha$ )Zn68(n, $\gamma$ )Zn69( $\beta^-$ )_Ga69(n, $\alpha$ )Cu66( $\beta^-$ )Zn66(n, $\alpha$ )Ni63	91.6						

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Ge70(n,α)Zn67(n,α)Ni64(n,γ)Ni65(β <sup>-</sup> ) Cu65(n,γ)Cu66(β <sup>-</sup> )Zn66(n,α)Ni63 Ge70(n,α)Zn66(n,α)Ni63 Ge70(n,α)Zn67(n,α)Ni63 Ge70(n,2α)Ni63 Ge70(n,2nα)Zn65(β <sup>+</sup> )Cu65(n,t)Ni63 Ge70(n,2n)Ge69(β <sup>+</sup> )Ga69(n,3n)Ga67(β <sup>+</sup> ) Zn67(n,α)Ni63 Ge70(n,3n)Ge68(β <sup>+</sup> )Ga68(β <sup>+</sup> )Zn68(n,2nα)Ni63 Ge70(n,t)Ga68(β <sup>+</sup> )Zn68(n,2nα)Ni63 Ge70(n,nt)Ga67(β <sup>+</sup> )Zn67(n,α)Ni63 Ge72(n,2n2α)Ni63	7.8			67.6 20.6 0.2	6.0 5.5 29.3 6.0 5.9	0.5 0.6 6.2 17.5 0.4	2.7 1.7 1.5 5.4	
Ni59	7.6 10 <sup>4</sup> y	Ge70(n,α)Zn66(n,2n)Zn65(n,2n)Zn64 (n,α)Ni60(n,2n)Ni59 Ge70(n,α)Zn66(n,α)Ni62(n,2n)Ni61 (n,2n)Ni60(n,2n)Ni59 Ge70(n,α)Zn66(n,2n)Zn65(n,α)Ni61 (n,2n)Ni60(n,2n)Ni59 Ge70(n,α)Zn66(n,2n)Zn65(β <sup>+</sup> )Cu65 (n,2n)Cu64(β <sup>-</sup> )Zn64(n,α)Ni60(n,2n)Ni59 Ge70(n,2n)Ge69(β <sup>+</sup> )Ga69(n,α)Cu65 (n,2n)Cu64(β <sup>-</sup> )Zn64(n,α)Ni60(n,2n)Ni59 Ge70(n,α)Zn66(n,2nα)Ni61(n,3n)Ni59 Ge70(n,α)Zn66(n,3n)Zn64(n,2nα)Ni59 Ge70(n,2nα)Zn65(n,2nα)Ni60(n,2n)Ni59 Ge70(n,2nα)Zn65(n,α)Ni61(n,3n)Ni59 Ge70(n,2nα)Zn65(β <sup>+</sup> )Cu65(n,α)Co61 (β <sup>-</sup> )Ni61(n,3n)Ni59 Ge70(n,3nα)Zn64(n,2nα)Ni59 Ge70(n,2nα)Zn65(n,3nα)Ni59				23.4 22.6 17.5 12.3 7.7	11.9 9.5 9.2 7.2 6.0	4.1 4.7 4.6 2.2 1.9		28.9 6.8
Kr81	2.1 10 <sup>3</sup> y	&Ge76(n,γ)Ge77m(β <sup>-</sup> )As77(β <sup>-</sup> )Se77 (n,γ)Se78(n,γ)Se79m(β <sup>-</sup> )Br79(n,γ)Br80 (β <sup>-</sup> )Kr80(n,γ)Kr81 &Ge76(n,γ)Ge77(β <sup>-</sup> )As77(β <sup>-</sup> )Se77(n,γ) Se78(n,γ)Se79m(β <sup>-</sup> )Br79(n,γ)Br80(β <sup>-</sup> ) Kr80(n,γ)Kr81 &Ge74(n,γ)Ge75(β <sup>-</sup> )As75(n,γ)As76(β <sup>-</sup> ) Se76(n,γ)Se77(n,γ)Se78(n,γ)Se79m(β <sup>-</sup> ) Br79(n,γ)Br80(β <sup>-</sup> )Kr80(n,γ)Kr81 &Ge76(n,γ)Ge77m(β <sup>-</sup> )As77(n,γ)As78 (β <sup>-</sup> )Se78(n,γ)Se79m(β <sup>-</sup> )Br79(n,γ)Br80 (β <sup>-</sup> )Kr80(n,γ)Kr81 &Ge76(n,γ)Ge77(β <sup>-</sup> )As77(n,γ)As78(β <sup>-</sup> ) Se78(n,γ)Se79m(β <sup>-</sup> )Br79(n,γ)Br80(β <sup>-</sup> ) Kr80(n,γ)Kr81	38.7 31.8 12.7	44.3 36.4	48.3 39.9		4.3 3.5			
Se79	1.1 10 <sup>6</sup> y	&Ge76(n,γ)Ge77m(β <sup>-</sup> )As77(β <sup>-</sup> )Se77 (n,γ)Se78(n,γ)Se79 &Ge74(n,γ)Ge75(β <sup>-</sup> )As75(n,γ)As76(β <sup>-</sup> ) Se76(n,γ)Se77(n,γ)Se78(n,γ)Se79 &Ge76(n,γ)Ge77(β <sup>-</sup> )As77(β <sup>-</sup> )Se77(n,γ) Se78(n,γ)Se79 &Ge76(n,γ)Ge77m(β <sup>-</sup> )As77(n,γ)As78 (β <sup>-</sup> )Se78(n,γ)Se79 &Ge76(n,γ)Ge77(β <sup>-</sup> )As77(n,γ)As78(β <sup>-</sup> ) Se78(n,γ)Se79	32.9 31.1 27.2	45.9 37.8	48.5 40.0	19.7 79.9	20.1 79.6	20.5 78.2	20.8 79.9	
Fe60	1.5 10 <sup>6</sup> y	Ge70(n,α)Zn66(n,α)Ni63(n,α)Fe60 Ge70(n,α)Zn67(n,α)Ni63(n,α)Fe60 Ge70(n,2nα)Zn65(β <sup>+</sup> )Cu65(n,2n)Cu64 (β <sup>+</sup> )Ni64(n,α)Fe60 Ge70(n,t)Ga68(β <sup>+</sup> )Zn68(n,α)Ni64(n,α)Fe60				68.3 20.8	0.2 0.1 11.4	9.1		7.4

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	Ge70(n,2n)Ge69(β <sup>+</sup> )Ga69(n,2nα)Cu64_ (β <sup>+</sup> )Ni64(n,nα)Fe60					10.3	12.5	
		Ge70(n,nα)Zn66(n,t)Cu64(β <sup>+</sup> )Ni64(n,nα)Fe60					9.7	6.8	1.3
		Ge70(n,3n)Ge68(β <sup>+</sup> )Ga68(β <sup>+</sup> )Zn68(n,nα)_ Ni64(n,nα)Fe60					9.7	2.3	
		Ge72(n,nα)Zn68(n,nα)Ni64(n,nα)Fe60					5.9	0.6	
		Ge70(n,d)Ga69(n,2nα)Cu64(β <sup>+</sup> )Ni64_ (n,nα)Fe60					5.7	8.0	
		Ge70(n,tα)Cu64(β <sup>+</sup> )Ni64(n,nα)Fe60						1.7	45.1
		Ge70(n,nt)Ga67(β <sup>+</sup> )Zn67(n,nt)Cu64(β <sup>+</sup> )_ Ni64(n,nα)Fe60						0.9	6.1

# Germanium activation characteristics

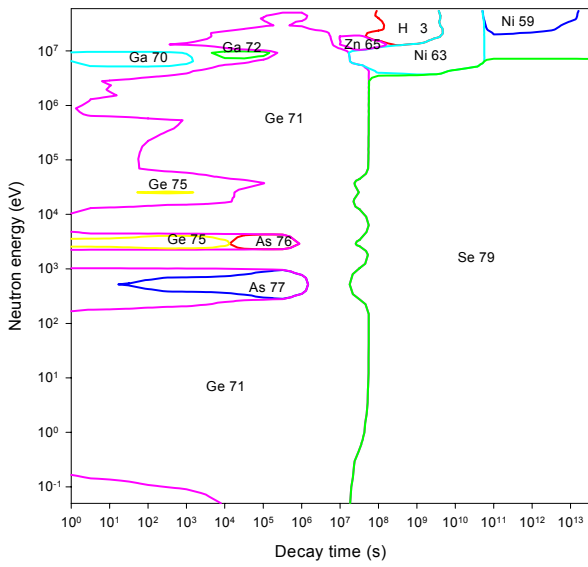


Decay time (years)

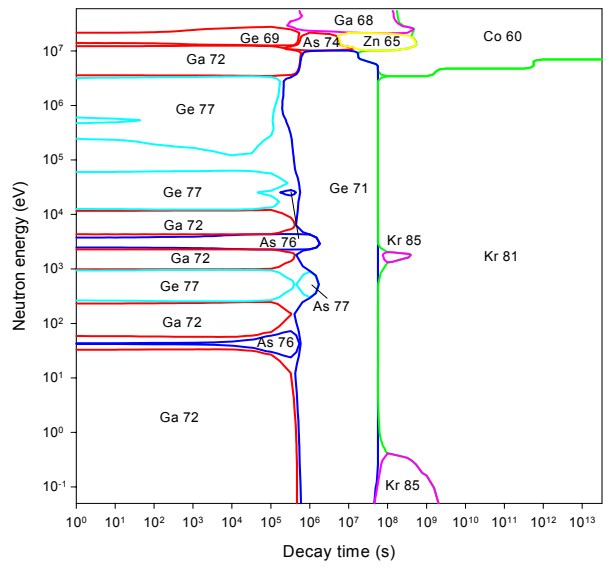
Decay time (years)

# Germanium importance diagrams & transmutation

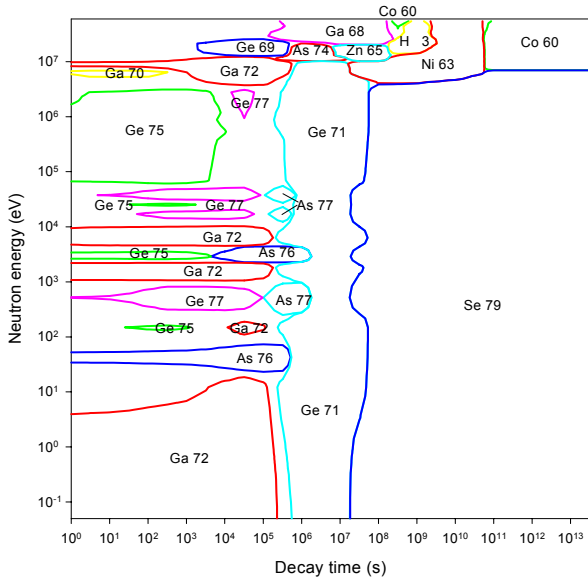
Activity



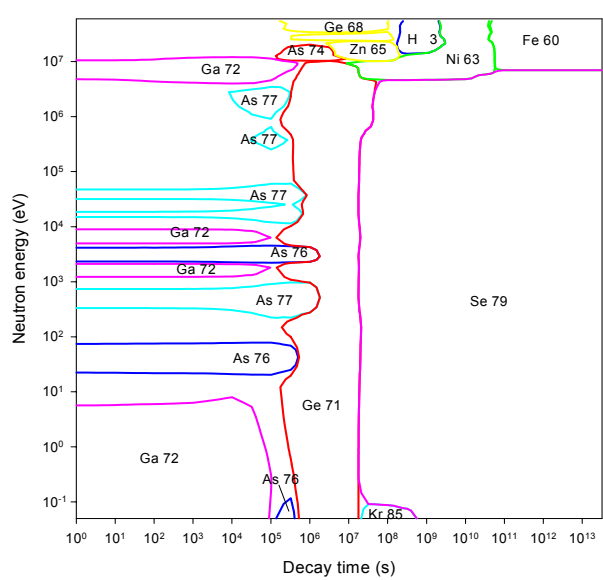
Dose rate



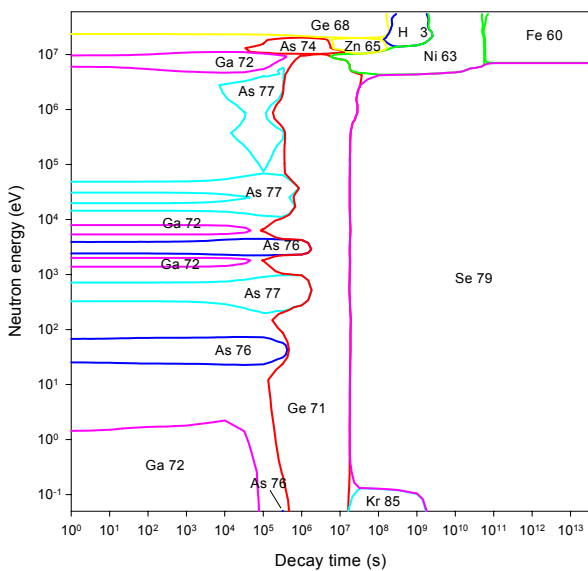
Heat output



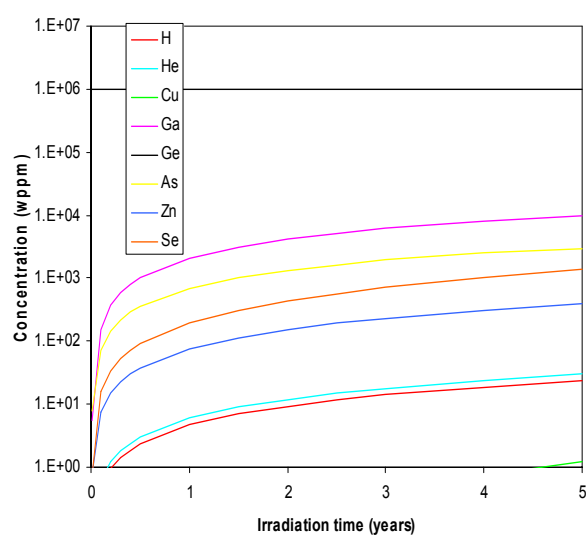
Ingestion dose



Inhalation dose



First wall transmutation



# Arsenic

## General properties

Atomic number	33	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	1.8	As75	100.0
Melting point / K	1090		
Boiling point / K	887 (sublimes)		
Density / kgm <sup>-3</sup>	5730		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	50		
Electrical resistivity /Ωm	2.6 10 <sup>-7</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	4.7 10 <sup>-6</sup>		
Crystal structure	rhombohedral		
Number of stable isotopes	1		
Mean atomic weight	74.9216		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	1.41E16	1.36E16	2.35E15	5.32E13	1.08E8	1.10E6	kW kg <sup>-1</sup>	3.12E0	3.10E0	4.33E-1	3.44E-3	1.08E-10	9.80E-12
As76	87.69	90.54	51.90				As76	94.24	94.58	66.98			
As74	5.69	5.89	29.60				As74	4.24	4.27	26.52			
Se75	3.11	3.22	18.30	99.77			Se75	0.91	0.92	6.48	99.97		
Se77m	3.01						Se77m	0.35					
H3				0.05	98.92		H3					90.37	
Se79					1.07	100.0	Se79					9.63	100.0
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	1.38E6	1.37E6	2.51E5	2.25E3	3.21E-12	2.31E-12	Sv kg <sup>-1</sup>	2.24E7	2.20E7	3.98E6	1.38E5	7.89E-3	3.18E-3
As76	88.55	88.67	48.03				As76	88.59	89.96	49.08			
As74	9.37	9.40	44.64				Se75	5.12	5.21	28.13	99.98		
Se75	1.35	1.36	7.29	99.99			As74	4.67	4.75	22.75			
Ga72	0.53	0.53	0.03				H3					57.04	
Kr81					99.95	100.0	Se79					42.94	99.97
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	1.18E7	1.14E7	2.93E6	6.91E4	3.58E-2	7.49E-3		1.81E12	1.76E12	6.23E11	5.30E10	1.08E3	6.09E0
As76	77.86	80.09	30.85				As76	68.52	70.18	19.62			
As74	14.35	14.79	49.94				Se75	24.36	25.01	69.19	100.0		
Se75	4.86	5.01	19.11	99.85			As74	4.45	4.56	11.19			
As77	0.03	0.03	0.02				Se77m	2.35	0.05				
As73	0.01	0.01	0.07	0.13			Ga72	0.04					
H3				0.01	77.71		H3					99.40	
Se79					22.16	99.55	Se79					0.60	100.0

# Arsenic

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Se77m	17.36 s	As75(n,γ)As76(β <sup>-</sup> )Se76(n,γ)Se77m	100.0	100.0	100.0	95.8	97.2	97.9	98.7
		As75(n,γ)As76(β <sup>-</sup> )Se76(n,γ)Se77(n,n')Se77m				1.3	0.9	0.7	0.4
Se79m	3.90 m	&As75(n,γ)As76(β <sup>-</sup> )Se76(n,γ)Se77(n,γ)_ Se78(n,γ)Se79m	99.8	94.7	99.2	98.2	98.6	99.2	99.5
		As75(n,γ)As76(n,γ)As77(β <sup>-</sup> )Se77(n,γ)_ Se78(n,γ)Se79m	0.1	5.1	0.8	0.1			
Ga68	1.128 h	As75(n,2n)As74(β <sup>-</sup> )Se74(n,α)Ge70_ (n,2n)Ge69(β <sup>+</sup> )Ga69(n,2n)Ga68				23.4	0.4		
		&As75(n,α)Ga72(β <sup>-</sup> )Ge72(n,α)Zn69(β <sup>-</sup> )_ Ga69(n,2n)Ga68				19.0			
		&As75(n,2n)As74(β <sup>+</sup> )Ge74(n,2n)Ge73_ (n,α)Zn69(β <sup>-</sup> )Ga69(n,2n)Ga68				8.9			
		As75(n,α)Ga71(n,2n)Ga70(β <sup>-</sup> )Ge70_ (n,2n)Ge69(β <sup>+</sup> )Ga69(n,2n)Ga68				6.9	0.6		
		As75(n,2n)As74(β <sup>-</sup> )Se74(n,α)Ge70(n,d)_ Ga69(n,2n)Ga68				6.3	0.2		
		As75(n,α)Ga71(n,3n)Ga69(n,2n)Ga68					20.1	0.7	
		&As75(n,3n)As73(β <sup>+</sup> )Ge73(n,α)Zn69_ (β <sup>-</sup> )Ga69(n,2n)Ga68					19.7	0.8	
		As75(n,3n)As73(β <sup>+</sup> )Ge73(n,3n)Ge71(β <sup>+</sup> )_ Ga71(n,3n)Ga69(n,2n)Ga68					8.2	0.4	
		As75(n,3n)As73(n,α)Ga69(n,2n)Ga68					4.9	0.1	
		As75(n,3n)As73(n,2n)Ga68					4.6	5.9	0.4
		As75(n,2n)Ga70(β <sup>-</sup> )Ge70(n,3n)Ge68(β <sup>+</sup> )Ga68					4.1	14.5	1.4
		As75(n,2n)Ga70(β <sup>-</sup> )Ge70(n,t)Ga68					3.3	33.3	3.7
		As75(n,3n)As73(β <sup>+</sup> )Ge73(n,4n)Ge70(n,t)Ga68						5.2	0.6
		As75(n,α)Ga71(n,4n)Ga68						5.1	2.7
		As75(n,3n)As73(β <sup>+</sup> )Ge73(n,3n)Ge71(β <sup>+</sup> )_ Ga71(n,4n)Ga68						4.7	0.5
		As75(n,3n)Ga69(n,2n)Ga68						1.5	8.5
		As75(n,2nt)Ge71(β <sup>+</sup> )Ga71(n,4n)Ga68						0.1	14.3
		As75(n,4n)Ga68							23.9
		As75(n,4n)As72(β <sup>+</sup> )Ge72(n,2nt)Ga68							6.8
		As75(n,nt)Ge72(n,2nt)Ga68							6.5
As75(n,5n)As71(β <sup>+</sup> )Ge71(β <sup>+</sup> )Ga71(n,4n)Ga68							5.8		
Other pathways					35.5	33.9	27.7	24.9	
Ge75	1.380 h	&As75(n,γ)As76(β <sup>-</sup> )Se76(n,γ)Se77(n,α)_ Ge74(n,γ)Ge75	96.3	84.6	88.4				
		&As75(n,γ)As76(n,γ)As77(β <sup>-</sup> )Se77(n,α)_ Ge74(n,γ)Ge75		4.6	0.7				
		&As75(n,p)Ge75				100.0	100.0	100.0	100.0
Ga72	14.10 h	As75(n,α)Ga72				97.5	31.3	18.1	53.4
		As75(n,3n)As73(β <sup>+</sup> )Ge73(n,d)Ga72					53.9	46.9	16.2
		&As75(n,t)Ge73(n,d)Ga72					5.3	12.9	9.2
		As75(n,2n)As74(β <sup>+</sup> )Ge74(n,t)Ga72					2.9	11.0	9.6
		As75(n,d)Ge74(n,t)Ga72					1.1	7.5	8.1
As72	1.083 d	As75(n,2n)As74(β <sup>-</sup> )Se74(n,d)As73(n,2n)As72				46.8	0.8		
		&As75(n,2n)As74(β <sup>-</sup> )Se74(n,2n)Se73m_ (β <sup>+</sup> )As73(n,2n)As72				25.6	0.1		
		As75(n,2n)As74(β <sup>-</sup> )Se74(n,2n)Se73(β <sup>+</sup> )_ As73(n,2n)As72				21.9	0.6		
		As75(n,2n)As74(n,2n)As73(n,2n)As72				5.2			
		As75(n,3n)As73(n,2n)As72					39.9	2.9	0.2
		As75(n,2n)As74(β <sup>-</sup> )Se74(n,3n)Se72(β <sup>+</sup> )As72					25.8	3.7	
		As75(n,2n)As74(β <sup>-</sup> )Se74(n,t)As72					25.0	11.7	1.0
		As75(n,2n)As74(n,3n)As72					5.0	0.4	



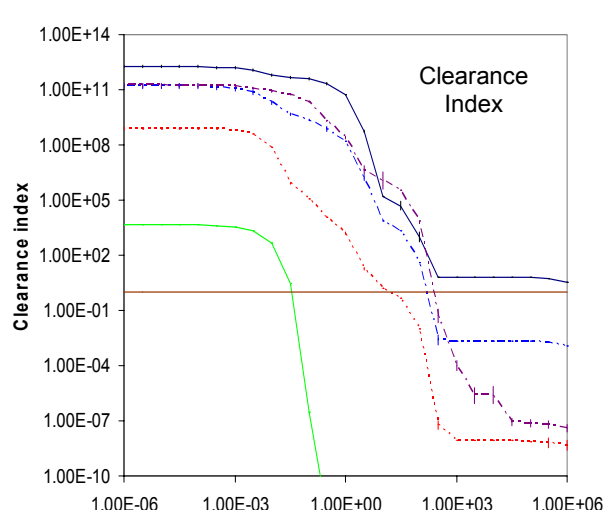
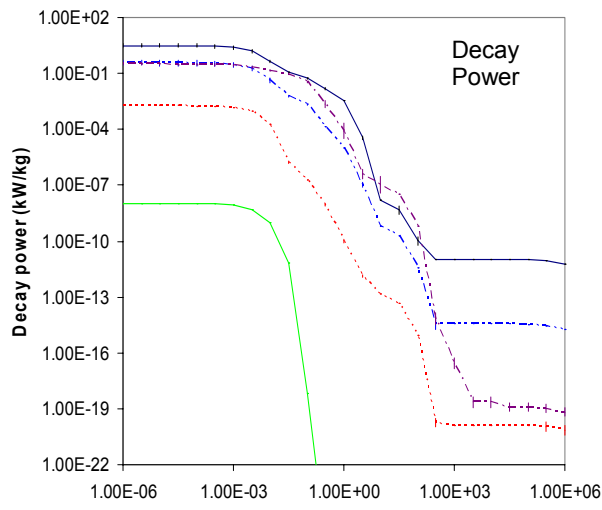
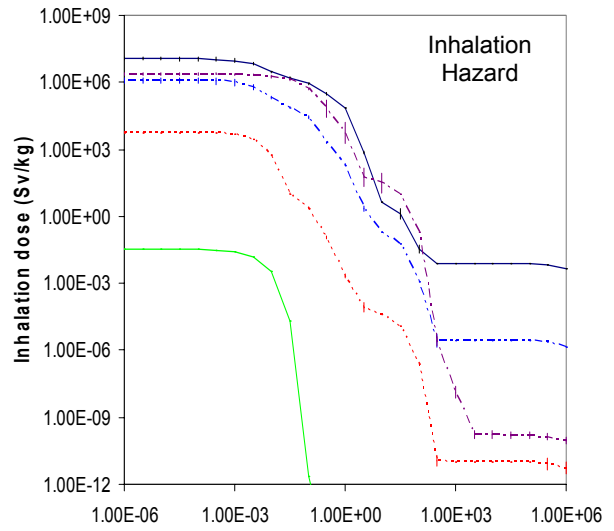
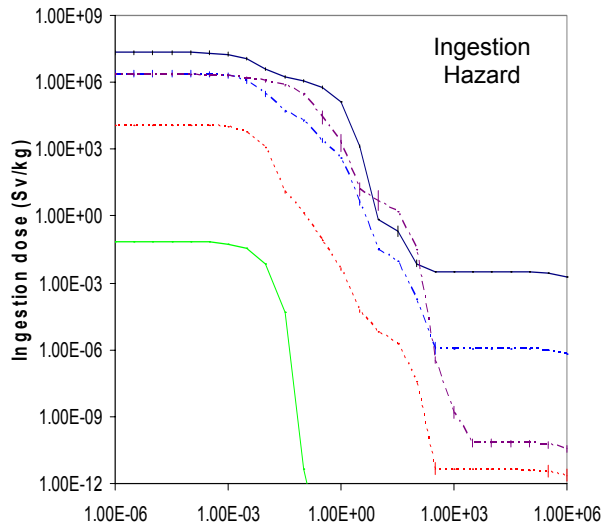
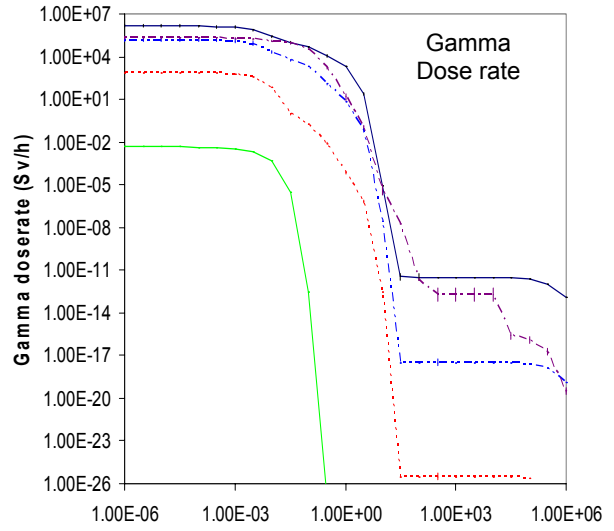
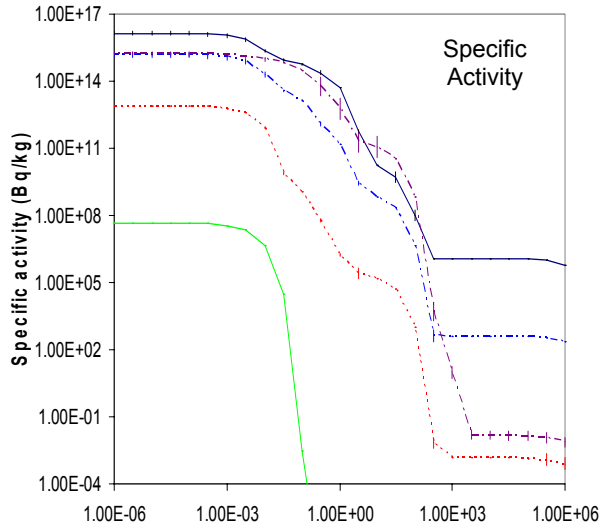
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	As75(n,4n)As72						80.8	98.4
As76	1.093 d	As75(n,γ)As76	100.0	100.0	100.0	98.8	99.5	99.7	99.8
Br82	1.472 d	&As75(n,γ)As76(β <sup>-</sup> )Se76(n,γ)Se77(n,γ) Se78(n,γ)Se79(n,γ)Se80(n,γ)Se81(β <sup>-</sup> ) Br81(n,γ)Br82 &As75(n,γ)As76(n,γ)As77(β <sup>-</sup> )Se77(n,γ) Se78(n,γ)Se79(n,γ)Se80(n,γ)Se81(β <sup>-</sup> ) Br81(n,γ)Br82	84.5 0.1	76.7 8.0	71.4 1.3				
As77	1.618 d	As75(n,γ)As76(n,γ)As77 &As75(n,γ)As76(β <sup>-</sup> )Se76(n,γ)Se77(n,p)As77	100.0	100.0	100.0	10.5 89.1	6.4 93.3	9.2 90.7	17.1 82.9
Ge71	11.43 d	As75(n,2n)As74(β <sup>-</sup> )Se74(n,α)Ge71 As75(n,α)Ga72(β <sup>-</sup> )Ge72(n,2n)Ge71 &As75(n,2n)As74(β <sup>+</sup> )Ge74(n,2n)Ge73 (n,2n)Ge72(n,2n)Ge71 As75(n,3n)As73(β <sup>+</sup> )Ge73(n,3n)Ge71 As75(n,t)Ge73(n,3n)Ge71 As75(n,nt)Ge72(n,2n)Ge71 As75(n,2n)As74(β <sup>+</sup> )Ge74(n,4n)Ge71 As75(n,d)Ge74(n,4n)Ge71 As75(n,2nt)Ge71 As75(n,5n)As71(β <sup>+</sup> )Ge71				41.2 35.9 16.0	0.5 0.7	0.3 0.2	0.7 0.2
As74	17.78 d	As75(n,2n)As74				98.7	99.4	99.5	99.7
As73	80.301 d	As75(n,2n)As74(β <sup>-</sup> )Se74(n,d)As73 &As75(n,2n)As74(β <sup>-</sup> )Se74(n,2n)Se73(β <sup>+</sup> )As73 As75(n,2n)As74(β <sup>-</sup> )Se74(n,2n)Se73m(β <sup>+</sup> )As73 As75(n,2n)As74(n,2n)As73 As75(n,3n)As73				46.9 40.6 7.0 5.3	2.0 2.1 0.3	0.6 0.6	0.7
Se75	119.64 d	As75(n,γ)As76(β <sup>-</sup> )Se76(n,2n)Se75 As75(n,2n)As74(β <sup>-</sup> )Se74(n,γ)Se75				60.4 39.4	78.7 21.2	76.3 23.7	76.4 23.6
Zn65	244.15 d	As75(n,2n)As74(β <sup>-</sup> )Se74(n,α)Ge70 (n,α)Zn66(n,2n)Zn65 As75(n,α)Ga71(n,2n)Ga70(β <sup>-</sup> )Ge70 (n,α)Zn66(n,2n)Zn65 As75(n,2n)As74(β <sup>-</sup> )Se74(n,α)Ge71(β <sup>+</sup> )Ga71 (n,2n)Ga70(β <sup>-</sup> )Ge70(n,α)Zn66(n,2n)Zn65 As75(n,α)Ga72(β <sup>-</sup> )Ge72(n,2n)Ge71(β <sup>+</sup> )Ga71 (n,2n)Ga70(β <sup>-</sup> )Ge70(n,α)Zn66(n,2n)Zn65 As75(n,α)Ga71(n,α)Cu67(β <sup>-</sup> )Zn67(n,3n)Zn65 As75(n,2nα)Ga70(β <sup>-</sup> )Ge70(n,2nα)Zn65 As75(n,α)Ga71(n,2n)Ga70(β <sup>-</sup> )Ge70 (n,2nα)Zn65 As75(n,2n)As74(β <sup>-</sup> )Se74(n,α)Ge70 (n,2nα)Zn65 As75(n,α)Ga71(n,3n)Ga69(n,3n)Ga67 (β <sup>+</sup> )Zn67(n,3n)Zn65 As75(n,nt)Ge72(n,3n)Ge70(n,2nα)Zn65 As75(n,3n)As73(β <sup>+</sup> )Ge73(n,4n)Ge70 (n,2nα)Zn65 As75(n,3n)As73(β <sup>+</sup> )Ge73(n,3n)Ge71(β <sup>+</sup> ) Ga71(n,α)Cu67(β <sup>-</sup> )Zn67(n,3n)Zn65 As75(n,3nα)Ga69(n,2nt)Zn65 As75(n,4n)As72(β <sup>+</sup> )Ge72(n,4nα)Zn65 As75(n,nt)Ge72(n,4nα)Zn65 As75(n,4nα)Ga68(β <sup>+</sup> )Zn68(n,4n)Zn65				57.9 17.1 4.6 4.2	0.9 1.3		
Co60	5.271 y	&As75(n,2n)As74(β <sup>-</sup> )Se74(n,α)Ge70 (n,α)Zn66(n,α)Ni62(n,2n)Ni61(n,d)Co60 &As75(n,2n)As74(β <sup>-</sup> )Se74(n,α)Ge70 (n,α)Zn66(n,2n)Zn65(n,α)Ni61(n,d)Co60 &As75(n,2n)As74(β <sup>-</sup> )Se74(n,α)Ge70 (n,α)Zn66(n,α)Ni63(β <sup>-</sup> )Cu63(n,α)Co60				13.5 11.4 6.7			

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&As75(n,α)Ga71(n,3n)Ga69(n,α) Cu65(n,2nα)Co60 &As75(n,2nα)Ga70(β <sup>-</sup> )Ge70(n,2nα) Zn65(β <sup>+</sup> )Cu65(n,2nα)Co60 &As75(n,2nα)Ga70(β <sup>-</sup> )Ge70(n,2nα) Ni62(n,t)Co60 &As75(n,2nα)Ga70(β <sup>-</sup> )Ge70(n,dα)Cu65 (n,2nα)Co60 &As75(n,3n)As73(β <sup>+</sup> )Ge73(n,α)Zn69 (β <sup>-</sup> )Ga69(n,α)Cu65(n,2nα)Co60 &As75(n,2nα)Ga70(β <sup>-</sup> )Ge70(n,2nα) Zn65(n,dα)Co60 &As75(n,3nα)Ga69(n,2n2α)Co60 Other pathways involving (n,α), (n,α), β <sup>-</sup>					9.5	0.2	
							3.3	35.9	0.2
							0.6	4.8	
							0.1	5.3	
								6.5	
								5.0	
									28.8
						68.4	86.5	42.3	71.0
Kr85	10.752 y	Very long pathways of (n,γ), β <sup>-</sup>	100.0	100.0	100.0				
H3	12.33 y	As75(n,γ)As76(n,X)H1(n,γ)H2(n,γ)H3 As75(n,X)H3 As75(n,2n)As74(n,X)H3 As75(n,3n)As73(β <sup>+</sup> )Ge73(n,X)H3 As75(n,2n)As74(β <sup>+</sup> )Ge74(n,X)H3	93.4	95.2	99.3				
						94.1	91.7	91.6	92.3
						4.3	0.2		
							3.9	3.6	1.3
							1.2	0.8	0.6
Ni63	100.6 y	As75(n,2n)As74(β <sup>-</sup> )Se74(n,α)Ge70 (n,α)Zn66(n,α)Ni63 As75(n,2n)As74(β <sup>-</sup> )Se74(n,α)Ge70 (n,α)Zn67(n,α)Ni63 As75(n,α)Ga71(n,2n)Ga70(β <sup>-</sup> )Ge70 (n,α)Zn66(n,α)Ni63 As75(n,α)Ga71(n,α)Cu67(β <sup>-</sup> )Zn67(n,α)Ni63   As75(n,3n)As73(β <sup>+</sup> )Ge73(n,2nα)Zn68 (n,2nα)Ni63 As75(n,α)Ga71(n,3n)Ga69(n,3n)Ga67 (β <sup>+</sup> )Zn67(n,α)Ni63 As75(n,3n)As73(n,2nα)Ga68(β <sup>+</sup> )Zn68 (n,2nα)Ni63 As75(n,t)Ge73(n,2nα)Zn68(n,2nα)Ni63 As75(n,2nα)Ga70(β <sup>-</sup> )Ge70(n,2nα)Zn65 (β <sup>+</sup> )Cu65(n,t)Ni63 As75(n,2nα)Ga70(β <sup>-</sup> )Ge70(n,t)Ga68(β <sup>+</sup> ) Zn68(n,2nα)Ni63 As75(n,3n)As73(β <sup>+</sup> )Ge73(n,3n)Ge71(β <sup>+</sup> ) Ga71(n,α)Cu67(β <sup>-</sup> )Zn67(n,α)Ni63 As75(n,3nα)Ga69(n,tα)Ni63 As75(n,4n)As72(β <sup>+</sup> )Ge72(n,2n2α)Ni63 As75(n,nt)Ge72(n,2n2α)Ni63 As75(n,4nα)Ga68(β <sup>+</sup> )Zn68(n,2nα)Ni63 Many other similar pathways				36.6	0.1		
							11.2		
							10.9	0.1	
							5.8	23.9	0.3
								5.2	19.2
								4.9	0.1
								0.8	5.9
								0.5	5.3
								0.3	6.0
								0.2	12.6
									0.3
									6.9
								0.1	27.1
									8.3
									7.9
									6.7
						35.5	64.0	43.6	48.9
Ni59	7.6 10 <sup>4</sup> y	As75(n,2n)As74(β <sup>-</sup> )Se74(n,α)Ge70 (n,α)Zn66(n,2n)Zn65(n,2n)Zn64(n,α) Ni60(n,2n)Ni59 As75(n,2n)As74(β <sup>-</sup> )Se74(n,α)Ge70 (n,α)Zn66(n,α)Ni62(n,2n)Ni61(n,2n) Ni60(n,2n)Ni59 As75(n,2n)As74(β <sup>-</sup> )Se74(n,α)Ge70 (n,α)Zn66(n,2n)Zn65(n,α)Ni61(n,2n) Ni60(n,2n)Ni59 As75(n,α)Ga71(n,2n)Ga70(β <sup>-</sup> )Ge70 (n,α)Zn66(n,2n)Zn65(n,2n)Zn64(n,α) Ni60(n,2n)Ni59 As75(n,α)Ga71(n,2n)Ga70(β <sup>-</sup> )Ge70 (n,α)Zn66(n,2n)Zn65(n,2n)Zn64(n,α) Ni60(n,2n)Ni59				13.5			
							11.2		
							10.1		
							4.8		
							4.2		
	▶								

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	As75(n,nα)Ga71(n,2n)Ga70(β <sup>-</sup> )Ge70_ (n,nα)Zn66(n,2n)Zn65(n,nα)Ni61(n,2n)_ Ni60(n,2n)Ni59 As75(n,nα)Ga71(n,2n)Ga70(β <sup>-</sup> )Ge70_ (n,nα)Zn66(n,nα)Ni62(n,2n)Ni61(n,2n)_ Ni60(n,2n)Ni59 As75(n,nα)Ga71(n,2n)Ga70(β <sup>-</sup> )Ge70_ (n,nα)Zn66(n,2n)Zn65(n,nα)Ni61(n,2n)_ Ni60(n,2n)Ni59 As75(n,nα)Ga71(n,3n)Ga69(n,2nα)Cu64_ (β <sup>-</sup> )Zn64(n,2nα)Ni59 As75(n,2nα)Ga70(β <sup>-</sup> )Ge70(n,3nα)Zn64_ (n,2nα)Ni59 As75(n,3nα)Ga69(n,2nα)Cu64(β <sup>-</sup> )Zn64_ (n,2nα)Ni59 As75(n,2nα)Ga70(β <sup>-</sup> )Ge70(n,2nα)Zn65_ (n,3nα)Ni59 As75(n,3nα)Ga69(n,3nα)Cu63(n,2nt)Ni59 As75(n,3nα)Ga69(n,2nt)Zn65(n,3nα)Ni59 Other pathways involving (n,nα), (n,α), β <sup>-</sup>				3.0				
						3.5				
						3.1				
							3.7	1.4		
								14.3	3.7	
								5.7	2.0	
								4.8	1.1	
									8.2	
									4.0	
						46.6	96.3	73.8	81.0	
Kr81	2.1 10 <sup>5</sup> y	&As75(n,γ)As76(β <sup>-</sup> )Se76(n,γ)Se77(n,γ)_ Se78(n,γ)Se79m(β <sup>-</sup> )Br79(n,γ)Br80(β <sup>-</sup> )_ Kr80(n,γ)Kr81 &As75(n,γ)As76(n,γ)As77(β <sup>-</sup> )Se77(n,γ)_ Se78(n,γ)Se79m(β <sup>-</sup> )Br79(n,γ)Br80(β <sup>-</sup> )_ Kr80(n,γ)Kr81	99.8	89.8	98.1					
				9.2	1.5					
Se79	1.1 10 <sup>6</sup> y	&As75(n,γ)As76(β <sup>-</sup> )Se76(n,γ)Se77(n,γ)_ Se78(n,γ)Se79 &As75(n,γ)As76(n,γ)As77(β <sup>-</sup> )Se77(n,γ)_ Se78(n,γ)Se79	99.9	93.2	98.9	99.5	99.6	99.8	99.8	
			0.1	6.3	1.0	0.1				
Fe60	1.5 10 <sup>6</sup> y	As75(n,2n)As74(β <sup>-</sup> )Se74(n,nα)Ge70_ (n,nα)Zn66(n,α)Ni63(n,α)Fe60 As75(n,2n)As74(β <sup>-</sup> )Se74(n,nα)Ge70_ (n,α)Zn67(n,nα)Ni63(n,α)Fe60 As75(n,nα)Ga71(n,2n)Ga70(β <sup>-</sup> )Ge70_ (n,nα)Zn66(n,α)Ni63(n,α)Fe60 As75(n,nα)Ga71(n,nα)Cu67(β <sup>-</sup> )Zn67_ (n,nα)Ni63(n,α)Fe60 As75(n,3n)As73(β <sup>+</sup> )Ge73(n,2nα)Zn68_ (n,nα)Ni64(n,nα)Fe60 As75(n,nα)Ga71(n,3n)Ga69(n,2nα)Cu64_ (β <sup>+</sup> )Ni64(n,nα)Fe60 As75(n,3n)As73(n,nα)Ga69(n,2nα)Cu64_ (β <sup>+</sup> )Ni64(n,nα)Fe60 As75(n,3nα)Ga69(n,2nα)Cu64(β <sup>+</sup> )Ni64_ (n,nα)Fe60 As75(n,4nα)Ga68(β <sup>+</sup> )Zn68(n,2nα)Fe60 As75(n,2nt)Ge71(β <sup>+</sup> )Ga71(n,4nα)Cu64_ (β <sup>+</sup> )Ni64(n,nα)Fe60 Many other similar pathways				35.3				
						10.8				
						10.6				
						7.1	0.7			
							15.3	3.4		
							11.7	3.8		
							5.1	1.4		
								15.7	14.7	
									6.2	
									6.1	
						36.2	67.2	75.7	73.0	
Mn53	3.7 10 <sup>6</sup> y	As75(n,2nα)Ga70(β <sup>-</sup> )Ge70(n,2nα)Zn65_ (n,2nα)Ni60(n,2nα)Fe55(n,t)Mn53 As75(n,2nα)Ga70(β <sup>-</sup> )Ge70(n,2nα)Zn65_ (n,2nα)Ni60(n,3n)Ni58(n,dα)Mn53 As75(n,2nα)Ga70(β <sup>-</sup> )Ge70(n,2nα)Zn65_ (n,2nα)Ni60(n,dα)Mn55(n,3n)Mn53 As75(n,2nα)Ga70(β <sup>-</sup> )Ge70(n,2nα)Zn65_ (n,2nα)Ni60(n,t)Co58(n,2nα)Mn53 As75(n,2nt)Ge71(β <sup>+</sup> )Ga71(n,3nα)Cu65_ (n,3nα)Co59(n,3nα)Mn53						6.6		
								2.6		
								1.6		
								1.3		
									2.2	
	▶									

<b>Nuclide</b>	<b>T<sub>1/2</sub></b>	<b>Pathway</b>	<b>210</b>	<b>186</b>	<b>151</b>	<b>42</b>	<b>30</b>	<b>21</b>	<b>6</b>
	◀	As75(n,3nα)Ga69(n,3nα)Cu63(n,nα)_ Co59(n,3nα)Mn53							1.5
		As75(n,3nα)Ga69(n,3n2α)Co59(n,3nα)Mn53							1.4
		Many other similar pathways				100.0	100.0	87.9	94.9

# Arsenic activation characteristics

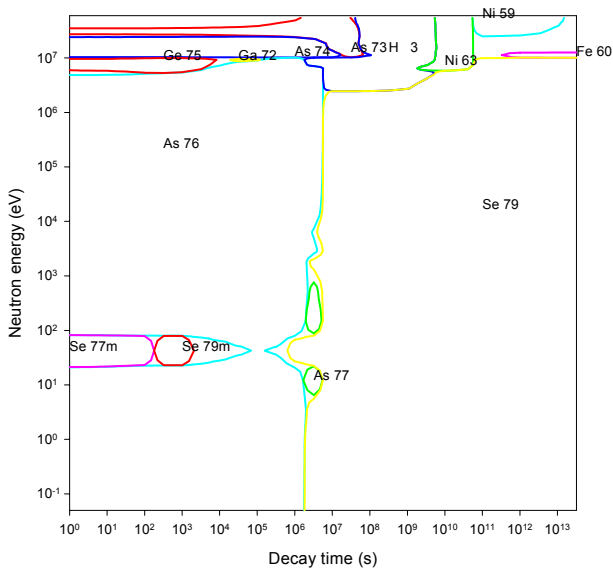


Decay time (years)

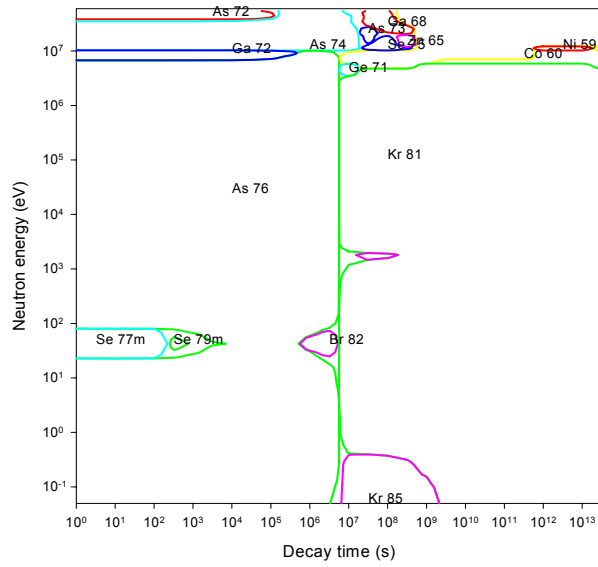
Decay time (years)

# Arsenic importance diagrams & transmutation

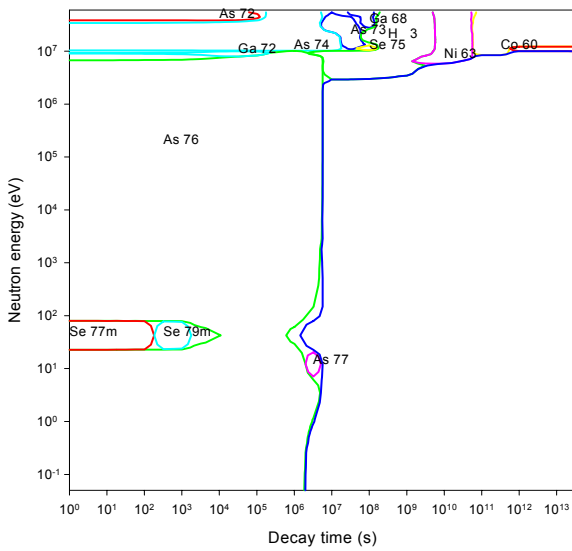
**Activity**



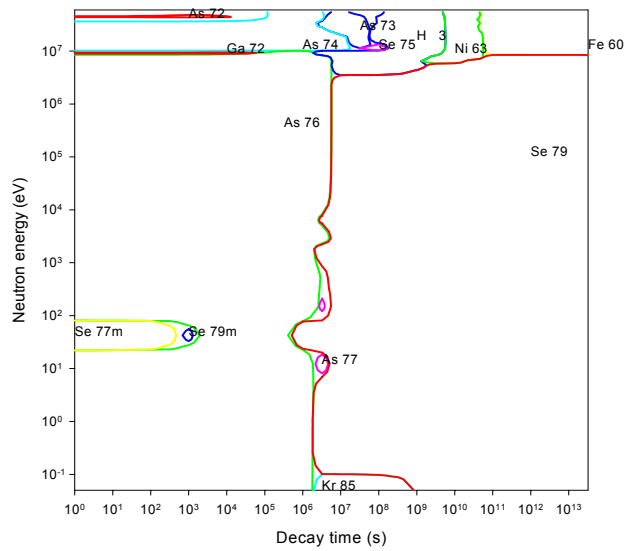
**Dose rate**



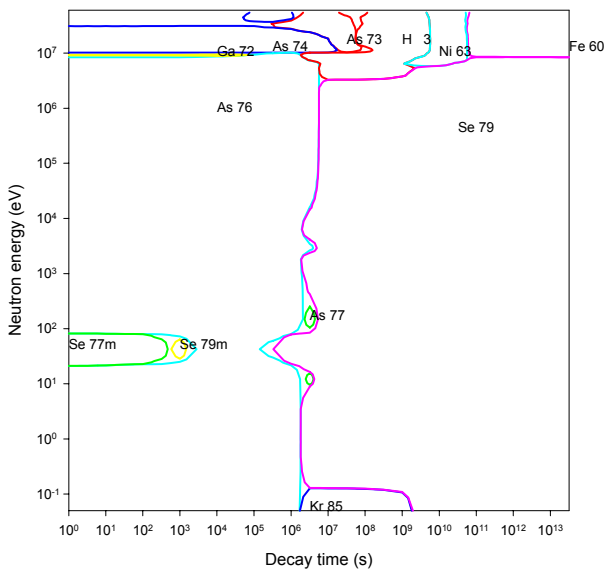
**Heat output**



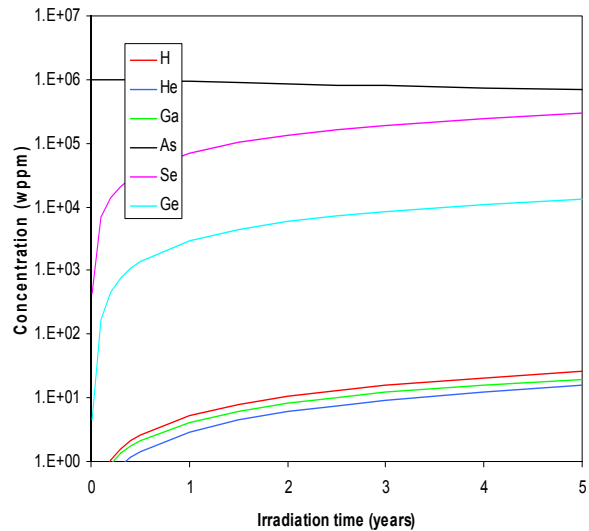
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**



# Selenium

## General properties

Atomic number	34	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	5.0 10 <sup>-2</sup>	Se74	0.89
Melting point / K	494	Se76	9.37
Boiling point / K	958.1	Se77	7.63
Density / kgm <sup>-3</sup>	4790	Se78	23.77
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	2.04	Se80	49.61
Electrical resistivity /Ωm	1.0 10 <sup>-2</sup>	Se82	8.73 (T <sub>1/2</sub> = 1.21 10 <sup>20</sup> y)
Coefficient of thermal expansion / K <sup>-1</sup>	3.69 10 <sup>-5</sup>		
Crystal structure	Hexagonal		
Number of stable isotopes	5 (6)		
Mean atomic weight	78.96		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	1.89E15	1.05E15	2.17E14	2.24E13	2.84E9	2.65E9	kW kg <sup>-1</sup>	1.40E-1	1.16E-1	2.26E-2	1.45E-3	2.52E-8	2.36E-8
Se77m	25.59						Br82	27.66	33.47	30.79			
Se79m	23.41	16.60					Se81	21.70	23.38				
Se81	16.23	26.08					As76	19.82	23.93	12.13			
Se75	9.81	17.69	83.52	99.79			Se77m	8.94					
Se81m	6.49	10.99					Se75	8.58	10.39	52.13	99.96		
As76	6.19	11.14	5.31				Se79m	4.84	2.30				
Br82	4.60	8.29	7.18				As80	1.56					
Br82m	4.28	4.24					Se81m	1.44	1.63				
Kr83m	0.90	1.58					As78	1.26	1.47				
As74	0.39	0.70	2.94				As74	0.86	1.05	4.67			
Se79				0.01	99.10	99.69	Br80	0.62	0.69				
H3				0.01	0.41		Se79					99.50	99.92
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	8.89E4	8.47E4	2.08E4	9.47E2	2.96E-6	1.19E-6	Sv kg <sup>-1</sup>	1.36E6	8.46E5	5.13E5	5.97E4	1.15E1	8.15E0
Br82	68.55	71.97	52.49				Se75	35.48	56.95	92.00	97.29		
As76	13.19	13.82	5.55				As76	13.78	22.07	3.60			
Se75	8.83	9.28	36.91	99.99			Br82	3.45	5.54	1.64			
Se77m	2.49						As74	0.71	1.14	1.62			
As78	1.83	1.85					Se81	0.61	0.87				
As74	1.35	1.42	5.01				Se81m	0.47	0.72				
As80	0.93						As77	0.16	0.27	0.10			
Kr81					58.91	100.0	As78	0.06	0.10				
Kr85					51.08*		Se79				0.01	70.64	93.91
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	1.03E6	5.38E5	3.30E5	8.42E4	1.37E2	3.55E1		3.87E11	3.22E11	1.99E11	2.23E10	1.60E4	1.47E4
Se75	23.31	44.80	71.56	34.46			Se75	47.83	57.59	91.24	100.0		
As76	8.37	16.06	2.59				Br82	22.44	27.01	7.84			
Kr85	5.68	10.92	17.82	65.43	68.13		Se77m	12.47					
Br82	5.30	10.18	2.98				Se81	5.65	6.05				
As74	1.50	2.88	4.08				As76	3.01	3.62	0.58			
Se81m	0.60	1.09					Se79m	2.53	1.20				
Se81	0.44	0.76					As78	1.59	1.85				
As77	0.21	0.41	0.15				As80	0.99					
Kr81			0.01	0.03	17.89	49.50	As74	0.19	0.22	0.32			
Se79			0.01	0.02	13.97	50.49	Se79					97.86	99.57

# Selenium

## Pathway analysis

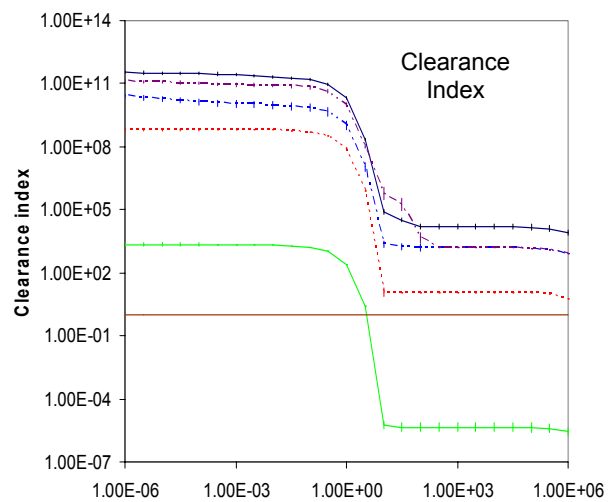
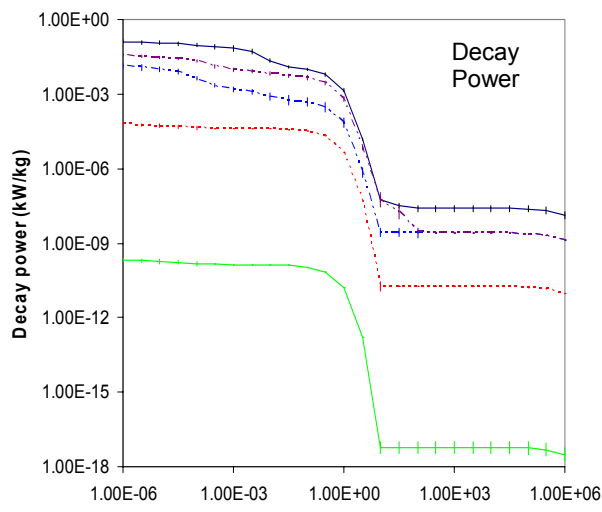
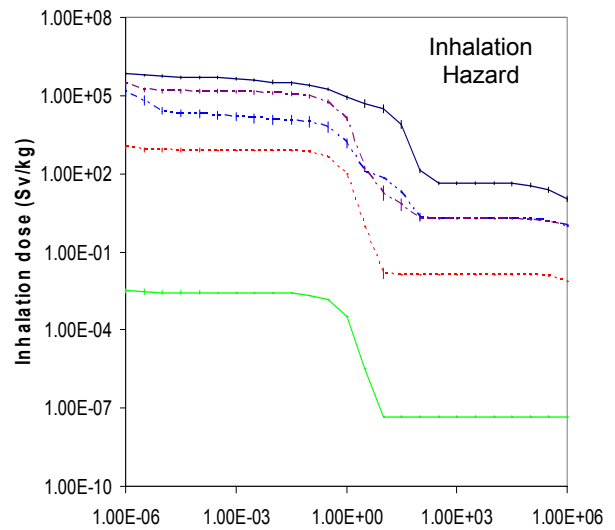
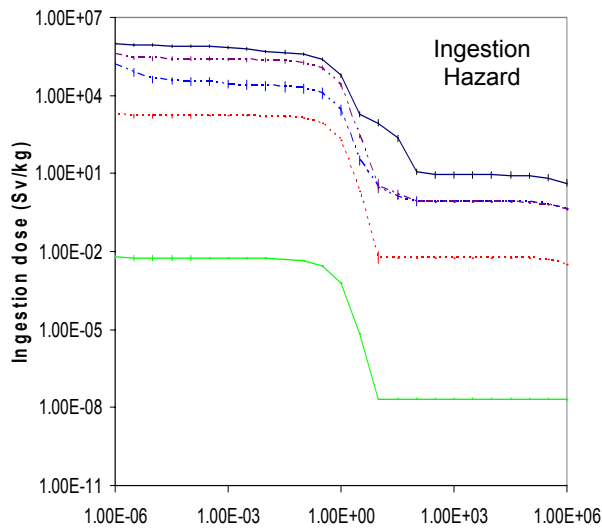
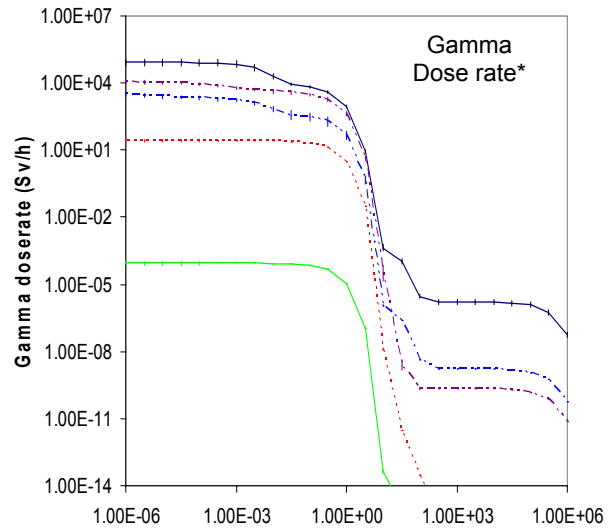
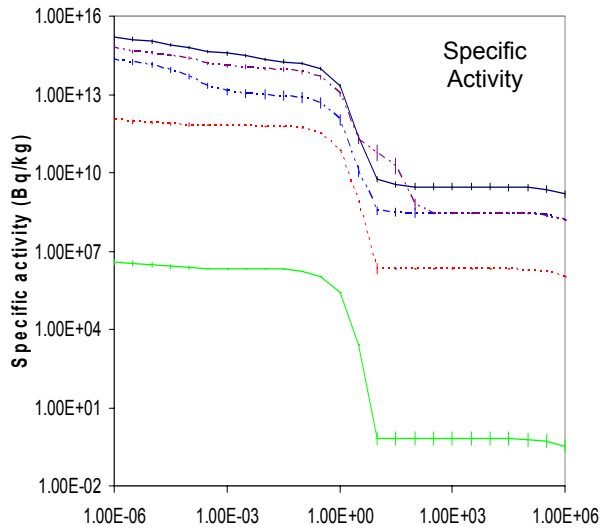
Nuclide	T <sub>1/2</sub>	Pathway	210	181	151	42	30	21	6	
Se77m	17.36 s	Se76(n,γ)Se77m	63.0	100.0	100.0					
		Se74(n,γ)Se75(n,γ)Se76(n,γ)Se77m	29.4							
		Se74(n,γ)Se75(β <sup>+</sup> )As75(n,γ)As76(β <sup>-</sup> )_	7.6							
		Se76(n,γ)Se77m								
		Se78(n,2n)Se77m				79.2	60.5	34.3	22.6	
		Se77(n,n')Se77m				11.5	9.5	7.9	5.1	
		&Se80(n,2n)Se79(n,2n)Se78(n,2n)Se77m				2.8	0.4			
		Se78(n,2n)Se77(n,n')Se77m				1.6	0.4	0.2		
		Se80(n,3n)Se78(n,2n)Se77m					14.0	6.7	1.6	
		&Se80(n,2n)Se79(n,3n)Se77m					9.5	4.5	1.0	
		Se80(n,d)As79(β <sup>-</sup> )Se79m(IT)Se79(n,3n)Se77m   Se80(n,4n)Se77m						1.2	1.5	
							38.9	64.3		
Se83m	1.168 m	Se82(n,γ)Se83m	100.0	100.0	100.0	99.9	99.3	99.4	99.7	
Se81	18.45 m	&Se80(n,γ)Se81	99.8	100.0	100.0	0.3	0.2	0.2	0.2	
		&Se82(n,2n)Se81				99.7	92.2	81.3	74.5	
		Se82(n,d)As81(β <sup>-</sup> )Se81					7.6	18.5	25.3	
Ga68	1.128 h	Se74(n,nα)Ge70(n,2n)Ge69(β <sup>+</sup> )Ga69(n,2n)Ga68				49.7	4.9	0.1		
		Se74(n,nα)Ge70(n,d)Ga69(n,2n)Ga68				13.3	2.7			
		Se74(n,nα)Ge70(n,3n)Ge68(β <sup>+</sup> )Ga68					18.0	2.3	0.2	
		Se74(n,nα)Ge70(n,t)Ga68					14.2	5.2	0.6	
		Se74(n,α)Ge71(β <sup>+</sup> )Ga71(n,2n)Ga70(β <sup>-</sup> )_					6.0			
		Ge70(n,2n)Ge69(β <sup>+</sup> )Ga69(n,2n)Ga68								
		Se74(n,2nα)Ge69(β <sup>+</sup> )Ga69(n,2n)Ga68						3.9	7.1	0.4
		Se76(n,2nα)Ge71(β <sup>+</sup> )Ga71(n,4n)Ga68							14.8	3.1
		Se76(n,3nα)Ge70(n,t)Ga68							1.0	4.7
		Se74(n,3nα)Ge68(β <sup>+</sup> )Ga68							0.9	9.4
		Se74(n,tα)Ga68							0.2	10.9
		Se77(n,3nα)Ge71(β <sup>+</sup> )Ga71(n,4n)Ga68							0.2	4.0
		Other pathways					37.0	50.3	68.2	66.7
Kr83m	1.83 h	&Se80(n,γ)Se81(β <sup>-</sup> )Br81(n,γ)Br82(β <sup>-</sup> )_	71.5	29.7	0.2					
		Kr82(n,γ)Kr83m								
		Se82(n,γ)Se83m(β <sup>-</sup> )Br83(β <sup>-</sup> )Kr83m	23.1	47.5	86.7	25.7	25.6	26.2	26.0	
		Se82(n,γ)Se83(β <sup>-</sup> )Br83(β <sup>-</sup> )Kr83m	3.4	7.1	12.9	74.3	74.4	73.8	74.0	
		&Se80(n,γ)Se81(β <sup>-</sup> )Br81(n,γ)Br82m(β <sup>-</sup> )_	1.6	0.7						
		Kr82(n,γ)Kr83m								
		&Se80(n,γ)Se81(β <sup>-</sup> )Br81(n,γ)Br82(n,γ)_ Br83(β <sup>-</sup> )Kr83m	0.2	15.0						
As76	1.093 d	Se74(n,γ)Se75(β <sup>+</sup> )As75(n,γ)As76	100.0	100.0	100.0					
		Se76(n,p)As76				66.2	9.7	3.0	1.2	
		Se77(n,d)As76				13.9	52.4	21.1	14.1	
		Se77(n,2n)Se76(n,p)As76				9.5	0.7	0.1		
		&Se78(n,2n)Se77(n,d)As76				7.2	14.7	3.0	1.3	
		Se78(n,t)As76					10.4	52.8	48.0	
		Se80(n,3n)Se78(n,t)As76					2.4	10.3	3.4	
		&Se80(n,4n)Se77(n,d)As76						3.6	3.7	
		Se80(n,2nt)As76							18.6	
Kr79	1.46 d	&Se82(n,2n)Se81(β <sup>-</sup> )Br81(n,2n)Br80(β <sup>-</sup> )_				93.2	85.5	74.7	67.7	
		Kr80(n,2n)Kr79								
		&Se82(n,d)As81(β <sup>-</sup> )Se81(β <sup>-</sup> )Br81(n,2n)_ Br80(β <sup>-</sup> )Kr80(n,2n)Kr79					4.0	10.3	13.8	
Br82	1.472 d	&Se80(n,γ)Se81(β <sup>-</sup> )Br81(n,γ)Br82	94.0	100.0	89.0	0.2				
		&Se82(n,2n)Se81(β <sup>-</sup> )Br81(n,γ)Br82				94.4	78.9	65.5	58.8	
		&Se82(n,γ)Se83(β <sup>-</sup> )Br83(β <sup>-</sup> )Kr83(n,d)Br82				0.2	7.1	10.5	8.1	
		&Se82(n,d)As81(β <sup>-</sup> )Se81(β <sup>-</sup> )Br81(n,γ)Br82					6.5	15.6	20.3	
		&Se82(n,γ)Se83m(β <sup>-</sup> )Br83(β <sup>-</sup> )Kr83m_ (IT)Kr83(n,d)Br82					2.4	3.7	2.9	



Nuclide	T <sub>1/2</sub>	Pathway	210	181	151	42	30	21	6
As74	17.78 d	Se76(n,2n)Se75( $\beta^+$ )As75(n,2n)As74 Se74(n,p)As74 Se77(n,2n)Se76(n,2n)Se75( $\beta^+$ )As75(n,2n)As74   Se76(n,d)As75(n,2n)As74 Se77(n,3n)Se75( $\beta^+$ )As75(n,2n)As74 Se76(n,t)As74 Se78(n,3n)Se76(n,2n)Se75( $\beta^+$ )As75(n,2n)As74   Se78(n,3n)Se76(n,t)As74 Se77(n,nt)As74 Se78(n,4n)Se75( $\beta^+$ )As75(n,2n)As74 &Se80(n,4n)Se77(n,nt)As74 Se78(n,2nt)As74 Se80(n,5n)Se76(n,t)As74				78.6 7.1 5.2 2.0 18.2 11.1 3.8 2.5 0.4 1.9 0.6	37.0 1.6 1.1 9.4 4.0 55.7 0.4 13.2 4.0 1.9 0.6	3.9 0.5 1.7 4.0 28.3 0.4 25.4 3.3 6.6	1.2 0.2 0.7 0.8 28.3 2.4 25.4 3.3 6.6 11.8 4.1
Se75	119.64 d	Se74(n, $\gamma$ )Se75 Se76(n,2n)Se75 Se77(n,2n)Se76(n,2n)Se75 &Se78(n,2n)Se77(n,2n)Se76(n,2n)Se75 Se77(n,3n)Se75 Se78(n,3n)Se76(n,2n)Se75 &Se78(n,2n)Se77(n,3n)Se75 Se78(n,4n)Se75 &Se80(n,4n)Se77(n,3n)Se75 Se80(n,3n)Se78(n,4n)Se75 Se80(n,5n)Se76(n,2n)Se75	100.0	100.0	100.0	85.3 11.2 2.6	50.1 3.1 0.3 24.8 10.3 6.3	30.2 1.0 30.8 6.5 4.0 14.4 4.8 2.5	18.3 0.4 11.9 1.4 1.0 51.3 2.7 3.3 2.4
Co60	5.271 y	&Se74(n, $\alpha$ )Ge70(n, $\alpha$ )Zn66(n, $\alpha$ )Ni62_ (n,2n)Ni61(n,d)Co60 &Se74(n, $\alpha$ )Ge70(n, $\alpha$ )Zn66(n,2n)Zn65_ (n, $\alpha$ )Ni61(n,d)Co60 &Se74(n, $\alpha$ )Ge70(n,2n $\alpha$ )Zn65( $\beta^+$ )Cu65_ (n,2n $\alpha$ )Co60 &Se74(n, $\alpha$ )Ge70(n, $\alpha$ )Zn66(n, $\alpha$ )Ni63_ ( $\beta^-$ )Cu63(n, $\alpha$ )Co60 &Se74(n, $\alpha$ )Ge70(n, $\alpha$ )Zn66(n,2n)Zn65_ (n,2n)Zn64(n,d)Cu63(n, $\alpha$ )Co60 &Se74(n, $\alpha$ )Ge70(n, $\alpha$ )Zn67(n, $\alpha$ )Ni63_ ( $\beta^-$ )Cu63(n, $\alpha$ )Co60 &Se74(n, $\alpha$ )Ge70(n, $\alpha$ )Zn66(n,2n)Zn65_ (n,2n)Zn64(n, $\alpha$ )Ni60(n,p)Co60 &Se74(n, $\alpha$ )Ge70(n, $\alpha$ )Zn66(n, $\alpha$ )Ni62_ (n,2n)Ni61(n,2n)Ni60(n,p)Co60 &Se74(n, $\alpha$ )Ge70(n, $\alpha$ )Zn66(n,2n)Zn65_ (n, $\alpha$ )Ni61(n,2n)Ni60(n,p)Co60 &Se74(n, $\alpha$ )Ge70(n, $\alpha$ )Zn66(n,2n $\alpha$ )_ Ni61(n,d)Co60 &Se74(n, $\alpha$ )Ge70(n, $\alpha$ )Zn66(n,3n)Zn64_ (n,p $\alpha$ )Co60 &Se74(n,2n $\alpha$ )Ge69( $\beta^+$ )Ga69(n, $\alpha$ )Cu65_ (n,2n $\alpha$ )Co60 &Se74(n, $\alpha$ )Ge70(n, $\alpha$ )Zn66(n, $\alpha$ )Ni62_ (n,t)Co60 &Se74(n, $\alpha$ )Ge70(n,2n $\alpha$ )Zn65(n, $\alpha$ )_ Ni61(n,d)Co60 &Se74(n,2n $\alpha$ )Zn66(n,2n $\alpha$ )Ni61(n,d)Co60 &Se76(n,2n $\alpha$ )Ge71( $\beta^+$ )Ga71(n,3n $\alpha$ )_ Cu65(n,2n $\alpha$ )Co60 &Se74(n,2n2 $\alpha$ )Zn65( $\beta^+$ )Cu65(n,2n $\alpha$ )Co60 &Se74(n,2n $\alpha$ )Ge69( $\beta^+$ )Ga69(n,2n2 $\alpha$ )Co60 Other pathways				21.3 16.4 10.5 10.5 6.4 3.3 2.7 2.5 2.1	0.5 0.3 6.3 3.4 2.7 2.6 2.4 2.3 2.2	6.0 6.0 0.1 4.9	0.9 2.8 92.8
Kr85	10.752 y	&Se82(n, $\gamma$ )Se83m( $\beta^-$ )Br83( $\beta^-$ )Kr83(n, $\gamma$ )_ Kr84(n, $\gamma$ )Kr85 &Se80(n, $\gamma$ )Se81( $\beta^-$ )Br81(n, $\gamma$ )Br82m( $\beta^-$ )_ Kr82(n, $\gamma$ )Kr83(n, $\gamma$ )Kr84(n, $\gamma$ )Kr85	50.3 32.4	63.6 9.0	86.9	24.5	25.4	26.1	26.0

Nuclide	T <sub>1/2</sub>	Pathway	210	181	151	42	30	21	6
	◀	&Se80(n,γ)Se81(β <sup>-</sup> )Br81(n,γ)Br82(β <sup>-</sup> ) Kr82(n,γ)Kr83(n,γ)Kr84(n,γ)Kr85 &Se80(n,γ)Se81(β <sup>-</sup> )Br81(n,γ)Br82(n,γ) Br83(β <sup>-</sup> )Kr83(n,γ)Kr84(n,γ)Kr85 &Se82(n,γ)Se83(β <sup>-</sup> )Br83(β <sup>-</sup> )Kr83(n,γ) Kr84(n,γ)Kr85	9.4	2.6					
				15.0					
						75.2	74.0	73.5	73.8
H3	12.33 y	Se74(n,γ)Se75(n,X)H1(n,γ)H2(n,γ)H3 Se77(n,X)H3 &Se80(n,2n)Se79(n,X)H3 &Se78(n,2n)Se77(n,X)H3 Se76(n,2n)Se75(β <sup>+</sup> )As75(n,X)H3 Se76(n,2n)Se75(n,X)H3 Se80(n,X)H3 Se78(n,X)H3 Se76(n,X)H3 Se82(n,X)H3 Se80(n,3n)Se78(n,X)H3	93.0	95.6	99.4				
						57.0	13.8	10.5	8.8
						17.2	3.1	1.3	0.7
						14.9	1.9	0.7	0.3
						3.9	0.8	0.3	0.2
						1.3	0.2		
							41.8	42.0	43.9
							17.3	20.3	21.2
							7.6	8.4	8.3
							5.0	6.5	7.3
							2.0	2.0	0.8
Kr81	2.1 10 <sup>5</sup> y	&Se78(n,γ)Se79m(β <sup>-</sup> )Br79(n,γ)Br80(β <sup>-</sup> ) Kr80(n,γ)Kr81 &Se77(n,γ)Se78(n,γ)Se79m(β <sup>-</sup> )Br79(n,γ) Br80(β <sup>-</sup> )Kr80(n,γ)Kr81 &Se76(n,γ)Se77(n,γ)Se78(n,γ)Se79m(β <sup>-</sup> ) Br79(n,γ)Br80(β <sup>-</sup> )Kr80(n,γ)Kr81 &Se82(n,2n)Se81(β <sup>-</sup> )Br81(n,2n)Br80(β <sup>-</sup> ) Kr80(n,γ)Kr81 &Se82(n,2n)Se81(β <sup>-</sup> )Br81(n,γ)Br82(β <sup>-</sup> ) Kr82(n,2n)Kr81 &Se82(n,γ)Se83(β <sup>-</sup> )Br83(β <sup>-</sup> )Kr83(n,2n) Kr82(n,2n)Kr81 &Se82(n,γ)Se83m(β <sup>-</sup> )Br83(β <sup>-</sup> )Kr83 (n,2n)Kr82(n,2n)Kr81 &Se82(n,γ)Se83(β <sup>-</sup> )Br83(β <sup>-</sup> )Kr83(n,3n)Kr81 &Se82(n,γ)Se83m(β <sup>-</sup> )Br83(β <sup>-</sup> )Kr83(n,3n)Kr81	81.8	75.9	99.3				
			10.8	1.0	0.3				
			7.3						
						42.8	5.0	1.7	1.9
						33.7	4.2	1.0	1.2
						17.1	2.3	0.5	0.6
						5.6	0.8	0.2	0.2
							64.0	69.8	69.2
							21.9	24.7	24.4
Se79	1.1 10 <sup>6</sup> y	&Se78(n,γ)Se79 &Se77(n,γ)Se78(n,γ)Se79 &Se76(n,γ)Se77(n,γ)Se78(n,γ)Se79 &Se80(n,2n)Se79 &Se80(n,d)As79(β <sup>-</sup> )Se79 &Se82(n,4n)Se79 Se82(n,nt)As79(β <sup>-</sup> )Se79m(IT)Se79	71.9	97.6	99.0				
			14.7	2.3	0.9				
			13.1	0.1					
						99.6	86.7	63.0	53.9
							11.2	21.4	26.4
								13.8	14.9
								0.3	3.7

# Selenium activation characteristics

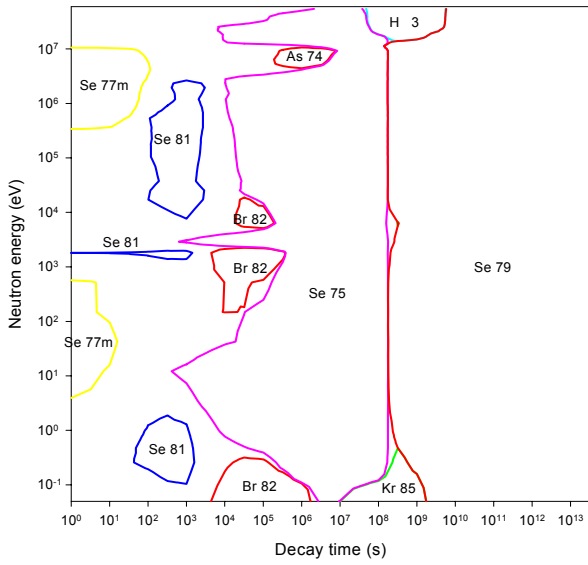


Decay time (years)

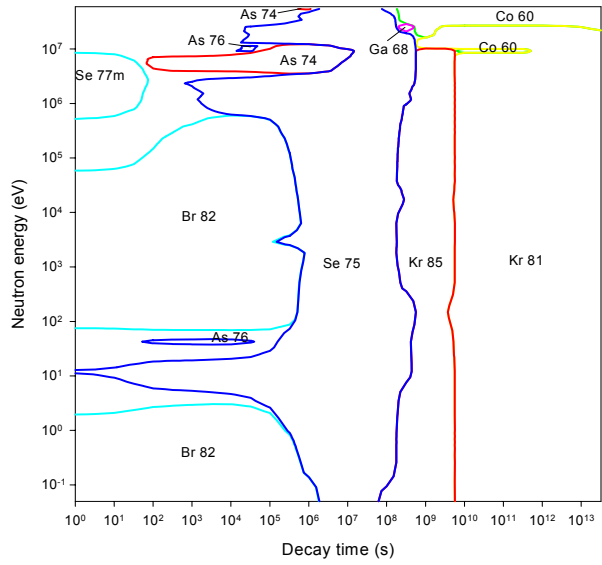
Decay time (years)

# Selenium importance diagrams & transmutation

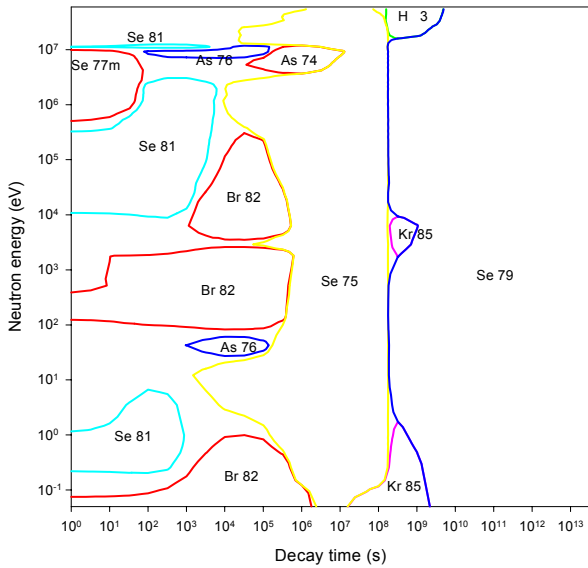
**Activity**



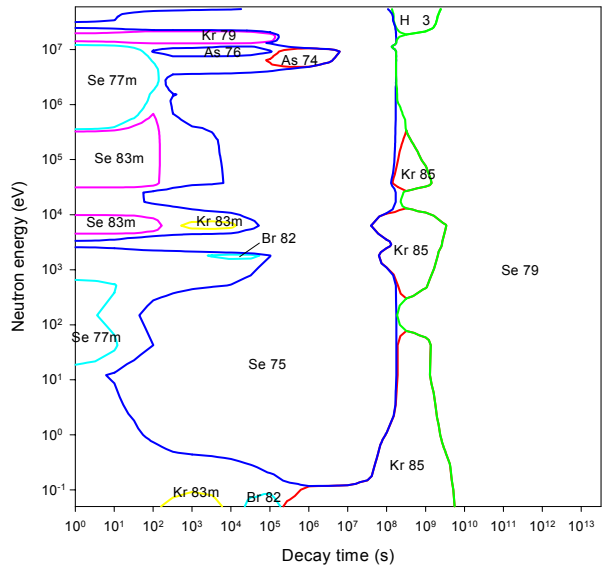
**Dose rate**



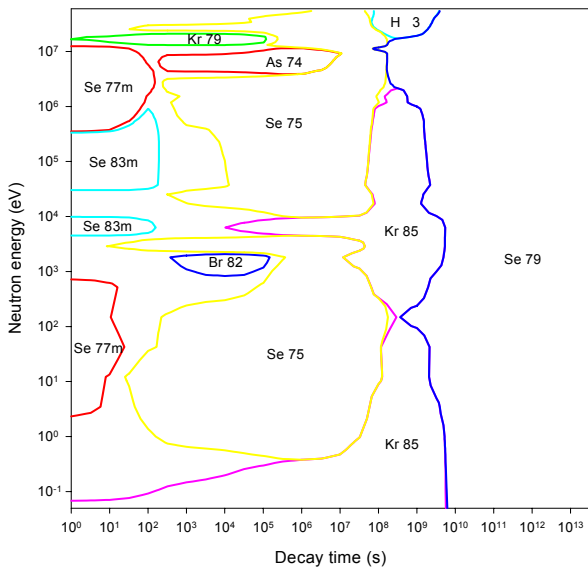
**Heat output**



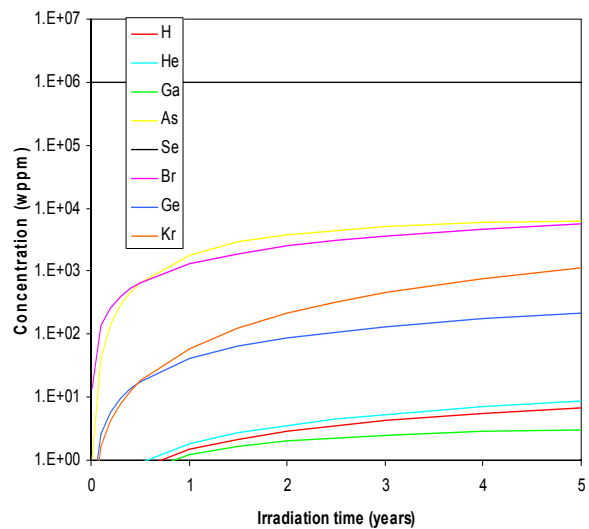
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**



# Bromine

## General properties

Atomic number	35	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	2.4	Br79	50.69
Melting point / K	266.0	Br81	49.31
Boiling point / K	332.0		
Density / kgm <sup>-3</sup>	3120		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	1.22 10 <sup>-1</sup>		
Electrical resistivity /Ωm	-		
Coefficient of thermal expansion / K <sup>-1</sup>	-		
Crystal structure	orthorhombic		
Number of stable isotopes	2		
Mean atomic weight	79.904		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	2.53E16	1.99E16	1.01E15	3.11E11	3.18E10	2.25E10	kW kg <sup>-1</sup>	3.77E0	3.50E0	4.37E-1	9.99E-6	8.06E-8	4.67E-8
Br80	33.76	36.96					Br82	64.39	69.34	99.71			
Br82	21.52	27.40	97.37				Br80	29.10	26.95				
Br82m	20.01	14.01					Br78	1.98	1.21				
Br80m	8.48	10.66					Br82m	1.68	0.99				
Kr83m	7.58	9.35					Kr81m	1.15					
Kr81m	5.65						Br80m	0.78	0.83				
Br79m	0.92						Kr83m	0.34	0.35				
Kr79	0.57	0.72	2.54				Kr85				93.84	16.66	
Kr85			0.02	81.75	1.35		Kr81				10.00	79.01	97.98
Kr81				10.00	98.08	99.53	H3				5.74	0.07	
H3				5.74	0.21		Se75				2.62		
Se75				2.62			Se79				0.03	1.24	2.02
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	3.97E6	3.91E6	6.74E5	4.73E-1	4.58E-3	3.14E-3	Sv kg <sup>-1</sup>	7.37E7	7.09E7	1.11E7	2.81E5	2.41E3	1.39E3
Br82	94.38	95.76	99.81				Kr79	78.53	81.48	92.70			
Br80	3.73	3.25					Kr83m	8.35	8.39				
Br78	1.23	0.71					Br78	4.01	2.37				
Kr81m	0.23						Br82	3.99	4.15	4.78			
Se75				72.67			Br82m	3.30	1.89				
Kr85				25.40*	4.31*		Kr85	0.40	0.41	2.69	99.30	19.64	
Kr81				0.95	95.69	100.0	Br80	0.35	0.32				
Rb84				0.82			Br80m	0.32	0.32				
							Kr81				0.68	80.34	99.98
							Se79					0.01	0.02
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	5.39E7	5.10E7	1.63E7	9.72E6	8.49E4	4.93E4		7.43E12	6.86E12	9.86E11	2.27E7	2.65E5	1.73E5
Kr79	56.35	59.48	32.85				Br82	73.42	79.47	99.30			
Kr85	19.08	20.17	62.96	99.29	19.23		Br80	17.19	16.00				
Br82	6.37	6.73	3.77				Br78	3.47	2.14				
Kr83m	5.70	5.83					Kr81m	2.64					
Br80m	0.30	0.31					Br85				62.07	9.00	
Br80	0.14	0.13					Se75				35.99		
Kr81	0.12	0.13	0.41	0.70	80.77	100.0	Kr81				1.05	90.50	99.66

# Bromine

## Pathway analysis

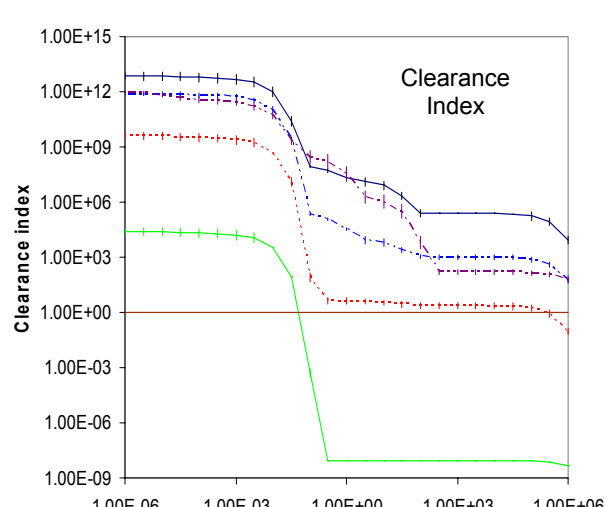
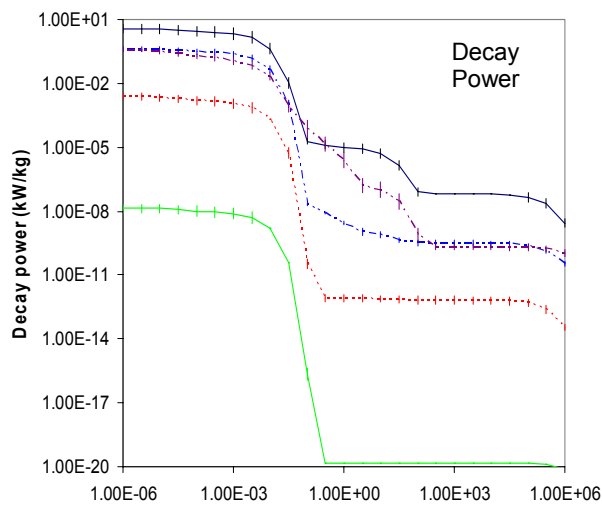
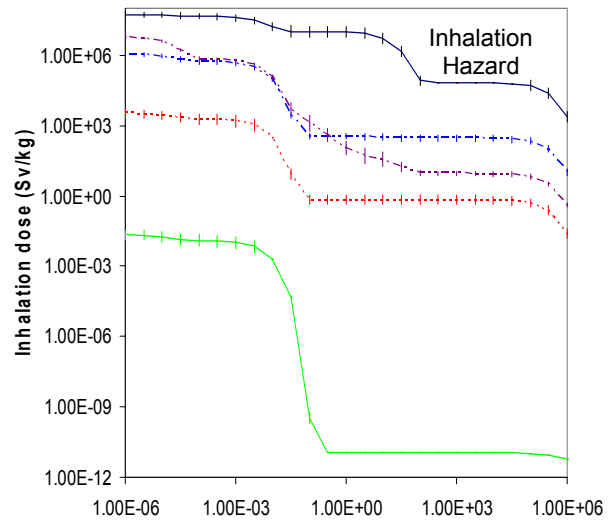
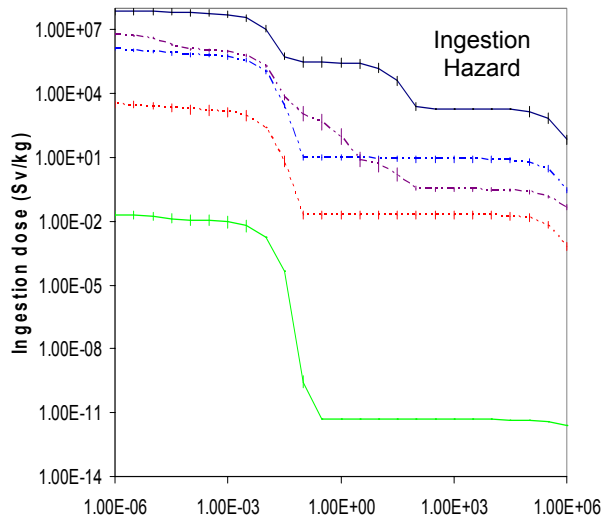
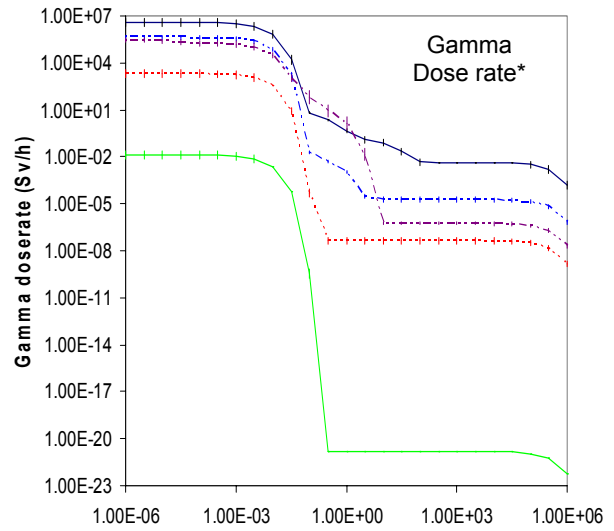
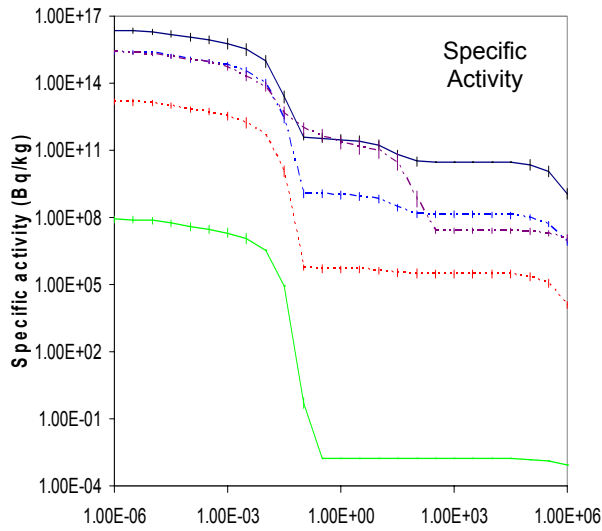
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Br79m	4.864 s	Br79(n,n')Br79m &Br81(n,2n)Br80(β <sup>-</sup> )Kr80(n,d)Br79m Br81(n,3n)Br79m				97.5 1.3	17.8 2.8 77.2	12.9 1.0 84.5	20.7 77.0
Br78	6.46 m	Br79(n,2n)Br78 &Br81(n,2n)Br80(β <sup>-</sup> )Kr80(n,2n)Kr79_ (β <sup>+</sup> )Br79(n,2n)Br78 &Br81(n,3n)Br79(n,2n)Br78 Br81(n,4n)Br78				98.8 1.0	90.8 1.9 8.4	70.4 6.5 20.2	41.6 0.9 55.9
Br80	17.6 m	&Br79(n,γ)Br80 &Br81(n,2n)Br80	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Ga68	1.128 h	&Br79(n,α)As76(β <sup>-</sup> )Se76(n,α)Ge73_ (n,nα)Zn69(β <sup>-</sup> )Ga69(n,2n)Ga68 &Br79(n,α)As76(β <sup>-</sup> )Se76(n,nα)Ge72_ (n,α)Zn69(β <sup>-</sup> )Ga69(n,2n)Ga68 &Br79(n,nα)As75(n,α)Ga72(β <sup>-</sup> )Ge72_ (n,α)Zn69(β <sup>-</sup> )Ga69(n,2n)Ga68 Br79(n,nα)As75(n,2n)As74(β <sup>-</sup> )Se74(n,nα)_ Ge70(n,2n)Ge69(β <sup>+</sup> )Ga69(n,2n)Ga68 &Br79(n,α)As76(β <sup>-</sup> )Se76(n,α)Ge73_ (n,2n)Ge72(n,α)Zn69(β <sup>-</sup> )Ga69(n,2n)Ga68 Br79(n,nα)As75(n,nα)Ga71(n,3n)Ga69_ (n,2n)Ga68 Br79(n,nα)As75(n,3n)As73(n,2nα)Ga68 Br79(n,nα)As75(n,2nα)Ga70(β <sup>-</sup> )Ge70_ (n,t)Ga68 Br79(n,2nα)As74(β <sup>+</sup> )Ge74(n,4n)Ge71_ (β <sup>+</sup> )Ga71(n,4n)Ga68 Br79(n,nt)Se76(n,2nα)Ge71(β <sup>+</sup> )Ga71_ (n,4n)Ga68 Br79(n,2nt)Se75(β <sup>+</sup> )As75(n,4nα)Ga68 Other pathways				15.7 9.6 6.4 5.8 4.6 7.8 4.9 1.9 5.4 5.3 3.9 57.9	85.4 7.8 4.9 1.9 5.4 5.3 3.9 85.4	83.4 1.5 4.4 5.4 5.3 3.9 83.4	93.8 0.9 1.4 3.9 93.8
Kr83m	1.83 h	&Br81(n,γ)Br82(β <sup>-</sup> )Kr82(n,γ)Kr83m &Br79(n,γ)Br80(β <sup>-</sup> )Kr80(n,γ)Kr81(n,γ)_ Kr82(n,γ)Kr83m Br81(n,γ)Br82m(β <sup>-</sup> )Kr82(n,γ)Kr83m &Br81(n,γ)Br82(β <sup>-</sup> )Kr82(n,γ)Kr83(n,n')Kr83m	74.1 24.0 1.7	97.7 2.2	97.0 2.2	94.5 1.1 2.3	95.7 1.1 1.3	96.4 1.1 1.1	97.0 1.1 0.7
Br80m	4.41 h	Br79(n,γ)Br80m Br81(n,2n)Br80m	100.0	100.0	100.0	98.6	98.9	99.2	99.6
Br76	16.2 h	&Br81(n,2n)Br80(β <sup>-</sup> )Kr80(n,2n)Kr79_ (n,2n)Kr78(n,d)Br77(n,2n)Br76 &Br81(n,2n)Br80(β <sup>-</sup> )Kr80(n,2n)Kr79_ (n,2n)Kr78(n,2n)Kr77(β <sup>+</sup> )Br77(n,2n)Br76 &Br81(n,2n)Br80(β <sup>-</sup> )Kr80(n,3n)Kr78(n,t)Br76 &Br81(n,2n)Br80(β <sup>-</sup> )Kr80(n,3n)Kr78_ (n,3n)Kr76(β <sup>+</sup> )Br76 &Br79(n,3n)Br77(n,2n)Br76 &Br81(n,3n)Br79(n,3n)Br77(n,2n)Br76 &Br79(n,4n)Br76 &Br81(n,3n)Br79(n,4n)Br76				23.2 10.5	44.6 23.4 22.3 1.3	1.5 0.2 90.7 7.6	97.7 1.3
As76	1.093 d	Br79(n,α)As76 &Br79(n,2n)Br78(β <sup>+</sup> )Se78(n,2n)Se77(n,d)As76 &Br79(n,3n)Br77(β <sup>+</sup> )Se77(n,d)As76 &Br79(n,t)Se77(n,d)As76 Br79(n,2n)Br78(β <sup>+</sup> )Se78(n,t)As76 Br79(n,d)Se78(n,t)As76 Br81(n,2nα)As76				96.3 1.2	30.4 2.4 45.8 5.5 3.4 1.0 0.7	9.1 0.2 20.6 6.5 9.2 4.6 39.6	25.0 5.7 3.4 5.9 3.5 32.4

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	Br81(n,4n)Br78(β <sup>+</sup> )Se78(n,t)As76 Br81(n,nt)Se78(n,t)As76 &Br81(n,5n)Br77(β <sup>+</sup> )Se77(n,d)As76						2.6 0.9	8.0 3.9 3.1
Kr79	1.460 d	&Br81(n,2n)Br80(β <sup>-</sup> )Kr80(n,2n)Kr79				96.0	93.9	93.9	93.6
Br82	1.472 d	&Br81(n,γ)Br82	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Br77	2.377 d	&Br81(n,2n)Br80(β <sup>-</sup> )Kr80(n,2n)Kr79_ (n,2n)Kr78(n,d)Br77 &Br81(n,2n)Br80(β <sup>-</sup> )Kr80(n,2n)Kr79_ (n,2n)Kr78(n,2n)Kr77(β <sup>+</sup> )Br77 &Br79(n,3n)Br77 &Br81(n,3n)Br79(n,3n)Br77 &Br81(n,5n)Br77				52.3 31.9		92.2 7.8	92.3 7.7 62.5 33.8
As74	17.78 d	Br79(n,α)As75(n,2n)As74 Br79(n,α)As76(β <sup>-</sup> )Se76(n,2n)Se75(β <sup>+</sup> )_ As75(n,2n)As74 &Br79(n,2n)Br78(β <sup>+</sup> )Se78(n,α)Ge75(β <sup>-</sup> )_ As75(n,2n)As74 &Br79(n,2n)Br78(β <sup>+</sup> )Se78(n,2n)Se77_ (n,2n)Se76(n,2n)Se75(β <sup>+</sup> )As75(n,2n)As74 &Br79(n,3n)Br77(β <sup>+</sup> )Se77(n,3n)Se75_ (β <sup>+</sup> )As75(n,2n)As74 Br79(n,2nα)As74 &Br81(n,3n)Br79(n,2nα)As74 &Br79(n,3n)Br77(β <sup>+</sup> )Se77(n,nt)As74 Br79(n,nt)Se76(n,t)As74 &Br79(n,4n)Br76(β <sup>+</sup> )Se76(n,t)As74 &Br79(n,t)Se77(n,nt)As74 &Br81(n,5n)Br77(β <sup>+</sup> )Se77(n,nt)As74 Br79(n,2nt)Se75(β <sup>+</sup> )As75(n,2n)As74 Br81(n,4nα)As74				45.5 28.9 16.7 4.3	47.7 0.4 0.2 19.4 9.9 0.9 0.8	2.1 0.3 71.1 4.4 2.9 5.5 1.2 1.0	0.9 41.2 1.4 8.6 8.8 6.6 5.2 4.7 3.3 3.2
Rb86	18.64 d	&Br81(n,γ)Br82(β <sup>-</sup> )Kr82(n,γ)Kr83(n,γ)_ Kr84(n,γ)Kr85m(β <sup>-</sup> )Rb85(n,γ)Rb86 &Br79(n,γ)Br80(β <sup>-</sup> )Kr80(n,γ)Kr81(n,γ)_ Kr82(n,γ)Kr83(n,γ)Kr84(n,γ)Kr85m(β <sup>-</sup> )_ Rb85(n,γ)Rb86 &Br81(n,γ)Br82(β <sup>-</sup> )Kr82(n,γ)Kr83(n,γ)_ Kr84(n,γ)Kr85(β <sup>-</sup> )Rb85(n,γ)Rb86 &Br81(n,γ)Br82m(β <sup>-</sup> )Kr82(n,γ)Kr83(n,γ)_ Kr84(n,γ)Kr85m(β <sup>-</sup> )Rb85(n,γ)Rb86 &Br81(n,γ)Br82(n,γ)Br83(β <sup>-</sup> )Kr83(n,γ)_ Kr84(n,γ)Kr85m(β <sup>-</sup> )Rb85(n,γ)Rb86 &Br81(n,γ)Br82(n,γ)Br83(β <sup>-</sup> )Kr83(n,γ)_ Kr84(n,γ)Kr85(β <sup>-</sup> )Rb85(n,γ)Rb86	86.7 6.9 3.0 1.9 0.3	47.4 1.5 0.9 47.2 2.1	92.6 2.5 2.0 2.1	79.5 19.2 1.2 0.1			
Se75	119.64 d	Br79(n,α)As76(β <sup>-</sup> )Se76(n,2n)Se75 &Br79(n,2n)Br78(β <sup>+</sup> )Se78(n,2n)Se77_ (n,2n)Se76(n,2n)Se75 &Br79(n,3n)Br77(β <sup>+</sup> )Se77(n,3n)Se75 &Br79(n,t)Se77(n,3n)Se75 Br79(n,2n)Br78(β <sup>+</sup> )Se78(n,3n)Se76(n,2n)Se75   &Br79(n,3n)Br77(β <sup>+</sup> )Se77(n,2n)Se76_ (n,2n)Se75 Br79(n,nt)Se76(n,2n)Se75 Br79(n,2n)Br78(β <sup>+</sup> )Se78(n,4n)Se75 &Br79(n,4n)Br76(β <sup>+</sup> )Se76(n,2n)Se75 Br79(n,2nt)Se75 Br79(n,5n)Br75(β <sup>+</sup> )Se75				73.5 22.2	1.2 65.2 7.8 5.1 4.1 0.5	0.3 51.0 16.0 1.0 0.9 6.8 4.2 1.5 0.4	0.2 3.5 2.0 4.9 4.6 3.7 47.2 13.6
Co60	5.271 y ▶	Br79(n,α)As75(n,2n)As74(β <sup>-</sup> )Se74_ (n,α)Ge70(n,α)Zn66(n,α)Ni62(n,2n)_ Ni61(n,d)Co60				2.9			

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Br79(n,nα)As75(n,2n)As74(β <sup>-</sup> )Se74_ (n,nα)Ge70(n,nα)Zn66(n,2n)Zn65(n,nα)_ Ni61(n,d)Co60 Br79(n,nα)As75(n,2n)As74(β <sup>-</sup> )Se74(n,nα)_ Ge70(n,nα)Zn66(n,α)Ni63(β <sup>-</sup> )Cu63(n,α)Co60 &Br79(n,nα)As75(n,nα)Ga71(n,3n)Ga69_ (n,nα)Cu65(n,2nα)Co60 &Br79(n,nα)As75(n,3n)As73(n,nα)Ga69_ (n,nα)Cu65(n,2nα)Co60 Br79(n,nα)As75(n,2nα)Ga70(β <sup>-</sup> )Ge70_ (n,2nα)Zn65(β <sup>+</sup> )Cu65(n,2nα)Co60 Br79(n,2nα)As74(β <sup>-</sup> )Se74(n,nα)Ge70_ (n,2nα)Zn65(β <sup>+</sup> )Cu65(n,2nα)Co60 &Br79(n,nt)Se76(n,2nα)Ge71(β <sup>+</sup> )Ga71_ (n,3nα)Cu65(n,2nα)Co60 Br79(n,2nα)As74(β <sup>-</sup> )Se74(n,2nα)Ge69_ (β <sup>+</sup> )Ga69(n,nα)Cu65(n,2nα)Co60 &Br79(n,3nα)As73(β <sup>+</sup> )Ge73(n,4nα)_ Zn66(n,tα)Co60 &Br79(n,2nt)Se75(β <sup>+</sup> )As75(n,3nα)Ga69_ (n,2n2α)Co60 &Br79(n,3nα)As73(β <sup>+</sup> )Ge73(n,2nt)Ga69_ (n,2n2α)Co60 Br79(n,3nα)As73(β <sup>+</sup> )Ge73(n,5n)Ge69_ (β <sup>+</sup> )Ga69(n,2n2α)Co60 &Br81(n,3nα)As75(n,3nα)Ga69(n,2n2α)Co60 Other pathways				2.6 2.6 4.5 2.3 1.2 0.3 1.7 1.6 5.9 3.1 2.7 1.7 1.5				
Kr85	10.752 y	&Br81(n,γ)Br82(β <sup>-</sup> )Kr82(n,γ)Kr83(n,γ)_ Kr84(n,γ)Kr85 &Br79(n,γ)Br80(β <sup>-</sup> )Kr80(n,γ)Kr81(n,γ)_ Kr82(n,γ)Kr83(n,γ)Kr84(n,γ)Kr85 &Br81(n,γ)Br82m(β <sup>-</sup> )Kr82(n,γ)Kr83(n,γ)_ Kr84(n,γ)Kr85 &Br81(n,γ)Br82(n,γ)Br83(β <sup>-</sup> )Kr83(n,γ)_ Kr84(n,γ)Kr85	89.7 7.8 2.0 0.3	50.5 1.2 48.3	95.6 2.1	98.1 1.1 0.4	98.2 1.1 0.4	98.1 1.0 0.4	97.5 0.8	
H3	12.33 y	&Br79(n,γ)Br80(β <sup>-</sup> )Kr80(n,γ)Kr81(n,X)_ H1(n,γ)H2(n,γ)H3 Br79(n,X)H1(n,γ)H2(n,γ)H3 Br79(n,X)H3 Br81(n,X)H3 &Br81(n,3n)Br79(n,X)H3	91.0 4.2	85.0 11.8	45.9 53.6	71.4 27.7	50.1 42.0 2.4	48.3 43.2 2.2	47.6 44.6 0.5	
Kr81	2.1 10 <sup>5</sup> y	&Br79(n,γ)Br80(β <sup>-</sup> )Kr80(n,γ)Kr81 &Br81(n,2n)Br80(β <sup>-</sup> )Kr80(n,γ)Kr81 &Br81(n,γ)Br82(β <sup>-</sup> )Kr82(n,2n)Kr81 &Br81(n,γ)Br82m(β <sup>-</sup> )Kr82(n,2n)Kr81	100.0	100.0	100.0	55.6 43.7 0.5	53.5 45.7 0.4	57.0 42.4 0.4	57.3 42.1	
Se79	1.1 10 <sup>6</sup> y	&Br79(n,γ)Br80(β <sup>-</sup> )Kr80(n,γ)Kr81(n,α)_ Se78(n,γ)Se79 &Br79(n,p)Se79 &Br81(n,2n)Br80(β <sup>+</sup> )Se80(n,2n)Se79 &Br81(n,d)Se80(n,2n)Se79 &Br81(n,t)Se79 &Br81(n,3n)Br79(n,p)Se79 Br81(n,h)As79(β <sup>-</sup> )Se79m(IT)Se79	93.6 6.4	20.1 79.8	0.2 96.0	77.1 19.1 2.7 0.2	48.8 3.1 6.0 37.6 2.3 0.3	17.5 0.4 1.9 77.1 0.7 1.2	9.3 0.9 86.9 1.6	



# Bromine activation characteristics

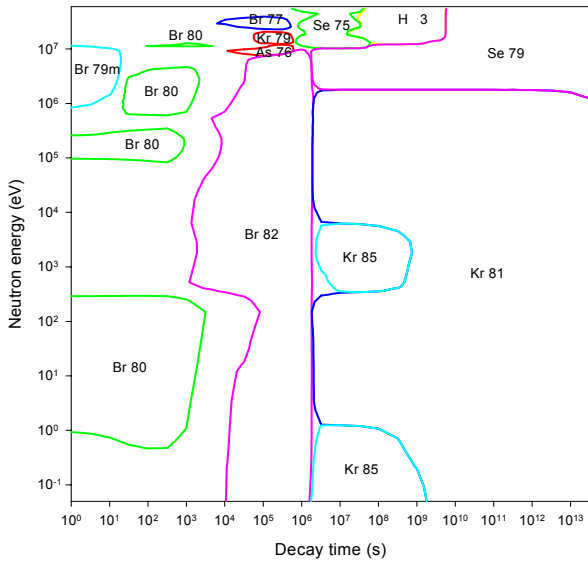


Decay time (years)

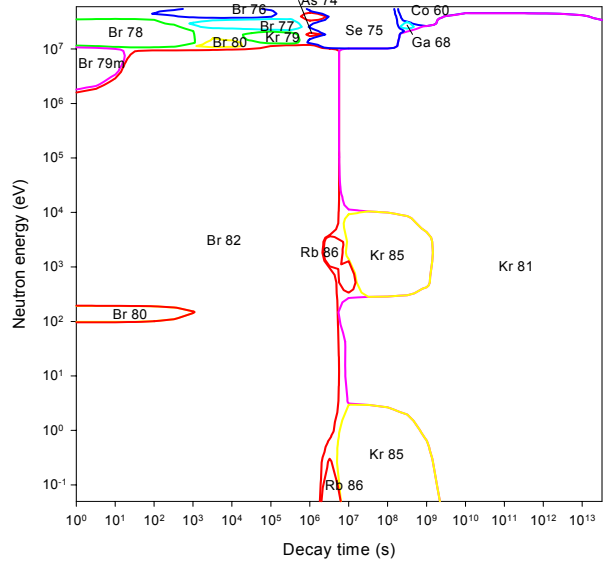
Decay time (years)

# Bromine importance diagrams & transmutation

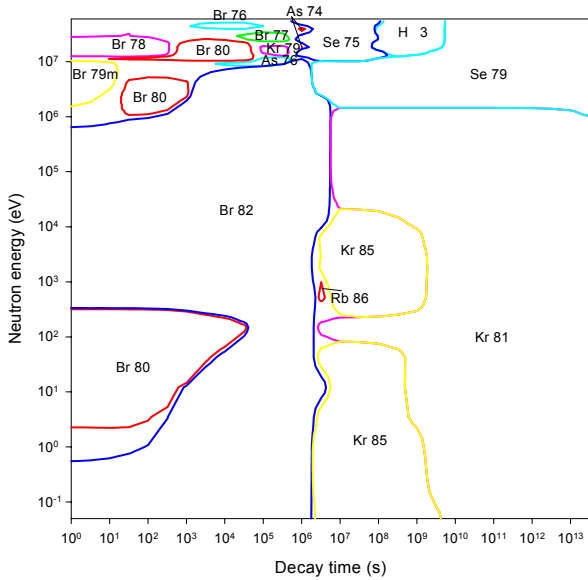
Activity



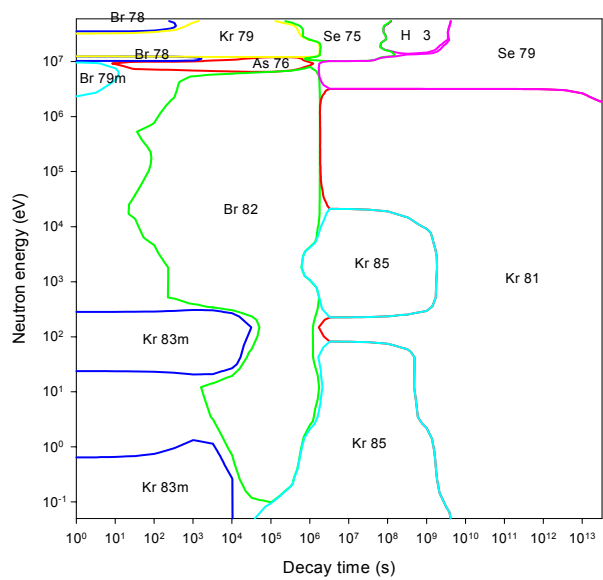
Dose rate



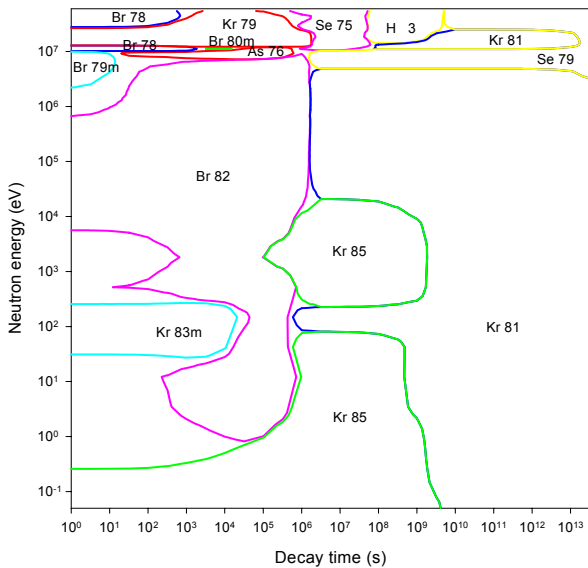
Heat output



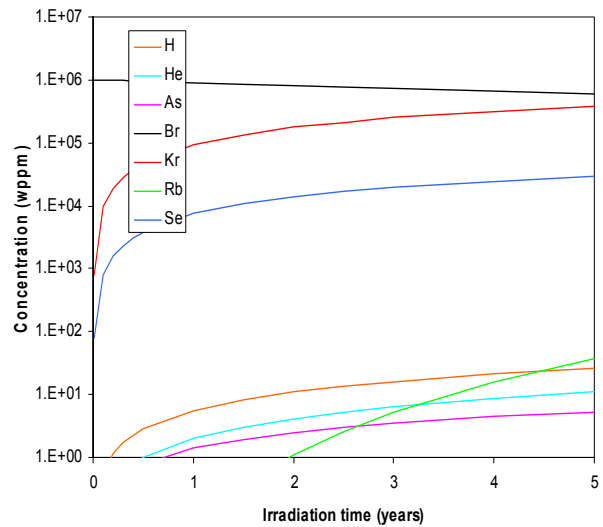
Ingestion dose



Inhalation dose



First wall transmutation



# Krypton

## General properties

Atomic number	36	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	1.0 10 <sup>-5</sup>	Kr78	0.35 (T <sub>1/2</sub> = 1.10 10 <sup>20</sup> y)
Melting point / K	116.6	Kr80	2.25
Boiling point / K	120.8	Kr82	11.60
Density / kgm <sup>-3</sup>	3.749	Kr83	11.50
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	9.49 10 <sup>-3</sup>	Kr84	57.00
Electrical resistivity /Ωm	-	Kr86	17.30
Coefficient of thermal expansion / K <sup>-1</sup>	-		
Crystal structure	FCC		
Number of stable isotopes	5 (6)		
Mean atomic weight	83.80		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	2.52E15	2.32E15	1.79E14	1.22E14	2.12E11	4.19E9	kW kg <sup>-1</sup>	8.82E-2	7.98E-2	1.09E-2	4.51E-3	7.63E-6	8.58E-9
Kr83m	53.67	56.50					Kr85m	56.82	61.89				
Kr85m	30.11	32.33					Kr83m	10.30	11.00				
Kr85	5.16	5.61	72.81	99.97	97.25		Kr85	5.45	6.02	44.11	99.94	99.84	
Kr81m	5.10						Rb86	4.54	5.01	32.09			
Rb86	1.32	1.43	16.27				Kr81m	4.46					
Kr79	1.24	1.35	3.10				Br84	3.02	2.98				
Br80	0.73	0.68					Br80	2.69	2.55				
Rb84	0.51	0.56	6.79				Rb84	2.45	2.70	18.42	0.02		
Rb84m	0.24	0.21					Br84m	2.21	1.33				
Br80m	0.18	0.19					Br82	1.64	1.80	2.38			
Br82	0.12	0.13	0.32				Kr79	1.61	1.77	2.30			
Br77	0.09	0.10	0.47				Br86	1.11					
Br83	0.08	0.09					Kr87	0.87	0.91				
Kr81					2.74	99.94	Kr81					0.15	99.74
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	2.75E4	2.30E4	4.40E3	6.63E1	1.08E-1	5.74E-4	Sv kg <sup>-1</sup>	2.06E8	2.05E8	1.45E8	1.34E8	2.27E5	2.60E2
Kr85m	34.04	40.11					Kr85	69.44	69.73	98.40	100.0	99.84	
Br84	11.31	12.05					Kr85m	22.09	21.89				
Br84m	9.70	6.31					Kr79	6.09	6.10	1.52			
Br82	8.23	9.82	9.25				Kr83m	2.10	2.04				
Kr79	5.62	6.70	6.22				Kr87	0.12	0.11				
Br86	4.49	0.10					Rb86	0.04	0.04	0.05			
Rb86	3.36	4.02	18.43				Rb84	0.01	0.01	0.02			
Kr81m	2.90						Sr85					0.15	100.0
Kr87	1.92	2.19											
Rb84	1.80	12.90	62.80	2.61									
Rb86m	1.69	0.05											
Rb84m	1.28	1.28											
Br80	1.18	1.21											
Br78	0.77	0.52											
Kr85	0.21	0.26*	1.37*	95.38*	99.17*								
Se75			0.09	0.89									
Kr81					0.82	100.0							

<b>Inh</b>	<b>0</b>	<b>10<sup>-5</sup> y</b>	<b>10<sup>-2</sup> y</b>	<b>1 y</b>	<b>100 y</b>	<b>10<sup>5</sup> y</b>	<b>Clear</b>	<b>0</b>	<b>10<sup>-5</sup> y</b>	<b>10<sup>-2</sup> y</b>	<b>1 y</b>	<b>100 y</b>	<b>10<sup>5</sup> y</b>
Sv kg <sup>-1</sup>	4.98E9	4.98E9	4.95E9	4.64E9	7.86E6	9.21E3		2.34E11	2.01E11	2.12E10	6.81E9	1.15E7	3.22E4
Kr85	96.36	99.37	99.98	100.0	99.84		Kr85m	58.96	67.94				
Kr85m	0.45	0.45					Kr81m	7.53					
Kr79	0.13	0.13	0.02				Rb84	5.07	5.93	51.92	0.09		
Rb86					0.16	100.0	Br84	4.47	4.66				
							Br84m	4.04	2.57				
							Kr83m	3.85	4.35				
							Kr79	3.52	4.11	6.86			
							Kr85	3.08	3.60	34.03	99.63	99.61	
							Br86	1.74					
							Br82	1.38	1.61	2.73			
							Br80	1.17	1.18				
							Rb84m	0.99	0.97				
							Rb86m	0.97					
							Br77	0.33	0.38	1.27			
							Rb86	0.14	0.16	1.36			
							Kr81					0.38	99.96

# Krypton

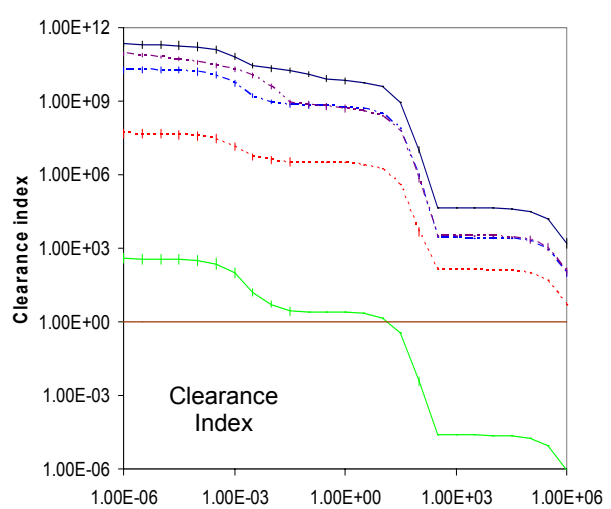
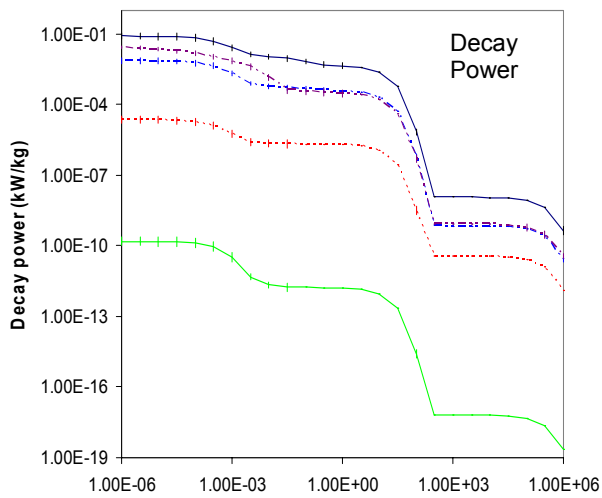
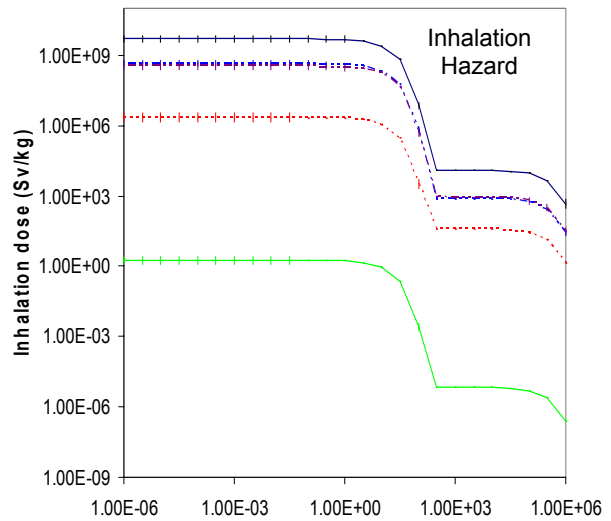
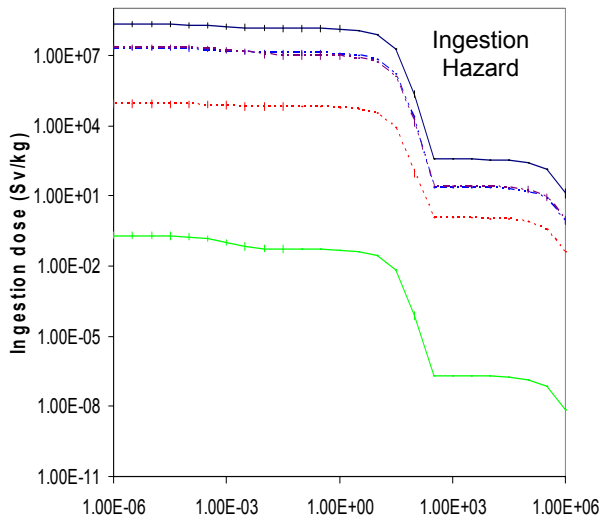
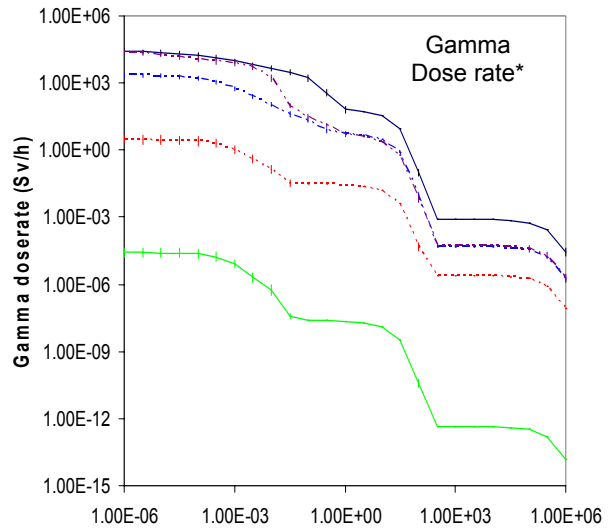
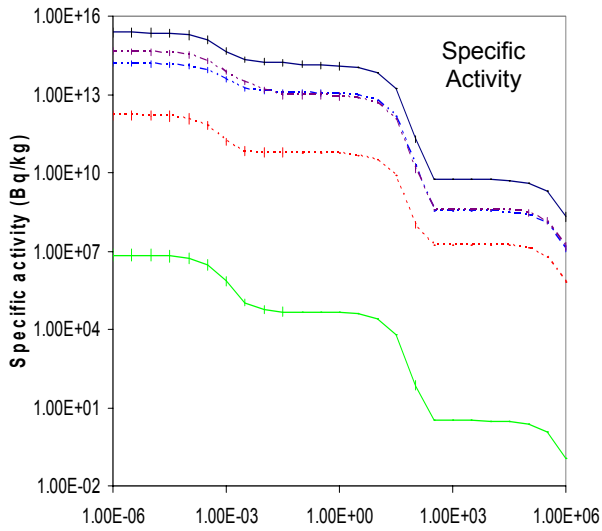
## Pathway analysis

Nuclide	$T_{1/2}$	Pathway	210	186	151	42	30	21	6	
Br78	6.46 m	&Kr80(n,2n)Kr79( $\beta^+$ )Br79(n,2n)Br78				82.9	35.2	2.0	0.5	
		Kr78(n,p)Br78				9.5	3.3	0.6	0.2	
		&Kr80(n,d)Br79(n,2n)Br78				4.6	13.1	1.2	0.4	
		Kr80(n,t)Br78					11.6	42.8	15.5	
		&Kr82(n,3n)Kr80(n,2n)Kr79( $\beta^+$ )Br79_					6.2	0.5		
		(n,2n)Br78								
		Kr82(n,3n)Kr80(n,t)Br78						4.0	20.1	2.6
		Kr84(n,3n)Kr82(n,3n)Kr80(n,t)Br78						0.9	5.1	0.2
		Kr84(n,4n)Kr81(n,nt)Br78							0.9	19.5
		Kr84(n,nt)Br81(n,4n)Br78							0.4	9.9
		Kr82(n,2nt)Br78								8.5
		Kr84(n,5n)Kr80(n,t)Br78								7.3
Kr87	1.272 h	Kr86(n, $\gamma$ )Kr87	100.0	100.0	100.0	99.7	99.0	99.1	99.5	
Kr83m	1.83 h	Kr82(n, $\gamma$ )Kr83m	92.9	99.4	100.0					
		&Kr80(n, $\gamma$ )Kr81(n, $\gamma$ )Kr82(n, $\gamma$ )Kr83m	7.1	0.6						
		Kr84(n,2n)Kr83m				84.4	39.2	20.6	13.7	
		Kr83(n,n')Kr83m				6.4	6.4	5.3	3.9	
		Kr84(n,2n)Kr83(n,n')Kr83m				4.7	2.6	1.0		
		Kr83(n,p)Br83( $\beta^-$ )Kr83m				1.0	2.0	1.5		
		Kr84(n,d)Br83( $\beta^-$ )Kr83m				0.3	42.2	59.3	58.6	
		Kr86(n,4n)Kr83m						5.5	6.1	
		Kr86(n,nt)Br83( $\beta^-$ )Kr83m						1.2	14.2	
Kr85m	4.48 h	Kr84(n, $\gamma$ )Kr85m	75.2	99.9	99.3	0.2	0.2			
		Kr83(n, $\gamma$ )Kr84(n, $\gamma$ )Kr85m	15.2		0.7					
		&Kr82(n, $\gamma$ )Kr83(n, $\gamma$ )Kr84(n, $\gamma$ )Kr85m	9.6							
		Kr86(n,2n)Kr85m				97.0	62.5	38.3	29.6	
		Kr86(n,2n)Kr85(n,n')Kr85m				1.8	1.3	0.5		
		Kr86(n,2n)Kr85(n,p)Br85( $\beta^-$ )Kr85m				0.5	1.0			
		Kr86(n,d)Br85( $\beta^-$ )Kr85m					35.9	61.5	71.1	
Kr79	1.460 d	&Kr78(n, $\gamma$ )Kr79	100.0	100.0	100.0					
		&Kr80(n,2n)Kr79				91.9	44.2	21.6	6.5	
		&Kr82(n,2n)Kr81(n,2n)Kr80(n,2n)Kr79				5.3	0.9			
		&Kr82(n,3n)Kr80(n,2n)Kr79					14.3	9.4	1.0	
		&Kr82(n,2n)Kr81(n,3n)Kr79					12.9	7.7	0.8	
		&Kr83(n,3n)Kr81(n,3n)Kr79					9.8	12.4	0.8	
		&Kr84(n,4n)Kr81(n,3n)Kr79						13.0	6.8	
		&Kr82(n,4n)Kr79						10.8	44.0	
		&Kr84(n,3n)Kr82(n,4n)Kr79						4.9	6.6	
		&Kr83(n,5n)Kr79							14.4	
Br82	1.472 d	&Kr78(n, $\gamma$ )Kr79( $\beta^+$ )Br79(n, $\gamma$ )Br80( $\beta^+$ )_	34.9	0.2	4.6					
		Se80(n, $\gamma$ )Se81( $\beta^-$ )Br81(n, $\gamma$ )Br82								
		&Kr80(n, $\gamma$ )Kr81m( $\beta^+$ )Br81(n, $\gamma$ )Br82	28.3	55.4	50.6					
		&Kr80(n, $\gamma$ )Kr81( $\beta^+$ )Br81(n, $\gamma$ )Br82	19.0	42.2	42.3					
		&Kr82(n,p)Br82				65.2	15.9	5.1	1.5	
		&Kr83(n,2n)Kr82(n,p)Br82				11.5	1.3			
		&Kr83(n,d)Br82				8.6	41.6	20.2	14.2	
		&Kr84(n,2n)Kr83(n,d)Br82				7.7	18.2	3.7	1.2	
		&Kr84(n,2n)Kr83(n,2n)Kr82(n,p)Br82				5.3	0.2			
		&Kr84(n,t)Br82					11.5	63.0	64.4	
		Kr84(n,3n)Kr82(n,p)Br82					7.1	2.4		
		Kr86(n,2nt)Br82							3.8	
		Rb86	18.64 d	&Kr84(n, $\gamma$ )Kr85m( $\beta^-$ )Rb85(n, $\gamma$ )Rb86	78.4	96.2	95.8			
&Kr83(n, $\gamma$ )Kr84(n, $\gamma$ )Kr85m( $\beta^-$ )Rb85_	13.5				0.3					
(n, $\gamma$ )Rb86										
&Kr82(n, $\gamma$ )Kr83(n, $\gamma$ )Kr84(n, $\gamma$ )Kr85m_	4.5									
( $\beta^-$ )Rb85(n, $\gamma$ )Rb86										
▶ &Kr84(n, $\gamma$ )Kr85( $\beta^-$ )Rb85(n, $\gamma$ )Rb86	3.0	3.8	3.8							

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&Kr83(n,γ)Kr84(n,γ)Kr85(β <sup>-</sup> )Rb85(n,γ)Rb86 &Kr86(n,γ)Kr87(β <sup>-</sup> )Rb87(n,2n)Rb86 &Kr86(n,2n)Kr85m(β <sup>-</sup> )Rb85(n,γ)Rb86 &Kr86(n,2n)Kr85(β <sup>-</sup> )Rb85(n,γ)Rb86 &Kr86(n,d)Br85(β <sup>-</sup> )Kr85m(β <sup>-</sup> )Rb85(n,γ)Rb86	0.8			78.6 12.7 8.2	82.8 6.4 6.6	71.8 7.8 7.3	58.3 9.5 8.7
Rb84	33.5 d	&Kr86(n,2n)Kr85m(β <sup>-</sup> )Rb85(n,2n)Rb84 &Kr86(n,2n)Kr85(β <sup>-</sup> )Rb85(n,2n)Rb84 &Kr86(n,2n)Kr85(n,n')Kr85m(β <sup>-</sup> )Rb85_ (n,2n)Rb84 &Kr86(n,d)Br85(β <sup>-</sup> )Kr85m(β <sup>-</sup> )Rb85_ (n,2n)Rb84 &Kr86(n,d)Br85(β <sup>-</sup> )Kr85m(IT)Kr85(β <sup>-</sup> )_ Rb85(n,2n)Rb84 &Kr86(n,2n)Kr85(n,p)Br85(β <sup>-</sup> )Kr85m_ (β <sup>-</sup> )Rb85(n,2n)Rb84				60.7 38.2 0.6	38.3 38.7 0.4	28.1 25.4 0.1	23.1 20.2 54.0 1.0
Rb83	86.2 d	&Kr86(n,2n)Kr85m(β <sup>-</sup> )Rb85(n,2n)Rb84_ (n,2n)Rb83 &Kr86(n,2n)Kr85(β <sup>-</sup> )Rb85(n,2n)Rb84_ (n,2n)Rb83 &Kr86(n,2n)Kr85m(β <sup>-</sup> )Rb85(n,2n)Rb84_ (β <sup>-</sup> )Sr84(n,2n)Sr83(β <sup>+</sup> )Rb83 &Kr86(n,2n)Kr85(β <sup>-</sup> )Rb85(n,2n)Rb84_ (β <sup>-</sup> )Sr84(n,2n)Sr83(β <sup>+</sup> )Rb83 Kr86(n,2n)Kr85m(β <sup>-</sup> )Rb85(n,3n)Rb83 &Kr86(n,2n)Kr85(β <sup>-</sup> )Rb85(n,3n)Rb83 Kr86(n,d)Br85(β <sup>-</sup> )Kr85m(β <sup>-</sup> )Rb85(n,3n)Rb83				46.1 19.1 15.9 6.2			38.7 37.7 21.1 28.3 24.8 44.3 23.2 19.7 54.4
Se75	119.64 d	Kr78(n,α)Se75 &Kr78(n,d)Br77(β <sup>+</sup> )Se77(n,2n)Se76(n,2n)Se75 Kr78(n,2n)Kr77(β <sup>+</sup> )Br77(β <sup>+</sup> )Se77(n,2n)_ Se76(n,2n)Se75 Kr80(n,nα)Se76(n,2n)Se75 &Kr78(n,d)Br77(β <sup>+</sup> )Se77(n,3n)Se75 Kr78(n,2n)Kr77(β <sup>+</sup> )Br77(β <sup>+</sup> )Se77(n,3n)Se75 Kr78(n,h)Se76(n,2n)Se75 Kr80(n,2nα)Se75 Kr82(n,3n)Kr80(n,2nα)Se75 &Kr82(n,2nα)Se77(n,3n)Se75 Kr78(n,nt)Br75(β <sup>+</sup> )Se75 Kr84(n,4n)Kr81(n,3nα)Se75 Kr84(n,3nα)Se78(n,4n)Se75	100.0	100.0	99.8	69.9 12.8 8.5 2.6	5.3 1.0 0.8 13.9 15.8 13.3 4.3 1.1 0.4	2.7 1.2 0.8 1.2 2.2 1.7 0.6 32.2 13.7 5.2 1.3	6.4 0.3 0.2 0.2 7.7 1.2 0.6 8.2 11.1 5.2
Kr85	10.752 y	&Kr84(n,γ)Kr85 &Kr83(n,γ)Kr84(n,γ)Kr85 &Kr82(n,γ)Kr83(n,γ)Kr84(n,γ)Kr85 &Kr86(n,2n)Kr85 Kr86(n,d)Br85(β <sup>-</sup> )Kr85m(IT)Kr85	79.5 14.7 5.7	99.9	99.6 0.4	0.2 99.7	0.2 97.2 2.0		0.1 90.3 9.3
H3	12.33 y	&Kr78(n,γ)Kr79(n,X)H1(n,γ)H2(n,γ)H3 Kr83(n,X)H3 &Kr84(n,2n)Kr83(n,X)H3 &Kr82(n,2n)Kr81(n,X)H3 Kr84(n,X)H3 Kr86(n,X)H3 Kr82(n,X)H3	93.3	94.6	98.7	56.2 26.9 9.2	20.4 4.8 1.3	15.0 1.5	13.0 49.9 14.4 10.3
Kr81	2.1 10 <sup>5</sup> y	&Kr80(n,γ)Kr81 &Kr82(n,2n)Kr81 &Kr83(n,2n)Kr82(n,2n)Kr81 &Kr84(n,2n)Kr83(n,2n)Kr82(n,2n)Kr81 &Kr83(n,3n)Kr81 &Kr84(n,3n)Kr82(n,2n)Kr81 &Kr84(n,2n)Kr83(n,3n)Kr81 Kr84(n,d)Br83(β <sup>-</sup> )Kr83m(IT)Kr83(n,3n)Kr81 &Kr84(n,4n)Kr81	99.6	100.0	100.0	88.6 8.4 2.6	43.0 1.9 0.2 34.8 10.0 7.9 0.9	19.9 33.4 5.0 3.0 1.2	10.0 9.0 76.4

<b>Nuclide</b>	<b>T<sub>1/2</sub></b>	<b>Pathway</b>	<b>210</b>	<b>186</b>	<b>151</b>	<b>42</b>	<b>30</b>	<b>21</b>	<b>6</b>
Se79	1.1 10 <sup>6</sup> y	&Kr80(n,γ)Kr81(n,γ)Kr82(n,α)Se79	80.2	99.9	99.8				
		&Kr78(n,γ)Kr79(n,α)Se76(n,γ)Se77(n,γ)_ Se78(n,γ)Se79	19.4						
		&Kr82(n,α)Se79				79.1	23.8	6.6	9.2
		&Kr83(n,2n)Kr82(n,α)Se79				7.4	1.0		0.1
		&Kr83(n,α)Se80(n,2n)Se79				4.7	0.4		
		&Kr80(n,2n)Kr79(β <sup>+</sup> )Br79(n,p)Se79				3.4	0.5		
		&Kr84(n,2n)Kr83(n,2n)Kr82(n,α)Se79				2.3	0.1		
		&Kr84(n,2n)Kr83(n,α)Se80(n,2n)Se79				1.2			
		&Kr83(n,nα)Se79				0.6	47.8	22.6	12.0
		&Kr84(n,2n)Kr83(n,nα)Se79				0.2	10.9	2.0	0.7
		&Kr84(n,3n)Kr82(n,α)Se79					5.6	1.5	0.7
		&Kr84(n,nα)Se80(n,2n)Se79					4.0	1.4	0.5
		&Kr84(n,2nα)Se79					0.2	56.3	63.2
		&Kr84(n,nt)Br81(n,t)Se79							3.5

# Krypton activation characteristics



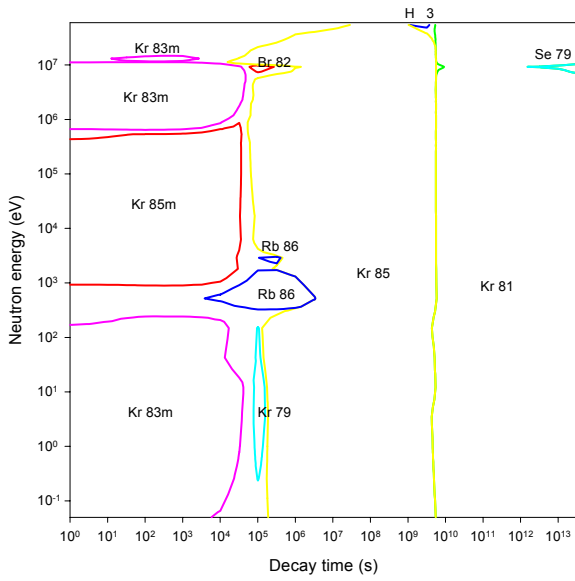
Decay time (years)

Decay time (years)

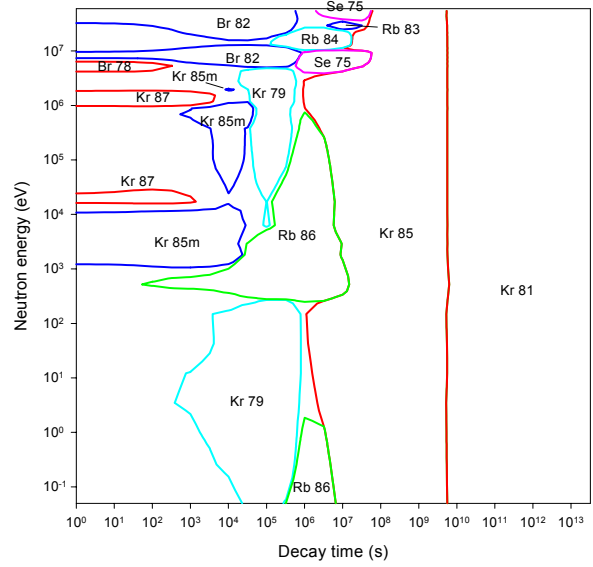


# Krypton importance diagrams & transmutation

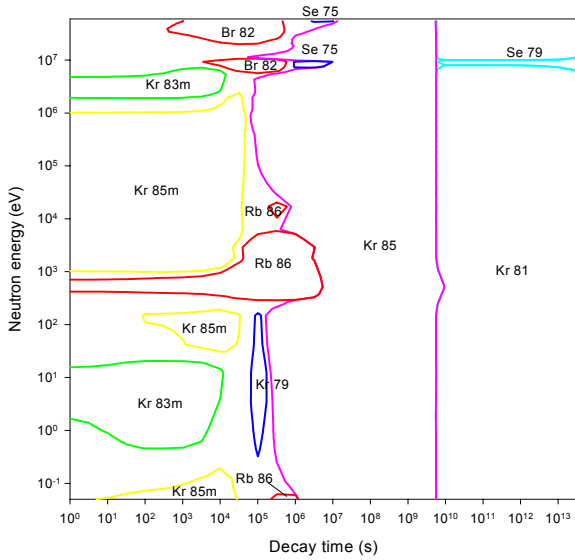
## Activity



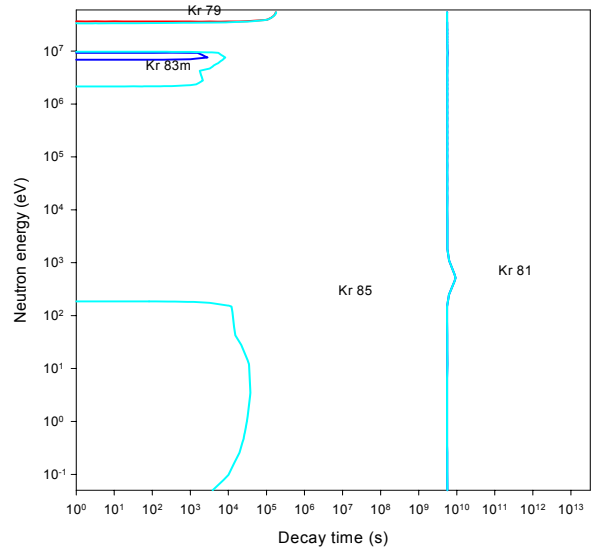
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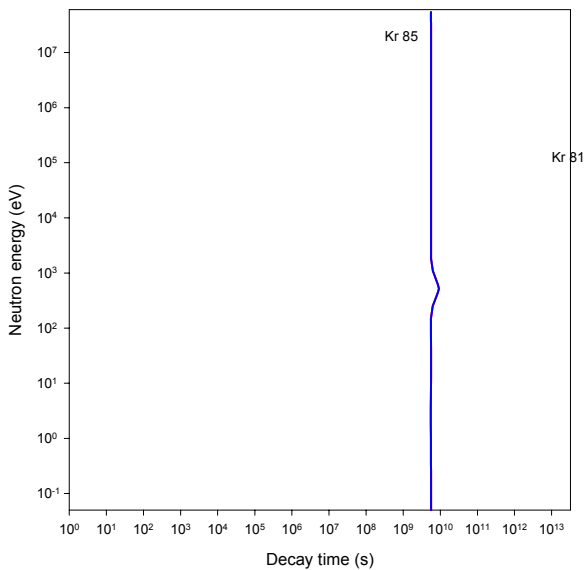
## Heat output



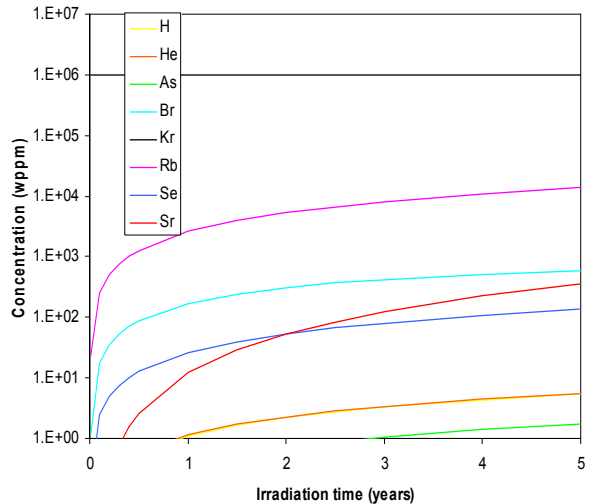
## Ingestion dose



## Inhalation dose



## First wall transmutation



Graphs for H, He are indistinguishable



# Rubidium

## General properties

Atomic number	37	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	90	Rb85	72.17
Melting point / K	312.5	Rb87	27.83 ( $T_{1/2} = 4.75 \cdot 10^{10}$ y)
Boiling point / K	961		
Density / $\text{kgm}^{-3}$	1532		
Thermal conductivity / $\text{Wm}^{-1}\text{K}^{-1}$	58.2		
Electrical resistivity / $\Omega\text{m}$	$1.25 \cdot 10^{-7}$		
Coefficient of thermal expansion / $\text{K}^{-1}$	$9.0 \cdot 10^{-5}$		
Crystal structure	BCC		
Number of stable isotopes	1 (2)		
Mean atomic weight	85.4678		

## Activation properties

Act	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Heat	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Bq $\text{kg}^{-1}$	3.52E15	3.11E15	2.32E15	5.56E12	7.50E9	1.46E6	kW $\text{kg}^{-1}$	4.79E-1	4.32E-1	3.05E-1	2.83E-4	2.76E-7	1.26E-11
Rb86	54.94	62.08	72.57	0.04			Rb86	48.49	53.74	66.51	0.10		
Rb84	18.28	20.66	25.65	6.04			Rb84	22.19	24.59	32.33	19.58		
Rb86m	9.38	0.29					Rb88	16.18	14.61				
Rb84m	8.22	7.77					Rb86m	6.14	0.18				
Rb88	5.04	4.64					Rb84m	4.48	4.15				
Sr87m	1.63	1.81					Sr87m	0.74	0.80				
Sr85	1.01	1.15	1.48	13.00			Sr85	0.63	0.70	0.95	21.53		
Kr85m	0.55	0.61					Kr85m	0.26	0.29				
Kr85	0.13	0.15	0.20	79.66	99.75		Kr85	0.03	0.04	0.05	57.63	99.98	
H3				0.07	0.22		Rb83	0.01	0.01	0.01	1.04		
Rb87					0.01	59.71	Rb87						90.41
Kr81					0.01	40.20	Kr81						9.50
Dose	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Ing	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{h}^{-1}$	3.01E5	2.55E5	1.85E5	1.57E2	3.82E-3	2.06E-7	Sv $\text{kg}^{-1}$	1.39E7	1.39E7	1.16E7	4.87E6	8.23E3	3.76E-2
Rb84	48.04	54.66	72.56	48.15			Rb86	38.90	39.01	40.70			
Rb86	17.67	20.84	25.13	0.04			Kr85	37.34	37.44	44.72	99.97	100.0	
Rb88	12.71	12.22					Rb84	12.94	12.98	14.38	0.01		
Rb86m	12.22	0.39					Sr85	0.14	0.14	0.16			
Rb84m	5.49	5.41					Rb88	0.11	0.09				
Sr85	1.24	1.46	1.94	48.13			Rb84m	0.10	0.08				
Br82	1.08	1.28	0.31				Br82	0.01	0.01				
Sr87m	0.95	1.09					Rb83			0.01			
Rb83	0.02	0.02	0.03	2.34			Kr81						96.52
Kr85				1.28*	99.99*		Rb87						3.46
Kr81						100.0							
Inh	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Clear	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{kg}^{-1}$	1.83E8	1.83E8	1.81E8	1.68E8	2.84E5	1.29E0		1.11E12	8.83E11	5.95E11	1.29E9	4.17E5	8.75E2
Kr85	98.24	98.25	98.79	100.0	100.0		Rb84	52.66	66.21	91.12	23.62		
Rb86	0.98	0.98	0.86				Rb86m	16.53	0.57				
Rb84	0.35	0.35	0.32				Rb88	14.54	14.89				
Kr85m	0.32	0.31					Rb84m	10.02	10.54				
Sr85	0.01	0.01	0.01				Sr85	3.22	4.05	5.79	55.59		
Kr81						99.96	Rb86	1.74	2.18	2.83			
Rb87						0.03	Br82	0.42	0.53	0.14			
							Sr87m	0.05	0.06				
							Rb83	0.03	0.03				
							Kr85		0.02	0.04	19.03	99.73	
							Rb87					0.20	99.48
							Kr81						0.51

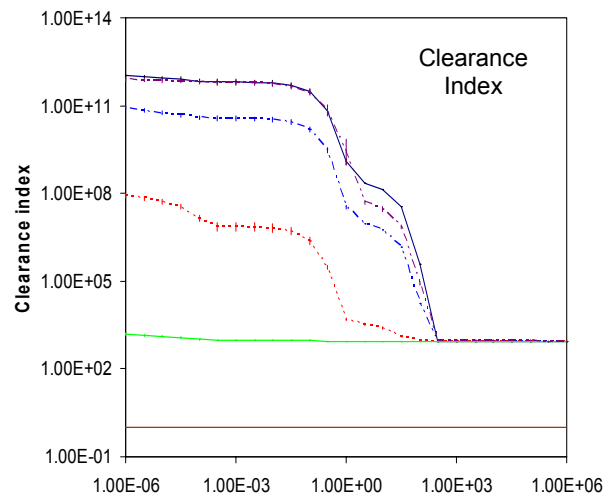
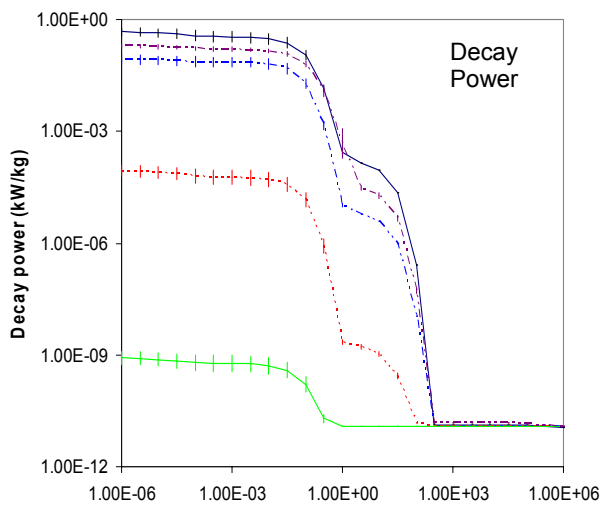
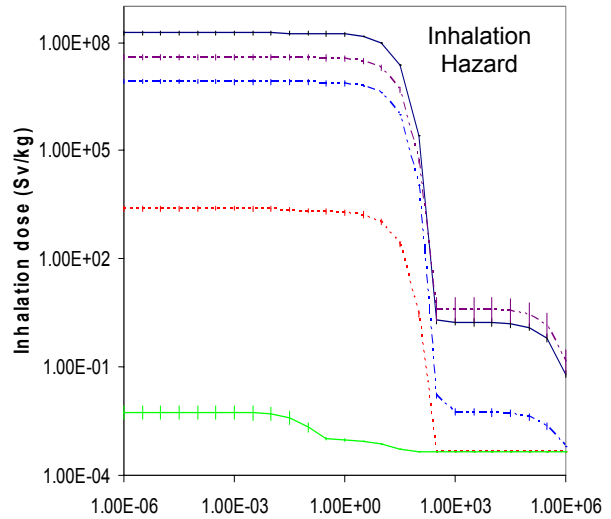
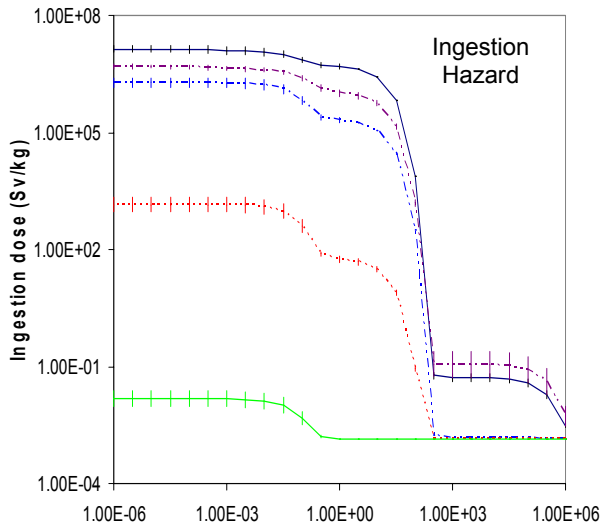
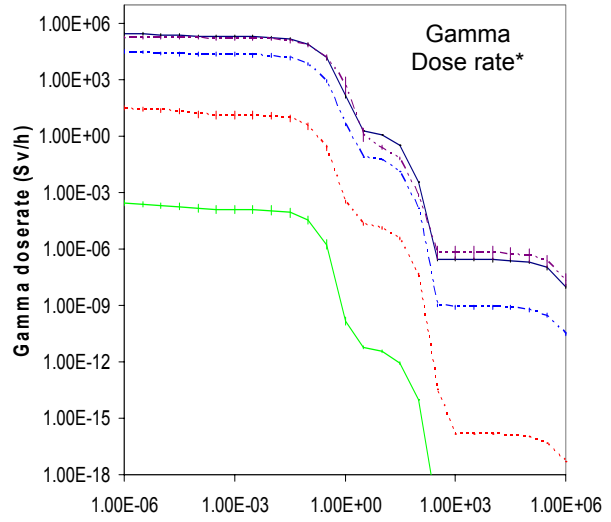
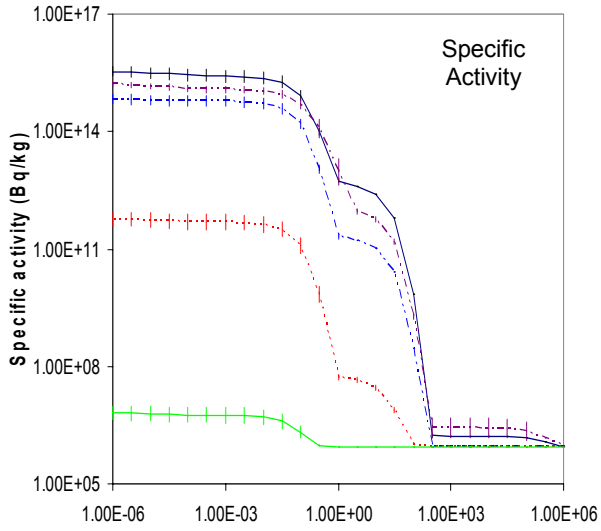
# Rubidium

## Pathway analysis

Nuclide	$T_{1/2}$	Pathway	210	186	151	42	30	21	6
Rb82m	6.472 h	&Rb85(n,2n)Rb84(n,2n)Rb83(n,2n)Rb82m &Rb85(n,2n)Rb84( $\beta^-$ )Sr84(n,2n)Sr83_ ( $\beta^+$ )Rb83(n,2n)Rb82m &Rb85(n,2n)Rb84( $\beta^-$ )Sr84(n,d)Rb83_ (n,2n)Rb82m Rb85(n,3n)Rb83(n,2n)Rb82m &Rb85(n,2n)Rb84(n,3n)Rb82m Rb87(n,3n)Rb85(n,3n)Rb83(n,2n)Rb82m &Rb85(n,2n)Rb84( $\beta^-$ )Sr84(n,t)Rb82m Rb85(n,4n)Rb82m Rb87(n,3n)Rb85(n,4n)Rb82m				55.5 38.2  5.3	0.1		
Br82	1.472 d	&Rb85(n, $\alpha$ )Br82 &Rb85(n,3n)Rb83( $\beta^+$ )Kr83(n,d)Br82 &Rb85(n,2n)Rb84( $\beta^+$ )Kr84(n,t)Br82 &Rb85(n,t)Kr83(n,d)Br82 &Rb85(n,d)Kr84(n,t)Br82 &Rb87(n,2n $\alpha$ )Br82 &Rb87(n,4n)Rb84( $\beta^+$ )Kr84(n,t)Br82				99.9	53.4 34.8 2.2 1.6 0.3	22.1 36.0 11.5 6.5 4.2	31.5 7.6 9.4 5.3 4.9
Y90	2.671 d	&Rb87(n, $\gamma$ )Rb88( $\beta^-$ )Sr88(n, $\gamma$ )Sr89( $\beta^-$ )_ Y89(n, $\gamma$ )Y90 &Rb85(n, $\gamma$ )Rb86( $\beta^-$ )Sr86(n, $\gamma$ )Sr87(n, $\gamma$ )_ Sr88(n, $\gamma$ )Sr89( $\beta^-$ )Y89(n, $\gamma$ )Y90 Rb87(n, $\gamma$ )Rb88( $\beta^-$ )Sr88(n, $\gamma$ )Sr89(n, $\gamma$ )_ Sr90( $\beta^-$ )Y90	96.7 2.9 0.2	99.8	99.0	97.1 0.7	94.4 0.9	94.5 0.9	95.6 0.8
Rb86	18.64 d	&Rb85(n, $\gamma$ )Rb86 &Rb87(n,2n)Rb86	100.0	100.0	99.9	98.7	98.7	98.9	99.3
Rb84	33.50 d	&Rb85(n,2n)Rb84 &Rb87(n,3n)Rb85(n,2n)Rb84 &Rb87(n,4n)Rb84				98.9	95.4 3.5	84.0 3.4 11.1	61.6 36.4
Sr89	50.57 d	Rb87(n, $\gamma$ )Rb88( $\beta^-$ )Sr88(n, $\gamma$ )Sr89 &Rb85(n, $\gamma$ )Rb86( $\beta^-$ )Sr86(n, $\gamma$ )Sr87(n, $\gamma$ )_ Sr88(n, $\gamma$ )Sr89	94.3 5.6	100.0	99.9	99.8	99.7	99.8	99.9
Sr85	64.849 d	&Rb87(n,2n)Rb86( $\beta^-$ )Sr86(n,2n)Sr85				99.6	99.7	99.6	99.7
Rb83	86.20 d	&Rb85(n,2n)Rb84(n,2n)Rb83 &Rb85(n,2n)Rb84( $\beta^-$ )Sr84(n,2n)Sr83( $\beta^+$ )Rb83 &Rb85(n,2n)Rb84( $\beta^-$ )Sr84(n,d)Rb83 Rb85(n,3n)Rb83 Rb87(n,3n)Rb85(n,3n)Rb83 Rb87(n,5n)Rb83				55.7 35.6 5.3	0.1		
Kr85	10.752 y	&Rb85(n, $\gamma$ )Rb86( $\beta^-$ )Sr86(n, $\gamma$ )Sr87(n, $\alpha$ )_ Kr84(n, $\gamma$ )Kr85 &Rb85(n,p)Kr85 Rb87(n,d)Kr86(n,2n)Kr85 &Rb87(n,t)Kr85 Rb87(n,3n)Rb85(n,p)Kr85	100.0		100.0		98.6 0.8	81.7 3.7 12.3 1.5	42.8 1.8 53.8 0.9
H3	12.33 y	&Rb85(n, $\gamma$ )Rb86(n,X)H1(n, $\gamma$ )H2(n, $\gamma$ )H3 Rb85(n,X)H3 &Rb85(n,2n)Rb84(n,X)H3 Rb87(n,X)H3 &Rb85(n,3n)Rb83( $\beta^+$ )Kr83(n,X)H3 &Rb85(n,2n)Rb84( $\beta^+$ )Kr84(n,X)H3 Rb87(n,3n)Rb85(n,X)H3 &Rb87(n,2n)Rb86( $\beta^-$ )Sr86(n,X)H3	93.5	95.3	99.4	80.5 13.3 3.8	69.7 0.4 21.0 3.1 1.5 1.3	67.7 0.8 22.9 1.4 1.0	67.5 24.0
Nb93m	16.126 y	&Rb87(n, $\gamma$ )Rb88( $\beta^-$ )Sr88(n, $\gamma$ )Sr89( $\beta^-$ )_ Y89(n, $\gamma$ )Y90(n, $\gamma$ )Y91( $\beta^-$ )Zr91(n, $\gamma$ )Zr92_ (n, $\gamma$ )Zr93( $\beta^-$ )Nb93m	65.0						

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&Rb87(n,γ)Rb88(β <sup>-</sup> )Sr88(n,γ)Sr89(β <sup>-</sup> )_Y89(n,γ)Y90(n,γ)Y91(n,γ)Y92(β <sup>-</sup> )Zr92_(n,γ)Zr93(β <sup>-</sup> )Nb93m &Rb87(n,γ)Rb88(β <sup>-</sup> )Sr88(n,γ)Sr89(β <sup>-</sup> )_Y89(n,γ)Y90(β <sup>-</sup> )Zr90(n,γ)Zr91(n,γ)Zr92_(n,γ)Zr93(β <sup>-</sup> )Nb93m Other long pathways involving (n,γ) and β <sup>-</sup>	23.3  8.8  2.9						
Sr90	28.79 y	Rb87(n,γ)Rb88(β <sup>-</sup> )Sr88(n,γ)Sr89(n,γ)Sr90 &Rb85(n,γ)Rb86(β <sup>-</sup> )Sr86(n,γ)Sr87(n,γ)_Sr88(n,γ)Sr89(n,γ)Sr90	96.9 3.0	100.0	100.0	99.8	99.5	99.6	99.7
Kr81	2.1 10 <sup>5</sup> y	&Rb85(n,α)Br82(β <sup>-</sup> )Kr82(n,2n)Kr81 &Rb85(n,2n)Rb84(β <sup>+</sup> )Kr84(n,2n)Kr83_(n,2n)Kr82(n,2n)Kr81 &Rb85(n,2n)Rb84(β <sup>-</sup> )Sr84(n,α)Kr81 &Rb85(n,2n)Rb84(n,2n)Rb83(β <sup>+</sup> )Kr83_(n,2n)Kr82(n,2n)Kr81 &Rb85(n,3n)Rb83(β <sup>+</sup> )Kr83(n,3n)Kr81 &Rb85(n,t)Kr83(n,3n)Kr81 &Rb85(n,3n)Rb83(n,3n)Rb81(β <sup>+</sup> )Kr81 &Rb85(n,3n)Rb83(n,t)Kr81 &Rb85(n,2n)Rb84(β <sup>+</sup> )Kr84(n,4n)Kr81 &Rb85(n,2nt)Kr81 &Rb85(n,5n)Rb81(β <sup>+</sup> )Kr81				67.1 22.1  5.7 1.7	1.9	0.2	
Rb87	4.8 10 <sup>10</sup> y	&Rb85(n,γ)Rb86(n,γ)Rb87 Nuclide present in starting material	0.1 99.9	100.0	100.0	100.0	100.0	100.0	100.0

# Rubidium activation characteristics

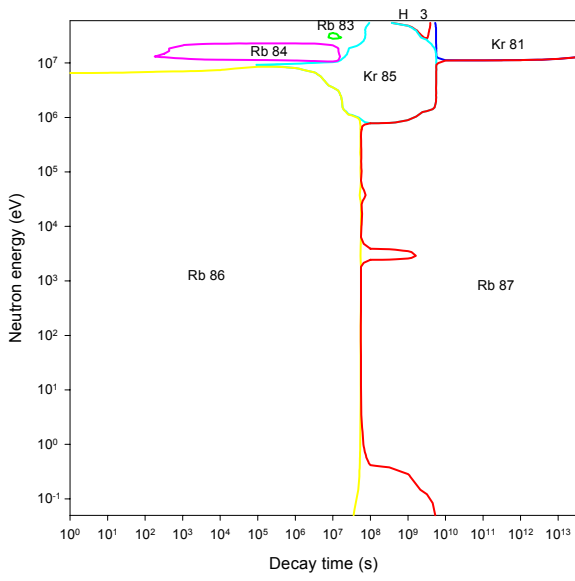


Decay time (years)

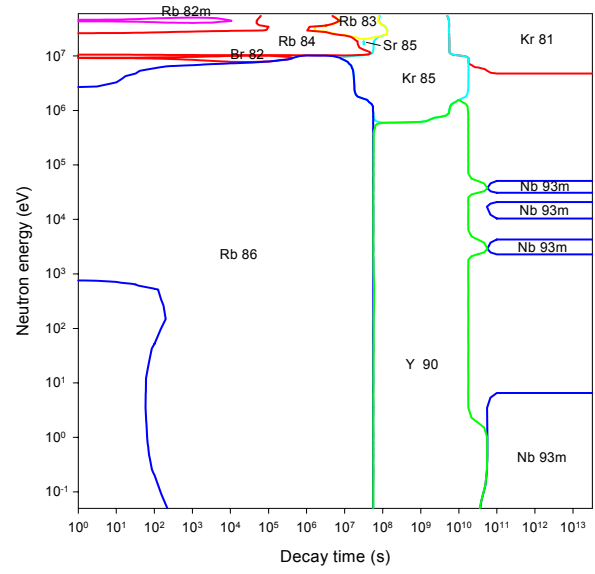
Decay time (years)

# Rubidium importance diagrams & transmutation

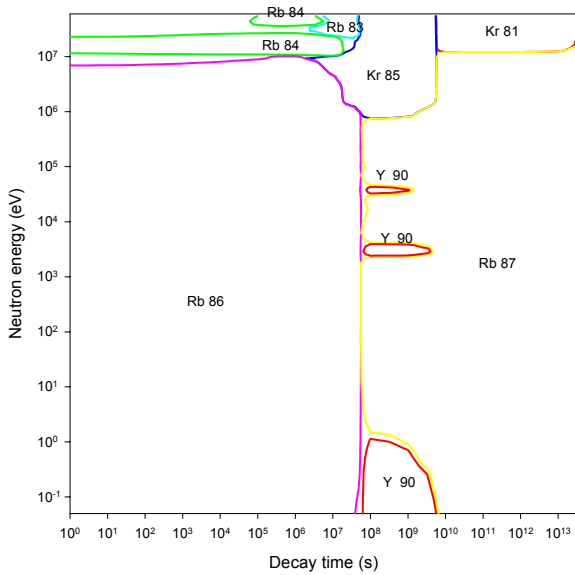
**Activity**



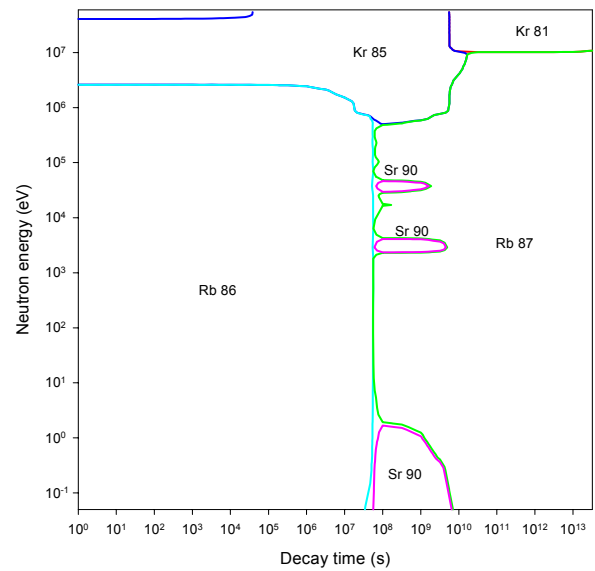
**Dose rate**



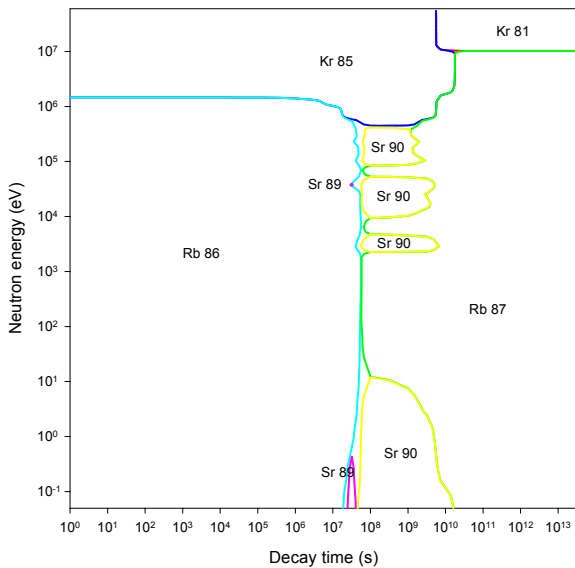
**Heat output**



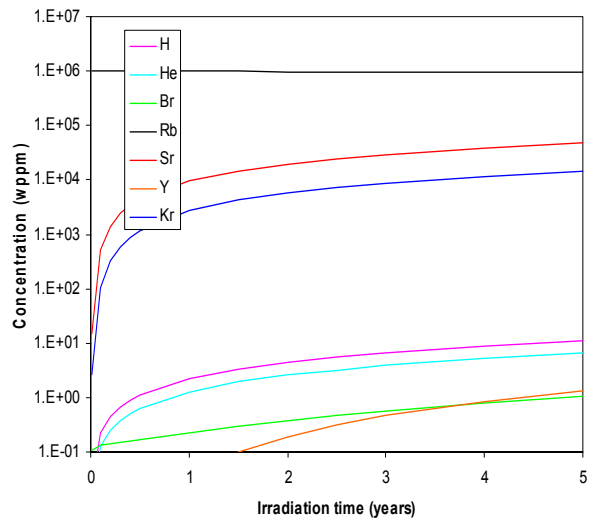
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**







# Strontium

## General properties

Atomic number	38	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	370	Sr84	0.56
Melting point / K	1050	Sr86	9.86
Boiling point / K	1655	Sr87	7.00
Density / kgm <sup>-3</sup>	2540	Sr88	82.58
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	35.3		
Electrical resistivity /Ωm	2.30 10 <sup>-7</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	2.25 10 <sup>-5</sup>		
Crystal structure	FCC		
Number of stable isotopes	4		
Mean atomic weight	87.62		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	5.09E14	4.95E14	1.32E14	2.94E12	1.00E9	1.26E6	Kw kg <sup>-1</sup>	3.84E-2	3.69E-2	1.18E-2	2.27E-4	4.06E-8	2.59E-12
Sr87m	62.97	63.28					Sr87m	51.57	52.56				
Sr85	18.56	19.06	68.83	64.79			Sr85	20.76	21.62	64.79	70.91		
Sr85m	6.41	6.23					Rb88	10.84	9.20				
Sr89	4.79	4.92	17.57	5.55			Sr89	5.94	6.18	18.34	6.74		
Rb86	1.96	2.01	6.60				Rb86	3.12	3.25	8.84			
Rb88	1.87	1.57					Sr85m	3.11	3.07				
Rb83	0.58	0.60	2.22	5.47			Rb84	1.21	1.26	3.66	0.10		
Rb84	0.55	0.57	1.98	0.05			Sr83	1.07	1.12	0.53			
Kr83m	0.50	0.51	1.67	4.10			Rb83	0.62	0.65	2.00	5.73		
Kr85	0.11	0.11	0.44	18.72	92.69		Y88	0.45	0.47	1.44	7.17		
Y88	0.07	0.08	0.29	1.27			Rb86m	0.44	0.01				
Y90	0.02	0.02	0.03	0.01	3.54		Kr85	0.05	0.05	0.18	8.94	84.46	
Sr90				0.01	3.54		Y90	0.04	0.04	0.05	0.02	13.09	
Kr81					0.17	99.98	Sr90					2.43	
H3					0.04		Kr81						99.91
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	3.06E4	2.95E4	1.09E4	2.45E2	5.10E-4	4.14E-7	Sv kg <sup>-1</sup>	8.89E5	8.87E5	8.01E5	6.07E5	1.02E3	7.84E-2
Sr87m	51.06	51.82					Kr85	72.62	72.73	80.48	99.63	99.88	
Sr85	31.90	33.08	85.99	80.28			Sr85	7.95	5.95	6.34	0.17		
Rb88	6.68	5.64					Sr89	7.13	7.14	7.52	0.06		
Sr85m	2.26	2.22					Rb86	3.14	3.15	3.04			
Rb84	2.06	2.14	5.36	0.13			Sr87m	1.08	1.06				
Sr83	1.61	1.67	0.69				Rb84	0.89	0.89	0.91			
Y88	1.11	1.15	3.05	12.97			Rb83	0.63	0.64	0.69	0.05		
Rb83	0.96	1.00	2.67	6.51			Sr83	0.15	0.15	0.02			
Rb86	0.89	0.92	2.18				Y88	0.05	0.05	0.06			
Kr85				0.10*	99.86*		Y90	0.03	0.03	0.01			
Kr81					0.13	100.0	Sr90					0.09	
							Kr81					0.01	100.0
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	2.26E7	2.26E7	2.26E7	2.09E7	3.54E4	2.78E0		1.16E11	1.13E11	9.62E10	2.12E9	8.73E4	9.89E0
Kr85	98.54	98.55	98.78	99.98	99.97		Sr85	81.10	83.51	94.37	89.84		
Sr89	0.85	0.85	0.81				Rb88	7.45	6.25				
Sr85	0.33	0.33	0.32				Sr87m	2.75	2.77				
Rb86	0.04	0.04	0.03				Rb84	2.21	2.27	2.48	0.06		
Sr87m	0.02	0.02					Sr83	1.84	1.89	0.34			
Rb84	0.01	0.01	0.01				Rb83	1.28	1.32	1.52	3.79		
Sr90					0.01		Y88	0.93	0.96	1.10	4.79		
Kr81					0.01	100.0	Sr85m	0.28	0.27				
							Rb86	0.08	0.08	0.09			
							Kr85	0.02	0.02	0.03	1.44	59.20	
							Sr90				0.01	40.74	
							Kr 81					0.01	98.31

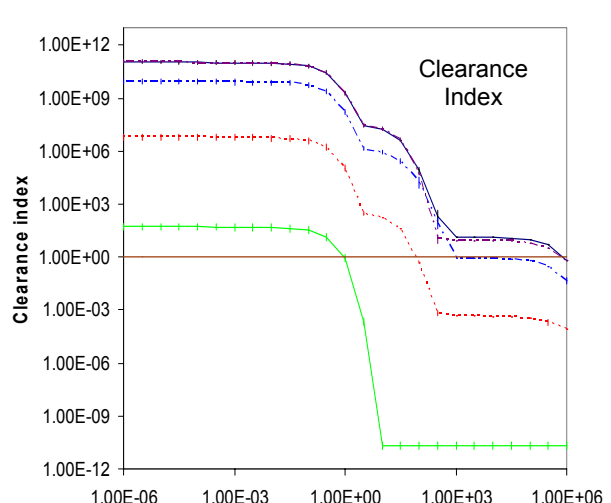
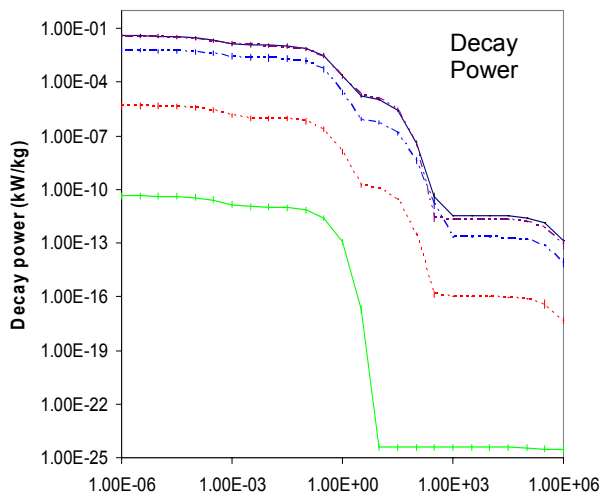
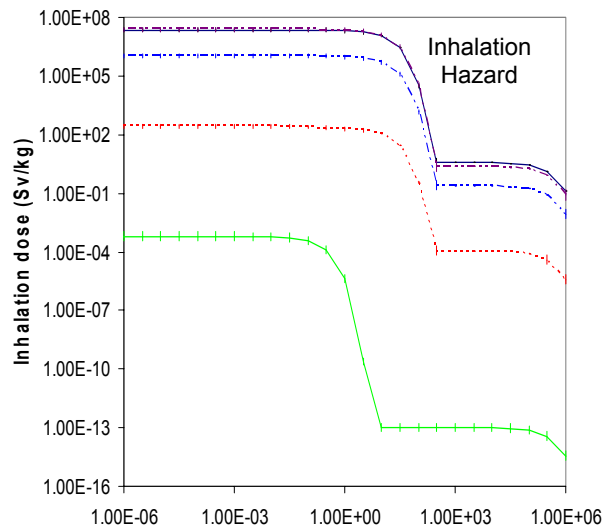
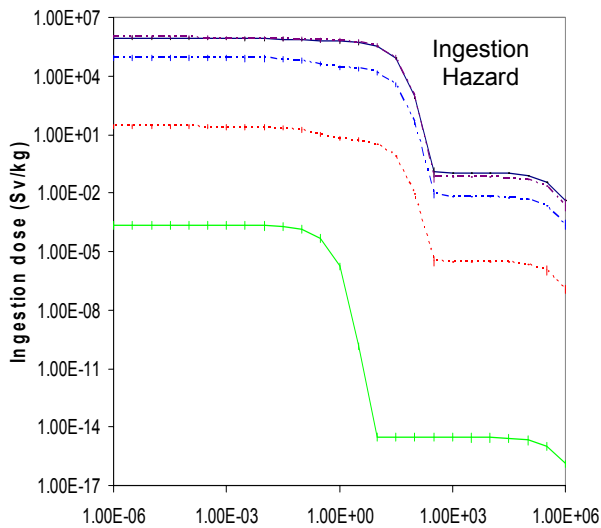
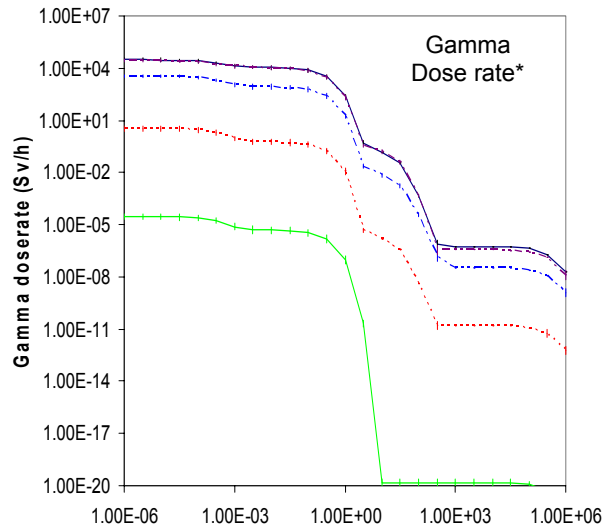
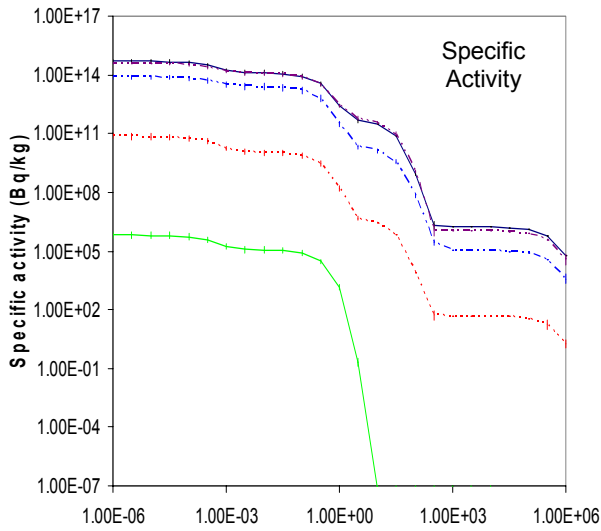
# Strontium

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Sr87m	2.803 h	Sr86(n,γ)Sr87m	100.0	100.0	100.0				
		Sr88(n,2n)Sr87m				92.6	94.5	94.0	94.3
		Sr88(n,2n)Sr87(n,n')Sr87m				3.5	2.4	1.7	
		Sr87(n,n')Sr87m				2.5	2.0	3.4	4.0
Y90	2.671 d	&Sr88(n,γ)Sr89(β <sup>-</sup> )Y89(n,γ)Y90	96.9	99.7	99.1	98.2	96.8	97.1	97.4
		Sr87(n,γ)Sr88(n,γ)Sr89(β <sup>-</sup> )Y89(n,γ)Y90	2.8						
		Sr88(n,γ)Sr89(n,γ)Sr90(β <sup>-</sup> )Y90	0.1	0.1	0.8	0.7	0.9	0.9	0.8
Rb86	18.64 d	&Sr84(n,γ)Sr85(β <sup>+</sup> )Rb85(n,γ)Rb86	88.9	88.6	89.4				
		&Sr84(n,γ)Sr85m(β <sup>+</sup> )Rb85(n,γ)Rb86	11.1	11.4	10.6				
		&Sr86(n,p)Rb86				62.4	10.5	3.6	
		&Sr88(n,2n)Sr87(n,d)Rb86				8.5	30.4	5.5	
		&Sr87(n,2n)Sr86(n,p)Rb86				8.1	0.9		
		&Sr88(n,2n)Sr87(n,2n)Sr86(n,p)Rb86				7.5	0.5		
		&Sr87(n,d)Rb86				4.6	21.1	10.2	7.0
		&Sr87(n,p)Rb87(n,2n)Rb86				2.3	0.3		
		&Sr88(n,2n)Sr87(n,p)Rb87(n,2n)Rb86				2.1	0.1		
		&Sr88(n,d)Rb87(n,2n)Rb86				1.9	17.3	5.5	
		&Sr88(n,2n)Sr87m(β <sup>+</sup> )Rb87(n,2n)Rb86				1.6			
		&Sr88(n,t)Rb86					11.9	70.3	85.1
&Sr88(n,3n)Sr86(n,p)Rb86					5.6	3.3			
Rb84	33.50 d	&Sr86(n,2n)Sr85(β <sup>+</sup> )Rb85(n,2n)Rb84				83.0	40.4	4.0	1.1
		&Sr87(n,2n)Sr86(n,2n)Sr85(β <sup>+</sup> )Rb85_				4.6	1.5		
		(n,2n)Rb84							
		&Sr84(n,p)Rb84				2.8	0.8	0.3	
		&Sr86(n,2n)Sr85m(β <sup>+</sup> )Rb85(n,2n)Rb84				2.8	0.7		
		&Sr88(n,2n)Sr87(n,2n)Sr86(n,2n)Sr85_				1.0	0.2		
		(β <sup>+</sup> )Rb85(n,2n)Rb84							
		&Sr86(n,d)Rb85(n,2n)Rb84				0.9	6.7	1.5	0.6
		&Sr87(n,3n)Sr85(β <sup>+</sup> )Rb85(n,2n)Rb84					12.0	4.7	0.6
		&Sr88(n,3n)Sr86(n,2n)Sr85(β <sup>+</sup> )Rb85_					9.4	1.5	
		(n,2n)Rb84							
		&Sr88(n,2n)Sr87(n,3n)Sr85(β <sup>+</sup> )Rb85_					6.1	1.0	
		(n,2n)Rb84							
		&Sr86(n,t)Rb84					4.2	35.2	21.5
		&Sr88(n,3n)Sr86(n,t)Rb84					2.2	31.8	6.7
		&Sr88(n,d)Rb87(n,4n)Rb84						3.3	6.2
&Sr88(n,4n)Sr85(β <sup>+</sup> )Rb85(n,2n)Rb84						2.6	12.5		
&Sr87(n,nt)Rb84						1.3	16.3		
&Sr88(n,2n)Sr87(n,nt)Rb84						0.6	4.8		
&Sr88(n,nt)Rb85(n,2n)Rb84						0.4	4.5		
&Sr88(n,2nt)Rb84							16.3		
Sr89	50.57 d	Sr88(n,γ)Sr89	95.1	99.9	99.9	99.5	99.1	99.3	99.7
		Sr87(n,γ)Sr88(n,γ)Sr89	4.7		0.1				
		&Sr86(n,γ)Sr87(n,γ)Sr88(n,γ)Sr89	0.2						
Sr85	64.849 d	&Sr84(n,γ)Sr85	100.0	100.0	100.0				
		&Sr86(n,2n)Sr85				80.2	41.5	21.6	6.3
		&Sr87(n,2n)Sr86(n,2n)Sr85				10.0	3.4	0.7	
		&Sr88(n,2n)Sr87(n,2n)Sr86(n,2n)Sr85				9.0	2.2		
		&Sr88(n,3n)Sr86(n,2n)Sr85					21.2	18.9	1.9
		&Sr88(n,2n)Sr87(n,3n)Sr85					17.2	14.1	1.1
&Sr87(n,3n)Sr85					12.6	25.8	4.0		
&Sr88(n,4n)Sr85						15.7	83.5		
Kr85	10.752 y	&Sr84(n,γ)Sr85(n,α)Kr82(n,γ)Kr83(n,γ)_	90.2	99.9					
		Kr84(n,γ)Kr85							
		&Sr87(n,α)Kr84(n,γ)Kr85	9.6		99.4				
		&Sr86(n,γ)Sr87(n,α)Kr84(n,γ)Kr85	0.2		0.4				
▶ &Sr88(n,α)Kr85				94.8	98.1	93.9	88.5		

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&Sr86(n,2n)Sr85(β <sup>+</sup> )Rb85(n,p)Kr85 Sr88(n,d)Rb87(n,t)Kr85 Sr87(n,h)Kr85				4.6	0.2	2.6	5.1
H3	12.33 y	&Sr84(n,γ)Sr85(n,X)H1(n,γ)H2(n,γ)H3 Sr87(n,X)H3 &Sr88(n,2n)Sr87(n,X)H3 Sr86(n,2n)Sr85(β <sup>+</sup> )Rb85(n,X)H3 Sr86(n,2n)Sr85(n,X)H3 Sr88(n,X)H3 Sr86(n,X)H3 Sr88(n,3n)Sr86(n,X)H3 Sr88(n,4n)Sr85(β <sup>+</sup> )Rb85(n,X)H3	93.6	95.4	99.3	38.1 36.3 12.3 1.4	8.5 6.3 0.8	7.4 1.8	7.2 1.1 73.9 8.4 1.4 1.9
Nb93m	16.126 y	&Sr88(n,γ)Sr89(β <sup>-</sup> )Y89(n,γ)Y90(n,γ) Y91(β <sup>-</sup> )Zr91(n,γ)Zr92(n,γ)Zr93(β <sup>-</sup> )Nb93m &Sr88(n,γ)Sr89(β <sup>-</sup> )Y89(n,γ)Y90(n,γ) Y91(n,γ)Y92(β <sup>-</sup> )Zr92(n,γ)Zr93(β <sup>-</sup> )Nb93m &Sr88(n,γ)Sr89(β <sup>-</sup> )Y89(n,γ)Y90(β <sup>-</sup> )Zr90_ (n,γ)Zr91(n,γ)Zr92(n,γ)Zr93(β <sup>-</sup> )Nb93m &Sr88(n,γ)Sr89(n,γ)Sr90(n,γ)Sr91(β <sup>-</sup> ) Y91(β <sup>-</sup> )Zr91(n,γ)Zr92(n,γ)Zr93(β <sup>-</sup> )Nb93m &Sr88(n,γ)Sr89(n,γ)Sr90(n,γ)Sr91(β <sup>-</sup> ) Y91(n,γ)Y92(β <sup>-</sup> )Zr92(n,γ)Zr93(β <sup>-</sup> )Nb93m	67.5 20.1 10.3 0.6 0.1		8.5 1.5 78.9 8.7 1.5				
Sr90	28.79 y	Sr88(n,γ)Sr89(n,γ)Sr90 Sr87(n,γ)Sr88(n,γ)Sr89(n,γ)Sr90	97.1 2.8	100.0	99.9	99.6	99.1	99.3	99.6
Kr81	2.1 10 <sup>5</sup> y	&Sr84(n,α)Kr81 &Sr84(n,2n)Sr83(β <sup>+</sup> )Rb83(β <sup>+</sup> )Kr83(n,2n) Kr82(n,2n)Kr81 &Sr86(n,α)Kr82(n,2n)Kr81 &Sr84(n,2n)Sr83(β <sup>+</sup> )Rb83(β <sup>+</sup> )Kr83(n,3n)Kr81 &Sr86(n,α)Kr83(n,3n)Kr81 &Sr86(n,2n)Sr85(β <sup>+</sup> )Rb85(n,3n)Rb83_ (β <sup>+</sup> )Kr83(n,3n)Kr81 &Sr86(n,2nα)Kr81 &Sr88(n,3n)Sr86(n,2nα)Kr81 &Sr84(n,nt)Rb81(β <sup>+</sup> )Kr81 &Sr87(n,3nα)Kr81 &Sr88(n,4n)Sr85(β <sup>+</sup> )Rb85(n,5n)Rb81(β <sup>+</sup> )Kr81 &Sr88(n,5n)Sr84(n,nt)Rb81(β <sup>+</sup> )Kr81				76.9 9.9 0.1	7.8 0.2 7.8 11.9 8.2 5.6 0.1	1.2 1.1 1.1 0.9 0.2 37.9 17.4 1.6	1.3 0.1 0.1 0.1 11.8 1.8 9.2 10.3 8.0 6.4
Zr93	1.5 10 <sup>6</sup> y	&Sr88(n,γ)Sr89(β <sup>-</sup> )Y89(n,γ)Y90(n,γ)Y91_ (β <sup>-</sup> )Zr91(n,γ)Zr92(n,γ)Zr93 &Sr88(n,γ)Sr89(β <sup>-</sup> )Y89(n,γ)Y90(n,γ)Y91_ (n,γ)Y92(β <sup>-</sup> )Zr92(n,γ)Zr93 &Sr88(n,γ)Sr89(β <sup>-</sup> )Y89(n,γ)Y90(β <sup>-</sup> )Zr90_ (n,γ)Zr91(n,γ)Zr92(n,γ)Zr93 &Sr87(n,γ)Sr88(n,γ)Sr89(β <sup>-</sup> )Y89(n,γ) Y90(n,γ)Y91(β <sup>-</sup> )Zr91(n,γ)Zr92(n,γ)Zr93 &Sr88(n,γ)Sr89(n,γ)Sr90(n,γ)Sr91(β <sup>-</sup> ) Y91(β <sup>-</sup> )Zr91(n,γ)Zr92(n,γ)Zr93 &Sr88(n,γ)Sr89(n,γ)Sr90(n,γ)Sr91(β <sup>-</sup> ) Y91(n,γ)Y92(β <sup>-</sup> )Zr92(n,γ)Zr93	68.7 16.7 12.1 0.9 0.5	80.5 3.6 14.6 1.0	7.7 1.1 81.5 7.8 1.0	1.5 0.6 71.7 19.7 5.7	1.7 0.4 70.9 18.7 5.3	2.0 0.1 69.8 19.5 5.2	
Rb87	4.8 10 <sup>10</sup> y	Sr86(n,γ)Sr87m(β <sup>+</sup> )Rb87 Sr87(n,p)Rb87 &Sr88(n,2n)Sr87(n,p)Rb87 Sr88(n,d)Rb87 Sr88(n,2n)Sr87m(β <sup>+</sup> )Rb87	99.7	100.0	100.0	28.8 27.0 23.9 19.2	1.9 1.3 95.8 0.5	1.0 0.3 98.1 0.2	0.6 99.0 0.1

# Strontium activation characteristics

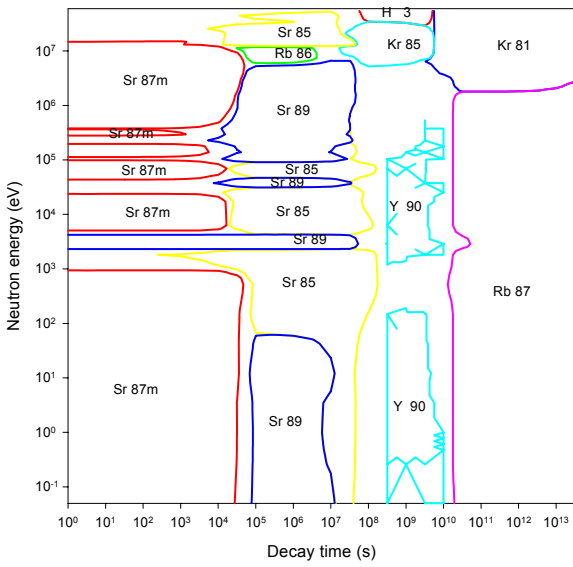


Decay time (years)

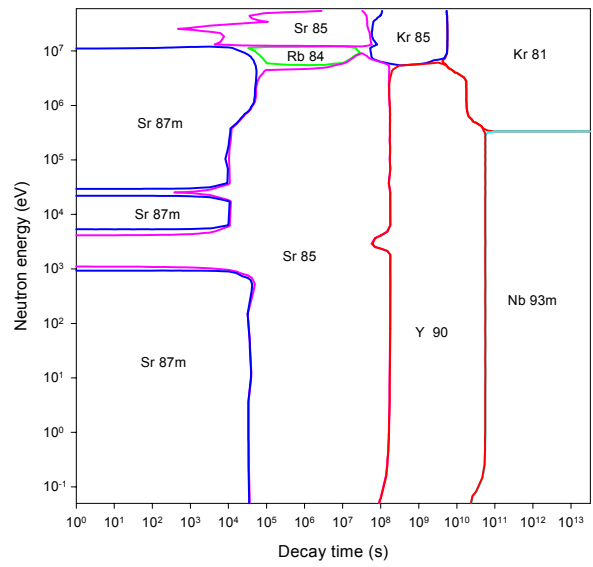
Decay time (years)

# Strontium importance diagrams & transmutation

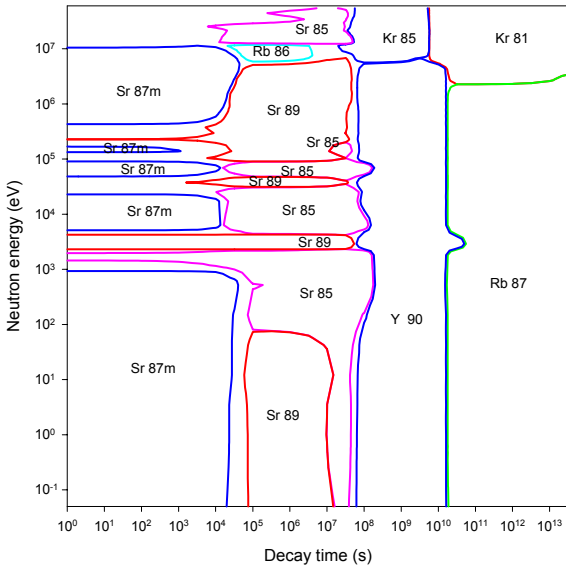
**Activity**



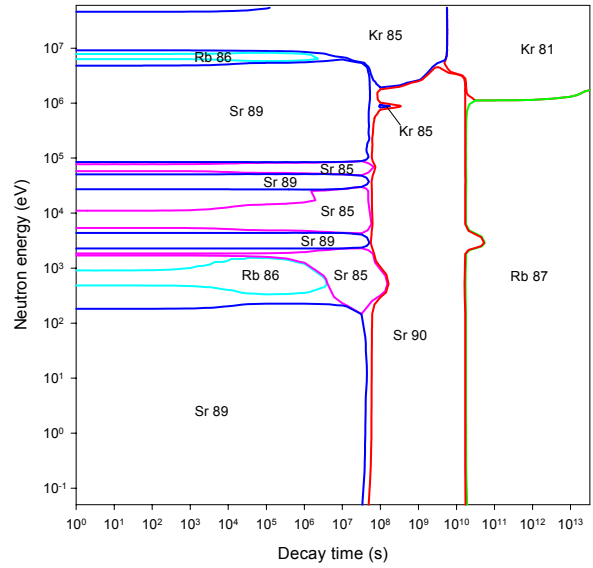
**Dose rate**



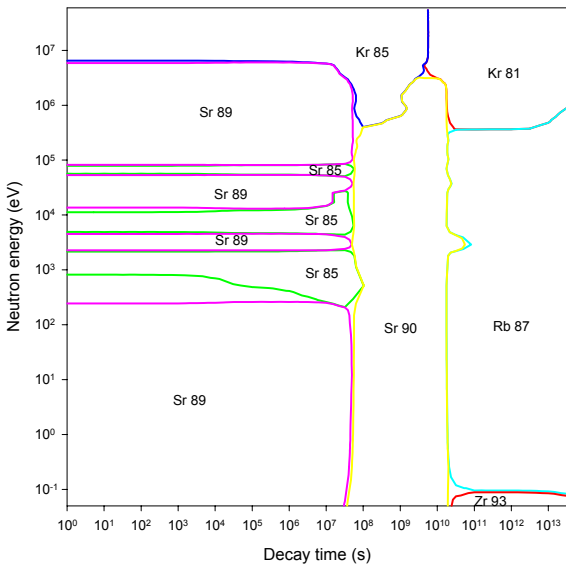
**Heat output**



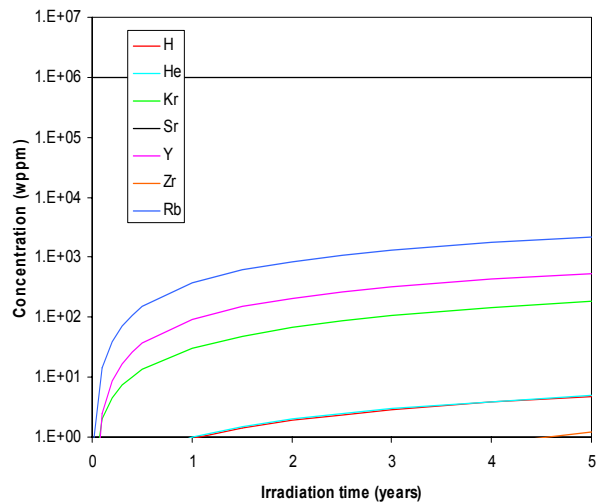
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**



*Graphs for H, He curves are indistinguishable*



# Yttrium

## General properties

Atomic number	39	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	33	Y89	100.0
Melting point / K	1799		
Boiling point / K	3609		
Density / kgm <sup>-3</sup>	4469		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	17.2		
Electrical resistivity /Ωm	5.70 10 <sup>-7</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	1.06 10 <sup>-5</sup>		
Crystal structure	HCP		
Number of stable isotopes	1		
Mean atomic weight	88.90585		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	1.92E15	1.03E15	8.80E14	7.43E13	9.19E7	1.66E1	kW kg <sup>-1</sup>	5.08E-1	3.77E-1	3.51E-1	3.21E-2	6.06E-9	8.45E-17
Y89m	46.20	0.24	0.13				Y88	67.82	91.29	96.01	99.96		
Y88	41.42	77.26	88.31	99.80			Y89m	25.44	0.09	0.04			
Y90	10.12	18.86	8.56		34.73		Y90	5.72	7.70	3.22		78.77	
Sr89	1.06	1.98	2.21	0.18			Sr89	0.37	0.50	0.52	0.04		
Sr90					34.72		Sr90					14.67	
H3					19.32		Kr85					6.28	
Kr85					11.24		H3					0.26	
Zr93						41.06	Nb93m						39.05
Nb93m						40.03	Rb87						33.67
Rb87						13.06	Zr93						24.90
Kr81						5.83	Kr81						2.34
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	8.83E5	6.66E5	6.49E5	6.18E4	4.09E-5	7.44E-13	Sv kg <sup>-1</sup>	1.78E6	1.64E6	1.29E6	1.03E5	1.23E1	7.18E-8
Y88	75.26	99.77	99.91	100.0			Y88	58.06	63.09	78.54	93.15		
Y89m	24.25	0.09	0.04				Y90	29.47	31.99	15.83		0.69	
Zr90m	0.35						Sr89	2.98	3.24	3.93	0.34		
Sr87m	0.02	0.02					Rb86	0.82	0.90	1.00			
Y90m		0.02					Kr85	0.40	0.43	0.22	6.49	92.06	
Kr85					99.96*		Sr90					7.23	
Y90					0.03*		Kr81						83.87
Nb93m						60.48	Zr93						10.47
Kr81						39.50	Rb87						4.54
							Nb93m						1.11
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	4.29E6	4.21E6	3.94E6	5.59E5	3.98E2	2.32E-6		2.97E12	2.16E12	2.10E12	2.00E11	3.27E4	3.53E-3
Y88	81.74	83.16	86.80	58.30			Y88	27.37	99.73	99.90	100.0		
Y90	6.81	6.92	2.87		0.01		Y89m	27.15	0.10	0.05			
Kr85	5.77	5.87	6.27	41.49	98.70		Sr90					97.60	
Sr89	3.77	3.84	3.90	0.19			Kr85					1.75	
Sr90					1.28		Y90					0.09	
Kr81						92.08	Rb87						61.57
Zr93						7.36	Zr93						19.35
Nb93m						0.51	Nb93m						18.87
Rb87						0.04	Kr81						0.21

# Yttrium

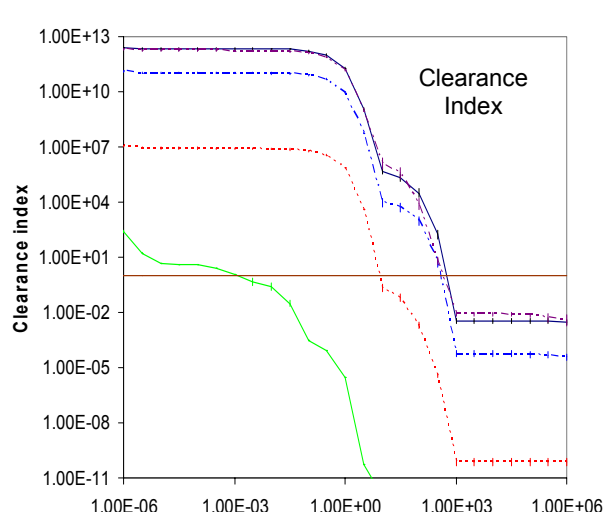
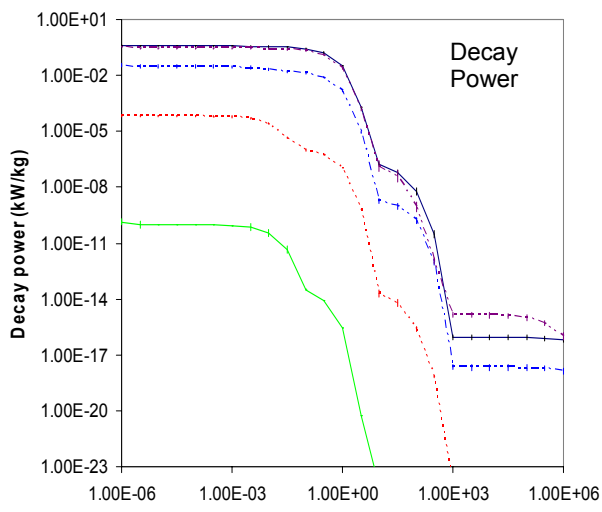
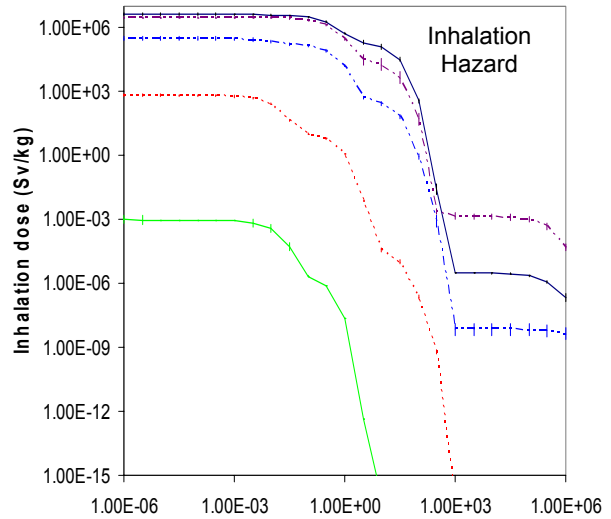
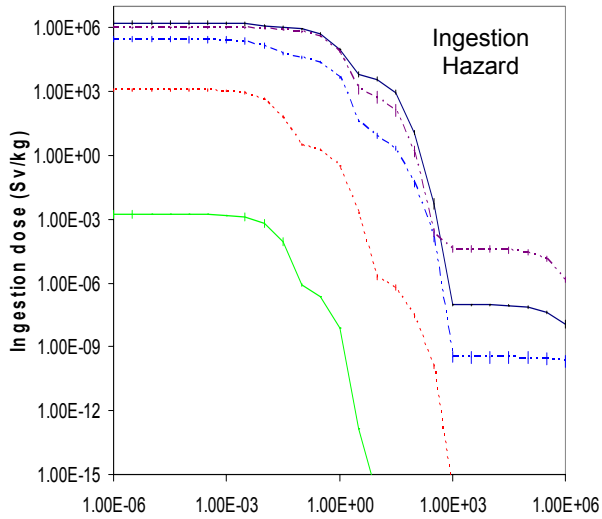
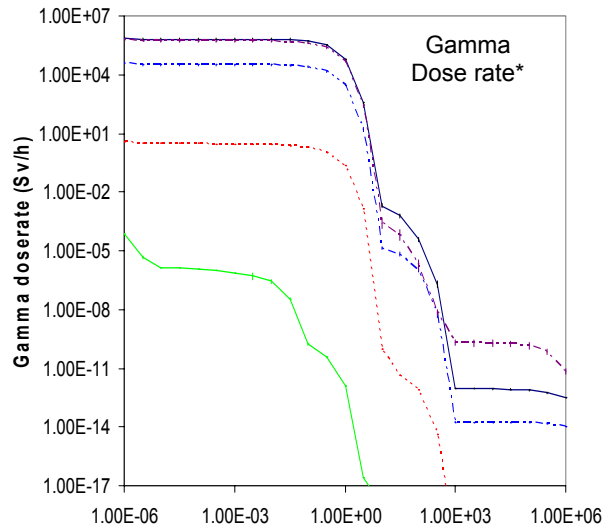
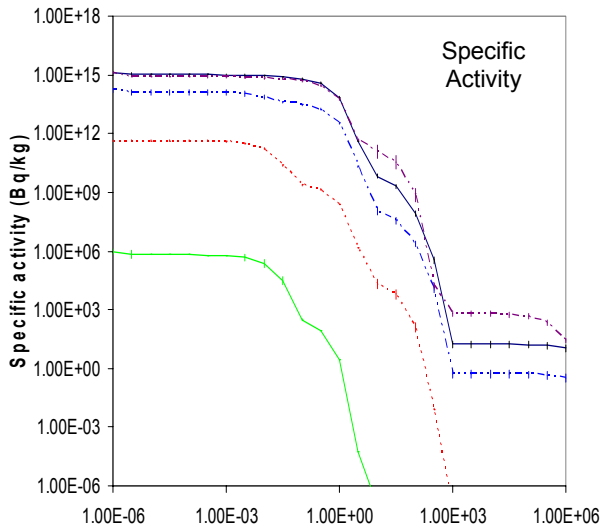
## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Y89m	15.663 s	&Y89(n,γ)Y90(n,γ)Y91(β <sup>-</sup> )Zr91(n,α) <sub>-</sub> Sr88(n,γ)Sr89(β <sup>-</sup> )Y89m Y89(n,γ)Y90(β <sup>-</sup> )Zr90(n,γ)Zr91(n,α)Sr88_ (n,γ)Sr89(β <sup>-</sup> )Y89m Y89(n,n')Y89m	78.8 21.1				99.6 99.5	99.7	99.8
Y90m	3.19 h	Y89(n,γ)Y90m	100.0	100.0	100.0	99.1	98.9	99.2	99.5
Y86	14.74 h	&Y89(n,2n)Y88(n,2n)Y87(n,2n)Y86 &Y89(n,2n)Y88(n,2n)Y87m(n,2n)Y86 &Y89(n,2n)Y88(n,3n)Y86 &Y89(n,3n)Y87(n,2n)Y86 &Y89(n,4n)Y86				86.6 13.4	97.0 2.2	30.6	69.4 100.0
Y90	2.671 d	&Y89(n,γ)Y90	99.9	99.9	100.0	100.0	100.0	100.0	100.0
Rb86	18.64 d	&Y89(n,α)Rb86 &Y89(n,2n)Y88(β <sup>+</sup> )Sr88(n,2n)Sr87(n,d)Rb86   &Y89(n,3n)Y87m(β <sup>+</sup> )Sr87(n,d)Rb86 &Y89(n,3n)Y87(β <sup>+</sup> )Sr87(n,d)Rb86 &Y89(n,t)Sr87(n,d)Rb86 &Y89(n,2n)Y88(β <sup>+</sup> )Sr88(n,t)Rb86 &Y89(n,2n)Y88(β <sup>+</sup> )Sr88(n,d)Rb87(n,2n)Rb86   &Y89(n,d)Sr88(n,t)Rb86 &Y89(n,nt)Sr86(n,p)Rb86 &Y89(n,4n)Y86(β <sup>+</sup> )Sr86(n,p)Rb86				96.7 0.6	61.3 3.0 15.9 7.1 3.0 2.8 1.8 0.5	25.4 0.4 31.2 10.0 10.4 13.1 0.5 5.6 0.4	48.3 11.2 3.3 9.0 13.9 0.1 7.3 2.0 2.8
Sr89	50.57 d	&Y89(n,γ)Y90(n,γ)Y91(β <sup>-</sup> )Zr91(n,α) <sub>-</sub> Sr88(n,γ)Sr89 Y89(n,γ)Y90(β <sup>-</sup> )Zr90(n,γ)Zr91(n,α)Sr88_ (n,γ)Sr89 Y89(n,p)Sr89	78.8 21.1	78.3 21.6	4.3 92.4		98.9 99.2	99.4	99.5
Y91	58.51 d	&Y89(n,γ)Y90(n,γ)Y91 &Y89(n,γ)Y90(β <sup>-</sup> )Zr90(n,γ)Zr91(n,p)Y91 &Y89(n,p)Sr89(n,γ)Sr90(n,γ)Sr91(β <sup>-</sup> )Y91	99.7	99.9	100.0	65.7 24.4 2.2	81.0 8.2 1.2	87.7 4.9 0.9	95.1 1.8 0.5
Y88	106.63 d	Y89(n,2n)Y88				99.7	99.8	99.8	99.9
Kr85	10.752 y	&Y89(n,2n)Y88(β <sup>+</sup> )Sr88(n,α)Kr85 &Y89(n,d)Sr88(n,α)Kr85 Y89(n,nα)Rb85(n,p)Kr85 &Y89(n,pα)Kr85 &Y89(n,3n)Y87(β <sup>+</sup> )Sr87(n,h)Kr85 &Y89(n,t)Sr87(n,h)Kr85 &Y89(n,h)Rb87(n,t)Kr85 &Y89(n,2nt)Sr85(β <sup>+</sup> )Rb85(n,p)Kr85 Y89(n,5n)Y85m(β <sup>+</sup> )Sr85(β <sup>+</sup> )Rb85(n,p)Kr85				93.1 6.1	81.3 15.6 1.2 0.2 0.1	48.9 22.1 3.7 5.8 7.1 1.5 1.2	34.6 19.7 2.1 7.5 6.7 3.7 4.6 5.9 3.2
H3	12.33 y	Y89(n,X)H3 Y89(n,2n)Y88(n,X)H3 Y89(n,2n)Y88(β <sup>+</sup> )Sr88(n,X)H3				78.9 19.5 1.6	95.3 0.9 1.2	93.5	92.3
Nb93m	16.126 y	&Y89(n,γ)Y90(n,γ)Y91(β <sup>-</sup> )Zr91(n,γ)Zr92_ (n,γ)Zr93(β <sup>-</sup> )Nb93m &Y89(n,γ)Y90(n,γ)Y91(n,γ)Y92(β <sup>-</sup> )Zr92_ (n,γ)Zr93(β <sup>-</sup> )Nb93m &Y89(n,γ)Y90(β <sup>-</sup> )Zr90(n,γ)Zr91(n,γ) <sub>-</sub> Zr92(n,γ)Zr93(β <sup>-</sup> )Nb93m	70.8 16.3 12.9	81.2 3.5 15.2	8.2 1.1 90.7	2.1 0.4 96.4	2.2 0.7 94.7		
Sr90	28.79 y	&89(n,γ)Y90(n,γ)Y91(β <sup>-</sup> )Zr91(n,α)Sr88_ (n,γ)Sr89(n,γ)Sr90 &89(n,γ)Y90(n,γ)Y91(β <sup>-</sup> )Zr91(n,γ)Zr92_ (n,γ)Zr93(n,α)Sr90 &89(n,γ)Y90(β <sup>-</sup> )Zr90(n,γ)Zr91(n,α)Sr88_ (n,γ)Sr89(n,γ)Sr90	55.9 22.9 11.8	2.0 79.2 0.4	6.0 1.2 78.4				



Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	&Y89(n,γ)Y90(n,γ)Y91(n,γ)Y92(β <sup>-</sup> )Zr92_ (n,γ)Zr93(n,α)Sr90 Y89(n,γ)Y90(β <sup>-</sup> )Zr90(n,γ)Zr91(n,γ)Zr92_ (n,γ)Zr93(n,α)Sr90 Y89(n,p)Sr89(n,γ)Sr90 &Y89(n,γ)Y90(n,p)Sr90	5.3 4.1	3.3 14.8	0.1 14.0		95.8 3.8	97.7 3.0	98.1 3.0	96.4 3.2
Kr81	2.1 10 <sup>5</sup> y	&Y89(n,α)Rb86(β <sup>-</sup> )Sr86(n,α)Kr83(n,2n)_ Kr82(n,2n)Kr81 &Y89(n,2n)Y88(n,α)Rb85(n,α)Br82(β <sup>-</sup> )_ Kr82(n,2n)Kr81 &Y89(n,α)Rb86(β <sup>-</sup> )Sr86(n,2n)Sr85_ (n,2n)Sr84(n,α)Kr81 &Y89(n,α)Rb86(β <sup>-</sup> )Sr86(n,2n)Sr85(n,α)_ Kr82(n,2n)Kr81 Y89(n,α)Rb86(β <sup>-</sup> )Sr86(n,2n)Sr85(β <sup>+</sup> )_ Rb85(n,α)Br82(β <sup>-</sup> )Kr82(n,2n)Kr81 &Y89(n,α)Rb86(β <sup>-</sup> )Sr86(n,α)Kr82(n,2n)Kr81   &Y89(n,α)Rb85(n,3n)Rb83(β <sup>+</sup> )Kr83_ (n,3n)Kr81 &Y89(n,3n)Y87(β <sup>+</sup> )Sr87(n,α)Kr83(n,3n)Kr81   &89(n,2nα)Rb84(β <sup>+</sup> )Kr84(n,4n)Kr81 &Y89(n,nt)Sr86(n,2nα)Kr81 &Y89(n,4n)Y86(β <sup>+</sup> )Sr86(n,2nα)Kr81 &Y89(n,3n)Y87(β <sup>+</sup> )Sr87(n,3nα)Kr81 &Y89(n,3nα)Rb83(β <sup>+</sup> )Kr83(n,3n)Kr81 &Y89(n,t)Sr87(n,3nα)Kr81 &Y89(n,2nt)Sr85(β <sup>+</sup> )Rb85(n,5n)Rb81(β <sup>+</sup> )Kr81   Long pathways involving (n,2n), (n,α), β <sup>+</sup>				28.7 9.2 7.5 6.0 3.0 2.1 20.3 22.2 8.1 1.5 10.0 7.2 5.3 4.5 43.5	0.4 24.7 56.7	5.6 5.9 22.2 8.1 1.5 10.0 7.2 5.3 4.5	11.0 7.2 10.5 10.0 7.2 5.3 4.5	
Se79	1.1 10 <sup>6</sup> y	&Y89(n,α)Rb86(β <sup>-</sup> )Sr86(n,α)Kr83(n,2n)_ Kr82(n,α)Se79 &Y89(n,α)Rb86(β <sup>-</sup> )Sr86(n,α)Kr83(n,α)_ Se80(n,2n)Se79 &Y89(n,2n)Y88(n,α)Rb85(n,α)Br82(β <sup>-</sup> )_ Kr82(n,α)Se79 &Y89(n,α)Rb86(β <sup>-</sup> )Sr86(n,2n)Sr85(n,α)_ Kr82(n,α)Se79 &Y89(n,α)Rb86(β <sup>-</sup> )Sr86(n,α)Kr83(n,α)Se79   &Y89(n,α)Rb85(n,3n)Rb83(β <sup>+</sup> )Kr83_ (n,α)Se79 &Y89(n,3n)Y87(β <sup>+</sup> )Sr87(n,α)Kr83(n,α)Se79   &Y89(n,2nα)Rb84(β <sup>+</sup> )Kr84(n,2nα)Se79 &Y89(n,3nα)Rb83(β <sup>+</sup> )Kr83(n,α)Se79 Long pathways involving (n,2n), (n,α), β <sup>+</sup>				22.8 14.7 7.3 4.7 3.9 46.6	1.0 30.1 24.7 44.2	5.0 5.5 50.8 38.7	0.1 25.1 25.3 49.5	
Zr93	1.5 10 <sup>6</sup> y	&Y89(n,γ)Y90(n,γ)Y91(β <sup>-</sup> )Zr91(n,γ)Zr92_ (n,γ)Zr93 &Y89(n,γ)Y90(β <sup>-</sup> )Zr90(n,γ)Zr91(n,γ)_ Zr92(n,γ)Zr93 &Y89(n,γ)Y90(n,γ)Y91(n,γ)Y92(β <sup>-</sup> )Zr92_ (n,γ)Zr93	71.9 15.6 12.5	79.6 17.8 2.5	6.9 92.4 0.7	1.4 97.6 0.1	1.9 95.5 0.3	2.2 95.0 0.3	3.0 93.4 0.5	
Rb87	4.8 10 <sup>10</sup> y	&Y89(n,γ)Y90(n,α)Rb87 Y89(n,2n)Y88(β <sup>+</sup> )Sr88(n,d)Rb87 Y89(n,2n)Y88(β <sup>+</sup> )Sr88(n,2n)Sr87m(β <sup>+</sup> )Rb87 &Y89(n,2n)Y88(β <sup>+</sup> )Sr88(n,2n)Sr87(n,p)Rb87 &Y89(n,2n)Y88(n,2n)Y87(β <sup>+</sup> )Sr87(n,p)Rb87 Y89(n,d)Sr88(n,d)Rb87 Y89(n,d)Sr88(n,2n)Sr87m(β <sup>+</sup> )Rb87 &Y89(n,d)Sr88(n,2n)Sr87(n,p)Rb87 &Y89(n,3n)Y87(β <sup>+</sup> )Sr87(n,p)Rb87 Y89(n,h)Rb87 &Y89(n,t)Sr87(n,p)Rb87 Y89(n,t)Sr87m(β <sup>+</sup> )Rb87	99.9	99.9	100.0	33.9 27.2 23.8 7.7 2.2 1.8 1.7	71.1 0.4 0.5 0.1 13.7 0.1 7.0 4.5 0.9 0.6	36.1 36.1 16.4 14.1	24.7 2.0 56.1 1.2 1.3	

# Yttrium activation characteristics

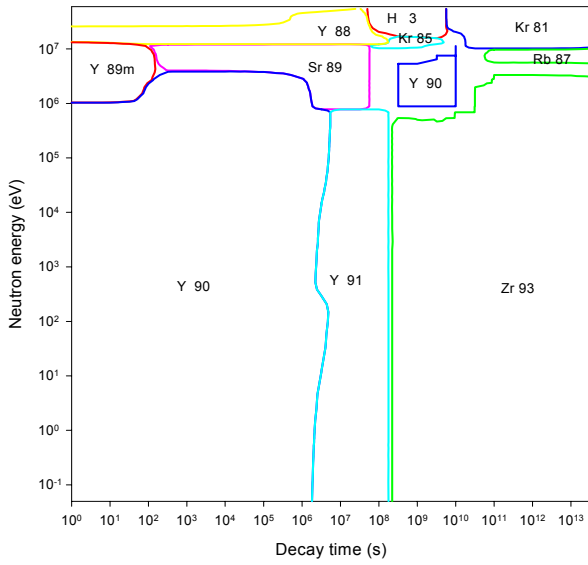


Decay time (years)

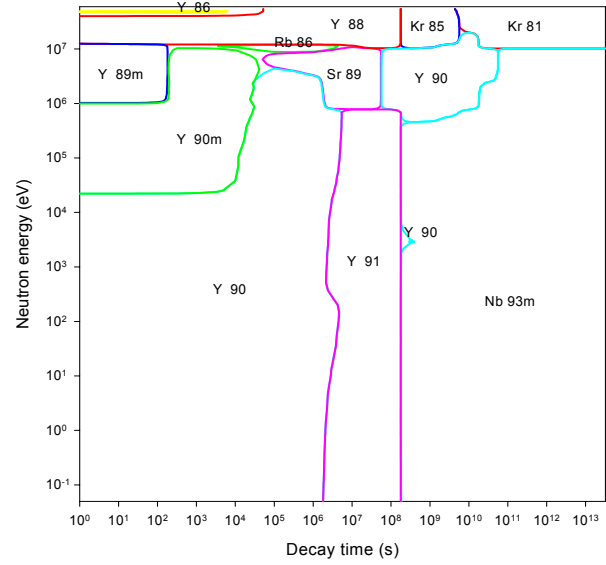
Decay time (years)

# Yttrium importance diagrams & transmutation

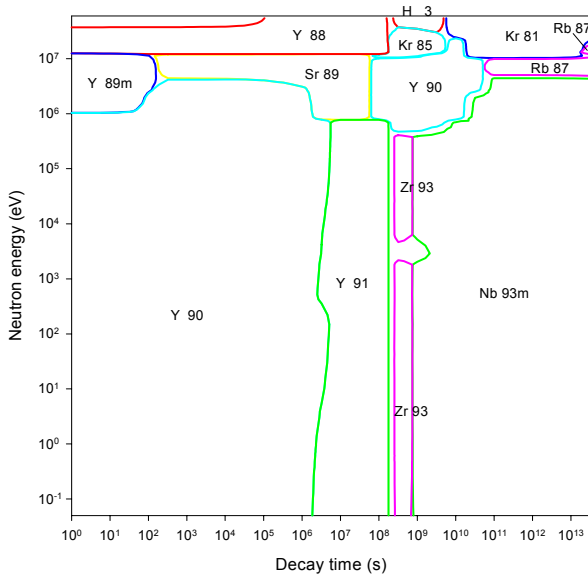
Activity



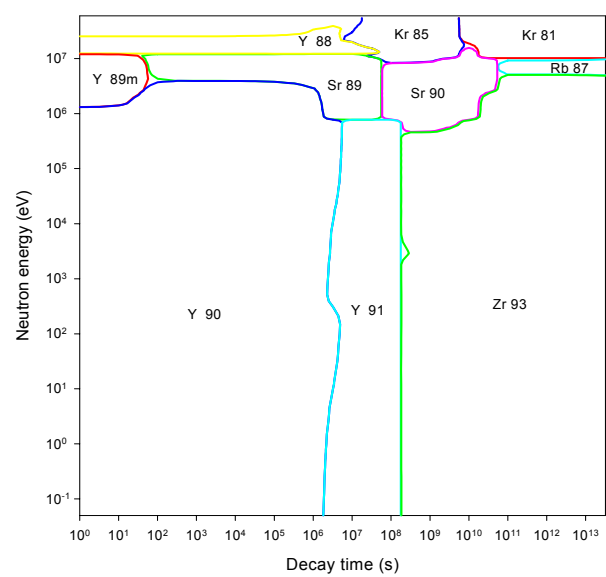
Dose rate



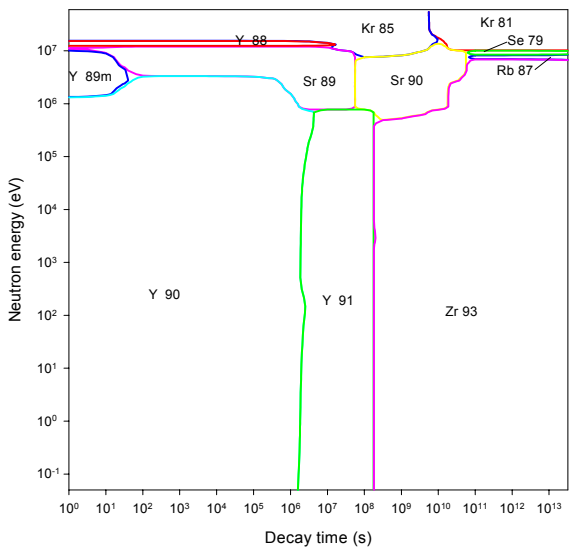
Heat output



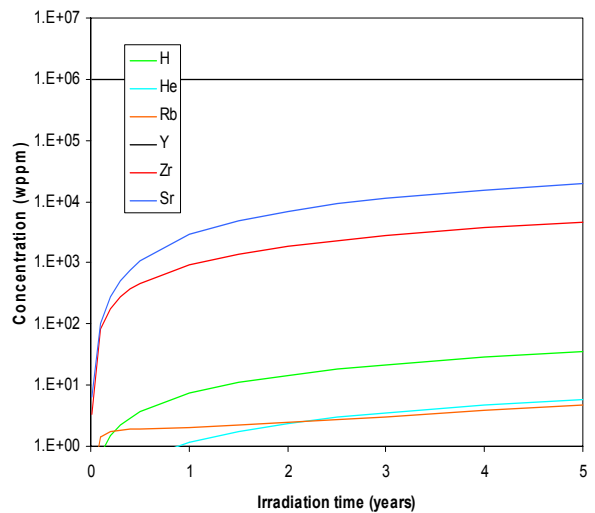
Ingestion dose



Inhalation dose



First wall transmutation





# Zirconium

## General properties

Atomic number	40	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	165	Zr90	51.45
Melting point / K	2128	Zr91	11.22
Boiling point / K	4682	Zr92	17.15
Density / kgm <sup>-3</sup>	6506	Zr94	17.38 (T <sub>½</sub> = 6.00 10 <sup>15</sup> y)
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	22.7	Zr96	2.80 (T <sub>½</sub> = 3.90 10 <sup>19</sup> y)
Electrical resistivity / Ωm	4.21 10 <sup>-7</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	5.70 10 <sup>-6</sup>		
Crystal structure	HCP		
Number of stable isotopes	3 (5)		
Mean atomic weight	91.224		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	1.44E15	8.69E14	4.03E14	4.45E12	2.41E9	1.18E9	kW kg <sup>-1</sup>	3.04E-1	1.02E-1	4.69E-2	7.36E-4	1.06E-7	4.81E-9
Zr90m	36.81						Zr90m	64.86					
Y89m	20.34	31.83	31.67				Y89m	14.04	39.66	39.62			
Zr89	19.21	31.87	31.71				Zr89	5.06	15.15	15.13			
Zr95	4.37	7.26	15.07	27.22			Zr95	2.83	8.49	17.69	22.50		
Nb95	4.23	7.03	15.19	58.71			Nb95	2.60	7.80	16.92	46.04		
Zr89m	2.95	2.05					Nb97	2.38	7.13	0.41			
Nb97	2.76	4.59	0.26				Zr97	1.81	5.40	0.31			
Zr97	2.76	4.57	0.26				Zr89m	1.50	1.88				
Nb97m	2.63	4.35	0.25				Nb97m	1.48	4.43	0.25			
Y90	1.78	2.96	2.51		23.15		Y90	1.26	3.79	3.23	0.12	78.43	
Y88	0.38	0.63	1.33	11.57			Y88	0.78	2.34	4.96	30.29		
Y91	0.31	0.51	1.07	1.33			Y91	0.14	4.32	0.89	0.78		
H3				0.30	2.18		Sr90				0.02	14.61	
Sr90				0.13	23.14		Nb93m					2.81	60.03
Zr93				0.01	25.94	50.60	Nb94					2.27	1.57
Nb93m					25.09	49.34	Zr93					1.80	38.28
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	5.40E5	1.27E5	6.37E4	1.11E3	4.10E-3	1.45E-4	Sv kg <sup>-1</sup>	5.49E5	5.45E5	2.67E5	3.73E3	1.80E1	7.29E-1
Zr90m	75.09						Zr89	39.90	40.14	37.83			
Y89m	13.06	52.37	48.10				Zr97	15.28	15.32	0.83			
Zr89	2.61	11.11	10.20				Y90	12.69	12.77	10.26		8.38	
Nb95	2.04	8.71	17.38	42.55			Zr95	10.93	11.00	21.61	30.81		
Zr95	2.02	8.62	16.52	18.90			Nb95	6.46	6.50	13.31	40.58		
Nb97m	1.21	5.13	0.27				Y91	1.96	1.98	3.88	3.82		
Nb97	1.17	4.97	0.26				Y88	1.30	1.31	2.62	17.92		
Zr89m	1.07	1.91					Sr89	0.82	0.83	1.62	0.81		
Y88	0.84	3.61	7.02	38.54			Nb97	0.49	0.49	0.02			
Zr97	0.30	1.30	0.06				Nb96	0.41	0.41	0.06			
Nb94					98.89	74.75	Sr90	0.03	0.03	0.06	4.53	86.95	
Nb93m					1.08	25.21	Zr93				0.01	3.83	90.30
							Nb93m					0.41	9.60

Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	8.24E5	8.22E5	6.44E5	1.68E4	1.09E2	1.60E1		1.79E12	5.20E11	2.88E11	5.22E9	7.70E5	1.21E5
Zr95	45.24	45.34	55.65	42.47			Zr90m	69.14					
Zr89	18.52	18.55	10.92				Y89m	14.94	48.37	40.35			
Nb95	13.37	13.40	17.12	27.95			Zr89	4.08	14.02	11.69			
Y91	4.86	4.87	5.96	3.14			Zr95	3.53	12.14	21.11	23.19		
Y90	4.70	4.70	2.36	0.05	0.76		Nb95	3.42	11.76	21.29	50.02		
Zr97	4.46	4.45	0.15				Nb97m	1.51	5.19	0.25			
Y88	2.94	2.95	3.67	13.46			Zr89m	1.49	2.14				
Sr89	1.67	1.68	2.04	0.55			Y88	0.83	2.86	5.05	26.63		
Nb97	0.21	0.21					Nb96	0.28	0.98	0.13			
Nb96	0.16	0.16	0.01				Zr97	0.22	0.76	0.03			
Sr90	0.12	0.12	0.15	5.75	81.81		Nb97	0.22	0.76	0.03			
Nb95m	0.07	0.07	0.09	0.06			Y90m	0.22	0.75				
Y90m	0.07	0.07					Sr90				0.11	72.47	
Zr93				0.09	14.33	93.33	Nb94					11.30	2.24
Nb93m					0.99	6.55	Zr93					8.12	49.33
Nb94						0.08	Nb93m					7.85	48.10

# Zirconium

## Pathway analysis

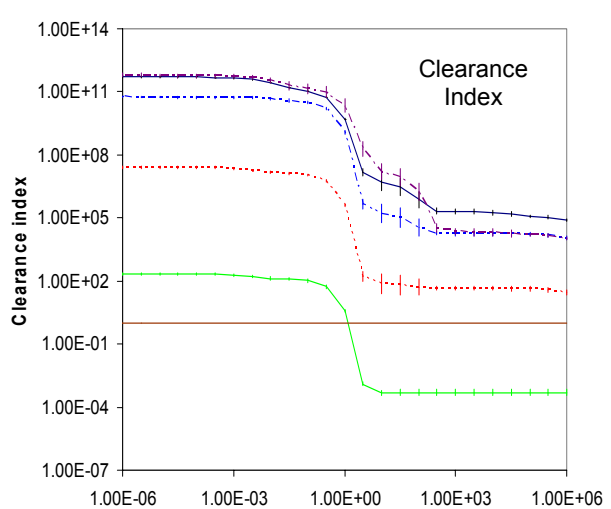
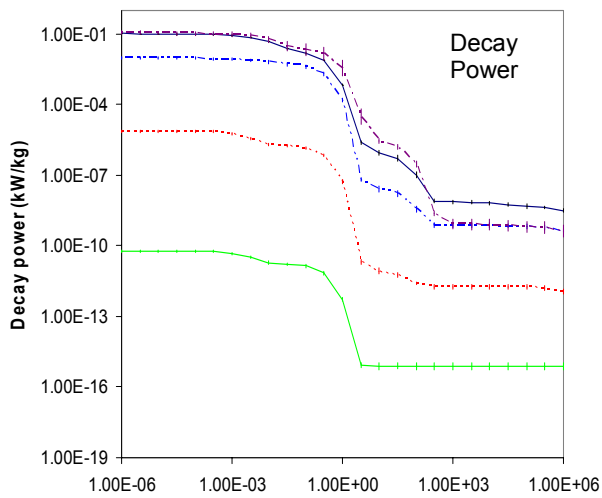
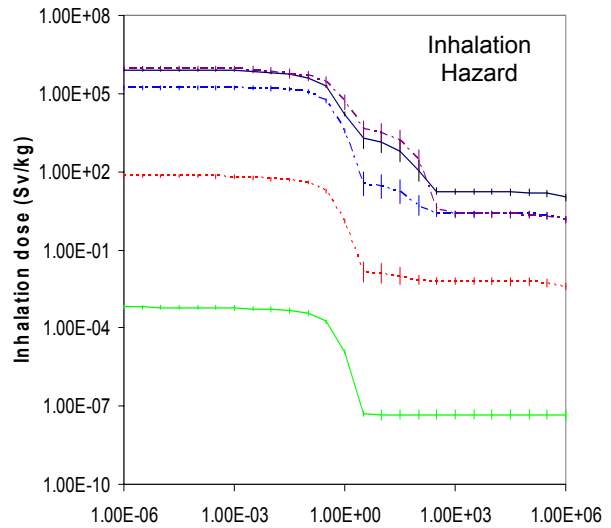
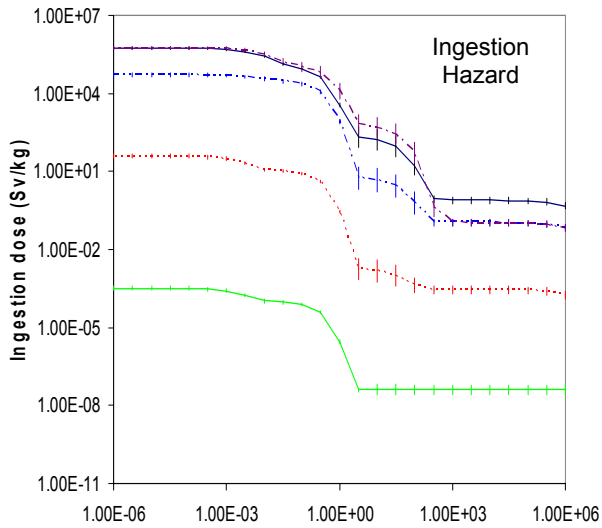
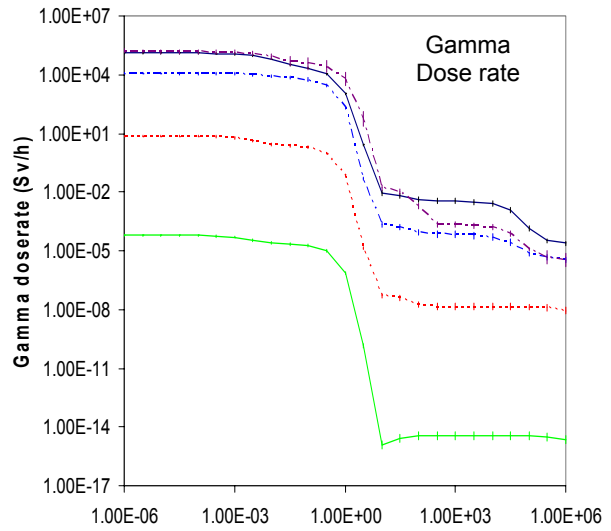
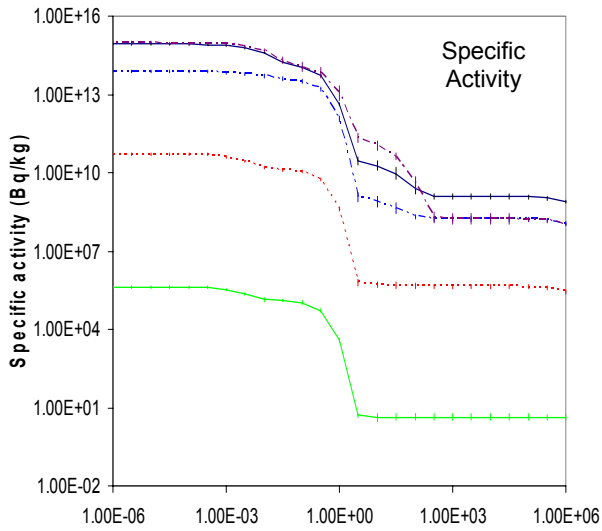
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Zr90m	0.809 s	Zr90(n,n')Zr90m Zr91(n,2n)Zr90m Zr92(n,2n)Zr91(n,2n)Zr90m Zr91(n,2n)Zr90(n,n')Zr90m Zr92(n,3n)Zr90m Zr94(n,3n)Zr92(n,3n)Zr90m Zr94(n,4n)Zr91(n,2n)Zr90m Zr94(n,5n)Zr90m				68.7 20.3 6.7 1.2	28.8 22.0 2.2 0.2	29.5 16.2 1.0	23.0 13.6
Y89m	15.663 s	Zr91(n,α)Sr88(n,γ)Sr89(β <sup>-</sup> )Y89m Zr92(n,α)Sr89(β <sup>-</sup> )Y89m &Zr90(n,2n)Zr89(β <sup>+</sup> )Y89m Zr90(n,d)Y89m &Zr91(n,2n)Zr90(n,2n)Zr89(β <sup>+</sup> )Y89m &Zr91(n,3n)Zr89(β <sup>+</sup> )Y89m &Zr92(n,3n)Zr90(n,2n)Zr89(β <sup>+</sup> )Y89m Zr91(n,t)Y89m &Zr92(n,4n)Zr89(β <sup>+</sup> )Y89m Zr94(n,4n)Zr91(n,3n)Zr89(β <sup>+</sup> )Y89m Zr92(n,nt)Y89m	99.4 0.4	99.0 0.9	98.4 1.0	87.2 3.4 3.2	73.5 11.2 1.3	48.6 14.7 15.7	41.3 15.3 8.4
Zr97	16.744 h	Zr96(n,γ)Zr97	100.0	100.0	100.0	99.9	99.4	99.5	99.7
Y90	2.671 d	&Zr91(n,α)Sr88(n,γ)Sr89(β <sup>-</sup> )Y89(n,γ)Y90 Zr92(n,γ)Zr93(n,α)Sr90(β <sup>-</sup> )Y90 Zr92(n,α)Sr89(β <sup>-</sup> )Y89(n,γ)Y90 &Zr90(n,p)Y90 &Zr91(n,d)Y90 &Zr91(n,2n)Zr90(n,p)Y90 &Zr92(n,2n)Zr91(n,d)Y90 &Zr92(n,t)Y90 &Zr94(n,3n)Zr92(n,t)Y90 &Zr94(n,4n)Zr91(n,d)Y90 &Zr94(n,2nt)Y90	93.0 5.9 0.8	3.5 96.1	42.7 55.5 0.9	90.6 3.6 3.6 1.2	50.6 29.8 1.0 2.8	29.1 34.1 1.4	15.3 20.3 36.2
Zr89	3.267 d	&Zr90(n,2n)Zr89 &Zr91(n,2n)Zr90(n,2n)Zr89 &Zr91(n,3n)Zr89 &Zr92(n,3n)Zr90(n,2n)Zr89 &Zr92(n,4n)Zr89 Zr94(n,4n)Zr91(n,3n)Zr89				94.8 4.1	83.5 1.6 8.7 3.3	61.1 19.8 1.7 10.2 2.4	57.7 11.8 23.6
Nb95	34.991 d	&Zr94(n,γ)Zr95(β <sup>-</sup> )Nb95 &Zr96(n,2n)Zr95(β <sup>-</sup> )Nb95 &Zr96(n,d)Y95(β <sup>-</sup> )Zr95(β <sup>-</sup> )Nb95	99.9	100.0	100.0	0.3 99.0	0.5 89.9 8.3	0.3 81.7 17.0	0.2 76.6 22.7
Y91	58.51 d	&Zr91(n,α)Sr88(n,γ)Sr89(β <sup>-</sup> )Y89(n,γ) Y90(n,γ)Y91 &Zr92(n,γ)Zr93(n,α)Sr90(n,γ)Sr91(β <sup>-</sup> )Y91 &Zr92(n,γ)Zr93(n,α)Sr90(β <sup>-</sup> )Y90(n,γ)Y91 &Zr92(n,γ)Zr93(β <sup>-</sup> )Nb93m(n,γ)Nb94 (n,α)Y91 &Zr91(n,p)Y91 &Zr92(n,2n)Zr91(n,p)Y91 &Zr94(n,α)Sr91(β <sup>-</sup> )Y91 &Zr92(n,d)Y91 &Zr94(n,2n)Zr93(n,t)Y91 &Zr94(n,3n)Zr92(n,d)Y91 &Zr94(n,nt)Y91	68.5 23.6 4.4 1.6	0.3 85.9 11.2 1.3	0.5 96.9 0.8 0.3	58.4 18.4 13.8 8.3 0.1	15.1 1.5 2.0 67.4 0.9 10.0 1.4	9.1 2.4 0.7 63.8 2.0 3.6 14.2	2.4 42.2 46.3
Zr95	64.032 d	Zr94(n,γ)Zr95 Zr96(n,2n)Zr95 Zr96(n,d)Y95(β <sup>-</sup> )Zr95	99.9	100.0	100.0	0.3 99.6	0.5 90.5 8.4	82.1 17.1	76.7 22.8
Y88	106.63 d	&Zr90(n,2n)Zr89(β <sup>+</sup> )Y89(n,2n)Y88				86.5	35.7	1.7	

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	&Zr90(n,d)Y89(n,2n)Y88 Zr90(n,3n)Zr88(β <sup>+</sup> )Y88 Zr90(n,t)Y88 &Zr91(n,3n)Zr89(β <sup>+</sup> )Y89m(IT)Y89(n,2n)Y88   Zr91(n,4n)Zr88(β <sup>+</sup> )Y88 Zr91(n,nt)Y88 Zr92(n,5n)Zr88(β <sup>+</sup> )Y88 Zr92(n,2nt)Y88				8.8	8.1	0.6		
							37.8	60.6	35.9	
							7.9	27.7	30.8	
							3.7	0.6		
								1.4	8.6	
								0.6	6.9	
									5.8	
									3.1	
Kr85	10.752 y	&Zr90(n,2n)Zr89(β <sup>+</sup> )Y89(n,2n)Y88(β <sup>+</sup> )_   Sr88(n,α)Kr85 &Zr90(n,d)Y89(n,2n)Y88(β <sup>+</sup> )Sr88(n,α)Kr85   &Zr91(n,α)Sr88(n,α)Kr85   &Zr90(n,2n)Zr89(β <sup>+</sup> )Y89(n,d)Sr88(n,α)Kr85   &Zr92(n,nα)Sr88(n,α)Kr85   &Zr90(n,3n)Zr88(β <sup>+</sup> )Y88(β <sup>+</sup> )Sr88(n,α)Kr85   &Zr90(n,t)Y88(β <sup>+</sup> )Sr88(n,α)Kr85   &Zr91(n,4n)Zr88(β <sup>+</sup> )Y88(β <sup>+</sup> )Sr88(n,α)Kr85   &Zr91(n,nt)Y88(β <sup>+</sup> )Sr88(n,α)Kr85   &Zr90(n,nt)Y87(β <sup>+</sup> )Sr87(n,h)Kr85				73.5	14.3	0.6	0.3	
							7.7	3.9	0.2	0.1
							5.5	0.8	0.2	0.4
							4.3	2.9	0.3	0.2
							1.2	5.0	1.0	0.7
								47.7	55.5	24.0
								11.4	29.1	23.6
									1.2	5.8
									0.6	5.3
										6.8
H3	12.33 y	Zr91(n,X)H3 Zr90(n,X)H3 Zr92(n,2n)Zr91(n,X)H3 Zr92(n,X)H3 Zr94(n,2n)Zr93(n,X)H3 Zr94(n,X)H3 Zr96(n,X)H3 &Zr90(n,d)Y89(n,X)H3 Zr94(n,3n)Zr92(n,X)H3 &Zr92(n,3n)Zr90(n,X)H3				52.5	14.3	11.5	11.7	
						22.7	43.6	49.2	45.8	
						8.8	0.7			
						5.6	14.1	13.9	15.5	
						4.8	0.5			
						1.7	12.5	13.2	15.2	
							1.7	1.9	2.3	
							1.3			
							1.1			
							1.0	0.6		
Nb93m	16.126 y	Zr92(n,γ)Zr93(β <sup>-</sup> )Nb93m Zr91(n,γ)Zr92(n,γ)Zr93(β <sup>-</sup> )Nb93m &Zr96(n,2n)Zr95(β <sup>-</sup> )Nb95(n,2n) Nb94(n,2n)Nb93m &Zr96(n,2n)Zr95(β <sup>-</sup> )Nb95(β <sup>-</sup> )Mo95_ (n,2n)Mo94(n,d)Nb93m &Zr96(n,2n)Zr95(β <sup>-</sup> )Nb95(β <sup>-</sup> )Mo95(n,t)Nb93m   Zr94(n,2n)Zr93(β <sup>-</sup> )Nb93m &Zr96(n,2n)Zr95(β <sup>-</sup> )Nb95(β <sup>-</sup> )Mo95(n,d)_ Nb94(n,2n)Nb93m Zr96(n,2n)Zr95(β <sup>-</sup> )Nb95(β <sup>-</sup> )Mo95(n,2n)_ Mo94(n,2n)Mo93(n,p)Nb93m &Zr96(n,2n)Zr95(β <sup>-</sup> )Nb95(n,2n)Nb94_ (n,2n)Nb93(n,n')Nb93m &Zr96(n,2n)Zr95(β <sup>-</sup> )Nb95(n,3n)Nb93m &Zr96(n,d)Y95(β <sup>-</sup> )Zr95(β <sup>-</sup> )Nb95(β <sup>-</sup> )_ Mo95(n,t)Nb93m Zr96(n,d)Y95(β <sup>-</sup> )Zr95(β <sup>-</sup> )Nb95(n,3n)Nb93m   &Zr96(n,2n)Zr95(β <sup>-</sup> )Nb95(β <sup>-</sup> )Mo95_ (n,3n)Mo93(n,p)Nb93m	98.7 1.3	99.7 0.3	99.8 0.2					
						41.9	0.2			
						33.1	3.8	0.9	0.5	
						10.2	56.0	74.3	71.7	
						6.1	0.4	0.2	0.2	
						3.5	0.9	0.3	0.1	
						1.7				
						1.2				
							25.9	5.4	3.5	
							5.1	15.5	21.3	
								2.4	1.1	1.0
							1.9	0.3		
Sr90	28.79 y	Zr92(n,γ)Zr93(n,α)Sr90 Zr91(n,α)Sr88(n,γ)Sr89(n,γ)Sr90 Zr91(n,γ)Zr92(n,γ)Zr93(n,α)Sr90 Zr94(n,2n)Zr93(n,α)Sr90 Zr94(n,nα)Sr90 Zr92(n,h)Sr90 Zr96(n,3n)Zr94(n,nα)Sr90 Zr96(n,3nα)Sr90	96.3 2.4 1.3	99.7 0.3	99.1 0.7 0.2					
						64.0	0.5			
						35.4	95.4	84.0	67.2	
							1.7	11.0	12.3	
							1.1			
								2.2	17.8	
Mo93	4000 y	&Zr96(n,2n)Zr95(β <sup>-</sup> )Nb95(β <sup>-</sup> )Mo95_ (n,2n)Mo94(n,2n)Mo93 &Zr96(n,2n)Zr95(β <sup>-</sup> )Nb95(β <sup>-</sup> )Mo95(n,3n)Mo93   &Zr96(n,d)Y95(β <sup>-</sup> )Zr95(β <sup>-</sup> )Nb95(β <sup>-</sup> )_ Mo95(n,3n)Mo93				99.4	0.7	0.4	0.3	
							89.9	81.9	76.2	
							8.2	17.1	22.5	



Nuclide	$T_{1/2}$	Pathway	210	186	151	42	30	21	6
Nb94	$2.0 \cdot 10^4$ y	&Zr92(n, $\gamma$ )Zr93( $\beta^-$ )Nb93m(n, $\gamma$ )Nb94	91.4	92.0	92.3				
		&Zr92(n, $\gamma$ )Zr93( $\beta^-$ )Nb93(n, $\gamma$ )Nb94	7.6	7.8	7.5				
		&Zr91(n, $\gamma$ )Zr92(n, $\gamma$ )Zr93( $\beta^-$ )Nb93m(n, $\gamma$ )_Nb94	1.0						
		&Zr96(n,2n)Zr95( $\beta^-$ )Nb95(n,2n)Nb94				84.9	15.4	10.4	9.8
		&Zr96(n,2n)Zr95( $\beta^-$ )Nb95( $\beta^-$ )Mo95(n,d)Nb94				10.5	74.2	71.1	68.4
		&Zr96(n,2n)Zr95( $\beta^-$ )Nb95( $\beta^-$ )Mo95_(n,2n)Mo94(n,p)Nb94				3.6	0.6	0.2	
		&Zr96(n,d)Y95( $\beta^-$ )Zr95( $\beta^-$ )Nb95( $\beta^-$ )_Mo95(n,d)Nb94					6.8	14.7	20.2
		&Zr96(n,d)Y95( $\beta^-$ )Zr95( $\beta^-$ )Nb95(n,2n)Nb94					1.4	2.2	2.4
Tc99	$2.1 \cdot 10^5$ y	&Zr96(n, $\gamma$ )Zr97( $\beta^-$ )Nb97( $\beta^-$ )Mo97(n, $\gamma$ )_Mo98(n, $\gamma$ )Mo99( $\beta^-$ )Tc99	4.9	4.5	5.0	99.6	99.5	99.5	99.6
		&Zr94(n, $\gamma$ )Zr95( $\beta^-$ )Nb95( $\beta^-$ )Mo95(n, $\gamma$ )_Mo96(n, $\gamma$ )Mo97(n, $\gamma$ )Mo98(n, $\gamma$ )Mo99( $\beta^-$ )_Tc99	0.8	7.4	0.1				
		Other pathways involving (n, $\gamma$ ) and $\beta^-$	94.3	88.1	94.9	0.4	0.5	0.5	0.4
Kr81	$2.1 \cdot 10^5$ y	&Zr90(n, $\alpha$ )Sr87(n,2n)Sr86(n, $\alpha$ )Kr83_(n,2n)Kr82(n,2n)Kr81				23.6			
		&Zr90(n, $\alpha$ )Sr87(n, $\alpha$ )Kr84(n,2n)Kr83_(n,2n)Kr82(n,2n)Kr81				16.7			
		&Zr90(n, $\alpha$ )Sr87(n,2n)Sr86(n,2n)Sr85_(n,2n)Sr84(n, $\alpha$ )Kr81				7.4			
		&Zr90(n, $\alpha$ )Sr87(n,2n)Sr86(n,2n)Sr85_(n, $\alpha$ )Kr82(n,2n)Kr81				5.7			
		&Zr90(n, $\alpha$ )Sr87(n, $\alpha$ )Kr83(n,3n)Kr81					11.8	0.3	
		&Zr90(n, $\alpha$ )Sr86(n, $\alpha$ )Kr83(n,3n)Kr81					7.8	0.3	
		&Zr90(n, $\alpha$ )Sr86(n, $\alpha$ )Kr82(n,2n)Kr81					7.5	0.3	
		&Zr90(n, $\alpha$ )Sr86(n,2n $\alpha$ )Kr81					0.2	18.6	0.9
		&Zr90(n,3n)Zr88( $\beta^+$ )Y88( $\beta^+$ )Sr88(n,3n)_Sr86(n,2n $\alpha$ )Kr81						8.8	
		&Zr90(n,nt)Y87( $\beta^+$ )Sr87(n,3n $\alpha$ )Kr81							16.0
		&Zr90(n,3n $\alpha$ )Sr84(n,nt)Rb81( $\beta^+$ )Kr81							15.3
		&Zr90(n,4n)Zr87( $\beta^+$ )Y87( $\beta^+$ )Sr87(n,3n $\alpha$ )Kr81							10.2
		Other pathways involving (n,2n), (n, $\alpha$ ), $\beta^+$				46.6	72.7	71.7	57.6
Zr93	$1.5 \cdot 10^6$ y	Zr92(n, $\gamma$ )Zr93	98.0	99.6	99.7				
		Zr91(n, $\gamma$ )Zr92(n, $\gamma$ )Zr93	2.0	0.4	0.3				
		Zr94(n,2n)Zr93				99.7	82.2	57.6	58.1
		&Zr94(n,d)Y93( $\beta^-$ )Zr93					14.0	18.2	24.5
		Zr96(n,4n)Zr93					2.0	23.0	13.0
		Zr96(n,3n)Zr94(n,2n)Zr93					1.0		
		&Zr96(n,nt)Y93( $\beta^-$ )Zr93							3.7

# Zirconium activation characteristics

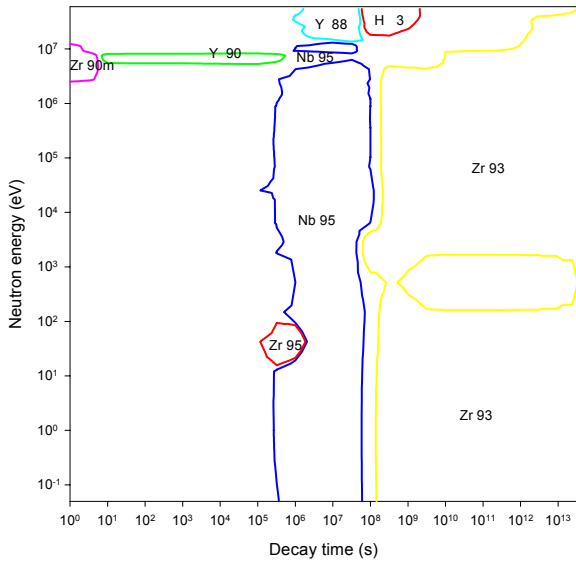


Decay time (years)

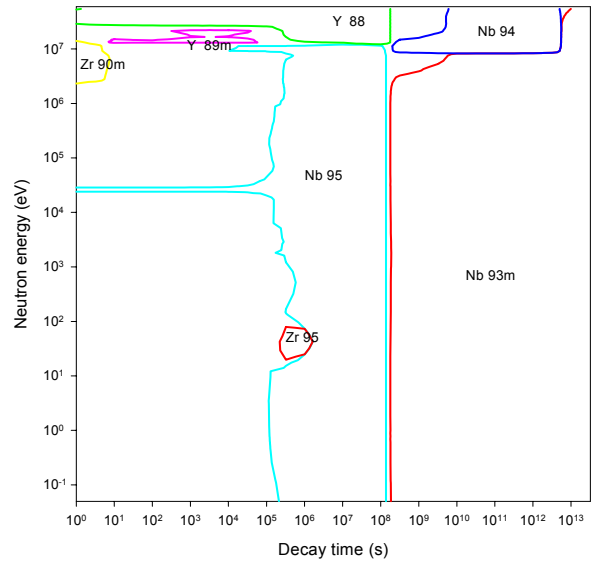
Decay time (years)

# Zirconium importance diagrams & transmutation

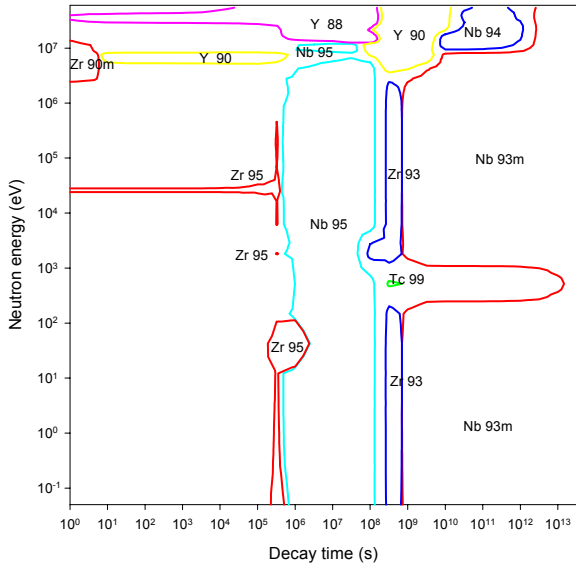
Activity



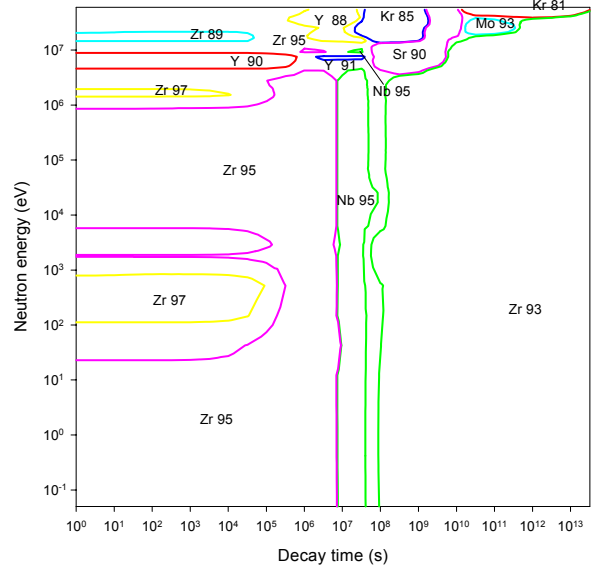
Dose rate



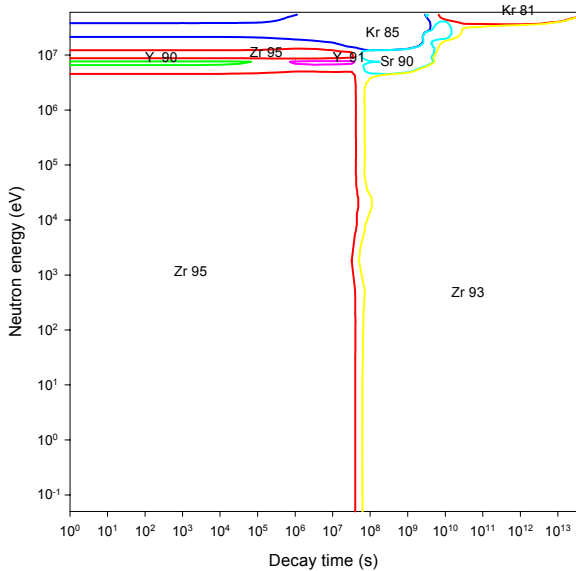
Heat output



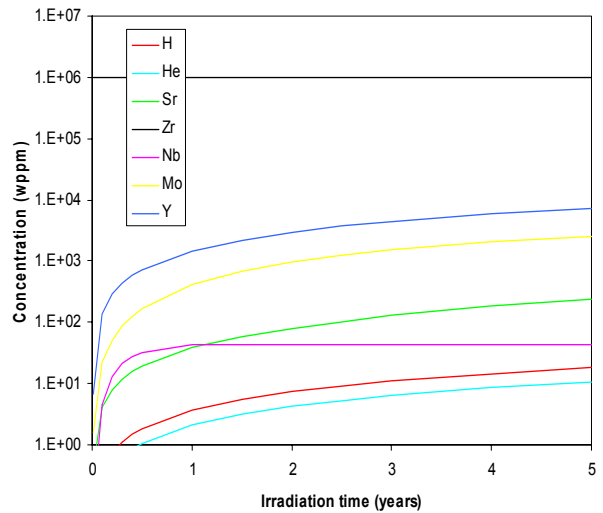
Ingestion dose



Inhalation dose



First wall transmutation





# Niobium

## General properties

Atomic number	41	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	20	Nb93	100.0
Melting point / K	2750		
Boiling point / K	5017		
Density / kgm <sup>-3</sup>	8570		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	53.7		
Electrical resistivity /Ωm	1.25 10 <sup>-7</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	7.3 10 <sup>-6</sup>		
Crystal structure	BCC		
Number of stable isotopes	1		
Mean atomic weight	92.90638		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	3.45E15	2.54E15	1.19E15	6.46E13	1.37E12	1.33E10	kW kg <sup>-1</sup>	2.05E-1	1.98E-1	1.54E-1	5.13E-4	1.21E-4	3.66E-6
Nb94m	59.47	45.10					Nb95	51.19	53.11	63.73	14.87		
Nb95	23.53	31.94	63.63	0.90			Nb92m	33.05	34.28	34.40			
Nb92m	12.58	17.08	28.45				Nb94m	7.57	4.39				
Nb93m	1.91	2.60	5.56	98.10	65.79	0.69	Nb96	5.75	5.95	0.56			
Nb95m	0.96	1.31	1.39				Y90	0.87	0.90	0.46			
Nb96	0.79	1.07	0.17				Nb95m	0.64	0.67	0.42			
Nb94	0.01	0.01	0.03	0.64	30.57	98.08	Nb93m	0.15	0.16	0.21	61.28	3.67	0.01
Nb91				0.08	3.59		Nb94	0.05	0.05	0.07	22.82	96.18	99.53
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	2.77E5	2.75E5	2.23E5	2.80E2	1.65E2	5.17E0	Sv kg <sup>-1</sup>	8.67E5	8.49E5	6.78E5	8.74E3	8.23E2	2.24E1
Nb95	52.26	52.78	60.65	37.48			Nb95	54.27	55.46	64.68	3.90		
Nb92m	39.89	40.20	38.63				Nb92m	30.02	30.68	29.91			
Nb96	5.96	5.99	0.54				Y90	3.72	3.80	1.88			
Nb94m	1.01	0.57					Nb96	3.47	3.53	0.32			
Nb94	0.05	0.06	0.07	58.90	99.93	99.53	Nb95m	2.15	2.20	1.36			
Y88	0.02	0.02	0.02	2.10			Nb93m	0.91	0.93	1.17	87.04	13.12	0.04
Nb93m				1.30	0.03		Nb94		0.08	0.10	8.15	86.34	99.15
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	2.00E6	1.97E6	1.74E6	1.36E5	2.23E4	6.46E2		1.37E12	1.35E12	1.11E12	1.11E10	4.27E9	1.31E8
Nb95	72.95	74.03	78.38	0.77			Nb95	59.34	60.12	68.00	5.27		
Nb92m	12.79	12.97	11.48				Nb92m	31.73	32.14	30.40			
Nb93m	5.95	6.04	6.85	83.75	7.25	0.02	Nb96	5.00	5.05	0.45			
Nb95m	1.46	1.48	0.83				Nb94m	2.38	1.34				
Nb94	1.02	1.04	1.18	15.08	91.79	99.21	Nb93m	0.48	0.49	0.59	56.88	2.10	
Nb96	0.90	0.91	0.07				Nb94	0.30	0.31	0.37	37.63	97.87	99.91
Y90	0.89	0.90	0.40				Nb95m	0.22	0.22	0.13			

# Niobium

## Pathway analysis

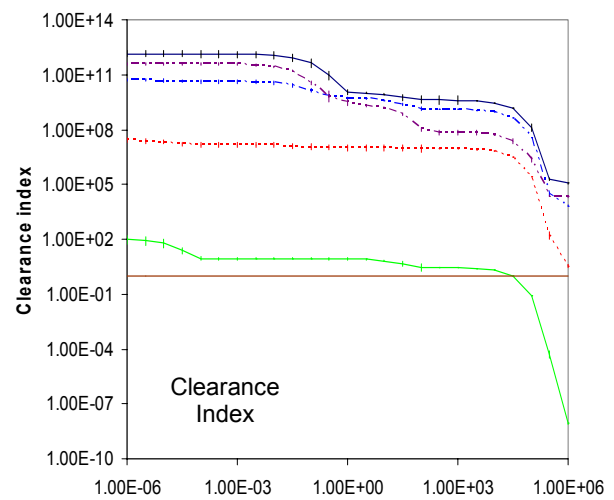
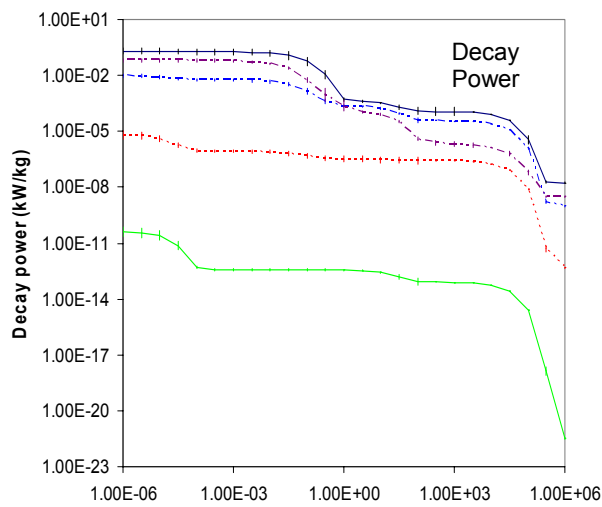
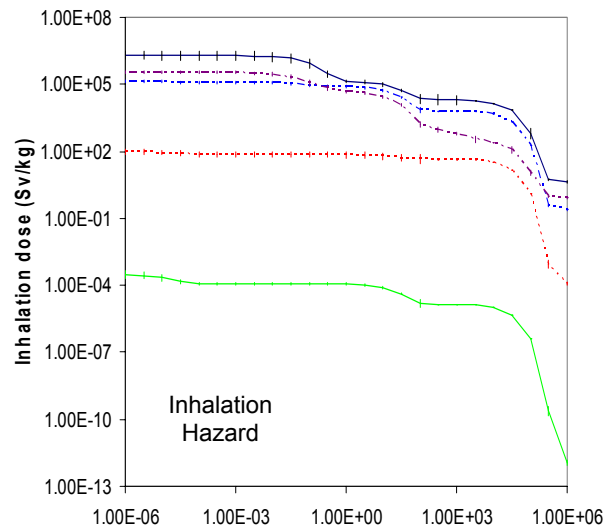
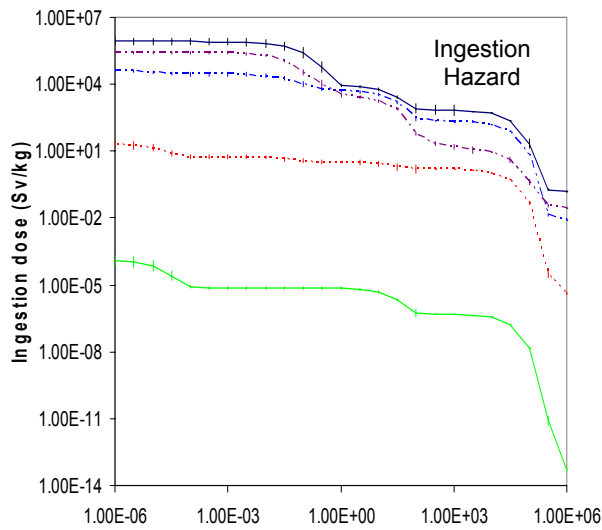
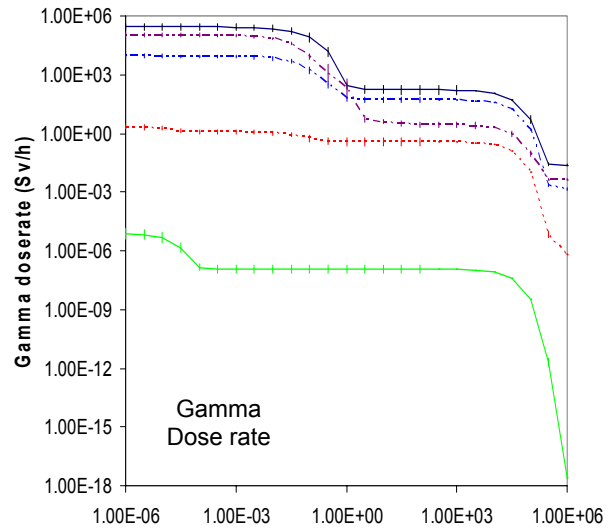
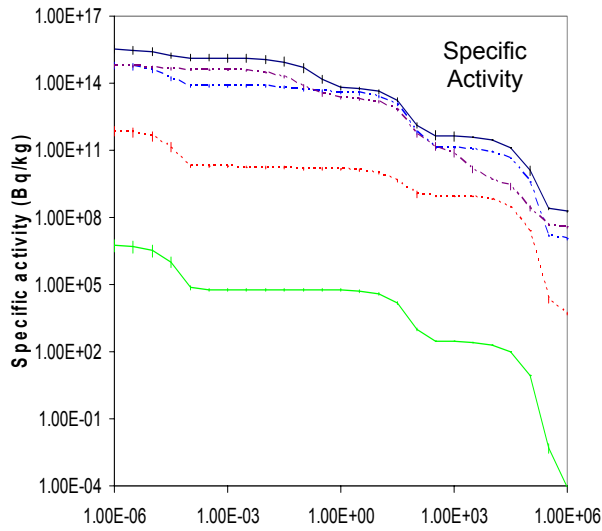
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Zr90m	0.809 s	Nb93(n,α)Y90m(β <sup>-</sup> )Zr90m Nb93(n,2n)Nb92m(β <sup>+</sup> )Zr92(n,2n)Zr91_(n,2n)Zr90m &Nb93(n,2n)Nb92(n,2n)Nb91(n,d)Zr90m &Nb93(n,α)Y90(β <sup>-</sup> )Zr90(n,n')Zr90m Nb93(n,d)Zr92(n,2n)Zr91(n,2n)Zr90m Nb93(n,2n)Nb92(n,d)Zr91(n,2n)Zr90m Nb93(n,2n)Nb92(n,t)Zr90m Nb93(n,t)Zr91(n,2n)Zr90m &Nb93(n,3n)Nb91(n,d)Zr90m Nb93(n,2n)Nb92m(β <sup>+</sup> )Zr92(n,3n)Zr90m Nb93(n,d)Zr92(n,3n)Zr90m Nb93(n,nt)Zr90m	100.0	100.0	100.0	52.0	0.5		
Nb94m	6.26 m	Nb93(n,γ)Nb94m Nb93(n,γ)Nb94(n,n')Nb94m Nb93(n,n')Nb93m(n,γ)Nb94m	100.0	100.0	100.0	94.0	96.5	97.3	98.1
Y90m	3.19 h	Nb93(n,α)Y90m Nb93(n,t)Zr91(n,d)Y90m Nb93(n,2n)Nb92m(β <sup>+</sup> )Zr92(n,t)Y90m Nb93(n,d)Zr92(n,t)Y90m &Nb93(n,3n)Nb91(n,2p)Y90m	100.0	100.0	100.0	98.3	58.4	34.2	68.9
Nb90	14.6 h	&Nb93(n,2n)Nb92(n,2n)Nb91(n,2n)Nb90 &Nb93(n,2n)Nb92(n,2n)Nb91m(n,2n)Nb90 &Nb93(n,3n)Nb91(n,2n)Nb90 &Nb93(n,2n)Nb92(n,3n)Nb90 &Nb93(n,4n)Nb90				93.7	1.7		
Nb96	23.35 h	&Nb93(n,γ)Nb94(n,γ)Nb95(n,γ)Nb96 &Nb93(n,γ)Nb94(n,γ)Nb95m(n,γ)Nb96	99.8	99.8	99.4	95.3	95.7	95.9	96.2
Y90	2.671 d	&Nb93(n,α)Y90 &Nb93(n,t)Zr91(n,d)Y90 &Nb93(n,2n)Nb92m(β <sup>+</sup> )Zr92(n,t)Y90 &Nb93(n,d)Zr92(n,t)Y90 &Nb93(n,nt)Zr90(n,p)Y90 &Nb93(n,4n)Nb90(β <sup>+</sup> )Zr90(n,p)Y90	100.0	100.0	100.0	99.9	55.9	33.0	66.7
Nb92m	10.15 d	Nb93(n,2n)Nb92m Nb93(n,2n)Nb92(n,n')Nb92m Nb93(n,n')Nb93m(n,2n)Nb92m				94.0	95.1	96.5	97.7
Nb95	34.991 d	&Nb93(n,γ)Nb94(n,γ)Nb95 Nb93(n,p)Zr93(n,γ)Zr94(n,γ)Zr95(β <sup>-</sup> )Nb95	100.0	100.0	100.0	98.9	99.0	99.2	99.6
Nb91m	60.90 d	Nb93(n,2n)Nb92(n,2n)Nb91m Nb93(n,2n)Nb92(n,2n)Nb91(n,n')Nb91m Nb93(n,3n)Nb91m Nb93(n,3n)Nb91(n,n')Nb91m				96.4	5.2	2.5	
Y88	106.63 d	&Nb93(n,nα)Y89(n,2n)Y88 &Nb93(n,2n)Nb92(n,2n)Nb91(n,α)Y88 &Nb93(n,2n)Nb92(n,α)Y89(n,2n)Y88 Nb93(n,2n)Nb92(n,nα)Y88 &Nb93(n,α)Y90(β <sup>-</sup> )Zr90(n,2n)Zr89(β <sup>+</sup> )_Y89(n,2n)Y88 Nb93(n,2n)Nb92m(β <sup>+</sup> )Zr92(n,α)Sr89(β <sup>-</sup> )_Y89(n,2n)Y88 &Nb93(n,3n)Nb91(n,α)Y88 Nb93(n,2nα)Y88 &Nb93(n,3n)Nb91(n,t)Zr89(β <sup>+</sup> )Y89m_(IT)Y89(n,2n)Y88 &Nb93(n,nt)Zr90(n,3n)Zr88(β <sup>+</sup> )Y88				50.5	20.8	1.1	0.6
						17.4	0.3		
						10.4			
						6.8	15.2	1.6	0.6
						6.4			
						3.0			
							16.0	1.3	2.1
							14.7	48.6	32.6
							8.6	1.0	
							0.4	11.0	7.7

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&Nb93(n,4n)Nb90(β <sup>+</sup> )Zr90(n,3n)Zr88(β <sup>+</sup> )Y88 &Nb93(n,nt)Zr90(n,t)Y88 &Nb93(n,4n)Nb90(β <sup>+</sup> )Zr90(n,t)Y88 &Nb93(n,3n)Nb91(n,nt)Zr88(β <sup>+</sup> )Y88 Nb93(n,t)Zr91(n,4n)Zr88(β <sup>+</sup> )Y88 Nb93(n,t)Zr91(n,nt)Y88 &Nb93(n,2nt)Zr89(β <sup>+</sup> )Y89m(IT)Y89(n,2n)Y88						10.4 5.3 5.1 2.6 1.4 0.6	7.1 7.0 6.5 12.1 3.9 3.4 3.4
Kr85	10.752 y	&Nb93(n,nα)Y89(n,2n)Y88(β <sup>+</sup> )Sr88(n,α)Kr85 &Nb93(n,2n)Nb92m(β <sup>+</sup> )Zr92(n,nα)Sr88_ (n,α)Kr85 &Nb93(n,2n)Nb92(n,2n)Nb91(n,α)Y88_ (β <sup>+</sup> )Sr88(n,α)Kr85 &Nb93(n,2n)Nb92(n,nα)Y88(β <sup>+</sup> )Sr88_ (n,α)Kr85 &Nb93(n,2n)Nb92(n,α)Y89(n,2n)Y88_ (β <sup>+</sup> )Sr88(n,α)Kr85 &Nb93(n,2nα)Y88(β <sup>+</sup> )Sr88(n,α)Kr85 &Nb93(n,3n)Nb91(n,α)Y88(β <sup>+</sup> )Sr88(n,α)Kr85 &Nb93(n,nt)Zr90(n,3n)Zr88(β <sup>+</sup> )Y88(β <sup>+</sup> )_ Sr88(n,α)Kr85 &Nb93(n,3nα)Y87(β <sup>+</sup> )Sr87(n,h)Kr85				50.8 9.2 8.9 6.9 5.5	15.4 3.1 0.2 11.6 0.8 32.1 11.8 0.2	0.5 0.2 0.8 0.2 70.4 0.5 4.6	0.2 0.2 0.2 40.6 0.8 2.7 10.8
H3	12.33 y	&Nb93(n,γ)Nb94(n,X)H1(n,γ)H2(n,γ)H3 Nb93(n,X)H1(n,γ)H2(n,γ)H3 Nb93(n,X)H3 Nb93(n,2n)Nb92(n,X)H3 &Nb93(n,3n)Nb91(n,X)H3	92.3 2.3	96.2	61.4 38.0				
Nb93m	16.126 y	&Nb93(n,γ)Nb94(n,γ)Nb95(β <sup>-</sup> )Mo95_ (n,α)Zr92(n,γ)Zr93(β <sup>-</sup> )Nb93m &Nb93(n,γ)Nb94(n,α)Y91(β <sup>-</sup> )Zr91(n,γ)_ Zr92(n,γ)Zr93(β <sup>-</sup> )Nb93m &Nb93(n,γ)Nb94(n,α)Y91(n,γ)Y92(β <sup>-</sup> )_ Zr92(n,γ)Zr93(β <sup>-</sup> )Nb93m Nb93(n,p)Zr93(β <sup>-</sup> )Nb93m &Nb93(n,γ)Nb94(n,γ)Nb95(β <sup>-</sup> )Mo95_ (n,γ)Mo96(n,α)Zr93(β <sup>-</sup> )Nb93m &Nb93(n,γ)Nb94(n,γ)Nb95(n,γ)Nb96(β <sup>-</sup> )_ Mo96(n,α)Zr93(β <sup>-</sup> )Nb93m Nb93(n,n')Nb93m	59.5 30.0 8.6 1.0 0.7	1.1 97.2					
Nb91	680.0 y	&Nb93(n,2n)Nb92(n,2n)Nb91 &Nb93(n,2n)Nb92m(n,2n)Nb91 &Nb93(n,3n)Nb91				98.5 0.9	1.7 97.5	0.8 98.7	
Nb94	2.0 10 <sup>4</sup> y	&Nb93(n,γ)Nb94 &Nb93(n,n')Nb93m(n,γ)Nb94	100.0	100.0	100.0	99.6 0.3	99.8	99.9	99.9
Kr81	2.1 10 <sup>5</sup> y	&Nb93(n,nα)Y89(n,α)Rb86(β <sup>-</sup> )Sr86_ (n,α)Kr83(n,2n)Kr82(n,2n)Kr81 &Nb93(n,nα)Y89(n,2n)Y88(n,α)Rb85_ (n,α)Br82(β <sup>-</sup> )Kr82(n,2n)Kr81 &Nb93(n,3n)Nb91(n,nα)Y87(β <sup>+</sup> )Sr87_ (n,nα)Kr83(n,3n)Kr81 &Nb93(n,2nα)Y88(β <sup>+</sup> )Sr88(n,3n)Sr86_ (n,2nα)Kr81 &Nb93(n,3n)Nb91(n,2nα)Y86(β <sup>+</sup> )Sr86_ (n,2nα)Kr81 &Nb93(n,2nα)Y88(β <sup>+</sup> )Sr88(n,2nα)Kr83_ (n,3n)Kr81 &Nb93(n,2nα)Y88(n,2nα)Rb83(β <sup>+</sup> )Kr83_ (n,3n)Kr81 &Nb93(n,2nα)Y88(n,3n)Y86(β <sup>+</sup> )Sr86_ (n,2nα)Kr81 &Nb93(n,3nα)Y87(β <sup>+</sup> )Sr87(n,3nα)Kr81 Other pathways involving (n,2n), (n,α), β <sup>+</sup>				12.1 4.7	14.8	0.3 17.5 8.2 5.1 4.0 3.1	0.2 0.1 28.3 71.4

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Tc99	2.1 10 <sup>5</sup> y	&Nb93(n,γ)Nb94(n,γ)Nb95(β <sup>-</sup> )Mo95(n,γ)_ Mo96(n,γ)Mo97(n,γ)Mo98(n,γ)Mo99(β <sup>-</sup> )_ Tc99	90.3	98.2	84.9				
		&Nb93(n,γ)Nb94(n,γ)Nb95(n,γ)Nb96(β <sup>-</sup> )_ Mo96(n,γ)Mo97(n,γ)Mo98(n,γ)Mo99(β <sup>-</sup> )_ Tc99	8.3	1.4	14.4				
		&Nb93(n,γ)Nb94(n,γ)Nb95(n,γ)Nb96(n,γ)_ Nb97(β <sup>-</sup> )Mo97(n,γ)Mo98(n,γ)Mo99(β <sup>-</sup> )Tc99	0.8						
Zr93	1.5 10 <sup>6</sup> y	&Nb93(n,γ)Nb94(n,γ)Nb95(β <sup>-</sup> )Mo95_ (n,α)Zr92(n,γ)Zr93	60.1		62.0				
		&Nb93(n,γ)Nb94(n,α)Y91(β <sup>-</sup> )Zr91(n,γ)_ Zr92(n,γ)Zr93	31.4		1.7				
		&Nb93(n,γ)Nb94(n,α)Y91(n,γ)Y92(β <sup>-</sup> )_ Zr92(n,γ)Zr93	7.0						
		&Nb93(n,γ)Nb94(n,γ)Nb95(β <sup>-</sup> )Mo95_ (n,γ)Mo96(n,α)Zr93	0.7	97.3					
		Nb93(n,p)Zr93	0.4		35.7	99.5	99.7	99.8	99.9
		&Nb93(n,γ)Nb94(n,γ)Nb95(n,γ)Nb96(β <sup>-</sup> )_ Mo96(n,α)Zr93		1.0					
Nb92	3.5 10 <sup>7</sup> y	Nb93(n,2n)Nb92				99.7	99.9	99.9	99.9
		Nb93(n,n')Nb93m(n,2n)Nb92				0.3			



# Niobium activation characteristics

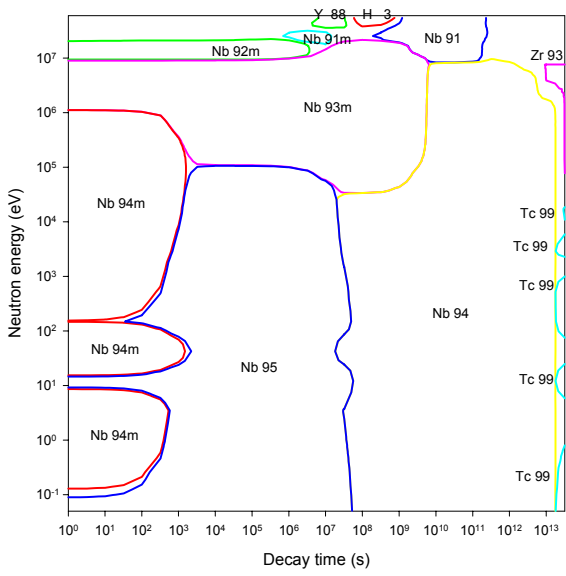


Decay time (years)

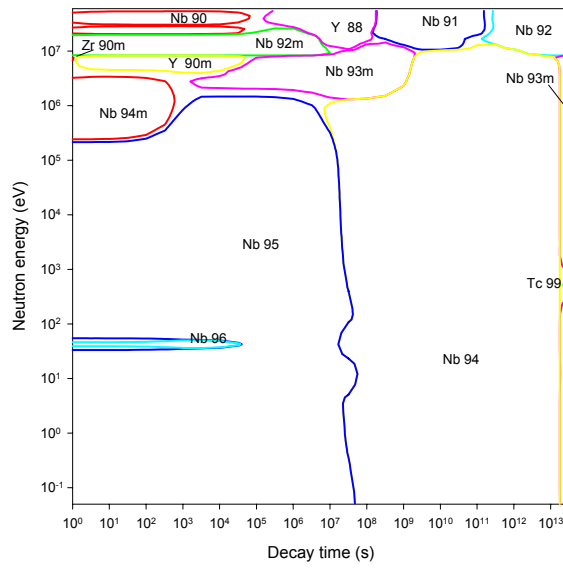
Decay time (years)

# Niobium importance diagrams & transmutation

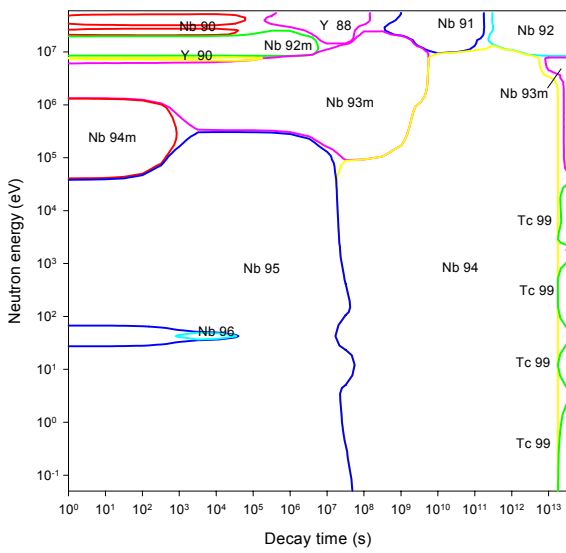
**Activity**



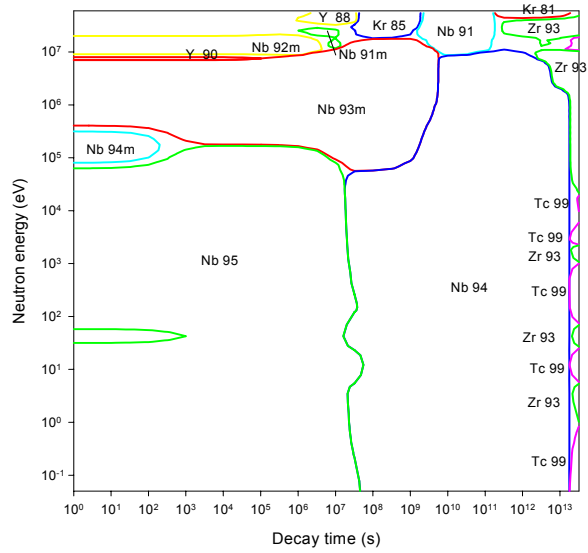
**Dose rate**



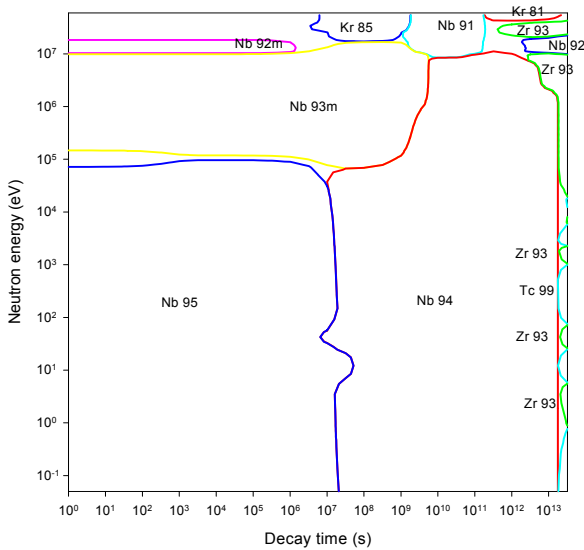
**Heat output**



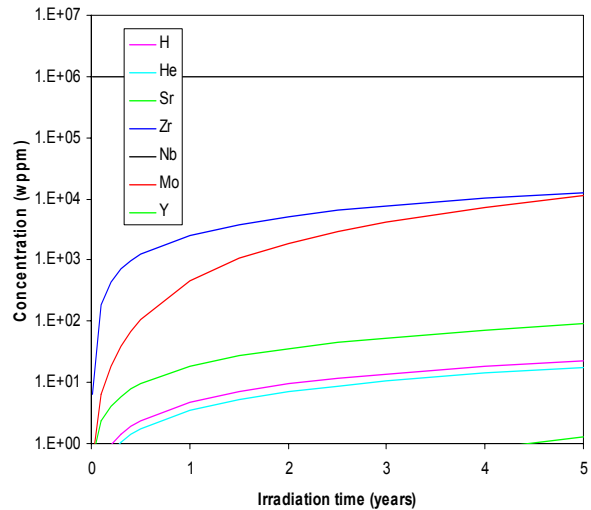
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**



# Molybdenum

## General properties

Atomic number	42	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	1.2	Mo92	14.84 ( $T_{1/2} = 1.90 \cdot 10^{20}$ y)
Melting point / K	2896	Mo94	9.25
Boiling point / K	4912	Mo95	15.92
Density / $\text{kgm}^{-3}$	10220	Mo96	16.68
Thermal conductivity / $\text{Wm}^{-1}\text{K}^{-1}$	138	Mo97	9.55
Electrical resistivity / $\Omega\text{m}$	$5.2 \cdot 10^{-8}$	Mo98	24.13 ( $T_{1/2} = 1.00 \cdot 10^{14}$ y)
Coefficient of thermal expansion / $\text{K}^{-1}$	$4.8 \cdot 10^{-6}$	Mo100	9.63 ( $T_{1/2} = 9.90 \cdot 10^{18}$ y)
Crystal structure	BCC		
Number of stable isotopes	4 (7)		
Mean atomic weight	95.94		

## Activation properties

Act	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Heat	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Bq $\text{kg}^{-1}$	1.64E15	1.34E15	4.89E14	1.50E12	9.30E11	5.00E9	kW $\text{kg}^{-1}$	1.88E-1	1.18E-1	2.88E-2	2.77E-5	3.29E-6	7.63E-8
Mo99	34.10	41.67	45.65				Tc100	30.84					
Mo101	30.44	6.47					Mo99	25.90	41.21	67.28			
Zr95	6.80	0.09	0.24	1.60			Mo101	18.73	23.25				
Mo91	6.79	1.31					Tc101	7.75	12.02				
Mo93	1.35		0.03		19.16		Tc99m	6.05	9.64	17.08			
Tc99m	1.24	37.22	44.23				Mo91	4.59	5.81				
Tc101	1.22	8.09					Nb92m	1.68	2.67	8.55			
Tc100	0.42						Nb96	1.00	1.59	0.48			
Nb91m	0.26	1.52	4.01	21.29			Nb95	0.48	0.77	3.00	26.45		
Y89m	0.19	0.24	0.30				Nb91m	0.22	0.36	1.43	24.38		
Nb93m	0.09		0.04	15.90	17.05	0.03	Zr95	0.09	0.14	0.57	11.95		
Nb92m	0.07	1.50	3.22				Y88		0.04	0.18	21.76		
Nb91	0.03	0.04	0.13	43.04	62.96		Nb91				6.91	52.55	
Nb95		0.52	1.36	3.75			Nb93m				4.28	23.85	0.02
Nb96		0.32	0.06				Mo93				1.65	13.71	
Y88			0.02	0.92			Nb94				0.83	6.98	9.43
Tc99				0.45	0.73	99.24	Tc99				0.33	2.85	89.08
Dose	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Ing	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{h}^{-1}$	9.26E4	7.55E4	1.42E4	2.98E1	7.81E-1	1.17E-2	Sv $\text{kg}^{-1}$	1.51E6	3.97E5	1.69E5	9.18E2	6.15E2	3.23E0
Mo101	46.67	44.58					Mo99	22.24	84.75	79.30			
Mo99	18.62	22.80	48.26				Nb91m	0.85	3.25	7.32	21.98		
Tc101	6.05	7.22					Nb92m	0.80	3.05	5.59			
Nb92m	5.58	6.84	28.34				Tc99m	0.72	2.77	2.81			
Tc100	4.81						Nb96	0.31	1.20	0.21			
Mo91	4.57	4.45					Mo101	0.30	0.90				
Nb96	2.86	3.49	1.38				Nb95	0.27	1.03	2.29	3.56		
Tc99m	2.32		6.53				Zr89	0.16	0.64	0.69			
Nb90	2.04	2.49	0.20				Tc101	0.14	0.52				
Nb95	1.36	1.67	8.42	33.94			Nb90	0.12	0.46	0.01			
Y89m	0.85	1.02	2.51				Zr95	0.07	0.30	0.68	2.50		
Zr95	0.23	0.28	1.46	13.94			Mo93	0.03	0.14	0.33	61.20	89.86	
Nb91m	0.18			9.16			Zr97	0.03	0.12				
Y88		0.14	0.72	38.71			Ru103	0.02	0.11	0.25	0.07		
Nb91				1.45	50.36		Y88	0.01	0.04	0.08	1.97		
Nb94				1.09	41.74	87.01	Nb91			0.02	4.51	6.09	
Mo93					6.59		Nb93m				3.12	3.09	0.01
Tc98					0.15	10.12	Tc99				0.47	0.71	98.25
Nb92					0.04	2.86	Nb94				0.15	0.22	1.35

<b>Inh</b>	<b>0</b>	<b>10<sup>-5</sup> y</b>	<b>10<sup>-2</sup> y</b>	<b>1 y</b>	<b>100 y</b>	<b>10<sup>5</sup> y</b>	<b>Clear</b>	<b>0</b>	<b>10<sup>-5</sup> y</b>	<b>10<sup>-2</sup> y</b>	<b>1 y</b>	<b>100 y</b>	<b>10<sup>5</sup> y</b>
Sv kg <sup>-1</sup>	1.67E6	6.62E5	3.07E5	4.71E3	3.22E3	6.61E1		2.58E11	1.87E11	5.27E10	2.02E8	5.65E7	5.23E6
Tc100	60.36						Mo99	21.71	30.00	42.31			
Mo99	33.17	83.82	72.06				Tc100	21.34					
Nb91m	2.81	7.11	14.73	15.63			Tc101	16.65	22.40				
Nb95	0.75	1.91	3.92	2.15			Mo91	9.66	10.61				
Nb92m	0.71	1.80	3.02				Nb92m	7.82	10.81	29.84			
Tc99m	0.59	1.51	1.41				Mo101	4.32					
Zr95	0.44	1.12	2.33	3.03			Nb96	4.22	5.83	1.53			
Nb96	0.17	0.43	0.06				Nb90	2.46	3.39	0.18			
Mo101	0.17	0.34					Nb95	2.27	3.77	12.67	27.79		
Nb91	0.15	0.39	0.86	56.32	74.41		Tc 99m	1.94	2.68	4.10			
Ru103	0.11	0.28		0.06			Tc99m	1.93	2.68	4.09			
Zr89	0.10	0.26	0.26				Mo91m	1.59					
Tc101	0.08	0.19					Y89m	1.16	1.57	2.57			
Nb90	0.06	0.15					Nb98m	0.75	0.96				
Mo91	0.05	0.10					Zr90m	0.71					
Nb95m	0.04	0.11	0.12				Zr95	0.48	0.67	2.30	11.99		
Y88	0.03	0.08	0.17	1.29			Mo93m	0.45	0.62				
Mo93	0.02	0.06	0.13	8.84	12.70		Nb91m	0.37	0.52	1.77	7.55		
Nb93m	0.02		0.14	9.13	8.84		Zr89	0.33	0.46	0.75			
Tc99			0.02	1.89	2.76	97.64	Ru103	0.24	0.33	1.10	0.49		
Nb94			0.01	0.86	1.25	1.91	Zr89m	0.22	0.13				
Tc98						0.24	Y88		0.18	0.63	18.63		
							Nb93m			0.04	11.85	28.06	
							Mo93			0.03	8.97	31.54	
							Nb91			0.01	4.21	13.63	
							Nb94			0.01	4.09	14.60	4.93
							Tc99			0.01	3.39	12.15	94.93
							Tc98						0.09
							Nb92						0.02

# Molybdenum

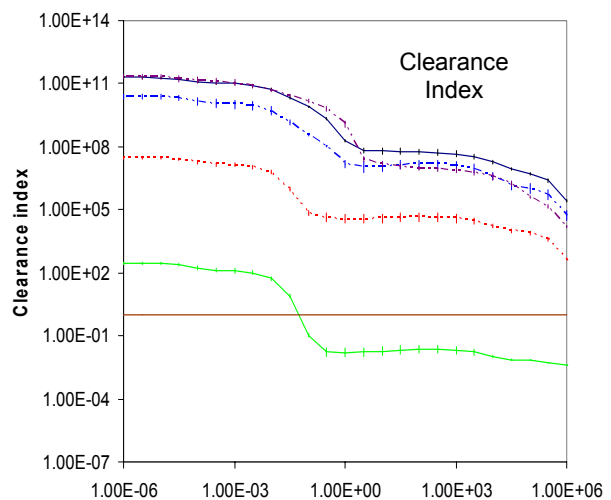
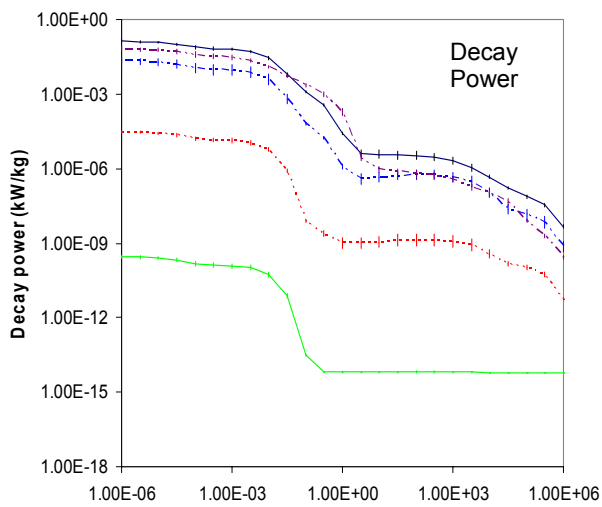
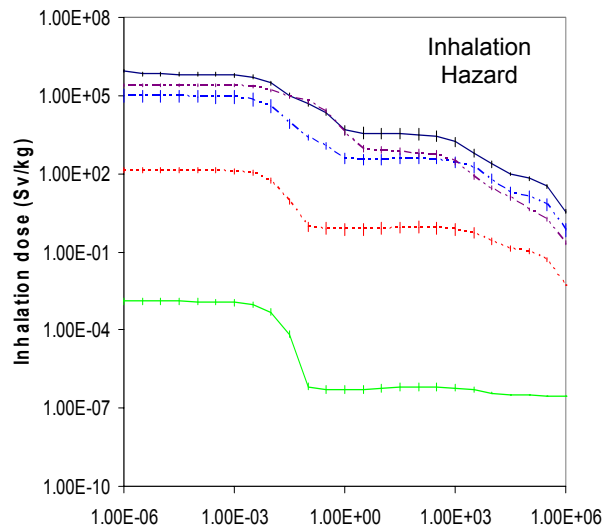
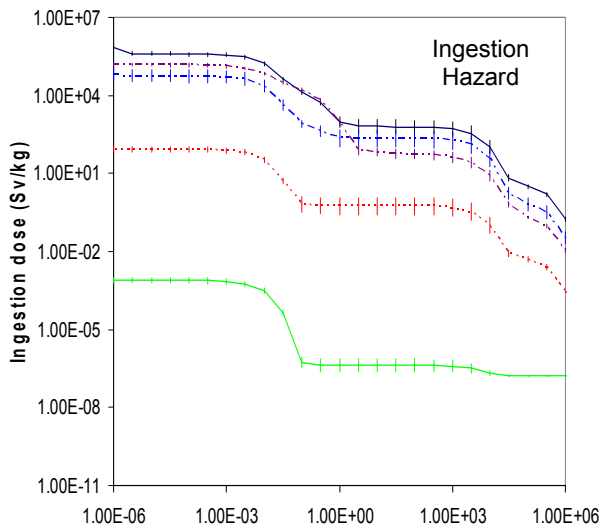
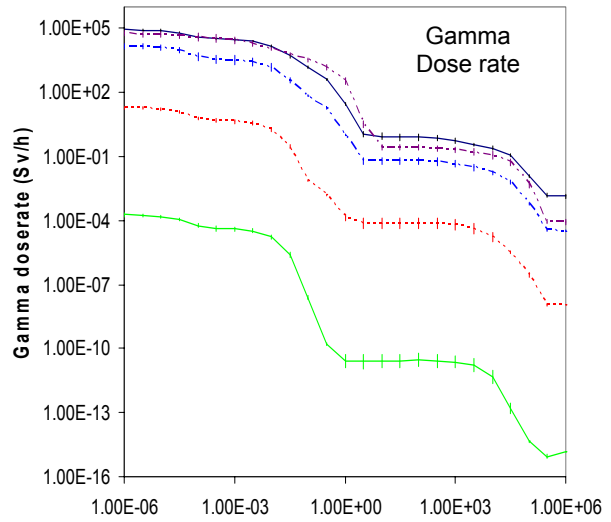
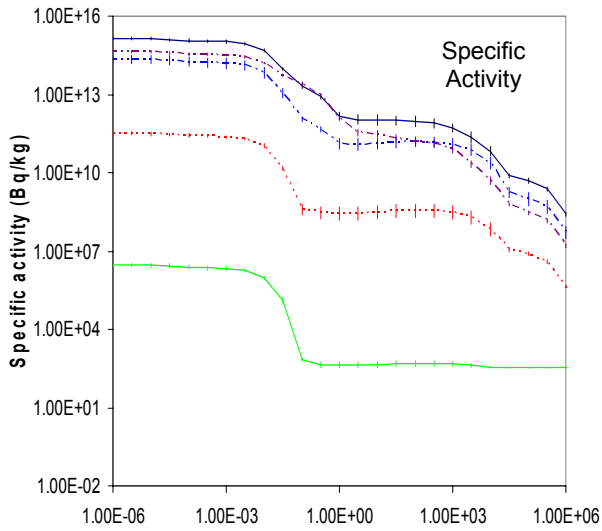
## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Tc100	15.8 s	&Mo98(n,γ)Mo99(β <sup>-</sup> )Tc99(n,γ)Tc100	97.6	94.7	99.0	0.3	0.5	0.3	0.3
		&Mo97(n,γ)Mo98(n,γ)Mo99(β <sup>-</sup> )Tc99_	2.4	1.9	0.9				
		(n,γ)Tc100							
		&Mo96(n,γ)Mo97(n,γ)Mo98(n,γ)Mo99_		2.7					
		(β <sup>-</sup> )Tc99(n,γ)Tc100							
		Mo95(n,γ)Mo96(n,γ)Mo97(n,γ)Mo98_		0.5					
		(n,γ)Mo99(β <sup>-</sup> )Tc99m(IT)Tc99(n,γ)Tc100							
		&Mo100(n,2n)Mo99(β <sup>-</sup> )Tc99(n,γ)Tc100				98.5	58.2	45.5	39.0
		Mo100(n,γ)Mo101(β <sup>-</sup> )Tc101(β <sup>-</sup> )Ru101_				0.4	0.6	0.3	0.1
		(n,2n)Ru100(n,p)Tc100							
Mo100(n,γ)Mo101(β <sup>-</sup> )Tc101(β <sup>-</sup> )Ru101_				0.3	32.1	40.8	44.9		
(n,d)Tc100									
&Mo100(n,d)Nb99(β <sup>-</sup> )Mo99(β <sup>-</sup> )Tc99_						6.6	10.8	13.5	
(n,γ)Tc100									
Mo100(n,d)Nb99m(β <sup>-</sup> )Mo99(β <sup>-</sup> )Tc99_						1.2	1.7	1.9	
(n,γ)Tc100									
Mo101	14.61 m	Mo100(n,γ)Mo101	100.0	100.0	100.0	99.9	99.5	99.6	99.8
Nb90	14.6 h	&Mo92(n,d)Nb91(n,2n)Nb90				71.4	28.1	1.6	1.3
		&Mo92(n,2n)Mo91(β <sup>+</sup> )Nb91(n,2n)Nb90				23.5	23.5	1.4	1.1
		&Mo92(n,t)Nb90					36.2	66.8	52.2
		Mo92(n,3n)Mo90(β <sup>+</sup> )Nb90					4.1	16.1	10.8
		&Mo94(n,3n)Mo92(n,t)Nb90					2.2	3.3	1.0
		&Mo95(n,4n)Mo92(n,t)Nb90						2.8	1.8
		&Mo94(n,2nt)Nb90							8.2
		&Mo96(n,4n)Mo93(n,nt)Nb90							2.3
Mo99	2.748 d	Mo98(n,γ)Mo99	96.0	91.9	98.1	0.3	0.8	0.6	
		Mo97(n,γ)Mo98(n,γ)Mo99	3.9	2.7	1.8				
		Mo96(n,γ)Mo97(n,γ)Mo98(n,γ)Mo99		4.3					
		Mo95(n,γ)Mo96(n,γ)Mo97(n,γ)Mo98(n,γ)Mo99		1.2					
		Mo100(n,2n)Mo99				99.3	86.8	77.5	70.5
		Mo100(n,d)Nb99(β <sup>-</sup> )Mo99					10.4	19.5	25.8
Mo100(n,d)Nb99m(β <sup>-</sup> )Mo99					2.0	3.0	3.7		
Nb92m	10.15 d	Mo92(n,p)Nb92m				89.0	13.5	4.5	1.7
		&Mo94(n,2n)Mo93(n,d)Nb92m				3.1	3.5	0.7	0.3
		Mo94(n,t)Nb92m					30.2	44.4	19.9
		&Mo95(n,3n)Mo93(n,d)Nb92m					16.0	3.5	1.0
		Mo96(n,3n)Mo94(n,t)Nb92m					7.4	6.5	1.2
		&Mo95(n,d)Nb94(n,3n)Nb92m					5.9	1.3	0.5
		Mo95(n,2n)Mo94(n,t)Nb92m					3.8	3.5	1.0
		Mo95(n,nt)Nb92m					1.5	14.2	33.5
		Mo96(n,2nt)Nb92m							18.9
Nb95	34.991 d	&Mo92(n,γ)Mo93(β <sup>+</sup> )Nb93m(n,γ)Nb94_	80.9	79.7	79.7				
		(n,γ)Nb95							
		&Mo92(n,γ)Mo93(β <sup>+</sup> )Nb93(n,γ)Nb94_	13.0	12.8	12.7				
		(n,γ)Nb95							
		&Mo98(n,α)Zr95(β <sup>-</sup> )Nb95				14.3	2.9	1.3	1.9
		&Mo97(n,α)Zr94(n,γ)Zr95(β <sup>-</sup> )Nb95	0.2	0.5	1.1				
		&Mo95(n,p)Nb95				61.4	22.0	12.4	5.1
		&Mo96(n,2n)Mo95(n,p)Nb95				14.2	1.5		0.1
		&Mo96(n,d)Nb95				6.5	45.6	37.1	25.6
		&Mo97(n,t)Nb95				0.1	7.7	19.5	15.6
		&Mo98(n,3n)Mo96(n,d)Nb95					10.1	3.7	1.2
&Mo98(n,nt)Nb95					0.9	10.9	40.7		
Mo100(n,2nα)Zr95(β <sup>-</sup> )Nb95					0.6	3.2	1.7		
Ru103	39.26 d	Mo100(n,γ)Mo101(β <sup>-</sup> )Tc101(β <sup>-</sup> )Ru101_	96.6	99.7	99.9	99.8	99.6	99.6	99.8
	▶	(n,γ)Ru102(n,γ)Ru103							

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&Mo98(n,γ)Mo99(β <sup>-</sup> )Tc99(n,γ)Tc100(β <sup>-</sup> ) Ru100(n,γ)Ru101(n,γ)Ru102(n,γ)Ru103	3.4	0.3					
Nb91m	60.90 d	Mo92(n,d)Nb91m Mo92(n,2n)Mo91m(β <sup>+</sup> )Nb91m Mo92(n,d)Nb91(n,n')Nb91m Mo95(n,3n)Mo93(n,t)Nb91m Mo94(n,3n)Mo92(n,d)Nb91m Mo94(n,nt)Nb91m Mo96(n,4n)Mo93(n,t)Nb91m Mo95(n,2nt)Nb91m Mo98(n,5n)Mo94(n,nt)Nb91m				81.4 10.4 4.1	52.7 24.4 1.7	39.3 14.6 0.8	20.3 7.5 1.2
Y88	106.63 d	&Mo92(n,α)Zr89(β <sup>+</sup> )Y89(n,2n)Y88 &Mo92(n,d)Nb91(n,α)Y88 &Mo92(n,2n)Mo91(β <sup>+</sup> )Nb91(n,α)Y88 &Mo92(n,2n)Mo91(β <sup>+</sup> )Nb91(n,α)Y88 Mo92(n,nα)Zr88(β <sup>+</sup> )Y88 Mo92(n,pα)Y88 Mo94(n,3n)Mo92(n,nα)Zr88(β <sup>+</sup> )Y88 &Mo92(n,t)Nb90(β <sup>+</sup> )Zr90(n,3n)Zr88(β <sup>+</sup> )Y88 &Mo92(n,h)Zr90(n,3n)Zr88(β <sup>+</sup> )Y88 &Mo92(n,t)Nb90(β <sup>+</sup> )Zr90(n,t)Y88 Mo92(n,3n)Mo90(β <sup>+</sup> )Nb90(β <sup>+</sup> )Zr90 (n,3n)Zr88(β <sup>+</sup> )Y88 &Mo92(n,d)Nb91(n,nt)Zr88(β <sup>+</sup> )Y88 Mo94(n,3nα)Zr88(β <sup>+</sup> )Y88 &Mo95(n,2nt)Nb91(n,nt)Zr88(β <sup>+</sup> )Y88				43.8 33.2 11.0 6.5 1.9	2.7 3.1 2.8 0.3 57.9 7.5 3.1 2.4 1.2 0.5 0.3	0.4 0.4 0.3 25.4 4.0 1.1 21.1 3.4 10.4 5.0	1.9 0.8 0.7 17.6 1.1 0.3 3.5 0.6 3.2 0.7 5.0 9.5 3.7
Kr85	10.752 y	&Mo92(n,α)Zr89(β <sup>+</sup> )Y89m(IT)Y89 (n,2n)Y88(β <sup>+</sup> )Sr88(n,α)Kr85 &Mo92(n,d)Nb91(n,α)Y88(β <sup>+</sup> )Sr88(n,α)Kr85 &Mo92(n,2n)Mo91(β <sup>+</sup> )Nb91(n,α)Y88 (β <sup>+</sup> )Sr88(n,α)Kr85 &Mo92(n,nα)Zr88(β <sup>+</sup> )Y88(β <sup>+</sup> )Sr88(n,α)Kr85 &Mo92(n,α)Zr89(β <sup>+</sup> )Y89m(IT)Y89(n,d) Sr88(n,α)Kr85 &Mo92(n,pα)Y88(β <sup>+</sup> )Sr88(n,α)Kr85 Mo92(n,t)Nb90(β <sup>+</sup> )Zr90(n,t)Y88(β <sup>+</sup> )Sr88 (n,α)Kr85 Mo92(n,2nα)Zr87(β <sup>+</sup> )Y87m(IT)Y87(β <sup>+</sup> ) Sr87(n,h)Kr85 &Mo94(n,3nα)Zr88(β <sup>+</sup> )Y88(β <sup>+</sup> )Sr88(n,α)Kr85 &Mo94(n,tα)Y88(β <sup>+</sup> )Sr88(n,α)Kr85 Other pathways involving (n,2n), (n,α), β <sup>+</sup>				41.5 32.0 10.1 4.7 3.0	1.5 1.2 74.2 0.2 10.9 0.2	0.2 0.2 42.0 0.1 7.5 5.0 1.7	0.4 0.3 23.2 0.5 1.6 1.3 3.4 12.2 3.3 53.8
H3	12.33 y	&Mo92(n,γ)Mo93(n,X)H1(n,γ)H2(n,γ)H3 Mo92(n,γ)Mo93m(n,X)H1(n,γ)H2(n,γ)H3 Mo95(n,X)H3 Mo97(n,X)H3 Mo98(n,X)H3 Mo98(n,2n)Mo97(n,X)H3 Mo96(n,2n)Mo95(n,X)H3 Mo94(n,X)H3 Mo92(n,p)Nb92(n,X)H3 Mo96(n,X)H3 Mo100(n,X)H3 Mo92(n,X)H3	94.5 0.1	95.9 0.4	96.8 2.7	41.8 17.7 10.1 5.4 5.1 2.2 2.2 1.1 0.4	20.1 11.5 21.0 0.9 0.7 8.2 12.7 6.9 6.2	17.6 10.2 20.4 0.5 0.2 8.4 13.9 7.9 9.0	16.0 9.8 21.3 0.3 0.2 8.3 14.6 8.5 10.5
Nb93m	16.126 y	&Mo92(n,γ)Mo93(β <sup>+</sup> )Nb93m Mo94(n,d)Nb93m Mo95(n,2n)Mo94(n,d)Nb93m Mo94(n,2n)Mo93(n,p)Nb93m &Mo94(n,p)Nb94(n,2n)Nb93m Mo95(n,t)Nb93m Mo96(n,3n)Mo94(n,d)Nb93m Mo96(n,nt)Nb93m	100.0	100.0	100.0	65.9 12.5 7.3 4.1 2.3	50.8 3.4 0.3 0.1 29.7 6.6 0.5	26.3 1.1 51.6 2.0 7.1	19.4 0.5 39.9 0.6 22.4

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	Mo98(n,4n)Mo95(n,t)Nb93m Mo97(n,2nt)Nb93m						3.2	1.2
Nb91	680.0 y	&Mo92(n,d)Nb91 &Mo92(n,2n)Mo91(β <sup>+</sup> )Nb91 Mo92(n,2n)Mo91m(β <sup>+</sup> )Nb91 &Mo94(n,nt)Nb91 &Mo94(n,4n)Mo91(β <sup>+</sup> )Nb91 Mo95(n,2nt)Nb91 &Mo95(n,5n)Mo91(β <sup>+</sup> )Nb91				73.2 24.2 1.5	47.3 42.6 2.6	40.0 32.1 1.9 10.3 1.1	22.7 18.9 1.1 19.2 5.7 16.6 3.3
Mo93	4000 y	&Mo92(n,γ)Mo93 &Mo94(n,2n)Mo93 &Mo95(n,2n)Mo94(n,2n)Mo93 &Mo95(n,3n)Mo93 &Mo96(n,4n)Mo93 Mo98(n,4n)Mo95(n,3n)Mo93 Mo98(n,3n)Mo96(n,4n)Mo93 &Mo97(n,5n)Mo93 &Mo98(n,6n)Mo93	100.0	100.0	100.0	0.6 83.0 15.1	0.1 15.8 1.0 73.6	8.1 8.1 45.7 35.6 2.5 1.7	7.1 0.2 26.8 35.9 0.7 0.8 19.2 3.6
Nb94	2.0 10 <sup>4</sup> y	&Mo92(n,γ)Mo93(β <sup>+</sup> )Nb93m(n,γ)Nb94 &Mo92(n,γ)Mo93(β <sup>+</sup> )Nb93(n,γ)Nb94 &Mo92(n,γ)Mo93m(β <sup>+</sup> )Nb93(n,γ)Nb94 &Mo94(n,p)Nb94 &Mo95(n,d)Nb94 &Mo95(n,2n)Mo94(n,p)Nb94 &Mo96(n,t)Nb94 &Mo97(n,nt)Nb94 &Mo98(n,2nt)Nb94	83.0 16.8 0.1	82.9 16.8 0.3	82.9 16.4 0.4	63.8 20.2 11.6	13.8 60.6 0.9 13.8 0.8	6.3 36.2 40.9 6.2	1.9 23.3 28.2 16.8 23.5
Tc99	2.1 10 <sup>5</sup> y	&Mo98(n,γ)Mo99(β <sup>-</sup> )Tc99 &Mo97(n,γ)Mo98(n,γ)Mo99(β <sup>-</sup> )Tc99 &Mo96(n,γ)Mo97(n,γ)Mo98(n,γ)Mo99(β <sup>-</sup> )Tc99   &Mo100(n,2n)Mo99(β <sup>-</sup> )Tc99 &Mo100(n,d)Nb99(β <sup>-</sup> )Mo99(β <sup>-</sup> )Tc99 &Mo100(n,d)Nb99m(β <sup>-</sup> )Mo99(β <sup>-</sup> )Tc99	97.6 2.4	94.8 1.9 2.7	99.0 0.9	0.3 99.5	0.7 87.1 9.8 1.8	0.6 77.8 18.4 2.8	0.5 71.2 24.5 3.4
Tc98	4.2 10 <sup>6</sup> y	&Mo100(n,2n)Mo99(β <sup>-</sup> )Tc99(n,2n)Tc98 &Mo100(n,d)Nb99(β <sup>-</sup> )Mo99(β <sup>-</sup> )Tc99_ (n,2n)Tc98 &Mo100(n,d)Nb99m(β <sup>-</sup> )Mo99(β <sup>-</sup> )Tc99_ (n,2n)Tc98				99.5	87.2 9.8 1.8	77.8 18.4 2.8	71.0 24.5 3.4
Nb92	3.5 10 <sup>7</sup> y	Mo92(β <sup>+</sup> )Nb92 Mo92(n,p)Nb92 Mo94(n,2n)Mo93(n,d)Nb92 Mo94(n,t)Nb92 &Mo95(n,3n)Mo93(n,d)Nb92 &Mo95(n,d)Nb94(n,3n)Nb92 Mo96(n,3n)Mo94(n,t)Nb92 Mo95(n,nt)Nb92 Mo96(n,2nt)Nb92	100.0	100.0	100.0	94.8 1.7	17.9 2.1 38.4 10.3 7.9 4.8 2.0	5.2 50.9 1.6 1.4 3.8 21.9	1.7 19.0 0.3 0.4 0.6 41.4 24.5

# Molybdenum activation characteristics



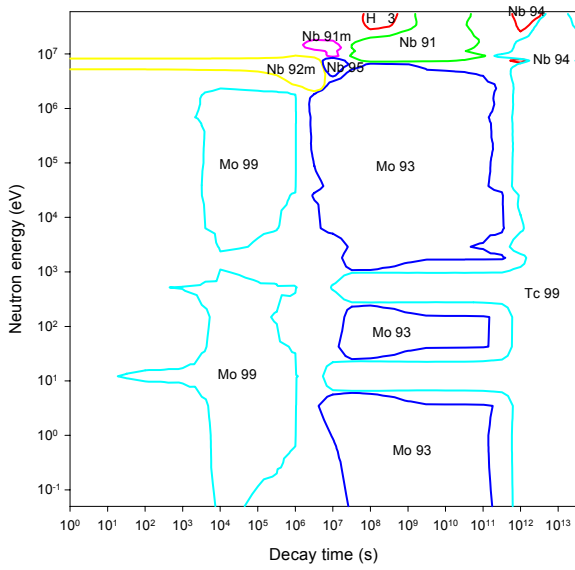
Decay time (years)

Decay time (years)

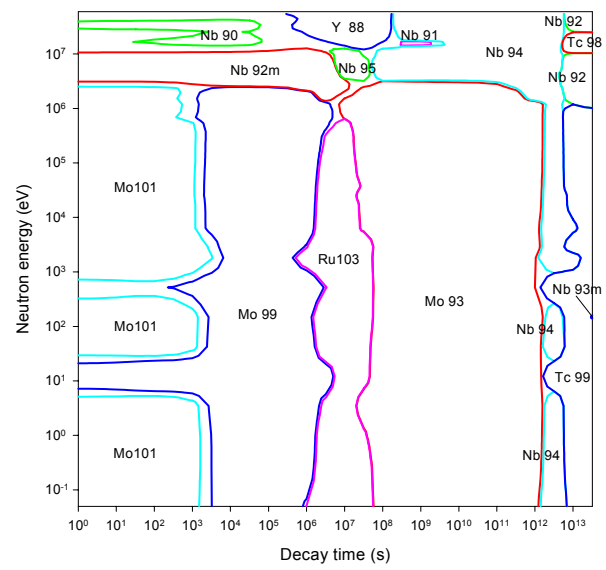


# Molybdenum importance diagrams & transmutation

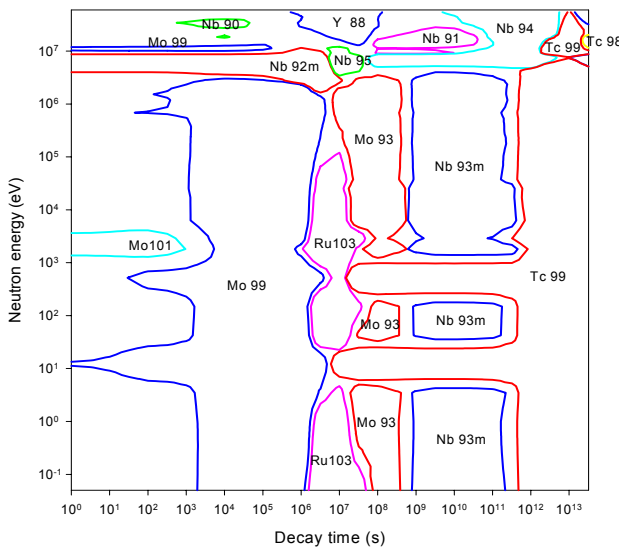
**Activity**



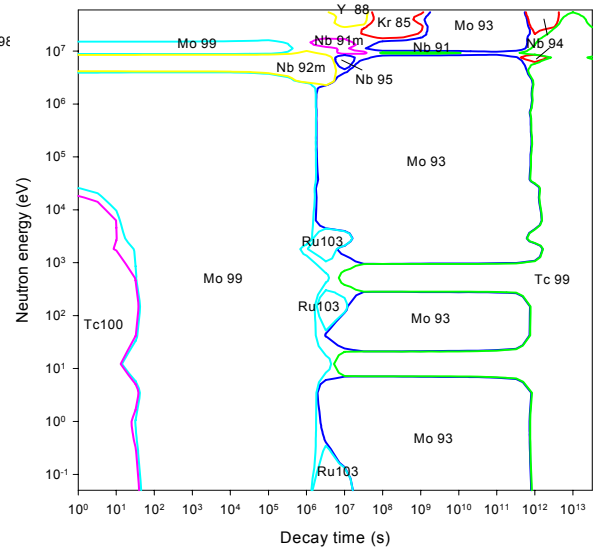
**Dose rate**



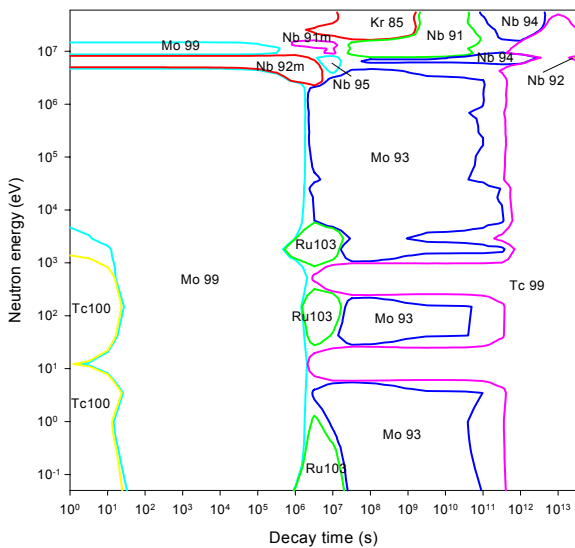
**Heat output**



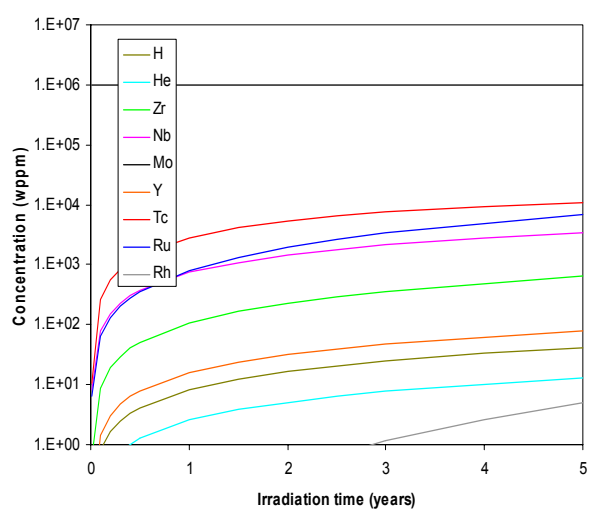
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**





# Ruthenium

## General properties

Atomic number	44	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	$1.0 \cdot 10^{-3}$	Ru96	5.54 ( $T_{1/2} = 6.70 \cdot 10^{16}$ y)
Melting point / K	2607	Ru98	1.87
Boiling point / K	4423	Ru99	12.76
Density / $\text{kgm}^{-3}$	12410	Ru100	12.60
Thermal conductivity / $\text{Wm}^{-1}\text{K}^{-1}$	117	Ru101	17.06
Electrical resistivity / $\Omega\text{m}$	$7.6 \cdot 10^{-8}$	Ru102	31.55
Coefficient of thermal expansion / $\text{K}^{-1}$	$6.4 \cdot 10^{-6}$	Ru104	18.62
Crystal structure	HCP		
Number of stable isotopes	6 (7)		
Mean atomic weight	101.07		

## Activation properties

Act	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Heat	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Bq $\text{kg}^{-1}$	2.39E15	2.15E15	1.24E15	4.91E12	3.61E9	3.49E8	kW $\text{kg}^{-1}$	1.90E-1	1.50E-1	6.22E-2	8.71E-4	2.24E-8	8.70E-9
Rh103m	25.17	28.03	44.24	18.76			Ru105	29.59	36.93				
Ru103	24.58	27.42	44.49	18.97			Ru103	27.94	35.35	80.00	9.64		
Ru105	12.72	14.00					Rh104	18.60	1.04				
Rh105	12.70	14.17	5.03				Rh105	5.92	7.49	3.71			
Rh104	9.24	0.45					Ru97	2.81	3.55	3.59			
Ru97	5.50	6.13	4.44				Ru95	2.71	3.30				
Rh105m	3.61	3.98					Tc96	2.59	3.28	4.41			
Tc95	1.43	1.60	0.14	0.03			Tc95	2.32	2.94	0.38	0.02		
Ru95	1.01	1.09					Rh103m	1.90	2.40	5.30	0.63		
Tc99m	0.87	0.96					Tc100	1.72					
Tc96	0.51	0.57					Rh105m	0.92	1.16				
Rh102m	0.14	0.15		20.29			Tc102m	0.53	0.29				
Rh102	0.12	0.11		39.79			Rh102	0.44	0.55	1.34	76.71		
Tc97m				0.81			Tc104	0.25	0.26				
H3				0.14	0.73		Rh102m	0.18	0.23	0.57	12.22		
Mo93				0.03	45.82		Nb93m					32.06	
Nb93m					40.09		Tc98					25.23	63.81
Tc99					7.76	58.11	Mo93					18.74	
Tc97					3.49	35.23	Tc99					17.16	31.91
Nb91					1.34		Nb94					4.20	0.33
Tc98					0.63	6.48	Tc97					1.56	3.92
Dose	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Ing	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{h}^{-1}$	1.38E5	1.35E5	6.12E4	1.17E3	9.53E-3	7.52E-3	Sv $\text{kg}^{-1}$	1.07E6	8.20E5	4.57E5	7.03E3	5.55E0	1.84E-1
Ru103	40.72	41.52	85.99	7.57			Ru103	39.97	52.39	88.05	9.67		
Ru105	35.39	35.60					Rh102m	30.44	0.49	0.87	17.02		
Tc96	5.65	5.76	7.08				Rh105	10.47	13.73	5.04			
Ru95	5.20	5.11					Ru105	7.36	9.52				
Tc95	4.62	4.71	0.55	0.02			Ru97	1.84	2.41	1.80			
Rh105	2.32	2.37	1.07				Tc96	1.25	1.64	1.64			
Ru97	2.15	2.19	2.02				Rh102	0.59	0.77	1.39	72.29		
Tc102m	0.97	0.43					Tc95	0.57	0.75	0.07			
Rh102	0.89	0.90	2.00	83.39			Mo93				0.07	92.46	
Rh102m	0.24	0.24		8.42			Tc99					3.23	70.69
Tc98					79.44	99.00	Nb93m					3.13	
Nb94					13.92	0.55	Tc98					0.82	24.64
Mo93					4.38		Tc97					0.15	4.55

<b>Inh</b>	<b>0</b>	<b>10<sup>-5</sup> y</b>	<b>10<sup>-2</sup> y</b>	<b>1 y</b>	<b>100 y</b>	<b>10<sup>5</sup> y</b>	<b>Clear</b>	<b>0</b>	<b>10<sup>-5</sup> y</b>	<b>10<sup>-2</sup> y</b>	<b>1 y</b>	<b>100 y</b>	<b>10<sup>5</sup> y</b>
Sv kg <sup>-1</sup>	2.38E6	2.16E6	1.76E6	4.34E4	1.17E1	3.88E0		7.56E11	7.23E11	5.75E11	5.64E9	6.71E5	2.49E5
Ru103	74.06	81.83	93.87	6.43			Ru103	77.80	81.40	95.91	16.51		
Rh105	4.46	4.93	1.23				Ru105	4.02	4.15				
Ru105	2.30	2.50					Ru95	4.02	4.05				
Rh102	1.75	1.93	2.36	76.44			Tc95	3.49	3.65	0.24	0.02		
Rh102m	1.00	1.10	1.33	16.28			Rh104	3.32	0.15				
Ru97	0.60	0.67	0.34				Ru97	1.74	1.82	0.95			
Tc96	0.36	0.39	0.27				Tc96	1.62	1.69	1.18			
Tc95	0.15	0.17	0.01				Rh102	0.69	0.72		73.69		
Tc95m	0.14	0.16	0.19	0.12			Rh105	0.40	0.42				
Tc97m	0.11	0.12	0.14	0.37			Rh102m	0.22	0.23	0.28	8.83		
Mo93					32.53		Tc99					41.78	81.62
Tc99					31.16	67.93	Mo93					24.65	
Nb93m					22.27		Nb93m					21.57	
Tc98					8.85	26.23	Nb94					5.02	0.42
Tc97					1.94	5.70	Tc97					1.88	4.94
Nb91					1.70		Tc98						13.01
Nb94					1.41	0.13							

# Ruthenium

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
Tc100	15.8 s	&Ru96(n,γ)Ru97(β <sup>+</sup> )Tc97(n,γ)Tc98_	100.0	99.9	99.9					
		(n,γ)Tc99(n,γ)Tc100				60.2	19.4	8.0	3.8	
		Ru100(n,p)Tc100				17.9	1.8	0.5		
		Ru101(n,2n)Ru100(n,p)Tc100				7.5	49.0	30.8	25.0	
		Ru101(n,d)Tc100				6.8				
		Ru104(n,2n)Ru103(β <sup>-</sup> )Rh103m(IT)_								
		Rh103(n,α)Tc100								
		Ru102(n,2n)Ru101(n,2n)Ru100(n,p)Tc100					4.0			
		Ru102(n,2n)Ru101(n,d)Tc100					3.3	6.0	2.4	
		Ru102(n,t)Tc100						11.7	49.1	50.3
		Ru102(n,3n)Ru100(n,p)Tc100						7.7	1.6	
		Ru104(n,4n)Ru101(n,d)Tc100							3.2	
Ru104(n,2nt)Tc100							0.2	15.0		
Rh106	30.0 s	&Ru104(n,γ)Ru105(β <sup>-</sup> )Rh105(n,γ)Rh106	99.7	96.6	87.7	25.3	5.7	7.4	10.6	
		&Ru102(n,γ)Ru103(n,γ)Ru104(n,γ)_	0.2	0.2						
		Ru105(β <sup>-</sup> )Rh105(n,γ)Rh106		3.0	12.3	15.4	12.4	16.5	26.7	
		Ru104(n,γ)Ru105(n,γ)Ru106(β <sup>-</sup> )Rh106				59.3	81.9	76.1	62.7	
		&Ru104(n,γ)Ru105(β <sup>-</sup> )Rh105(β <sup>-</sup> )_								
Pd105(n,γ)Pd106(n,p)Rh106										
Rh104	42.3 s	&Ru102(n,γ)Ru103(β <sup>-</sup> )Rh103(n,γ)Rh104	91.6	80.8	95.3		0.2	0.1		
		&Ru101(n,γ)Ru102(n,γ)Ru103(β <sup>-</sup> )_	7.4	19.0	3.3					
		Rh103(n,γ)Rh104								
		&Ru100(n,γ)Ru101(n,γ)Ru102(n,γ)_	0.7							
		Ru103(β <sup>-</sup> )Rh103m(IT)Rh103(n,γ)Rh104								
		&Ru104(n,2n)Ru103(β <sup>-</sup> )Rh103(n,γ)Rh104				97.4	61.0	49.9	40.4	
		&Ru104(n,γ)Ru105(β <sup>-</sup> )Rh105(β <sup>-</sup> )_				0.3	28.1	34.6	38.6	
Pd105(n,d)Rh104										
&Ru104(n,d)Tc103(β <sup>-</sup> )Ru103(β <sup>-</sup> )_					6.5	11.3	13.2			
Rh103m(IT)Rh103(n,γ)Rh104										
Tc102m	4.35 m	Ru102(n,p)Tc102m				99.2	82.3	42.7	21.3	
		Ru104(n,t)Tc102m					9.0	55.0	78.0	
Ru97	2.90 d	Ru96(n,γ)Ru97	100.0	100.0	100.0	0.1				
		Ru99(n,2n)Ru98(n,2n)Ru97				55.3	3.8	1.3	0.6	
		Ru98(n,2n)Ru97				38.3	7.1	4.1	2.9	
		Ru100(n,2n)Ru99(n,2n)Ru98(n,2n)Ru97				5.7				
		Ru99(n,3n)Ru97					63.4	43.0	20.8	
		Ru101(n,3n)Ru99(n,3n)Ru97					11.2	3.7	0.5	
		Ru100(n,3n)Ru98(n,2n)Ru97					6.0	2.3	0.7	
		Ru100(n,2n)Ru99(n,3n)Ru97					4.4	1.8	0.6	
		Ru100(n,4n)Ru97						24.0	24.9	
		Ru102(n,4n)Ru99(n,3n)Ru97						7.8	2.1	
		Ru102(n,3n)Ru100(n,4n)Ru97						4.8	2.1	
		Ru101(n,5n)Ru97							29.7	
Tc96	4.28 d	Ru96(β <sup>+</sup> )Tc96	100.0	100.0	100.0					
		&Ru96(n,p)Tc96				51.8	13.9	4.8	1.5	
		&Ru98(n,2n)Ru97(β <sup>+</sup> )Tc97(n,2n)Tc96				26.7	3.5	0.6	0.1	
		&Ru99(n,2n)Ru98(n,2n)Ru97(β <sup>+</sup> )Tc97_				19.0	0.8			
		(n,2n)Tc96								
		&Ru99(n,3n)Ru97(β <sup>+</sup> )Tc97(n,2n)Tc96					31.6	11.1	1.1	
		&Ru99(n,d)Tc98(n,3n)Tc96					9.8	2.3	0.5	
		&Ru98(n,t)Tc96					6.9	13.8	4.4	
		&Ru100(n,3n)Ru98(n,t)Tc96					5.5	7.7	1.0	
		&Ru99(n,2n)Ru98(n,t)Tc96					3.5	4.4	0.9	
		&Ru99(n,nt)Tc96					1.0	17.3	40.2	
		&Ru101(n,4n)Ru98(n,t)Tc96						8.0	1.6	
		&Ru100(n,2nt)Tc96							17.0	
Ru103	39.26 d▶	Ru102(n,γ)Ru103	90.8	77.4	93.6	0.2	0.4	0.3		

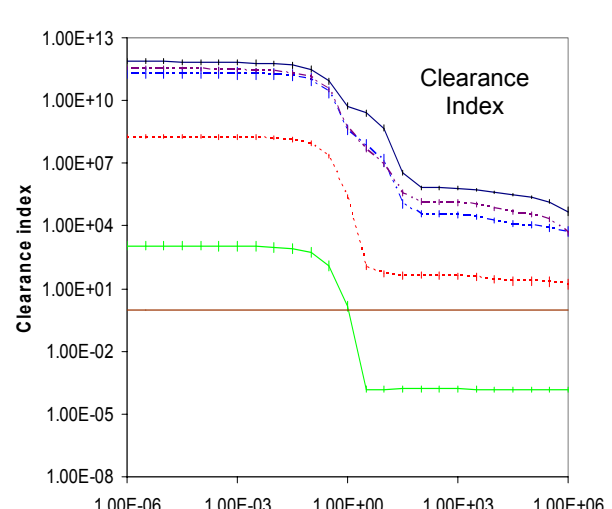
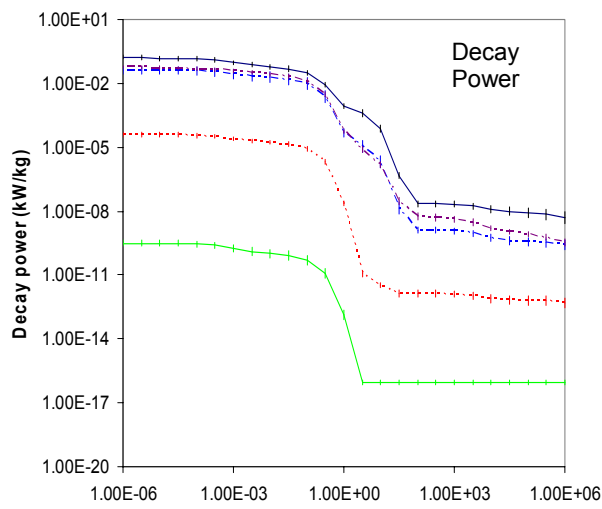
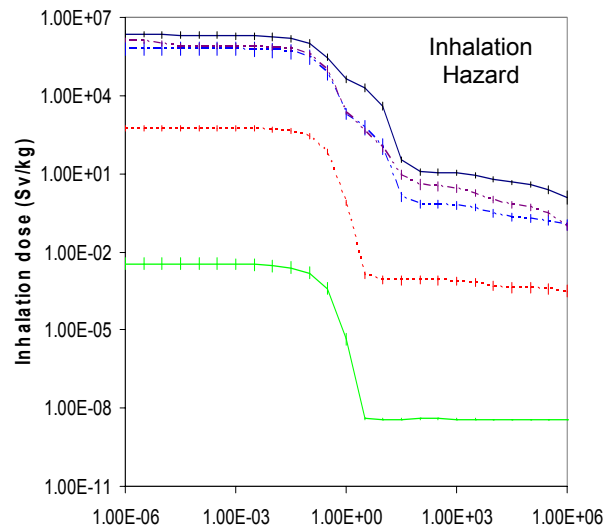
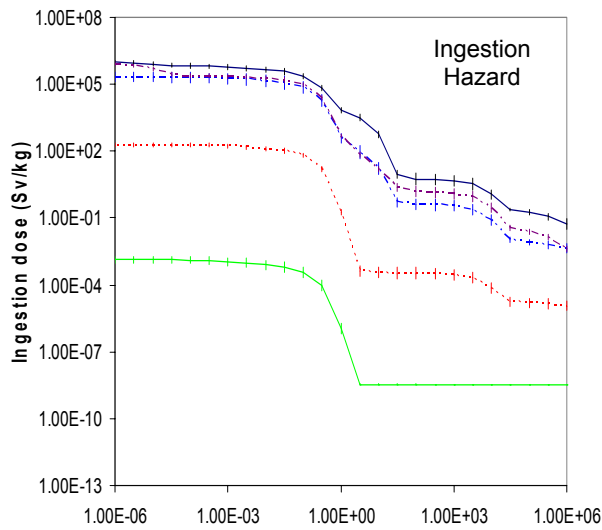
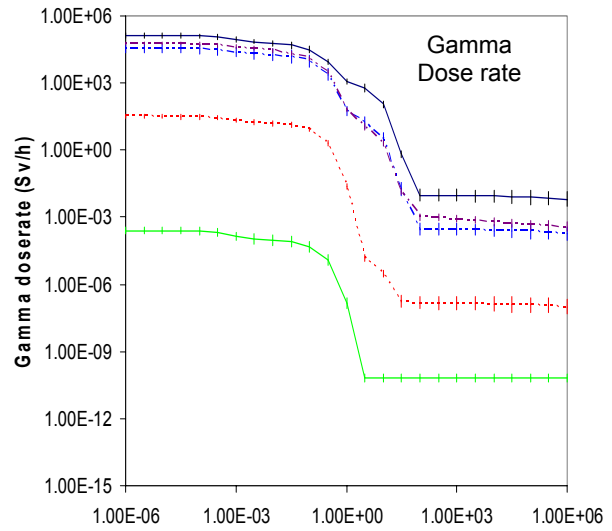
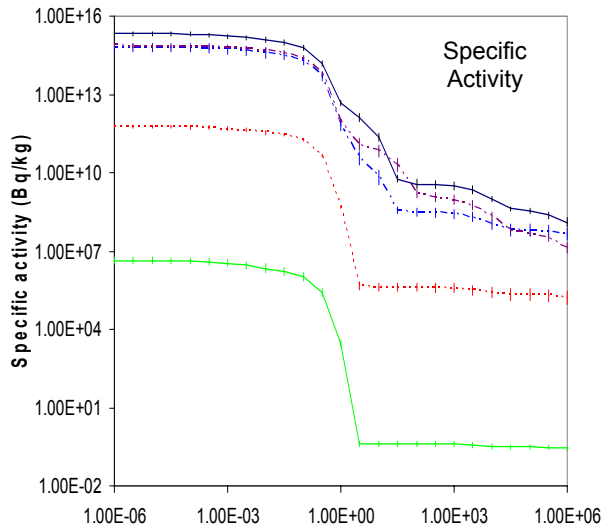
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	Ru101(n,γ)Ru102(n,γ)Ru103 Ru100(n,γ)Ru101(n,γ)Ru102(n,γ)Ru103 Ru104(n,2n)Ru103 Ru104(n,d)Tc103(β <sup>-</sup> )Ru103	8.2 0.8	22.5 0.1	6.3	99.4	88.6 9.5	80.1 18.4	74.3 24.5
Tc97m	90.2 d	Ru96(n,γ)Ru97(β <sup>+</sup> )Tc97m Ru99(n,2n)Ru98(n,d)Tc97m Ru98(n,d)Tc97m Ru98(n,2n)Ru97(β <sup>+</sup> )Tc97(n,n')Tc97m Ru99(n,2n)Ru98(n,2n)Ru97(β <sup>+</sup> )Tc97_ (n,n')Tc97m Ru99(n,d)Tc98(n,2n)Tc97m Ru100(n,2n)Ru99(n,2n)Ru98(n,d)Tc97m Ru98(n,p)Tc98(n,2n)Tc97m Ru99(n,t)Tc97m Ru100(n,3n)Ru98(n,d)Tc97m Ru99(n,3n)Ru97(β <sup>+</sup> )Tc97(n,n')Tc97m Ru101(n,3n)Ru99(n,t)Tc97m Ru100(n,d)Tc99(n,3n)Tc97m Ru100(n,nt)Tc97m Ru102(n,4n)Ru99(n,t)Tc97m Ru101(n,4n)Ru98(n,d)Tc97m Ru101(n,2nt)Tc97m Ru102(n,5n)Ru98(n,d)Tc97m	99.9	100.0	99.8	29.5 21.9 16.4 11.2	6.3 12.7 0.8	1.7 5.7 0.2	0.7 3.5
Y88	106.63 d	&Ru96(n,α)Mo92(n,α)Zr89(β <sup>+</sup> )Y89m_ (IT)Y89(n,2n)Y88 &Ru96(n,α)Mo92(n,d)Nb91(n,α)Y88 Ru96(n,α)Mo92(n,2n)Mo91(β <sup>+</sup> )Nb91_ (n,α)Y88 &Ru96(n,α)Mo93(n,α)Zr89(β <sup>+</sup> )Y89m_ (IT)Y89(n,2n)Y88 Ru96(n,α)Mo92(n,α)Zr88(β <sup>+</sup> )Y88 Ru96(n,α)Mo92(n,pα)Y88 Ru96(n,t)Tc94(β <sup>+</sup> )Mo94(n,3n)Mo92_ (n,α)Zr88(β <sup>+</sup> )Y88 Ru96(n,nt)Tc93(β <sup>+</sup> )Mo93(n,2nα)Zr88_ (β <sup>+</sup> )Y88 Other pathways involving (n,2n), (n,α), β <sup>+</sup>				35.9 27.1 8.5 4.7 2.9	1.1 1.1 1.0 0.4 41.4 5.8 5.6		0.1 2.1 0.1 4.8
Ag110m	249.78 d	&Ru104(n,γ)Ru105(β <sup>-</sup> )Rh105(n,γ)_ Rh106(β <sup>-</sup> )Pd106(n,γ)Pd107(n,γ)Pd108_ (n,γ)Pd109(β <sup>-</sup> )Ag109(n,γ)Ag110m &Ru104(n,γ)Ru105(β <sup>-</sup> )Rh105(n,γ)_ Rh106m(β <sup>-</sup> )Pd106(n,γ)Pd107(n,γ)_ Pd108(n,γ)Pd109(β <sup>-</sup> )Ag109(n,γ)Ag110m &Ru104(n,γ)Ru105(β <sup>-</sup> )Rh105(β <sup>-</sup> )_ Pd105(n,γ)Pd106(n,γ)Pd107(n,γ)Pd108_ (n,γ)Pd109(β <sup>-</sup> )Ag109(n,γ)Ag110m &Ru102(n,γ)Ru103(β <sup>-</sup> )Rh103(n,γ)Rh104(β <sup>-</sup> )_ Pd104(n,γ)Pd105(n,γ)Pd106(n,γ)Pd107(n,γ)_ Pd108(n,γ)Pd109(β <sup>-</sup> )Ag109(n,γ)Ag110m	42.3 35.6 21.5	0.3	83.5 99.2				
Ru106	1.020 y	Ru104(n,γ)Ru105(n,γ)Ru106 Ru102(n,γ)Ru103(n,γ)Ru104(n,γ)_ Ru105(n,γ)Ru106	99.7 0.3	99.7 0.2	100.0	99.9	99.6	99.7	99.8
Rh102	2.902 y	&Ru104(n,2n)Ru103(β <sup>-</sup> )Rh103(n,2n)Rh102 &Ru104(n,d)Tc103(β <sup>-</sup> )Ru103(β <sup>-</sup> )_ Rh103(n,2n)Rh102				99.5	89.5 9.2	80.7 17.7	74.5 23.5
Kr85	10.752 y	&Ru96(n,α)Mo92(n,d)Nb91(n,α)Y88_ (β <sup>+</sup> )Sr88(n,α)Kr85 Ru96(n,α)Mo92(n,2n)Mo91(β <sup>+</sup> )Nb91_ (n,α)Y88(β <sup>+</sup> )Sr88(n,α)Kr85 &Ru96(n,α)Mo92(n,α)Zr88(β <sup>+</sup> )Y88_ (β <sup>+</sup> )Sr88(n,α)Kr85				24.5 7.1 4.6	0.7		1.8

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&Ru96(n,α)Mo92(n,α)Y88(β <sup>+</sup> )Sr88_ (n,α)Kr85 &Ru96(n,dα)Nb91(n,α)Y88(β <sup>+</sup> )Sr88_ (n,α)Kr85 &Ru96(n,n2α)Zr88(β <sup>+</sup> )Y88(β <sup>+</sup> )Sr88_ (n,α)Kr85 Other pathways involving (n,2n), (n,α), β <sup>+</sup>					8.2	0.9	0.1
							3.1	1.9	0.6
								11.0	9.2
						63.8	38.1	81.3	88.3
H3	12.33 y	Ru96(n,γ)Ru97(n,X)H1(n,γ)H2(n,γ)H3 Ru101(n,X)H3 Ru99(n,X)H3 Ru104(n,2n)Ru103(β <sup>-</sup> )Rh103m(IT) Rh103(n,X)H3 Ru102(n,2n)Ru101(n,X)H3 Ru100(n,2n)Ru99(n,X)H3 Ru96(n,X)H3 Ru100(n,X)H3 Ru102(n,X)H3 Ru104(n,X)H3	93.2	94.5	98.4	33.4 30.2 15.5	22.3 17.3	19.0 14.4	17.8 13.0 0.3
						7.6	1.4	0.8	0.5
						3.2	0.6		0.2
						1.0	5.0	5.0	4.7
						0.3	8.8	10.0	10.6
						0.2	20.3	24.0	26.2
							10.5	13.2	14.9
Nb93m	16.126 y	&Ru96(n,α)Mo93(β <sup>+</sup> )Nb93m Ru96(n,α)Mo93(n,p)Nb93m Ru96(n,2n)Ru95(β <sup>+</sup> )Tc95(β <sup>+</sup> )Mo95_ (n,2n)Mo94(n,d)Nb93m Ru98(n,2n)Ru97(β <sup>+</sup> )Tc97(n,α)Nb93m Ru96(n,d)Tc95(β <sup>+</sup> )Mo95(n,2n)Mo94_ (n,d)Nb93m Ru99(n,2n)Ru98(n,2n)Ru97(β <sup>+</sup> )Tc97_ (n,α)Nb93m Ru96(n,2n)Ru95(β <sup>+</sup> )Tc95(β <sup>+</sup> )Mo95(n,t) Nb93m Ru96(n,d)Tc95(β <sup>+</sup> )Mo95(n,t)Nb93m Ru96(n,t)Tc94(β <sup>+</sup> )Mo94(n,d)Nb93m Ru99(n,3n)Ru97(β <sup>+</sup> )Tc97(n,α)Nb93m Ru96(n,3n)Ru94(β <sup>+</sup> )Tc94m(β <sup>+</sup> )Mo94_ (n,d)Nb93m Ru99(n,2nα)Mo94(n,d)Nb93m Ru100(n,2nα)Mo95(n,t)Nb93m &Ru99(n,nt)Tc96(β <sup>+</sup> )Mo96(n,nt)Nb93m Ru99(n,tα)Nb93m Ru99(n,2nt)Tc95(β <sup>+</sup> )Mo95(n,t)Nb93m Other pathways from high mass Ru isotopes	100.0	100.0	100.0	8.3 31.9 14.6	0.1 0.3	0.2 0.2 0.1	0.5 0.3
						11.8	1.6	0.3	
						6.5	0.7	0.1	
						5.9	0.3		
						4.2	10.2	10.1	3.6
						1.9	9.4	8.2	2.9
							19.8	18.4	4.2
							14.1	2.8	0.6
							13.5	7.0	1.7
							2.2	4.6	1.2
							0.2	3.4	1.0
								0.7	5.6
								0.2	12.7
									6.4
						14.9	27.6	43.7	59.3
Nb91	680.0 y	&Ru96(n,α)Mo92(n,d)Nb91 &Ru96(n,α)Mo92(n,2n)Mo91(β <sup>+</sup> )Nb91 &Ru96(n,α)Mo93(n,2n)Mo92(n,d)Nb91 &Ru96(n,dα)Nb91 &Ru96(n,2nα)Mo91(β <sup>+</sup> )Nb91 &Ru96(n,t)Tc94(β <sup>+</sup> )Mo94(n,nt)Nb91 &Ru96(n,nt)Tc93(β <sup>+</sup> )Mo93(n,t)Nb91				65.1 21.7 7.0	18.6 16.8	1.0 0.8	1.5 1.2
							34.2	37.8	16.5
							2.6	25.8	13.1
								5.2	3.8
								3.1	4.4
Mo93	4000 y	&Ru96(n,α)Mo93 Ru96(n,2n)Ru95(β <sup>+</sup> )Tc95(β <sup>+</sup> )Mo95_ (n,2n)Mo94(n,2n)Mo93 &Ru96(n,2n)Ru95(β <sup>+</sup> )Tc95(β <sup>+</sup> )Mo95_ (n,3n)Mo93 &Ru96(n,d)Tc95(β <sup>+</sup> )Mo95(n,3n)Mo93 &Ru99(n,α)Mo95(n,3n)Mo93 &Ru96(n,t)Tc94(β <sup>+</sup> )Mo94(n,2n)Mo93 &Ru98(n,2nα)Mo93 &Ru96(n,nt)Tc93(β <sup>+</sup> )Mo93 &Ru99(n,3nα)Mo93	100.0	100.0	100.0	92.3 4.4	12.9 0.2	11.2	15.8
							24.3	3.2	0.3
							22.4	2.8	0.2
							6.4	0.8	
							5.9	2.3	0.2
							2.9	8.1	1.2
							0.6	39.0	40.6
								5.5	14.6
Nb94	2.0 10 <sup>4</sup> y ▶	&Ru96(n,γ)Ru97(β <sup>+</sup> )Tc97(n,α)Nb94 &Ru96(n,α)Mo93(β <sup>+</sup> )Nb93m(n,γ)Nb94	96.5 2.6	99.9	94.7 4.1				

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&Ru96(n,2n)Ru95(β <sup>+</sup> )Tc95(β <sup>+</sup> )Mo95_ (n,d)Nb94 &Ru98(n,2n)Ru97(β <sup>+</sup> )Tc97(n,α)Nb94 &Ru96(n,d)Tc95(β <sup>+</sup> )Mo95(n,d)Nb94 &Ru99(n,2n)Ru98(n,2n)Ru97(β <sup>+</sup> )Tc97_ (n,α)Nb94 Ru96(n,2n)Ru95(β <sup>+</sup> )Tc95(β <sup>+</sup> )Mo95_ (n,2n)Mo94(n,p)Nb94 &Ru96(n,d)Tc95(β <sup>+</sup> )Mo95(n,2n)Mo94_ (n,p)Nb94 &Ru99(n,nα)Mo95(n,d)Nb94 &Ru99(n,d)Tc98(n,nα)Nb94 &Ru96(n,t)Tc94(β <sup>+</sup> )Mo94(n,p)Nb94 &Ru99(n,3n)Ru97(β <sup>+</sup> )Tc97(n,α)Nb94 &Ru96(n,3n)Ru94(β <sup>+</sup> )Tc94m(β <sup>+</sup> )Mo94_ (n,p)Nb94 &Ru99(n,dα)Nb94 &Ru100(n,tα)Nb94 &Ru99(n,2nt)Tc95(β <sup>+</sup> )Mo95(n,d)Nb94 Pathways from high mass Ru isotopes				26.7	23.1	8.6	2.6
						23.1	0.5		0.1
						11.8	21.4	7.0	2.2
						11.3			
						5.8	0.2		
						4.5	0.1		
						0.5	6.1	2.2	0.8
						0.5	5.2	1.7	0.7
							6.0	5.4	0.7
							5.2	1.7	1.0
							4.1	2.1	0.2
								8.0	6.8
									13.1
									4.8
			0.9	0.1	1.2	15.8	28.1	63.3	67.0
Tc99	2.1 10 <sup>5</sup> y	&Ru96(n,γ)Ru97(β <sup>+</sup> )Tc97(n,γ)Tc98_ (n,γ)Tc99 &Ru99(n,p)Tc99 &Ru102(n,α)Mo99(β <sup>-</sup> )Tc99 &Ru100(n,2n)Ru99(n,p)Tc99 &Ru100(n,d)Tc99 &Ru101(n,t)Tc99 &Ru102(n,3n)Ru100(n,d)Tc99 &Ru102(n,nt)Tc99 &Ru104(n,2nα)Mo99(β <sup>-</sup> )Tc99	100.0	100.0	99.9				
						64.0	18.9	8.9	3.0
						20.3	6.1	1.8	1.9
						6.6	0.7	0.1	
						6.4	40.0	25.6	15.5
						0.2	17.9	35.9	23.7
							7.9	2.6	0.7
							0.9	13.1	47.2
							0.3	4.2	2.2
Tc97	2.6 10 <sup>6</sup> y	Ru96(n,γ)Ru97(β <sup>+</sup> )Tc97 Ru98(n,2n)Ru97(β <sup>+</sup> )Tc97 Ru99(n,2n)Ru98(n,2n)Ru97(β <sup>+</sup> )Tc97 Ru99(n,3n)Ru97(β <sup>+</sup> )Tc97 &Ru99(n,t)Tc97 Ru101(n,3n)Ru99(n,3n)Ru97(β <sup>+</sup> )Tc97 Ru100(n,4n)Ru97(β <sup>+</sup> )Tc97 &Ru100(n,nt)Tc97 &Ru101(n,2nt)Tc97 Ru101(n,5n)Ru97(β <sup>+</sup> )Tc97	100.0	100.0	100.0	0.1			
						53.0	7.1	3.5	2.0
						38.7	1.9	0.6	0.2
							63.3	37.2	14.5
							7.5	16.0	9.5
							5.6	1.6	0.3
								20.7	17.3
								2.5	11.9
								0.1	8.6
									20.7
Tc98	4.2 10 <sup>6</sup> y	Ru96(n,γ)Ru97(β <sup>+</sup> )Tc97(n,γ)Tc98 Ru99(n,d)Tc98 Ru98(n,p)Tc98 Ru99(n,2n)Ru98(n,p)Tc98 &Ru99(n,p)Tc99(n,2n)Tc98 &Ru102(n,α)Mo99(β <sup>-</sup> )Tc99(n,2n)Tc98 Ru100(n,2n)Ru99(n,d)Tc98 Ru100(n,t)Tc98 Ru101(n,3n)Ru99(n,d)Tc98 Ru102(n,3n)Ru100(n,t)Tc98 Ru101(n,nt)Tc98 Ru102(n,4n)Ru99(n,d)Tc98 Ru102(n,2nt)Tc98	100.0	100.0	100.0	34.3	63.9	32.3	16.9
						24.5	4.1	1.7	
						17.9	1.1	0.3	
						11.8	0.6	0.2	
						3.8			
						3.6	2.2	0.7	
							11.4	36.8	17.9
							5.6	1.4	
							2.3	3.7	
							1.2	12.1	28.7
								2.9	
								0.3	27.7



# Ruthenium activation characteristics

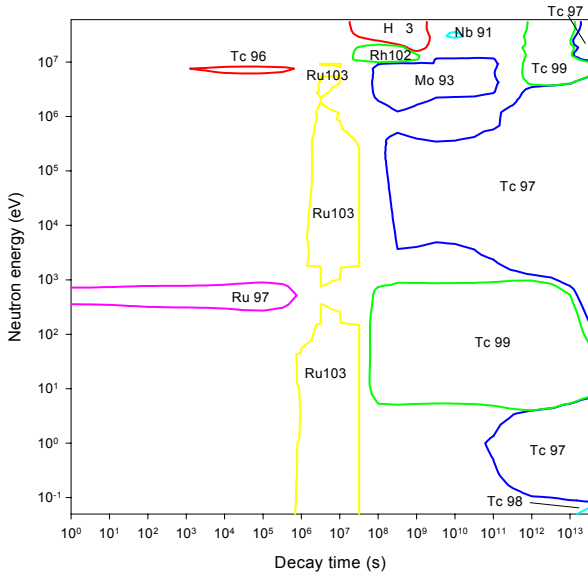


Decay time (years)

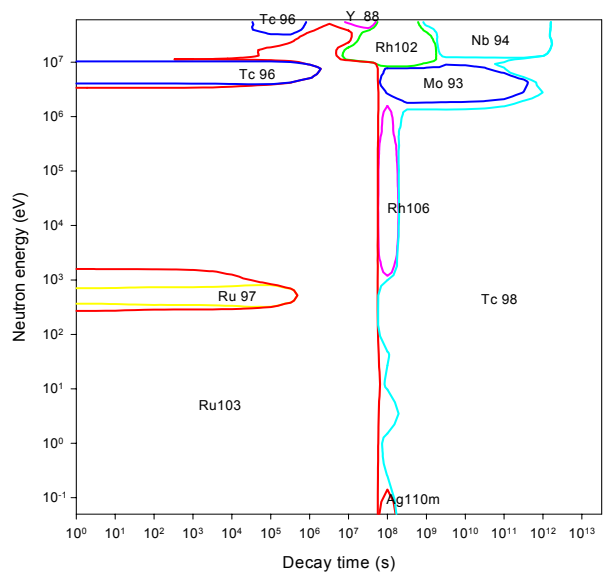
Decay time (years)

# Ruthenium importance diagrams & transmutation

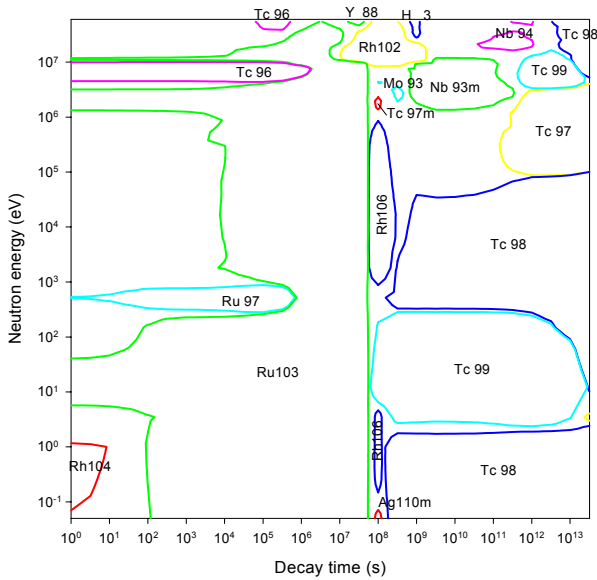
**Activity**



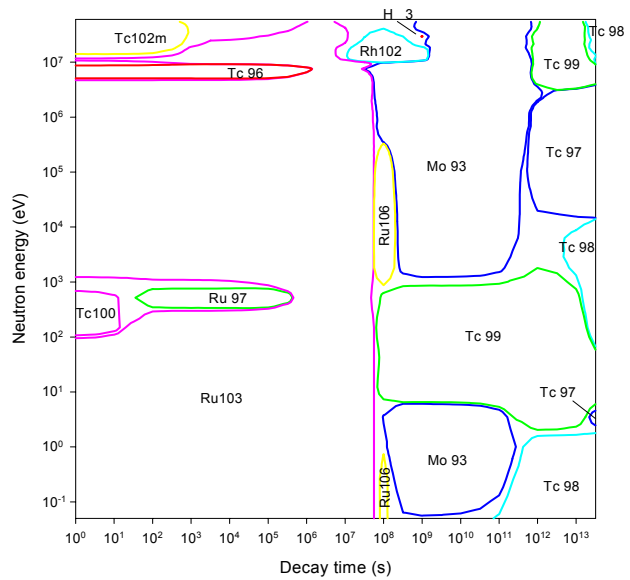
**Dose rate**



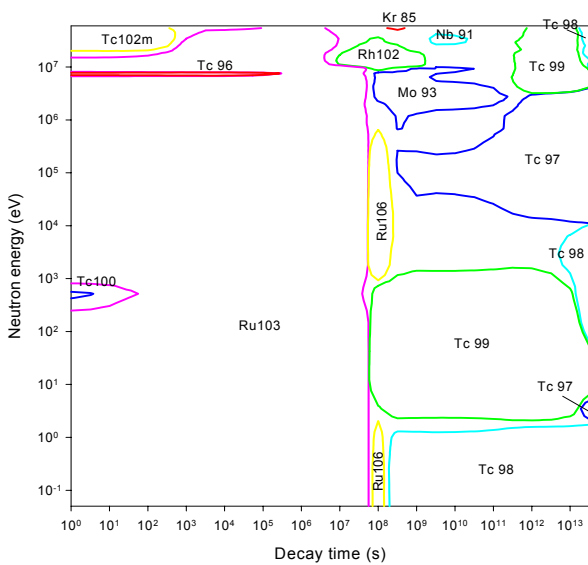
**Heat output**



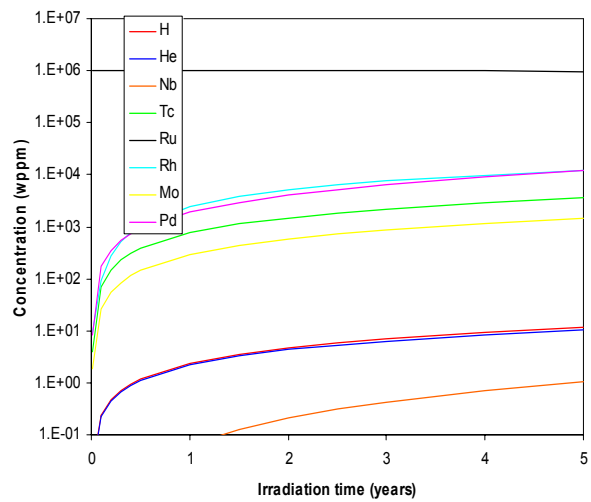
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**



*Graphs for H, He curves are indistinguishable*

# Rhodium

## General properties

Atomic number	45	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	$1.0 \cdot 10^{-3}$	Rh103	100.0
Melting point / K	2237		
Boiling point / K	3968		
Density / $\text{kgm}^{-3}$	12410		
Thermal conductivity / $\text{Wm}^{-1}\text{K}^{-1}$	150		
Electrical resistivity / $\Omega\text{m}$	$4.51 \cdot 10^{-8}$		
Coefficient of thermal expansion / $\text{K}^{-1}$	$8.20 \cdot 10^{-6}$		
Crystal structure	FCC		
Number of stable isotopes	1		
Mean atomic weight	102.9055		

## Activation properties

Act	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Heat	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Bq $\text{kg}^{-1}$	1.43E16	3.05E15	1.15E15	2.17E14	3.58E8	4.93E6	kW $\text{kg}^{-1}$	1.90E0	1.89E-1	9.40E-2	5.97E-2	4.55E-10	6.09E-11
Rh104	78.29	16.37					Rh104	93.65	42.16				
Rh103m	9.73	43.60	32.56	0.01			Rh102	3.51	35.49	71.10	89.07		
Rh104m	6.00	12.14					Rh102m	1.14	11.59	23.00	10.85		
Pd103	2.88	13.50	30.72				Rh104m	0.94	4.13				
Rh102m	1.43	6.72	17.53	27.93			Rh103m	0.43	4.23	2.40			
Rh102	1.37	6.42	16.94	71.62			Ru103	0.10	1.05	1.98			
Ru103	0.15	0.72	1.79	0.01			Pd103	0.07	0.71	1.24			
Rh101		0.03	0.08	0.37			H3					70.55	
H3				0.04	98.11		Tc99					17.68	95.68
Tc99					1.64	86.27	Ag108m					10.82	
Pd107					0.18	13.59	Tc98					0.36	2.68
Dose	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Ing	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{h}^{-1}$	1.47E5	1.22E5	1.19E5	8.31E4	6.84E-5	2.17E-6	Sv $\text{kg}^{-1}$	9.09E5	8.66E5	8.37E5	4.78E5	1.90E-2	2.76E-3
Rh102	66.17	79.86	81.53	92.83			Rh102	56.07	58.82	60.75	84.66		
Rh104	17.57	0.94					Rh102m	27.06	28.38	29.03	15.24		
Rh102m	13.67	16.50	16.68	7.15			Pd103	8.61	9.02	8.05			
Ru103	1.41	1.71	1.64				Ru103	1.77	1.86	1.81			
Rh104m	0.47	0.24					Rh104	1.60	0.07				
Ru105	0.31	0.37					Rh103m	0.58	0.58	0.17			
Ag108m					96.65		H3					77.70	
Tc98					3.22	99.98	Tc99					19.83	98.62
Inh	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Clear	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{kg}^{-1}$	5.09E6	5.06E6	4.99E6	3.08E6	1.75E-1	5.60E-2		1.86E12	6.22E11	5.40E11	3.62E11	9.72E3	4.27E3
Rh102	65.40	65.88	66.61	85.87			Rh104	68.15	9.11				
Rh102m	28.56	28.77	28.80	13.99			Rh102	22.36	66.99	77.08	91.54		
Pd103	3.63	3.66	3.19				Rh102m	5.49	16.46	18.75	8.38		
Ru103	1.30	1.31	1.24				Rh104m	2.55	3.30				
Rh104	0.24	0.01					Ru103	1.18	3.55	3.84			
Rh101	0.10	0.10	0.10	0.14			Pd103	0.02	0.06	0.06			
Rh103m	0.07	0.07	0.02				Rh103m		0.02				
H3					52.06		Tc99					60.56	99.76
Tc99					43.59	98.76	H3					36.16	
Ag108m					3.93		Ag108m					3.15	
Tc98					0.17	0.53	Tc98					0.09	0.22

# Rhodium

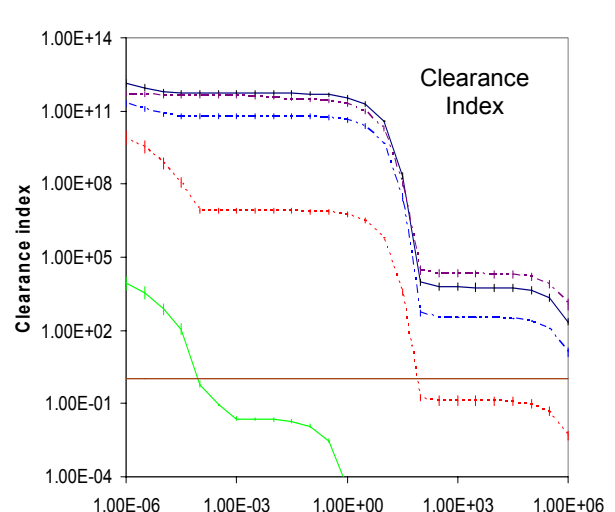
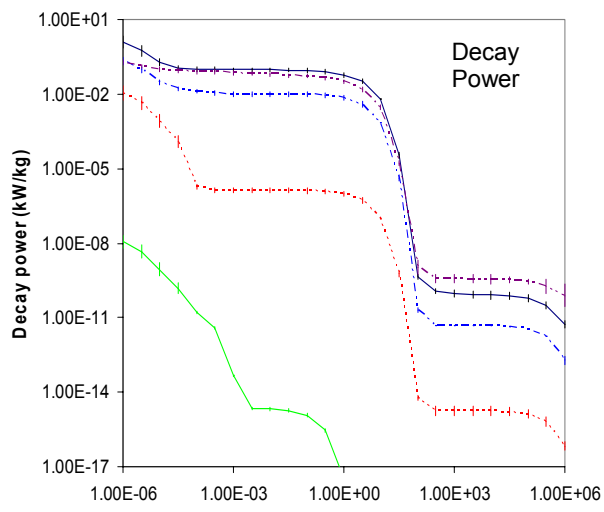
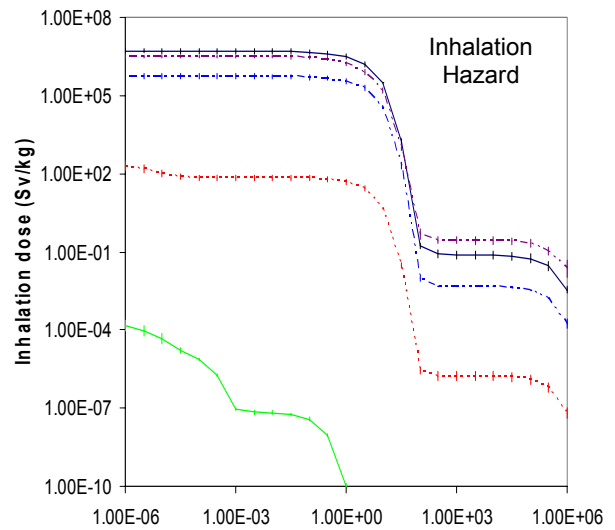
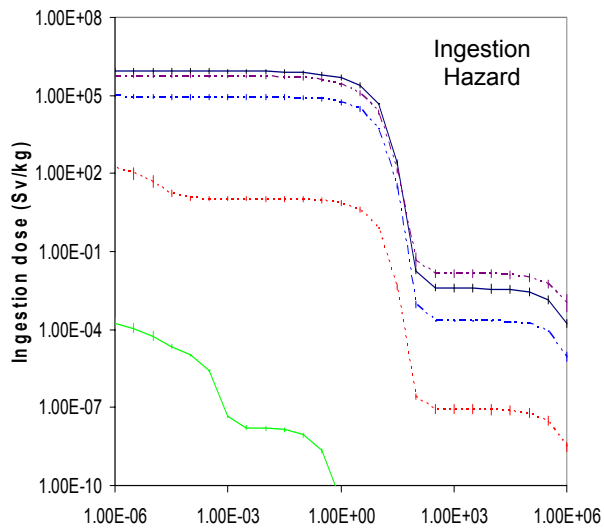
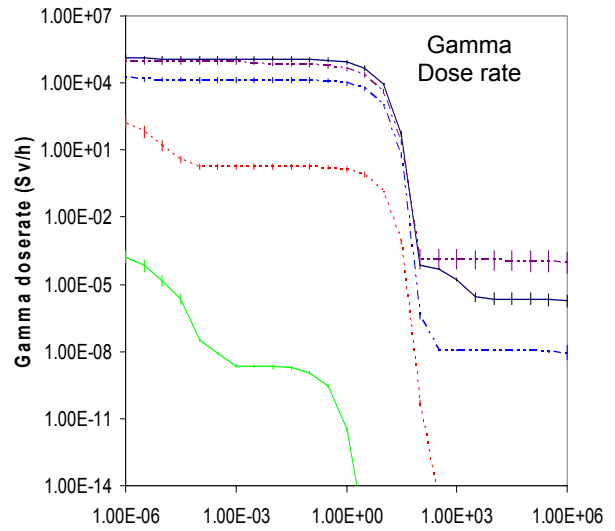
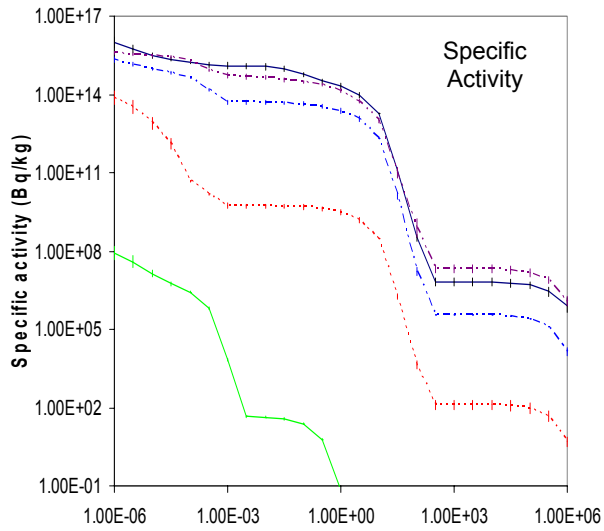
## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Rh106	30.0 s	&Rh103(n,γ)Rh104(β <sup>+</sup> )Ru104(n,γ) Ru105(β <sup>-</sup> )Rh105(n,γ)Rh106 &Rh103(n,γ)Rh104(β <sup>+</sup> )Ru104(n,γ) Ru105(n,γ)Ru106(β <sup>-</sup> )Rh106 &Rh103(n,γ)Rh104(β <sup>-</sup> )Pd104(n,γ) Pd105(n,γ)Pd106(n,p)Rh106	100.0	97.3	90.5	0.2		0.1	0.3
				2.7	9.5		0.4	0.5	1.1
						97.5	97.3	97.3	96.8
Rh104	42.3 s	&Rh103(n,γ)Rh104	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Rh104m	4.34 m	Rh103(n,γ)Rh104m Rh103(n,γ)Rh104(β <sup>-</sup> )Pd104(n,p)Rh104m	100.0	100.0	100.0	99.1	97.4	98.2	98.9
						0.3	0.4	0.3	0.2
Rh103m	56.114 m	&Rh103(n,γ)Rh104(β <sup>-</sup> )Pd104(n,γ)Pd105 (n,α)Ru102(n,γ)Ru103(β <sup>-</sup> )Rh103m &Rh103(n,γ)Rh104(β <sup>-</sup> )Pd104(n,α)Ru101 (n,γ)Ru102(n,γ)Ru103(β <sup>-</sup> )Rh103m Rh103(n,n')Rh103m Rh103(n,p)Ru103(β <sup>-</sup> )Rh103m	94.6	91.5					
			5.0	8.4					
					100.0	90.9	78.8	79.1	82.5
						8.3	20.4	20.3	17.1
Rh106m	2.20 h	&Rh103(n,γ)Rh104(β <sup>+</sup> )Ru104(n,γ) Ru105(β <sup>-</sup> )Rh105(n,γ)Rh106m &Rh103(n,γ)Rh104(β <sup>-</sup> )Pd104(n,γ) Pd105(n,γ)Pd106(n,p)Rh106m &Rh103(n,γ)Rh104(β <sup>-</sup> )Pd104(n,γ) Pd105(n,p)Rh105(n,γ)Rh106m Rh103(n,γ)Rh104(β <sup>+</sup> )Ru104(n,γ)Ru105(β <sup>-</sup> ) Rh105(β <sup>-</sup> )Pd105(n,γ)Pd106(n,p)Rh106m	100.0	100.0	100.0	0.9	0.4	0.6	0.9
						96.3	97.1	97.1	96.8
						0.8			
						0.1			
Ru105	4.44 h	&Rh103(n,γ)Rh104(β <sup>+</sup> )Ru104(n,γ)Ru105 Rh103(n,p)Ru103(n,γ)Ru104(n,γ)Ru105	100.	100.0	100.0	96.1	97.1	98.0	98.9
						1.6	1.3	0.9	0.5
Rh100	20.8 h	&Rh103(n,2n)Rh102(n,2n)Rh101(n,2n)Rh100 &Rh103(n,2n)Rh102m(n,2n)Rh101 (n,2n)Rh100 &Rh103(n,2n)Rh102(n,3n)Rh100 &Rh103(n,3n)Rh101(n,2n)Rh100 &Rh103(n,2n)Rh102m(n,3n)Rh100 Rh103(n,2n)Rh102m(β <sup>-</sup> )Pd102(n,3n) Pd100(β <sup>+</sup> )Rh100 &Rh103(n,4n)Rh100				75.8			
						11.8			
							38.1		
							34.5		
							13.5		
							7.1		
								98.2	100.0
Rh105	1.473 d	&Rh103(n,γ)Rh104(β <sup>+</sup> )Ru104(n,γ) Ru105(β <sup>-</sup> )Rh105 &Rh103(n,γ)Rh104(β <sup>-</sup> )Pd104(n,γ) Pd105(n,p)Rh105 &Rh103(n,p)Ru103(n,γ)Ru104(n,γ) Ru105(β <sup>-</sup> )Rh105	100.0	100.0	97.9	55.5	76.1	81.1	89.1
						41.4	21.2	17.3	10.5
						1.0	1.1	0.8	0.4
Rh101m	4.34 d	&Rh103(n,2n)Rh102(n,2n)Rh101m Rh103(n,2n)Rh102m(n,2n)Rh101m Rh103(n,2n)Rh102m(β <sup>-</sup> )Pd102(n,2n) Pd101(β <sup>+</sup> )Rh101m Rh103(n,3n)Rh101m				69.6	0.9		
						15.2	0.3		
						12.0			
							97.1	98.1	98.5
Ru103	39.26 d	&Rh103(n,γ)Rh104(β <sup>-</sup> )Pd104(n,γ) Pd105(n,α)Ru102(n,γ)Ru103 &Rh103(n,γ)Rh104(β <sup>-</sup> )Pd104(n,α) Ru101(n,γ)Ru102(n,γ)Ru103 Rh103(n,p)Ru103	94.6	91.5	85.5				
			5.0	8.5	14.2				
						98.5	98.9	99.1	99.2
Ag110m	249.78 d	&Rh103(n,γ)Rh104(β <sup>-</sup> )Pd104(n,γ) Pd105(n,γ)Pd106(n,γ)Pd107(n,γ)Pd108 (n,γ)Pd109(β <sup>-</sup> )Ag109(n,γ)Ag110m	98.9	99.8	99.5				
Ru106	1.02 y	&Rh103(n,γ)Rh104(β <sup>+</sup> )Ru104(n,γ) Ru105(n,γ)Ru106	100.0	100.0	100.0	97.9	97.3	98.1	99.0

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Rh103(n,p)Ru103(n,γ)Ru104(n,γ)_ Ru105(n,γ)Ru106				1.6	1.3	0.9	0.5	
Rh102	2.902 y	&Rh103(n,2n)Rh102				99.6	99.6	99.8	94.0	
Rh101	3.30 y	&Rh103(n,2n)Rh102(n,2n)Rh101 &Rh103(n,2n)Rh102m(n,2n)Rh101 &Rh103(n,3n)Rh101				84.5 12.4	0.4 0.1	99.2	99.3	
H3	12.33 y	Rh103(n,X)H3 &Rh103(n,2n)Rh102(n,X)H3 Rh103(n,2n)Rh102m(n,X)H3 Rh103(n,3n)Rh101m(β <sup>+</sup> )Ru101(n,X)H3 Rh103(n,5n)Rh99m(β <sup>+</sup> )Ru99(n,X)H3				82.4 14.8 2.3	92.1 1.2 0.5	91.6 0.6	91.0 1.0 1.1	
Ag108m	418.0 y	&Rh103(n,γ)Rh104(β <sup>-</sup> )Pd104(n,γ)_ Pd105(n,γ)Pd106(n,γ)Pd107(β <sup>-</sup> )Ag107_ (n,γ)Ag108m	98.9	99.9	99.6					
Mo93	4000 y	&Rh103(n,α)Tc100(β <sup>-</sup> )Ru100(n,2n)_ Ru99(n,2n)Ru98(n,nα)Mo94(n,2n)Mo93 &Rh103(n,α)Tc100(β <sup>-</sup> )Ru100(n,2n)Ru99_ (n,nα)Mo95(n,2n)Mo94(n,2n)Mo93 &Rh103(n,2n)Rh102m(β <sup>-</sup> )Pd102(n,nα)_ Ru98(n,nα)Mo94(n,2n)Mo93 &Rh103(n,nα)Tc99(n,nα)Nb95(β <sup>-</sup> )_ Mo95(n,2n)Mo94(n,2n)Mo93 Rh103(n,3n)Rh101m(β <sup>+</sup> )Ru101(n,3n)_ Ru99(n,nα)Mo95(n,3n)Mo93 &Rh103(n,nα)Tc99(n,nα)Nb95(β <sup>-</sup> )_ Mo95(n,3n)Mo93 Rh103(n,3n)Rh101m(β <sup>+</sup> )Ru101(n,nα)_ Mo97(n,3n)Mo95(n,3n)Mo93 Rh103(n,nα)Tc99(n,3n)Tc97(n,3n)_ Tc95(β <sup>+</sup> )Mo95(n,3n)Mo93 &Rh103(n,3n)Rh101m(β <sup>+</sup> )Ru101(n,4n)_ Ru98(n,2nα)Mo93 &Rh103(n,4n)Rh100(β <sup>+</sup> )Ru100(n,3n)_ Ru98(n,2nα)Mo93 &Rh103(n,4n)Rh100(β <sup>+</sup> )Ru100(n,2nα)_ Mo95(n,3n)Mo93 &Rh103(n,2nt)Ru99(n,3nα)Mo93 &Rh103(n,5n)Rh99m(β <sup>+</sup> )Ru99(n,3nα)Mo93 &Rh103(n,3nα)Tc97(n,2nt)Mo93 &Rh103(n,4nα)Tc96(β <sup>+</sup> )Mo96(n,4n)Mo93 &Rh103(n,3nα)Tc97(n,5n)Tc93(β <sup>+</sup> )Mo93 &Rh103(n,4n)Rh100(β <sup>+</sup> )Ru100(n,4nα)Mo93 Other pathways involving (n,2n), (n,α), β <sup>+</sup>				18.7 13.6 10.7 9.8	12.6	9.1 8.9 7.0	0.1 11.0 13.0 6.5 0.1	10.0 18.5 9.1 7.8 7.2 7.1 40.2
Nb94	2.0 10 <sup>4</sup> y	&Rh103(n,2n)Rh102(n,nα)Tc98(n,nα)Nb94 &Rh103(n,nα)Tc99(n,2n)Tc98(n,nα)Nb94 &Rh103(n,2n)Rh102m(n,nα)Tc98(n,nα)Nb94 &Rh103(n,2n)Rh102(n,α)Tc99(n,2n)_ Tc98(n,nα)Nb94 &Rh103(n,2n)Rh102(n,nα)Tc98(n,2n)_ Tc97(n,α)Nb94 &Rh103(n,nα)Tc99(n,2nα)Nb94 &Rh103(n,2nα)Tc98(n,nα)Nb94 &Rh103(n,3nα)Tc97(n,α)Nb94 &Rh103(n,2n2α)Nb94 &Rh103(n,4nα)Tc96(β <sup>+</sup> )Mo96(n,t)Nb94 &Rh103(n,4n)Rh100(β <sup>+</sup> )Ru100(n,tα)Nb94				27.5 21.5 8.4 6.8	2.2 5.1 1.3	0.1	2.5 3.0 4.3 31.7 16.4 6.5	
Tc99	2.1 10 <sup>5</sup> y	&Rh103(n,γ)Rh104(β <sup>-</sup> )Pd104(n,α)_ Ru101(n,α)Mo98(n,γ)Mo99(β <sup>-</sup> )Tc99 &Rh103(n,α)Tc100(β <sup>-</sup> )Ru100(n,γ)_ Ru101(n,α)Mo98(n,γ)Mo99(β <sup>-</sup> )Tc99 ▶ &Rh103(n,nα)Tc99	97.2 2.8	100.0	99.8 0.2					
						50.2	89.6	64.7	53.9	

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&Rh103(n,2n)Rh102(n,α)Tc99 &Rh103(n,2n)Rh102m(n,α)Tc99 &Rh103(n,2n)Rh102m(β <sup>+</sup> )Ru102(n,α) <sub>-</sub> Mo99(β <sup>-</sup> )Tc99 &Rh103(n,2n)Rh102(β <sup>+</sup> )Ru102(n,α) <sub>-</sub> Mo99(β <sup>-</sup> )Tc99 &Rh103(n,3n)Rh101m(β <sup>+</sup> )Ru101(n,t)Tc99   &Rh103(n,t)Ru101(n,t)Tc99   &Rh103(n,4n)Rh100(β <sup>+</sup> )Ru100(n,d)Tc99   &Rh103(n,nt)Ru100(n,d)Tc99   &Rh103(n,d)Ru102(n,nt)Tc99   &Rh103(n,2n)Rh102m(β <sup>+</sup> )Ru102(n,nt)Tc99				28.8 6.8 6.6 6.0	0.1 0.2		0.1 6.5 4.2 9.1 5.0 4.0 2.0
Tc97	2.6 10 <sup>6</sup> y	&Rh103(n,2n)Rh102(n,α)Tc98(n,2n)Tc97 &Rh103(n,α)Tc99(n,2n)Tc98(n,2n)Tc97   &Rh103(n,2n)Rh102(n,2n)Rh101(n,α)Tc97   Rh103(n,α)Tc100(β <sup>-</sup> )Ru100(n,2n)Ru99 <sub>-</sub> (n,2n)Ru98(n,2n)Ru97(β <sup>+</sup> )Tc97   &Rh103(n,2n)Rh102m(n,α)Tc98(n,2n)Tc97   &Rh103(n,2n)Rh102(n,α)Tc99(n,2n) <sub>-</sub> Tc98(n,2n)Tc97 &Rh103(n,α)Tc99(n,3n)Tc97 Rh103(n,3n)Rh101m(β <sup>+</sup> )Ru101(n,3n) <sub>-</sub> Ru99(n,3n)Ru97(β <sup>+</sup> )Tc97 &Rh103(n,3n)Rh101(n,α)Tc97 &Rh103(n,3nα)Tc97 Rh103(n,4n)Rh100(β <sup>+</sup> )Ru100(n,4n) <sub>-</sub> Ru97(β <sup>+</sup> )Tc97 Rh103(n,nt)Ru100(n,4n)Ru97(β <sup>+</sup> )Tc97 &Rh103(n,4n)Rh100(β <sup>+</sup> )Ru100(n,nt)Tc97   Rh103(n,5n)Rh99m(β <sup>+</sup> )Ru99(n,3n) <sub>-</sub> Ru97(β <sup>+</sup> )Tc97				26.1 17.2 10.5 8.5 8.1 6.5	0.1 0.3		0.3 52.9 2.8 4.1 4.8 4.2
Tc98	4.2 10 <sup>6</sup> y	&Rh103(n,2n)Rh102(n,α)Tc98 &Rh103(n,α)Tc99(n,2n)Tc98 &Rh103(n,2n)Rh102(n,α)Tc99(n,2n)Tc98   Rh103(n,2n)Rh102m(n,α)Tc98   &Rh103(n,2n)Rh102(n,2n)Rh101(n,α)Tc98   &Rh103(n,2n)Rh102m(n,α)Tc99(n,2n)Tc98   Rh103(n,2nα)Tc98 Rh103(n,3n)Rh101m(β <sup>+</sup> )Ru101(n,3n) <sub>-</sub> Ru99(n,d)Tc98 Rh103(n,3n)Rh101m(β <sup>+</sup> )Ru101(n,nt)Tc98   Rh103(n,t)Ru101(n,nt)Tc98 &Rh103(n,4n)Rh100(β <sup>+</sup> )Ru100(n,t)Tc98 Rh103(n,nt)Ru100(n,t)Tc98 Rh103(n,5n)Rh99m(β <sup>+</sup> )Ru99(n,d)Tc98				35.0 29.2 12.2 8.9 4.7 3.4	6.8 16.2	0.8	0.2 0.7 0.1 63.5 5.8 3.8 7.7 4.3 4.9
Pd107	6.5 10 <sup>6</sup> y	&Rh103(n,γ)Rh104(β <sup>-</sup> )Pd104(n,γ) <sub>-</sub> Pd105(n,γ)Pd106(n,γ)Pd107 Rh103(n,γ)Rh104(β <sup>+</sup> )Ru104(n,γ)Ru105(β <sup>-</sup> ) <sub>-</sub> Rh105(β <sup>-</sup> )Pd105(n,γ)Pd106(n,γ)Pd107	99.1	99.9	99.6	99.2	97.8	98.2	98.4
							0.2	0.2	0.2

# Rhodium activation characteristics

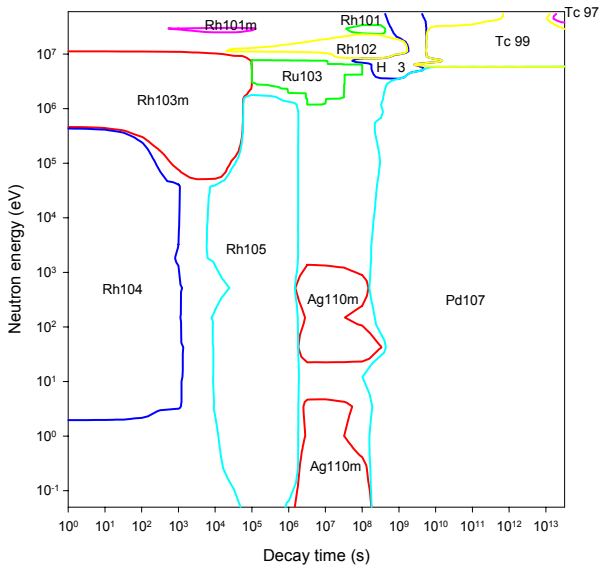


Decay time (years)

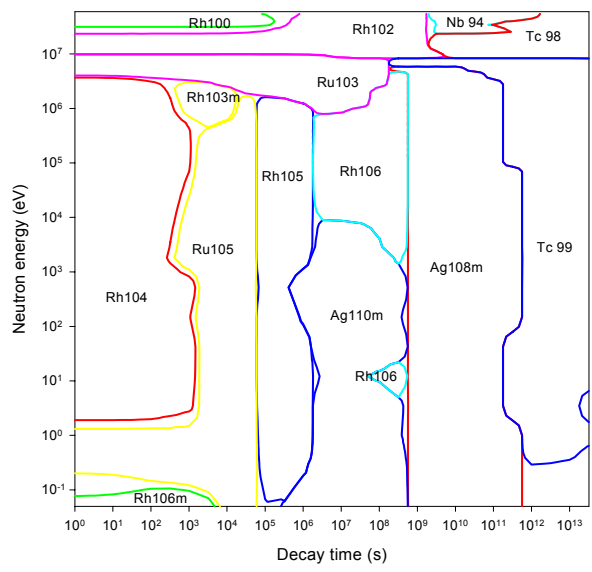
Decay time (years)

# Rhodium importance diagrams & transmutation

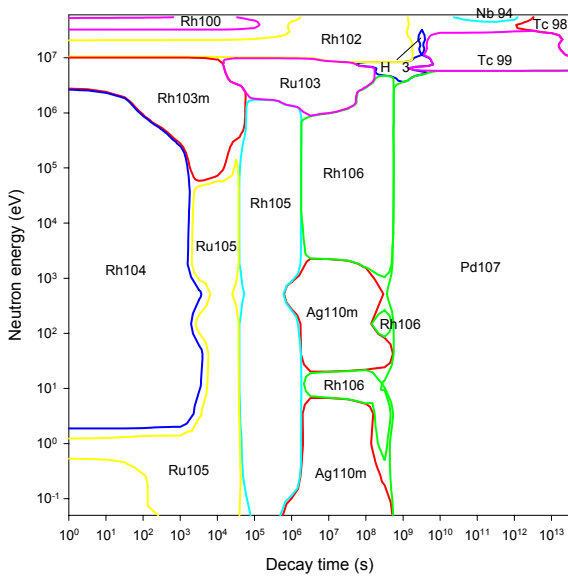
**Activity**



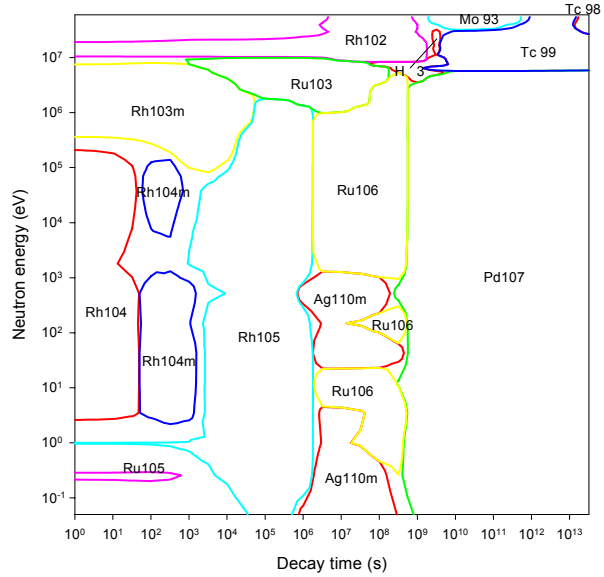
**Dose rate**



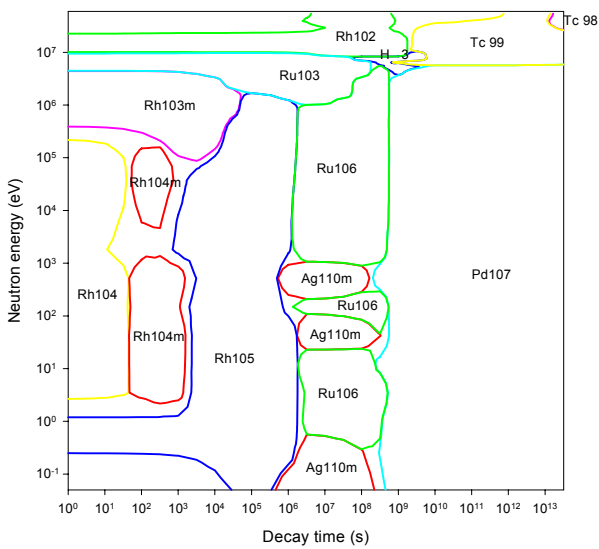
**Heat output**



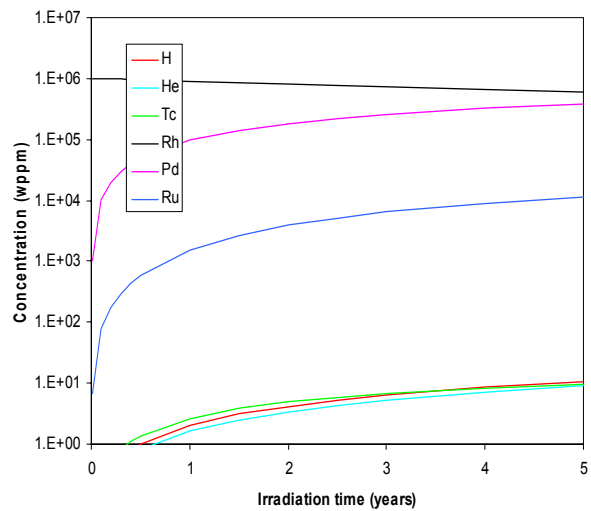
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**





# Palladium

## General properties

Atomic number	46	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	1.5 10 <sup>-2</sup>	Pd102	1.02
Melting point / K	1828	Pd104	11.14
Boiling point / K	3236	Pd105	22.33
Density / kgm <sup>-3</sup>	12020	Pd106	27.33
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	71.8	Pd108	26.46
Electrical resistivity /Ωm	1.08 10 <sup>-7</sup>	Pd110	11.72 (T <sub>½</sub> = 6.00 10 <sup>17</sup> y)
Coefficient of thermal expansion / K <sup>-1</sup>	1.18 10 <sup>-5</sup>		
Crystal structure	FCC		
Number of stable isotopes	5 (6)		
Mean atomic weight	106.42		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	1.22E16	7.96E15	6.40E14	8.29E13	8.32E10	2.96E8	kW kg <sup>-1</sup>	1.11E0	3.33E-1	6.12E-2	1.84E-2	2.07E-5	4.42E-10
Ag110	31.77	0.02	0.22	0.63			Ag110	68.06	0.11	0.45	0.55		
Ag109m	29.79	44.81	12.22	25.35			Pd109	18.49	61.42	3.97			
Pd109	28.95	44.33	6.57				Ag109m	4.57	14.94	1.78	1.58		
Ag111	1.34	2.07	18.44				Ag110m	4.37	14.60	78.60	95.68		
Rh103m	1.22	1.88	19.56				Pd111	0.99	2.90				
Pd103	1.17	1.80	19.32				Rh104	0.90	0.17				
Ag111m	1.00	0.93					Ag111	0.89	3.00	11.66			
Pd109m	0.98	0.69					Pd109m	0.32	0.49				
Ag110m	0.97	1.34	16.55	46.84			Ag108	0.28	0.20			2.31	
Cd109	0.29	0.45	5.64	25.35			Rh103m	0.08	0.27	1.22			
Ag108	0.25	0.08			7.95		Pd103	0.04	0.14	0.66			
Rh101	0.05		0.05	0.31			Rh102		0.09	0.51	1.35		
Rh102m			0.20	0.46			Rh102m			0.22	0.22		
Rh102			0.14	0.88			Ag108m			0.08	0.12	96.76	
Ag108m			0.01	0.10	91.44		Rh101			0.02	0.07		
Pd107					0.35	100.0	Pd107						99.95
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	1.23E5	8.40E4	7.78E4	2.85E4	2.71E1	4.75E-8	Sv kg <sup>-1</sup>	2.59E6	2.58E6	5.77E5	1.54E5	1.79E2	1.10E-2
Ag110m	67.34	91.90	98.25	98.44			Pd109	75.20	75.25				
Ag110	24.80*		0.01*	0.01*			Ag110m	11.55	11.61	51.44	70.58		
Rh106m	1.43	1.90					Ag111	8.27	8.31	0.50			
Pd107m	0.85						Cd109	2.80	2.81		27.28		
Pd111	0.78	0.93					Pd103	1.05	1.05	0.01			
Pd111m	0.76	1.03					Rh102	0.09	0.09	0.58	1.23		
Ag111	0.48	0.65	0.50				Rh102m	0.06	0.06	0.16	0.30		
Rh102	0.40	0.54	0.58	1.28			Cd113m	0.02	0.02		0.36	2.40	
Pd101	0.39	0.53					Ag108m			0.04	0.13	97.59	
Rh102m		0.15	0.16	1.33			Rh101				0.09		
Ag108m		0.03	0.04	0.11	99.89		Pd107						99.91
Tc98						99.59	Tc99						0.08
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	3.30E6	3.29E6	1.87E6	6.59E5	2.83E3	1.75E-1		1.87E12	1.25E12	1.10E12	4.12E11	1.25E8	2.84E2
Pd109	39.82	39.76	0.83				Ag110m	57.20	85.39	95.91	94.30		
Ag110m	38.97	39.08	67.84	70.73			Ag110	31.05			0.01		
Cd109	8.93	8.95	15.62	25.84			Ag109m	3.68	5.37	0.13	0.09		
Ag111	8.52	8.54	10.70				Pd109	1.89	2.81				
Pd103	1.96	1.96	2.96				Pd109m	0.76	0.52				
Rh102	0.47	0.47	0.83	1.89			Pd107m	0.68					
Rh102m	0.28	0.28	0.48	0.41			Pd111	0.54	0.71				
Ru103	0.12	0.12	0.21				Rh106m	0.35	0.51				
Ag108m	0.10	0.10	0.17	0.50	99.27		Pd111m	0.26	0.38				
Cd113m	0.08	0.08	0.15	0.40	0.72		Rh102	0.10	0.15	0.17	0.37		
Rh101	0.05	0.05	0.09	0.21			Ag111	0.08	0.13	0.10			
Pd107						99.89	Ag108m			0.01	0.03	99.56	
Tc99						0.10	Pd107						94.93

# Palladium

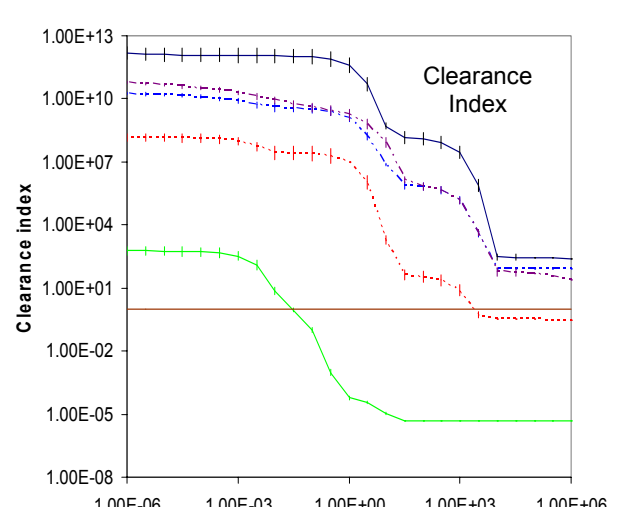
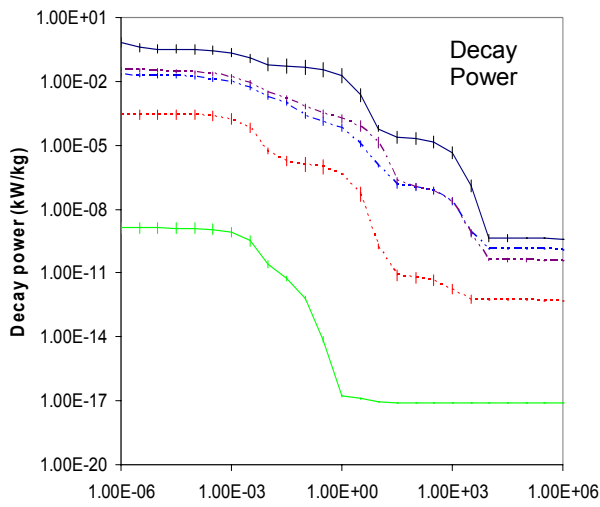
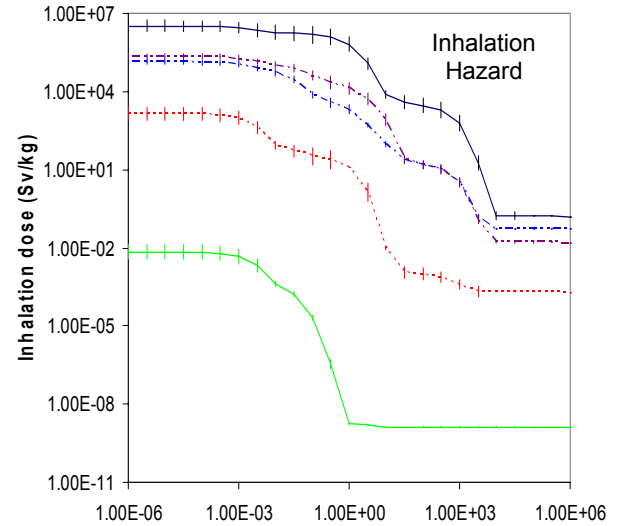
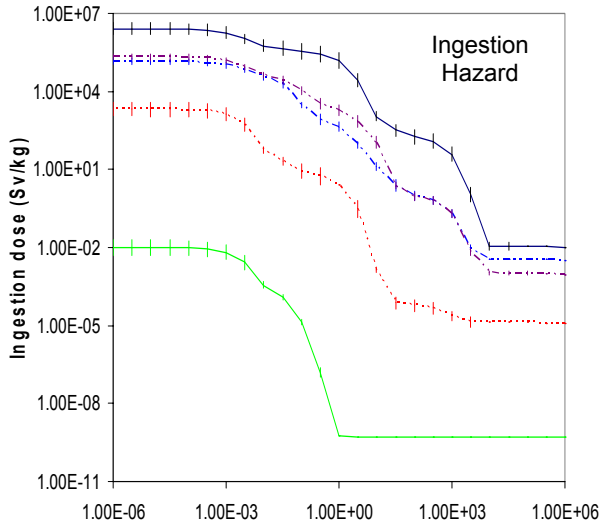
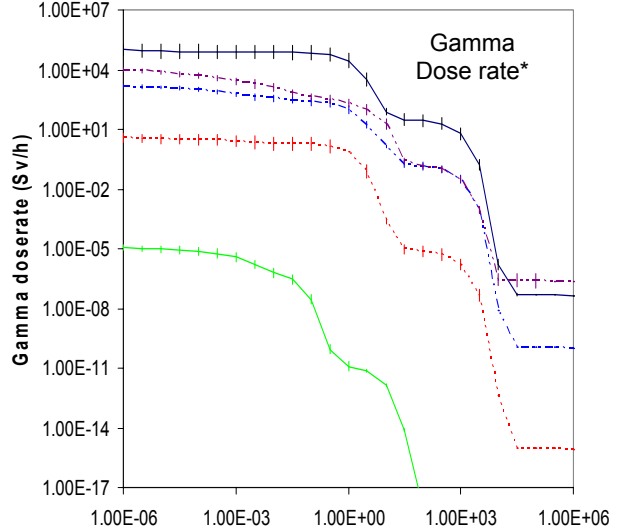
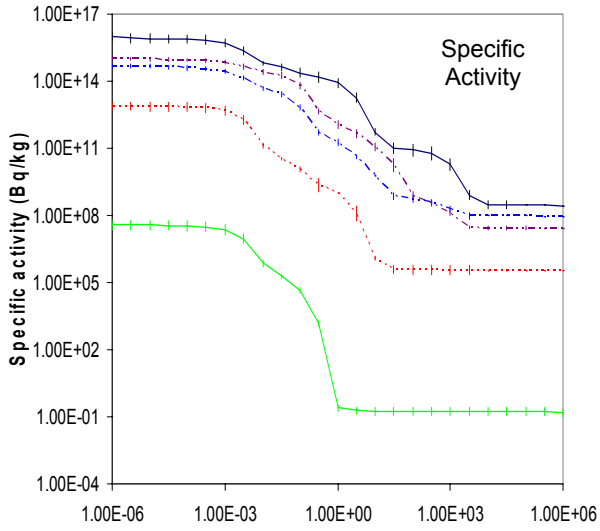
## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Ag110	24.56 s	&Pd108(n,γ)Pd109(β <sup>-</sup> )Ag109(n,γ)Ag110 &Pd110(n,2n)Pd109(β <sup>-</sup> )Ag109(n,γ)Ag110 &Pd110(n,γ)Pd111(β <sup>-</sup> )Ag111(n,2n)Ag110 &Pd110(n,γ)Pd111(β <sup>-</sup> )Ag111(β <sup>-</sup> ) Cd111(n,d)Ag110 &Pd110(n,d)Rh109(β <sup>-</sup> )Pd109(β <sup>-</sup> ) Ag109(n,γ)Ag110 &Pd110(n,γ)Pd111m(β <sup>-</sup> )Ag111(β <sup>-</sup> ) Cd111(n,d)Ag110	99.9	99.8	99.8	98.6 0.5	76.5 0.3 7.7	61.9 0.3 16.9	47.4 0.3 27.1
Pd111m	5.50 h	Pd110(n,γ)Pd111m	99.8	100.0	100.0	99.9	99.5	99.6	99.8
Pd109	13.701 h	&Pd108(n,γ)Pd109 Pd106(n,γ)Pd107(n,γ)Pd108(n,γ)Pd109 &Pd110(n,2n)Pd109 Pd110(n,d)Rh109(β <sup>-</sup> )Pd109	100.0	99.9	99.7 0.3	100.0	90.9 9.1	81.2 18.8	74.3 25.7
Rh100	20.8 h	&Pd102(n,2n)Pd101(β <sup>+</sup> )Rh101m(IT) Rh101(n,2n)Rh100 &Pd102(n,d)Rh101(n,2n)Rh100 Pd104(n,2n)Pd103(β <sup>+</sup> )Rh103m(IT)Rh103 (n,2n)Rh102(n,2n)Rh101(n,2n)Rh100 &Pd102(n,2n)Pd101(β <sup>+</sup> )Rh101m(n,2n)Rh100 Pd104(n,3n)Pd102(n,3n)Pd100(β <sup>+</sup> )Rh100 Pd102(n,3n)Pd100(β <sup>+</sup> )Rh100 &Pd104(n,3n)Pd102(n,t)Rh100 Pd106(n,3n)Pd104(n,3n)Pd102(n,3n) Pd100(β <sup>+</sup> )Rh100 &Pd102(n,t)Rh100 &Pd105(n,3n)Pd103(β <sup>+</sup> )Rh103m(IT) Rh103(n,4n)Rh100 Pd105(n,4n)Pd102(n,3n)Pd100(β <sup>+</sup> )Rh100 &Pd106(n,4n)Pd103(β <sup>+</sup> )Rh103m(IT) Rh103(n,4n)Rh100 &Pd105(n,4n)Pd102(n,t)Rh100 &Pd104(n,2n)Pd103(β <sup>+</sup> )Rh103m(IT) Rh103(n,4n)Rh100 Pd104(n,5n)Pd100(β <sup>+</sup> )Rh100 &Pd104(n,2nt)Rh100				52.5 16.8 4.5 3.6	36.3 30.2 6.6 6.5 5.6	8.5 9.6 7.4 1.1 8.0 11.7	1.1 3.3 1.2 3.4 3.2
Ag111	7.45 d	&Pd108(n,γ)Pd109(β <sup>-</sup> )Ag109(n,γ) Ag110m(n,γ)Ag111 &Pd110(n,γ)Pd111(β <sup>-</sup> )Ag111 &Pd110(n,γ)Pd111m(β <sup>-</sup> )Ag111	55.0 43.2 1.8	95.8 4.0	95.9 4.0	88.4 11.6	88.0 12.0	86.9 12.2	87.7 11.8
Pd103	16.98 d	Pd102(n,γ)Pd103 Pd104(n,2n)Pd103 Pd105(n,2n)Pd104(n,2n)Pd103 Pd106(n,2n)Pd105(n,2n)Pd104(n,2n)Pd103 Pd105(n,3n)Pd103 Pd106(n,3n)Pd104(n,2n)Pd103 Pd106(n,2n)Pd105(n,3n)Pd103 Pd106(n,4n)Pd103 Pd108(n,4n)Pd105(n,3n)Pd103 Pd108(n,3n)Pd106(n,4n)Pd103 Pd108(n,6n)Pd103 Pd108(n,5n)Pd104(n,2n)Pd103	99.8	100.0	100.0	65.3 29.9 4.0	18.9 2.9 0.1 61.8 6.5 5.7	12.0 1.1 39.6 2.8 2.1 32.4 3.9 2.4	11.9 0.7 26.5 1.1 0.9 45.0 1.3 1.4
Ag110m	249.78 d	&Pd108(n,γ)Pd109(β <sup>-</sup> )Ag109(n,γ)Ag110m &Pd110(n,2n)Pd109(β <sup>-</sup> )Ag109(n,γ)Ag110m &Pd110(n,γ)Pd111(β <sup>-</sup> )Ag111(β <sup>-</sup> ) Cd111(n,d)Ag110m	99.9	99.9	99.9	98.6	69.0 19.0	50.4 31.2	35.2 44.6

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	Pd110(n,d)Rh109(β <sup>-</sup> )Pd109(β <sup>-</sup> )_ Ag109m(IT)Ag109(n,γ)Ag110m &Pd110(n,γ)Pd111m(β <sup>-</sup> )Ag111(β <sup>-</sup> )_ Cd111(n,d)Ag110m					6.6	11.5	12.0
							2.7	4.4	6.0
Rh102	2.902 y	&Pd104(n,2n)Pd103(β <sup>+</sup> )Rh103(n,2n)Rh102   &Pd105(n,2n)Pd104(n,2n)Pd103(β <sup>+</sup> )_ Rh103(n,2n)Rh102 &Pd102(n,p)Rh102 &Pd104(n,d)Rh103(n,2n)Rh102 &Pd105(n,3n)Pd103(β <sup>+</sup> )Rh103m(IT)_ Rh103(n,2n)Rh102 &Pd104(n,t)Rh102 &Pd106(n,3n)Pd104(n,t)Rh102 &Pd105(n,nt)Rh102 &Pd106(n,4n)Pd103(β <sup>+</sup> )Rh103m(IT)_ Rh103(n,2n)Rh102 &Pd106(n,2nt)Rh102				79.5 12.8	12.1 0.6	1.8	0.4
						4.2	3.8	1.1	0.3
						0.7	3.2	0.8	0.2
							39.6	6.1	0.8
							20.6	47.7	19.4
							4.2	6.6	1.0
							1.5	17.8	45.9
								5.0	1.4
								0.1	20.3
H3	12.33 y	Pd104(n,γ)Pd105(n,X)H1(n,γ)H2(n,γ)H3 Pd105(n,X)H3 Pd104(n,2n)Pd103(β <sup>+</sup> )Rh103m(IT)_ Rh103(n,X)H3 Pd106(n,2n)Pd105(n,X)H3 &Pd108(n,2n)Pd107(n,X)H3 &Pd110(n,2n)Pd109(β <sup>-</sup> )Ag109(n,X)H3 Pd104(n,X)H3 Pd106(n,X)H3 Pd108(n,X)H3 Pd110(n,X)H3 Pd105(n,3n)Pd103(β <sup>+</sup> )Rh103m(IT)_ Rh103(n,X)H3	92.8	94.9		59.0 13.5	32.1 0.9	26.0 0.3	23.6 0.2
						8.2	1.5	0.7	0.4
						6.6	1.1	0.6	0.3
						4.6	0.7	0.4	0.1
						0.3	8.4	9.2	9.5
						0.2	18.9	21.5	23.0
						0.1	17.3	20.3	22.0
							7.2	8.7	9.5
							3.0	1.1	0.4
Cd113m	14.1 y	&Pd108(n,γ)Pd109(β <sup>-</sup> )Ag109(n,γ)_ Ag110(β <sup>-</sup> )Cd110(n,γ)Cd111(n,γ)Cd112_ (n,γ)Cd113m &Pd110(n,γ)Pd111(β <sup>-</sup> )Ag111(β <sup>-</sup> )_ Cd111(n,γ)Cd112(n,γ)Cd113m &Pd108(n,γ)Pd109(β <sup>-</sup> )Ag109(n,γ)_ Ag110m(n,γ)Ag111(β <sup>-</sup> )Cd111(n,γ)_ Cd112(n,γ)Cd113m &Pd108(n,γ)Pd109(β <sup>-</sup> )Ag109(n,γ)_ Ag110m(β <sup>-</sup> )Cd110(n,γ)Cd111(n,γ)_ Cd112(n,γ)Cd113m &Pd110(n,γ)Pd111m(β <sup>-</sup> )Ag111(β <sup>-</sup> )_ Cd111(n,γ)Cd112(n,γ)Cd113m &Pd110(n,γ)Pd111(β <sup>-</sup> )Ag111(n,γ)_ Ag112(β <sup>-</sup> )Cd112(n,γ)Cd113m	78.8	24.9					
			10.0	68.3	93.6	84.4	83.6	83.9	84.7
			4.3						
			1.4	0.6					
			0.3	2.9	2.8	8.2	11.8	11.8	11.4
				1.1	1.1	2.2	1.1	1.1	1.1
Ag108m	418.0 y	&Pd106(n,γ)Pd107(β <sup>-</sup> )Ag107(n,γ)Ag108m   &Pd105(n,γ)Pd106(n,γ)Pd107(β <sup>-</sup> )_ Ag107(n,γ)Ag108m &Pd110(n,2n)Pd109(β <sup>-</sup> )Ag109(n,2n)Ag108m   Pd110(n,d)Rh109(β <sup>-</sup> )Pd109(β <sup>-</sup> )_ Ag109m(IT)Ag109(n,2n)Ag108m	82.7 17.3	65.9 33.9	96.6 3.5				
						99.7	90.9	81.1	74.3
							8.6	18.5	25.3
Mo93	4000 y	&Pd102(n,α)Ru98(n,α)Mo94(n,2n)Mo93   &Pd102(n,α)Ru99(n,2n)Ru98(n,α)_ Mo94(n,2n)Mo93 &Pd102(n,α)Ru98(n,α)Mo95(n,2n)_ Mo94(n,2n)Mo93 &Pd102(n,α)Ru99(n,α)Mo95(n,2n)_ Mo94(n,2n)Mo93 &Pd102(n,α)Ru98(n,2nα)Mo93 &Pd104(n,3n)Pd102(n,α)Ru98(n,2nα)Mo93   &Pd104(n,2nα)Ru99(n,3nα)Mo93 &Pd105(n,3nα)Ru99(n,3nα)Mo93				54.4 13.2	1.3		
							10.4		
							9.6		
								14.8	3.5
								6.4	1.2
									5.2
									1.8
									0.8
									6.7

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
		Other pathways involving (n,2n), (n,α), β <sup>+</sup>				12.4	77.5	89.3	91.0
Nb94	2.0 10 <sup>4</sup> y	&Pd102(n,α)Ru98(n,2n)Ru97(β <sup>+</sup> ) Tc97(n,α)Nb94 &Pd102(n,α)Ru99(n,2n)Ru98(n,2n) Ru97(β <sup>+</sup> )Tc97(n,α)Nb94 Pd105(n,3n)Pd103(β <sup>+</sup> )Rh103m(IT) Rh103(n,2nα)Tc98(n,α)Nb94 Pd105(n,3n)Pd103(β <sup>+</sup> )Rh103m(IT) Rh103(n,α)Tc99(n,2nα)Nb94 &Pd102(n,2nα)Ru97(β <sup>+</sup> )Tc97(n,α)Nb94 &Pd104(n,5n)Pd100(β <sup>+</sup> )Rh100(β <sup>+</sup> ) Ru100(n,α)Nb94 Other pathways involving (n,2n), (n,α), β <sup>+</sup>				56.1	0.7		
						13.8		5.4	1.8
								5.3	1.2
								3.1	2.2
									0.4
									3.7
						30.1	85.5	93.8	95.9
Tc99	2.1 10 <sup>5</sup> y	&Pd102(n,α)Ru99(n,α)Mo96(n,γ) Mo97(n,γ)Mo98(n,γ)Mo99(β <sup>-</sup> )Tc99 &Pd104(n,α)Ru101(n,α)Mo98(n,γ) Mo99(β <sup>-</sup> )Tc99 &Pd104(n,2n)Pd103(β <sup>+</sup> )Rh103(n,α)Tc99 &Pd104(n,2n)Pd103(β <sup>+</sup> )Rh103m(IT) Rh103(n,2n)Rh102(n,α)Tc99 &Pd105(n,2n)Pd104(n,2n)Pd103(β <sup>+</sup> ) Rh103(n,α)Tc99 &Pd105(n,α)Ru102(n,α)Mo99(β <sup>-</sup> )Tc99 &Pd105(n,3n)Pd103(β <sup>+</sup> )Rh103m(IT) Rh103(n,α)Tc99 &Pd104(n,4n)Pd101(β <sup>+</sup> )Rh101m(β <sup>+</sup> ) Ru101(n,t)Tc99 &Pd106(n,4n)Pd103(β <sup>+</sup> )Rh103m(IT) Rh103(n,α)Tc99 &Pd105(n,α)Tc99 &Pd105(n,5n)Pd101(β <sup>+</sup> )Rh101m(β <sup>+</sup> ) Ru101(n,t)Tc99	91.8	96.5	81.0				
			0.2	2.6	18.1				
						45.0	13.9	3.2	0.8
						18.2			
						6.7	0.6		
						2.5			
							45.4	10.4	1.7
								13.2	7.0
								8.5	2.7
									15.4
									10.4
Tc98	4.2 10 <sup>6</sup> y	&Pd104(n,2n)Pd103(β <sup>+</sup> )Rh103(n,2n) Rh102(n,α)Tc98 &Pd102(n,2n)Pd101(β <sup>+</sup> )Rh101(n,α)Tc98 &Pd104(n,2n)Pd103(β <sup>+</sup> )Rh103(n,α) Tc99(n,2n)Tc98 Pd102(n,α)Ru98(n,p)Tc98 &Pd104(n,2n)Pd103(β <sup>+</sup> )Rh103(n,2n) Rh102m(n,α)Tc98 Pd102(n,α)Ru99(n,d)Tc98 Pd105(n,3n)Pd103(β <sup>+</sup> )Rh103m(IT) Rh103(n,2nα)Tc98 Pd104(n,2n)Pd103(β <sup>+</sup> )Rh103m(IT) Rh103(n,2nα)Tc98 Pd105(n,2nα)Ru100(n,t)Tc98 Pd105(n,t)Rh103m(IT)Rh103(n,2nα)Tc98 Pd106(n,4n)Pd103(β <sup>+</sup> )Rh103m(IT) Rh103(n,2nα)Tc98 Pd104(n,4n)Pd101(β <sup>+</sup> )Rh101m(β <sup>+</sup> ) Ru101(n,nt)Tc98 Pd104(n,nt)Rh101m(β <sup>+</sup> )Ru101(n,nt)Tc98 Pd105(n,5n)Pd101(β <sup>+</sup> )Rh101m(β <sup>+</sup> ) Ru101(n,nt)Tc98 Pd105(n,2nt)Rh101m(β <sup>+</sup> )Ru101(n,nt)Tc98				18.5	0.6		
						16.2	0.1		
						14.1	1.1		
						5.8	1.3		
						5.7	0.4		
						5.5	0.7		
							25.7	18.2	1.9
							7.9	5.5	0.9
							1.3	6.3	1.3
							1.1	4.2	0.8
								14.9	3.3
								3.7	7.4
								0.5	5.6
									11.1
									5.4
Pd107	6.5 10 <sup>6</sup> y	&Pd106(n,γ)Pd107 &Pd105(n,γ)Pd106(n,γ)Pd107 &Pd108(n,2n)Pd107 Pd108(n,d)Rh107(β <sup>-</sup> )Pd107 &Pd110(n,4n)Pd107 Pd110(n,nt)Rh107(β <sup>-</sup> )Pd107	76.1	57.6	93.4				
			23.9	42.3	6.5				
						99.6	80.4	38.8	41.0
							13.4	13.7	20.6
								44.7	27.7
									9.2

# Palladium activation characteristics

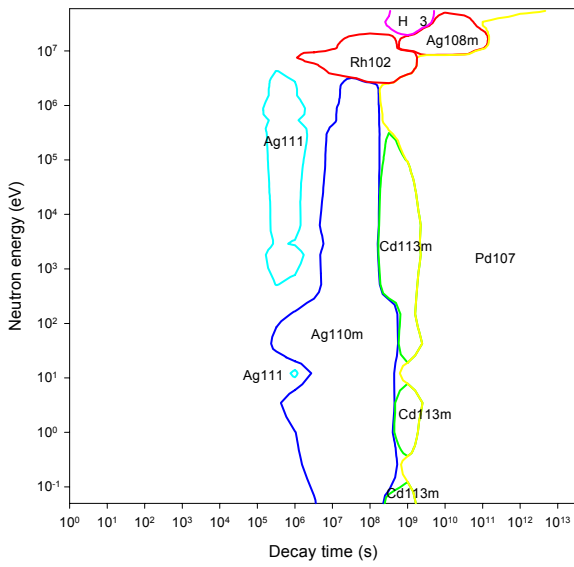


Decay time (years)

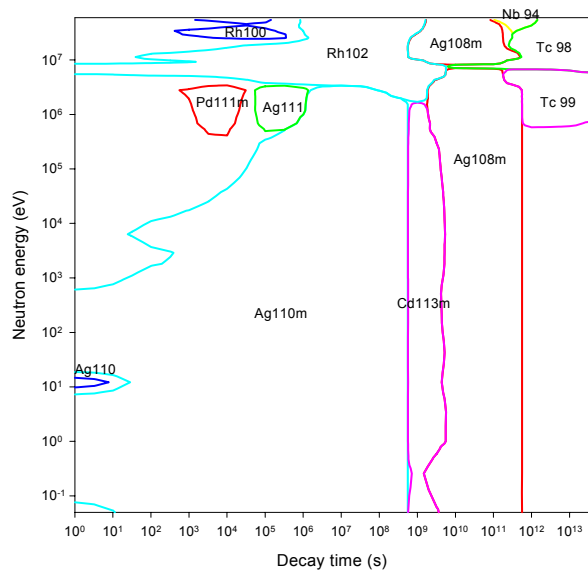
Decay time (years)

# Palladium importance diagrams & transmutation

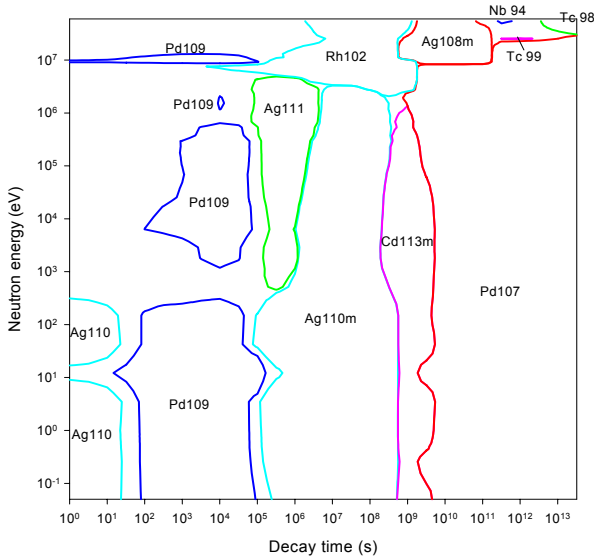
Activity



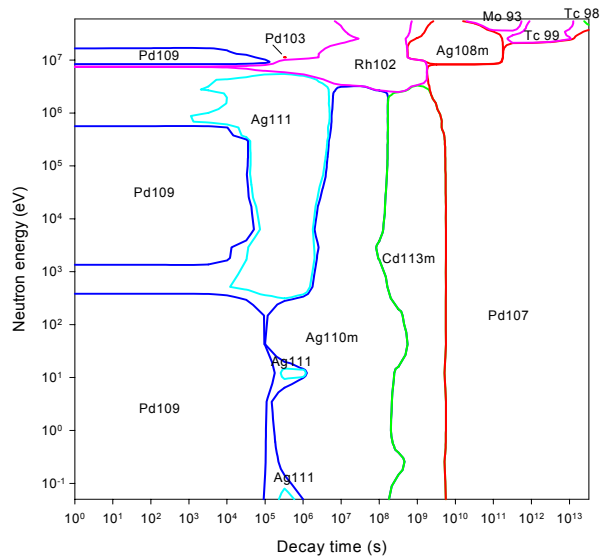
Dose rate



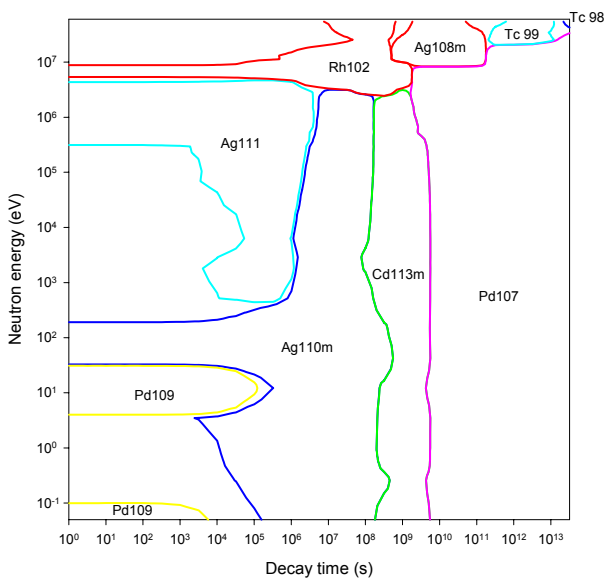
Heat output



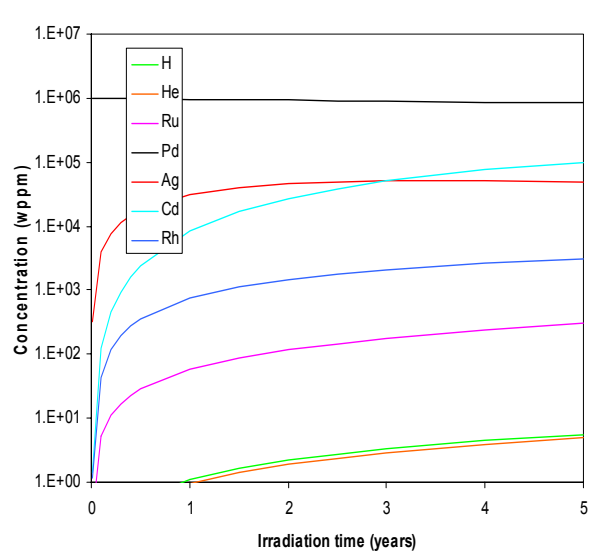
Ingestion dose



Inhalation dose



First wall transmutation



# Silver

## General properties

Atomic number	47	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	7.5 10 <sup>-2</sup>	Ag107	51.839
Melting point / K	1235	Ag109	48.161
Boiling point / K	2435		
Density / kgm <sup>-3</sup>	10500		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	429		
Electrical resistivity /Ωm	1.59 10 <sup>-5</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	1.89 10 <sup>-5</sup>		
Crystal structure	FCC		
Number of stable isotopes	2		
Mean atomic weight	107.8682		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	1.18E16	3.34E15	1.44E15	6.96E14	4.43E11	1.08E7	kW kg <sup>-1</sup>	1.49E0	3.06E-1	1.28E-1	2.89E-2	1.11E-4	1.61E-11
Ag108	48.89	33.26		0.01	7.97		Ag110	51.97	0.15	0.28	0.46		
Ag110	33.77	0.07	0.13	0.10			Ag108	34.20	36.58		0.01	3.21	
Ag109m	6.55	19.75	38.40	46.24			Ag106m	4.55	22.26	39.28			
Cd109	4.70	16.67	38.32	46.24			Ag110m	4.26	20.82	49.05	79.83		
Ag107m	3.94	4.34					Ag106	2.48	10.41				
Ag106	1.62	4.92					Ag109m	0.72	3.00	6.02	15.51		
Ag106m	1.30	4.60	7.88				Ag107m	0.46	0.96				
Cd107	1.21	4.26					Ag111	0.45	2.20	3.73			
Ag110m	1.18	4.19	9.60	7.30			Pd109	0.39	1.93	0.05			
Ag111	0.94	3.33	5.49				Cd111m	0.19	0.86				
Pd109	0.86	3.05	0.08				Cd109	0.12	0.60	1.44	3.71		
Cd111m	0.38	1.26					Ag108m	0.01	0.04	0.09	0.43	96.74	
Ag108m		0.01	0.03	0.07	91.65		Pd107						99.99
Pd107						100.0							
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	2.91E5	2.31E5	1.76E5	3.64E4	1.42E2	9.74E-12	Sv kg <sup>-1</sup>	1.97E6	1.96E6	1.78E6	7.92E5	9.66E2	3.99E-4
Ag106m	36.75	44.75	43.58				Cd109	56.60	56.74	62.34	81.34		
Ag110m	35.44	43.16	56.12	99.44			Ag110m	19.95	20.00	21.87	17.98		
Ag110	10.20	0.01	0.01	0.01			Ag106m	11.71	11.73	9.61			
Ag106	8.70	9.10					Ag111	7.36	7.38	5.81			
Ag108	8.17*	2.17*			0.11	2.21	Pd109	2.86	2.86	0.04			
Cd111m	0.31	0.35					Cd113m	0.22	0.22	0.24	0.52	3.31	
Ag108m	0.06	0.07	0.09	0.45	99.88		Ag108m	0.06	0.06	0.06	0.13	96.68	
Tc98						97.77	Pd107						99.99
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	6.65E6	6.65E6	6.45E6	3.26E6	1.52E4	6.36E-3		3.60E12	2.64E12	2.27E12	8.37E11	6.69E8	9.83E0
Cd109	67.79	67.83	69.53	80.09			Ag110m	38.95	53.10	61.13	60.72		
Ag110m	25.29	25.30	25.81	18.74			Ag110	16.56	0.01	0.01	0.01		
Ag111	2.85	2.85	2.09				Cd109	15.47	21.09	24.39	38.44		
Ag106m	2.53	2.54	1.94				Ag106m	11.85	16.15	13.93			
Pd109	0.57	0.56	0.01				Ag108	11.74	3.50			0.44	
Cd113m	0.31	0.31	0.32	0.61	1.01		Ag106	4.08	4.78				
Ag108m	0.26	0.26	0.27	0.54	98.99		Ag109m	0.40	0.47	0.46	0.72		
Cd107	0.17	0.17					Cd111m	0.37	0.46				
Cd111m	0.10	0.09					Ag107m	0.27	0.11				
Pd107						99.95	Ag111	0.03	0.04	0.04			
Tc99						0.01	Ag108m		0.03	0.03	0.09	99.55	
							Pd107						99.75

# Silver

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
Ag110	24.56 s	&Ag109(n,γ)Ag110 &Ag107(n,γ)Ag108(β <sup>-</sup> )Cd108(n,γ) Cd109(β <sup>+</sup> )Ag109(n,γ)Ag110 &Ag107(n,γ)Ag108(β <sup>+</sup> )Pd108(n,γ) Pd109(β <sup>-</sup> )Ag109(n,γ)Ag110 &Ag107(n,γ)Ag108m(n,γ)Ag109(n,γ) Ag110	56.0 16.4 14.2 13.4	85.4 3.5 0.5 10.6	99.7	99.3	96.9	97.9	98.8	
Ag109m	39.6 s	Ag107(n,γ)Ag108(β <sup>-</sup> )Cd108(n,γ) Cd109(β <sup>+</sup> )Ag109m &Ag107(n,γ)Ag108(β <sup>+</sup> )Pd108(n,γ) Pd109(β <sup>-</sup> )Ag109m Ag107(n,γ)Ag108m(n,γ)Ag109m Ag109(n,n')Ag109m &Ag109(n,p)Pd109(β <sup>-</sup> )Ag109m	46.7 39.3 14.0	44.7 5.8 49.1	95.5 1.6 2.5					
Ag107m	44.3 s	Ag107(n,n')Ag107m Ag109(n,2n)Ag108m(n,2n)Ag107m Ag109(n,2n)Ag108(β <sup>-</sup> )Cd108(n,2n) Cd107(β <sup>+</sup> )Ag107m Ag109(n,2n)Ag108(β <sup>-</sup> )Cd108(n,d)Ag107m Ag109(n,3n)Ag107m Ag109(n,3n)Ag107(n,n')Ag107m				53.7 23.2 20.4	19.6 1.9 1.2	23.6 1.3 0.7	30.2	
Ag108	2.4 m	Ag107(n,γ)Ag108 &Ag109(n,2n)Ag108 Ag109(n,2n)Ag108m(n,n')Ag108	100.0	100.0	100.0	98.1 0.9	97.8 1.2	98.3	99.1	
In116m	54.6 m	&Ag109(n,γ)Ag110(β <sup>-</sup> )Cd110(n,γ) Cd111(n,γ)Cd112(n,γ)Cd113(n,γ) Cd114(n,γ)Cd115(β <sup>-</sup> )In115(n,γ)In116m &Ag109(n,γ)Ag110(β <sup>-</sup> )Cd110(n,γ)Cd111 (n,γ)Cd112(n,γ)Cd113(n,γ)Cd114(n,γ) Cd115m(β <sup>-</sup> )In115(n,γ)In116m &Ag109(n,γ)Ag110m(n,γ)Ag111(β <sup>-</sup> ) Cd111(n,γ)Cd112(n,γ)Cd113(n,γ) Cd114(n,γ)Cd115(β <sup>-</sup> )In115(n,γ)In116m &Ag109(n,γ)Ag110m(β <sup>-</sup> )Cd110(n,γ) Cd111(n,γ)Cd112(n,γ)Cd113(n,γ) Cd114(n,γ)Cd115(β <sup>-</sup> )In115(n,γ)In116m &Ag109(n,γ)Ag110m(n,γ)Ag111(β <sup>-</sup> ) Cd111(n,γ)Cd112(n,γ)Cd113(n,γ)Cd114 (n,γ)Cd115m(β <sup>-</sup> )In115(n,γ)In116m Other pathways involving (n,γ), β <sup>-</sup>	65.7 4.3 3.9 1.2 0.5 24.4	70.5 4.1 4.6 1.6 0.6 23.8	67.8 1.5 4.6 1.4 0.6 24.1					
Pd109	13.701 h	&Ag107(n,γ)Ag108(β <sup>+</sup> )Pd108(n,γ) Pd109 Ag107(n,γ)Ag108m(β <sup>+</sup> )Pd108(n,γ)Pd109 &Ag109(n,p)Pd109	100.0	99.8	99.4 0.1	100.0	100.0	100.0	100.0	
Ag111	7.45 d	&Ag109(n,γ)Ag110m(n,γ)Ag111 &Ag107(n,γ)Ag108(β <sup>-</sup> )Cd108(n,γ) Cd109(β <sup>+</sup> )Ag109(n,γ)Ag110m(n,γ)Ag111 &Ag107(n,γ)Ag108m(n,γ)Ag109(n,γ) Ag110m(n,γ)Ag111 &Ag107(n,γ)Ag108(β <sup>+</sup> )Pd108(n,γ) Pd109(β <sup>-</sup> )Ag109(n,γ)Ag110m(n,γ)Ag111 &Ag109(n,γ)Ag110(β <sup>+</sup> )Pd110(n,γ) Pd111(β <sup>-</sup> )Ag111 &Ag109(n,γ)Ag110(β <sup>+</sup> )Pd110(n,γ) Pd111m(β <sup>-</sup> )Ag111	77.0 8.8 8.6 7.8 1.8	50.7 0.9 2.2	97.1	95.2 1.2 0.3	89.1 1.7 0.4	91.6 1.6 0.3	94.2 1.7 0.3	

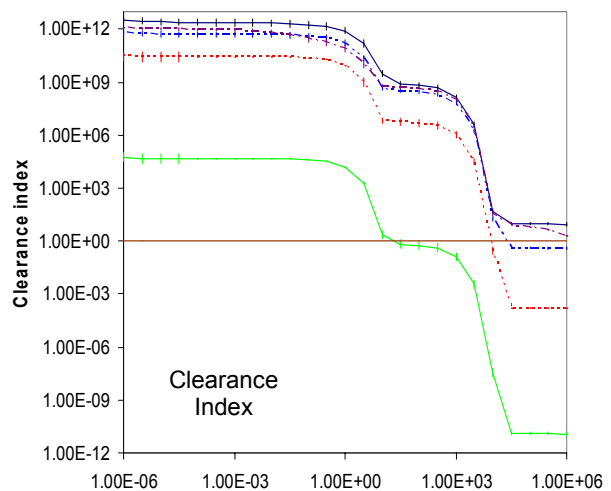
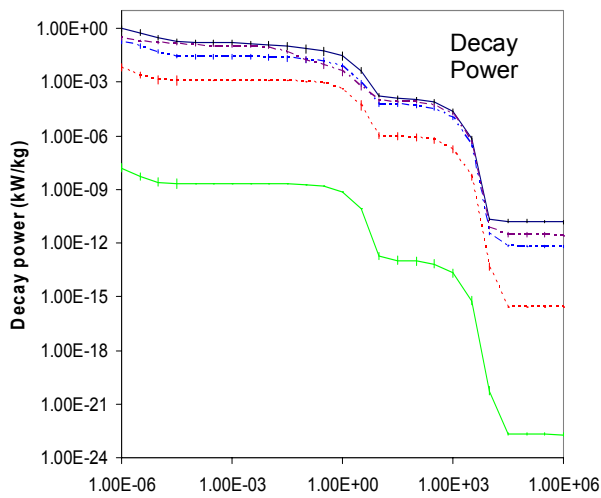
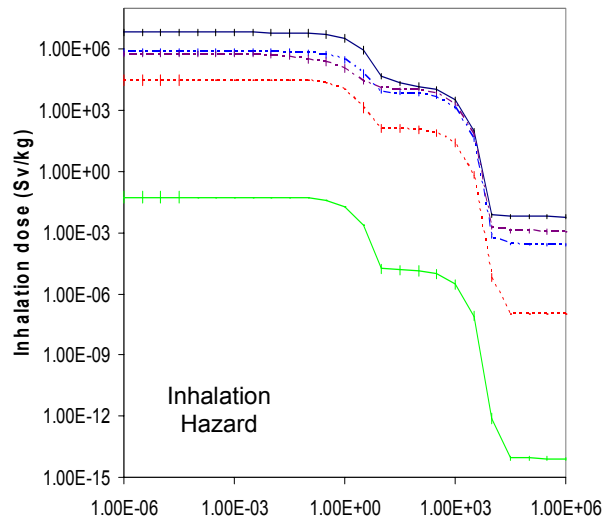
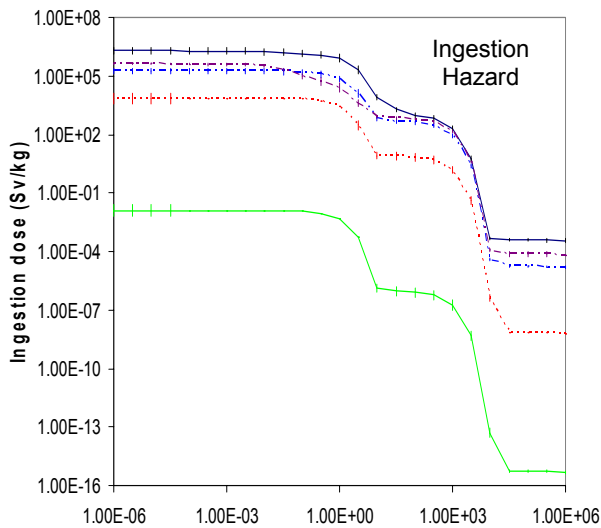
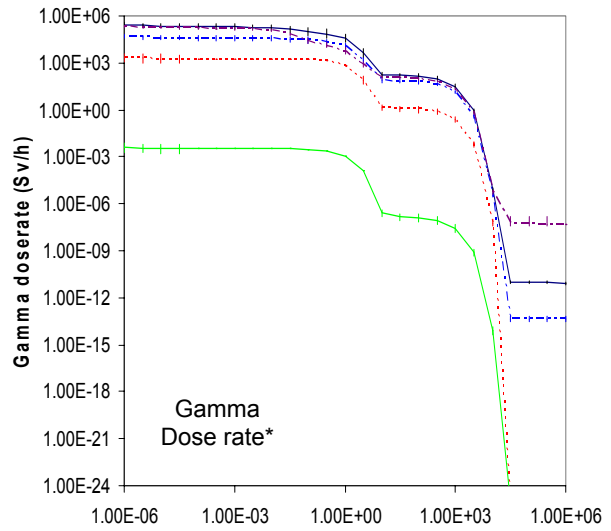
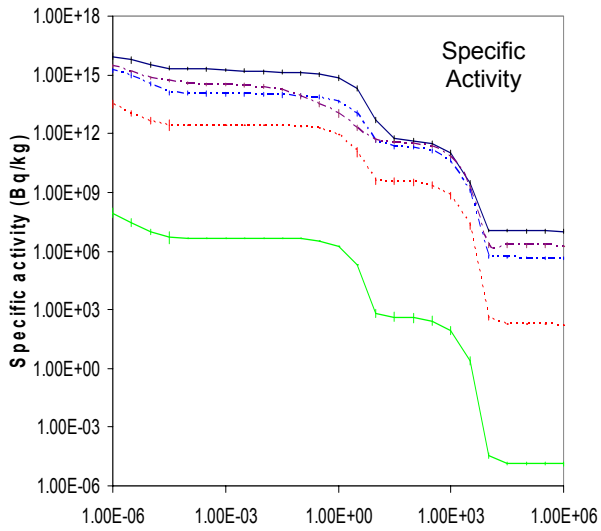


Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&Ag109(n,γ)Ag110(β <sup>-</sup> )Cd110(n,γ) Cd111(n,p)Ag111				1.0	1.8	1.2	0.4
Ag106m	8.46 d	Ag107(n,2n)Ag106m &Ag109(n,2n)Ag108m(n,2n)Ag107 (n,2n)Ag106m &Ag109(n,3n)Ag107(n,2n)Ag106m Ag109(n,2n)Ag108m(n,3n)Ag106m Ag109(n,4n)Ag106m				97.8 1.2	79.2 10.9 9.4	36.9 2.4 2.4 57.2	36.5 61.0
Ag105	41.3 d	&Ag107(n,2n)Ag106m(n,2n)Ag105 Ag107(n,2n)Ag106(β <sup>-</sup> )Cd106(n,2n) Cd105(β <sup>+</sup> )Ag105 &Ag107(n,2n)Ag106(β <sup>-</sup> )Cd106(n,d)Ag105 &Ag107(n,3n)Ag105 &Ag109(n,3n)Ag107(n,3n)Ag105 Ag109(n,2n)Ag108m(n,4n)Ag105m(IT)Ag105 &Ag109(n,5n)Ag105				68.7 23.0 6.5	87.4 90.4 11.8 6.6 1.8	42.9 53.3	
Ag110m	249.78 d	Ag109(n,γ)Ag110m &Ag107(n,γ)Ag108(β <sup>-</sup> )Cd108(n,γ) Cd109(β <sup>+</sup> )Ag109(n,γ)Ag110m &Ag107(n,γ)Ag108m(n,γ)Ag109(n,γ) Ag110m &Ag107(n,γ)Ag108(β <sup>+</sup> )Pd108(n,γ) Pd109(β <sup>-</sup> )Ag109(n,γ)Ag110m	73.7 9.2 8.8 8.3	96.8 2.5	99.8	99.5	98.9	97.9	98.7
Cd109	1.267 y	Ag107(n,γ)Ag108(β <sup>-</sup> )Cd108(n,γ)Cd109 Ag109(n,2n)Ag108(β <sup>-</sup> )Cd108(n,γ)Cd109 &Ag109(n,γ)Ag110(β <sup>-</sup> )Cd110(n,2n)Cd109 Ag109(n,γ)Ag110m(β <sup>-</sup> )Cd110(n,2n)Cd109 Ag109(n,2n)Ag108m(n,n')Ag108(β <sup>-</sup> ) Cd108(n,γ)Cd109	100.0	100.0	100.0	61.7 26.2 11.6 0.2	49.7 33.8 15.1 0.2	58.4 28.1 12.5 0.2	69.0 21.0 9.4 0.1
Rh102	2.902 y	&Ag107(n,α)Rh103(n,2n)Rh102 &Ag107(n,α)Rh104m(IT)Rh104(β <sup>-</sup> ) Pd104(n,2n)Pd103(β <sup>+</sup> )Rh103m(IT) Rh103(n,2n)Rh102 &Ag107(n,α)Rh104(β <sup>-</sup> )Pd104(n,2n)Pd103 (β <sup>+</sup> )Rh103m(IT)Rh103(n,2n)Rh102 &Ag107(n,2n)Ag106(β <sup>+</sup> )Pd106(n,α)Ru103 (β <sup>-</sup> )Rh103m(IT)Rh103(n,2n)Rh102 &Ag107(n,2n)Ag106m(β <sup>+</sup> )Pd106(n,α) Ru103(β <sup>-</sup> )Rh103m(IT)Rh103(n,2n)Rh102 &Ag107(n,2nα)Rh102 &Ag107(n,4n)Ag104(β <sup>+</sup> )Pd104(n,t)Rh102 &Ag109(n,4nα)Rh102 &Ag109(n,5n)Ag105(β <sup>+</sup> )Pd105(n,nt)Rh102				43.8 15.8 14.2 6.5 5.5	16.6 45.6	0.8 74.8 6.1	0.4 37.7 4.5 18.0 6.4
H3	12.33 y	Ag107(n,γ)Ag108m(n,X)H1(n,γ)H2(n,γ)H3 Ag107(n,X)H3 Ag109(n,X)H3 Ag109(n,2n)Ag108m(n,X)H3 &Ag109(n,3n)Ag107(n,X)H3	94.0	95.5	99.5	80.5 12.2 6.3	50.7 38.6 1.8 3.6	47.7 42.3 0.9 1.6	47.1 43.2
Cd113m	14.10 y	&Ag109(n,γ)Ag110(β <sup>-</sup> )Cd110(n,γ) Cd111(n,γ)Cd112(n,γ)Cd113m &Ag109(n,γ)Ag110m(n,γ)Ag111(β <sup>-</sup> ) Cd111(n,γ)Cd112(n,γ)Cd113m &Ag109(n,γ)Ag110m(β <sup>-</sup> )Cd110(n,γ) Cd111(n,γ)Cd112(n,γ)Cd113m Ag107(n,γ)Ag108(β <sup>-</sup> )Cd108(n,γ)Cd109 (n,γ)Cd110(n,γ)Cd111(n,γ)Cd112(n,γ) Cd113m &Ag109(n,γ)Ag110m(n,γ)Ag111(n,γ) Ag112(β <sup>-</sup> )Cd112(n,γ)Cd113m	89.4 7.6 1.8 0.6	96.9 2.9	87.5 9.9 2.2	59.0 18.7 19.0 0.6	57.7 20.9 18.5 0.4	56.7 22.6 18.2 0.4	56.6 23.3 18.2
Ag108m	418.0 y	Ag107(n,γ)Ag108m Ag109(n,2n)Ag108m	100.0	100.0	100.0	99.7	99.7	99.7	99.9

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
Mo93	4000 y	Ag107(n,n $\alpha$ )Rh103m(IT)Rh103(n, $\alpha$ )_Tc100( $\beta^-$ )Ru100(n,2n)Ru99(n,2n)Ru98_(n, $\alpha$ )Mo94(n,2n)Mo93				5.7				
		Ag107(n,n $\alpha$ )Rh103m(IT)Rh103(n, $\alpha$ )_Tc100( $\beta^-$ )Ru100(n,2n)Ru99(n, $\alpha$ )_Mo95(n,2n)Mo94(n,2n)Mo93				4.1				
		Ag107(n, $\alpha$ )Rh104m(IT)Rh104( $\beta^-$ )_Pd104(n,n $\alpha$ )Ru100(n,2n)Ru99(n,2n)_Ru98(n,n $\alpha$ )Mo94(n,2n)Mo93				4.1				
		Ag107(n, $\alpha$ )Rh104( $\beta^-$ )Pd104(n,n $\alpha$ )_Ru100(n,2n)Ru99(n,2n)Ru98(n,n $\alpha$ )_Mo94(n,2n)Mo93				3.7				
		Ag107(n,n $\alpha$ )Rh103m(IT)Rh103(n,2n)_Rh102m( $\beta^-$ )Pd102(n,n $\alpha$ )Ru98(n,n $\alpha$ )_Mo94(n,2n)Mo93				3.5				
		Ag107(n,3n)Ag105m(IT)Ag105( $\beta^+$ )Pd105_(n,2n $\alpha$ )Ru100(n,3n)Ru98(n,2n $\alpha$ )Mo93						4.2		
		&Ag107(n,3n $\alpha$ )Rh101m( $\beta^+$ )Ru101_(n,4n)Ru98(n,2n $\alpha$ )Mo93							3.6	1.0
		&Ag107(n,4n $\alpha$ )Rh100m(IT)Rh100( $\beta^+$ )_Ru100(n,4n $\alpha$ )Mo93								3.8
		Other pathways involving (n,2n), (n, $\alpha$ ), $\beta^+$					78.9	95.8	96.4	95.2
		Nb94	2.0 10 <sup>4</sup> y	&Ag107(n,n $\alpha$ )Rh103m(IT)Rh103_(n,2n)Rh102(n,n $\alpha$ )Tc98(n,n $\alpha$ )Nb94				14.6	0.6	
&Ag107(n,n $\alpha$ )Rh103m(IT)Rh103_(n,n $\alpha$ )Tc99(n,2n)Tc98(n,n $\alpha$ )Nb94						9.0	1.2			
&Ag107(n,n $\alpha$ )Rh103m(IT)Rh103_(n,2n)Rh102m(n,n $\alpha$ )Tc98(n,n $\alpha$ )Nb94						5.0	0.4			
&Ag107(n,n $\alpha$ )Rh103(n,2n)Rh102_(n,n $\alpha$ )Tc98(n,n $\alpha$ )Nb94						3.2				
&Ag107(n,n $\alpha$ )Rh103m(IT)Rh103_(n,n $\alpha$ )Tc99(n,2n $\alpha$ )Nb94							11.4	1.5		
&Ag107(n,n $\alpha$ )Rh103m(IT)Rh103_(n,2n $\alpha$ )Tc98(n,n $\alpha$ )Nb94							10.6	2.2		
&Ag107(n,2n $\alpha$ )Rh102(n,n $\alpha$ )Tc98(n,n $\alpha$ )Nb94							4.6	1.0		
&Ag107(n,2n $\alpha$ )Tc99(n,2n $\alpha$ )Nb94								3.6	0.4	
&Ag107(n,2nt)Pd103( $\beta^+$ )Rh103m(IT)_Rh103(n,2n $\alpha$ )Nb94										6.5
Ag107(n,5n)Ag103( $\beta^+$ )Pd103( $\beta^+$ )_Rh103m(IT)Rh103(n,2n $\alpha$ )Nb94										4.4
Tc99	2.1 10 <sup>5</sup> y	&Ag107(n,n $\alpha$ )Rh103(n,n $\alpha$ )Tc99				22.2	31.4	6.6	0.9	
		&Ag107(n, $\alpha$ )Rh104( $\beta^-$ )Pd104(n,2n)_Pd103( $\beta^+$ )Rh103(n,n $\alpha$ )Tc99				17.0				
		&Ag107(n,n $\alpha$ )Rh103m(IT)Rh103_(n,2n)Rh102(n, $\alpha$ )Tc99				9.2				
		&Ag107(n,n $\alpha$ )Rh103(n,n $\alpha$ )Tc99				4.9	3.9	0.6		
		&Ag107(n,2n)Ag106( $\beta^+$ )Pd106(n, $\alpha$ )_Ru103( $\beta^-$ )Rh103(n,n $\alpha$ )Tc99				3.1				
		&Ag107(n,2n)Ag106( $\beta^+$ )Pd106(n,2n)_Pd105(n,2n)Pd104(n,2n)Pd103( $\beta^+$ )_Rh103(n,n $\alpha$ )Tc99				1.8				
		&Ag107(n,2n $\alpha$ )Tc99							10.4	7.4
		&Ag107(n,2n $\alpha$ )Rh102m( $\beta^+$ )Ru102(n,nt)Tc99							6.1	3.2
		&Ag107(n,3n $\alpha$ )Rh101m( $\beta^+$ )Ru101(n,t)Tc99							5.8	18.1
		&Ag107(n,2nt)Pd103( $\beta^+$ )Rh103m(IT)_Rh103(n,n $\alpha$ )Tc99							0.2	7.2

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&Ag107(n,5n)Ag103(β <sup>+</sup> )Pd103(β <sup>+</sup> ) Rh103m(IT)Rh103(n,α)Tc99 Other pathways involving (n,2n), (n,α), β <sup>+</sup>				41.8	64.7	70.3	55.9
Tc98	4.2 10 <sup>6</sup> y	&Ag107(n,α)Rh103(n,2n)Rh102(n,α)Tc98 &Ag107(n,α)Rh103(n,α)Tc99(n,2n)Tc98 &Ag107(n,α)Rh104(β <sup>-</sup> )Pd104(n,2n) Pd103(β <sup>+</sup> )Rh103(n,2n)Rh102(n,α)Tc98 &Ag107(n,α)Rh104(β <sup>-</sup> )Pd104(n,2n) Pd103(β <sup>+</sup> )Rh103(n,α)Tc99(n,2n)Tc98 &Ag107(n,α)Rh103(n,2n)Rh102m_ (n,α)Tc98 &Ag107(n,α)Rh103m(IT)Rh103_ (n,2n)Rh102(n,α)Tc99(n,2n)Tc98 &Ag107(n,α)Rh103(n,2n)Tc98 Ag107(n,2n)Rh102(n,α)Tc98 Ag107(n,2n)Rh102m(n,α)Tc98 Ag107(n,3n)Rh101m(β <sup>+</sup> )Ru101(n,nt)Tc98 Ag107(n,2nt)Pd103(β <sup>+</sup> )Rh103m(IT) Rh103(n,2n)Tc98 Ag107(n,2n)Tc98 Ag107(n,5n)Ag103(β <sup>+</sup> )Pd103(β <sup>+</sup> ) Rh103m(IT)Rh103(n,2n)Tc98 Other pathways involving (n,2n), (n,α), β <sup>+</sup>				20.2 15.5 9.8 6.6 6.2 4.1 37.6	1.8 4.1 1.0 22.6 8.1 4.2 58.2	14.2 5.6 3.4 1.8 0.5 74.5	1.0 0.4 0.2 16.2 7.1 18.6 7.2 49.3
Pd107	6.5 10 <sup>6</sup> y	Ag107(n,γ)Ag108(β <sup>-</sup> )Cd108(n,γ)Cd109_ (n,α)Pd106(n,γ)Pd107 Ag109(n,γ)Ag110m(n,α)Rh107(β <sup>-</sup> )Pd107 &Ag107(n,p)Pd107 &Ag109(n,2n)Ag108(β <sup>+</sup> )Pd108(n,2n)Pd107 &Ag109(n,d)Pd108(n,2n)Pd107 &Ag109(n,2n)Ag108m(n,d)Pd107 &Ag109(n,t)Pd107 &Ag109(n,3n)Ag107(n,p)Pd107 Ag109(n,h)Rh107(β <sup>-</sup> )Pd107	95.0 0.5	14.5 83.5	91.0 4.5	84.7 6.4 3.4 2.9 0.5	44.9 3.8 3.6 43.0 1.7 0.2	18.0 1.6 0.9 76.1 1.2	10.0 85.7 1.6
Cd108	4.1 10 <sup>17</sup> y	Ag107(n,γ)Ag108(β <sup>-</sup> )Cd108 Ag109(n,2n)Ag108(β <sup>-</sup> )Cd108 Ag109(n,2n)Ag108m(n,n')Ag108(β <sup>-</sup> )Cd108	100.0	100.0	100.0	99.3 0.5	0.2 97.8 0.6	0.1 98.4 0.4	99.1 0.2

# Silver activation characteristics

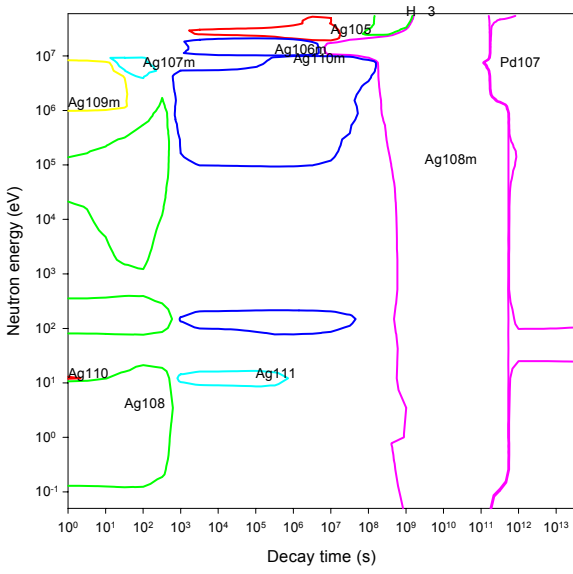


Decay time (years)

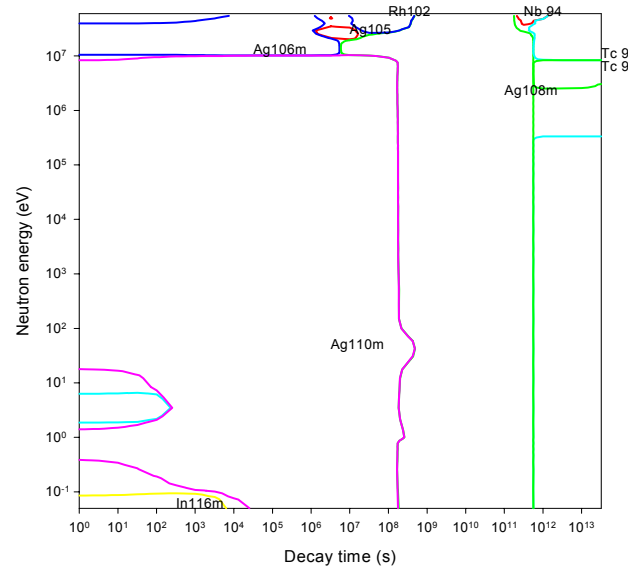
Decay time (years)

# Silver importance diagrams & transmutation

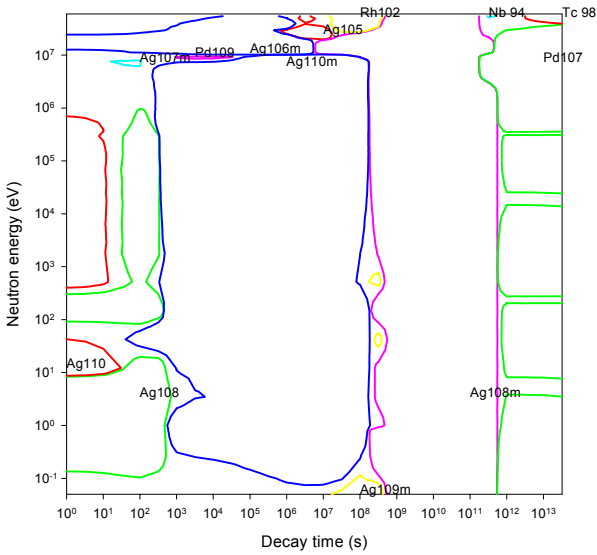
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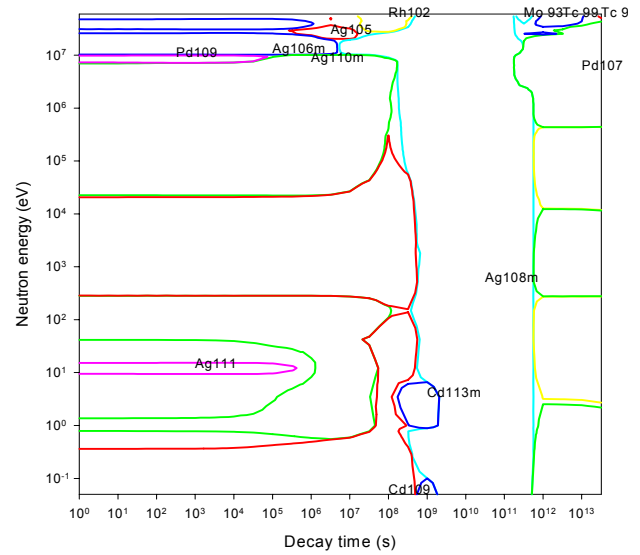
**Dose rate**



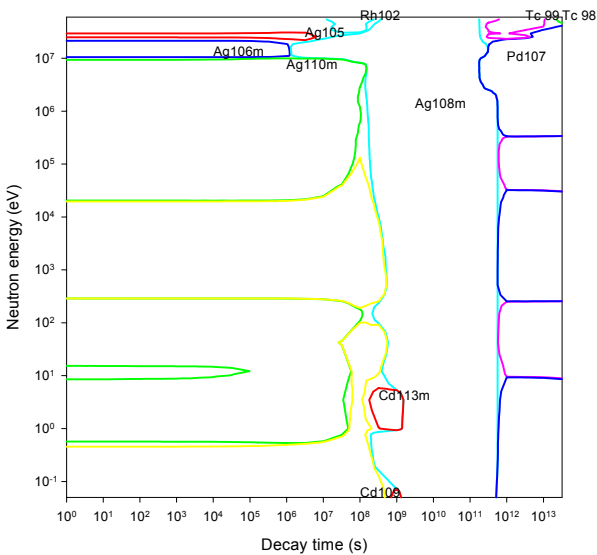
**Heat output**



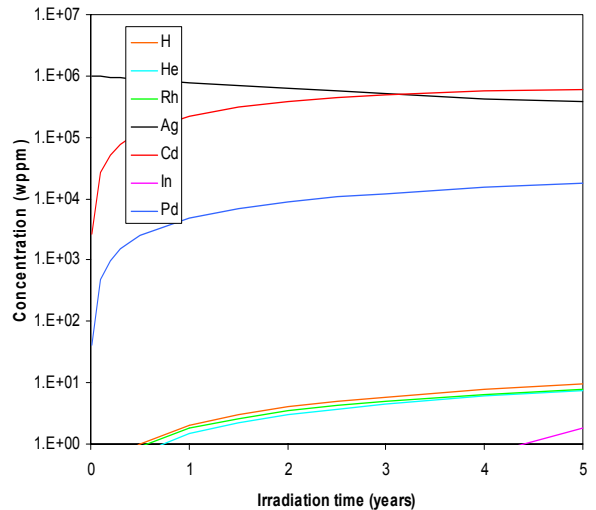
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**





# Cadmium

## General properties

Atomic number	48	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	0.15	Cd106	1.25 ( $T_{1/2} = 6.60 \cdot 10^{18}$ y)
Melting point / K	594.2	Cd108	0.89 ( $T_{1/2} = 4.10 \cdot 10^{17}$ y)
Boiling point / K	1040	Cd110	12.49
Density / $\text{kgm}^{-3}$	8650	Cd111	12.80
Thermal conductivity / $\text{Wm}^{-1}\text{K}^{-1}$	96.8	Cd112	24.13
Electrical resistivity / $\Omega\text{m}$	$6.83 \cdot 10^{-8}$	Cd113	12.22 ( $T_{1/2} = 7.70 \cdot 10^{15}$ y)
Coefficient of thermal expansion / $\text{K}^{-1}$	$3.08 \cdot 10^{-5}$	Cd114	28.73 ( $T_{1/2} = 6.00 \cdot 10^{17}$ y)
Crystal structure	HCP	Cd116	7.49 ( $T_{1/2} = 3.40 \cdot 10^{19}$ y)
Number of stable isotopes	3 (8)		
Mean atomic weight	112.411		

## Activation properties

Act	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Heat	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Bq $\text{kg}^{-1}$	4.51E15	3.77E15	1.19E15	1.18E14	2.87E11	3.45E5	kW $\text{kg}^{-1}$	6.17E-1	5.26E-1	7.82E-2	2.20E-3	8.90E-6	5.14E-13
In115m	25.87	30.99	34.21				In116m	53.64	58.89				
Cd115	25.72	30.77	31.34	0.55			Cd115	15.40	18.05	39.00			
In116m	16.33	18.31					In115m	10.18	11.95	27.98			
In116n	8.74						In116	7.06					
In116	4.42						Cd115m	3.13	3.67	23.38	3.01		
Cd115m	4.20	5.03	15.07				Ag110	1.92		0.01	0.08		
Cd111m	3.66	4.07					Cd111m	1.67	1.82				
Ag109m	1.56	1.84	5.72	33.54			In116n	1.66					
Cd109	1.51	1.81	5.72	33.54			Cd117	1.10	1.26				
Ag110	1.35			0.59			Cd117m	0.82	0.94				
Cd113m	0.86	1.03	3.27	31.45	99.43		In114	0.60	0.50	3.19	0.75		
Ag107m	0.68	0.79					Cd113m	0.18	0.22	1.48	50.20	95.45	
In114	0.67	0.57	1.69	0.11			Ag109m	0.15	0.18	1.21	25.08		
Cd107	0.66	0.79					Ag110m	0.14	0.16	1.10	14.40		
In117	0.62	0.75					Cd109			0.29	6.01		
Cd117	0.62	0.73					Ag108m				0.02	4.40	
In114m	0.48	0.58	1.75	0.11			Pd107						99.90
Pd107						99.99	Tc99						0.06
Dose	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Ing	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{h}^{-1}$	6.41E5	6.04E5	2.52E4	5.20E2	5.33E-1	1.29E-11	Sv $\text{kg}^{-1}$	3.63E6	3.61E6	2.28E6	9.37E5	6.57E3	1.30E-5
In116m	85.22	84.66					Cd115	44.82	44.96	22.87			
Cd115	6.25	6.63	51.24				Cd113m	24.73	24.83	39.30	91.05	99.95	
In115m	3.61*	3.84*	32.14*				Cd115m	17.25	17.33	25.92	0.22		
Cd117m	1.35	1.40					Cd109	3.77	3.79	5.97	8.44		
Cd117	1.27	1.32					In115m	2.77	2.78	1.53			
Cd115m	0.26*	0.28*	6.48*	1.13*			In114m	2.48	2.49	3.75	0.06		
Ag110m	0.21	0.23	5.47	97.12			In116m	1.30	1.22				
Ag106m	0.10	0.10	1.90				Cd111m	0.50	0.46				
Ag105	0.07	0.07	1.69	0.18			Pd107						98.41
Ag108m				0.11	99.63		In115						1.29
Tc98						99.91	Tc99						0.12

Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	8.04E6	8.02E6	6.88E6	4.42E6	3.15E4	2.06E-4		2.29E12	2.10E12	1.44E11	4.81E10	7.74E6	3.44E-1
Cd113m	53.33	53.45	62.27	92.41	99.83		In116m	80.47	82.29				
Cd115m	18.15	18.19	20.03	0.11			Cd115	5.06	5.53	1.24			
Cd115	15.88	15.90	5.95				Cd109	2.98	3.26	47.32	82.31		
Cd109	6.89	6.90	8.00	7.25			Cd111m	2.12	2.15				
In114m	2.54	2.54	2.82	0.02			Cd117	1.38	1.47				
In115m	0.85	0.85	0.34				In116n	1.32					
In116m	0.41	0.38					Cd117m	1.25	1.35				
Cd111m	0.30	0.28					In116	1.22					
Ag110m	0.28	0.28	0.33	0.18			Ag110m	0.83	0.91	13.24	14.51		
Ag111	0.08	0.08	0.07				In115m	0.50	0.55	2.82			
Sn117m	0.07	0.07	0.07				Ag105	0.23	0.25	3.56	0.02		
Ag105	0.05	0.05	0.06				Ag106m	0.11	0.12	1.35			
Ag108m					0.17		In114m	0.09	0.10	1.45	0.02		
Pd107						98.80	Cd115m	0.08	0.09	1.25			
In115						0.99	Ag109m		0.06	0.86	1.55		
Tc99						0.15	Cd113m		0.03	0.50	1.42	68.34	
							Ag108m					31.52	
							Pd107						90.98
							Tc99						7.22
							In115						1.52
							Cd113						0.25



# Cadmium

## Pathway analysis

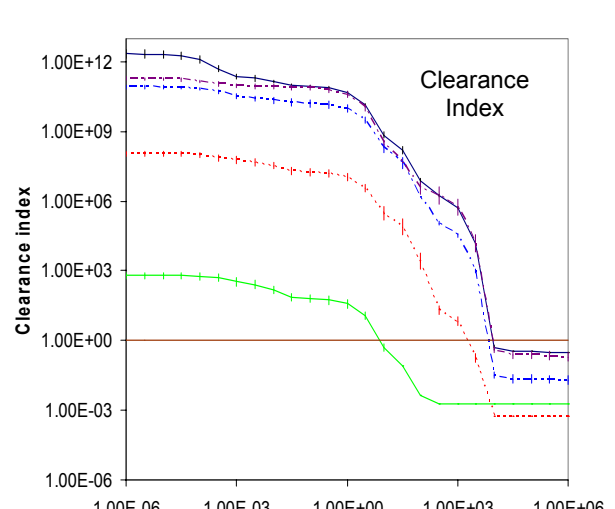
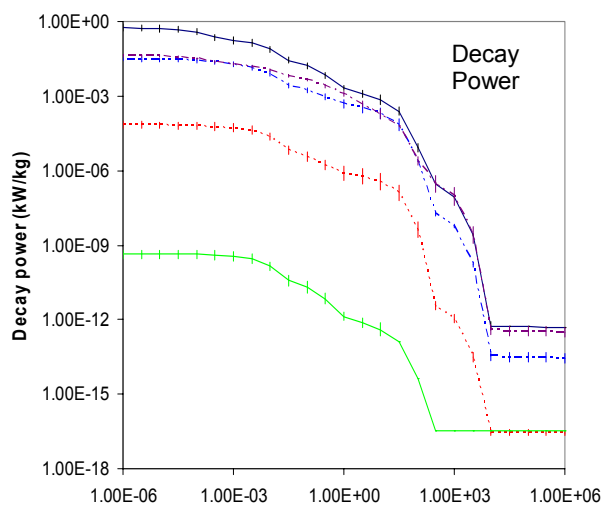
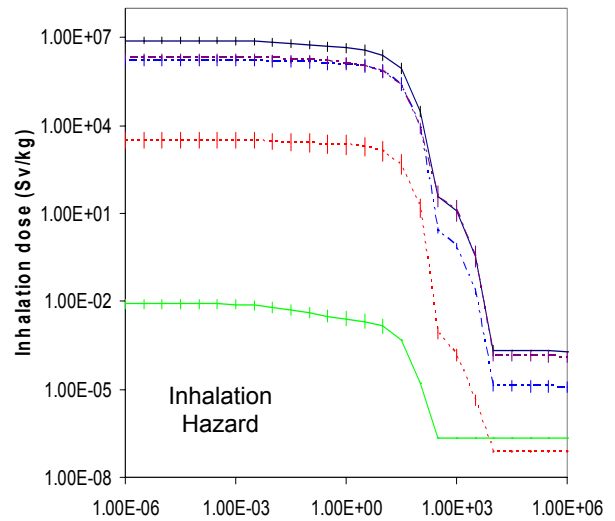
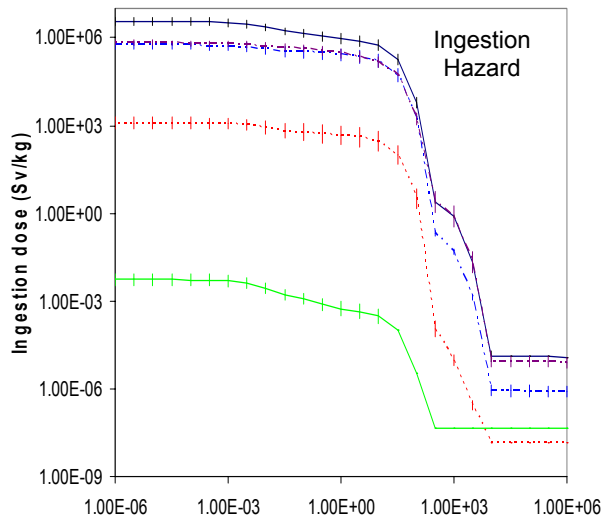
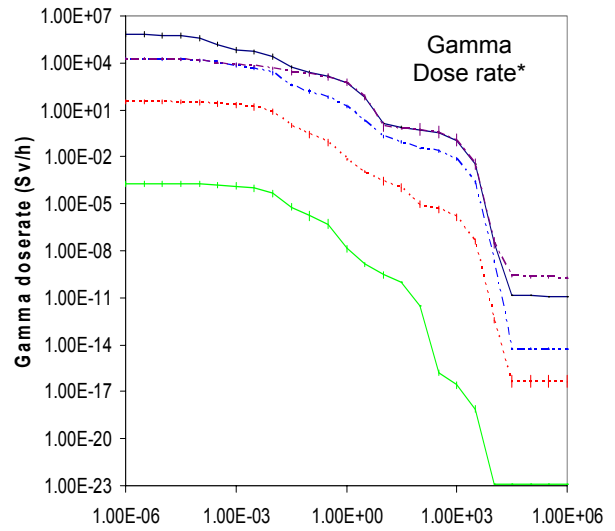
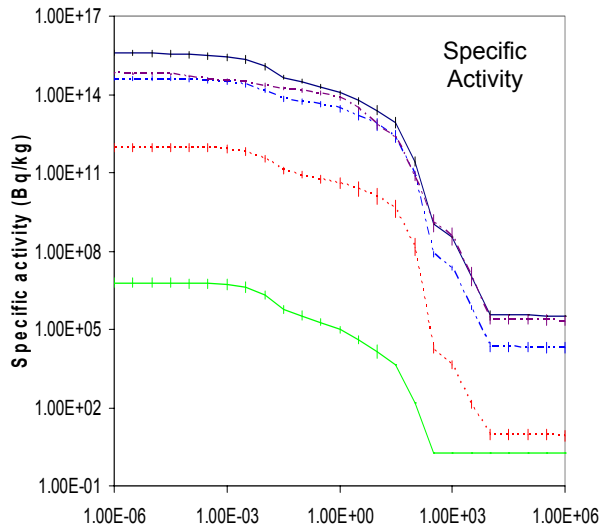
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
Ag109m	39.6 s	Cd108(n,γ)Cd109(β <sup>+</sup> )Ag109m &Cd106(n,γ)Cd107(β <sup>+</sup> )Ag107(n,γ) Ag108m(n,γ)Ag109m Cd110(n,2n)Cd109(β <sup>+</sup> )Ag109m Cd111(n,2n)Cd110(n,2n)Cd109(β <sup>+</sup> )Ag109m   &Cd112(n,2n)Cd111(n,2n)Cd110(n,2n) Cd109(β <sup>+</sup> )Ag109m Cd110(n,d)Ag109m Cd111(n,3n)Cd109(β <sup>+</sup> )Ag109m Cd112(n,3n)Cd110(n,2n)Cd109(β <sup>+</sup> )Ag109m   Cd111(n,t)Ag109m Cd112(n,4n)Cd109(β <sup>+</sup> )Ag109m Cd112(n,nt)Ag109m Cd113(n,5n)Cd109(β <sup>+</sup> )Ag109m	91.7 1.9	99.9	99.6	79.7 14.0 2.2	24.2 1.3	12.2	8.6 3.5 10.8	
Cd111m	48.54 m	Cd110(n,γ)Cd111m Cd112(n,2n)Cd111m Cd113(n,2n)Cd112(n,2n)Cd111m Cd111(n,n')Cd111m Cd112(n,2n)Cd111(n,n')Cd111m Cd114(n,2n)Cd113(n,2n)Cd112(n,2n)Cd111m   Cd114(n,2n)Cd113m(n,2n)Cd112(n,2n) Cd111m Cd113(n,3n)Cd111m Cd114(n,3n)Cd112(n,2n)Cd111m Cd114(n,2n)Cd113m(n,3n)Cd111m Cd114(n,2n)Cd113(n,3n)Cd111m Cd114(n,4n)Cd111m Cd116(n,6n)Cd111m	99.5	100.0	100.0	76.7 9.5 7.7 1.7 1.2 1.0	37.7 1.3 5.1 0.2	20.1 3.7 4.0	22.6 4.0 14.2 50.3 2.7	
In116m	54.60 m	&Cd114(n,γ)Cd115(β <sup>-</sup> )In115(n,γ)In116m   &Cd113(n,γ)Cd114(n,γ)Cd115m(β <sup>-</sup> ) In115(n,γ)In116m &Cd114(n,γ)Cd115m(β <sup>-</sup> )In115(n,γ)In116m   &Cd113(n,γ)Cd114(n,γ)Cd115(β <sup>-</sup> ) In115(n,γ)In116m &Cd112(n,γ)Cd113(n,γ)Cd114(n,γ) Cd115(β <sup>-</sup> )In115(n,γ)In116m &Cd116(n,2n)Cd115m(β <sup>-</sup> )In115(n,γ)In116m   &Cd116(n,2n)Cd115(β <sup>-</sup> )In115(n,γ)In116m   &Cd116(n,γ)Cd117m(β <sup>-</sup> )In117(β <sup>-</sup> ) Sn117(n,d)In116m &Cd116(n,γ)Cd117(β <sup>-</sup> )In117m(β <sup>-</sup> ) Sn117(n,d)In116m &Cd116(n,γ)Cd117(β <sup>-</sup> )In117(β <sup>-</sup> ) Sn117(n,d)In116m &Cd116(n,d)Ag115(β <sup>-</sup> )Cd115(β <sup>-</sup> ) In115m(IT)In115(n,γ)In116m &Cd116(n,d)Ag115m(β <sup>-</sup> )Cd115(β <sup>-</sup> ) In115m(IT)In115(n,γ)In116m	57.6 14.3	75.3 1.5	84.9 0.2	7.8 6.4	9.8 12.4	11.6 1.9	49.1 47.3	28.4 21.2 10.0 6.2 6.2 10.7 7.3
Cd115	2.228 d	Cd114(n,γ)Cd115 Cd113(n,γ)Cd114(n,γ)Cd115 Cd116(n,2n)Cd115 Cd112(n,γ)Cd113(n,γ)Cd114(n,γ)Cd115 Cd111(n,γ)Cd112(n,γ)Cd113(n,γ) Cd114(n,γ)Cd115 &Cd116(n,d)Ag115(β <sup>-</sup> )Cd115 Cd116(n,d)Ag115m(β <sup>-</sup> )Cd115	82.8 9.2 6.6 1.4	80.2 19.7	95.7 4.2 0.1	0.3 99.4	0.4 79.5	0.3 60.7	0.3 51.4 30.5 17.5	

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6		
Ag106m	8.46 d	&Cd108(n,2n)Cd107(β <sup>+</sup> )Ag107(n,2n)Ag106m				53.8	7.5	0.4	0.1		
		Cd106(n,p)Ag106m				36.5	10.2	1.4	0.6		
		Cd110(n,3n)Cd108(n,t)Ag106m					13.3	11.8	1.7		
		Cd108(n,t)Ag106m					7.2	8.2	3.3		
		Cd110(n,3n)Cd108(n,2n)Cd107(β <sup>+</sup> )_Ag107m(IT)Ag107(n,2n)Ag106m					6.9	0.3			
		Cd111(n,3n)Cd109(β <sup>+</sup> )Ag109m(IT)_Ag109(n,2n)Ag108m(n,3n)Ag106m						5.5	0.2		
		Cd112(n,4n)Cd109(β <sup>+</sup> )Ag109m(IT)_Ag109(n,4n)Ag106m							16.4	6.7	
		Cd111(n,3n)Cd109(β <sup>+</sup> )Ag109m(IT)_Ag109(n,4n)Ag106m							10.6	2.5	
		Cd111(n,4n)Cd108(n,t)Ag106m							8.0	2.2	
		Cd110(n,2n)Cd109(β <sup>+</sup> )Ag109m(IT)_Ag109(n,4n)Ag106m							5.7	2.0	
		Cd110(n,2nt)Ag106m									26.9
		Other pathways					9.7	49.4	37.0		54.0
		Cd115m	44.60 d	Cd114(n,γ)Cd115m	89.8	80.6	95.7	0.2	0.3		
				Cd112(n,γ)Cd113(n,γ)Cd114(n,γ)Cd115m	6.9		0.1				
				Cd111(n,γ)Cd112(n,γ)Cd113(n,γ)_Cd114(n,γ)Cd115m	1.5						
				Cd112(n,γ)Cd113m(n,γ)Cd114(n,γ)_Cd115m	1.1						
Cd113(n,γ)Cd114(n,γ)Cd115m	0.4			19.4	4.0						
Cd110(n,γ)Cd111(n,γ)Cd112(n,γ)_Cd113(n,γ)Cd114(n,γ)Cd115m	0.3										
Cd116(n,2n)Cd115m											
							99.6	98.5	96.7	95.7	
Ag110m	249.78 d	Cd108(n,γ)Cd109(β <sup>+</sup> )Ag109m(IT)_Ag109(n,γ)Ag110m	93.2	99.9	99.9						
		Cd110(n,p)Ag110m				72.7	28.0	11.9	4.6		
		Cd111(n,2n)Cd110(n,p)Ag110m				14.7	1.7	0.4	0.1		
		Cd111(n,d)Ag110m				6.4	40.5	24.7	14.6		
		&Cd112(n,2n)Cd111(n,2n)Cd110(n,p)_Ag110m				2.6					
		&Cd112(n,2n)Cd111(n,d)Ag110m				2.2	4.6	1.6	0.6		
		Cd112(n,t)Ag110m					7.7	40.7	34.9		
		Cd112(n,3n)Cd110(n,p)Ag110m					6.5	1.7	0.2		
		&Cd113(n,3n)Cd111(n,d)Ag110m					5.1	1.3	0.4		
		Cd114(n,3n)Cd112(n,t)Ag110m					1.3	3.3	1.2		
		Cd113(n,nt)Ag110m					0.5	4.8	18.9		
		&Cd114(n,4n)Cd111(n,d)Ag110m							3.9	1.3	
		Cd114(n,2nt)Ag110m							0.2	17.2	
Cd109	1.267 y	Cd108(n,γ)Cd109	96.6	100.0	99.6						
		Cd110(n,2n)Cd109				82.8	27.3	14.5	11.4		
		Cd111(n,2n)Cd110(n,2n)Cd109				14.5	1.4	0.5	0.2		
		Cd111(n,3n)Cd109					51.6	27.2	14.3		
		&Cd113(n,3n)Cd111(n,3n)Cd109					5.6	1.3	0.2		
		Cd112(n,3n)Cd110(n,2n)Cd109					5.5	1.8	0.5		
		&Cd112(n,2n)Cd111(n,3n)Cd109					5.2	1.6	0.5		
		Cd112(n,4n)Cd109							42.1	38.4	
Cd113(n,5n)Cd109								22.7			
Cd113m	14.1 y	Cd112(n,γ)Cd113m	67.4	69.0	95.9	0.1	0.2				
		Cd111(n,γ)Cd112(n,γ)Cd113m	25.4	30.6	4.0						
		Cd110(n,γ)Cd111(n,γ)Cd112(n,γ)Cd113m	7.1	0.4							
		Cd114(n,2n)Cd113m				89.0	81.8	50.0	60.5		
		Cd113(n,n')Cd113m				9.4	14.2	10.4	12.4		
Cd116(n,4n)Cd113m					0.3	37.6	24.9				
Ag108m	418.0 y	&Cd106(n,γ)Cd107(β <sup>+</sup> )Ag107(n,γ)Ag108m	99.9	99.9	99.9						
		&Cd110(n,2n)Cd109(β <sup>+</sup> )Ag109(n,2n)Ag108m				88.1	13.6	1.7	0.4		
		&Cd111(n,2n)Cd110(n,2n)Cd109(β <sup>+</sup> )_Ag109(n,2n)Ag108m				6.1					
		Cd108(n,p)Ag108m				2.3	3.7	1.0	0.3		
		&Cd110(n,d)Ag109(n,2n)Ag108m				0.5	5.2	1.2	0.4		

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	Cd111(n,3n)Cd109(β <sup>+</sup> )Ag109m(IT) <sub>-</sub> Ag109(n,2n)Ag108m Cd110(n,t)Ag108m Cd111(n,3n)Cd109(n,d)Ag108m Cd110(n,3n)Cd108(n,p)Ag108m Cd112(n,3n)Cd110(n,t)Ag108m Cd111(n,nt)Ag108m Cd112(n,4n)Cd109(β <sup>+</sup> )Ag109m(IT) <sub>-</sub> Ag109(n,2n)Ag108m Cd112(n,2nt)Ag108m					25.9	3.1	0.5
							21.3	56.8	29.4
							5.3	0.9	0.2
							3.5	0.7	
							3.1	5.1	1.0
							1.1	9.8	29.1
								4.8	1.4
								0.1	22.1
Mo93	4000 y	&Cd106(n,nα)Pd102(n,nα)Ru98(n,nα) <sub>-</sub> Mo94(n,2n)Mo93 Cd106(n,nα)Pd102(n,nα)Ru99(n,2n) <sub>-</sub> Ru98(n,nα)Mo94(n,2n)Mo93 Cd106(n,nα)Pd102(n,nα)Ru98(n,nα) <sub>-</sub> Mo95(n,2n)Mo94(n,2n)Mo93 Cd106(n,nα)Pd102(n,nα)Ru99(n,nα) <sub>-</sub> Mo95(n,2n)Mo94(n,2n)Mo93 &Cd106(n,nα)Pd102(n,nα)Ru98(n,2nα)Mo93   &Cd106(n,2nα)Ru98(n,2nα)Mo93 Cd106(n,2nα)Pd101(β <sup>+</sup> )Rh101m(β <sup>+</sup> ) <sub>-</sub> Ru101(n,4n)Ru98(n,2nα)Mo93 Cd106(n,2nα)Pd101(β <sup>+</sup> )Rh101m(β <sup>+</sup> ) <sub>-</sub> Ru101(n,2nα)Mo96(n,4n)Mo93 Cd106(n,3nα)Pd100(β <sup>+</sup> )Rh100(β <sup>+</sup> ) <sub>-</sub> Ru100(n,4nα)Mo93 &Cd106(n,tα)Rh100(β <sup>+</sup> )Ru100(n,4nα)Mo93   Other pathways involving (n,2n), (n,α), β <sup>+</sup>				57.1	1.2		
							11.0		
							8.6		
							8.0		
								19.1	0.7
								0.6	6.2
								19.1	0.1
									9.3
									6.5
									3.6
							15.3	79.1	64.7
									89.6
Nb94	2.0 10 <sup>4</sup> y	Cd106(n,nα)Pd102(n,nα)Ru98(n,2n) <sub>-</sub> Ru97(β <sup>+</sup> )Tc97(n,α)Nb94 &Cd106(n,nα)Pd102(n,2nα)Ru97(β <sup>+</sup> ) <sub>-</sub> Tc97(n,α)Nb94 Cd106(n,2nα)Pd101(β <sup>+</sup> )Rh101m(β <sup>+</sup> ) <sub>-</sub> Ru101(n,t)Tc99(n,2nα)Nb94 Cd106(n,2nα)Pd101(β <sup>+</sup> )Rh101m(β <sup>+</sup> ) <sub>-</sub> Ru101(n,2nα)Mo96(n,t)Nb94 &Cd106(n,3nα)Pd100(β <sup>+</sup> )Rh100(β <sup>+</sup> ) <sub>-</sub> Ru100(n,tα)Nb94 &Cd106(n,tα)Rh100(β <sup>+</sup> )Ru100(n,tα)Nb94   Cd106(n,nt)Ag103(β <sup>+</sup> )Pd103(β <sup>+</sup> ) <sub>-</sub> Rh103m(IT)Rh103(n,2n2α)Nb94 Other pathways involving (n,2n), (n,α), β <sup>+</sup>				12.9	0.3		
								4.1	0.4
								1.1	6.5
								0.9	8.2
									8.9
									4.5
									3.6
							87.1	93.6	84.9
									82.7
Tc99	2.1 10 <sup>5</sup> y	&Cd106(n,α)Pd103(β <sup>+</sup> )Rh103(n,nα)Tc99 &Cd106(n,α)Pd103(β <sup>+</sup> )Rh103(n,2n) <sub>-</sub> Rh102(n,α)Tc99 &Cd106(n,2nα)Pd101(β <sup>+</sup> )Rh101m(β <sup>+</sup> ) <sub>-</sub> Ru101(n,t)Tc99 Cd106(n,nα)Pd102(n,3n)Pd100(β <sup>+</sup> ) <sub>-</sub> Rh100(β <sup>+</sup> )Ru100(n,d)Tc99 &Cd108(n,2nα)Pd103(β <sup>+</sup> )Rh103m(IT) <sub>-</sub> Rh103(n,nα)Tc99 Cd106(n,nt)Ag103(β <sup>+</sup> )Pd103(β <sup>+</sup> ) <sub>-</sub> Rh103m(IT)Rh103(n,nα)Tc99 &Cd106(n,dα)Rh101m(β <sup>+</sup> )Ru101(n,t)Tc99   &Cd106(n,3nα)Pd100(β <sup>+</sup> )Rh100(β <sup>+</sup> ) <sub>-</sub> Ru100(n,d)Tc99 &Cd106(n,tα)Rh100(β <sup>+</sup> )Ru100(n,d)Tc99 Other pathways involving (n,2n), (n,α), β <sup>+</sup>				53.5	9.5	0.9	1.9
							20.8		
								8.2	39.1
								5.0	0.4
								1.8	2.9
								0.3	4.7
									5.7
									3.4
									1.1
									8.1
									3.8
							25.7	75.2	47.5
									73.8
Tc98	4.2 10 <sup>6</sup> y	&Cd106(n,α)Pd103(β <sup>+</sup> )Rh103(n,2n) <sub>-</sub> Rh102(n,nα)Tc98					29.5	0.4	

Nuclide	T <sub>½</sub>	Pathway	210	186	151	42	30	21	6	
	◀	<b>&amp;</b> Cd106(n,α)Pd103(β <sup>+</sup> )Rh103(n,α) <sub>-</sub> Tc99(n,2n)Tc98 <b>&amp;</b> Cd106(n,α)Pd103(β <sup>+</sup> )Rh103(n,2n) <sub>-</sub> Rh102m(n,α)Tc98 Cd106(n,α)Pd102(n,2n)Pd101(β <sup>+</sup> ) <sub>-</sub> Rh101m(IT)Rh101(n,α)Tc98 <b>&amp;</b> Cd106(n,α)Pd102(n,p)Rh102(n,α)Tc98   Cd106(n,α)Pd102(n,2n)Pd101(β <sup>+</sup> ) <sub>-</sub> Rh101(n,α)Tc98 Cd106(n,2nα)Pd101(β <sup>+</sup> )Rh101m(β <sup>+</sup> ) <sub>-</sub> Ru101(n,3n)Ru99(n,d)Tc98 Cd106(n,α)Pd102(n,3n)Pd100(β <sup>+</sup> ) <sub>-</sub> Rh100(β <sup>+</sup> )Ru100(n,t)Tc98 Cd106(n,α)Pd103(β <sup>+</sup> )Rh103m(IT) <sub>-</sub> Rh103(n,2nα)Tc98 Cd106(n,α)Pd102(n,pα)Tc98 Cd106(n,2nα)Pd101(β <sup>+</sup> )Rh101m(β <sup>+</sup> ) <sub>-</sub> Ru101(n,nt)Tc98 Cd108(n,2nα)Pd103(β <sup>+</sup> )Rh103m(IT) <sub>-</sub> Rh103(n,2nα)Tc98 Cd106(n,nt)Ag103(β <sup>+</sup> )Pd103(β <sup>+</sup> ) <sub>-</sub> Rh103m(IT)Rh103(n,2nα)Tc98 Cd106(n,3nα)Pd100(β <sup>+</sup> )Rh100(β <sup>+</sup> ) <sub>-</sub> Ru100(n,t)Tc98 Other pathways involving (n,2n), (n,α), β <sup>+</sup>				19.4	0.7			
						9.2	0.2			
						5.2	0.2			
						0.6	0.4			
						0.2				
							5.5	1.1		
							5.4	0.7		
							5.0	2.1	2.0	
							5.0	0.2		
							1.7	14.6	5.1	
							1.0	6.9	0.4	
							0.2	14.0	7.9	
								1.7	7.4	
						35.9	74.3	58.7	77.2	
Pd107	6.5 10 <sup>6</sup> y	<b>&amp;</b> Cd108(n,γ)Cd109(n,α)Pd106(n,γ)Pd107 <b>&amp;</b> Cd110(n,α)Pd107 <b>&amp;</b> Cd111(n,2n)Cd110(n,α)Pd107 <b>&amp;</b> Cd111(n,α)Pd108(n,2n)Pd107 <b>&amp;</b> Cd111(n,α)Pd107 <b>&amp;</b> Cd112(n,3n)Cd110(n,α)Pd107 <b>&amp;</b> Cd112(n,2nα)Pd107 <b>&amp;</b> Cd112(n,4n)Cd109(β <sup>+</sup> )Ag109m(IT) <sub>-</sub> Ag109(n,t)Pd107 <b>&amp;</b> Cd113(n,3nα)Pd107 <b>&amp;</b> Cd114(n,4nα)Pd107	99.2	99.2	99.8	75.6	30.3	9.9	8.9	
						9.4	1.1	0.2		
						6.2	0.3			
						2.4	45.0	23.9	11.9	
							4.4	0.9	0.2	
							1.6	37.5	23.7	
								3.7	2.0	
								1.4	21.6	
									12.9	
In115	4.4 10 <sup>14</sup> y	Cd114(n,γ)Cd115(β <sup>-</sup> )In115m(IT)In115 Cd114(n,γ)Cd115m(β <sup>-</sup> )In115 Cd113(n,γ)Cd114(n,γ)Cd115(β <sup>-</sup> ) <sub>-</sub> In115m(IT)In115 Cd112(n,γ)Cd113(n,γ)Cd114(n,γ) <sub>-</sub> Cd115(β <sup>-</sup> )In115m(IT)In115 Cd113(n,γ)Cd114(n,γ)Cd115m(β <sup>-</sup> )In115 Cd116(n,2n)Cd115m(β <sup>-</sup> )In115 Cd116(n,2n)Cd115(β <sup>-</sup> )In115m(IT)In115 Cd116(n,d)Ag115(β <sup>-</sup> )Cd115(β <sup>-</sup> ) <sub>-</sub> In115m(IT)In115 Cd116(n,d)Ag115m(β <sup>-</sup> )Cd115(β <sup>-</sup> ) <sub>-</sub> In115m(IT)In115	75.6	75.8	86.0	0.1	0.2	0.2	0.2	
			10.3	9.9	11.7	0.1	0.1	0.1	0.1	
			8.4	12.7	1.9					
			5.7							
				1.6	0.3					
						49.7	55.6	47.3	41.9	
						49.7	34.7	31.3	29.5	
							4.2	10.5	14.9	
							3.4	7.4	10.1	
Cd113	7.7 10 <sup>15</sup> y	Cd112(n,γ)Cd113 Cd111(n,γ)Cd112(n,γ)Cd113 Cd110(n,γ)Cd111(n,γ)Cd112(n,γ)Cd113 Cd114(n,2n)Cd113 <b>&amp;</b> Cd114(n,d)Ag113(β <sup>-</sup> )Cd113 Cd116(n,4n)Cd113 Nuclide also present in starting material	67.5	0.4	6.5					
			25.4	0.2	0.3					
			7.1							
						20.5	5.1	3.4	2.2	
							1.4	2.1	2.0	
								2.3	0.9	
				99.4	93.2	79.5	93.5	92.2	94.9	
Cd114	6.0 10 <sup>17</sup> y	Cd112(n,γ)Cd113(n,γ)Cd114 Cd113(n,γ)Cd114 Cd116(n,3n)Cd114 Nuclide also present in starting material	1.8		0.1					
				19.7	4.2					
							4.5	1.7	0.8	
			98.2	80.3	95.7	100.0	95.5	98.3	99.2	

# Cadmium activation characteristics

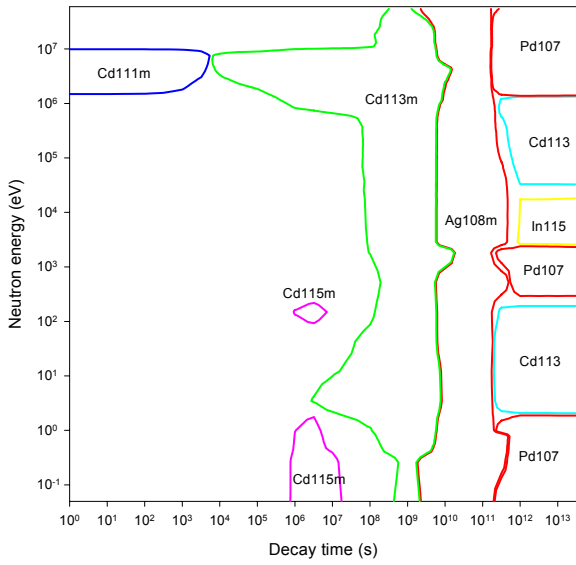


Decay time (years)

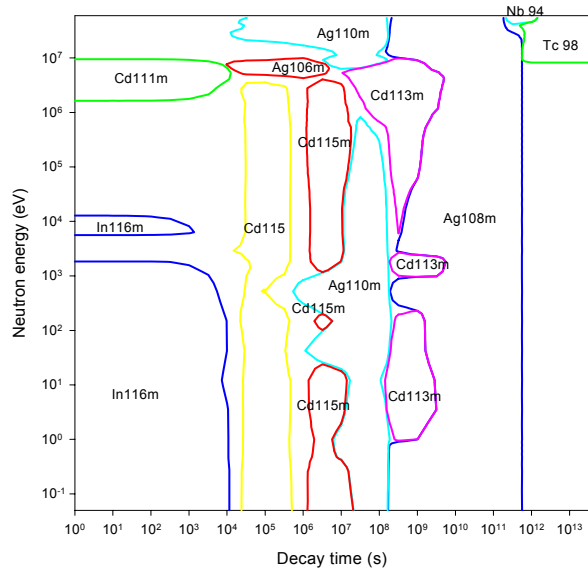
Decay time (years)

# Cadmium importance diagrams & transmutation

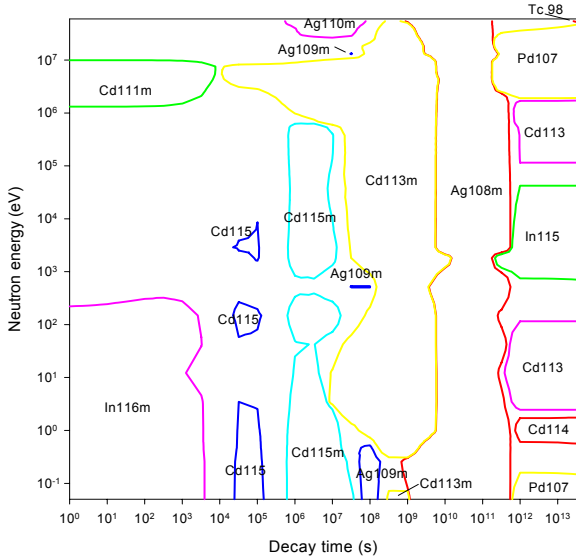
**Activity**



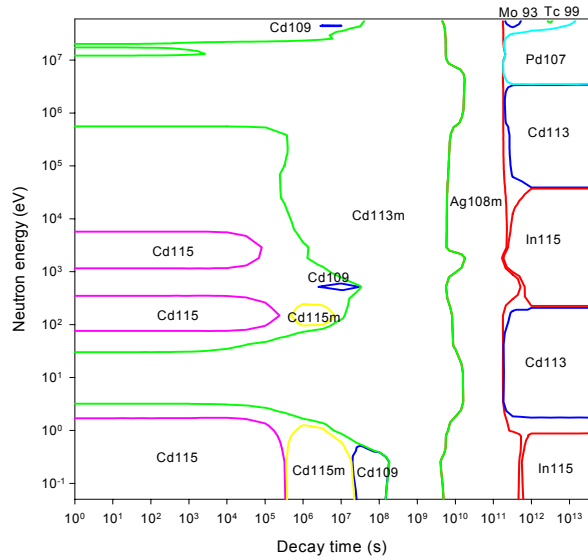
**Dose rate**



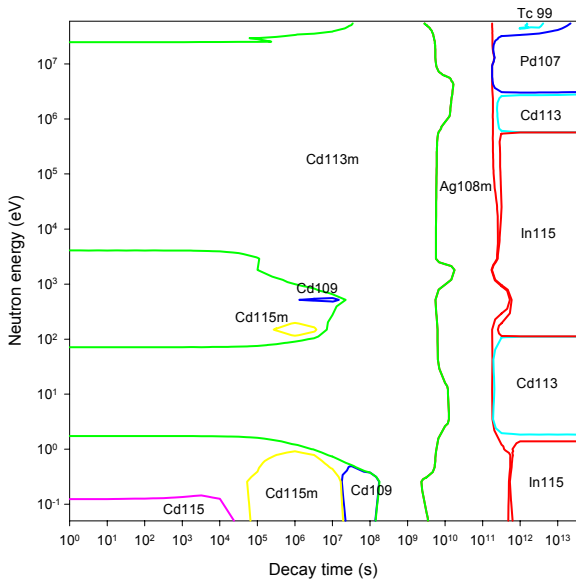
**Heat output**



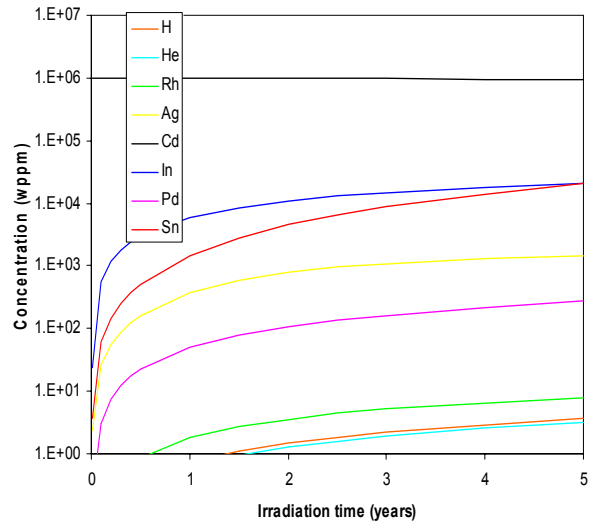
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**



# Indium

## General properties

Atomic number	49	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	0.25	In113	4.29
Melting point / K	429.8	In115	95.71 ( $T_{1/2} = 4.41 \cdot 10^{14}$ y)
Boiling point / K	2345		
Density / $\text{kgm}^{-3}$	7310		
Thermal conductivity / $\text{Wm}^{-1}\text{K}^{-1}$	81.6		
Electrical resistivity / $\Omega\text{m}$	$8.37 \cdot 10^{-8}$		
Coefficient of thermal expansion / $\text{K}^{-1}$	$3.21 \cdot 10^{-5}$		
Crystal structure	FCT		
Number of stable isotopes	1 (2)		
Mean atomic weight	114.818		

## Activation properties

Act	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Heat	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Bq $\text{kg}^{-1}$	1.65E16	8.99E15	9.38E14	1.18E13	1.72E9	6.62E1	kW $\text{kg}^{-1}$	4.48E0	3.60E0	7.02E-2	6.48E-4	5.07E-8	1.44E-15
In116m	50.60	86.94					In116m	83.82	97.65				
In116n	27.09						In116	11.04					
In116	13.72						In116n	2.59					
In115m	6.19	1.12	0.14				In114	1.83	1.48	70.29	50.64		
In114	4.02	4.78	42.40	22.46			In114m	0.35	0.44	21.65	15.59		
In114m	2.62	4.82	43.94	23.28			In115m	0.12	0.15				
Sn117m	0.50	0.93	7.41				Sn117m	0.09	0.11	4.97			
In113m	0.19	0.35	2.88	26.05			In113m	0.04	0.05	2.42	29.72		
Sn113	0.16	0.30	2.88	26.04			Sn113			0.18	2.24		
Cd113m				1.87	98.77		Cd113m				1.01	99.90	
In115						88.55	In115						99.21
Pd107						11.45	Pd107						0.78
Dose	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Ing	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{h}^{-1}$	6.19E6	5.79E6	5.89E3	1.38E2	7.71E-5	1.77E-13	Sv $\text{kg}^{-1}$	5.46E6	4.92E6	1.78E6	1.88E4	3.91E1	1.88E-6
In116m	99.73	99.83					Sn113m	55.17	51.38				
In114m	0.07	0.07	74.26	20.64			In114m	32.59	36.14	95.02	59.96		
In113m	0.01	0.01	15.20	71.94			In116m	9.80	10.17				
In114			4.27*	1.18*			Sn117m	1.09	1.20	2.77			
Sn117m			4.24				Sn113	0.37	0.41	1.11	11.94		
Ag110m			0.34	5.25			In115m	0.16	0.17				
Ag108m					84.31		Cd113m	0.09	0.10	0.30	27.10	100.0	
Cd113m					15.60*		Cd115m	0.07	0.08	0.22	0.07		
Tc98						99.99	In113m	0.01	0.01	0.04	0.45		
							In115						99.98
Inh	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Clear	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{kg}^{-1}$	9.38E6	8.61E6	4.12E6	5.84E4	1.87E2	2.29E-5		2.17E13	1.97E13	1.14E11	3.70E9	3.19E4	5.86E-2
Sn113m	49.35	45.02					In116m	96.24	99.33				
In114m	42.99	46.88	93.14	43.68			In116n	1.58					
In116m	4.00	4.08					In116	1.47					
Sn117m	2.14	2.33	4.05				In114	0.25	0.18	29.04	5.95		
Sn113	0.79	0.86	1.77	14.19			In114m	0.19	0.22	36.11	7.40		
Cd113m	0.27	0.29	0.62	41.63	99.99		Sn117m	0.06	0.07	10.51			
Cd115m	0.10	0.11	0.22	0.05			Sn113	0.12		23.72	82.89		
In115m	0.06	0.06					Ag110m			0.23	2.69		
Cd115	0.04	0.05	0.03				In113m			0.23	0.82		
In113m	0.01	0.01	0.01	0.11			Cd113m				0.11	98.72	
Cd109				0.05			In115						99.99
In115						99.98							

# Indium

## Pathway analysis

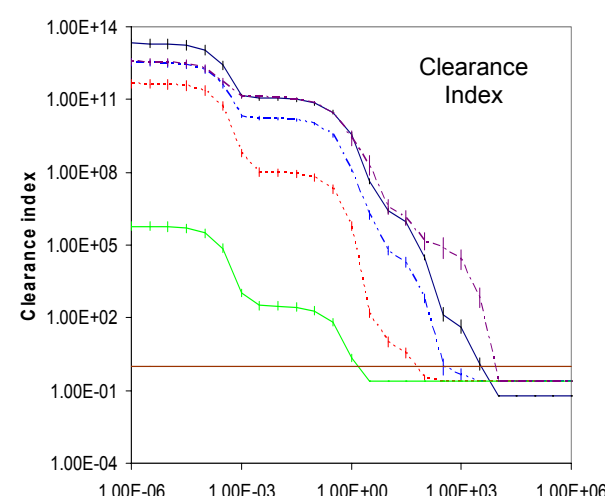
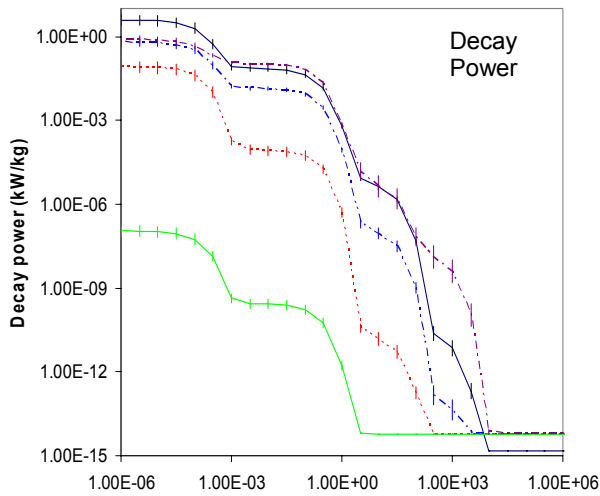
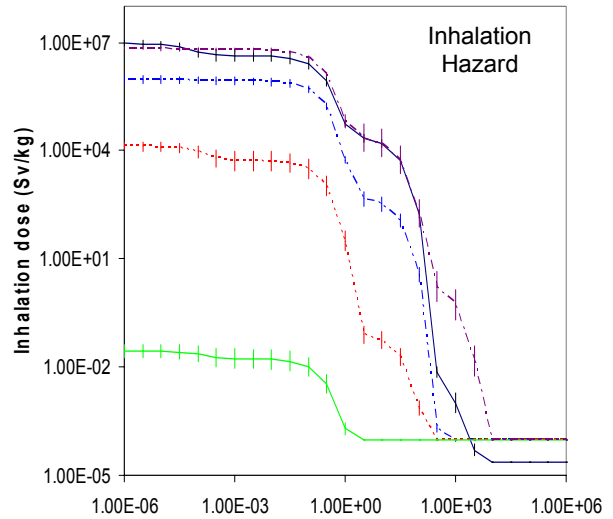
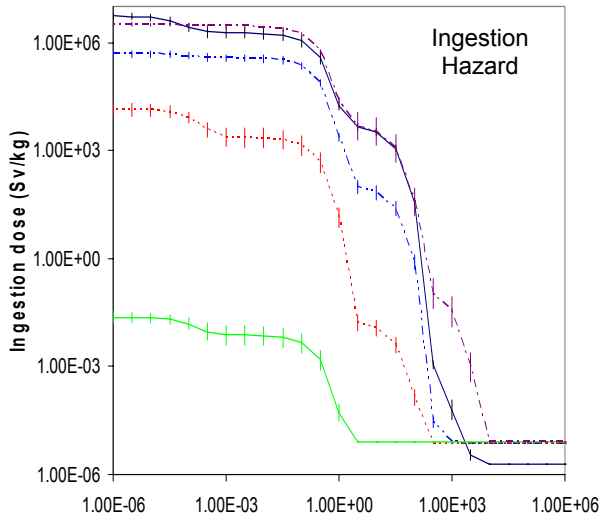
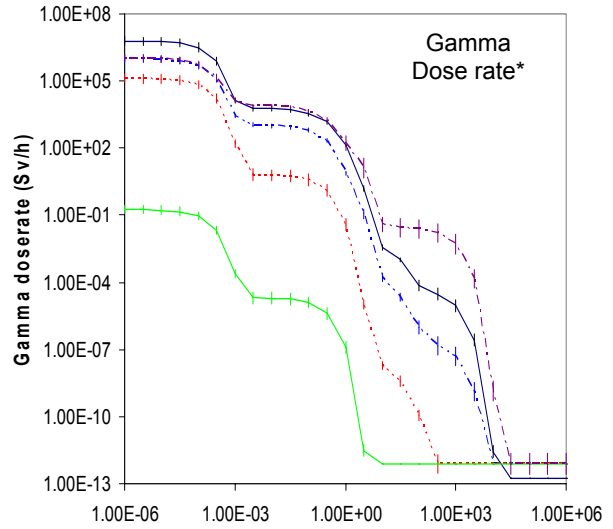
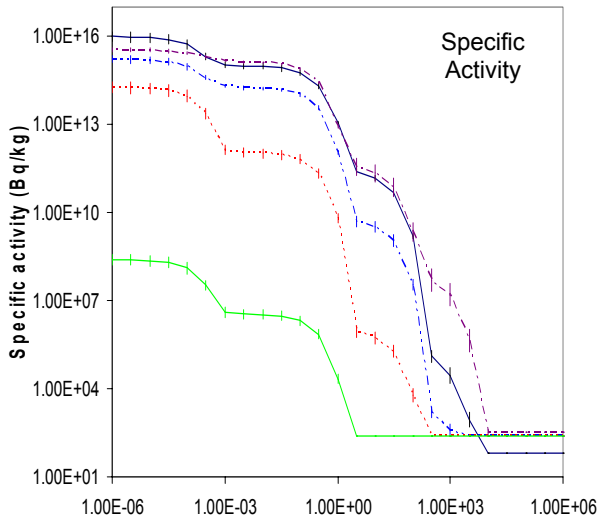
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
In114	1.198 m	&In113(n, $\gamma$ )In114 &In115(n,2n)In114	100.0	100.0	100.0				
						99.4	99.2	99.4	99.6
Sn109	18.0 m	&In115(n,4n)In112( $\beta^-$ )Sn112(n,4n)Sn109 In113(n,2n)In112m(IT)In112( $\beta^-$ ) Sn112(n,4n)Sn109 In115(n,2n)In114( $\beta^-$ )Sn114(n,3n) Sn112(n,4n)Sn109						87.5	93.6
								1.7	1.7
								1.4	
Sn113m	20.9 m	In115(n,2n)In114( $\beta^-$ )Sn114(n,2n)Sn113m In115(n,2n)In114m(IT)In114( $\beta^-$ ) Sn114(n,2n)Sn113(n,n')Sn113m In115(n,n')In115m( $\beta^-$ )Sn115(n,3n)Sn113m				99.2	98.5	97.6	98.6
						0.1			
							0.6	1.5	
In116m	54.6 m	&In113(n, $\gamma$ )In114m(n, $\gamma$ )In115(n, $\gamma$ ) In116m &In115(n, $\gamma$ )In116m	99.3						
			0.7	100.0	100.0	100.0	100.0	100.0	100.0
In113m	1.658 h	&In115(n,2n)In114( $\beta^-$ )Sn114(n,2n) Sn113( $\beta^+$ )In113m In113(n,n')In113m In115(n,2n)In114m(n,2n)In113m &In115(n,2n)In114( $\beta^-$ )Sn114(n,d)In113m In115(n,3n)In113m In115(n,3n)In113(n,n')In113m				97.4	27.9	16.8	14.3
						0.8	0.6	1.0	1.6
						0.5			
						0.2	2.1	2.8	3.4
							66.6	76.6	78.9
							2.0	1.9	1.1
In115m	4.486 h	In113(n, $\gamma$ )In114m(n, $\gamma$ )In115m In113(n, $\gamma$ )In114m( $\beta^+$ )Cd114(n, $\gamma$ ) Cd115( $\beta^-$ )In115m &In113(n, $\gamma$ )In114( $\beta^+$ )Cd114(n, $\gamma$ ) Cd115( $\beta^-$ )In115m In115(n,n')In115m In115(n,p)Cd115( $\beta^-$ )In115m	97.7	99.9	90.2				
			1.8		7.7				
			0.5		1.8				
						91.5	83.2	82.2	84.2
						8.5	16.4	17.5	15.7
Sn121	1.128 d	&In115(n, $\gamma$ )In116m( $\beta^-$ )Sn116(n, $\gamma$ ) Sn117(n, $\gamma$ )Sn118(n, $\gamma$ )Sn119(n, $\gamma$ )Sn120 (n, $\gamma$ )Sn121 &In115(n, $\gamma$ )In116( $\beta^-$ )Sn116(n, $\gamma$ ) Sn117(n, $\gamma$ )Sn118(n, $\gamma$ )Sn119(n, $\gamma$ ) Sn120(n, $\gamma$ )Sn121	77.4	77.3	84.0				
			21.2	21.2	15.4				
Sn117m	13.6 d	&In115(n, $\gamma$ )In116m( $\beta^-$ )Sn116(n, $\gamma$ ) Sn117m In115(n, $\gamma$ )In116( $\beta^-$ )Sn116(n, $\gamma$ )Sn117m &In115(n, $\gamma$ )In116m( $\beta^-$ )Sn116(n, $\gamma$ ) Sn117(n,n')Sn117m In115(n, $\gamma$ )In116( $\beta^-$ )Sn116(n, $\gamma$ )Sn117 (n,n')Sn117m	78.5	78.5	84.4	82.5	83.8	84.6	85.4
			21.4	21.5	15.6	15.0	14.7	14.4	14.1
						1.3	0.6	0.4	0.3
						0.2	0.1		
In114m	50.0 d	In113(n, $\gamma$ )In114m In115(n,2n)In114m	100.0	100.0	100.0				
						99.5	99.3	99.4	99.7
Ag110m	249.78 d	In113(n, $\gamma$ )In114m(n, $\alpha$ )Ag111( $\beta^-$ ) Cd111(n, $\alpha$ )Pd108(n, $\gamma$ )Pd109( $\beta^-$ ) Ag109m(IT)Ag109(n, $\gamma$ )Ag110m In113(n, $\alpha$ )Ag110m &In115(n,2n)In114( $\beta^-$ )Sn114(n,2n) Sn113( $\beta^+$ )In113(n, $\alpha$ )Ag110m &In115(n,3n)In113(n, $\alpha$ )Ag110m In115(n,3n)In113(n,3n)In111( $\beta^+$ ) Cd111(n,d)Ag110m In115(n,2n $\alpha$ )Ag110m &In113(n,3n)In111( $\beta^+$ )Cd111(n,d)Ag110m &In115(n,4n)In112( $\beta^+$ )Cd112(n,t)Ag110m	35.0	35.8					
						73.5	14.4	1.1	1.4
						19.7			
							40.3	1.7	0.8
							10.7	0.9	0.1
							10.5	76.3	49.5
							8.7	1.2	0.4
								10.6	10.3



Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	In115(n,nt)Cd112(n,t)Ag110m In115(n,5n)In111(β <sup>+</sup> )Cd111(n,d)Ag110m						1.0	6.4 14.6	
Sn119m	293.0 d	&In115(n,γ)In116m(β <sup>-</sup> )Sn116(n,γ) Sn117(n,γ)Sn118(n,γ)Sn119m &In115(n,γ)In116(β <sup>-</sup> )Sn116(n,γ) Sn117(n,γ)Sn118(n,γ)Sn119m &In115(n,γ)In116m(β <sup>-</sup> )Sn116(n,γ) Sn117m(n,γ)Sn118(n,γ)Sn119m In115(n,γ)In116(β <sup>-</sup> )Sn116(n,γ) Sn117m(n,γ)Sn118(n,γ)Sn119m	78.3 21.4 0.1	78.3 21.4 0.2	84.4 15.5	79.1 14.4 4.1 0.8	76.6 13.4 7.4 1.3	77.3 13.1 7.3 1.2	78.7 13.0 6.6 1.1	
Cd113m	14.1 y	&In113(n,γ)In114(β <sup>-</sup> )Sn114(n,γ)Sn115 (n,α)Cd112(n,γ)Cd113m In113(n,γ)In114m(n,γ)In115m(β <sup>-</sup> ) Sn115(n,α)Cd111(n,γ)Cd113m &In113(n,γ)In114m(n,α)Ag111(β <sup>-</sup> ) Cd111(n,γ)Cd112(n,γ)Cd113m &In113(n,γ)In114m(n,α)Ag111(n,γ) Ag112(β <sup>-</sup> )Cd112(n,γ)Cd113m In115(n,2n)In114m(β <sup>+</sup> )Cd114(n,2n)Cd113m In113(n,p)Cd113m &In115(n,2n)In114(β <sup>+</sup> )Cd114(n,2n)Cd113m In115(n,d)Cd114(n,2n)Cd113m In115(n,2n)In114m(n,d)Cd113m In115(n,t)Cd113m In115(n,3n)In113(n,p)Cd113m	61.8 27.2 10.8	0.2 0.2 97.6 1.7	93.2 3.6 3.0					
Sn121m	55.0 y	&In115(n,γ)In116m(β <sup>-</sup> )Sn116(n,γ) Sn117(n,γ)Sn118(n,γ)Sn119(n,γ)Sn120 (n,γ)Sn121m &In115(n,γ)In116(β <sup>-</sup> )Sn116(n,γ)Sn117 (n,γ)Sn118(n,γ)Sn119(n,γ)Sn120(n,γ) Sn121m	77.3 21.1	77.2 21.1	84.0 15.4					
Ag108m	418.0 y	&In113(n,2n)In112(β <sup>-</sup> )Sn112(n,α) Cd109(β <sup>+</sup> )Ag109(n,2n)Ag108m &In113(n,α)Ag109(n,2n)Ag108m &In113(n,2n)In112(β <sup>+</sup> )Cd112(n,α) Pd109(β <sup>-</sup> )Ag109(n,2n)Ag108m &In113(n,α)Ag110m(n,2n)Ag109 (n,2n)Ag108m In115(n,3n)In113(n,2nα)Ag108m In113(n,2nα)Ag108m &In115(n,3n)In113(n,α)Ag109(n,2n) Ag108m In113(n,3n)In111(β <sup>+</sup> )Cd111(n,3n)Cd109 (β <sup>+</sup> )Ag109m(IT)Ag109(n,2n)Ag108m In115(n,4nα)Ag108m &In115(n,5n)In111(β <sup>+</sup> )Cd111(n,nt)Ag108m In113(n,α)Ag110(β <sup>-</sup> )Cd110(n,2n)Cd109 (β <sup>+</sup> )Ag109m(IT)Ag109(n,2n)Ag108m Other similar long pathways				37.9 16.6 7.0 6.5				
Mo93	4000 y	Pathways involving (n,α), (n,nα), (n,2n), β <sup>-</sup> , β <sup>+</sup>				100.0	100.0	100.0	100.0	
Nb94	2.0 10 <sup>4</sup> y	Pathways involving (n,α), (n,nα), (n,2n), β <sup>-</sup> , β <sup>+</sup>				100.0	100.0	100.0	100.0	
Tc98	4.2 10 <sup>6</sup> y	Pathways involving (n,α), (n,nα), (n,2n), β <sup>-</sup> , β <sup>+</sup>				100.0	100.0	100.0	100.0	
Pd107	6.5 10 <sup>6</sup> y	&In113(n,α)Ag110(β <sup>-</sup> )Cd110(n,α)Pd107 &In113(n,2n)In112(β <sup>+</sup> )Cd112(n,2n) Cd111(n,2n)Cd110(n,α)Pd107 &In113(n,2n)In112(β <sup>+</sup> )Cd112(n,2n) Cd111(n,α)Pd108(n,2n)Pd107 &In113(n,α)Ag110m(β <sup>-</sup> )Cd110(n,α)Pd107 &In113(n,2n)In112(β <sup>+</sup> )Cd112(n,2n) Cd111(n,nα)Pd107				18.4 12.4 8.2 7.7 6.6				

Nuclide	T <sub>½</sub>	Pathway	210	186	151	42	30	21	6
	◀	&In113(n,2n)In112(β <sup>-</sup> )Sn112(n,2n)Sn111 <sub>-</sub> (β <sup>+</sup> )In111(β <sup>+</sup> )Cd111(n,2n)Cd110(n,α)Pd107				5.5			
		&In113(n,2n)In112(β <sup>-</sup> )Sn112(n,2n) <sub>-</sub> Sn111(β <sup>+</sup> )In111(β <sup>+</sup> )Cd111(n,α)Pd107				4.5			
		&In115(n,2n)In114(β <sup>-</sup> )Sn114(n,α) <sub>-</sub> Cd111(n,2n)Cd110(n,α)Pd107				4.1			
		&In113(n,2n)In112(β <sup>-</sup> )Sn112(n,2n)Sn111 <sub>-</sub> (β <sup>+</sup> )In111(β <sup>+</sup> )Cd111(n,α)Pd108(n,2n)Pd107				4.0			
		In113(n,α)Ag110m(n,α)Rh107(β <sup>-</sup> )Pd107				1.9			
		&In115(n,α)Ag111(β <sup>-</sup> )Cd111(n,α)Pd107				0.1	15.2	4.8	0.8
		&In115(n,3n)In113(n,3n)In111(β <sup>+</sup> ) <sub>-</sub> Cd111(n,α)Pd107					35.0	3.6	0.1
		&In113(n,3n)In111(β <sup>+</sup> )Cd111(n,α)Pd107					30.4	6.1	0.6
		&In115(n,4n)In112(β <sup>+</sup> )Cd112(n,2nα)Pd107						47.1	11.9
		&In115(n,nt)Cd112(n,2nα)Pd107						4.4	7.4
		&In115(n,3nα)Ag109(n,t)Pd107						1.0	11.7
		&In115(n,t)Cd113m(n,3nα)Pd107						0.7	6.5
		&In115(n,t)Cd113(n,3nα)Pd107						0.4	4.4
		&In115(n,5n)In111(β <sup>+</sup> )Cd111(n,α)Pd107							21.7
		Other similar pathways				26.6	19.4	31.9	34.9
In115	4.4 10 <sup>14</sup> y	&In113(n,γ)In114m(n,γ)In115	98.3						
		In113(n,γ)In114m(β <sup>+</sup> )Cd114(n,γ) <sub>-</sub>	0.8						
		Cd115(β <sup>-</sup> )In115m(IT)In115							
		In113(n,γ)In114m(β <sup>+</sup> )Cd114(n,γ) <sub>-</sub>	0.1						
		Cd115m(β <sup>-</sup> )In115							
		Nuclide also present in starting material	0.8	100.0	100.0	100.0	100.0	100.0	100.0

# Indium activation characteristics

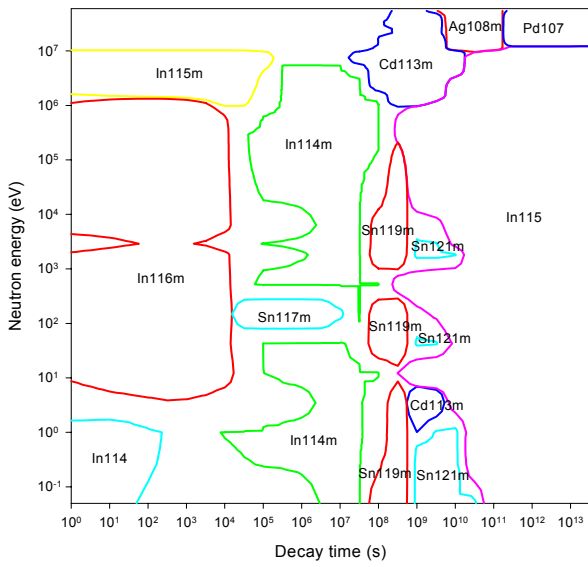


Decay time (years)

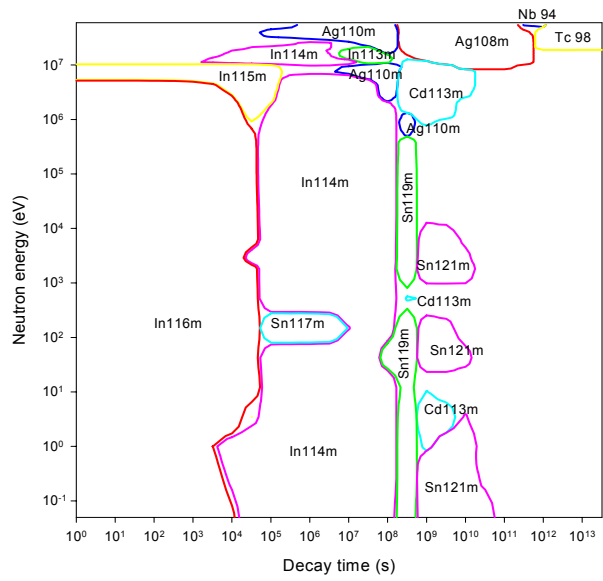
Decay time (years)

# Indium importance diagrams & transmutation

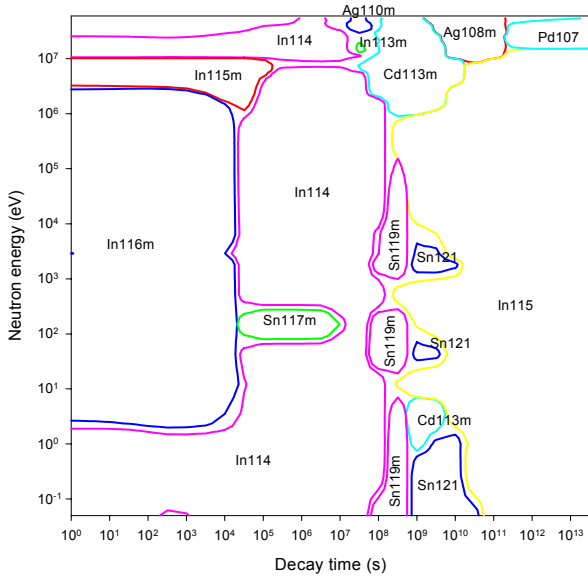
Activity



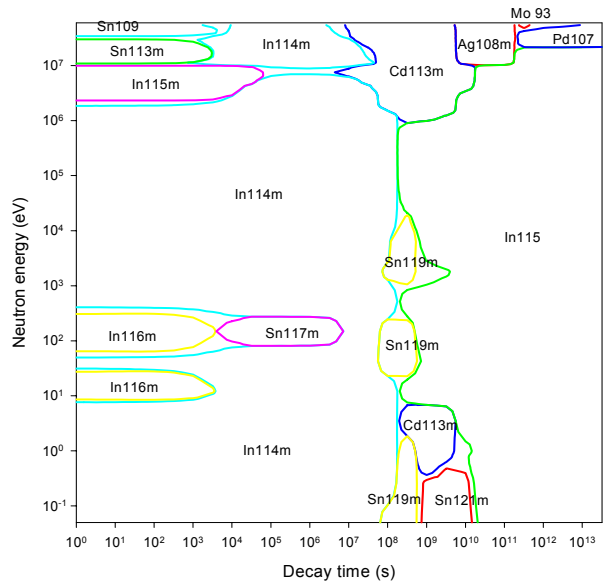
Dose rate



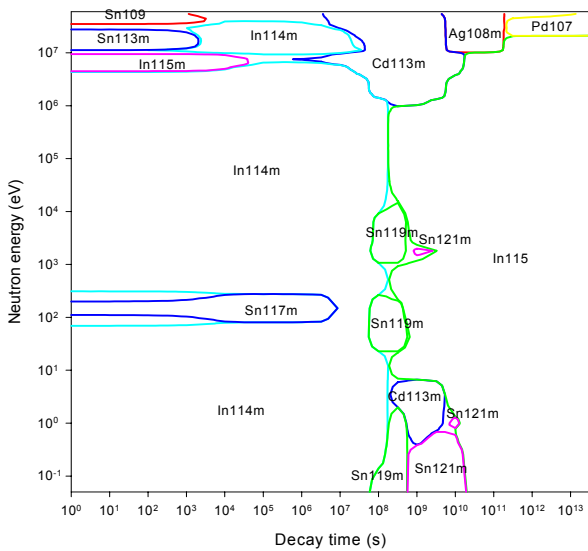
Heat output



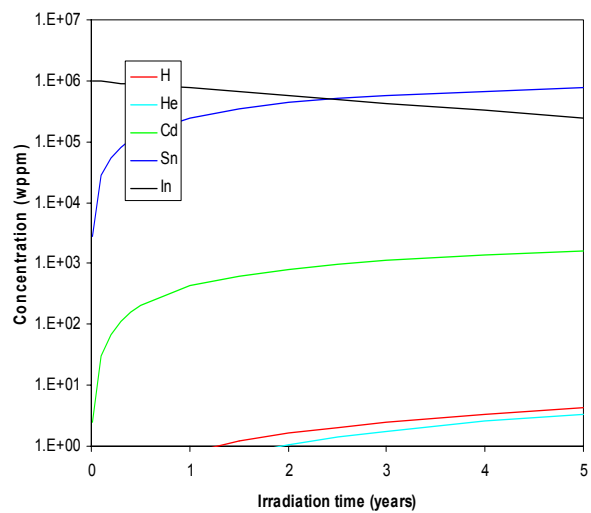
Ingestion dose



Inhalation dose



First wall transmutation



# Tin

## General properties

Atomic number	50	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	2.3	Sn112	0.97
Melting point / K	505.1	Sn114	0.66
Boiling point / K	2875	Sn115	0.34
Density / kgm <sup>-3</sup>	5750	Sn116	14.54
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	66.6	Sn117	7.68
Electrical resistivity /Ωm	1.10 10 <sup>-7</sup>	Sn118	24.22
Coefficient of thermal expansion / K <sup>-1</sup>	2.2 10 <sup>-5</sup>	Sn119	8.59
Crystal structure	Cubic	Sn120	32.58
Number of stable isotopes	9 (10)	Sn122	4.63
Mean atomic weight	118.710	Sn124	5.79 (T <sub>½</sub> = 1.00 10 <sup>17</sup> y)

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	9.95E14	9.45E14	6.47E14	1.52E14	8.51E11	7.74E4	kW kg <sup>-1</sup>	7.00E-2	6.27E-2	3.75E-2	5.72E-3	9.98E-6	1.25E-11
Sn119m	20.18	21.25	30.79	55.66			Sn125m	17.10	13.03				
Sn117m	18.05	19.00	23.06				Sn117m	12.87	14.38	19.97			
Sn121	12.94	13.49	2.27	0.85	43.68		Sb122	12.63	14.11	9.24			
Sn125m	6.51	4.67					Sb124	11.97	13.38	21.46	2.18		
Sb122	5.52	5.80	3.32				Sn123	6.12	6.84	11.23	10.56		
Sn123	5.08	5.35	7.66	4.68			Sb125	5.75	6.43	10.74	54.83		
In113m	5.06	5.33	7.59	3.66			In113m	4.51	5.04	8.22	6.09		
Sn113	5.04	5.31	7.59	3.65			Sn123m	4.29	4.38				
Sb125	4.70	4.95	7.22	23.98			Sn119m	4.11	4.60	7.63	21.23		
Sn123m	3.05	4.67					In114	3.82	2.33	3.55	0.15		
Sb124	2.35	2.48	3.47	0.23			Sn121	3.36	3.75	0.72	0.41	68.80	
In114	2.17	1.24	1.66	0.04			Sb126m	1.78	1.65				77.75
Sn113m	1.75	1.55					In116m	1.42	1.48				
In114m	1.17	1.23	1.72	0.04			Sb126	1.37	1.53	2.10			15.40
Te125m	1.07	1.13	1.65	5.69			Sn111	1.04	1.05				
Sb126m	0.35	0.31				35.59	Sn125	0.65	0.73	0.94			
Sb126n	0.32					23.82	In114m	0.61	0.68	1.09			
Sn121m			0.26	1.09	56.29		Te125m			0.64	3.40		
Sb126			0.24			4.98	Sn121m			0.02	0.18	31.11	
Sn126						35.59	Sn126						6.31
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	3.48E4	3.21E4	2.18E4	3.49E3	9.48E-3	1.20E-5	Sv kg <sup>-1</sup>	6.20E7	4.28E7	5.37E5	9.93E4	2.74E2	1.74E-4
Sb124	35.79	38.77	54.78	5.32			Sn125m	95.27	94.01				
Sb122	13.25	14.34	8.28				Sn113m	3.67	4.46				
Sb125	11.43	12.38	18.20	88.70			Sn117m	0.20	0.29	19.73			
Sn125m	8.75	6.46					Sn123	0.17	0.24	19.40	15.07		
In116m	4.74	4.80					Sb122	0.15	0.21	6.81			
In113m	4.60	4.98	7.15	5.06			Sn119m	0.11	0.15	12.62	28.98		
Sb126m	3.54	3.20			0.13	79.89	Sb124	0.09	0.13	10.47	0.88		
Sb126	3.47	3.76	4.52		0.03	20.05	Sb125	0.08	0.12	9.58	40.38		
In118m	2.29	1.10					In114m	0.07	0.11	8.50	0.30		
Sn111	2.07	2.02					Sn113	0.05	0.08	6.68	4.09		
Sb120m	2.05	2.22	2.11				Sn121	0.04	0.06	0.63	29.00	31.17	
Sn117m	1.73	1.87	2.29				Te125m	0.01	0.02	1.73			
In120m	1.40						Sn125	0.01	0.01	1.12	7.57		
Sn121m					94.58		Sb126		0.01	0.70			5.32
Ag108m					5.23		Cd113m			0.17	0.88	2.46	
							Sn121m			0.11	0.63	66.37	
							Sn126						74.50
							Sn124						19.50
							Sb126m						0.57

<b>Inh</b>	<b>0</b>	<b>10<sup>-5</sup> y</b>	<b>10<sup>-2</sup> y</b>	<b>1 y</b>	<b>100 y</b>	<b>10<sup>5</sup> y</b>	<b>Clear</b>	<b>0</b>	<b>10<sup>-5</sup> y</b>	<b>10<sup>-2</sup> y</b>	<b>1 y</b>	<b>100 y</b>	<b>10<sup>5</sup> y</b>
Sv kg <sup>-1</sup>	1.03E8	7.18E7	2.31E6	7.51E5	2.27E3	9.09E-4		6.61E11	6.44E11	5.86E11	3.73E11	8.27E6	5.79E1
Sn125m	94.21	92.45					Sb125	70.85	72.78	79.77	97.72		
Sb125	0.54	0.78	24.33	58.25			Sn113	7.59	7.80	8.38	1.49		
Sn119m	0.42	0.61	19.00	24.79			Sn117m	4.68	4.81	4.38			
Sn117m	0.41	0.60	15.52				Sn125m	4.26	2.98				
Sn123	0.39	0.57	17.42	7.68			Sb124	3.54	3.64	3.83	0.09		
Sb124	0.19	0.28	8.38	0.40			Sb126m	0.87	0.75				77.97
Sn113	0.13	0.18	5.75	2.00			Sn123m	0.86	0.81				
In114m	0.10	0.15	4.48	0.09			Sb122	0.83	0.85	0.36			
Sb122	0.05	0.08	1.02				In116m	0.83	0.80				
Te125m	0.04	0.06	1.95	4.83			Sb126	0.81	0.83	0.74			18.50
Sn121	0.02	0.04	0.14		3.76		Sn126	0.81					3.17
Te123m	0.01	0.01	0.54	0.20			Sn119m	0.58	0.60	0.65	0.43		
Sn121m		0.01	0.32	0.99	94.82		Sn111	0.52	0.48				
Sn125		0.01	0.26				Sn123	0.44	0.46	0.49	0.11		
Sb126			0.21			1.35	In118m	0.43	0.19				
Cd113m			0.19	0.55	1.14		Sb120m	0.41	0.42	0.30			
Te121m			0.08				Sn121	0.22	0.22	0.02		51.65	
Sn126						84.84	In113m			0.08	0.01		
Sn124						13.74	In111			0.04			
Sb126m						0.06	Sn121m					48.25	

# Tin

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Sn125m	9.52 m	Sn124(n,γ)Sn125m	100.0	100.0	100.0	99.9	99.7	99.8	99.9
Sb126m	19.1 m	&Sn124(n,γ)Sn125m(β <sup>-</sup> )Sb125(n,γ) <i>Sb126m</i>	93.0	95.7	93.4	39.1	40.5	43.6	45.4
		&Sn124(n,γ)Sn125(β <sup>-</sup> )Sb125(n,γ) <i>Sb126m</i>	3.2	3.6	3.3	59.6	57.9	55.0	53.3
Sn113m	20.9 m	Sn112(n,γ)Sn113m	100.0	100.0	100.0				
		Sn114(n,2n)Sn113m				56.5	7.7	1.8	0.7
		Sn116(n,2n)Sn115(n,2n)Sn114(n,2n)Sn113m				33.8	0.9		
		Sn115(n,2n)Sn114(n,2n)Sn113m				6.7	0.4		
		Sn116(n,2n)Sn115(n,3n)Sn113m					26.9	6.1	0.9
		Sn116(n,3n)Sn114(n,2n)Sn113m					21.4	4.7	0.6
		Sn117(n,3n)Sn115(n,3n)Sn113m					20.5	6.0	0.5
		Sn115(n,3n)Sn113m					5.8	2.8	0.6
		Sn116(n,4n)Sn113m						43.9	44.8
		Sn118(n,4n)Sn115(n,3n)Sn113m						11.6	2.8
		Sn118(n,3n)Sn116(n,4n)Sn113m						8.6	3.0
		Sn117(n,5n)Sn113m							19.1
		Sn120(n,5n)Sn116(n,4n)Sn113m							7.3
In116m	54.6 m	&Sn112(n,γ) <i>Sn113</i> (β <sup>+</sup> )In113m(IT) In113(n,γ)In114m(n,γ) <i>In115</i> (n,γ) <i>In116m</i>	89.4	87.1	91.1				
		&Sn112(n,γ)Sn113m(β <sup>+</sup> )In113(n,γ) In114m(n,γ) <i>In115</i> (n,γ) <i>In116m</i>	2.6	2.8	3.3				
		&Sn116(n,p) <i>In116m</i>				82.6	31.9	11.9	4.1
		&Sn117(n,2n)Sn116(n,p) <i>In116m</i>				10.4	1.2	0.3	
		&Sn118(n,2n) <i>Sn117</i> (n,2n)Sn116(n,p) <i>In116m</i>				3.4			
		&Sn117(n,d) <i>In116m</i>				1.9	30.1	19.3	11.1
		&Sn118(n,2n) <i>Sn117</i> (n,d) <i>In116m</i>				1.4	8.8	2.8	0.9
		&Sn118(n,3n)Sn116(n,p) <i>In116m</i>					7.7	2.2	0.2
		&Sn118(n,t) <i>In116m</i>					7.2	41.4	42.4
		&Sn119(n,3n) <i>Sn117</i> (n,d) <i>In116m</i>					5.5	1.5	0.3
		&Sn120(n,3n)Sn118(n,t) <i>In116m</i>					1.7	5.4	2.1
		&Sn119(n,nt) <i>In116m</i>					0.4	3.5	14.4
		&Sn120(n,4n) <i>Sn117</i> (n,d) <i>In116m</i>						6.6	2.3
		&Sn120(n,2nt) <i>In116m</i>							16.4
In113m	1.658 h	&Sn112(n,γ) <i>Sn113</i> (β <sup>+</sup> )In113m	100.0	100.0	100.0				
		&Sn114(n,2n) <i>Sn113</i> (β <sup>+</sup> )In113m				60.4	8.5	2.0	0.8
		&Sn116(n,2n)Sn115(n,2n)Sn114(n,2n) <i>Sn113</i> (β <sup>+</sup> )In113m				30.2	0.8		
		&Sn115(n,2n)Sn114(n,2n) <i>Sn113</i> (β <sup>+</sup> )In113m				6.6	0.3		
		&Sn116(n,2n)Sn115(n,3n) <i>Sn113</i> (β <sup>+</sup> )In113m					25.0	5.3	0.7
		&Sn116(n,3n)Sn114(n,2n) <i>Sn113</i> (β <sup>+</sup> )In113m					21.7	4.8	0.6
		&Sn117(n,3n)Sn115(n,3n) <i>Sn113</i> (β <sup>+</sup> )In113m					19.1	5.3	0.4
		&Sn115(n,3n) <i>Sn113</i> (β <sup>+</sup> )In113m					6.0	2.7	0.6
		&Sn116(n,4n) <i>Sn113</i> (β <sup>+</sup> )In113m						44.5	43.5
		&Sn118(n,4n)Sn115(n,3n) <i>Sn113</i> (β <sup>+</sup> )In113m						10.1	2.6
		&Sn118(n,3n)Sn116(n,4n) <i>Sn113</i> (β <sup>+</sup> )In113m						7.9	2.6
&Sn117(n,5n) <i>Sn113</i> (β <sup>+</sup> )In113m							18.9		
&Sn120(n,5n)Sn116(n,4n) <i>Sn113</i> (β <sup>+</sup> )In113m							6.5		
Sn121	1.128 d	Sn120(n,γ)Sn121	97.0	93.7	99.1	1.4	4.1	1.1	1.2
		Sn119(n,γ)Sn120(n,γ)Sn121	2.9	6.3	0.8				
		&Sn122(n,2n) <i>Sn121</i>				96.9	49.7	12.4	11.3
		Sn122(n,d)In121(β <sup>-</sup> )Sn121					16.6	15.8	24.5
		Sn124(n,3n)Sn122(n,2n)Sn121					11.5	1.1	
		Sn122(n,d)In121m(β <sup>-</sup> )Sn121					4.9	3.3	4.6
		&Sn124(n,4n) <i>Sn121</i>					4.5	60.3	25.7
		Sn124(n,nt)In121(β <sup>-</sup> )Sn121					0.1	1.7	27.3
Sn124(n,nt)In121m(β <sup>-</sup> )Sn121							3.6		
Sb122	2.70 d▶	&Sn120(n,γ)Sn121(β <sup>-</sup> )Sb121(n,γ) <i>Sb122</i>	98.0	95.2	98.8				

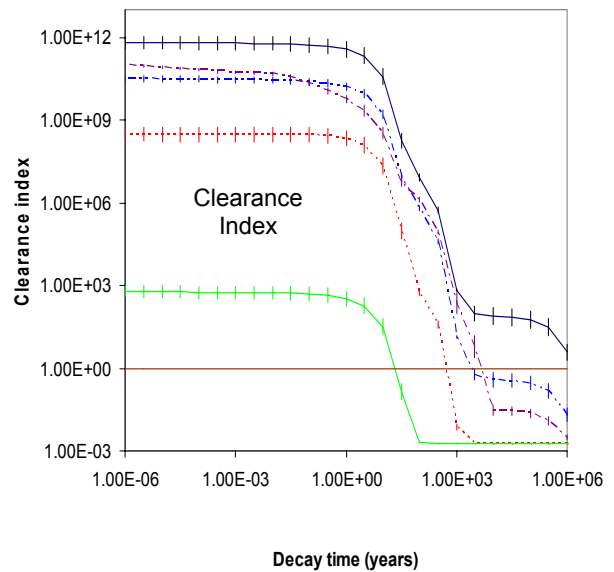
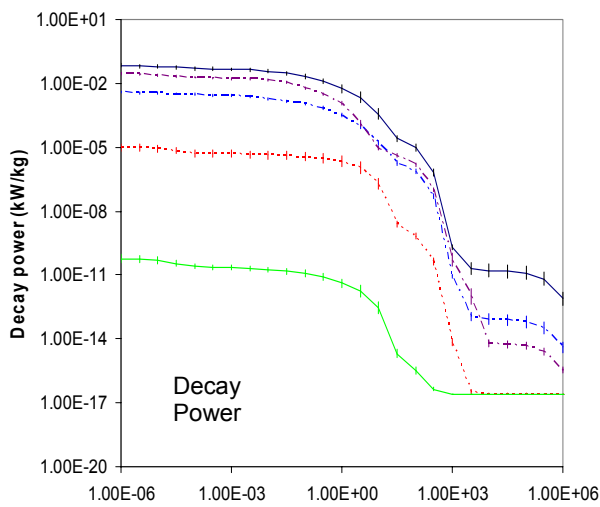
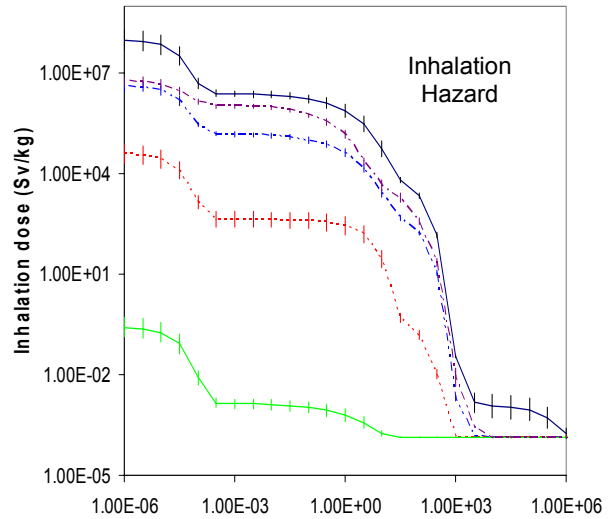
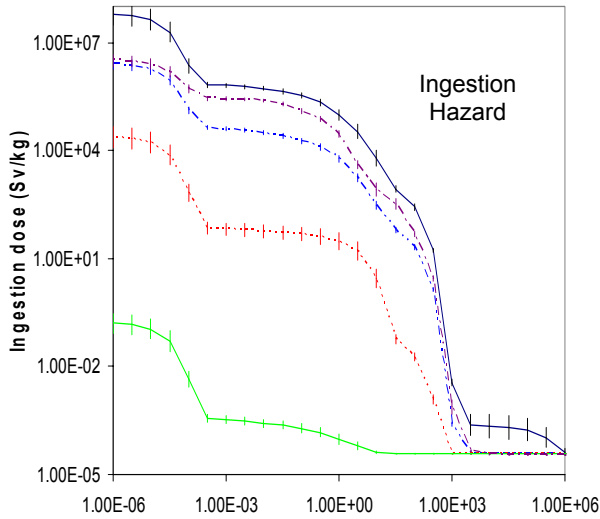
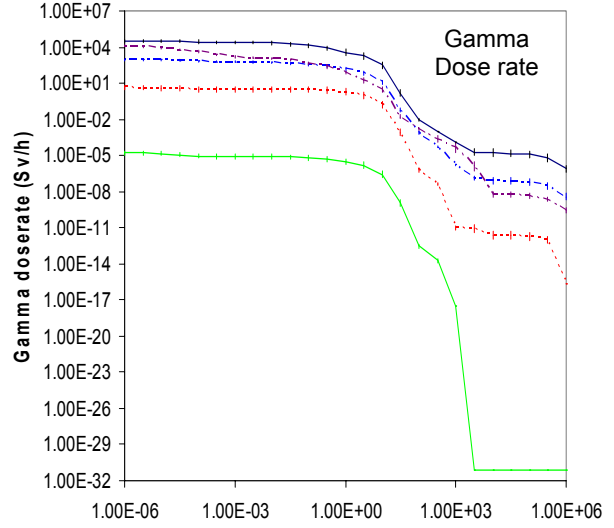
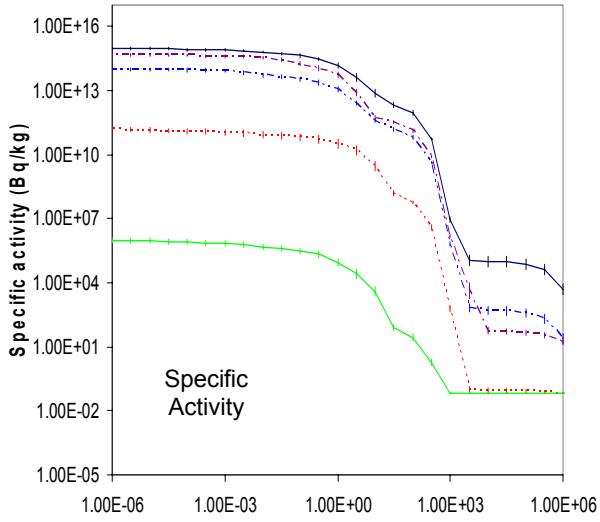
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&Sn119(n,γ)Sn120(n,γ)Sn121(β <sup>-</sup> ) <sub>-</sub> Sb121(n,γ)Sb122 &Sn124(n,2n)Sn123(β <sup>-</sup> )Sb123(n,2n)Sb122   &Sn124(n,2n)Sn123m(β <sup>-</sup> )Sb123(n,2n)Sb122   &Sn124(n,d)In123(β <sup>-</sup> )Sn123m(β <sup>-</sup> ) <sub>-</sub> Sb123(n,2n)Sb122 &Sn124(n,d)In123m(β <sup>-</sup> )Sn123m(β <sup>-</sup> ) <sub>-</sub> Sb123(n,2n)Sb122	1.5	4.7	0.4				
						66.7	76.5	67.8	62.1
						31.3	16.8	13.7	11.7
							2.4	7.4	20.6
							0.6	1.4	3.4
Sn117m	13.60 d	Sn116(n,γ)Sn117m Sn115(n,γ)Sn116(n,γ)Sn117m Sn118(n,2n)Sn117m Sn119(n,2n)Sn118(n,2n)Sn117m Sn117(n,n')Sn117m &Sn120(n,2n)Sn119(n,2n)Sn118(n,2n) <sub>-</sub> Sn117m Sn118(n,2n)Sn117(n,n')Sn117m Sn119(n,3n)Sn117m Sn120(n,3n)Sn118(n,2n)Sn117m &Sn120(n,2n)Sn119(n,3n)Sn117m Sn120(n,4n)Sn117m Sn122(n,6n)Sn117m	98.2 1.8	99.6	99.9 0.1				
						80.2	47.4	24.0	24.1
						7.3	1.2	0.4	
						4.9	2.3	1.7	1.5
						2.7			
						1.8	0.2		
							26.5	13.4	9.0
							11.5	3.3	
							6.2	1.9	
								50.2	56.6
									1.1
Sb124	60.20 d	&Sn122(n,γ)Sn123m(β <sup>-</sup> )Sb123(n,γ)Sb124   Sn122(n,γ)Sn123(β <sup>-</sup> )Sb123(n,γ)Sb124   &Sn120(n,γ)Sn121(β <sup>-</sup> )Sb121(n,γ) <sub>-</sub> Sb122(n,γ)Sb123(n,γ)Sb124 Sn119(n,γ)Sn120(n,γ)Sn121(β <sup>-</sup> )Sb121 <sub>-</sub> (n,γ)Sb122(n,γ)Sb123(n,γ)Sb124 &Sn124(n,2n)Sn123(β <sup>-</sup> )Sb123(n,γ) <sub>-</sub> Sb124 &Sn124(n,2n)Sn123m(β <sup>-</sup> )Sb123(n,γ) <sub>-</sub> Sb124 &Sn124(n,γ)Sn125(β <sup>-</sup> )Sb125(n,2n) <sub>-</sub> Sb124 &Sn124(n,γ)Sn125m(β <sup>-</sup> )Sb125(n,2n) <sub>-</sub> Sb124 &Sn124(n,d)In123(β <sup>-</sup> )Sn123m(β <sup>-</sup> ) <sub>-</sub> Sb123(n,γ)Sb124 &Sn124(n,d)In123m(β <sup>-</sup> )Sn123m(β <sup>-</sup> ) <sub>-</sub> Sb123(n,γ)Sb124	99.1 0.6 0.3	61.0 0.4 37.6	98.6 1.4				
							0.9		
						51.9	67.4	60.6	55.2
						24.8	14.9	12.4	10.4
						13.8	7.1	4.9	4.6
						9.1	4.3	4.0	3.9
							4.0	11.9	17.5
							0.9	2.2	2.9
Sn113	115.09 d	&Sn112(n,γ)Sn113 &Sn114(n,2n)Sn113 &Sn116(n,2n)Sn115(n,2n)Sn114(n,2n)Sn113   &Sn115(n,2n)Sn114(n,2n)Sn113 &Sn116(n,2n)Sn115(n,3n)Sn113 &Sn116(n,3n)Sn114(n,2n)Sn113 &Sn117(n,3n)Sn115(n,3n)Sn113 &Sn115(n,3n)Sn113 &Sn116(n,4n)Sn113 &Sn118(n,4n)Sn115(n,3n)Sn113 &Sn118(n,3n)Sn116(n,4n)Sn113 &Sn117(n,5n)Sn113 &Sn120(n,5n)Sn116(n,4n)Sn113	100.0	100.0	100.0				
						60.9	9.0	2.1	0.9
						30.5	0.8		
						6.6	0.3		
							26.2	5.6	0.8
							22.7	5.1	0.7
							19.8	5.5	0.5
							6.2	2.8	0.6
								46.6	45.8
								10.7	2.7
								8.3	2.8
									19.8
									6.8
Sn123	129.2 d	Sn122(n,γ)Sn123 Sn124(n,2n)Sn123	99.9	99.9	100.0		0.2		
						99.9	99.0	98.1	97.3
Ag110m	249.78 d	Sn112(n,α)Cd109(β <sup>+</sup> )Ag109m(IT) <sub>-</sub> Ag109(n,γ)Ag110m &Sn114(n,2n)Sn113(β <sup>+</sup> )In113m(IT) <sub>-</sub> In113(n,α)Ag110m Sn112(n,2n)Sn111(β <sup>+</sup> )In111(β <sup>+</sup> )Cd111 <sub>-</sub> (n,2n)Cd110(n,p)Ag110m Sn112(n,2n)Sn111(β <sup>+</sup> )In111(β <sup>+</sup> )Cd111 <sub>-</sub> (n,d)Ag110m	100.0	100.0	100.0	0.2			
						44.8	2.7	0.2	
						20.9	0.6		
						17.4	28.0	5.9	1.4



Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&Sn112(n,d)In111(β <sup>+</sup> )Cd111(n,d)Ag110m Sn112(n,3n)Sn110(β <sup>+</sup> )In110m(β <sup>+</sup> ) Cd110(n,p)Ag110m Sn116(n,nα)Cd112(n,t)Ag110m &Sn116(n,d)In115(n,2nα)Ag110m &Sn116(n,2nα)Cd111(n,d)Ag110m Sn118(n,3nα)Cd112(n,t)Ag110m Sn116(n,tα)Ag110m Other pathways involving (n,2n), (n,α), β <sup>+</sup>				0.8	13.1	3.7	1.1
							12.8	6.3	0.6
							1.1	4.8	1.9
							0.3	7.6	1.7
							0.2	6.3	2.2
								0.1	6.0
									6.0
						15.9	41.2	65.1	79.1
Sn119m	293.0 d	Sn118(n,γ)Sn119m Sn117(n,γ)Sn118(n,γ)Sn119m Sn116(n,γ)Sn117(n,γ)Sn118(n,γ)Sn119m Sn120(n,2n)Sn119m Sn119(n,n')Sn119m Sn120(n,2n)Sn119(n,n')Sn119m Sn122(n,4n)Sn119m Sn124(n,6n)Sn119m	98.6 1.4	99.5 0.4 0.1	98.8 1.2				
						91.5	84.0	57.0	58.3
						5.0	10.3	9.0	9.1
						1.9			
							0.2	27.1	17.2
									10.7
Sb125	2.759 y	Sn124(n,γ)Sn125m(β <sup>-</sup> )Sb125 Sn124(n,γ)Sn125(β <sup>-</sup> )Sb125 Sn122(n,γ)Sn123m(β <sup>-</sup> )Sb123(n,γ) Sb124(n,γ)Sb125	95.7 3.7 0.6	96.3 3.7	96.2 3.8	39.6 60.4	41.1 58.8	44.3 55.5	46.1 53.7
H3	12.33 y	&Sn120(n,γ)Sn121(β <sup>-</sup> )Sb121(n,γ) Sb122(n,X)H1(n,γ)H2(n,γ)H3 &Sn112(n,γ)Sn113(n,X)H1(n,γ)H2(n,γ)H3 Sn117(n,X)H3 Sn119(n,X)H3 &Sn118(n,2n)Sn117(n,X)H3 Sn116(n,2n)Sn115(n,X)H3 &Sn120(n,2n)Sn119(n,X)H3 Sn124(n,2n)Sn123(β <sup>-</sup> )Sb123(n,X)H3 &Sn122(n,2n)Sn121(β <sup>-</sup> )Sb121(n,X)H3 Sn116(n,X)H3 Sn120(n,X)H3 Sn118(n,X)H3	84.5 7.0	94.0 0.5	18.6 76.9				
						27.8	12.4	9.5	8.4
						20.1	13.1	10.2	9.2
						10.7	1.9	0.8	0.3
						8.9	1.4	0.5	0.3
						7.6	1.4	0.6	0.4
						6.6	0.3	0.1	
						5.2			
						0.1	12.6	12.9	13.1
							21.0	25.0	27.1
							18.2	20.0	21.0
Cd113m	14.1 y	Sn115(n,α)Cd112(n,γ)Cd113m &Sn112(n,γ)Sn113(n,α)Cd110(n,γ) Cd111(n,γ)Cd112(n,γ)Cd113m Sn114(n,γ)Sn115(n,α)Cd112(n,γ)Cd113m Sn116(n,α)Cd113m Sn117(n,2n)Sn116(n,α)Cd113m Sn117(n,α)Cd114(n,2n)Cd113m Sn117(n,nα)Cd113m Sn117(n,nα)Cd113m Sn118(n,3n)Sn116(n,α)Cd113m &Sn118(n,2n)Sn117(n,nα)Cd113m Sn118(n,2nα)Cd113m &Sn120(n,4n)Sn117(n,nα)Cd113m Sn119(n,3nα)Cd113m Sn120(n,4nα)Cd113m	97.8 1.0 0.8	49.7 48.4 1.2	96.6 1.4				
						84.2	51.2	17.9	12.3
						5.8	1.1	0.2	0.1
						3.6	0.3		
						3.0			
						0.4	26.4	19.1	8.7
							6.8	1.8	0.4
							4.1	1.6	0.4
							0.5	38.1	30.9
								3.5	1.0
								0.6	18.7
									12.6
Sn121m	55.0 y	Sn120(n,γ)Sn121m Sn119(n,γ)Sn120(n,γ)Sn121m Sn122(n,2n)Sn121m Sn124(n,4n)Sn121m Sn124(n,3n)Sn122(n,2n)Sn121m Sn124(n,2n)Sn123(n,3n)Sn121m Sn122(n,d)In121(β <sup>-</sup> )Sn121m	98.3 1.7	95.9 4.1	99.6 0.4	0.7	3.0		
						98.9	67.1	7.2	12.0
							13.9	90.9	82.6
							8.5		
							4.4		
							1.9		
Ag108m	418.0 y	Sn112(n,α)Cd109(β <sup>+</sup> )Ag109m(IT) Ag109(n,2n)Ag108m Sn112(n,3n)Sn110(β <sup>+</sup> )In110m(β <sup>+</sup> ) Cd110(n,t)Ag108m				88.4	12.7	0.6	0.4
							12.8	19.4	2.2

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Sn112(n,d)In111(β <sup>+</sup> )Cd111(n,3n)Cd109_ (β <sup>+</sup> )Ag109m(IT)Ag109(n,2n)Ag108m Sn112(n,pα)Ag108m Sn112(n,t)In110(β <sup>+</sup> )Cd110(n,t)Ag108m Sn112(n,t)In110m(β <sup>+</sup> )Cd110(n,t)Ag108m &Sn116(n,4n)Sn113(β <sup>+</sup> )In113m(IT)_ In113(n,2nα)Ag108m Sn116(n,3nα)Cd110(n,t)Ag108m Other pathways involving (n,2n), (n,α), β <sup>+</sup>					5.3			
							4.2	1.5	0.3	
							1.2	6.5	1.0	
							1.1	6.0	1.0	
								17.7	5.9	
								0.2	4.9	
							11.6	62.7	48.1	
Mo93	4000 y	Pathways involving (n,α), (n,nα), (n,2n), β <sup>-</sup> , β <sup>+</sup>				100.0	100.0	100.0	100.0	
Nb94	2.0 10 <sup>4</sup> y	Pathways involving (n,α), (n,nα), (n,2n), β <sup>-</sup> , β <sup>+</sup>				100.0	100.0	100.0	100.0	
Tc98	4.2 10 <sup>6</sup> y	Pathways involving (n,α), (n,nα), (n,2n), β <sup>-</sup> , β <sup>+</sup>				100.0	100.0	100.0	100.0	
Pd107	6.5 10 <sup>6</sup> y	&Sn112(n,α)Cd109(n,α)Pd106(n,γ)Pd107 Sn112(n,2n)Sn111(β <sup>+</sup> )In111(β <sup>+</sup> )Cd111_ (n,2n)Cd110(n,α)Pd107 Sn112(n,2n)Sn111(β <sup>+</sup> )In111(β <sup>+</sup> )Cd111_ (n,α)Pd108(n,2n)Pd107 &Sn112(n,2n)Sn111(β <sup>+</sup> )In111(β <sup>+</sup> )_ Cd111(n,nα)Pd107 &Sn112(n,d)In111(β <sup>+</sup> )Cd111(n,2n)_ Cd110(n,α)Pd107 &Sn112(n,d)In111(β <sup>+</sup> )Cd111(n,nα)Pd107 &Sn112(n,3n)Sn110(β <sup>+</sup> )In110m(β <sup>+</sup> )_ Cd110(n,α)Pd107 &Sn116(n,nα)Cd112(n,2nα)Pd107 &Sn116(n,2nα)Cd111(n,nα)Pd107m_ (IT)Pd107 &Sn117(n,2nα)Cd112(n,2nα)Pd107 &Sn116(n,2nα)Pd107 Sn118(n,3nα)Cd112(n,2nα)Pd107m_ (IT)Pd107 Pathways involving (n,2n), (n,α), β <sup>+</sup>	99.9	99.3	100.0		24.0	0.2		
							18.5			
							17.3	36.9	2.1	
							2.0	0.2		
							0.7	17.3	4.2	
								16.5	1.9	
								0.2	5.9	
								0.1	7.4	
									4.2	
									5.9	
									2.9	
			0.1	0.7		37.5	28.6	74.3	91.2	
Sn124	1.0 10 <sup>17</sup> y	Nuclide present in starting material	100.0	100.0	100.0	100.0	100.0	100.0	100.0	

# Tin activation characteristics

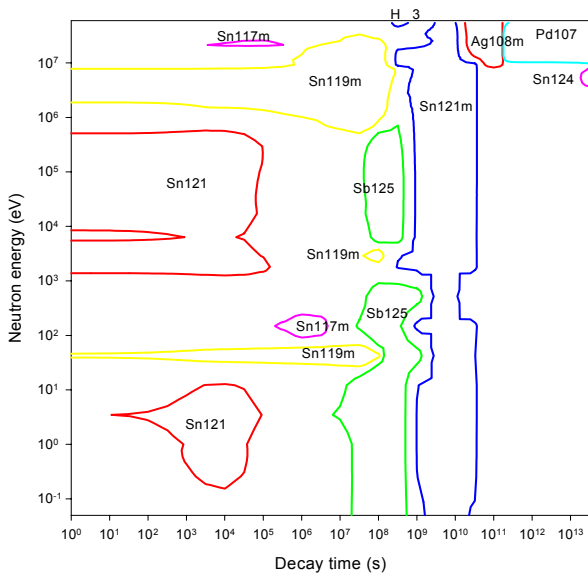


Decay time (years)

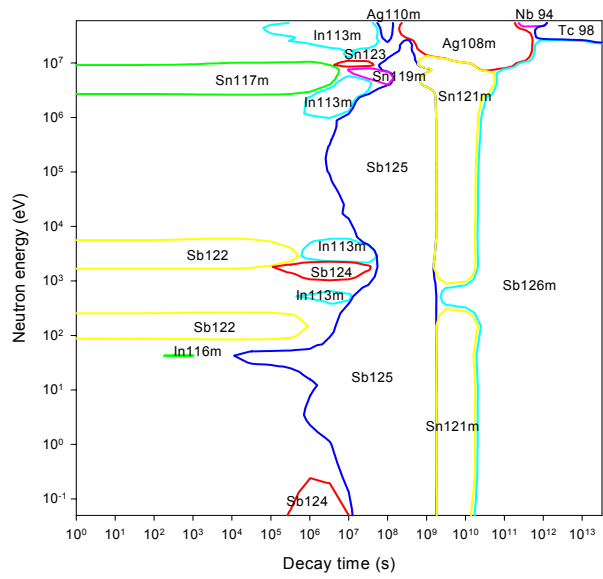
Decay time (years)

# Tin importance diagrams & transmutation

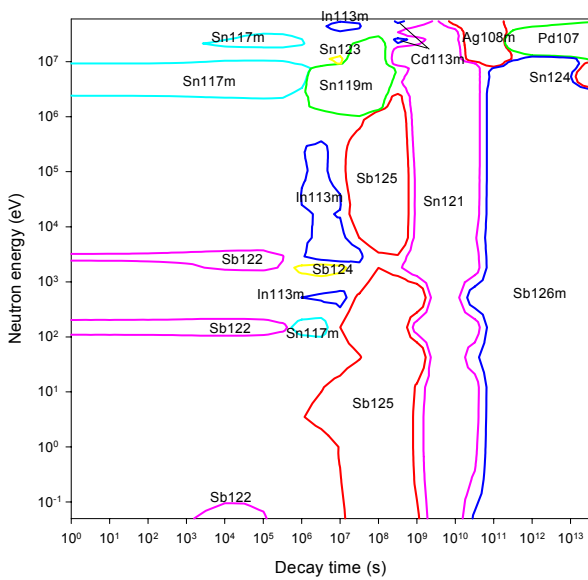
**Activity**



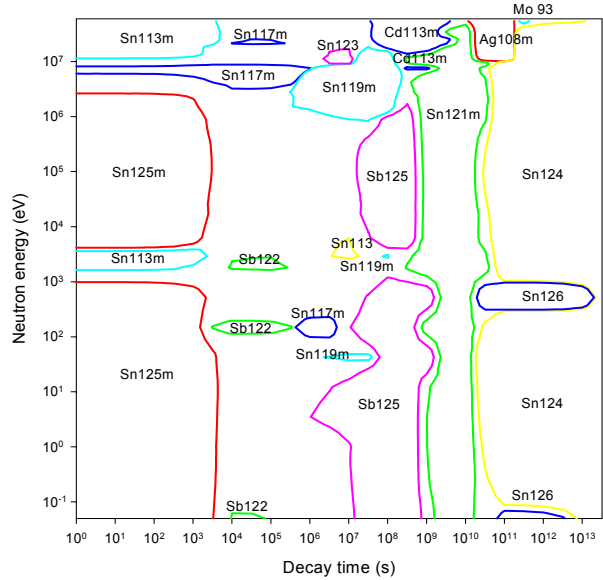
**Dose rate**



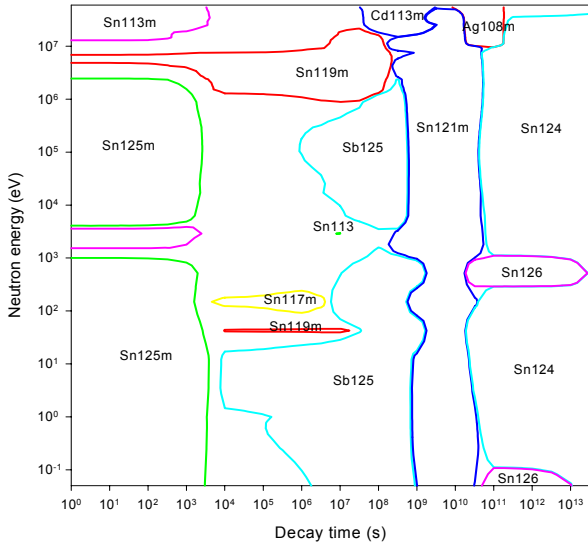
**Heat output**



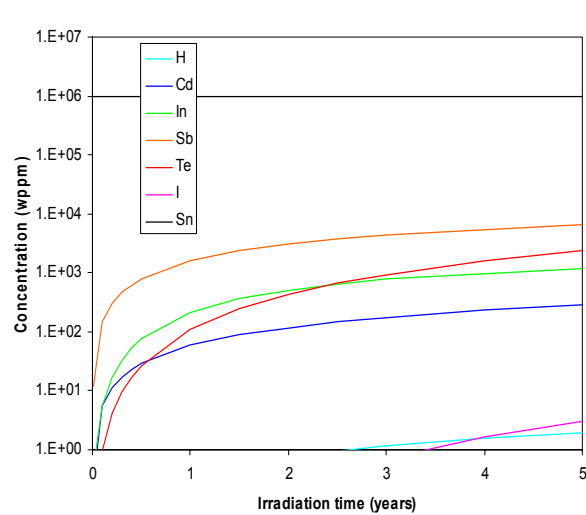
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**



# Antimony

## General properties

Atomic number	51	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	0.2	Sb121	57.21
Melting point / K	903.8	Sb123	42.79
Boiling point / K	1860		
Density / kgm <sup>-3</sup>	6691		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	24.3		
Electrical resistivity /Ωm	3.90 10 <sup>-7</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	1.1 10 <sup>-5</sup>		
Crystal structure	Rhombohedral		
Number of stable isotopes	2		
Mean atomic weight	121.76		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	1.10E16	1.06E16	6.47E15	2.56E14	9.85E10	7.99E1	kW kg <sup>-1</sup>	2.25E0	2.23E0	1.56E0	2.96E-2	1.15E-6	1.23E-14
Sb122	52.51	54.32	34.97				Sb124	51.63	52.06	71.22	58.52		
Sb124	29.47	30.51	48.05	18.92			Sb122	41.45	41.76	23.35			
Te123m	5.99	6.20	9.98	31.00			Sb120m	2.08	2.09	1.92			
Sb122m	4.13	1.79					Sb120	1.40	1.12				
Sb120	2.32	1.91					Te123m	1.15	1.16	1.62	10.47		
Te121	1.54	1.60	2.46	7.13			Te121	0.71	0.72	0.96	5.81		
Sb120m	1.05	1.09	1.16				Sb122m	0.53	0.22				
Te121m	0.85	0.88	1.42	7.04			Sb125	0.35	0.36	0.51	20.83		
Sb125	0.84	0.87	1.42	27.98			Sb124m	0.25	0.08				
Te125m	0.22	0.23	0.38	6.65			Te121m	0.20	0.20	0.28	2.90		
Sn121	0.08	0.08	0.02	0.06	43.66		Sb126m	0.11	0.10				77.41
Sn119m	0.06	0.06	0.10	1.09			Sb126	0.08	0.09	0.10			15.33
Sb126m	0.06	0.05				33.90	Te125m	0.03	0.03	0.04	1.30		
Sb126n	0.06						Sn121	0.01	0.01		0.01	68.86	
Sb126	0.03	0.04	0.05			4.75	Sn126	0.08	0.09	0.10			15.33
Sn121m				0.08	56.26		Sn121m					31.13	
Sn126						33.90	Sb126n						0.54
I129						4.75	I129						0.43
Te123						0.03							
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	2.34E6	2.33E6	1.92E6	3.42E4	1.01E-3	1.18E-8	Sv kg <sup>-1</sup>	1.94E7	1.94E7	1.30E7	3.76E5	3.10E1	5.55E-7
Sb124	73.62	73.93	86.13	75.17			Sb122	50.57	50.55	29.53			
Sb122	20.57	20.64	9.83				Sb124	41.73	41.75	59.66	32.16		
Sb120m	3.18	3.19	2.50				Te123m	4.75	4.75	6.94	29.52		
Sb120	0.91	0.73					Te121m	1.10	1.10	1.62	11.01		
Te121	0.73	0.73	0.83	5.36			Sb125	0.52	0.52	0.77	20.93		
Sb125	0.33	0.33	0.40	17.67			Te121	0.38	0.38	0.53	2.09		
Sb124m	0.26	0.08					Te125m	0.11	0.11	0.16	3.94		
Sb126	0.10	0.10	0.10			20.06	Sn121	0.01	0.01		0.01	31.96	
Sb126m	0.10	0.09				79.88	Sn121m				0.02	68.04	
Te123m	0.09	0.09	0.10	0.71			I129						75.18
Te121m	0.08	0.08	0.10	1.09			Sn126						22.92
Sn121m					100.0		Te123						0.02

<b>Inh</b>	<b>0</b>	<b>10<sup>-5</sup> y</b>	<b>10<sup>-2</sup> y</b>	<b>1 y</b>	<b>100 y</b>	<b>10<sup>5</sup> y</b>	<b>Clear</b>	<b>0</b>	<b>10<sup>-5</sup> y</b>	<b>10<sup>-2</sup> y</b>	<b>1 y</b>	<b>100 y</b>	<b>10<sup>5</sup> y</b>
Sv kg <sup>-1</sup>	3.96E7	3.96E7	3.44E7	1.87E6	2.59E2	9.09E-7		6.02E12	5.95E12	5.20E12	8.58E11	9.57E5	4.36E-1
Sb124	70.43	70.45	77.65	22.27			I129						86.98
Sb122	16.06	16.05	7.23				Sb124	53.87	54.50	59.75	5.64		
Te123m	8.49	8.50	9.56	21.64			Sb125	15.28	15.46	17.63	83.39		
Sb125	2.79	2.79	3.20	45.95			Te123m	10.95	11.08	12.41	9.24		
Te121m	1.34	1.34	1.52	5.49			Sb122	9.60	9.71	4.35			
Te125m	0.26	0.26	0.30	3.82			Sb120m	4.70	4.75	3.50			
Te121	0.18	0.18	0.19	0.40			Te121	1.66	1.68	1.80	1.25		
Sn121	0.01	0.01			3.82		Te121m	0.35	0.36	0.40	0.48		
Sn121m				0.05	96.18		Sb126m	0.19	0.16				10.17
Sn126						83.42	Sb126	0.18	0.18	0.17			2.41
I129						15.03	Sn121					51.66	
Te123						0.01	Sn121m					48.26	
							Sn126						0.41

# Antimony

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6		
Sn113m	20.9 m	&Sb121(n,α)In118m(β <sup>-</sup> )Sn118(n,2n) <sub>-</sub> <i>Sn117</i> (n,2n)Sn116(n,2n)Sn115(n,2n) <sub>-</sub> Sn114(n,2n)Sn113m				14.0					
		&Sb121(n,α)In118(β <sup>-</sup> )Sn118(n,2n) <sub>-</sub> <i>Sn117</i> (n,2n)Sn116(n,2n)Sn115(n,2n) <sub>-</sub> Sn114(n,2n)Sn113m				12.9					
		Sb121(n,α)In117(β <sup>-</sup> )Sn117(n,2n)Sn116_ (n,2n)Sn115(n,2n)Sn114(n,2n)Sn113m				10.4					
		&Sb121(n,3n)Sb119(β <sup>+</sup> )Sn119(n,3n) <sub>-</sub> <i>Sn117</i> (n,3n)Sn115(n,3n)Sn113m					62.4	1.3			
		Sb121(n,α)In117(β <sup>-</sup> )Sn117(n,3n) <sub>-</sub> Sn115(n,3n)Sn113m					13.0	1.0			
		Sb121(n,3n)Sb119(β <sup>+</sup> )Sn119(n,4n) <sub>-</sub> Sn116(n,4n)Sn113m						19.7	1.0		
		Sb121(n,4n)Sb118(β <sup>+</sup> )Sn118(n,4n) <sub>-</sub> Sn115(n,3n)Sn113m						16.3	0.6		
		Sb121(n,4n)Sb118(β <sup>+</sup> )Sn118(n,3n) <sub>-</sub> Sn116(n,4n)Sn113m						12.1	0.6		
		&Sb121(n,2nα)In116m(β <sup>-</sup> )Sn116(n,4n) <sub>-</sub> Sn113m						8.0	2.2		
		Sb121(n,4n)Sb118m(β <sup>+</sup> )Sn118(n,4n) <sub>-</sub> Sn115(n,3n)Sn113m						7.0	0.5		
		Sb121(n,4n)Sb118m(β <sup>+</sup> )Sn118(n,3n) <sub>-</sub> Sn116(n,4n)Sn113m						5.2	0.5		
		Sb121(n,5n)Sb117(β <sup>+</sup> )Sn117(n,5n)Sn113m								54.0	
		&Sb121(n,2nt) <i>Sn117</i> (n,5n)Sn113m								8.1	
		Other pathways involving (n,2n), (n,α), β <sup>+</sup>					62.7	24.6	29.4	32.5	
		In113m	1.658 h	&Sb121(n,α)In117(β <sup>-</sup> )Sn117(n,2n) <sub>-</sub> Sn116(n,2n)Sn115(n,2n)Sn114(n,2n) <sub>-</sub> <i>Sn113</i> (β <sup>+</sup> )In113m				11.1			
				&Sb121(n,3n)Sb119(β <sup>+</sup> )Sn119(n,3n) <sub>-</sub> <i>Sn117</i> (n,3n)Sn115(n,3n) <i>Sn113</i> (β <sup>+</sup> )In113m					23.4	0.2	
				&Sb121(n,α)In117(β <sup>-</sup> )Sn117(n,3n) <sub>-</sub> Sn115(n,3n) <i>Sn113</i> (β <sup>+</sup> )In113m					13.3		
&Sb121(n,3n)Sb119(β <sup>+</sup> )Sn119(n,4n) <sub>-</sub> Sn116(n,4n) <i>Sn113</i> (β <sup>+</sup> )In113m								19.2	0.9		
&Sb121(n,4n)Sb118(β <sup>+</sup> )Sn118(n,4n) <sub>-</sub> Sn115(n,3n) <i>Sn113</i> (β <sup>+</sup> )In113m								15.1	0.5		
&Sb121(n,4n)Sb118(β <sup>+</sup> )Sn118(n,3n) <sub>-</sub> Sn116(n,4n) <i>Sn113</i> (β <sup>+</sup> )In113m								11.8	0.5		
&Sb121(n,2nα)In116m(β <sup>-</sup> )Sn116(n,4n) <sub>-</sub> <i>Sn113</i> (β <sup>+</sup> )In113m								8.5			
&Sb121(n,4n)Sb118m(β <sup>+</sup> )Sn118(n,4n) <sub>-</sub> Sn115(n,3n) <i>Sn113</i> (β <sup>+</sup> )In113m								6.4	0.4		
&Sb121(n,4n)Sb118m(β <sup>+</sup> )Sn118(n,3n) <sub>-</sub> Sn116(n,4n) <i>Sn113</i> (β <sup>+</sup> )In113m								5.0	0.4		
&Sb121(n,5n)Sb117(β <sup>+</sup> )Sn117(n,5n) <sub>-</sub> <i>Sn113</i> (β <sup>+</sup> )In113m										52.9	
&Sb121(n,2nt) <i>Sn117</i> (n,5n) <i>Sn113</i> (β <sup>+</sup> )In113m										7.9	
Other pathways involving (n,2n), (n,α), β <sup>+</sup>							88.9	63.3	33.8	36.5	
Sn121	1.128 d			&Sb121(n,γ)Sb122(β <sup>-</sup> )Te122(n,γ) <sub>-</sub> Te123m(n,α)Sn120(n,γ)Sn121	83.8	83.5	42.3				
		&Sb121(n,γ)Sb122(β <sup>-</sup> )Te122(n,γ) <sub>-</sub> <i>Te123</i> (n,α)Sn120(n,γ)Sn121	6.7	7.3	32.4						
		&Sb123(n,γ)Sb124(β <sup>-</sup> )Te124(n,α) <i>Sn121</i>	1.8		24.8						

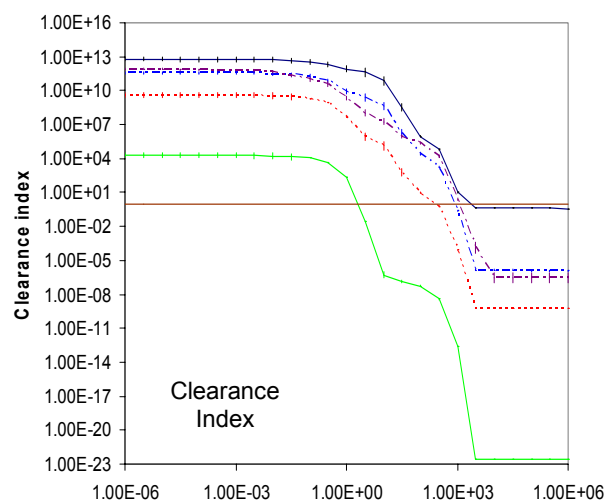
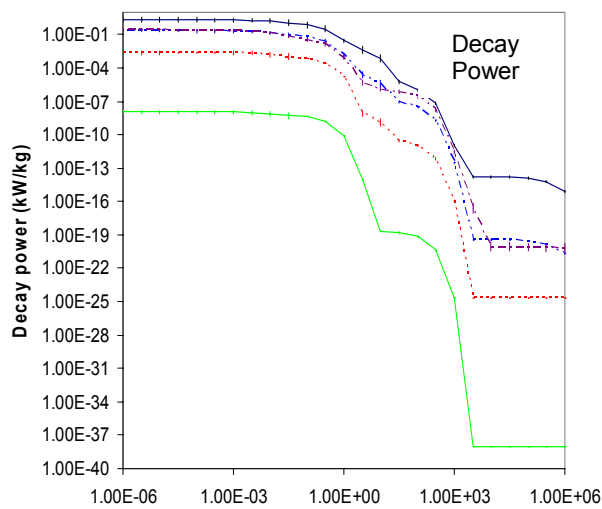
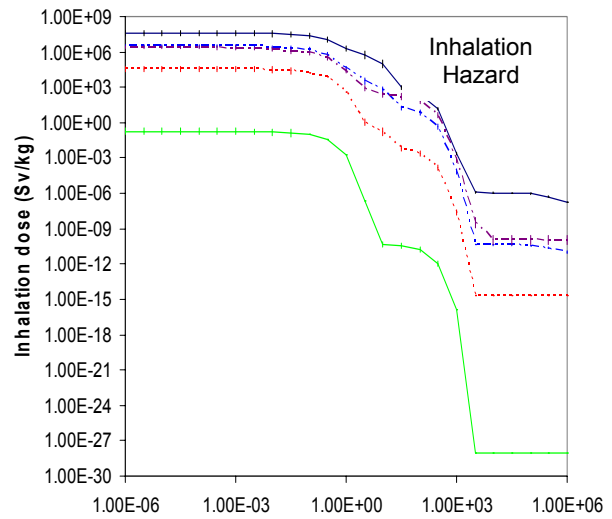
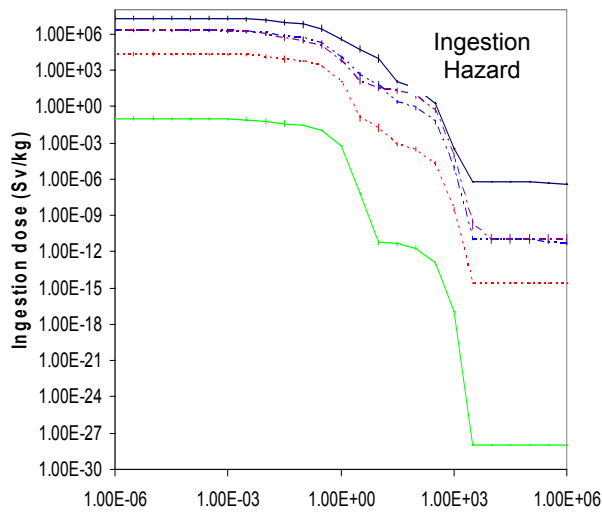
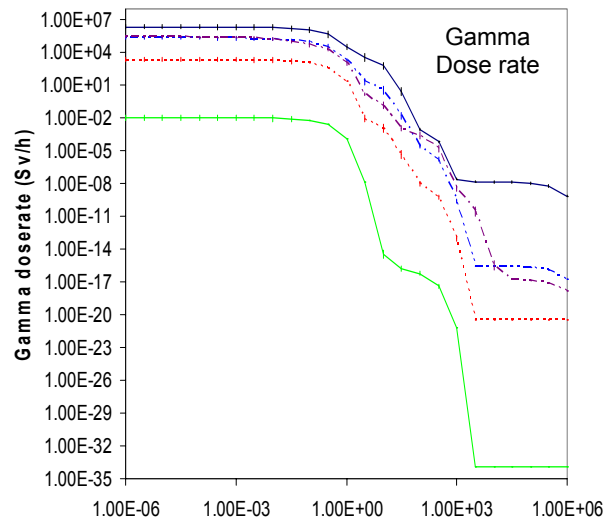
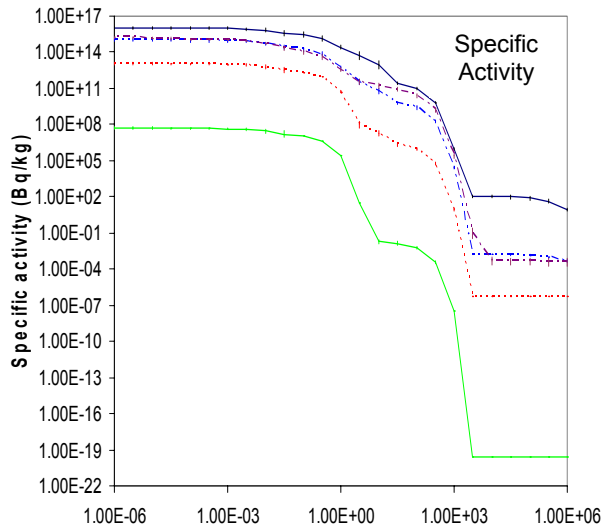
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&Sb121(n,γ)Sb122(β <sup>-</sup> )Te122(n,γ) Te123(n,γ)Te124(n,α)Sn121 &Sb121(n,p)Sn121 &Sb123(n,2n)Sb122(β <sup>+</sup> )Sn122(n,2n)Sn121 &Sb123(n,2n)Sb122m(IT)Sb122(β <sup>+</sup> ) Sn122(n,2n)Sn121 &Sb123(n,d)Sn122(n,2n)Sn121 Sb121(n,2n)Sb120(β <sup>+</sup> )Sn120(n,γ)Sn121 Sb121(n,2n)Sb120m(β <sup>+</sup> )Sn120(n,γ)Sn121 &Sb123(n,t)Sn121 &Sb123(n,3n)Sb121(n,p)Sn121 Sb123(n,d)Sn122(n,d)In121(β <sup>-</sup> )Sn121 Sb123(n,h)In121(β <sup>-</sup> )Sn121	0.2			40.8 30.5 14.4	31.2 0.6 1.2	8.0 2.0	2.6 90.4 2.4
Sb119	1.596 d	Sb121(n,2n)Sb120m(n,2n)Sb119 &Sb123(n,2n)Sb122(β <sup>-</sup> )Te122(n,2n) Te121m(n,2n)Te120(n,2n)Te119(β <sup>+</sup> )Sb119 &Sb123(n,2n)Sb122(β <sup>-</sup> )Te122(n,2n) Te121m(n,2n)Te120(n,2n)Te119m(β <sup>+</sup> )Sb119 &Sb123(n,2n)Sb122(β <sup>-</sup> )Te122(n,2n) Te121(n,2n)Te120(n,2n)Te119(β <sup>+</sup> )Sb119 &Sb123(n,2n)Sb122(β <sup>-</sup> )Te122(n,2n)Te121 (n,2n)Te120(n,2n)Te119m(β <sup>+</sup> )Sb119 Sb121(n,3n)Sb119 Sb123(n,3n)Sb121(n,3n)Sb119 Sb123(n,5n)Sb119				57.5 19.0 17.1 2.7 2.4		87.5 91.5 38.9	91.5 6.7 58.2
Sb122	2.70 d	&Sb121(n,γ)Sb122 &Sb123(n,2n)Sb122	100.0	100.0	100.0	0.2 99.8	0.4 99.6	100.0	100.0
Sb120m	5.76 d	Sb121(n,2n)Sb120m Sb123(n,2n)Sb122(β <sup>-</sup> )Te122(n,2n) Te121(β <sup>+</sup> )Sb121(n,2n)Sb120m Sb123(n,3n)Sb121(n,2n)Sb120m Sb123(n,4n)Sb120m				98.1 0.6	87.7 11.9	51.5 3.7 44.2	58.1 39.6
Te121	19.16 d	&Sb123(n,2n)Sb122(β <sup>-</sup> )Te122(n,2n)Te121				99.6	99.3	98.9	98.8
Sb124	60.20 d	&Sb123(n,γ)Sb124 Sb121(n,γ)Sb122(n,γ)Sb123(n,γ)Sb124	99.8 0.1	98.7 1.2	100.0	99.7	99.6	99.6	94.6
Te123m	119.5 d	&Sb121(n,γ)Sb122(β <sup>-</sup> )Te122(n,γ)Te123m &Sb123(n,2n)Sb122(β <sup>-</sup> )Te122(n,γ)Te123m &Sb123(n,γ)Sb124(β <sup>-</sup> )Te124(n,2n)Te123m &Sb123(n,γ)Sb124m(β <sup>-</sup> )Te124(n,2n)Te123m	99.9	100.0	100.0	47.9 42.8 7.0	32.2 56.8 9.6	35.1 54.5 9.1	33.1 56.6 9.4
Sn123	129.2 d	&Sb121(n,γ)Sb122(β <sup>+</sup> )Sn122(n,γ)Sn123 Sb123(n,p)Sn123 Sb123(n,2n)Sb122(β <sup>+</sup> )Sn122(n,γ)Sn123	99.9	100.0	100.0	99.8 0.1	99.8	99.8	99.8
Te121m	154.0 d	&Sb123(n,2n)Sb122(β <sup>-</sup> )Te122(n,2n)Te121m Sb121(n,γ)Sb122(β <sup>-</sup> )Te122(n,2n)Te121m				99.7 0.2	99.3 0.4	98.8	98.8
Ag110m	249.78 d	Pathways involving (n,α), (n,nα), (n,2n), β <sup>-</sup> , β <sup>+</sup>				100.0	100.0	100.0	100.0
Sn119m	293.0 d	&Sb121(n,γ)Sb122(β <sup>-</sup> )Te122(n,α)Sn119m Sb121(n,2n)Sb120(β <sup>+</sup> )Sn120(n,2n)Sn119m Sb121(n,2n)Sb120m(β <sup>+</sup> )Sn120(n,2n)Sn119m Sb121(n,d)Sn120(n,2n)Sn119m Sb121(n,t)Sn119m Sb121(n,3n)Sb119(β <sup>+</sup> )Sn119(n,n')Sn119m Sb123(n,3n)Sb121(n,t)Sn119m Sb123(n,4n)Sb120(β <sup>+</sup> )Sn120(n,2n)Sn119m Sb123(n,d)Sn122(n,4n)Sn119m Sb123(n,2nt)Sn119m	99.9	99.9	100.0	65.6 31.1 0.7	14.4 11.4 4.5 32.6	3.0 2.4 1.8 66.1 6.7	1.1 1.5 1.5 1.2 19.6
Sb125	2.759 y	&Sb123(n,γ)Sb124(n,γ)Sb125 Sb121(n,γ)Sb122(n,γ)Sb123(n,γ)Sb124 (n,γ)Sb125	99.9	98.9 1.0	100.0	99.6	99.5	99.5	99.7
H3	12.33 y ▶	&Sb121(n,γ)Sb122(n,X)H1(n,γ)H2(n,γ)H3 Sb121(n,X)H3 Sb123(n,X)H3	93.3	94.5	99.3	70.6 27.9	54.8 35.9	53.6 37.2	52.6 37.6



Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Sb123(n,3n)Sb121(n,X)H3 Sb121(n,3n)Sb119(β <sup>+</sup> )Sn119(n,X)H3 Sb121(n,5n)Sb117(β <sup>+</sup> )Sn117(n,X)H3 Sb123(n,5n)Sb119(β <sup>+</sup> )Sn119(n,X)H3					3.7 3.0	2.0 2.1	1.3 1.3	
Cd113m	14.1 y	&Sb121(n,α)In118m(β <sup>-</sup> )Sn118(n,2n) Sn117(n,2n)Sn116(n,α)Cd113m &Sb121(n,α)In118(β <sup>-</sup> )Sn118(n,2n) Sn117(n,2n)Sn116(n,α)Cd113m &Sb121(n,2n)Sb120(β <sup>+</sup> )Sn120(n,2n) Sn119(n,2n)Sn118(n,2n)Sn117(n,2n) Sn116(n,α)Cd113m &Sb121(n,α)In118m(β <sup>-</sup> )Sn118(n,2n) Sn117(n,α)Cd114(n,2n)Cd113m Sb121(n,α)In117(β <sup>-</sup> )Sn117(n,2n) Sn116(n,α)Cd113m &Sb121(n,α)In118(β <sup>-</sup> )Sn118(n,2n) Sn117(n,α)Cd114(n,2n)Cd113m Sb121(n,α)In117(β <sup>-</sup> )Sn117(n,α)Cd113m &Sb121(n,3n)Sb119(β <sup>+</sup> )Sn119(n,3n) Sn117(n,α)Cd113m Sb121(n,4n)Sb118(β <sup>+</sup> )Sn118(n,2n)Cd113m Sb121(n,4n)Sb118m(β <sup>+</sup> )Sn118(n,2n)Cd113m Sb121(n,3n)Sb119(β <sup>+</sup> )Sn119(n,3n)Cd113m &Sb121(n,3n)Sn115(n,t)Cd113m Sb123(n,5n)Sb119(β <sup>+</sup> )Sn119(n,3n)Cd113m Sb121(n,5n)Sb117(β <sup>+</sup> )Sn117(n,α)Cd113m Other pathways involving (n,2n), (n,α), β <sup>+</sup>					11.0 10.1 7.7 6.8 6.4 6.4 0.7 60.6 37.3 15.9 3.3 0.7 22.1 12.0 50.9	0.3 0.3 2.2 3.0 37.3 15.9 3.3 0.7 22.1 12.0 37.6	0.3 6.5 5.2 14.7 6.2 22.1 12.0 33.0	
Sn121m	55.0 y	&Sb121(n,γ)Sb122(β <sup>-</sup> )Te122(n,γ) Te123m(n,α)Sn120(n,γ)Sn121m &Sb123(n,γ)Sb124(β <sup>-</sup> )Te124(n,α)Sn121m &Sb121(n,γ)Sb122(β <sup>-</sup> )Te122(n,γ) Te123(n,α)Sn120(n,γ)Sn121m Sb121(n,γ)Sb122(β <sup>-</sup> )Te122(n,γ) Te123(n,γ)Te124(n,α)Sn121m &Sb121(n,γ)Sb122(β <sup>-</sup> )Te122(n,α) Sn119(n,γ)Sn120(n,γ)Sn121m Sb121(n,p)Sn121m &Sb123(n,2n)Sb122(β <sup>+</sup> )Sn122(n,2n)Sn121m Sb123(n,d)Sn122(n,2n)Sn121m Sb121(n,2n)Sb120(β <sup>+</sup> )Sn120(n,γ)Sn121m Sb123(n,t)Sn121m Sb123(n,3n)Sb121(n,p)Sn121m	62.3 24.7 5.0 1.6 0.2	84.1 7.1 0.8	61.8 36.1 1.9					
Ag108m	418.0 y	Pathways involving (n,2n), (n,α), β <sup>-</sup>				100.0	100.0	100.0	100.0	
Mo93	4000 y	Pathways involving (n,α), (n,nα), (n,2n), β <sup>-</sup> , β <sup>+</sup>				100.0	100.0	100.0	100.0	
Nb94	2.0 10 <sup>4</sup> y	Pathways involving (n,α), (n,nα), (n,2n), β <sup>-</sup> , β <sup>+</sup>				100.0	100.0	100.0	100.0	
Sn126	2.3 10 <sup>5</sup> y	&Sb121(n,γ)Sb122(β <sup>+</sup> )Sn122(n,γ) Sn123(n,γ)Sn124(n,γ)Sn125(n,γ)Sn126 &Sb123(n,γ)Sb124(n,p)Sn124(n,γ) Sn125(n,γ)Sn126 Sb123(n,p)Sn123(n,γ)Sn124(n,γ)Sn125 (n,γ)Sn126 &Sb123(n,γ)Sb124(n,γ)Sb125(n,p) Sn125(n,γ)Sn126 &Sb123(n,γ)Sb124(n,γ)Sb125(n,γ) Sb126(n,p)Sn126	95.9 1.1	89.7 7.3	96.9	14.9 50.5 21.9 7.7	8.3 31.7 42.6 9.3	7.6 30.3 43.3 10.7	6.7 30.9 42.7 11.6	
Tc98	4.2 10 <sup>6</sup> y	Pathways involving (n,α), (n,nα), (n,2n), β <sup>-</sup> , β <sup>+</sup>				100.0	100.0	100.0	100.0	
Pd107	6.5 10 <sup>6</sup> y	Pathways involving (n,α), (n,nα), (n,2n), β <sup>-</sup> , β <sup>+</sup>				100.0	100.0	100.0	100.0	
I129	1.6 10 <sup>7</sup> y ▶	&Sb123(n,γ)Sb124(β <sup>-</sup> )Te124(n,γ) Te125(n,γ)Te126(n,γ)Te127m(n,γ) Te128(n,γ)Te129(β <sup>-</sup> )I129	42.2	1.2	14.8					

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	&Sb123(n,γ)Sb124(β <sup>-</sup> )Te124(n,γ) Te125(n,γ)Te126(n,γ)Te127(n,γ) Te128(n,γ)Te129(β <sup>-</sup> )I129 &Sb123(n,γ)Sb124(n,γ)Sb125(β <sup>-</sup> ) Te125(n,γ)Te126(n,γ)Te127m(n,γ) Te128(n,γ)Te129(β <sup>-</sup> )I129 &Sb123(n,γ)Sb124(n,γ)Sb125(n,γ) Sb126m(β <sup>-</sup> )Te126(n,γ)Te127m(n,γ) Te128(n,γ)Te129(β <sup>-</sup> )I129 &Sb123(n,γ)Sb124(n,γ)Sb125(n,γ) Sb126(β <sup>-</sup> )Te126(n,γ)Te127m(n,γ) Te128(n,γ)Te129(β <sup>-</sup> )I129 &Sb123(n,γ)Sb124(n,γ)Sb125(β <sup>-</sup> ) Te125(n,γ)Te126(n,γ)Te127(n,γ)Te128 (n,γ)Te129(β <sup>-</sup> )I129 &Sb123(n,γ)Sb124(n,γ)Sb125(n,γ) Sb126(β <sup>-</sup> )Te126(n,γ)Te127(n,γ)Te128 (n,γ)Te129(β <sup>-</sup> )I129 &Sb123(n,γ)Sb124(n,γ)Sb125(n,γ) Sb126(n,γ)Sb127(β <sup>-</sup> )Te127m(n,γ) Te128(n,γ)Te129(β <sup>-</sup> )I129 &Sb123(n,γ)Sb124(n,γ)Sb125(n,γ) Sb126(n,γ)Sb127(n,γ)Sb128(n,γ)Sb29 (β <sup>-</sup> )Te129(β <sup>-</sup> )I129 &Sb123(n,γ)Sb124(n,γ)Sb125(n,γ) Sb126(n,γ)Sb127(n,γ)Sb128(β <sup>-</sup> )Te128 (n,γ)Te129(β <sup>-</sup> )I129 Other pathways	16.3		0.2					
			4.8	1.4	4.8					
			4.4	0.7	1.0					
			4.1	2.6	5.1					
			2.1							
			1.6							
			1.0	21.6	1.2					
				10.2	0.1					
				4.0	0.1					
			23.5	58.3	72.7					
In115	4.4 10 <sup>14</sup> y	&Sb121(n,2n)Sb120(β <sup>+</sup> )Sn120(n,2n) Sn119(n,α)Cd116(n,2n)Cd115(β <sup>-</sup> ) In115m(IT)In115 &Sb121(n,2n)Sb120(β <sup>+</sup> )Sn120(n,2n) Sn119(n,α)Cd116(n,2n)Cd115m(β <sup>-</sup> )In115 &Sb121(n,2n)Sb120(β <sup>+</sup> )Sn120(n,2n) Sn119(n,2n)Sn118(n,α)Cd115(β <sup>-</sup> ) In115m(IT)In115 Sb121(n,3n)Sb119(β <sup>+</sup> )Sn119(n,nα) Cd115(β <sup>-</sup> )In115m(IT)In115 Sb121(n,3n)Sb119(β <sup>+</sup> )Sn119(n,nα) Cd115m(β <sup>-</sup> )In115 &Sb121(n,3nα)In115 &Sb121(n,4n)Sb118(β <sup>+</sup> )Sn118(n,nt)In115 &Sb121(n,5n)Sb117(β <sup>+</sup> )Sn117(n,t)In115 Other pathways involving (n,2n), (n,α), β <sup>+</sup>				18.0				
						16.3				
						7.9				
							45.2	11.8	0.3	
							30.7	5.7	0.1	
								23.0	64.5	
								6.5	3.9	
									8.3	
							57.8	24.1	53.0	
									22.9	
Te123	9.2 10 <sup>16</sup> y	&Sb121(n,γ)Sb122(β <sup>-</sup> )Te122(n,γ)Te123 &Sb123(n,2n)Sb122(β <sup>-</sup> )Te122(n,γ)Te123 &Sb123(n,γ)Sb124(β <sup>-</sup> )Te124(n,2n)Te123 &Sb123(n,γ)Sb124m(β <sup>-</sup> )Te124(n,2n)Te123	100.0	99.9	100.0		0.1	0.1	0.2	
						59.7	49.9	52.3	57.5	
						33.9	42.1	40.1	37.3	
						5.8	7.4	7.2	6.2	
Sn124	1.0 10 <sup>17</sup> y	&Sb121(n,γ)Sb122(β <sup>+</sup> )Sn122(n,γ) Sn123(n,γ)Sn124 &Sb123(n,γ)Sb124(n,p)Sn124 Sb123(n,p)Sn123(n,γ)Sn124	99.3	94.3	100.0					
			0.7	5.6		22.8	20.7	19.9	17.9	
						77.1	79.0	79.8	81.8	

# Antimony activation characteristics

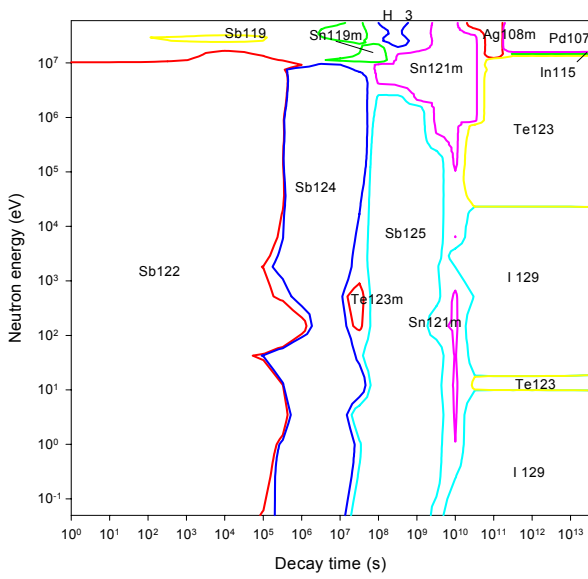


Decay time (years)

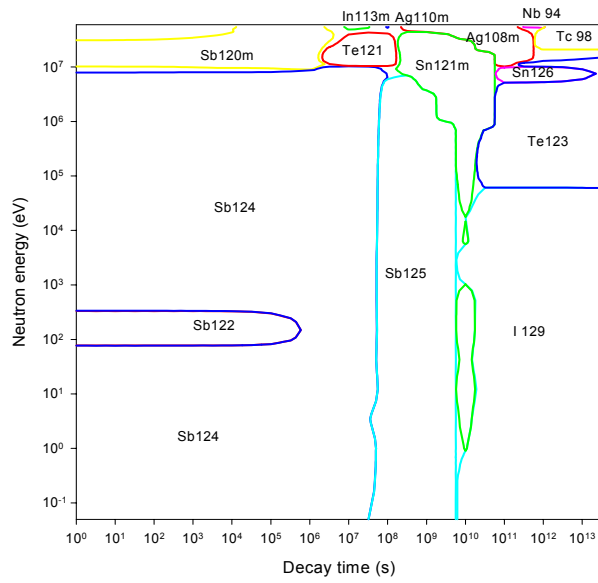
Decay time (years)

# Antimony importance diagrams & transmutation

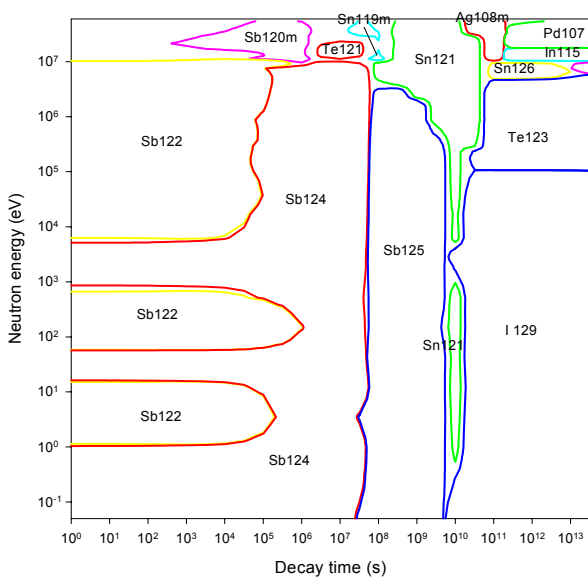
**Activity**



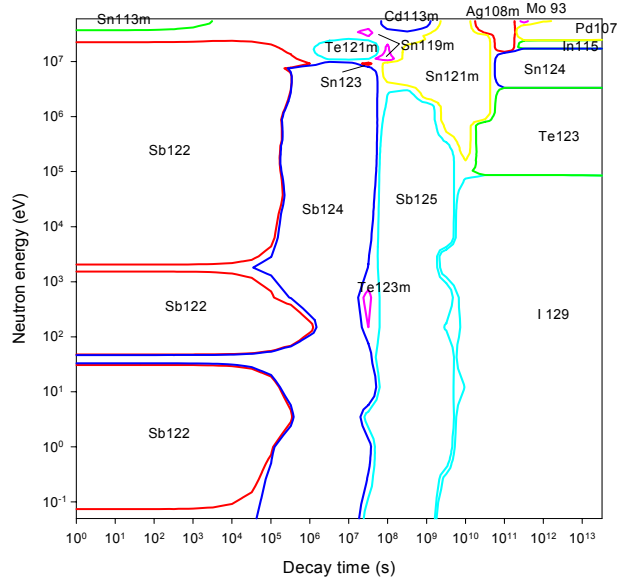
**Dose rate**



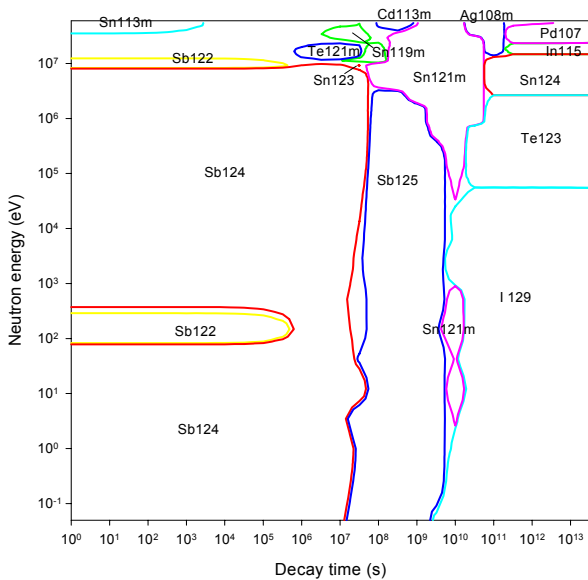
**Heat output**



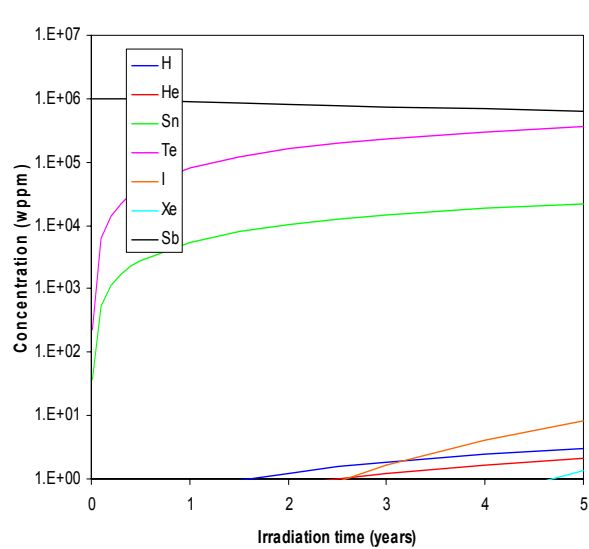
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**



# Tellurium

## General properties

Atomic number	52	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	1.0 10 <sup>-3</sup>	Te120	0.09
Melting point / K	722.7	Te122	2.55
Boiling point / K	1261	Te123	0.89 (T <sub>½</sub> = 9.92 10 <sup>16</sup> y)
Density / kgm <sup>-3</sup>	6240	Te124	4.74
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	2.35	Te125	7.07
Electrical resistivity /Ωm	4.36 10 <sup>-3</sup>	Te126	18.84
Coefficient of thermal expansion / K <sup>-1</sup>	16.75 10 <sup>-6</sup>	Te128	31.74 (T <sub>½</sub> = 2.20 10 <sup>24</sup> y)
Crystal structure	Hexagonal	Te130	34.08 (T <sub>½</sub> = 7.90 10 <sup>23</sup> y)
Number of stable isotopes	5 (8)		
Mean atomic weight	127.60		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	2.45E15	2.36E15	1.15E15	5.92E13	1.57E9	1.07E8	kW kg <sup>-1</sup>	1.81E-1	1.72E-1	5.12E-2	1.83E-3	1.85E-8	1.50E-9
Te127	27.46	28.33	18.56	36.03			I128	26.05	23.76				
Te129	17.96	18.02	13.37	0.15			Te129	23.49	24.00	29.12	0.47		
I128	14.59	13.07					I130	15.08	15.87	0.40			
Te129m	10.73	11.12	21.20	0.24			Te127	13.61	14.30	15.31	42.69		
Te127m	9.07	9.40	18.88	36.79			Te129m	6.97	7.36	22.94	0.37		
Te125m	7.25	7.52	14.78	3.75			Te131	2.32	2.13				
Te123m	3.36	3.49	7.02	16.73			Te125m	2.20	2.32	7.48	2.72		
I130	2.89	2.99	0.05				Te127m	1.84	1.94	6.37	17.82		
I130m	1.88	1.30					Te123m	1.77	1.87	6.15	21.08		
I131	1.03	1.07	1.64				I131	1.28	1.35	3.39			
Te131	0.91	0.82					I130m	1.26	0.89				
I126	0.67	0.70	1.18				I126	0.84	0.89	2.46			
Te121	0.65	0.67	1.29	2.89			Te121	0.82	0.87	2.73	8.78		
Te121m	0.36	0.37	0.75	2.86			Sb122	0.71	0.75	0.99			
Xe127	0.31	0.33	0.62	0.01			Te121m	0.23	0.24	0.80	4.39		
Sn121m				0.01	52.09		Sb125			0.06	1.22		
Sn121					40.43		Sn121					63.24	
I129					6.87	99.98	Sn121m					28.59	
H3					0.61		I129					8.10	99.83
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	5.79E4	5.62E4	9.03E3	2.92E2	2.57E-5	9.53E-6	Sv kg <sup>-1</sup>	1.60E7	1.59E7	1.40E7	8.54E4	1.23E1	1.18E1
I130	58.01	59.66	2.75				Xe127	67.41	67.65	71.52	12.01		
I128	9.84	8.77					Xe129m	8.50	8.53	7.27			
Te129	8.58	8.56	19.22	0.34			Te129m	4.94	4.96	5.21	0.49		
Te131	3.23	2.90					I131	3.48	3.49	2.96			
Te129m	3.15	3.25	18.75	0.34			Te127m	3.20	3.21	3.56	58.62		
Te121	2.78	2.87	16.72	59.85			I126	2.99	3.00	2.80			
Te131m	2.39	2.46	2.02				Te125m	0.97	0.97	1.05	2.26		
I126	2.36	2.44	12.47				I130	0.89	0.89	0.01			
I131	2.28	2.35	10.94				Te123m	0.72	0.73	0.81	16.23		
I130m	1.78	1.23					Te127	0.72	0.72	0.26	4.24		
Sb122	1.17	1.20	2.94				Te129	0.17	0.17	0.07	0.01		
Te127	0.96*	0.98*	1.95*	6.04*			Te121m	0.13	0.13	0.14	4.55		
Sb124	0.44	0.46	2.71	1.31			I128	0.10	0.09				
Te123m	0.43	0.44	2.67	10.18			Sb122	0.09	0.09	0.04			
Te121m	0.31	0.32	1.98	12.04			Te121			0.05	0.86		
Sb126m	0.28	0.24			10.75	21.48	Te131m			0.01			
Xe127	0.25	0.26	1.51	0.05			Sb125				0.34		
Sb126			0.80		2.70	5.40	Cs134				0.29		
Sb125			0.32	7.66			I129				0.01	96.29	100.0
Cs134				1.66			Sn121m					2.52	
Sn121m					56.98		Sn121					1.19	
I129					27.20	73.11							
Ba133					1.80								

<b>Inh</b>	<b>0</b>	<b>10<sup>-5</sup> y</b>	<b>10<sup>-2</sup> y</b>	<b>1 y</b>	<b>100 y</b>	<b>10<sup>5</sup> y</b>	<b>Clear</b>	<b>0</b>	<b>10<sup>-5</sup> y</b>	<b>10<sup>-2</sup> y</b>	<b>1 y</b>	<b>100 y</b>	<b>10<sup>5</sup> y</b>
Sv kg <sup>-1</sup>	5.26E7	5.25E7	4.84E7	3.33E5	7.71E0	3.87E0		2.36E11	2.24E11	1.50E11	1.63E10	1.08E7	1.07E7
Xe127	83.28	83.42	84.39	12.54			Te123m	34.96	36.68	53.75	60.88		
Te127m	4.14	4.15	4.39	64.06			I128	24.46	22.18				
Te129m	3.95	3.95	3.98	0.33			Te129m	11.15	11.70	16.24	0.09		
Xe129m	2.97	2.97	2.42				Te127m	9.43	9.89	14.46	13.39		
Xe131m	1.70	1.70	1.58				Te121	3.96	4.15	5.82	6.19		
Te125m	1.42	1.42	1.47	2.80			I130	3.00	3.14	0.04			
Te123m	0.80	0.80	0.85	15.16			I130m	2.72	1.90				
I131	0.36	0.36	0.29				Te129	1.87	1.90	1.02	0.01		
I126	0.31	0.31	0.27				Sb125	1.42	1.49	2.22	15.99		
Te127	0.18	0.18	0.06	0.90			I131	1.07	1.13	1.26			
Te121m	0.10	0.10	0.10	2.89			Xe127	0.93	0.98	1.37	0.01		
I130	0.09	0.09					Te121m	0.84	0.89	1.30	2.36		
Te129	0.03	0.03	0.01				I126	0.70	0.73	0.90			
Sb122	0.02	0.02	0.01				Sb122	0.34	0.36	0.21			
I128	0.01						Te127	0.29	0.30	0.14	0.13		
Te121		0.01	0.01	0.21			Sb124	0.20	0.21	0.30	0.04		
Sb125			0.01	0.94			Cs134			0.12	0.81		
Sb124			0.01	0.02			Te125m			0.11	0.01		
I129					50.35	100.0	I129				0.07	99.87	100.0
Sn121m					47.72		Sn121					0.07	
Sn121					1.89		Sn121m					0.06	

# Tellurium

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Ba137m	2.552 m	&Te130(n,γ)Te131(β <sup>-</sup> )I131(β <sup>-</sup> ) Xe131(n,γ)Xe132(n,γ)Xe133(β <sup>-</sup> ) Cs133(n,γ)Cs134(n,γ)Cs135(n,γ) Cs136(β <sup>-</sup> )Ba136(n,γ)Ba137m	73.5	0.3	58.6				
		&Te130(n,γ)Te131(β <sup>-</sup> )I131(β <sup>-</sup> ) Xe131(n,γ)Xe132(n,γ)Xe133(β <sup>-</sup> ) Cs133(n,γ)Cs134(n,γ)Cs135(n,γ) Cs136(n,γ)Cs137(β <sup>-</sup> )Ba137m	11.6	82.1	15.9				
		&Te130(n,γ)Te131m(β <sup>-</sup> )I131(β <sup>-</sup> ) Xe131(n,γ)Xe132(n,γ)Xe133(β <sup>-</sup> ) Cs133(n,γ)Cs134(n,γ)Cs135(n,γ) Cs136(β <sup>-</sup> )Ba136(n,γ)Ba137m	9.1		7.2				
		&Te130(n,γ)Te131m(β <sup>-</sup> )I131(β <sup>-</sup> ) Xe131(n,γ)Xe132(n,γ)Xe133(β <sup>-</sup> ) Cs133(n,γ)Cs134(n,γ)Cs135(n,γ) Cs136(n,γ)Cs137(β <sup>-</sup> )Ba137m &Te130(n,γ)Te131m(β <sup>-</sup> )I131(β <sup>-</sup> )Xe131(n,γ) Xe132(n,γ)Xe133(β <sup>-</sup> )Cs133(n,γ)Cs134(β <sup>-</sup> ) Ba134(n,γ)Ba135(n,γ)Ba136(n,γ)Ba137m	1.4	10.1	2.0			1.3	
Sb126m	19.1 m	&Te120(n,γ)Te121(β <sup>+</sup> )Sb121(n,γ) Sb122(n,γ)Sb123(n,γ)Sb124(n,γ) Sb125(n,γ)Sb126m	95.7	97.6	92.8				
		&Te126(n,p)Sb126m				83.8	46.7	12.6	2.9
		&Te130(n,2n)Te129(β <sup>-</sup> )I129(n,α)Sb126m				10.5	0.4		
		&Te130(n,2n)Te129m(β <sup>-</sup> )I129(n,α)Sb126m				3.2	0.2		
		&Te128(n,2n)Te127m(n,d)Sb126m				0.2	1.0		
		&Te128(n,t)Sb126m					27.7	79.0	71.2
		&Te128(n,3n)Te126(n,p)Sb126m					15.4	1.2	
		&Te130(n,3n)Te128(n,t)Sb126m &Te130(n,3n)Te128(n,3n)Te126(n,p)Sb126m &Te130(n,2nt)Sb126m					5.6	3.0	1.4
					1.7			22.8	
I128	24.99 m	&Te126(n,γ)Te127(β <sup>-</sup> )I127(n,γ)I128	98.3	82.9	98.5				
		&Te125(n,γ)Te126(n,γ)Te127(β <sup>-</sup> )I127 (n,γ)I128	1.5	16.8	1.1				
		&Te130(n,2n)Te129(β <sup>-</sup> )I129(n,2n)I128				76.6	64.8	56.8	52.0
		Te130(n,2n)Te129m(β <sup>-</sup> )I129(n,2n)I128				22.9	24.8	22.6	21.2
		Te130(n,d)Sb129(β <sup>-</sup> )Te129(β <sup>-</sup> )I129(n,2n)I128					6.8	13.6	18.2
		Te130(n,d)Sb129(β <sup>-</sup> )Te129m(β <sup>-</sup> )I129 (n,2n)I128 Te130(n,d)Sb129m(β <sup>-</sup> )Te129m(β <sup>-</sup> )I129 (n,2n)I128 &Te130(n,4n)Te127(β <sup>-</sup> )I127(n,γ)I128					0.5	1.0	1.3
					0.4	0.8	1.1		
						1.0	0.4		
Te129	1.16 h	&Te128(n,γ)Te129	99.5	100.0	100.0				
		&Te130(n,2n)Te129				99.5	88.9	76.8	69.4
		Te130(n,d)Sb129(β <sup>-</sup> )Te129					9.8	19.3	25.5
Te127	9.35 h	&Te126(n,γ)Te127	96.7	78.7	97.9		0.1		
		&Te125(n,γ)Te126(n,γ)Te127	2.9	21.1	2.2				
		&Te128(n,2n)Te127				99.2	68.4	19.8	27.5
		&Te130(n,3n)Te128(n,2n)Te127					13.8		
		&Te128(n,d)Sb127(β <sup>-</sup> )Te127					9.2	5.3	10.9
		&Te130(n,4n)Te127 &Te130(n,3n)Te128(n,d)Sb127(β <sup>-</sup> )Te127 Te130(n,nt)Sb127(β <sup>-</sup> )Te127					4.2	70.4	44.0
					2.0			11.8	
					0.1				
I130	12.36 h	&Te128(n,γ)Te129(β <sup>-</sup> )I129(n,γ)I130	96.3	97.0	91.1				
		&Te128(n,γ)Te129m(β <sup>-</sup> )I129(n,γ)I130	2.7	2.7	2.6				
		&Te130(n,2n)Te129(β <sup>-</sup> )I129(n,γ)I130				74.1	46.7	34.6	28.5

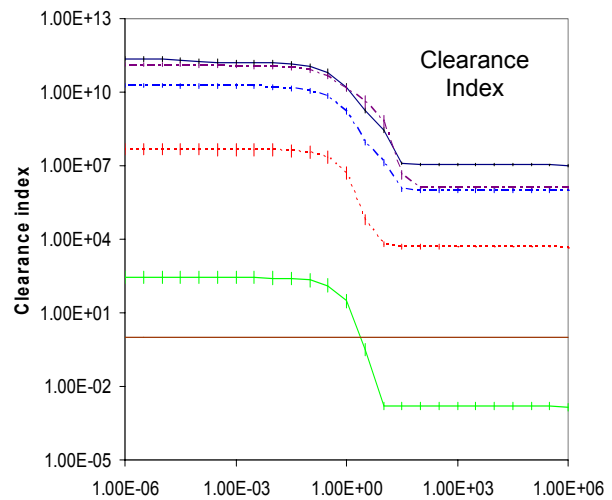
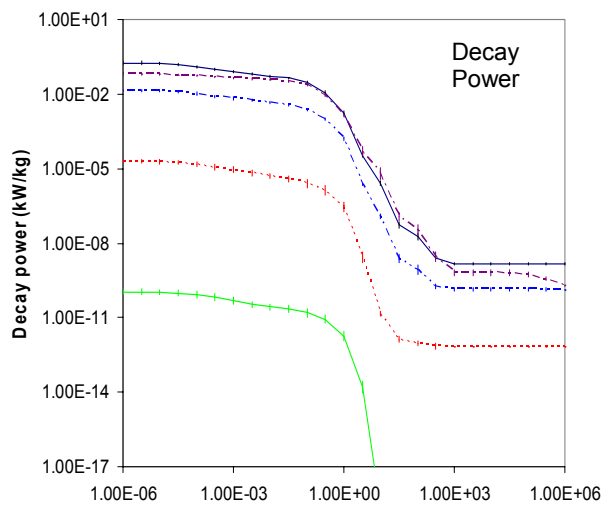
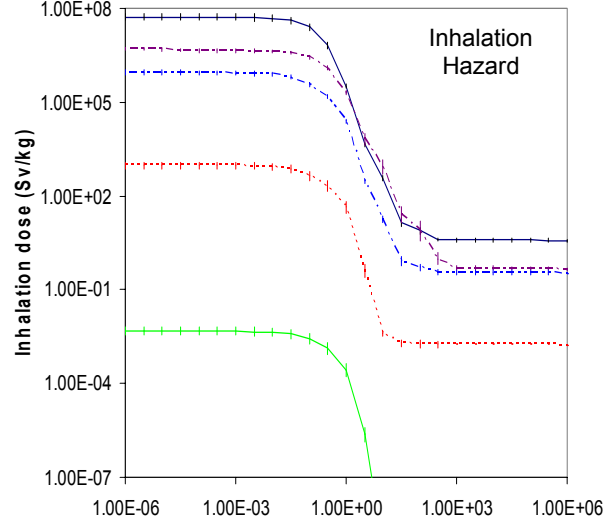
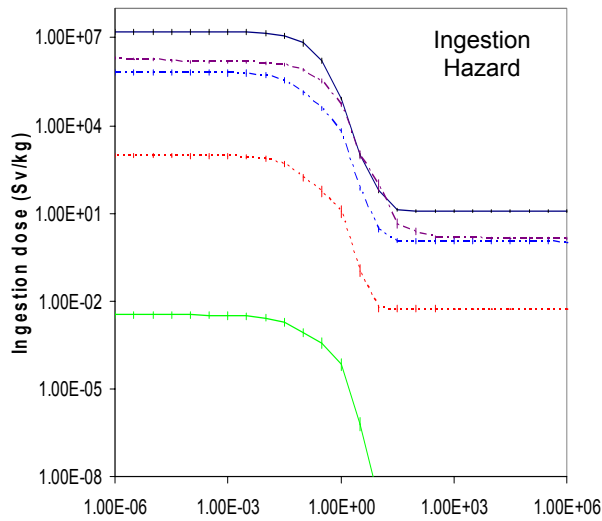
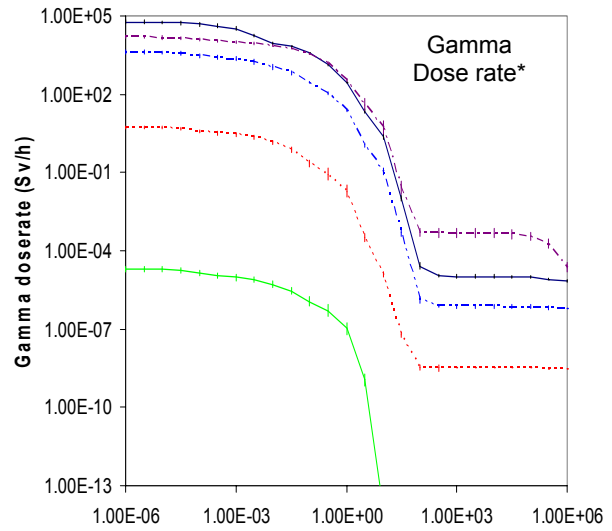
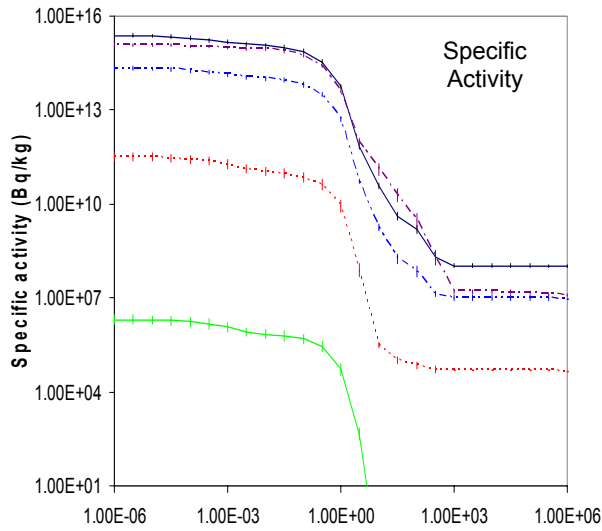
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&Tel30(n,2n)Te129m(β <sup>-</sup> )I129(n,γ)I130 &Tel30(n,γ)Te131(β <sup>-</sup> )I131(β <sup>-</sup> )Xe131_ (n,d)I130 &Tel30(n,γ)Te131m(β <sup>-</sup> )I131(β <sup>-</sup> ) Xe131(n,d)I130 &Tel30(n,d)Sb129(β <sup>-</sup> )Te129(β <sup>-</sup> )I129(n,γ)I130				22.5	18.1	13.9	11.7
							15.7	23.3	28.9
							8.5	12.5	12.6
							5.1	8.8	10.6
Sn121	1.128 d	Te122(n,γ)Te123(n,α)Sn120(n,γ)Sn121 Te123(n,α)Sn120(n,γ)Sn121 Te122(n,γ)Te123(n,α)Sn120(n,γ)Sn121 &Tel24(n,α)Sn121 &Tel25(n,2n)Te124(n,α)Sn121 &Tel25(n,α)Sn122(n,2n)Sn121 &Tel26(n,2n)Te125(n,2n)Te124(n,α)Sn121 &Tel22(n,2n)Te121(β <sup>+</sup> )Sb121(n,p)Sn121 &Tel25(n,nα)Sn121 &Tel26(n,2n)Te125(n,nα)Sn121 &Tel26(n,3n)Te124(n,α)Sn121 &Tel26(n,2nα)Sn121 &Tel28(n,3n)Te126(n,2nα)Sn121 &Tel28(n,nα)Sn124(n,4n)Sn121 &Tel28(n,4n)Te125(n,nα)Sn121 &Tel26(n,nt)Sb123(n,t)Sn121 &Tel28(n,4nα)Sn121	70.3 21.7 5.6 2.2	10.6 87.0 1.0 0.8	5.4 80.2 4.0 8.4	48.8 18.2 7.8 6.1 6.0 3.4 2.2	9.9 0.9 0.2 0.7 49.7 9.0 6.6 2.2 35.6 0.6 0.3	2.7 0.2 18.1 2.0 0.8 4.2 5.7 8.4 0.6	3.5 0.1 9.2 0.5 0.4 1.1 0.9 1.5 5.6 17.1
I131	8.023 d	&Tel30(n,γ)Te131(β <sup>-</sup> )I131 Tel30(n,γ)Tel31m(β <sup>-</sup> )I131	88.7 11.3	88.7 11.3	88.7 11.3	65.5 34.4	65.6 34.0	64.7 34.1	70.2 29.6
Xe131m	11.93 d	&Tel30(n,γ)Te131(β <sup>-</sup> )I131(β <sup>-</sup> )Xe131m &Tel28(n,γ)Te129(β <sup>-</sup> )I129(n,γ)I130_ (β <sup>-</sup> )Xe130(n,γ)Xe131m Tel130(n,γ)Tel31m(β <sup>-</sup> )I131(β <sup>-</sup> )Xe131m Tel128(n,γ)Tel29(β <sup>-</sup> )I129(n,γ)I130m_ (β <sup>-</sup> )Xe130(n,γ)Xe131m &Tel30(n,γ)Te131(β <sup>-</sup> )I131(β <sup>-</sup> )Xe131_ (n,n')Xe131m Tel130(n,γ)Tel31m(β <sup>-</sup> )I131(β <sup>-</sup> )Xe131_ (n,n')Xe131m	50.1 37.8 6.4 3.9	85.7 11.3	85.0 0.7 11.2	23.8 12.5 36.9 22.5	28.4 14.7 36.5 19.0	33.9 17.6 31.3 16.3	43.8 18.5 25.9 10.9
Te121	19.16 d	&Tel20(n,γ)Te121 &Tel22(n,2n)Te121 &Tel23(n,2n)Te122(n,2n)Te121 &Tel25(n,3n)Te123(n,3n)Te121 &Tel23(n,3n)Te121 &Tel24(n,3n)Te122(n,2n)Te121 &Tel24(n,2n)Te123(n,3n)Te121 &Tel24(n,4n)Te121 &Tel26(n,4n)Te123(n,3n)Te121 &Tel26(n,3n)Te124(n,4n)Te121 &Tel28(n,5n)Te124(n,4n)Te121 &Tel25(n,5n)Te121 &Tel28(n,4n)Te125(n,5n)Te121	99.8	99.9	99.9	87.5 7.0	32.6 0.7 20.0 17.6 8.7 6.5	13.3 0.1 3.4 7.3 2.4 1.4 32.1 11.4 10.8 0.1	5.9 0.3 2.1 0.4 0.2 17.2 1.6 2.1 9.0 33.0 5.5
Te129m	33.6 d	Te128(n,γ)Te129m Tel130(n,2n)Te129m &Tel30(n,d)Sb129(β <sup>-</sup> )Te129m Tel130(n,d)Sb129m(β <sup>-</sup> )Te129m	99.4	100.0	100.0	99.2	95.7	92.0	89.2 5.6 4.5
Xe127	36.4 d	&Tel30(n,2n)Te129(β <sup>-</sup> )I129(n,2n)I128_ (β <sup>-</sup> )Xe128(n,2n)Xe127 &Tel30(n,2n)Te129m(β <sup>-</sup> )I129(n,2n)_ I128(β <sup>-</sup> )Xe128(n,2n)Xe127 &Tel30(n,d)Sb129(β <sup>-</sup> )Te129(β <sup>-</sup> )I129_ (n,2n)I128(β <sup>-</sup> )Xe128(n,2n)Xe127 &Tel30(n,γ)Te131(β <sup>-</sup> )I131(β <sup>-</sup> )Xe131_ (n,3n)Xe129(n,3n)Xe127				77.0 22.7	59.8 22.7 7.0 4.1	51.5 20.3 13.6 1.4	15.4 6.2 5.9 0.2



Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6		
	◀	&Te130(n,γ)Te131m(β <sup>-</sup> )I131(β <sup>-</sup> )_Xe131(n,3n)Xe129(n,3n)Xe127 &Te130(n,γ)Te131(β <sup>-</sup> )I131(β <sup>-</sup> )Xe131_(n,5n)Xe127 &Te130(n,γ)Te131m(β <sup>-</sup> )I131(β <sup>-</sup> )Xe131_(n,5n)Xe127					2.5	0.8		47.4 20.2	
Te125m	57.4 d	Te124(n,γ)Te125m Te123(n,γ)Te124(n,γ)Te125m &Te122(n,γ)Te123(n,γ)Te124(n,γ)Te125m Te126(n,2n)Te125m Te125(n,n')Te125m Te128(n,3n)Te126(n,2n)Te125m Te128(n,4n)Te125m Te130(n,3n)Te128(n,4n)Te125m Te126(n,4n)Te123m Te125(n,3n)Te123m &Te128(n,4n)Te125(n,3n)Te123m Te124(n,2n)Te123m Te128(n,3n)Te126(n,4n)Te123m Te130(n,6n)Te125m	78.7 15.0 4.9	83.9 15.8 0.2	98.3 1.5					16.1 2.5 0.9 40.1 1.3 51.1 16.6 8.0 7.1 6.0 28.1	
Te127m	109.0 d	Te126(n,γ)Te127m Te125(n,γ)Te126(n,γ)Te127m Te128(n,2n)Te127m Te130(n,3n)Te128(n,2n)Te127m Te130(n,4n)Te127m Te128(n,d)Sb127(β <sup>-</sup> )Te127m	96.7 2.9	79.2 20.6	98.0 2.0		0.1			32.8 58.3	
Te123m	119.5 d	Te122(n,γ)Te123m Te124(n,2n)Te123m Te125(n,2n)Te124(n,2n)Te123m &Te126(n,2n)Te125(n,2n)Te124(n,2n)Te123m Te123(n,n')Te123m Te125(n,3n)Te123m Te126(n,3n)Te124(n,2n)Te123m &Te126(n,2n)Te125(n,3n)Te123m Te126(n,4n)Te123m &Te128(n,4n)Te125(n,3n)Te123m Te128(n,3n)Te126(n,4n)Te123m Te130(n,5n)Te126(n,4n)Te123m Te128(n,6n)Te123m Te128(n,5n)Te124(n,2n)Te123m	99.6	100.0	100.0						6.9 0.3 0.5 10.8 0.9 0.7 44.1 1.9 2.4 6.3 14.5 3.7
Cs134	2.065 y	&Te130(n,γ)Te131(β <sup>-</sup> )I131(β <sup>-</sup> )Xe131_(n,γ)Xe132(n,γ)Xe133(β <sup>-</sup> )Cs133(n,γ)_Cs134 &Te130(n,γ)Te131m(β <sup>-</sup> )I131(β <sup>-</sup> )_Xe131(n,γ)Xe132(n,γ)Xe133(β <sup>-</sup> )Cs133_(n,γ)Cs134 &Te128(n,γ)Te129(β <sup>-</sup> )I129(n,γ)I130_(β <sup>-</sup> )Xe130(n,γ)Xe131(n,γ)Xe132(n,γ)_Xe133(β <sup>-</sup> )Cs133(n,γ)Cs134 &Te130(n,γ)Te131(β <sup>-</sup> )I131(n,γ)I132(β <sup>-</sup> )_Xe132(n,γ)Xe133(β <sup>-</sup> )Cs133(n,γ)Cs134 &Te130(n,γ)Te131m(β <sup>-</sup> )I131(n,γ)I132_(β <sup>-</sup> )Xe132(n,γ)Xe133(β <sup>-</sup> )Cs133(n,γ)Cs134	87.0 11.0 1.0	82.7 10.8	84.8 11.2	55.3 31.2 3.0 1.5	51.1 29.2 6.0 3.0	49.8 28.7 6.9 3.4		50.1 23.7 9.7 3.9	
Sb125	2.759 y	&Te120(n,γ)Te121(β <sup>+</sup> )Sb121(n,γ)_Sb122(n,γ)Sb123(n,γ)Sb124(n,γ)Sb125 Te120(n,γ)Te121(β <sup>+</sup> )Sb121(n,γ)Sb122_(β <sup>+</sup> )Sn122(n,γ)Sn123m(β <sup>-</sup> )Sb123(n,γ)_Sb124(n,γ)Sb125 Te125(n,p)Sb125 Te128(n,α)Sn125m(β <sup>-</sup> )Sb125 Te128(n,α)Sn125(β <sup>-</sup> )Sb125 &Te126(n,2n)Te125(n,p)Sb125	97.0 1.4	98.6	94.2 3.5						0.6 1.2 0.8 0.6

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Te126(n,d)Sb125 Te128(n,3n)Te126(n,d)Sb125 Te128(n,nt)Sb125 Te130(n,2nα)Sn125(β <sup>-</sup> )Sb125 Te130(n,2nα)Sn125m(β <sup>-</sup> )Sb125 Te130(n,5n)Te126(n,d)Sb125 Te130(n,3nt)Sb125				12.5	67.5	64.6	31.0	
H3	12.33 y	Te120(n,γ)Te121m(n,X)H1(n,γ)H2(n,γ)H3 &Te120(n,γ)Te121(β <sup>+</sup> )Sb121(n,γ) <sub>-</sub> Sb122(n,X)H1(n,γ)H2(n,γ)H3 &Te120(n,γ)Te121(n,X)H1(n,γ)H2(n,γ)H3 Te125(n,X)H3 Te130(n,X)H3 &Te126(n,2n)Te125(n,X)H3 &Te128(n,2n)Te127(β <sup>-</sup> )I127(n,X)H3 &Te130(n,2n)Te129(β <sup>-</sup> )I129(n,X)H3 Te123(n,X)H3 &Te124(n,2n)Te123(n,X)H3 Te128(n,X)H3 Te126(n,X)H3 Te122(n,X)H3 Te124(n,X)H3	82.8 5.7 5.0	62.9 26.7 3.9						
Cs137	30.041 y	&Te130(n,γ)Te131(β <sup>-</sup> )I131(β <sup>-</sup> )Xe131_ (n,γ)Xe132(n,γ)Xe133(β <sup>-</sup> )Cs133(n,γ) <sub>-</sub> Cs134(n,γ)Cs135(n,γ)Cs136(n,γ)Cs137 &Te130(n,γ)Te131m(β <sup>-</sup> )I131(β <sup>-</sup> )Xe131_ (n,γ)Xe132(n,γ)Xe133(β <sup>-</sup> )Cs133(n,γ) <sub>-</sub> Cs134(n,γ)Cs135(n,γ)Cs136(n,γ)Cs137 &Te130(n,γ)Te131(β <sup>-</sup> )I131(β <sup>-</sup> )Xe131_ (n,γ)Xe132(n,γ)Xe133(n,γ)Xe134(n,γ) <sub>-</sub> Xe135(n,γ)Xe136(n,γ)Xe137(β <sup>-</sup> )Cs137	84.2 10.5 3.0	82.2 10.5	84.2 11.0					
Sn121m	55.0 y	Te122(n,γ)Te123m(n,α)Sn120(n,γ)Sn121m Te124(n,α)Sn121m Te123(n,α)Sn120(n,γ)Sn121m Te123(n,γ)Te124(n,α)Sn121m &Te122(n,γ)Te123(n,α)Sn120(n,γ)Sn121m Te125(n,α)Sn121m Te125(n,2n)Te124(n,α)Sn121m Te125(n,α)Sn122(n,2n)Sn121m &Te122(n,2n)Te121(β <sup>+</sup> )Sb121(n,p)Sn121m &Te126(n,2n)Te125(n,α)Sn121m &Te126(n,2n)Te125(n,2n)Te124(n,α)Sn121m &Te126(n,2n)Te125(n,α)Sn122(n,2n)Sn121m Te126(n,3n)Te124(n,α)Sn121m Te126(n,2nα)Sn121m Te128(n,3n)Te126(n,2nα)Sn121m Te128(n,α)Sn124(n,4n)Sn121m &Te128(n,4n)Te125(n,α)Sn121m Te130(n,5n)Te126(n,2nα)Sn121m Te128(n,4nα)Sn121m	37.9 31.1 20.3 5.7 3.5	7.1 92.1 0.7	5.6 90.2 4.1					
Sn126	2.3 10 <sup>5</sup> y	Te128(n,γ)Te129m(n,α)Sn126 &Te128(n,γ)Te129(n,α)Sn126 Te130(n,2n)Te129m(n,α)Sn126 Te130(n,nα)Sn126 Te128(n,h)Sn126	94.1 5.6	95.1 4.9	94.6 5.4					
I129	1.6 10 <sup>7</sup> y	&Te128(n,γ)Te129(β <sup>-</sup> )I129 Te128(n,γ)Te129m(β <sup>-</sup> )I129 &Te130(n,2n)Te129(β <sup>-</sup> )I129 Te130(n,2n)Te129m(β <sup>-</sup> )I129 &Te130(n,d)Sb129(β <sup>-</sup> )Te129(β <sup>-</sup> )I129	96.9 2.7	97.3 2.7	97.3 2.7					
						64.6 35.2	99.4 0.4	91.1 8.4	84.7 14.7	
						77.0 23.0	65.4 25.1	57.8 23.0	52.8 21.5	
							7.8	15.8	21.3	

# Tellurium activation characteristics

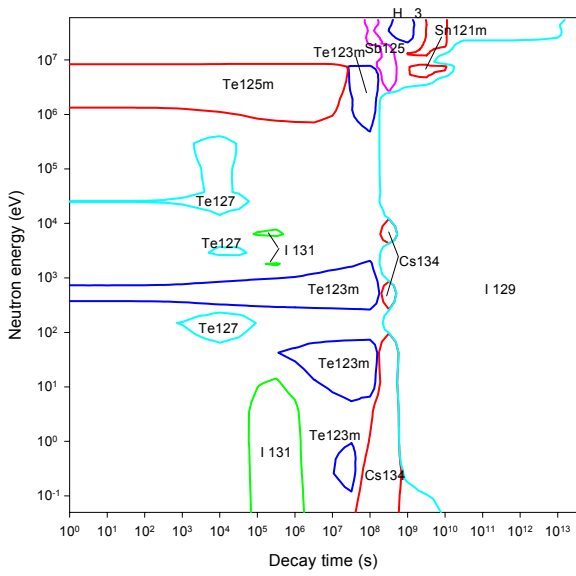


Decay time (years)

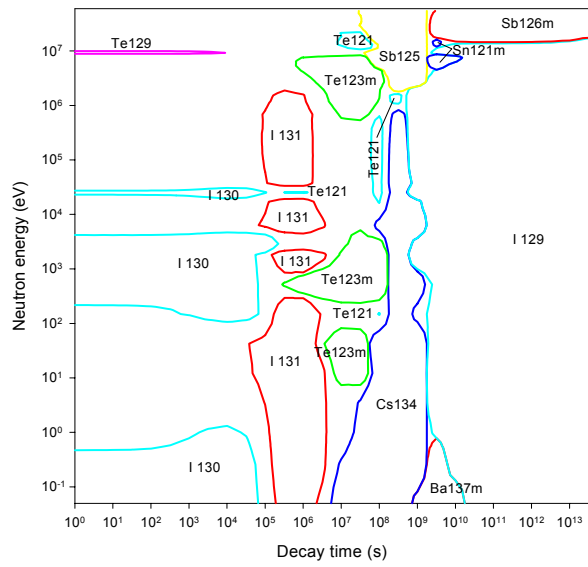
Decay time (years)

# Tellurium importance diagrams & transmutation

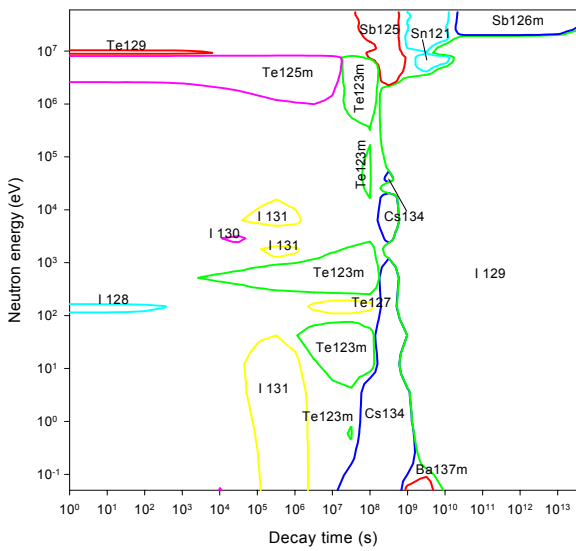
**Activity**



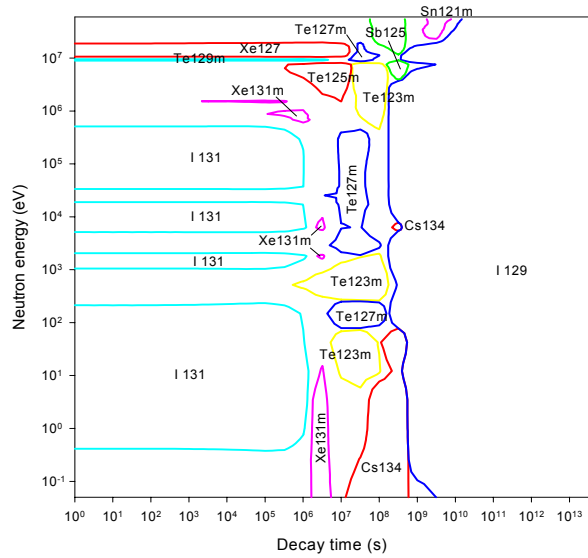
**Dose rate**



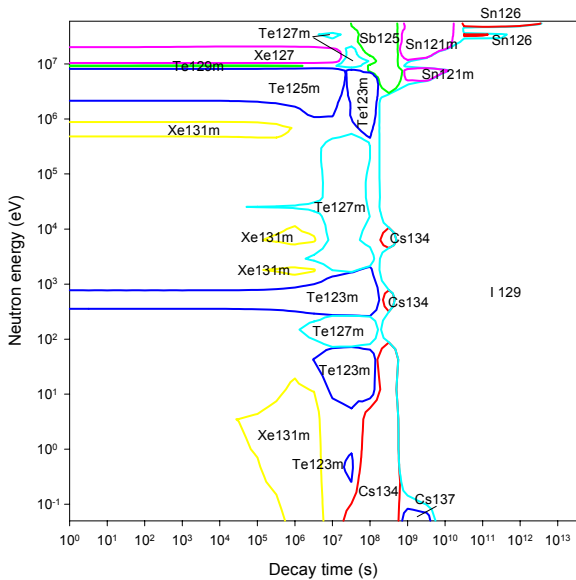
**Heat output**



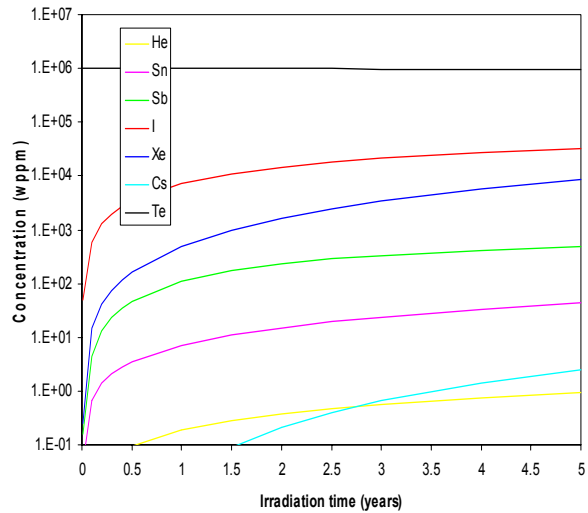
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**



# Iodine

## General properties

Atomic number	53	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	0.45	I127	100.0
Melting point / K	386.9		
Boiling point / K	457.6		
Density / kgm <sup>-3</sup>	4930		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	0.449		
Electrical resistivity /Ωm	1.37 10 <sup>7</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	9.3 10 <sup>-5</sup>		
Crystal structure	Orthorhombic		
Number of stable isotopes	1		
Mean atomic weight	126.90447		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	1.18E16	1.03E16	1.09E15	5.50E12	3.26E7	1.57E6	kW kg <sup>-1</sup>	1.46E0	1.27E0	7.05E-2	1.61E-4	6.18E-11	2.19E-11
I128	87.97	87.25					I128	93.81	93.29				
Xe127	5.08	5.83	51.15	10.38			I126	3.23	3.71	55.08			
I126	4.31	4.95	38.29				Xe127	2.04	2.34	39.41	17.63		
Xe127m	0.92	0.05					Xe129m	0.18	0.20	2.76			
Xe129m	0.59	0.68	4.77				Te127	0.16	0.19	1.21	52.83		
Te127	0.55	0.63	2.12	42.13			Te127m	0.03	0.03	0.50	22.05		
Te127m	0.21	0.24	2.16	43.02			Sb124	0.02	0.03	0.48	3.28		
Te125m	0.09	0.10	0.93	2.48			Te125m	0.02	0.02	0.32	1.91		
I125	0.03	0.03	0.29	0.84			Sb125			0.01	1.79		
H3				0.14	91.93		H3					44.41	
I129					4.83	99.99	I129					35.53	99.88
Sn121m					1.82		Sn121					13.77	
Sn121					1.41		Sn121m					6.23	
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	2.12E5	1.90E5	4.40E4	2.29E1	1.44E-7	1.22E-7	Sv kg <sup>-1</sup>	9.16E8	9.16E8	8.40E8	8.06E5	1.75E-1	1.73E-1
I128	74.90	72.21					Xe127	91.49	91.51	93.12	99.16		
I126	19.15	21.36	75.99				Xe129m	6.58	6.58	5.40			
Xe127	5.05	5.63	22.72	44.79			I126	1.61	1.61	1.44			
Sb124	0.25	0.27	1.14	34.14			I128	0.05	0.05				
Te127	0.02	0.03	0.04	8.04*			Te127m	0.01	0.01	0.01	0.68		
Sb126m	0.01	0.01			19.23	16.71	I125	0.01	0.01	0.01	0.09		
Sb126			0.01		4.83	4.20	Te127				0.05		
Sb125			0.01	12.13			Te125m				0.02		
I129					67.64	79.08	I129					99.09	100.0
Sn121m					7.28		H3					0.72	
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	3.49E9	3.49E9	3.24E9	3.28E6	6.74E-2	5.65E-2		1.93E12	1.68E12	2.09E11	7.58E8	1.58E5	1.57E5
Xe127	97.82	97.82	98.25	99.24			I128	86.79	86.01				
Xe129m	1.99	1.99	1.61				Xe127	8.88	10.18	76.29	21.53		
I126	0.14	0.14	0.13				I126	2.64	3.03	19.99			
Te127m	0.01	0.01	0.01	0.71			Xe129m	0.26	0.30	1.78			
I128	0.01	0.01					Te127m	0.13	0.14	1.13	31.22		
Te125m				0.02			Sb124	0.05	0.06	0.46	1.95		
I125				0.01			Sb125	0.02	0.03	0.21	44.17		
Te127				0.01			Te127			0.01	0.31		
Sb125				0.01			Te125m			0.01	0.02		
I129					84.29	100.0	I129				0.02	99.80	100.0
H3					11.58		H3				0.01	0.19	
Sn121m					3.97								

# Iodine

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6		
Ba137m	2.552 m	&I127(n,γ)I128(β <sup>-</sup> )Xe128(n,γ)Xe129_ (n,γ)Xe130(n,γ)Xe131(n,γ)Xe132(n,γ)Xe133(β <sup>-</sup> )Cs133(n,γ)Cs134(n,γ)Cs135_ (n,γ)Cs136(β <sup>-</sup> )Ba136(n,γ)Ba137m	80.1	0.3							
		&I127(n,γ)I128(β <sup>-</sup> )Xe128(n,γ)Xe129_ (n,γ)Xe130(n,γ)Xe131(n,γ)Xe132(n,γ)Xe133(β <sup>-</sup> )Cs133(n,γ)Cs134(n,γ)Cs135_ (n,γ)Cs136(n,γ)Cs137(β <sup>-</sup> )Ba137m	12.7	93.3							
Sb126m	19.1 m	&I127(n,γ)I128(n,α)Sb125(n,γ)Sb126m	100.0	99.8	95.3						
		&I127(n,α)Sb124(n,γ)Sb125(n,γ)Sb126m		0.2							
		&I127(n,2n)I126(β <sup>+</sup> )Te126(n,p)Sb126m				97.0	73.6	57.1	27.0		
		&I127(n,d)Te126(n,p)Sb126m				0.7	23.1	34.4	27.2		
		&I127(n,p)Te127m(n,d)Sb126m					1.1	1.9			
		&I127(n,2p)Sb126m					4.8	36.8			
I128	24.99 m	I127(n,γ)I128	100.0	100.0	100.0	99.3	98.8	99.1	99.5		
Te129	1.16 h	&I127(n,γ)I128(β <sup>+</sup> )Te128(n,γ)Te129	100.0	100.0	100.0	99.5	99.1	99.3	99.7		
Te127	9.35 h	&I127(n,γ)I128(β <sup>-</sup> )Xe128(n,γ)Xe129_ (n,α)Te126(n,γ)Te127	93.2	99.8	99.6						
		&I127(n,γ)I128(β <sup>-</sup> )Xe128(n,α)Te125_ (n,γ)Te126(n,γ)Te127			0.1						
		&I127(n,p)Te127				97.0	99.4	99.6	99.7		
		&I127(n,2n)I126(β <sup>+</sup> )Te126(n,γ)Te127				1.7					
I130	12.36 h	&I127(n,γ)I128(β <sup>+</sup> )Te128(n,γ)Te129_ (β <sup>-</sup> )I129(n,γ)I130	94.5	96.6	96.3	78.7	75.4	76.7	78.1		
		&I127(n,γ)I128(n,γ)I129(n,γ)I130	2.9	0.7	0.9						
		&I127(n,γ)I128(β <sup>+</sup> )Te128(n,γ)Te129m_ (β <sup>-</sup> )I129(n,γ)I130	2.6	2.7	2.6	15.2	14.6	14.8	15.1		
		&I127(n,γ)I128(β <sup>-</sup> )Xe128(n,γ)Xe129_ (n,p)I129(n,γ)I130				0.5	2.4	1.9	1.0		
		I127(n,γ)I128(β <sup>-</sup> )Xe128(n,γ)Xe129(n,γ)Xe130(n,p)I130				0.2	1.8	1.2	0.3		
Sn121	1.128 d	&I127(n,2n)I126(β <sup>+</sup> )Te126(n,2n)Te125_ (n,2n)Te124(n,α)Sn121				23.2					
		&I127(n,2n)I126(β <sup>+</sup> )Te126(n,α)_ Sn122(n,2n)Sn121				13.1	0.6	0.2			
		&I127(n,2n)I126(β <sup>-</sup> )Xe126(n,2n)Xe125_ (β <sup>+</sup> )I125(β <sup>+</sup> )Te125(n,2n)Te124(n,α)Sn121				10.6					
		&I127(n,2n)I126(β <sup>+</sup> )Te126(n,2n)Te125_ (n,α)Sn122(n,2n)Sn121				9.8					
		&I127(n,2n)I126(β <sup>-</sup> )Xe126(n,2n)_ Xe125(β <sup>+</sup> )I125(β <sup>+</sup> )Te125(n,α)Sn121				8.4					
		&I127(n,α)Sb124(β <sup>-</sup> )Te124(n,α)Sn121				8.3					
		&I127(n,2n)I126(β <sup>-</sup> )Xe126(n,2n)Xe125_ (β <sup>+</sup> )I125(β <sup>+</sup> )Te125(n,α)Sn122(n,2n)Sn121				4.5					
		&I127(n,3n)I125(β <sup>+</sup> )Te125(n,α)Sn121					88.8	44.7	15.3		
		&127(n,α)Sb123(n,t)Sn121					1.3	9.6	14.7		
		&127(n,t)Te125(n,t)Sb123(n,t)Sn121					1.0	4.5	5.3		
		&127(n,2n)I126(β <sup>+</sup> )Te126(n,2nα)Sn121					0.3	9.3	6.3		
		&127(n,d)Te126(n,2nα)Sn121					0.1	5.6	5.1		
		&127(n,4n)I124(β <sup>+</sup> )Te124(n,α)Sn121						9.6	13.6		
		&127(n,nt)Te124(n,α)Sn121						0.4	4.1		
		&127(n,5n)I123(β <sup>+</sup> )Te123(n,h)Sn121							9.7		
		&127(n,tα)Sn121							4.9		
		I124	4.176 d	&I127(n,2n)I126(β <sup>-</sup> )Xe126(n,2n)Xe125_ (β <sup>+</sup> )I125(n,2n)I124				96.8			

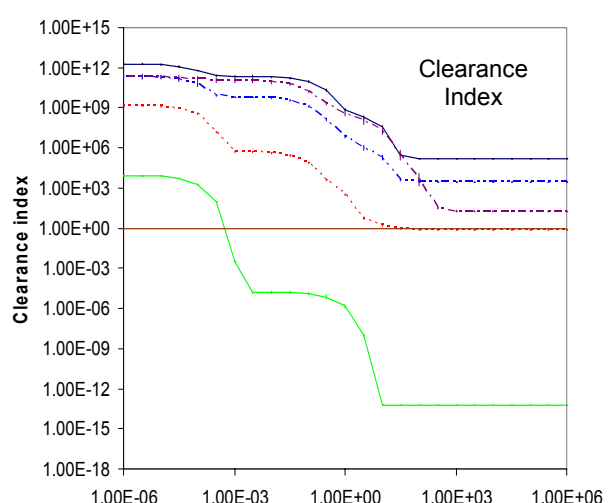
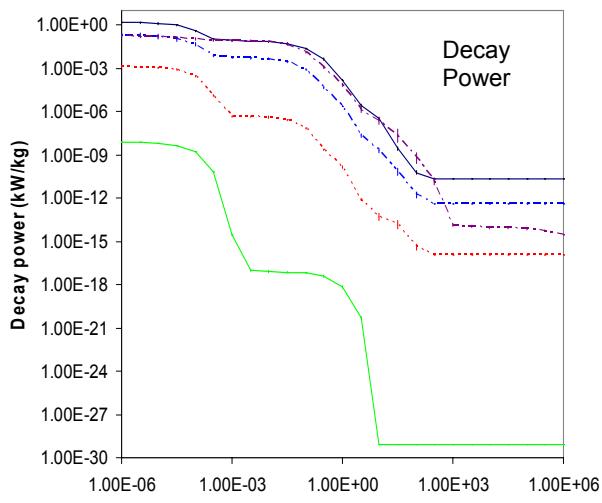
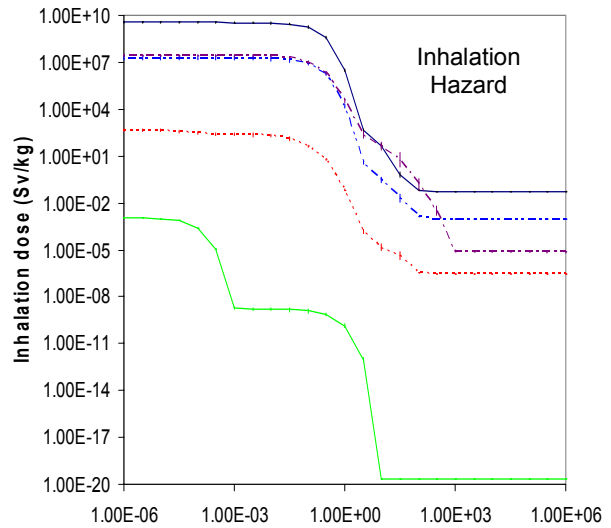
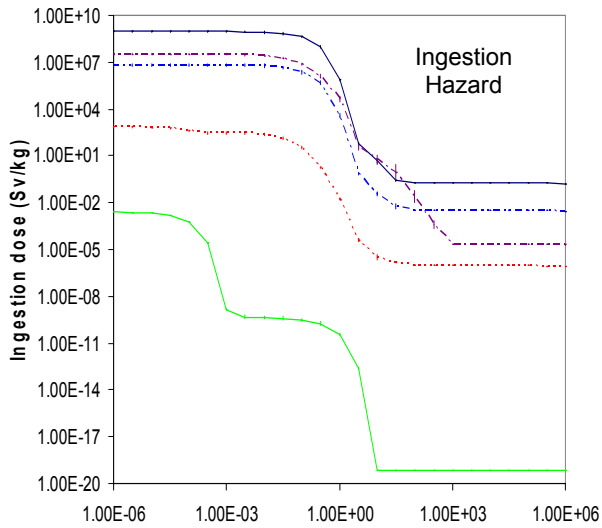
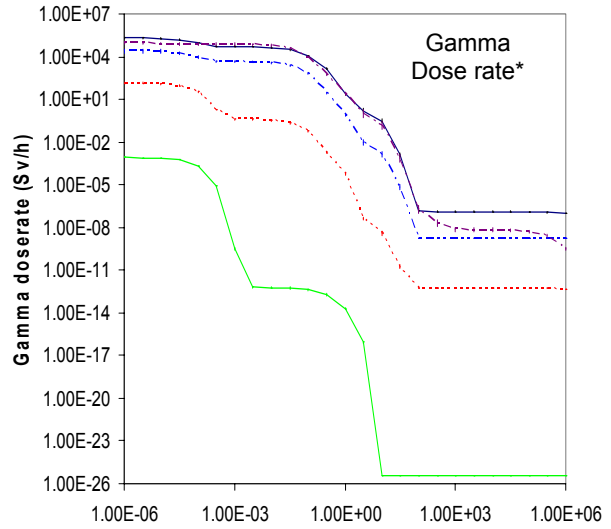
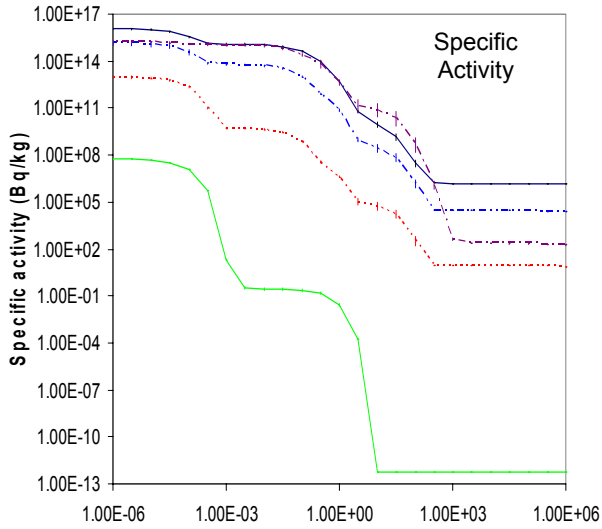
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	I127(n,2n)I126(n,2n)I125(n,2n)I124 I127(n,2n)I126(β <sup>-</sup> )Xe126(n,d)I125(n,2n)I124   I127(n,3n)I125(n,2n)I124 I127(n,2n)I126(n,3n)I124 I127(n,2n)I126(β <sup>-</sup> )Xe126(n,t)I124 I127(n,4n)I124				2.5 0.5	74.1 13.2 10.1	99.1	99.3
Xe129m	8.88 d	I127(n,γ)I128(β <sup>-</sup> )Xe128(n,γ)Xe129m I127(n,γ)I128(β <sup>-</sup> )Xe128(n,γ)Xe129_ (n,n')Xe129m	100.0	100.0	100.0	97.5 1.3	97.8 1.3	98.4 0.9	98.9 0.6
Xe131m	11.93 d	&I127(n,γ)I128(β <sup>-</sup> )Xe128(n,γ)Xe129_ (n,γ)Xe130(n,γ)Xe131m &I127(n,γ)I128(β <sup>+</sup> )Te128(n,γ)Te129_ (β <sup>-</sup> )I129(n,γ)I130(β <sup>-</sup> )Xe130(n,γ)Xe131m I127(n,γ)I128(β <sup>-</sup> )Xe128(n,γ)Xe129m_ (n,γ)Xe130(n,γ)Xe131m &I127(n,γ)I128(β <sup>-</sup> )Xe128(n,γ)Xe129_ (n,γ)Xe130(n,γ)Xe131(n,n')Xe131m I127(n,γ)I128(β <sup>+</sup> )Te128(n,γ)Te129m_ (β <sup>-</sup> )I129(n,γ)I130(β <sup>-</sup> )Xe130(n,γ)Xe131m	97.2 0.4 0.1	96.9 0.9 0.2	96.3 0.8 0.1	87.4 2.1 0.8 0.6 0.6	90.6 1.2 0.7 0.4 0.3	90.5 1.4 0.7 0.3 0.4	88.7 2.0 0.7 0.1 0.5
I126	12.98 d	I127(n,2n)I126				99.3	99.2	99.3	99.5
Cs136	13.03 d	&I127(n,γ)I128(β <sup>-</sup> )Xe128(n,γ)Xe129(n,γ)_ Xe130(n,γ)Xe131(n,γ)Xe132(n,γ)Xe133_ (β <sup>-</sup> )Cs133(n,γ)Cs134(n,γ)Cs135(n,γ)Cs136	94.2	93.7	95.6				
Te121	19.16 d	&I127(n,2n)I126(β <sup>-</sup> )Xe126(n,α)_ Te122(n,2n)Te121 &I127(n,2n)I126(β <sup>-</sup> )Xe126(n,α)Te123_ (n,2n)Te122(n,2n)Te121 &I127(n,α)Sb123(n,2n)Sb122(β <sup>-</sup> )_ Te122(n,2n)Te121 &I127(n,α)Sb124(β <sup>-</sup> )Te124(n,2n)_ Te123(n,2n)Te122(n,2n)Te121 &I127(n,3n)I125(β <sup>+</sup> )Te125(n,3n)Te123_ (n,3n)Te121 &I127(n,3n)I125(β <sup>+</sup> )Te125(n,3n)_ Te123m(n,3n)Te121 &I127(n,3n)I125(n,3n)I123(β <sup>+</sup> )Te123_ (n,3n)Te121 &I127(n,4n)I124(β <sup>+</sup> )Te124(n,4n)Te121 &I127(n,nt)Te124(n,4n)Te121 &I127(n,3n)I125(β <sup>+</sup> )Te125(n,5n)Te121 &I127(n,5n)I123(β <sup>+</sup> )Te123(n,3n)Te121 &I127(n,t)Te125(n,5n)Te121 Other pathways involving (n,2n), (n,α), β <sup>+</sup>				14.2 13.9 9.4 7.2 68.3 11.6 7.6 55.3	0.1 0.1 68.3 2.5 11.6 7.6 12.3	73.8 25.3 8.3 22.9 22.7 9.4 19.8	
Te129m	33.60 d	I127(n,γ)I128(β <sup>-</sup> )Te128(n,γ)Te129m	100.0	100.0	100.0	99.5	99.1	99.3	99.6
I125	59.407 d	&I127(n,2n)I126(β <sup>-</sup> )Xe126(n,2n)Xe125_ (β <sup>+</sup> )I125 I127(n,2n)I126(n,2n)I125 I127(n,3n)I125				96.8 2.5	98.3	98.8	98.4
Sb124	60.20 d	&I127(n,γ)I128(β <sup>-</sup> )Xe128(n,α)Te125_ (n,α)Sn122(n,γ)Sn123m(β <sup>-</sup> )Sb123(n,γ)_ Sb124 &127(n,α)Sb124 &I127(n,3n)I125(β <sup>+</sup> )Te125(n,d)Sb124 &I127(n,2n)I126(β <sup>+</sup> )Te126(n,t)Sb124 &I127(n,t)Te125(n,d)Sb124 &I127(n,d)Te126(n,t)Sb124 &I127(n,4n)I124(β <sup>+</sup> )Te124(n,p)Sb124	98.9	100.0		97.4	33.0 59.9 1.4 0.7 0.4	18.8 48.2 8.3 6.0 5.0 10.2	46.2 19.8 10.4 8.1 8.4 4.0
Te127m	109.0 d	I127(n,γ)I128(β <sup>-</sup> )Xe128(n,γ)Xe129_ (n,α)Te126(n,γ)Te127m I127(n,p)Te127m I127(n,2n)I126(β <sup>+</sup> )Te126(n,γ)Te127m	94.0	94.1	93.1	98.1 1.5	99.4	99.6	99.7

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Ag110m	249.78 d	Pathways involving (n,α), (n,nα), (n,2n), β <sup>-</sup> ,β <sup>+</sup>				100.0	100.0	100.0	100.0
Cs134	2.065 y	&I127(n,γ)I128(β <sup>-</sup> )Xe128(n,γ)Xe129_ (n,γ)Xe130(n,γ)Xe131(n,γ)Xe132(n,γ)_ Xe133(β <sup>-</sup> )Cs133(n,γ)Cs134	98.2	97.7	98.0				
Sb125	2.759 y	I127(n,γ)I128(n,α)Sb125 &I127(n,α)Sb124(n,γ)Sb125 I127(n,2n)I126(β <sup>+</sup> )Te126(n,d)Sb125 &I127(n,2n)I126(β <sup>+</sup> )Te126(n,2n)Te125_ (n,p)Sb125 &I127(n,2n)I126(β <sup>-</sup> )Xe126(n,2n)Xe125_ (β <sup>+</sup> )I125(β <sup>+</sup> )Te125(n,p)Sb125 I127(n,2n)I126(β <sup>+</sup> )Te126(n,2n)Te125m_ (n,p)Sb125 I127(n,2n)I126(n,2n)I125(β <sup>+</sup> )Te125_ (n,p)Sb125 I127(n,d)Te126(n,d)Sb125 I127(n,3n)I125(β <sup>+</sup> )Te125(n,p)Sb125 I127(n,h)Sb125 &I127(n,t)Te125(n,p)Sb125	100.0	99.6 0.4	100.0	43.3 31.1 19.9 2.7 1.4 0.3	45.3	32.9	24.8 20.1 20.0 2.7 50.9 1.1
H3	12.33 y	I127(n,X)H1(n,γ)H2(n,γ)H3 I127(n,X)H3 I127(n,2n)I126(n,X)H3 I127(n,3n)I125(β <sup>+</sup> )Te125(n,X)H3 I127(n,2n)I126(β <sup>+</sup> )Te126(n,X)H3 I127(n,2n)I126(β <sup>-</sup> )Xe126(n,X)H3 I127(n,4n)I124(β <sup>+</sup> )Te124(n,X)H3 I127(n,5n)I123(β <sup>+</sup> )Te123(n,X)H3	93.3	94.7		94.2 3.9	88.2 0.1 7.5 0.8 0.8	89.1 4.0 0.7 0.6 2.7	88.9 1.5 1.8 3.1
Cs137	30.041 y	&I127(n,γ)I128(β <sup>-</sup> )Xe128(n,γ)Xe129_ (n,γ)Xe130(n,γ)Xe131(n,γ)Xe132(n,γ)_ Xe133(β <sup>-</sup> )Cs133(n,γ)Cs134(n,γ)Cs135_ (n,γ)Cs136(n,γ)Cs137 &I127(n,γ)I128(β <sup>-</sup> )Xe128(n,γ)Xe129_ (n,γ)Xe130(n,γ)Xe131(n,γ)Xe132(n,γ)_ Xe133(n,γ)Xe134(n,γ)Xe135(n,γ)Xe136_ (n,γ)Xe137(β <sup>-</sup> )Cs137	90.1 3.9	93.6	93.3				
Sn121m	55.0 y	&I127(n,2n)I126(β <sup>+</sup> )Te126(n,2n)Te125_ (n,nα)Sn121m &I127(n,2n)I126(β <sup>-</sup> )Xe126(n,2n)Xe125_ (β <sup>+</sup> )I125(β <sup>+</sup> )Te125(n,nα)Sn121m &I127(n,2n)I126(β <sup>+</sup> )Te126(n,2n)Te125_ (n,2n)Te124(n,α)Sn121m &I127(n,2n)I126(β <sup>+</sup> )Te126(n,2n)Te125_ (n,α)Sn122(n,2n)Sn121m &I127(n,α)Sb124(β <sup>-</sup> )Te124(n,α)Sn121m &I127(n,2n)I126(β <sup>-</sup> )Xe126(n,2n)Xe125_ (β <sup>+</sup> )I125(β <sup>+</sup> )Te125(n,2n)Te124(n,α)Sn121m &I127(n,2n)I126(β <sup>-</sup> )Xe126(n,2n)Xe125_ (β <sup>+</sup> )I125(β <sup>+</sup> )Te125(n,α)Sn122(n,2n)Sn121m I127(n,3n)I125(β <sup>+</sup> )Te125(n,nα)Sn121m &I127(n,t)Te125(n,nα)Sn121m I127(n,nα)Sb123(n,t)Sn121m I127(n,2n)I126(β <sup>+</sup> )Te126(n,2nα)Sn121m I127(n,d)Te126(n,2nα)Sn121m I127(n,4n)I124(β <sup>+</sup> )Te124(n,α)Sn121m I127(n,tα)Sn121m I127(n,nt)Te124(n,α)Sn121m I127(n,5n)I123(β <sup>+</sup> )Te123(n,h)Sn121m				24.0 15.3 11.2 10.3 8.0 5.1 4.7			93.2 59.1 21.5 1.6 7.5 8.9 1.0 5.0 6.5 0.3 9.3 10.3 0.1 5.7 8.4 7.7 15.6 11.2 5.1 4.5
Sn126	2.3 10 <sup>5</sup> y	I127(n,γ)I128(β <sup>+</sup> )Te128(n,γ)Te129m_ (n,α)Sn126 &I127(n,γ)I128(β <sup>+</sup> )Te128(n,γ)Te129_ (n,α)Sn126	94.3 5.7	94.7 5.3	94.5 5.5				



Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&I127(n,2n)I126(β <sup>+</sup> )Te126(n,p)Sb126_ (n,p)Sn126 &I127(n,d)Te126(n,p)Sb126(n,p)Sn126 I127(n,γ)I128(β <sup>+</sup> )Te128(n,h)Sn126 I127(n,p)Te127m(n,2p)Sn126 I127(n,p)Te127m(n,p)Sb127(n,d)Sn126 &I127(n,p)Te127m(n,d)Sb126(n,p)Sn126				98.7	58.0	6.0	
						0.7	19.4	3.7	
							11.3	54.3	54.3
							2.7	32.1	62.3
							2.6	0.5	
							1.5		
Cs135	2.3 10 <sup>6</sup> y	&I127(n,γ)I128(β <sup>-</sup> )Xe128(n,γ)Xe129_ (n,γ)Xe130(n,γ)Xe131(n,γ)Xe132(n,γ) Xe133(β <sup>-</sup> )Cs133(n,γ)Cs134(n,γ)Cs135	97.9	97.5	97.7				
Pd107	6.5 10 <sup>6</sup> y	Pathways involving (n,α), (n,nα), (n,2n), β <sup>-</sup> , β <sup>+</sup>				100.0	100.0	100.0	100.0
I129	1.6 10 <sup>7</sup> y	&I127(n,γ)I128(β <sup>+</sup> )Te128(n,γ)Te129_ (β <sup>-</sup> )I129 I127(n,γ)I128(n,γ)I129 I127(n,γ)I128(β <sup>+</sup> )Te128(n,γ)Te129m_ (β <sup>-</sup> )I129 &I127(n,γ)I128(β <sup>-</sup> )Xe128(n,γ)Xe129_ (n,p)I129	94.5	96.7	96.3	83.4	81.4	82.1	83.1
			2.9	0.6	1.0				
			2.6	2.7	2.6	15.6	15.3	15.4	15.6
						0.6	2.6	1.9	1.0
Xe124	2.0 10 <sup>14</sup> y	&I127(n,2n)I126(β <sup>-</sup> )Xe126(n,2n)Xe125_ (n,2n)Xe124 I127(n,2n)I126(β <sup>-</sup> )Xe126(n,3n)Xe124				99.9			
							99.8	99.9	99.1

# Iodine activation characteristics

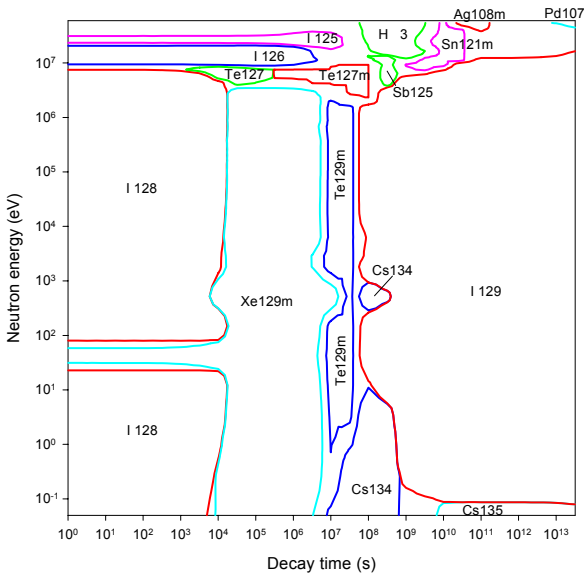


Decay time (years)

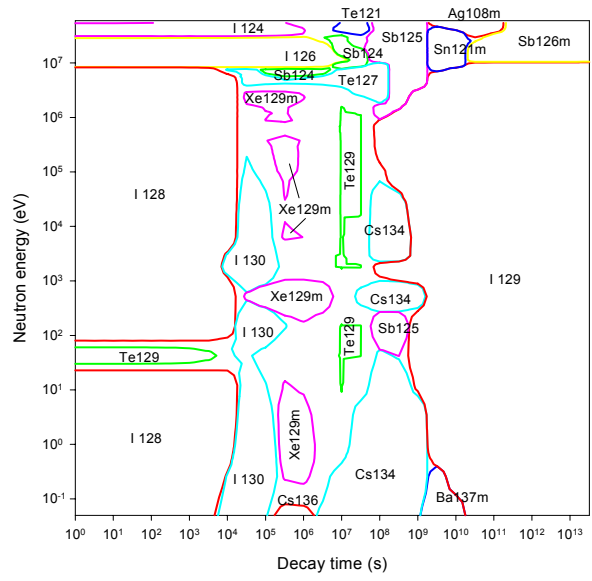
Decay time (years)

# Iodine importance diagrams & transmutation

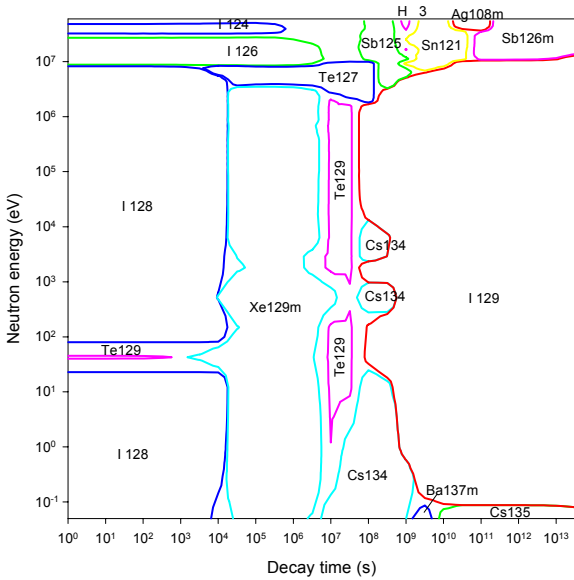
Activity



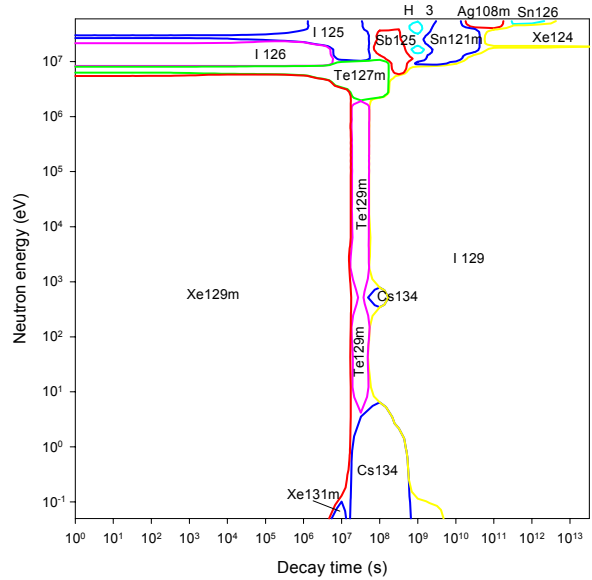
Dose rate



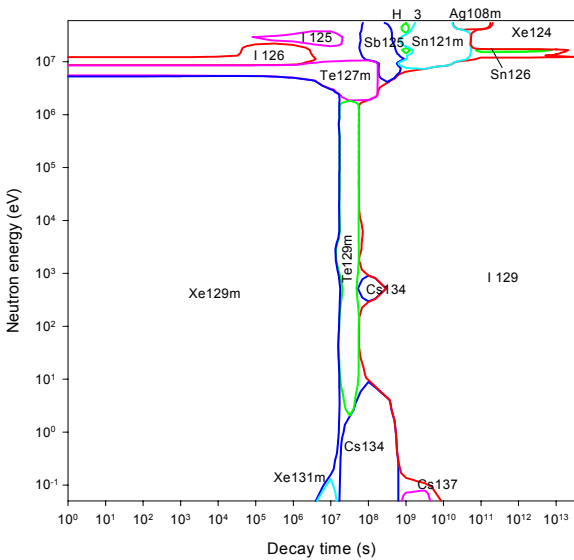
Heat output



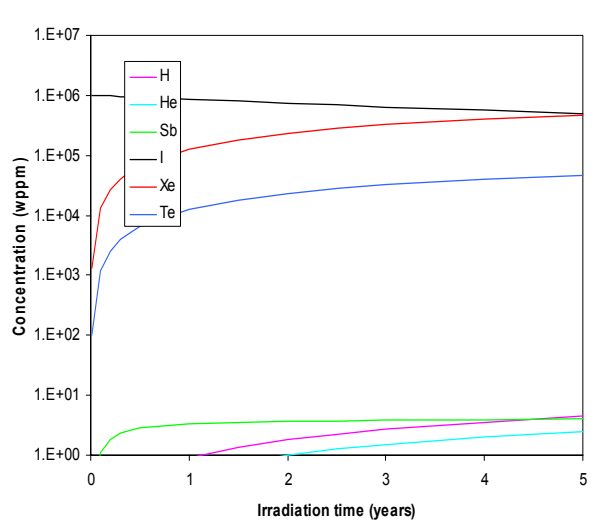
Ingestion dose



Inhalation dose



First wall transmutation





# Xenon

## General properties

Atomic number	54	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	3.0 10 <sup>-5</sup>	Xe124	0.095 (T <sub>1/2</sub> = 2.00 10 <sup>14</sup> y)
Melting point / K	161.4	Xe126	0.089
Boiling point / K	165	Xe128	1.91
Density / kgm <sup>-3</sup>	5.887	Xe129	26.4
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	5.69 10 <sup>-3</sup>	Xe130	4.071
Electrical resistivity /Ωm	-	Xe131	21.232
Coefficient of thermal expansion / K <sup>-1</sup>	-	Xe132	26.909
Crystal structure	FCC	Xe134	10.436 (T <sub>1/2</sub> = 1.10 10 <sup>16</sup> y)
Number of stable isotopes	6 (9)	Xe136	8.857 (T <sub>1/2</sub> = 2.10 10 <sup>20</sup> y)
Mean atomic weight	131.293		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	1.18E15	1.15E15	7.28E14	5.85E13	2.46E10	1.42E8	kW kg <sup>-1</sup>	8.08E-2	7.72E-2	5.12E-2	1.60E-2	1.64E-6	2.03E-9
Xe131m	29.12	29.78	38.23				Cs134	27.71	29.00	43.57	99.84		
Xe133	23.58	24.12	25.61				Cs136	14.54	15.21	18.89			
Xe129m	10.56	10.80	12.89				Xe135	12.10	12.61	0.03			
Xe135	9.17	9.34	0.02				Xe131m	11.08	11.59	14.14			
Cs134	6.88	7.04	11.13	99.30			Xe133	9.92	10.38	10.47			
Xe133m	5.66	5.79	2.89				Xe129m	5.76	6.02	6.83			
Xe135m	3.89	3.13					Xe135m	4.73	3.90				
Xe127	2.98	3.05	4.51	0.06			Xe133m	3.07	3.20	1.52			
Cs136	2.71	2.78	3.63				I128	3.01	2.72				
I128	1.55	1.37					Xe127	2.17	2.27	3.19	0.01		
Cs134m	1.33	1.33					Xe134m	2.10					
Xe134m	0.46						Cs132	0.83	0.87	0.89			
Cs137			0.02	0.21	50.85		Ba137m			0.03	0.08	76.29	
Ba137m			0.02	0.20	48.00		Cs137				0.02	23.04	
Cs135					0.59	99.82	Cs135					0.13	99.82
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	5.82E4	5.48E4	4.50E4	2.07E4	1.61E0	1.63E-8	Sv kg <sup>-1</sup>	6.10E8	6.09E8	4.30E8	1.15E6	3.88E2	3.11E-1
Cs134	49.58	52.70	63.86	99.90			Xe131m	36.67	36.69	42.03			
Cs136	30.85	32.78	32.83				Xe133	26.04	26.05	24.69			
Xe135m	5.85	4.90					Xe129m	17.80	17.81	18.97			
Xe134m	4.34						Xe127	8.08	8.09	10.68	4.07		
Xe135	3.60	3.81	0.01				Xe133m	7.24	7.24	3.23			
Cs132	1.56	1.65	1.37				Xe135	3.73	3.72	0.01			
Xe127	1.07	1.14	1.29				Cs134	0.25	0.25	0.36	95.58		
I132	0.75	0.78					Cs136	0.02	0.02	0.02			
I130	0.58	0.62	0.01				I126	0.01	0.01	0.01			
Ba137m		0.03	0.04	0.08	99.71		Cs137				0.14	41.97	
I129						98.01	Cs135					0.08	91.04
Sb126m						1.59	I129					0.01	8.96
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	8.34E8	8.34E8	6.49E8	1.36E6	6.33E2	1.23E0		9.65E11	9.47E11	8.76E11	5.82E11	1.32E8	2.67E4
Xe131m	39.40	40.01	41.54				Cs134	84.24	85.76	92.43	99.77		
Xe127	24.05	24.05	28.80	14.06			Cs136	3.32	3.38	3.01			
Xe133	15.70	15.70	13.49				Xe135	3.12	3.16	0.01			
Xe129m	14.96	14.96	14.44				Xe135m	2.07	1.66				
Xe133m	3.61	3.61	1.46				Xe133	1.70	1.73	1.25			
Xe135	1.43	1.42					Xe131m	1.23	1.25	1.10			
Cs134	0.20	0.20	0.25	85.41			Xe134m	1.07					
Cs136	0.01	0.01	0.01				Xe127	1.04	1.06	1.07			
Cs137				0.35	77.19		Xe129m	0.92	0.94	0.77			
Ba137m				0.10	22.42		Cs137	0.13	0.13	0.14	0.21	94.69	
Ba133				0.06	0.19		Cs132	0.06	0.06	0.04			
Cs135					0.20	99.25	Ba137m		0.01	0.01	0.01	5.26	
I129						0.74	I129					0.02	94.71
							Cs135						5.29

# Xenon

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6		
Xe134m	0.29 s	&Xe132(n,γ)Xe133(n,γ)Xe134m	51.0	17.2	92.6						
		&Xe131(n,γ)Xe132(n,γ)Xe133(n,γ)_Xe134m	42.4	0.2	2.9						
		&Xe129(n,γ)Xe130(n,γ)Xe131(n,γ)_Xe132(n,γ)Xe133(n,γ)Xe134m	2.5								
		Xe132(n,γ)Xe133m(n,γ)Xe134m	2.4	81.6	4.3						
		Xe131(n,γ)Xe132(n,γ)Xe133m(n,γ)_Xe134m	2.0	0.8	0.1						
		&Xe130(n,γ)Xe131(n,γ)Xe132(n,γ)_Xe133(n,γ)Xe134m	1.4								
		Xe134(n,n')Xe134m				99.4	6.5	11.7	14.7		
		Xe136(n,3n)Xe134m					92.0	87.0	84.0		
		Ba137m	2.552 m	Xe136(n,γ)Xe137(β <sup>-</sup> )Cs137(β <sup>-</sup> )Ba137m	99.1	99.2	99.9	98.9	99.1	99.3	99.7
				Xe134(n,γ)Xe135(n,γ)Xe136(n,γ)_Xe137(β <sup>-</sup> )Cs137(β <sup>-</sup> )Ba137m	0.7						
Xe135m	15.29 m	Xe134(n,γ)Xe135m	99.6	100.0	100.0		0.3	0.2	0.2		
		Xe132(n,γ)Xe133(n,γ)Xe134(n,γ)Xe135m	0.2								
		Xe131(n,γ)Xe132(n,γ)Xe133(n,γ)_Xe134(n,γ)Xe135m	0.1								
		Xe136(n,2n)Xe135m				99.9	84.8	65.7	53.2		
		Xe136(n,d)I135(β <sup>-</sup> )Xe135m					14.9	34.1	46.6		
Sb126m	19.10 m	&Xe124(n,γ)Xe125(β <sup>+</sup> )I125(n,γ)I126_(n,α)Sb123(n,γ)Sb124(n,γ)Sb125(n,γ)_Sb126m	83.7	23.7							
		&Xe124(n,α)Te121(β <sup>+</sup> )Sb121(n,γ)_Sb122(n,γ)Sb123(n,γ)Sb124(n,γ)Sb125_(n,γ)Sb126m	0.2	7.3							
		&Xe126(n,γ)Xe127(β <sup>+</sup> )I127(n,γ)I128_(n,α)Sb125(n,γ)Sb126m		60.4							
		&Xe129(n,α)Te126(n,p)Sb126m				12.6	4.6	1.3	0.9		
		&Xe129(n,p)I129(n,α)Sb126m				10.1	4.0	0.7	0.3		
		&Xe129(n,3n)Xe127(β <sup>+</sup> )I127(n,d)_Te126(n,p)Sb126m					8.0	1.6	0.1		
		Xe129(n,3n)Xe127(β <sup>+</sup> )I127(n,2n)I126_(β <sup>+</sup> )Te126(n,p)Sb126m					6.3	0.5			
		&Xe132(n,α)Te128(n,t)Sb126m					5.1	23.0	13.0		
		&Xe131(n,α)Te127m(n,d)Sb126m					4.8	3.2	1.1		
		&Xe131(n,t)I129(n,α)Sb126m					2.6	3.6	5.1		
		&Xe129(n,d)I128(β <sup>+</sup> )Te128(n,t)Sb126m					2.5	12.4	8.5		
		&Xe131(n,2nα)Te126(n,p)Sb126m					1.2	7.4	1.9		
		&Xe131(n,α)Te128(n,t)Sb126m					1.0	2.7	5.5		
		&Xe129(n,nt)I126(β <sup>+</sup> )Te126(n,p)Sb126m					0.9	5.4	8.1		
		&Xe132(n,nt)I129(n,α)Sb126m					0.1	0.7	5.5		
		&Xe131(n,nt)I128(β <sup>+</sup> )Te128(n,t)Sb126m						1.7	7.7		
		&Xe134(n,3nα)Te128(n,t)Sb126m							6.8		
		Other pathways involving (n,2n), (n,α), β <sup>+</sup>	16.1	8.6		77.3	58.9	35.8	35.5		
		Xe135	9.14 h	&Xe134(n,γ)Xe135	99.6	100.0	100.0		0.2		
				&Xe136(n,2n)Xe135				100.0	66.1	46.7	36.5
&Xe136(n,d)I135(β <sup>-</sup> )Xe135							33.9	47.9	56.7		
Sn121	1.128 d	&Xe124(n,γ)Xe125(n,α)Te122(n,γ)_Te123m(n,α)Sn120(n,γ)Sn121	72.7	0.2							
		&Xe124(n,α)Te121(β <sup>+</sup> )Sb121(n,γ)_Sb122(β <sup>-</sup> )Te122(n,γ)Te123m(n,α)_Sn120(n,γ)Sn121	9.5	3.8							

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	&Xe124(n,γ)Xe125(n,α)Te122(n,γ) Te123(n,α)Sn120(n,γ)Sn121 &Xe126(n,α)Te123(n,α)Sn120(n,γ)Sn121 Xe126(n,α)Te123m(n,α)Sn120(n,γ)Sn121 Xe126(n,2n)Xe125(β <sup>+</sup> )I125(β <sup>+</sup> )Te125 (n,2n)Te124(n,α)Sn121 Xe129(n,3n)Xe127(β <sup>+</sup> )I127(n,3n)I125 (β <sup>+</sup> )Te125(n,α)Sn121 Xe126(n,2n)Xe125(β <sup>+</sup> )I125(β <sup>+</sup> )Te125 (n,α)Sn122(n,2n)Sn121 &Xe126(n,2n)Xe125(β <sup>+</sup> )I125(β <sup>+</sup> )Te125 (n,α)Sn121 &Xe124(n,p)I124(β <sup>+</sup> )Te124(n,α)Sn121 &Xe129(n,α)Te125(n,α)Sn121 &Xe128(n,4n)Xe125(β <sup>+</sup> )I125(β <sup>+</sup> )Te125 (n,α)Sn121 &Xe131(n,2nα)Te126(n,2nα)Sn121 &Xe129(n,5n)Xe125(β <sup>+</sup> )I125(β <sup>+</sup> )Te125 (n,α)Sn121 Other pathways involving (n,2n), (n,α), β <sup>+</sup>	5.6							
			0.4	55.9						
			0.3	37.0						
						19.5				
						14.5	1.4			
						8.2				
						7.6	0.5	0.1		
						5.7				
						0.5	15.8	8.2	1.1	
								9.7	1.9	
								4.0	1.1	
									32.4	
			11.5	3.1		44.0	82.3	78.0	63.5	
I124	4.176 d	Xe124(β <sup>+</sup> )I124 Xe124(n,p)I124 &Xe126(n,2n)Xe125(β <sup>+</sup> )I125(n,2n)I124 &Xe129(n,3n)Xe127(β <sup>+</sup> )I127(n,3n)I125 (n,2n)I124 Xe128(n,3n)Xe126(n,t)I124 &Xe129(n,3n)Xe127(β <sup>+</sup> )I127(n,2n)I126 (n,3n)I124 Xe129(n,2n)Xe128(n,3n)Xe126(n,t)I124 Xe126(n,t)I124 Xe129(n,4n)Xe126(n,t)I124 &Xe129(n,3n)Xe127(β <sup>+</sup> )I127(n,4n)I124 Xe129(n,t)I127(n,4n)I124 &Xe130(n,4n)Xe127(β <sup>+</sup> )I127(n,4n)I124 &Xe131(n,5n)Xe127(β <sup>+</sup> )I127(n,4n)I124 Xe129(n,3nt)I124 Xe128(n,2nt)I124 Other pathways involving (n,2n), (n,α), β <sup>+</sup>	100.0	100.0	100.0					
						55.2	7.8	0.1		
						25.6	0.3			
							37.0			
							12.6	1.1	0.4	
							6.9			
							6.1	0.3		
							3.7	0.4	0.5	
							0.3	12.2	7.8	
								48.3	13.9	
								8.8	7.3	
								8.4	3.1	
									25.7	
									3.9	
									3.7	
						19.2	25.3	20.4	33.7	
Xe133	5.244 d	&Xe132(n,γ)Xe133 &Xe131(n,γ)Xe132(n,γ)Xe133 &Xe129(n,γ)Xe130(n,γ)Xe131(n,γ) Xe132(n,γ)Xe133 &Xe130(n,γ)Xe131(n,γ)Xe132(n,γ)Xe133 &Xe134(n,2n)Xe133 Xe134(n,d)I133(β <sup>-</sup> )Xe133 &Xe136(n,4n)Xe133 &Xe136(n,3n)Xe134(n,2n)Xe133 &Xe136(n,3n)Xe134(n,d)I133(β <sup>-</sup> )Xe133 Xe136(n,nt)I133(β <sup>-</sup> )Xe133	53.0	98.8	97.0		0.5			
			41.7	1.1	3.0					
			3.6							
			1.7							
						100.0	45.1	6.2	8.7	
							26.9	7.3	15.2	
							12.5	84.9	59.4	
							7.6			
							4.2			
							0.3	0.8	12.5	
Xe129m	8.88 d	Xe128(n,γ)Xe129m Xe131(n,2n)Xe130(n,2n)Xe129m Xe129(n,n')Xe129m Xe130(n,2n)Xe129m &Xe132(n,2n)Xe131(n,2n)Xe130(n,2n) Xe129m Xe131(n,3n)Xe129m Xe132(n,3n)Xe130(n,2n)Xe129m &Xe132(n,2n)Xe131(n,3n)Xe129m Xe132(n,4n)Xe129m Xe134(n,6n)Xe129m	99.2	100.0	100.0					
						35.9	1.6	0.6		
						28.8	9.2	6.7	9.0	
						26.8	4.9	2.9	3.8	
						6.1				
							67.7	27.5	25.6	
							6.1	1.5		
							5.7	1.6		
								52.7	46.0	
									6.5	
Xe131m	11.93 d	Xe129(n,γ)Xe130(n,γ)Xe131m Xe130(n,γ)Xe131m	81.3	86.3	32.2					
			17.8	13.7	67.8					

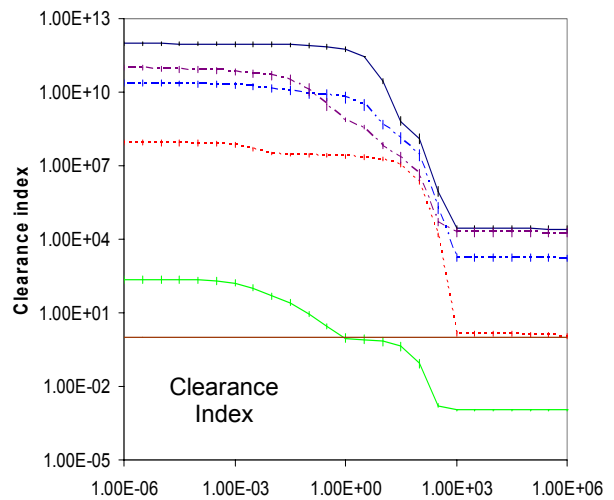
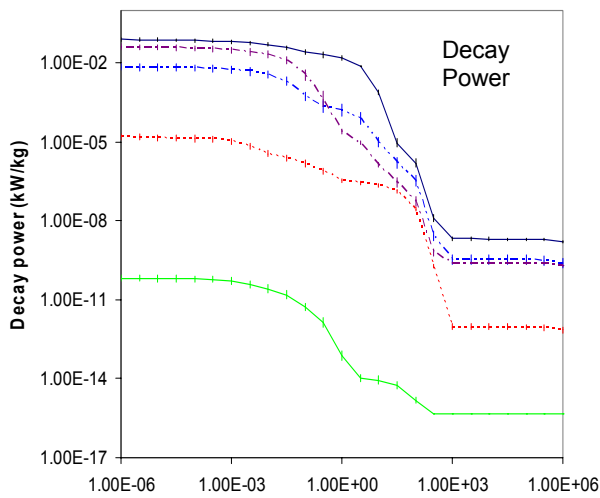
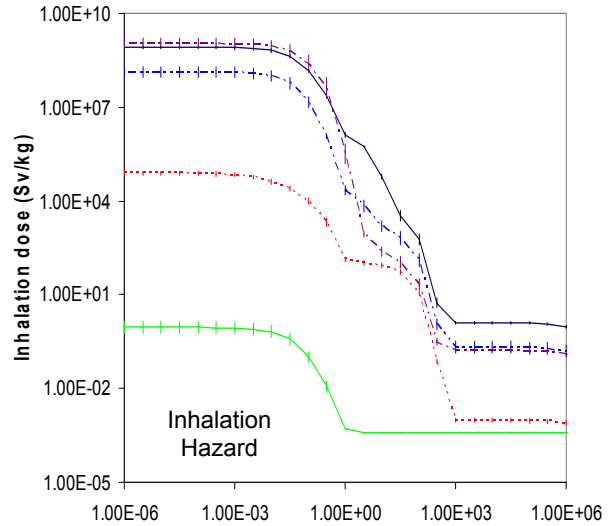
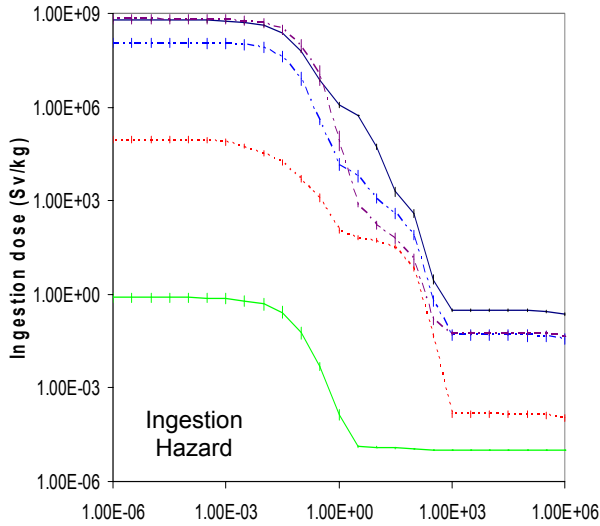
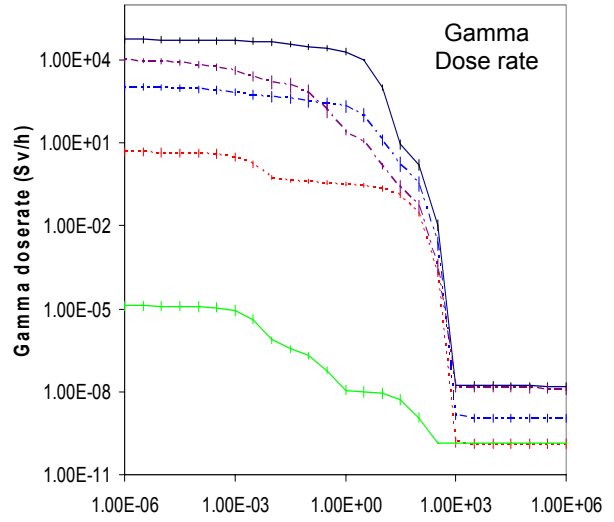
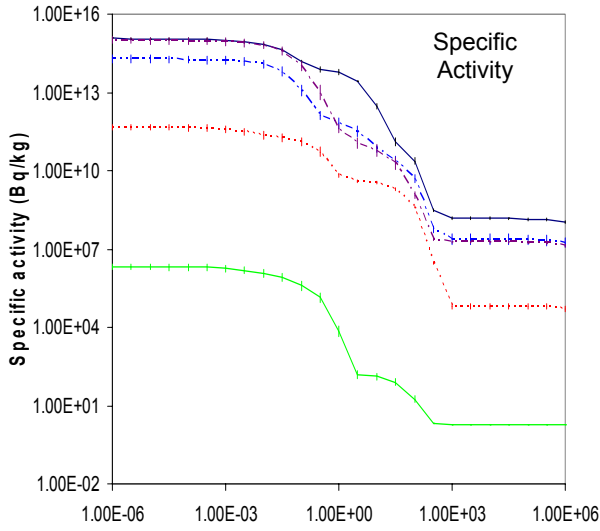
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&Xe128(n,γ)Xe129(n,γ)Xe130(n,γ)_ Xe131m Xe132(n,2n)Xe131m Xe131(n,n')Xe131m Xe132(n,2n)Xe131(n,n')Xe131m Xe134(n,4n)Xe131m Xe136(n,6n)Xe131m	0.8			87.8 8.4 1.0	75.3 15.6 0.3	39.0 8.7 45.8	45.0 10.0 25.5 14.4
Cs136	13.03 d	&Xe132(n,γ)Xe133(β <sup>-</sup> )Cs133(n,γ)_ Cs134(n,γ)Cs135(n,γ)Cs136 &Xe131(n,γ)Xe132(n,γ)Xe133(β <sup>-</sup> )_ Cs133(n,γ)Cs134(n,γ)Cs135(n,γ)Cs136 &Xe134(n,γ)Xe135(β <sup>-</sup> )Cs135(n,γ)Cs136 &Xe136(n,γ)Xe137(β <sup>-</sup> )Cs137(n,2n)Cs136 &Xe136(n,2n)Xe135(β <sup>-</sup> )Cs135(n,γ)Cs136 &Xe136(n,d)I135(β <sup>-</sup> )Xe135(β <sup>-</sup> )Cs135_ (n,γ)Cs136	62.9 33.6 1.9	90.4 0.3 8.9	100.0	50.0 50.0	56.6 28.5 14.1	45.2 24.9 28.9	36.9 22.4 39.5
Te121	19.16 d	&Xe124(n,α)Te121 Xe124(n,2n)Xe123(β <sup>+</sup> )I123(β <sup>+</sup> )Te123_ (n,2n)Te122(n,2n)Te121 &Xe124(n,2n)Xe123(β <sup>+</sup> )I123(β <sup>+</sup> )Te123_ (n,3n)Te121 &Xe124(n,3n)Xe122(β <sup>+</sup> )I122(β <sup>+</sup> )Te122_ (n,2n)Te121 &Xe124(n,d)I123(β <sup>+</sup> )Te123(n,3n)Te121 &Xe129(n,4n)Xe126(n,2nα)Te121 &Xe129(n,2nα)Te124(n,4n)Te121 Xe129(n,4n)Xe126(n,3n)Xe124(n,4n)_ Xe121(β <sup>+</sup> )I121(β <sup>+</sup> )Te121 Xe124(n,4n)Xe121(β <sup>+</sup> )I121(β <sup>+</sup> )Te121 &Xe129(n,5n)Xe125(β <sup>+</sup> )I125(β <sup>+</sup> )Te125_ (n,5n)Te121 &Xe129(n,2nt)I125(β <sup>+</sup> )Te125(n,5n)Te121 Other pathways involving (n,2n), (n,α), β <sup>+</sup>	100.0	100.0	99.9	18.8 40.6 20.3	1.4 0.1 0.9 9.0 3.8	0.1 17.8 11.6 4.5 2.7	0.1 1.4 1.5 0.6 2.2 11.8 4.3 78.2
Xe127	36.40 d	&Xe126(n,γ)Xe127 &Xe124(n,γ)Xe125(β <sup>+</sup> )I125(n,γ)I126_ (β <sup>-</sup> )Xe126(n,γ)Xe127 &Xe129(n,2n)Xe128(n,2n)Xe127 &Xe128(n,2n)Xe127 &Xe129(n,3n)Xe127 &Xe131(n,3n)Xe129(n,3n)Xe127 &Xe130(n,4n)Xe127 &Xe132(n,4n)Xe129(n,3n)Xe127 &Xe132(n,3n)Xe130(n,4n)Xe127 &Xe131(n,5n)Xe127	94.5 3.9	99.9	99.9	75.0 21.7	1.3 1.4 80.1 11.7	0.8 1.3 62.0 3.4 10.8 6.9 5.6	0.2 0.8 26.1 0.6 5.9 1.1 1.3 48.2
I125	59.407 d	&Xe124(n,γ)Xe125(β <sup>+</sup> )I125 &Xe126(n,2n)Xe125(β <sup>+</sup> )I125 &Xe129(n,2n)Xe128(n,2n)Xe127(β <sup>+</sup> )I127_ (n,2n)I126(β <sup>-</sup> )Xe126(n,2n)Xe125(β <sup>+</sup> )I125 &Xe128(n,2n)Xe127(β <sup>+</sup> )I127(n,2n)I126_ (β <sup>-</sup> )Xe126(n,2n)Xe125(β <sup>+</sup> )I125 &Xe129(n,3n)Xe127(β <sup>+</sup> )I127(n,3n)I125 &Xe131(n,4n)Xe128(n,4n)Xe125(β <sup>+</sup> )I125 &Xe128(n,4n)Xe125(β <sup>+</sup> )I125 &Xe129(n,4n)Xe126(n,2n)Xe125(β <sup>+</sup> )I125 &Xe129(n,2n)Xe128(n,4n)Xe125(β <sup>+</sup> )I125 Xe129(n,2nt)I125 &Xe129(n,5n)Xe125(β <sup>+</sup> )I125	100.0	100.0	100.0	57.3 14.1 13.1	0.6 0.3 77.5	0.3 20.4 15.3 12.6 8.4 7.5 0.4	1.0 1.8 3.7 1.3 1.4 6.8 58.7
Cs134	2.065 y ▶	&Xe132(n,γ)Xe133(β <sup>-</sup> )Cs133(n,γ)Cs134 &Xe131(n,γ)Xe132(n,γ)Xe133(β <sup>-</sup> )_ Cs133(n,γ)Cs134	58.8 38.9	99.4 0.4	98.7 1.2				



Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	&Xe129(n,γ)Xe130(n,γ)Xe131(n,γ)_ Xe132(n,γ)Xe133(β <sup>-</sup> )Cs133(n,γ)Cs134 &Xe130(n,γ)Xe131(n,γ)Xe132(n,γ)_ Xe133(β <sup>-</sup> )Cs133(n,γ)Cs134 &Xe136(n,2n)Xe135(β <sup>-</sup> )Cs135(n,2n)Cs134 Xe136(n,d)I135(β <sup>-</sup> )Xe135(β <sup>-</sup> )Cs135_ (n,2n)Cs134	1.2 0.7				99.6 65.9 30.6	44.9 49.2	35.4 58.7	
Sb125	2.759 y	&Xe124(n,γ)Xe125(β <sup>+</sup> )I125(n,γ)I126_ (n,α)Sb123(n,γ)Sb124(n,γ)Sb125 &Xe124(n,α)Te121(β <sup>+</sup> )Sb121(n,γ)_ Sb122(n,γ)Sb123(n,γ)Sb124(n,γ)Sb125 &Xe126(n,γ)Xe127(β <sup>+</sup> )I127(n,γ)I128_ (n,α)Sb125 &Xe126(n,2n)Xe125(β <sup>+</sup> )I125(β <sup>+</sup> )Te125_ (n,p)Sb125 Xe128(n,2n)Xe127(β <sup>+</sup> )I127(n,2n)I126_ (β <sup>+</sup> )Te126(n,d)Sb125 &Xe129(n,nα)Te125(n,p)Sb125 &Xe129(n,3n)Xe127(β <sup>+</sup> )I127(n,d)_ Te126(n,d)Sb125 Xe129(n,3n)Xe127(β <sup>+</sup> )I127(n,2n)I126_ (β <sup>+</sup> )Te126(n,d)Sb125 &Xe129(n,3n)Xe127(β <sup>+</sup> )I127(n,h)Sb125 Xe131(n,t)I129(n,nα)Sb125 Xe131(n,2nα)Te126(n,d)Sb125 Xe129(n,nt)I126(β <sup>+</sup> )Te126(n,d)Sb125 Xe132(n,3nα)Te126(n,d)Sb125 &Xe129(n,5n)Xe125(β <sup>+</sup> )I125(β <sup>+</sup> )Te125_ (n,p)Sb125 Other pathways involving (n,2n), (n,α), β <sup>+</sup>	99.5 0.3	28.7 8.3 61.9	13.2 44.9 32.1		47.5 6.5 2.1	0.3 0.3 6.0 7.0 5.9 4.0 3.8 1.1 1.0	1.8 2.7 0.8 8.0 7.9 13.8 10.0 0.3	0.3 0.3 0.1 1.8 3.4 5.6 23.1 6.3 8.8
Ba133	10.54 y	&Xe136(n,2n)Xe135(β <sup>-</sup> )Cs135(n,2n)_ Cs134(β <sup>-</sup> )Ba134(n,2n)Ba133 &Xe136(n,d)I135(β <sup>-</sup> )Xe135(β <sup>-</sup> )Cs135_ (n,2n)Cs134(β <sup>-</sup> )Ba134(n,2n)Ba133 &Xe136(n,γ)Xe137(β <sup>-</sup> )Cs137(β <sup>-</sup> )_ Ba137(n,5n)Ba133				99.5	56.4 20.7	37.8 32.6	27.8 36.0 10.0	
H3	12.33 y	&Xe124(n,γ)Xe125(β <sup>+</sup> )I125(n,γ)I126_ (n,X)H1(n,γ)H2(n,γ)H3 Xe129(n,X)H3 Xe131(n,X)H3 &Xe132(n,2n)Xe131(n,X)H3 Xe132(n,X)H3 Xe134(n,X)H3 Xe136(n,X)H3 Xe130(n,X)H3	92.1	94.5			54.7 31.0 5.3 0.2	33.7 24.8 1.1 14.7 5.3 4.1 2.6	29.4 22.1 0.5 18.5 6.6 5.1 3.1	27.7 21.1 0.3 20.5 7.3 5.7 3.4
Cs137	30.041 y	Xe136(n,γ)Xe137(β <sup>-</sup> )Cs137 Xe134(n,γ)Xe135(n,γ)Xe136(n,γ)_ Xe137(β <sup>-</sup> )Cs137 Xe132(n,γ)Xe133(β <sup>-</sup> )Cs133(n,γ)Cs134_ (n,γ)Cs135(n,γ)Cs136(n,γ)Cs137	99.2 0.7	99.2	100.0	100.0	99.8	99.9	99.9	
Sn121m	55.0 y	&Xe124(n,γ)Xe125(n,α)Te122(n,γ)_ Te123m(n,α)Sn120(n,γ)Sn121m &Xe126(n,γ)Xe127(n,α)Te124(n,α)_ Sn121m &Xe124(n,α)Te121(β <sup>+</sup> )Sb121(n,γ)_ Sb122(β <sup>-</sup> )Te122(n,γ)Te123m(n,α)_ Sn120(n,γ)Sn121m &Xe124(n,γ)Xe125(n,α)Te122(n,γ)_ Te123(n,α)Sn120(n,γ)Sn121m &Xe126(n,α)Te123(n,α)Sn120(n,γ)_ Sn121m	52.6 28.5 4.9 4.0 0.3	0.2						

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Xe126(n,α)Te123m(n,α)Sn120(n,γ)_ Sn121m &Xe126(n,2n)Xe125(β <sup>+</sup> )I125(β <sup>+</sup> )Te125_ (n,α)Sn121m Xe126(n,2n)Xe125(β <sup>+</sup> )I125(β <sup>+</sup> )Te125_ (n,2n)Te124(n,α)Sn121m Xe126(n,2n)Xe125(β <sup>+</sup> )I125(β <sup>+</sup> )Te125_ (n,α)Sn122(n,2n)Sn121m Xe124(n,p)I124(β <sup>+</sup> )Te124(n,α)Sn121m &Xe129(n,α)Te125(n,α)Sn121m Xe129(n,3n)Xe127(β <sup>+</sup> )I127(n,3n)I125_ (β <sup>+</sup> )Te125(n,α)Sn121m &Xe128(n,4n)Xe125(β <sup>+</sup> )I125(β <sup>+</sup> )Te125_ (n,α)Sn121m Xe131(n,2nα)Te126(n,2nα)Sn121m Xe129(n,nt)I126(β <sup>+</sup> )Te126(n,2nα)Sn121m Xe129(n,2nt)I125(β <sup>+</sup> )Te125(n,α)Sn121m &Xe129(n,5n)Xe125(β <sup>+</sup> )I125(β <sup>+</sup> )Te125_ (n,α)Sn121m Other pathways involving (n,2n), (n,α), β <sup>+</sup>	0.3	39.1	13.8		25.4	1.3	0.4	
						11.3				
						10.5				
						5.1				
						1.1	22.0	12.3	1.6	
							14.4	1.5		
								16.2	3.0	
								4.7	1.6	
								3.4	6.6	
								0.5	5.5	
									47.3	
			9.4	3.7	6.7	46.6	62.3	61.0	34.4	
Ag108m	418.0 y	Pathways involving (n,α), (n,nα), (n,2n), β <sup>-</sup> , β <sup>+</sup>				100.0	100.0	100.0	100.0	
Cs135	2.3 10 <sup>6</sup> y	&Xe132(n,γ)Xe133(β <sup>-</sup> )Cs133(n,γ)_ Cs134(n,γ)Cs135 &Xe131(n,γ)Xe132(n,γ)Xe133(β <sup>-</sup> )_ Cs133(n,γ)Cs134(n,γ)Cs135 &Xe134(n,γ)Xe135(β <sup>-</sup> )Cs135 &Xe129(n,γ)Xe130(n,γ)Xe131(n,γ)_ Xe132(n,γ)Xe133(β <sup>-</sup> )Cs133(n,γ)Cs134_ (n,γ)Cs135 &Xe136(n,2n)Xe135(β <sup>-</sup> )Cs135 &Xe136(n,d)I135(β <sup>-</sup> )Xe135(β <sup>-</sup> )Cs135	62.9	90.7	0.2					
			33.9	0.3						
			2.0	8.9	99.7		0.4	0.1		
			0.5							
						99.6	66.1	45.6	35.7	
							33.0	53.8	63.9	
I129	1.6 10 <sup>7</sup> y	&Xe124(n,γ)Xe125(β <sup>+</sup> )I125(n,γ)I126_ (n,γ)I127(n,γ)I128(β <sup>+</sup> )Te128(n,γ)Te129_ (β <sup>-</sup> )I129 &Xe126(n,γ)Xe127(β <sup>+</sup> )I127(n,γ)I128_ (β <sup>+</sup> )Te128(n,γ)Te129(β <sup>-</sup> )I129 Xe129(n,p)I129 &Xe132(n,α)Te129(β <sup>-</sup> )I129 Xe132(n,α)Te129m(β <sup>-</sup> )I129 Xe131(n,2n)Xe130(n,d)I129 Xe130(n,d)I129 Xe131(n,t)I129 Xe132(n,3n)Xe130(n,d)I129 Xe132(n,nt)I129	81.5							
			6.2	97.6	95.3					
						76.9	25.4	9.4	2.7	
						13.5	9.9	2.0	1.5	
						2.6	3.5	0.8	0.6	
						2.6				
						1.7	17.7	12.7	6.4	
						0.8	22.2	50.8	38.3	
							11.1	3.4	0.7	
							1.2	9.8	41.8	

# Xenon activation characteristics

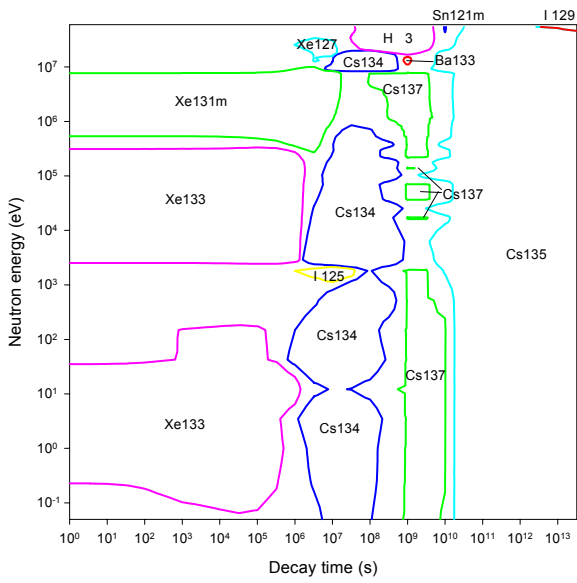


Decay time (years)

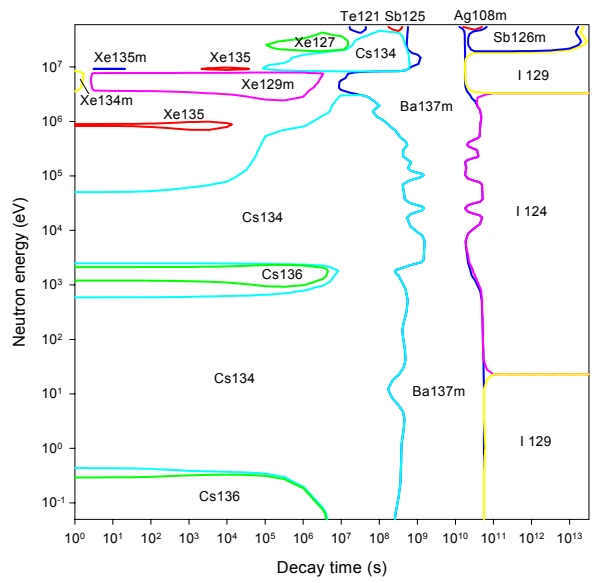
Decay time (years)

# Xenon importance diagrams & transmutation

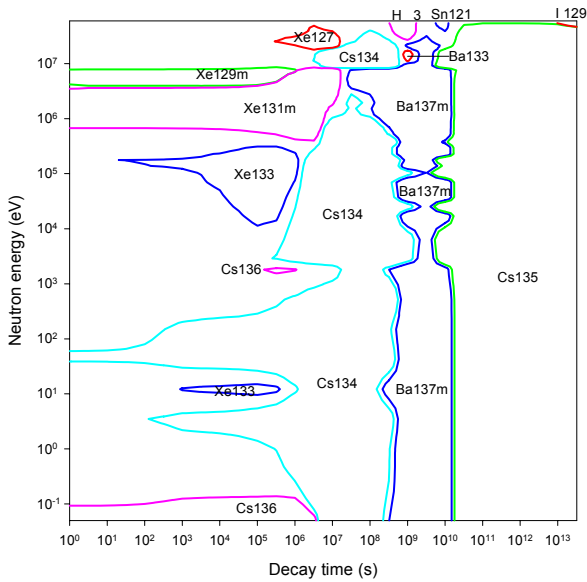
Activity



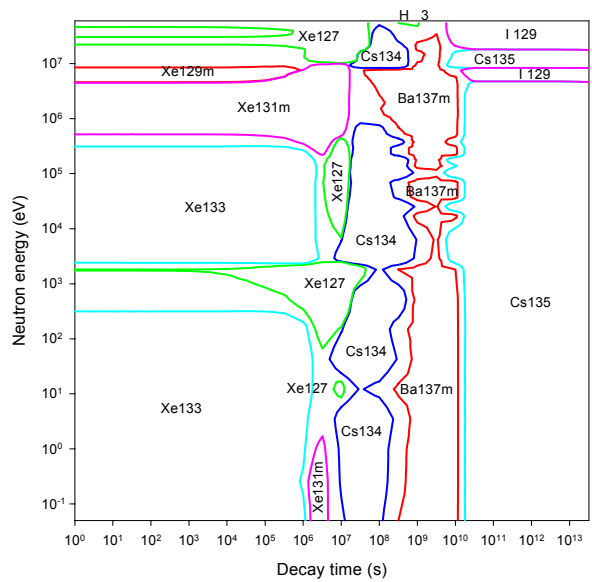
Dose rate



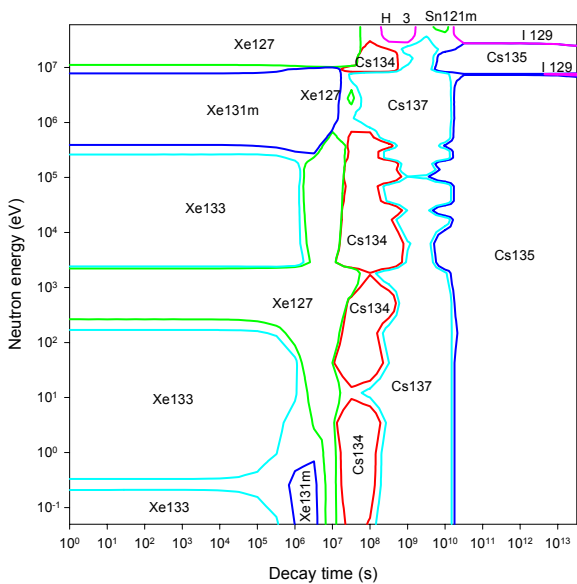
Heat output



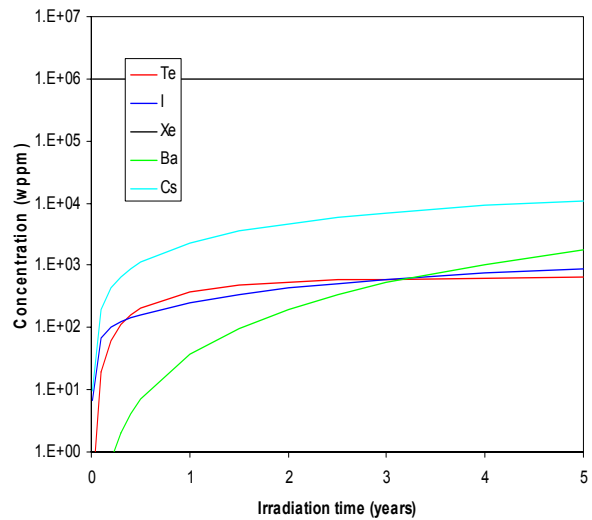
Ingestion dose



Inhalation dose



First wall transmutation



# Caesium

## General properties

Atomic number	55	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	3.0	Cs133	100.0
Melting point / K	301.6		
Boiling point / K	944		
Density / kgm <sup>-3</sup>	1873		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	35.9		
Electrical resistivity /Ωm	2.0 10 <sup>-7</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	9.7 10 <sup>-5</sup>		
Crystal structure	BCC		
Number of stable isotopes	1		
Mean atomic weight	132.90543		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	1.28E16	1.28E16	1.13E16	7.66E15	5.83E10	1.80E9	kW kg <sup>-1</sup>	3.17E0	3.17E0	3.09E0	2.10E0	4.07E-6	2.58E-8
Cs134	83.22	83.42	93.89	99.59			Cs134	92.58	92.66	94.88	99.89		
Cs134m	8.02	7.87					Cs136	4.70	4.71	3.98			
Cs136	3.18	3.18	2.96				Cs132	1.40	1.41	0.98			
Cs132	2.98	2.98	2.29				Cs134m	0.72	0.71				
Ba133m	1.16	1.16	0.27				Ba133m	0.22	0.22	0.05			
Ba135m	0.83	0.83	0.11				Ba135m	0.14	0.14	0.02			
Ba133	0.26	0.26	0.30	0.41	80.09		Ba133	0.08	0.08	0.08	0.11	83.59	
Cs137					8.48		Ba137m					12.10	
Ba137m					8.01		Cs137					3.65	
Cs135					3.19	100.0	Cs135					0.65	100.0
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	4.02E6	4.02E6	3.94E6	2.67E6	2.34E0	1.90E-9	Sv kg <sup>-1</sup>	2.22E8	2.22E8	2.16E8	1.45E8	2.27E2	3.60E0
Cs134	92.75	92.78	94.24	99.96			Cs134	91.21	91.21	93.53	99.97		
Cs136	5.60	5.60	4.70				Cs136	0.55	0.55	0.47			
Cs132	1.48	1.48	1.02				Ba133	0.02	0.02	0.02	0.03	30.89	
Ba133	0.03	0.03	0.03	0.04	73.32		Ba137m					39.12	
Ba137m					26.68		Cs137					28.35	
I129						99.84	Cs135					1.64	99.98
							I129						0.02
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	2.36E8	2.36E8	2.30E8	1.53E8	7.32E2	1.55E1		1.07E14	1.07E14	1.07E14	7.63E13	7.09E7	1.87E4
Cs134	90.29	90.29	92.51	99.79			Cs134	99.53	99.54	99.64	99.98		
Cs136	0.48	0.48	0.41				Cs136	0.38	0.38	0.31			
Ba133	0.14	0.14	0.15	0.21	63.80		Ba133	0.01	0.01	0.01	0.02	26.34	
Cs132	0.05	0.05	0.03				Cs137					69.75	
Cs137					26.36		Ba137m					3.87	
Cs135					2.18	100.0	Cs135					0.03	96.54

# Caesium

## Pathway analysis

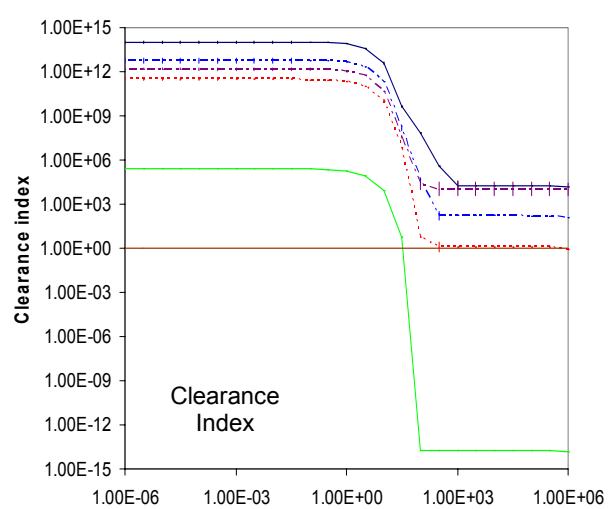
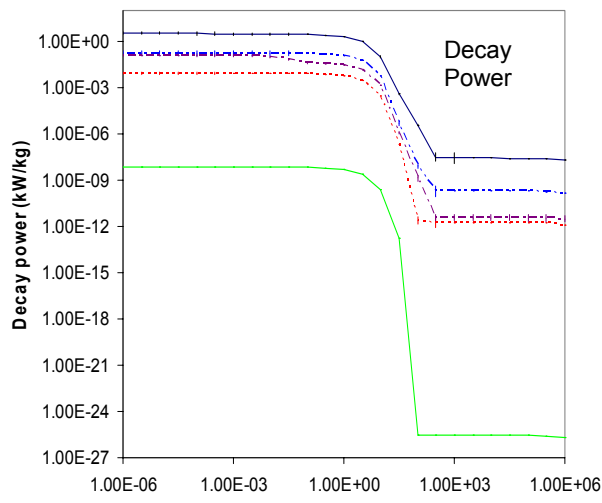
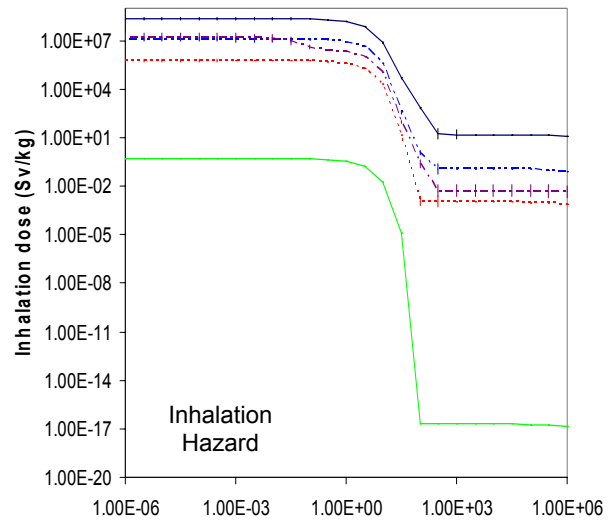
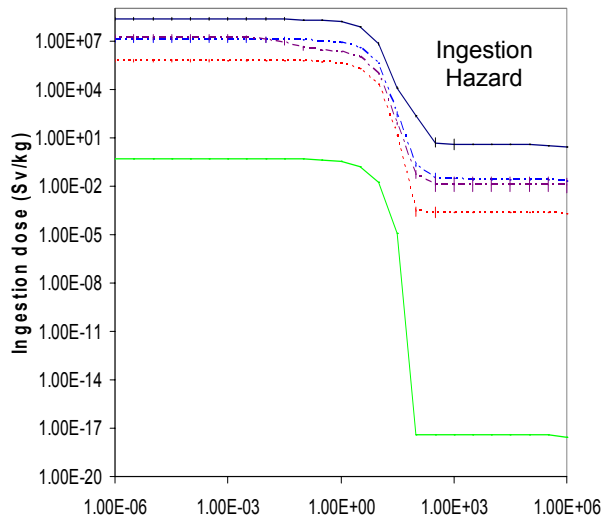
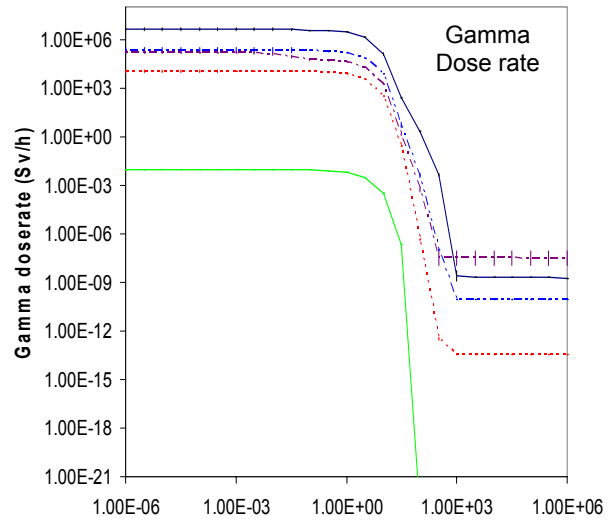
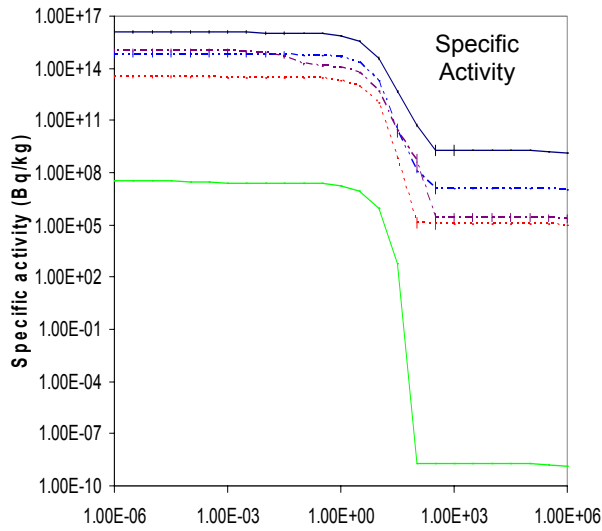
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
Ba137m	2.552 m	&Cs133(n,γ)Cs134(n,γ)Cs135(n,γ) Cs136(β <sup>-</sup> )Ba136(n,γ)Ba137m	85.4	0.3	63.3	63.6	79.6	79.9	80.2	
		&Cs133(n,γ)Cs134(n,γ)Cs135(n,γ) Cs136(n,γ)Cs137(β <sup>-</sup> )Ba137m	13.1	99.5	16.8	0.1	0.2	0.2	0.2	
		&Cs133(n,γ)Cs134(n,γ)Cs135(n,γ) Cs136m(β <sup>-</sup> )Ba136(n,γ)Ba137m	0.6		0.5	2.9	3.6	3.5	3.5	
		&Cs133(n,γ)Cs134(β <sup>-</sup> )Ba134(n,γ) Ba135(n,γ)Ba136(n,γ)Ba137m	0.5		19.0	30.8	10.5	9.9	9.5	
Cs130	29.21 m	&Cs133(n,2n)Cs132(β <sup>-</sup> )Ba132(n,2n) Ba131(β <sup>+</sup> )Cs131(n,2n)Cs130				72.7				
		Cs133(n,2n)Cs132(n,2n)Cs131(n,2n)Cs130				24.9				
		Cs133(n,3n)Cs131(n,2n)Cs130					68.1			
		Cs133(n,2n)Cs132(n,3n)Cs130					30.1			
		&Cs133(n,4n)Cs130						100.0	100.0	
Sn121	1.128 d	Cs133(n,nα)I129(n,3n)I127(n,3n)I125 (β <sup>+</sup> )Te125(n,nα)Sn121					10.3	0.2		
		&Cs133(n,3n)Cs131(β <sup>+</sup> )Xe131(n,2nα) Te126(n,2nα)Sn121					0.2	7.9	0.4	
		&Cs133(n,nα)I129(n,4n)I126(β <sup>+</sup> ) Te126(n,2nα)Sn121						4.3	0.2	
		&Cs133(n,4n)Cs130(β <sup>+</sup> )Xe130(n,nα) Te126(n,2nα)Sn121						2.7	4.5	
		&Cs133(n,4n)I126(β <sup>+</sup> )Te126(n,2nα)Sn121							5.6	
		Cs133(n,5n)Cs129(β <sup>+</sup> )Xe129(n,nt)I126 (β <sup>+</sup> )Te126(n,2nα)Sn121							3.5	
		Cs133(n,5n)Cs129(β <sup>+</sup> )Xe129(n,2nt) I125(β <sup>+</sup> )Te125(n,nα)Sn121							3.4	
		Other pathways involving (n,2n), (n,α), β <sup>+</sup>					100.0	89.5	84.9	82.4
Xe133	5.244 d	&Cs133(n,γ)Cs134(n,α)I131(β <sup>-</sup> )Xe131 (n,γ)Xe132(n,γ)Xe133	94.4	2.6	27.1					
		&Cs133(n,γ)Cs134(β <sup>-</sup> )Ba134(n,γ) Ba135(n,α)Xe132(n,γ)Xe133	4.0	0.5	70.7					
		&Cs133(n,γ)Cs134(n,γ)Cs135(n,γ) Cs136(n,α)I133(β <sup>-</sup> )Xe133		96.6						
		&Cs133(n,p)Xe133				100.0	100.0	100.0	100.0	
Cs132	6.53 d	Cs133(n,2n)Cs132				99.8	99.7	99.8	99.9	
Xe129m	8.88 d	Cs133(n,2n)Cs132(β <sup>+</sup> )Xe132(n,2n) Xe131(n,2n)Xe130(n,2n)Xe129m				89.6				
		&Cs133(n,α)I130(β <sup>-</sup> )Xe130(n,2n)Xe129m				8.5				
		Cs133(n,3n)Cs131(β <sup>+</sup> )Xe131(n,3n)Xe129m					92.8	38.0	9.0	
		&Cs133(n,t)Xe131(n,3n)Xe129m					1.4	4.7	3.1	
		&Cs133(n,4n)Cs130(β <sup>+</sup> )Xe130(n,2n)Xe129m						20.6	4.1	
		Cs133(n,2n)Cs132(β <sup>+</sup> )Xe132(n,4n)Xe129m						18.3	7.1	
		Cs133(n,d)Xe132(n,4n)Xe129m						13.7	7.3	
		Cs133(n,2nt)Xe129m						0.8	53.3	
		Cs133(n,nt)Xe130(n,2n)Xe129m						0.7	3.1	
		Cs133(n,5n)Cs129(β <sup>+</sup> )Xe129(n,n')Xe129m							5.9	
Cs131	9.69 d	&Cs133(n,2n)Cs132(β <sup>-</sup> )Ba132(n,2n) Ba131(β <sup>+</sup> )Cs131				63.0				
		Cs133(n,2n)Cs132(n,2n)Cs131				26.6				
		Cs133(n,3n)Cs131					99.7	99.8	99.9	
Xe131m	11.93 d	&Cs133(n,γ)Cs134(n,α)I131(β <sup>-</sup> )Xe131m	99.8	99.8	92.6					
		&Cs133(n,γ)Cs134(β <sup>-</sup> )Ba134(n,α)Xe131m	0.2	0.2	3.0					
		Cs133(n,2n)Cs132(β <sup>+</sup> )Xe132(n,2n)Xe131m				96.9	29.5	8.6		
		Cs133(n,d)Xe132(n,2n)Xe131m				1.3	11.7	6.5		
		Cs133(n,3n)Cs131(β <sup>+</sup> )Xe131(n,n')Xe131m					31.4	7.6		

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6		
	◀	Cs133(n,t)Xe131m					26.1	75.9	90.4		
Cs136	13.03 d	&Cs133(n,γ)Cs134(n,γ)Cs135(n,γ)Cs136	99.8	99.8	100.0	99.5	98.3	99.6	99.7		
Xe127	36.40 d	&Cs133(n,nα)I129(n,2n)I128(β <sup>-</sup> )_Xe128(n,2n)Xe127 Cs133(n,2n)Cs132(β <sup>+</sup> )Xe132(n,2n)_Xe131(n,2n)Xe130(n,2n)Xe129(n,2n)_Xe128(n,2n)Xe127 Cs133(n,2n)Cs132(β <sup>+</sup> )Xe132(n,α)_Te129(β <sup>-</sup> )I129(n,2n)I128(β <sup>-</sup> )Xe128_(n,2n)Xe127 Cs133(n,α)I130(β <sup>-</sup> )Xe130(n,2n)Xe129_(n,2n)Xe128(n,2n)Xe127 &Cs133(n,3n)Cs131(β <sup>+</sup> )Xe131(n,3n)_Xe129(n,3n)Xe127 &Cs133(n,4n)Cs130(β <sup>+</sup> )Xe130(n,4n)Xe127 &Cs133(n,nt)Xe130(n,4n)Xe127 &Cs133(n,3n)Cs131(β <sup>+</sup> )Xe131(n,5n)Xe127 &Cs133(n,5n)Cs129(β <sup>+</sup> )Xe129(n,3n)Xe127 &Cs133(n,t)Xe131(n,5n)Xe127 Other pathways involving (n,2n), (n,α), β <sup>+</sup>				9.2 6.2 5.8 1.6 88.8 77.2		0.7 81.5 2.8 0.1 25.5 26.2 10.6 9.9		20.6 7.2 25.5 26.2 10.6 9.9	
Cs134	2.065 y	&Cs133(n,γ)Cs134	100.0	100.0	100.0	99.8	99.7	99.8	99.9		
Sb125	2.759 y	Cs133(n,nα)I129(n,nα)Sb125 Cs133(n,2n)Cs132(β <sup>+</sup> )Xe132(n,α)_Te129(β <sup>-</sup> )I129(n,nα)Sb125 Cs133(n,2n)Cs132(β <sup>+</sup> )Xe132(n,α)_Te129m(β <sup>-</sup> )I129(n,nα)Sb125 Cs133(n,2n)Cs132(β <sup>+</sup> )Xe132(n,nα)_Te128(n,α)Sn125m(β <sup>-</sup> )Sb125 Cs133(n,2n)Cs132(β <sup>+</sup> )Xe132(n,nα)Te128(n,α)Sn125(β <sup>-</sup> )Sb125 Cs133(n,3n)Cs131(β <sup>+</sup> )Xe131(n,t)_I129(n,nα)Sb125 Cs133(n,3n)Cs131(β <sup>+</sup> )Xe131(n,2nα)_Te126(n,d)Sb125 Cs133(n,3n)Cs131(β <sup>+</sup> )Xe131(n,nα)_Te127m(n,t)Sb125 &Cs133(n,4n)Cs130(β <sup>+</sup> )Xe130(n,nα)_Te126(n,d)Sb125 &Cs133(n,4n)Cs130(β <sup>+</sup> )Xe130(n,d)_I129(n,nα)Sb125 Cs133(n,nα)I129(n,4n)I126(β <sup>+</sup> )_Te126(n,d)Sb125 Cs133(n,4nα)I126(β <sup>+</sup> )Te126(n,d)Sb125 Cs133(n,2nα)I128(β <sup>+</sup> )Te128(n,nt)Sb125 Cs133(n,2nα)Sb125 Cs133(n,3nα)I127(n,h)Sb125 Other pathways involving (n,2n), (n,α), β <sup>+</sup>				13.3 11.6 3.3 2.5 2.3 5.7 1.7 1.4 8.9 7.3 5.2 67.0	80.5 0.2 0.2 0.1 0.1 5.5 9.6 1.4 8.9 7.3 5.2 10.1	31.6 31.6 31.6 31.6 31.6 5.5 9.6 1.4 8.9 7.3 5.2 30.5	8.2 8.2 8.2 8.2 8.2 5.5 9.6 1.4 8.9 7.3 5.2 55.6		21.6 6.9 4.6 3.1 55.6
Ba133	10.54 y	&Cs133(n,γ)Cs134(β <sup>-</sup> )Ba134(n,2n)Ba133 &Cs133(n,2n)Cs132(β <sup>-</sup> )Ba132(n,γ)Ba133				84.9 15.0	97.3 2.6	96.8 3.2	96.6 2.6		
H3	12.33 y	&Cs133(n,γ)Cs134(n,X)H1(n,γ)H2(n,γ)H3 Cs133(n,X)H3 Cs133(n,2n)Cs132(n,X)H3 Cs133(n,3n)Cs131(β <sup>+</sup> )Xe131(n,X)H3 Cs133(n,2n)Cs132(β <sup>+</sup> )Xe132(n,X)H3 Cs133(n,4n)Cs130(β <sup>+</sup> )Xe130(n,X)H3 Cs133(n,5n)Cs129(β <sup>+</sup> )Xe129(n,X)H3	93.6	94.8	99.5	97.5 1.5	89.7 7.6 0.9 1.2	89.6 4.0 0.8 1.2	89.0 1.5 3.7		
Cs137	30.041 y	&Cs133(n,γ)Cs134(n,γ)Cs135(n,γ)_Cs136(n,γ)Cs137	99.8	99.8	100.0	96.9	95.9	96.0	96.2		
Sn121m	55.0 y ▶	Cs133(n,nα)I129(n,3n)I127(n,3n)I125_(β <sup>+</sup> )Te125(n,nα)Sn121m					12.0	0.2			

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Cs133(n,3n)Cs131(β <sup>+</sup> )Xe131(n,3n)_ Xe129(n,nα)Te125(n,nα)Sn121m Cs133(n,3n)Cs131(β <sup>+</sup> )Xe131(n,2nα)_ Te126(n,2nα)Sn121m &s133(n,4n)Cs130(β <sup>+</sup> )Xe130(n,nα)_ Te126(n,2nα)Sn121m Cs133(n,nα)I129(n,4n)I126(β <sup>+</sup> )Te126_ (n,2nα)Sn121m &s133(n,4n)Cs130(β <sup>+</sup> )Xe130(n,2nα)_ Te125(n,nα)Sn121m Cs133(n,4nα)I126(β <sup>+</sup> )Te126(n,2nα)Sn121m   Cs133(n,5n)Cs129(β <sup>+</sup> )Xe129(n,2nt)_ I125(β <sup>+</sup> )Te125(n,nα)Sn121m Other pathways involving (n,2n), (n,α), β <sup>+</sup>					1.7			
							0.3	8.5	0.7	
								7.9	0.6	
								4.6	0.3	
								4.1	0.3	
									10.4	
									4.2	
							100.0	86.0	74.7	83.5
Ag108m	418.0 y	Pathways involving (n,α), (n,nα), (n,2n), β <sup>-</sup> , β <sup>+</sup>					100.0	100.0	100.0	100.0
Ho166m	1200 y	Threshold for production lies below 0.26eV								
Cs135	2.3 10 <sup>6</sup> y	&Cs133(n,γ)Cs134(n,γ)Cs135	99.9	99.9	100.0	99.9	99.5	99.7	99.8	
I129	1.6 10 <sup>7</sup> y	&Cs133(n,γ)Cs134(n,α)I131(β <sup>-</sup> )Xe131_ (n,α)Te128(n,γ)Te129(β <sup>-</sup> )I129 &Cs133(n,γ)Cs134(n,α)I131(β <sup>-</sup> )Xe131_ (n,α)Te128(n,γ)Te129m(β <sup>-</sup> )I129 &Cs133(n,γ)Cs134(β <sup>-</sup> )Ba134(n,α)_ Xe131(n,α)Te128(n,γ)Te129(β <sup>-</sup> )I129 &Cs133(n,2n)Cs132(β <sup>+</sup> )Xe132(n,α)_ Te129(β <sup>-</sup> )I129 Cs133(n,nα)I129 Cs133(n,2n)Cs132(β <sup>+</sup> )Xe132(n,α)_ Te129m(β <sup>-</sup> )I129 Cs133(n,2n)Cs132(n,α)I129 Cs133(n,3n)Cs131(β <sup>+</sup> )Xe131(n,t)I129 Cs133(n,t)Xe131m(IT)Xe131(n,t)I129 &Cs133(n,4n)Cs130(β <sup>+</sup> )Xe130(n,d)I129 Cs133(n,2n)Cs132(β <sup>+</sup> )Xe132(n,nt)I129 Cs133(n,nt)Xe130(n,d)I129 Cs133(n,d)Xe132(n,nt)I129 Cs133(n,5n)Cs129(β <sup>+</sup> )Xe129(n,p)I129	96.1	95.5	94.5					
			2.5	2.5	2.4					
					0.5					
						55.1	0.3			
						31.2	87.0	60.7	60.3	
						10.6	0.3			
						1.3				
							8.6	14.6	9.5	
							0.1	1.5	3.3	
								19.0	4.9	
								0.7	4.6	
								0.7	3.7	
								0.5	4.7	
									1.3	
La138	1.0 10 <sup>11</sup> y	&Cs133(n,γ)Cs134(n,γ)Cs135(n,γ)_ Cs136(β <sup>-</sup> )Ba136(n,γ)Ba137(n,γ)Ba138_ (n,γ)Ba139(β <sup>-</sup> )La139(n,γ)La140(β <sup>-</sup> )_ Ce140(n,γ)Ce141(β <sup>-</sup> )Pr141(n,α)La138 &Cs133(n,γ)Cs134(n,γ)Cs135(n,γ)_ Cs136(β <sup>-</sup> )Ba136(n,γ)Ba137(n,γ)Ba138_ (n,γ)Ba139(β <sup>-</sup> )La139(n,γ)La140(n,γ)_ La141(β <sup>-</sup> )Ce141(β <sup>-</sup> )Pr141(n,α)La138	91.7							
			4.7							



# Caesium activation characteristics

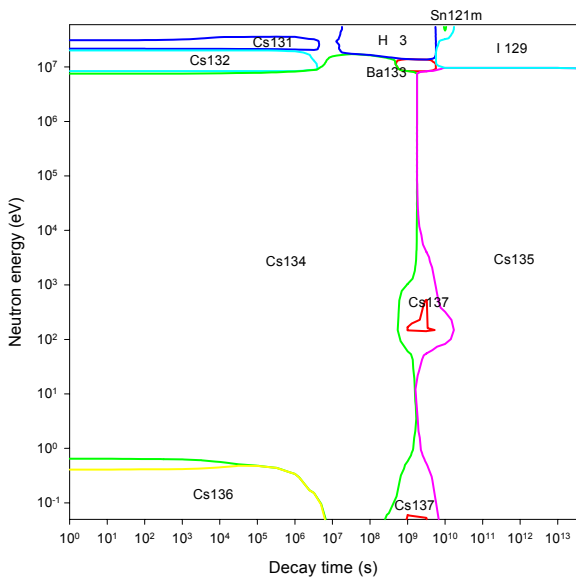


Decay time (years)

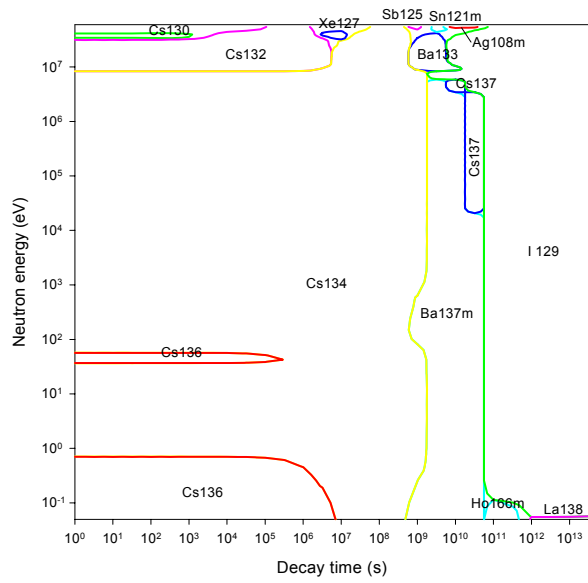
Decay time (years)

# Caesium importance diagrams & transmutation

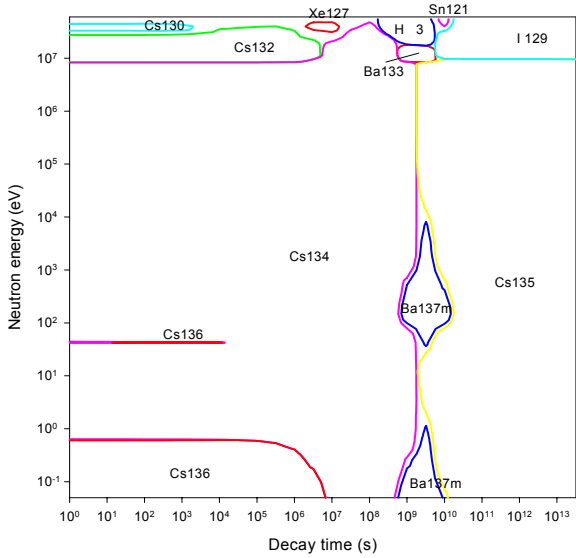
**Activity**



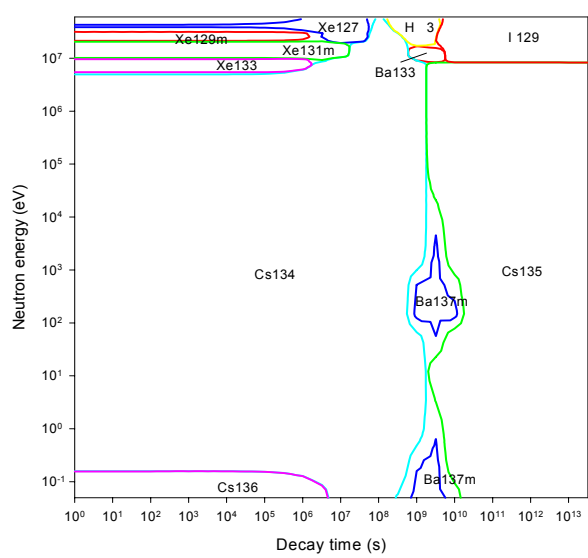
**Dose rate**



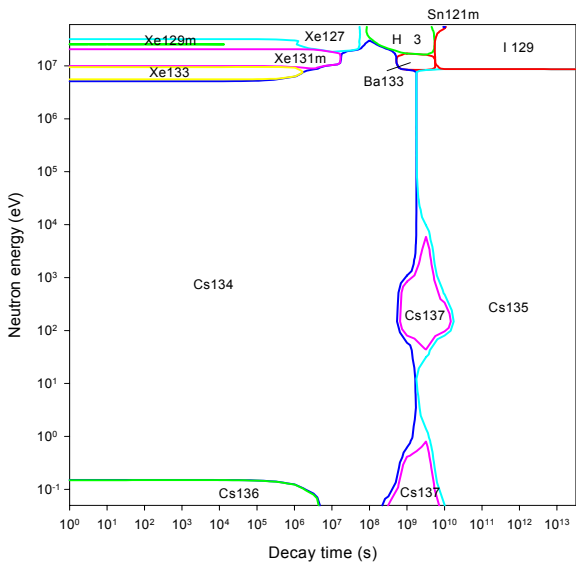
**Heat output**



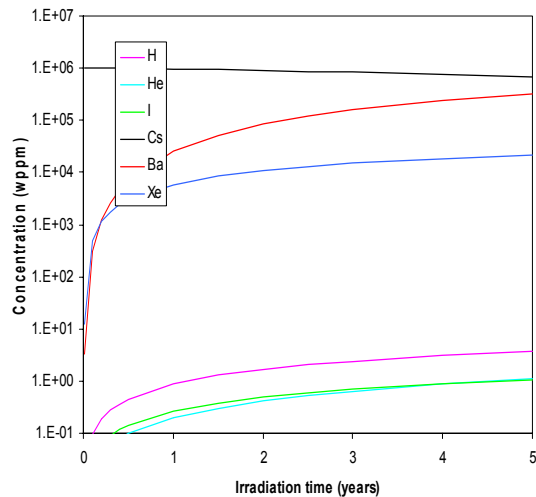
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**



# Barium

## General properties

Atomic number	56	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	425	Ba130	0.106
Melting point / K	1000	Ba132	0.101
Boiling point / K	2170	Ba134	2.417
Density / kgm <sup>-3</sup>	3500	Ba135	6.592
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	18.4	Ba136	7.854
Electrical resistivity /Ωm	5.0 10 <sup>-7</sup>	Ba137	11.232
Coefficient of thermal expansion / K <sup>-1</sup>	2.06 10 <sup>-5</sup>	Ba138	71.698
Crystal structure	BCC		
Number of stable isotopes	7		
Mean atomic weight	137.327		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	6.65E14	2.66E14	4.35E13	7.28E12	2.32E10	1.55E6	kW kg <sup>-1</sup>	7.54E-2	2.07E-2	2.52E-3	7.10E-4	1.61E-6	2.18E-11
Ba137m	67.20	40.27	0.16	0.91	29.11		Ba137m	62.60	54.67	0.29	0.99	44.41	
Ba135m	15.00	37.41	27.65				Ba136m	24.69					
Ba136m	8.61						Ba135m	5.66	20.57	20.43			
Ba133m	1.74	4.35	5.44				Ba139	2.12	7.37				
Ba131	1.66	4.16	20.47				Ba131	1.19	4.33	28.65			
Cs131	1.65	4.12	24.67				Ba133m	0.71	2.58	4.34			
Ba139	1.59	3.79					Cs138	0.70	2.34				
Ba133	1.00	2.51	15.35	85.86	40.03		Ba133	0.65	2.35	19.33	64.18	42.18	
Ba131m	0.46	0.89					Cs134	0.46	1.66	13.59	34.53		
Cs134	0.19	0.47	2.86	12.23			La140	0.32	1.17	2.13			
Cs136	0.14	0.32					Cs136	0.31	1.14	7.74			
Xe131m	0.06	0.16	0.78				Cs131	0.07	0.25	2.01			
Cs137			0.17	0.97	30.84		Cs137			0.09	0.30	13.41	
Cs135						97.62	Cs135						99.12
La137						2.38	La137						0.87
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	9.33E4	1.76E4	1.68E3	5.50E2	1.25E0	1.37E-8	Sv kg <sup>-1</sup>	9.80E6	3.31E6	3.91E5	2.85E4	2.35E2	3.03E-3
Ba137m	64.44	81.91	0.54	1.62	72.83		Ba137m	86.74	61.48	0.33	4.43	54.54	
Ba136m	32.04						Ba129m	3.37	9.69				
Ba131	0.73	3.86	32.48				Xe131m	2.79	8.23	56.39			
Cs138	0.69	3.35					Ba129	2.00	5.77				
Cs134	0.47	2.49	25.96	56.91			Xe135	1.99	5.86	0.07			
Cs136	0.39	2.05	17.65				Xe133	1.52	4.49	25.24			
La140	0.38	2.03	4.72				Ba135m	0.44	1.29	1.32			
Ba135m	0.30	1.60	2.03				Xe133m	0.36	1.11	2.95			
Ba133	0.26	1.38	14.48	41.47	27.16		Cs134	0.24	0.71	6.02	59.42		
Ba133m	0.04	0.21	0.45				Xe129m	0.11	0.33	2.11			
Cs132	0.04	0.19	1.38				Ba133	0.10	0.30	2.56	32.93	5.92	
La137						84.47	Ba133m	0.06	0.19	0.33			
La138						15.45	Ba131	0.05	0.15	1.02			
							Cs136	0.02	0.06	0.41			
							Ba139	0.01	0.04				
							Cs137	0.01	0.03	0.24	3.21	39.53	
							La140	0.01	0.03	0.06			
							Cs131		0.02	0.16			
							Cs135						99.75

Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	6.57E6	2.47E6	5.51E5	8.39E4	4.53E2	1.33E-2		4.04E11	9.31E10	1.87E10	1.21E10	7.93E7	2.02E1
Ba137m	81.71	52.03	0.15	0.95	17.89		Ba137m	65.16	67.76	0.21	0.32	5.01	
Xe131m	6.20	16.47	59.75				Ba136m	27.30					
Ba129m	3.44	8.88					Cs134	3.09	13.38	66.53	73.30		
Ba129	2.08	5.39					Ba135m	2.06	8.92	5.37			
Xe133	1.87	4.97	14.78				Ba133	0.66	2.87	14.30	20.58	4.69	
Xe135	1.56	4.11	0.02				Ba139	0.35	1.47				
Ba133	1.02	2.70	12.10	74.53	20.51		Ba131	0.27	1.19	4.77			
Ba135m	0.55	1.45	0.79				Ba133m	0.26	1.13	1.15			
Cs134	0.38	1.01	4.50	21.23			Cs137	0.18	0.77	3.86	5.79	90.30	
Xe127	0.20	0.54	2.26	0.02			Cs136	0.16	0.69	2.85			
Ba131	0.15	0.39	1.40				La140	0.13	0.57	0.63			
Ba133m	0.08	0.22	0.20				Cs138	0.02	0.09				
Cs137	0.04	0.11	0.51	3.27	61.60		Cs131			0.06			
Cs136	0.03	0.07	0.27				Cs135						74.65
La140	0.01	0.02	0.02				I129						20.54
Ba139	0.01	0.02					La137						4.78
Cs131		0.02	0.09										
Cs135						97.57							
La137						2.40							

# Barium

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Ba137m	2.552 m	Ba136(n,γ)Ba137m	81.4	97.0	96.2				
		Ba135(n,γ)Ba136(n,γ)Ba137m	18.1	1.3	3.7				
		Ba134(n,γ)Ba135(n,γ)Ba136(n,γ)Ba137m	0.4						
		Ba138(n,2n)Ba137m				94.5	95.2	90.6	90.4
		Ba137(n,n')Ba137m				2.0	4.1	4.4	3.8
		Ba138(n,2n)Ba137(n,n')Ba137m				1.6	0.6		
		Ba138(n,d)Cs137(β <sup>-</sup> )Ba137m					1.5	3.4	
Ba139	1.384 h	Ba138(n,γ)Ba139	96.4	99.8	99.9	99.9	99.7	99.7	99.9
		Ba137(n,γ)Ba138(n,γ)Ba139	3.6	0.2	0.1				
Ba135m	1.196 d	Ba134(n,γ)Ba135m	99.8	99.9	100.0				
		Ba136(n,2n)Ba135m				52.0	10.8	3.2	4.8
		&Ba137(n,2n)Ba136(n,2n)Ba135m				20.3	1.0		
		&Ba138(n,2n)Ba137(n,2n)Ba136(n,2n)Ba135m				17.1			
		Ba135(n,n')Ba135m				7.4	2.1	0.7	1.0
		Ba137(n,3n)Ba135m					44.1	8.1	8.8
		&Ba138(n,2n)Ba137(n,3n)Ba135m					20.6	2.3	
		&Ba138(n,3n)Ba136(n,2n)Ba135m					19.4	2.4	
Ba138(n,4n)Ba135m							81.4	80.7	
La140	1.679 d	Ba138(n,γ)Ba139(β <sup>-</sup> )La139(n,γ)La140	98.0	99.9	99.9	99.9	99.7	99.8	99.9
		Ba137(n,γ)Ba138(n,γ)Ba139(β <sup>-</sup> )La139(n,γ)La140	2.0						
Xe133	5.244 d	&Ba130(n,γ)Ba131(β <sup>+</sup> )Cs131(β <sup>+</sup> )Xe133	96.6	28.3	92.9				
		Xe131(n,γ)Xe132(n,γ)Xe133							
		Ba130(n,γ)Ba131(β <sup>+</sup> )Cs131(n,γ)Cs132(β <sup>+</sup> )Xe132(n,γ)Xe133	1.2	71.1	3.1				
		&Ba136(n,α)Xe133				41.5	8.0	1.6	3.5
		&Ba137(n,2n)Ba136(n,α)Xe133				15.3	0.8		
		&Ba137(n,α)Xe134(n,2n)Xe133				11.9			
		&Ba138(n,2n)Ba137(n,2n)Ba136(n,α)Xe133				11.8			
		&Ba138(n,2n)Ba137(n,α)Xe134(n,2n)Xe133				9.2			
		&Ba138(n,2n)Ba137(n,α)Xe133				1.9	19.6	5.3	1.6
		&Ba137(n,nα)Xe133				1.2	47.0	18.1	9.6
		&Ba138(n,3n)Ba136(n,α)Xe133					13.4	1.2	1.1
		&Ba138(n,2nα)Xe133					2.1	60.3	64.5
		Other pathways involving (n,2n), (n,α), β <sup>+</sup>	2.2	0.6	4.0	7.2	9.1	13.5	19.7
Cs131	9.69 d	&Ba130(n,γ)Ba131(β <sup>+</sup> )Cs131	100.0	100.0	100.0				
		&Ba132(n,2n)Ba131(β <sup>+</sup> )Cs131				54.0	2.0	0.5	0.1
		&Ba134(n,2n)Ba133(n,2n)Ba132(n,2n)Ba131(β <sup>+</sup> )Cs131				34.9			
		&Ba135(n,2n)Ba134(n,2n)Ba133(n,2n)Ba132(n,2n)Ba131(β <sup>+</sup> )Cs131				8.4			
		&Ba135(n,3n)Ba133(n,3n)Ba131(β <sup>+</sup> )Cs131					39.4	4.1	0.2
		&Ba134(n,4n)Ba131(β <sup>+</sup> )Cs131					21.9	6.2	
		&Ba134(n,3n)Ba132(n,2n)Ba131(β <sup>+</sup> )Cs131					8.2	1.3	0.1
		&Ba135(n,3n)Ba133(β <sup>+</sup> )Cs133(n,3n)Cs131					7.5	0.8	
		&Ba134(n,2n)Ba133(n,3n)Ba131(β <sup>+</sup> )Cs131					6.3	0.7	
		&Ba137(n,4n)Ba134(n,4n)Ba131(β <sup>+</sup> )Cs131						12.6	1.3
		&Ba136(n,3n)Ba134(n,4n)Ba131(β <sup>+</sup> )Cs131						6.5	0.6
		&Ba136(n,4n)Ba133(n,3n)Ba131(β <sup>+</sup> )Cs131						6.5	0.4
		&Ba135(n,4n)Ba132(n,2n)Ba131(β <sup>+</sup> )Cs131						3.7	0.4
		&Ba138(n,5n)Ba134(n,4n)Ba131(β <sup>+</sup> )Cs131						0.1	16.4
		&Ba135(n,5n)Ba131(β <sup>+</sup> )Cs131							25.0
		&Ba138(n,4n)Ba135(n,5n)Ba131(β <sup>+</sup> )Cs131							12.7
		Ba138(n,5n)Ba134(n,nt)Cs131							5.5
		&Ba138(n,nt)Cs135(n,5n)Cs131							4.3

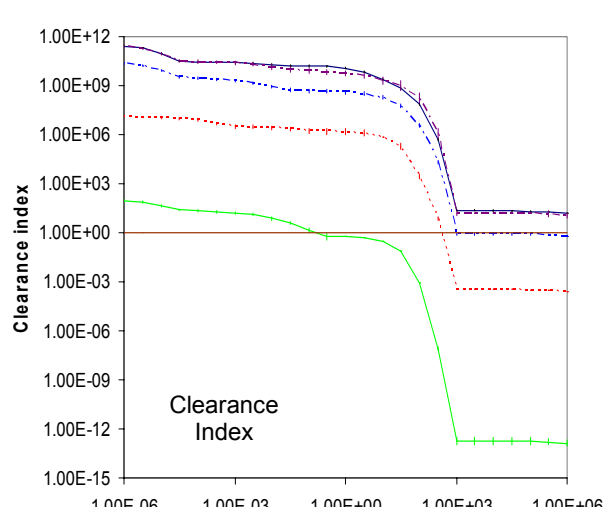
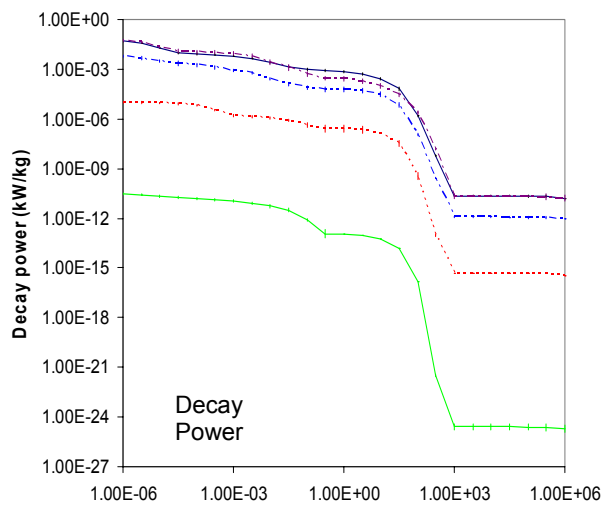
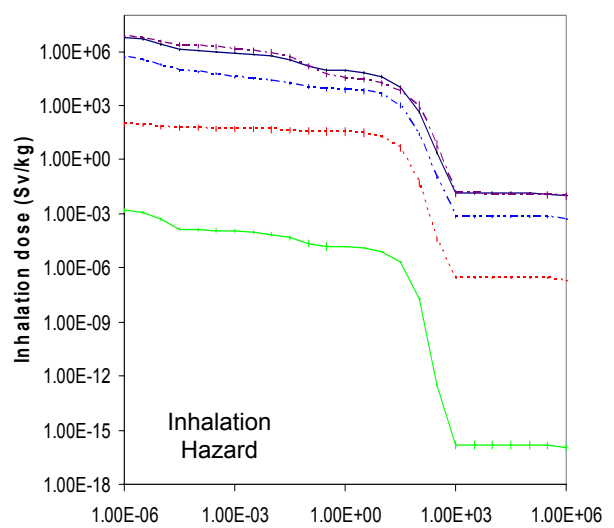
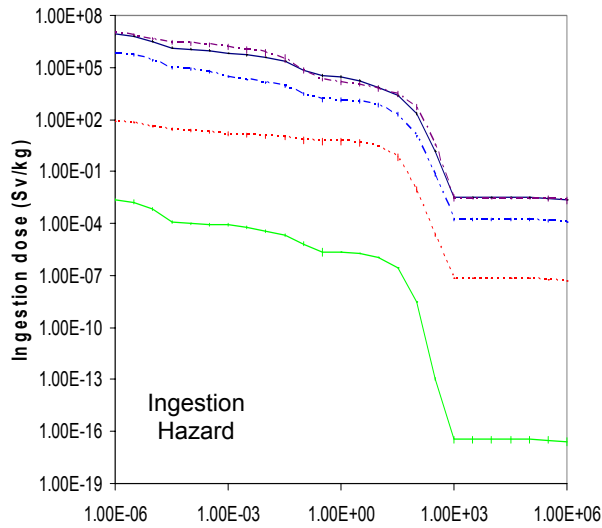
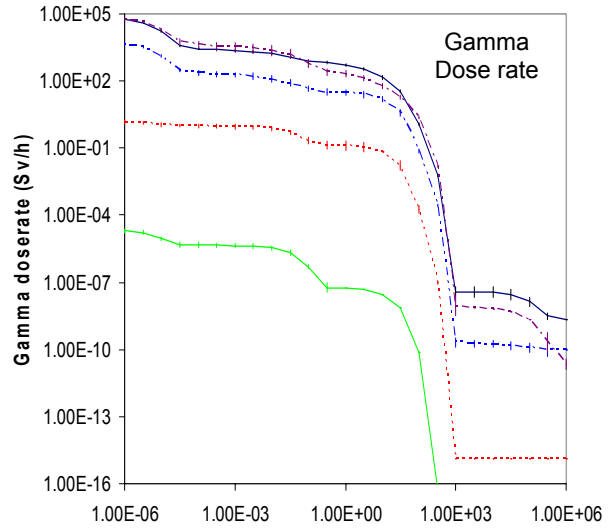
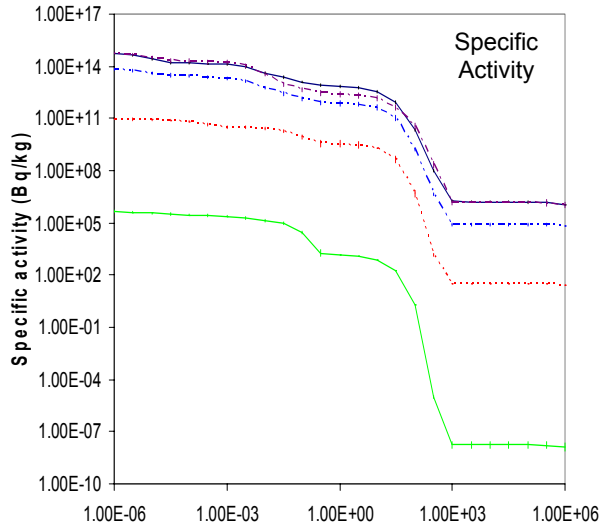
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6		
Ba131	11.55 d	&Ba130(n,γ)Ba131	100.0	100.0	100.0						
		&Ba132(n,2n)Ba131				54.5	2.5	0.7	0.2		
		&Ba134(n,2n)Ba133(n,2n)Ba132(n,2n)Ba131				32.1					
		&Ba135(n,2n)Ba134(n,2n)Ba133(n,2n)Ba132(n,2n)Ba131				5.3					
		&Ba135(n,3n)Ba133(n,3n)Ba131					50.6	5.1	0.4		
		&Ba134(n,3n)Ba132(n,2n)Ba131					10.5	1.7	0.2		
		&Ba137(n,3n)Ba135(n,3n)Ba133(n,3n)Ba131					8.8	0.1			
		&Ba134(n,2n)Ba133(n,3n)Ba131					8.0	1.0			
		&Ba136(n,3n)Ba134(n,3n)Ba132(n,2n)Ba131					3.2	0.2			
		&Ba134(n,4n)Ba131						27.1	8.3		
		&Ba137(n,4n)Ba134(n,4n)Ba131						15.7	1.7		
		&Ba136(n,3n)Ba134(n,4n)Ba131						8.2	0.9		
		&Ba136(n,4n)Ba133(n,3n)Ba131						8.1	0.6		
		&Ba135(n,4n)Ba132(n,2n)Ba131						4.6	0.6		
		&Ba135(n,2n)Ba134(n,4n)Ba131						3.2	0.5		
		&Ba138(n,5n)Ba134(n,4n)Ba131						0.2	22.1		
		&Ba135(n,5n)Ba131							33.2		
&Ba138(n,4n)Ba135(n,5n)Ba131							17.2				
Xe131m	11.93 d	&Ba132(n,γ)Ba133(n,α)Xe130(n,γ)Xe131m	61.6	78.4	56.5						
		Ba130(n,γ)Ba131(β <sup>+</sup> )Cs131(n,γ)Cs132(n,α)I129(n,γ)I130(β <sup>-</sup> )Xe130(n,γ)Xe131m	20.3								
		Ba134(n,α)Xe131m	1.6	6.3	43.0	13.4	4.2	0.9	1.1		
		Ba132(n,γ)Ba133(β <sup>+</sup> )Cs133(n,γ)Cs134(n,α)I131(β <sup>-</sup> )Xe131m	0.4	10.7							
		&Ba134(n,2n)Ba133(β <sup>+</sup> )Cs133(n,2n)Cs132(β <sup>+</sup> )Xe132(n,2n)Xe131m				28.5					
		&Ba132(n,2n)Ba131(β <sup>+</sup> )Cs131(β <sup>+</sup> )Xe131(n,n')Xe131m				12.0	0.3				
		Ba135(n,α)Xe132(n,2n)Xe131m				11.1	0.4				
		Ba135(n,2n)Ba134(n,α)Xe131m				9.4	0.8	0.1			
		Ba135(n,nα)Xe131m				2.3	41.9	16.9	6.1		
		&Ba137(n,3n)Ba135(n,nα)Xe131m					14.0	2.0	0.3		
		&Ba138(n,3n)Ba136(n,2nα)Xe131m					0.9	7.9	2.4		
		Ba136(n,2nα)Xe131m					0.5	10.2	7.0		
		&Ba138(n,4n)Ba135(n,nα)Xe131m						21.8	3.2		
		&Ba138(n,nα)Xe134(n,4n)Xe131m						12.6	2.0		
		Ba137(n,3nα)Xe131m						0.6	14.9		
		Ba138(n,4nα)Xe131m							20.1		
		Other pathways involving (n,2n), (n,α), β <sup>+</sup>	16.1	4.6	0.5	23.3	37.0	27.0	44.0		
		Cs136	13.03 d	&Ba132(n,γ)Ba133(β <sup>+</sup> )Cs133(n,γ)Cs134(n,γ)Cs135(n,γ)Cs136	94.7	97.8	90.7				
				&Ba136(n,p)Cs136				27.7	4.8	1.4	
&Ba137(n,p)Cs137(n,2n)Cs136						17.1	0.5				
&Ba138(n,2n)Ba137(n,p)Cs137(n,2n)Cs136						14.6					
&Ba137(n,2n)Ba136(n,p)Cs136						10.7	0.4				
&Ba138(n,2n)Ba137(n,d)Cs136						10.1	16.1	5.8			
&Ba138(n,2n)Ba137(n,2n)Ba136(n,p)Cs136						8.8					
&Ba137(n,d)Cs136						6.1	34.5	18.4	11.7		
&Ba138(n,d)Cs137(n,2n)Cs136						4.7	11.0	4.3	1.4		
&Ba138(n,t)Cs136							23.5	68.7	83.4		
&Ba138(n,3n)Ba136(n,p)Cs136					8.6	0.6					
Ce141	32.5 d	Ba138(n,γ)Ba139(β <sup>-</sup> )La139(n,γ)La140(β <sup>-</sup> )Ce140(n,γ)Ce141	97.5	1.0	94.1	99.1	97.6	97.7	97.6		
		Ba137(n,γ)Ba138(n,γ)Ba139(β <sup>-</sup> )La139(n,γ)La140(β <sup>-</sup> )Ce140(n,γ)Ce141	1.3								
		Ba138(n,γ)Ba139(β <sup>-</sup> )La139(n,γ)La140(n,γ)La141(β <sup>-</sup> )Ce141	1.2	98.9	5.9	0.8	2.2	2.2	2.3		
Xe127	36.40 d	&Ba130(n,α)Xe127	100.0	100.0	99.7	13.0	2.3	0.2			
		&Ba130(n,2n)Ba129(β <sup>+</sup> )Cs129(β <sup>+</sup> )Xe129(n,2n)Xe128(n,2n)Xe127				43.1					

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	&Ba130(n,2n)Ba129m(β <sup>+</sup> )Cs129(β <sup>+</sup> )_Xe129(n,2n)Xe128(n,2n)Xe127 &Ba130(n,2n)Ba129m(β <sup>+</sup> )Cs129(β <sup>+</sup> )_Xe129(n,3n)Xe127 &Ba130(n,3n)Ba128(β <sup>+</sup> )Cs128(β <sup>+</sup> )_Xe128(n,2n)Xe127 &Ba130(n,2n)Ba129(β <sup>+</sup> )Cs129(β <sup>+</sup> )_Xe129(n,3n)Xe127 &Ba130(n,d)Cs129(β <sup>+</sup> )Xe129(n,3n)Xe127 &Ba130(n,4n)Ba127(β <sup>+</sup> )Cs127(β <sup>+</sup> )Xe127 &Ba135(n,4n)Ba132(n,2nα)Xe127 &Ba135(n,2nα)Xe130(n,4n)Xe127 &Ba138(n,4n)Ba135(n,2nα)Xe130(n,4n)Xe127 &Ba135(n,5n)Ba131(β <sup>+</sup> )Cs131(β <sup>+</sup> )_Xe131(n,5n)Xe127 &Ba134(n,5n)Ba130(n,4n)Ba127(β <sup>+</sup> )_Cs127(β <sup>+</sup> )Xe127 Other pathways involving (n,2n), (n,α), β <sup>+</sup>				40.8	0.1	18.5	0.9	
							5.1	7.5	1.0	
								6.7	0.3	
								5.1	0.6	
								7.9	2.8	
								6.6	0.4	
								5.5	0.3	
								3.4		
									4.9	
									4.5	
						0.3	3.1	59.8	73.6	87.1
Cs134	2.065 y	&Ba132(n,γ)Ba133(β <sup>+</sup> )Cs133(n,γ)Cs134 &Ba130(n,γ)Ba131(n,γ)Ba132(n,γ)_Ba133(β <sup>+</sup> )Cs133(n,γ)Cs134 &Ba138(n,α)Xe135(β <sup>-</sup> )Cs135(n,2n)Cs134	93.9 0.1	98.1 0.9	100.0					
						38.1	2.5			
		&Ba134(n,p)Cs134 &Ba135(n,d)Cs134 &Ba135(n,2n)Ba134(n,p)Cs134 &Ba135(n,p)Cs135(n,2n)Cs134 &Ba136(n,2n)Ba135(n,d)Cs134 &Ba137(n,3n)Ba135(n,d)Cs134 &Ba138(n,3n)Ba136(n,t)Cs134 &Ba136(n,t)Cs134 &Ba137(n,nt)Cs134 &Ba138(n,d)Cs137(n,4n)Cs134 &Ba138(n,4n)Ba135(n,d)Cs134 &Ba138(n,2nt)Cs134				23.7 12.2 10.7 7.9 2.4	5.2 49.6 0.6 0.3 2.6	1.3 22.2	0.4 10.6	
								10.5	1.4	0.3
								7.0	8.4	3.1
								6.2	17.3	14.7
								1.3	5.6	19.1
								0.2	15.9	2.6
									17.8	3.4
									0.6	37.7
Ba133	10.54 y	&Ba132(n,γ)Ba133 &Ba130(n,γ)Ba131(n,γ)Ba132(n,γ)Ba133 &Ba134(n,2n)Ba133 &Ba135(n,2n)Ba134(n,2n)Ba133 &Ba136(n,2n)Ba135(n,2n)Ba134(n,2n)Ba133 &Ba135(n,3n)Ba133 &Ba137(n,3n)Ba135(n,3n)Ba133 &Ba136(n,3n)Ba134(n,2n)Ba133 &Ba136(n,2n)Ba135(n,3n)Ba133 &Ba136(n,4n)Ba133 &Ba138(n,3n)Ba136(n,4n)Ba133 &Ba138(n,4n)Ba135(n,3n)Ba133 &Ba137(n,5n)Ba133 &Ba138(n,6n)Ba133 &Ba138(n,5n)Ba134(n,2n)Ba133	99.6 0.3	98.2 1.7	100.0					
						70.3 26.4 2.8	10.2 1.0	4.6	2.6	
							65.0	22.3	8.7	
							11.4	1.2		
							3.4			
							2.8			
								35.1	14.4	
								14.3		
								14.2		1.1
										37.3
										22.3
										3.8
Cs137	30.041 y	&Ba132(n,γ)Ba133(β <sup>+</sup> )Cs133(n,γ)_Cs134(n,γ)Cs135(n,γ)Cs136(n,γ)Cs137 Ba138(n,γ)Ba139(β <sup>-</sup> )La139(n,γ)La140_(n,α)Cs137 &Ba130(n,γ)Ba131(β <sup>+</sup> )Cs131(n,γ)_Cs132(n,γ)Cs133(n,γ)Cs134(n,γ)Cs135_(n,γ)Cs136(n,γ)Cs137 Ba137(n,p)Cs137 &Ba138(n,2n)Ba137(n,p)Cs137 Ba138(n,d)Cs137	94.3 1.0	97.3	79.6 20.2					
								46.8	4.7	2.3
								40.3		1.4
								12.8	94.0	97.2
Hol66m	1200 y	Very long pathways of (n,γ), (β <sup>-</sup> )	100.0							
La137	6.0 10 <sup>4</sup> y ▶	Ba138(n,γ)Ba139(β <sup>-</sup> )La139(n,2n)_La138(n,2n)La137				100.0				

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Ba138(n,γ)Ba139(β <sup>-</sup> )La139(n,3n)La137					98.9	99.2	99.2	
Cs135	2.3 10 <sup>6</sup> y	&Ba132(n,γ)Ba133(β <sup>+</sup> )Cs133(n,γ) Cs134(n,γ)Cs135 &Ba138(n,α)Xe135(β <sup>-</sup> )Cs135 &Ba135(n,p)Cs135 &Ba136(n,d)Cs135 &Ba136(n,2n)Ba135(n,p)Cs135 &Ba137(n,t)Cs135 &Ba138(n,3n)Ba136(n,d)Cs135 &Ba138(n,d)Cs137(n,3n)Cs135 &Ba138(n,nt)Cs135	94.2	97.3	99.9	76.8 16.0 2.6 2.4 0.2	27.0 3.4 21.3 6.4	7.3 1.5 21.9 22.9	1.6 7.9 13.2	
I129	1.6 10 <sup>7</sup> y	&Ba130(n,γ)Ba131(β <sup>+</sup> )Cs131(n,γ) Cs132(n,α)I129 Ba130(n,2n)Ba129(β <sup>+</sup> )Cs129(β <sup>+</sup> )Xe129 (n,p)I129 Ba130(n,2n)Ba129m(β <sup>+</sup> )Cs129(β <sup>+</sup> ) Xe129(n,p)I129 &Ba134(n,2n)Ba133(β <sup>+</sup> )Cs133(n,α)I129 &Ba135(n,3n)Ba133(β <sup>+</sup> )Cs133(n,α)I129 &Ba135(n,3n)Ba133(n,3n)Ba131(β <sup>+</sup> ) Cs131(β <sup>+</sup> )Xe131(n,t)I129 Ba134(n,α)Xe130(n,d)I129 Ba134(n,d)Cs133(n,α)I129 &Ba137(n,α)Xe133(β <sup>-</sup> )Cs133(n,α)I129 &Ba135(n,α)Xe131(n,t)I129 Ba135(n,t)Cs133(n,α)I129 Ba135(n,2nα)Xe130(n,d)I129 &Ba134(n,4n)Ba131(β <sup>+</sup> )Cs131(β <sup>+</sup> ) Xe131(n,t)I129 Ba135(n,nt)Cs132(β <sup>+</sup> )Xe132(n,nt)I129 &Ba135(n,5n)Ba131(β <sup>+</sup> )Cs131(β <sup>+</sup> ) Xe131(n,t)I129 Ba138(n,3nα)Xe132(n,nt)I129 Ba138(n,nt)Cs135(n,3nα)I129 Other pathways involving (n,2n), (n,α), β <sup>+</sup>	99.5	99.7	92.3	44.2 41.9 2.3	0.5 1.3 3.2 20.2 4.9 4.5 4.5 4.2 3.9 3.0 0.9	0.3 1.4 0.4 1.1 1.0 0.6 2.6 2.1 3.4	0.2 0.2 0.6 0.6 0.5 0.7 24.5 0.3	0.2 0.2 0.6 0.6 0.5 0.7 5.3 3.5 21.6 5.4 4.6
La138	1.0 10 <sup>11</sup> y	Ba138(n,γ)Ba139(β <sup>-</sup> )La139(n,γ)La140 (β <sup>-</sup> )Ce140(n,γ)Ce141(β <sup>-</sup> )Pr141(n,α)La138 Ba138(n,γ)Ba139(β <sup>-</sup> )La139(n,γ)La140 (n,γ)La141(β <sup>-</sup> )Ce141(β <sup>-</sup> )Pr141(n,α)La138 Ba137(n,γ)Ba138(n,γ)Ba139(β <sup>-</sup> )La139 (n,γ)La140(β <sup>-</sup> )Ce140(n,γ)Ce141(β <sup>-</sup> ) Pr141(n,α)La138 Ba138(n,γ)Ba139(β <sup>-</sup> )La139(n,2n)La138	97.0 2.1 0.9	0.6 99.4	88.9 11.0					
			0.5	0.3	7.7	11.6	53.1	62.3	57.4	
						100.0	99.9	99.9	100.0	



# Barium activation characteristics

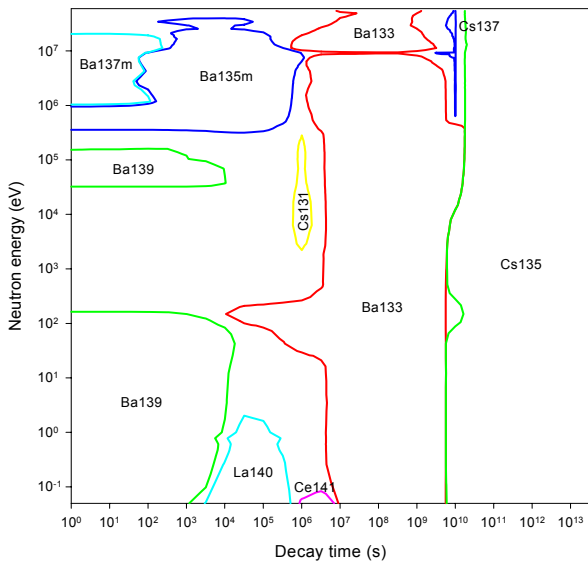


Decay time (years)

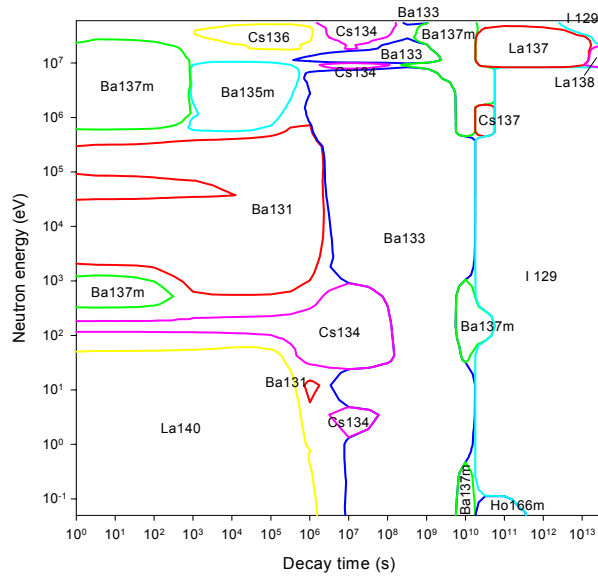
Decay time (years)

# Barium importance diagrams & transmutation

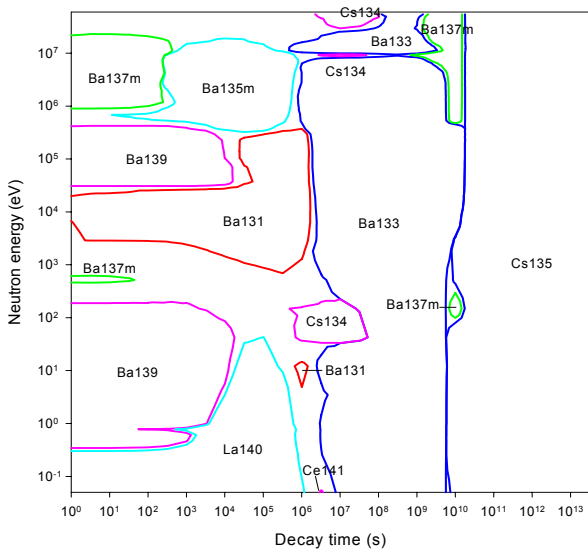
**Activity**



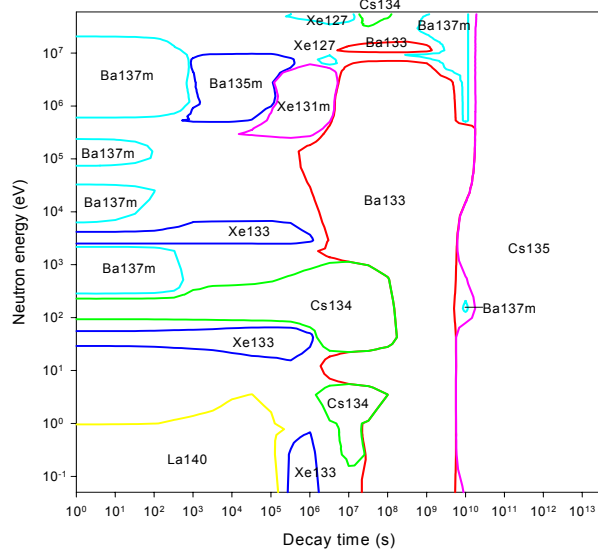
**Dose rate**



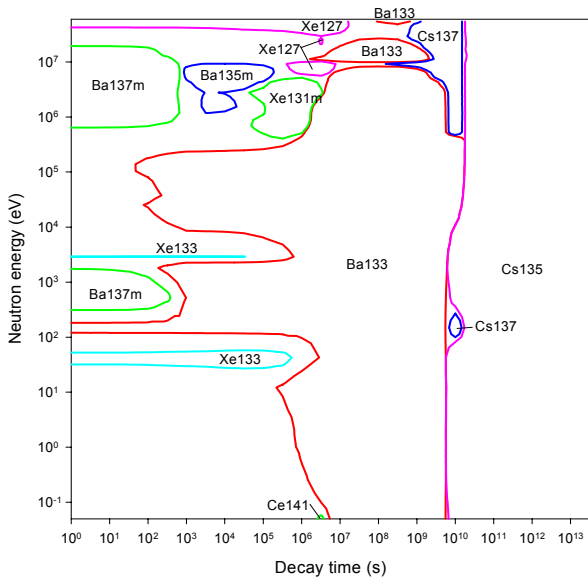
**Heat output**



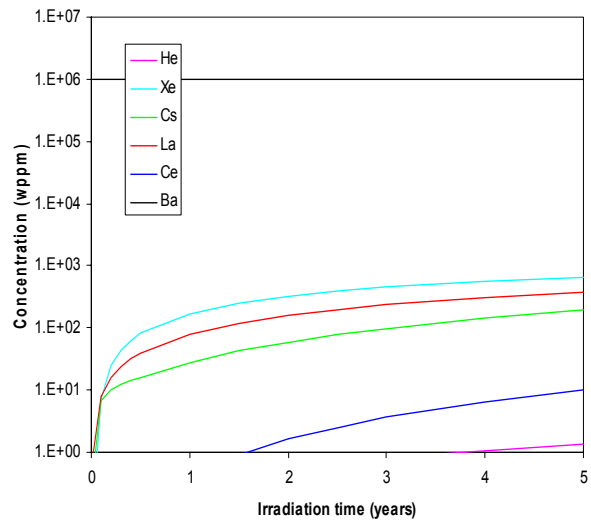
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**



# Lanthanum

## General properties

Atomic number	57	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	39.0	La138	0.09 ( $T_{1/2} = 1.02 \cdot 10^{11}$ y)
Melting point / K	1193	La139	99.91
Boiling point / K	3728		
Density / $\text{kgm}^{-3}$	6145		
Thermal conductivity / $\text{Wm}^{-1}\text{K}^{-1}$	13.5		
Electrical resistivity / $\Omega\text{m}$	$5.7 \cdot 10^{-7}$		
Coefficient of thermal expansion / $\text{K}^{-1}$	$1.21 \cdot 10^{-5}$		
Crystal structure	Hexagonal		
Number of stable isotopes	1 (2)		
Mean atomic weight	138.9055		

## Activation properties

Act	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Heat	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Bq $\text{kg}^{-1}$	1.38E15	1.35E15	3.30E14	6.23E12	9.23E8	2.58E8	kW $\text{kg}^{-1}$	6.01E-1	5.97E-1	1.33E-1	1.92E-4	8.80E-9	1.33E-9
La140	94.83	96.57	87.51				La140	99.11	99.61	98.78			
Ce139	2.84	2.90	11.64	99.79			Ce139m	0.49	0.01				
Ce139m	1.78	0.04					Ce139	0.20	0.20	0.89	99.81		
Ba137m	0.01			0.01	3.58		Ba137m				0.02	39.68	
H3				0.16	4.05		Cs137				0.01	11.98	
La137				0.01	88.57	99.97	H3				0.01	0.39	
Cs137				0.01	3.79		La137					47.88	99.52
Dose	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Ing	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{h}^{-1}$	8.73E5	8.68E5	1.93E5	1.67E1	4.62E-3	8.60E-5	Sv $\text{kg}^{-1}$	2.63E6	2.62E6	5.92E5	1.65E3	1.15E0	2.10E-2
La140	99.47	99.90	99.66				La140	99.27	99.36	97.58			
Ce139	0.01	0.01	0.05	97.64			Ce139	0.39	0.39	1.69	98.12		
Cs134				2.10			Cs136	0.14	0.14	0.51			
Ba137m				0.26	94.56		Cs134			0.01	1.17		
La137					5.23	88.56	Cs137				0.27	39.54	
La138					0.21	11.44	La137					5.76	99.41
Inh	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Clear	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{kg}^{-1}$	1.52E6	1.52E6	4.00E5	1.19E4	8.89E0	2.25E0		1.36E12	1.34E12	3.28E11	6.23E9	3.91E5	6.81E3
La140	94.25	94.34	79.36				La140	95.69	96.93	87.98			
Ce139	4.88	4.89	18.24	99.58			Ce139	2.87	2.91	11.71	99.78		
Ce141	0.47	0.47	1.67	0.03			Ce139m	1.29	0.03				
Cs136	0.23	0.23	0.71				Ba137m	0.01				4.97	
Cs137				0.11	15.36		Cs137				0.06	89.43	
La137				0.06	80.02	99.80	La137					5.50	99.58

# Lanthanum

## Pathway analysis

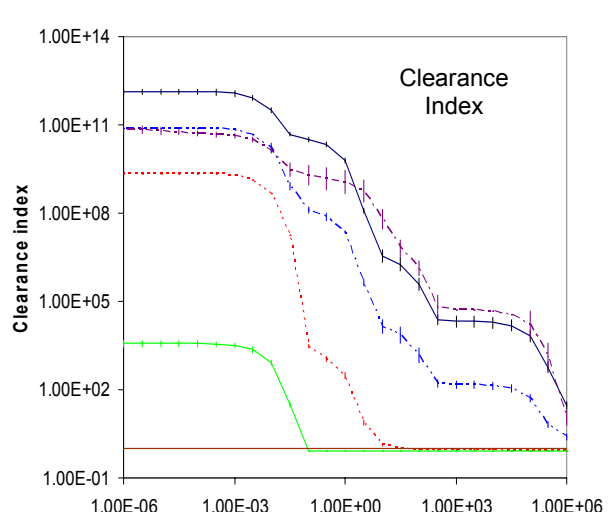
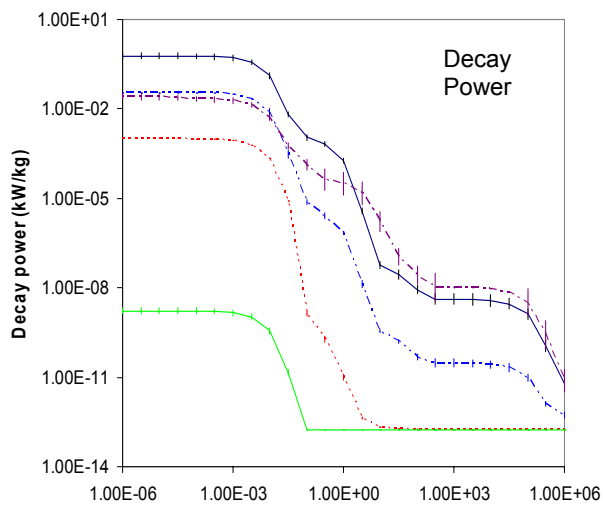
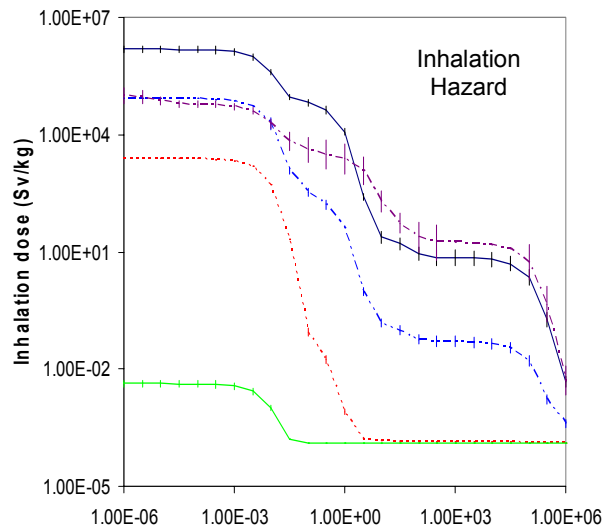
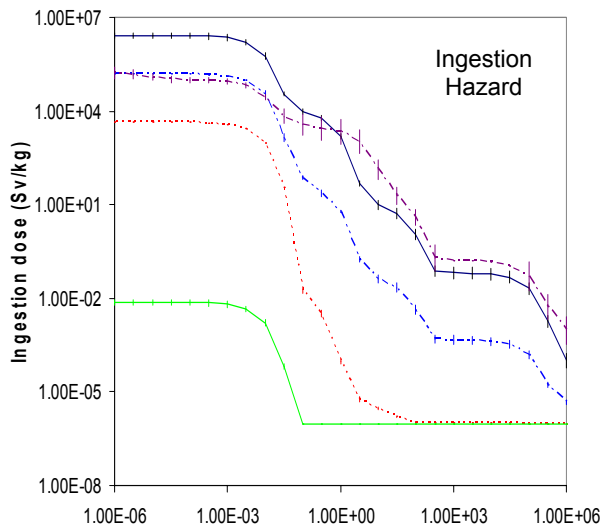
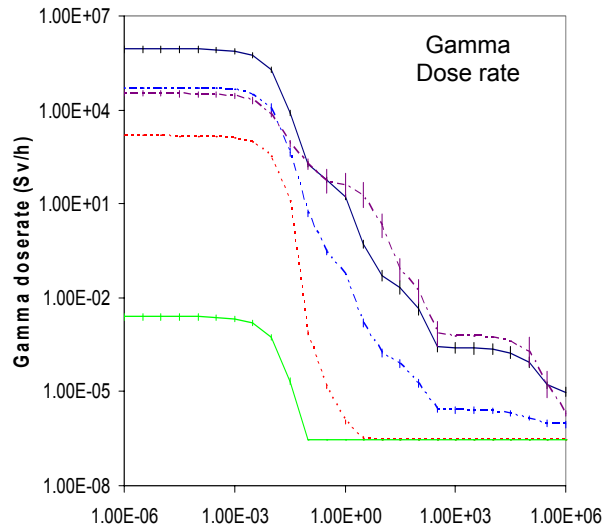
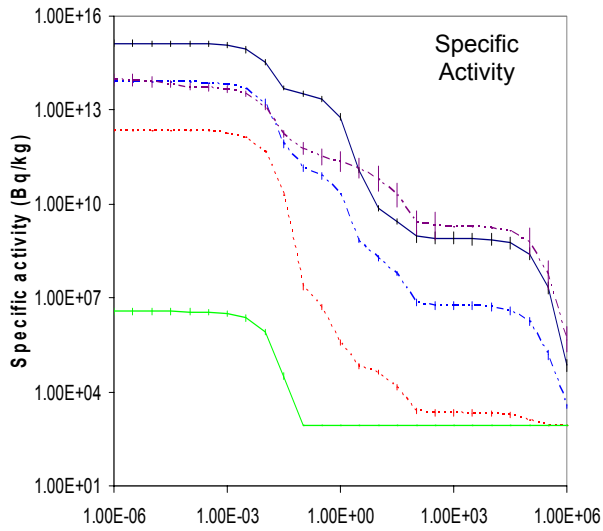
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
Ba137m	2.552 m	La139(n,γ)La140(n,α)Cs137(β <sup>-</sup> )Ba137m La139(n,γ)La140(β <sup>-</sup> )Ce140(n,α)Ba137m &La138(n,α)Cs135(n,γ)Cs136(n,γ)Cs137_ (β <sup>-</sup> )Ba137m La139(n,2n)La138(n,d)Ba137m La139(n,d)Ba138(n,2n)Ba137m La139(n,2n)La138(n,2n)La137(n,p)Ba137m La139(n,2n)La138(n,p)Ba138(n,2n)Ba137m La139(n,t)Ba137m La139(n,3n)La137(n,p)Ba137m	99.3 0.5	79.6 20.3	99.6 0.3					
La136	9.87 m	&La139(n,2n)La138(n,2n)La137(n,2n)La136 &La139(n,2n)La138(n,3n)La136 &La139(n,3n)La137(n,2n)La136 &La139(n,4n)La136				96.4	0.6 51.3 44.3	2.1 2.1 94.2	1.2 1.2 97.1	
La135	19.5 h	&La139(n,γ)La140(β <sup>-</sup> )Ce140(n,2n)Ce139_ (n,2n)Ce138(n,2n)Ce137m(n,2n)Ce136_ (n,2n)Ce135(β <sup>+</sup> )La135 &La139(n,γ)La140(β <sup>-</sup> )Ce140(n,2n)Ce139_ (n,2n)Ce138(n,2n)Ce137(n,2n)Ce136_ (n,2n)Ce135(β <sup>+</sup> )La135 &La139(n,γ)La140(β <sup>-</sup> )Ce140(n,2n)Ce139(n,2n)Ce138(n,2n)Ce137m(n,2n)Ce136(n,d)La135 &La139(n,γ)La140(β <sup>-</sup> )Ce140(n,2n)Ce139(n,2n)_ Ce138(n,2n)Ce137(n,2n)Ce136(n,d)La135 La139(n,3n)La137(n,3n)La135 La139(n,2n)La138(n,4n)La135 La138(n,4n)La135 La139(n,5n)La135				70.0 17.6 0.6 0.3	98.4	62.3 35.8 0.7	96.6	
Ba135m	1.196 d	&La139(n,2n)La138(n,2n)La137(n,2n)_ La136(β <sup>+</sup> )Ba136(n,2n)Ba135m &La139(n,α)Cs136(β <sup>-</sup> )Ba136(n,2n)Ba135m La139(n,α)Cs136m(β <sup>-</sup> )Ba136(n,2n)Ba135m				89.4 6.4 1.1				
La140	1.679 d	La139(n,γ)La140	99.9	99.9	100.0	99.8	99.6	99.7	99.8	
Cs136	13.03 d	&La138(n,α)Cs135(n,γ)Cs136 &La139(n,α)Cs136 &La139(n,t)Ba137(n,d)Cs136 La139(n,2n)La138(n,3n)La136(β <sup>+</sup> )Ba136_ (n,p)Cs136 &La139(n,3n)La137(n,2n)La136(β <sup>+</sup> )Ba136_ (n,p)Cs136 &La139(n,d)Ba138(n,t)Cs136 La139(n,2n)La138(n,h)Cs136 &La139(n,4n)La136(β <sup>+</sup> )Ba136(n,p)Cs136	74.1 25.7	99.9 0.1	42.3 57.8	99.1	87.5 3.1 2.0 1.8 1.7 0.2	40.1 18.5 13.2	63.3 13.2 14.3 2.2	
Ce141	32.5 d	La139(n,γ)La140(β <sup>-</sup> )Ce140(n,γ)Ce141 La139(n,γ)La140(n,γ)La141(β <sup>-</sup> )Ce141	99.4 0.5	2.0 97.9	97.0 3.0	99.5 0.4	98.7 1.1	98.7 1.1	98.8 1.2	
Xe127	36.40 d	Pathways involving (n,α), (n,nα), (n,2n), β <sup>-</sup> , β <sup>+</sup>				100.0	100.0	100.0	100.0	
Ce139	137.64 d	&La139(n,γ)La140(β <sup>-</sup> )Ce140(n,γ)Ce141_ (β <sup>-</sup> )Pr141(n,γ)Pr142(β <sup>-</sup> )Nd142(n,α)Ce139 &La139(n,γ)La140(n,γ)La141(β <sup>-</sup> )Ce141_ (β <sup>-</sup> )Pr141(n,γ)Pr142(β <sup>-</sup> )Nd142(n,α)Ce139 &La138(β <sup>-</sup> )Ce138(n,γ)Ce139 &La139(n,γ)La140(β <sup>-</sup> )Ce140(n,2n)Ce139	98.1 1.7		47.1 4.8 76.0					
Cs134	2.065 y	&La138(n,α)Cs135(n,γ)Cs136(n,α)I133_ (β <sup>-</sup> )Xe133(β <sup>-</sup> )Cs133(n,γ)Cs134	64.8	99.6						

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
		&La139(n,α)Cs136(n,α)I133(β <sup>-</sup> )Xe133_ (β <sup>-</sup> )Cs133(n,γ)Cs134 &La138(n,α)Cs135(n,γ)Cs136(β <sup>-</sup> )Ba136_ (n,α)Xe133(β <sup>-</sup> )Cs133(n,γ)Cs134 &La139(n,α)Cs136(β <sup>-</sup> )Ba136(n,α)Xe133_ (β <sup>-</sup> )Cs133(n,γ)Cs134 &La139(n,2n)Lal138(n,2n)Lal137(n,α)Cs134 &La139(n,2n)Lal138(n,α)Cs135(n,2n)Cs134 &La139(n,2n)Lal138(n,α)Cs134 &La139(n,α)Cs135(n,2n)Cs134 &La139(n,3n)Lal137(n,3n)Lal135(β <sup>+</sup> )Ba135_ (n,d)Cs134 &La139(n,3n)Lal137(n,α)Cs134 &La139(n,2nα)Cs134 &La139(n,4n)Lal136(β <sup>+</sup> )Ba136(n,t)Cs134 &La139(n,nt)Ba136(n,t)Cs134 &La139(n,t)Ba137(n,nt)Cs134 &La139(n,5n)Lal135(β <sup>+</sup> )Ba135(n,d)Cs134	31.1							
			2.0							
			1.2							
						41.9	0.1			
						34.8				
						13.8	33.0	2.2	1.0	
						7.1	16.0	2.1	0.5	
							19.4	1.2		
							18.6	1.0	0.6	
								24.1	13.2	
								0.6	3.6	
								0.4	3.3	
									18.6	
Pm147	2.623 y	&La139(n,γ)Lal140(β <sup>-</sup> )Ce140(n,γ)Ce141_ (β <sup>-</sup> )Pr141(n,γ)Pr142(β <sup>-</sup> )Nd142(n,γ)Nd143_ (n,γ)Nd144(n,γ)Nd145(n,γ)Nd146(n,γ)_ Nd147(β <sup>-</sup> )Pm147 &La139(n,γ)Lal140(n,γ)Lal141(β <sup>-</sup> )Ce141(β <sup>-</sup> )_ Pr141(n,γ)Pr142(β <sup>-</sup> )Nd142(n,γ)Nd143(n,γ)_ Nd144(n,γ)Nd145(n,γ)Nd146(n,γ)Nd147(β <sup>-</sup> )_ Pm147 La139(n,γ)Lal140(β <sup>-</sup> )Ce140(n,γ)Ce141(n,γ)_ Ce142(n,γ)Ce143(β <sup>-</sup> )Pr143(β <sup>-</sup> )Nd143(n,γ)_ Nd144(n,γ)Nd145(n,γ)Nd146(n,γ)Nd147(β <sup>-</sup> )_ Pm147 &La139(n,γ)Lal140(β <sup>-</sup> )Ce140(n,γ)Ce141(β <sup>-</sup> )_ Pr141(n,γ)Pr142(n,γ)Pr143(β <sup>-</sup> )Nd143(n,γ)_ Nd144(n,γ)Nd145(n,γ)Nd146(n,γ)Nd147(β <sup>-</sup> )_ Pm147 La139(n,γ)Lal140(n,γ)Lal141(β <sup>-</sup> )Ce141(n,γ)_ Ce142(n,γ)Ce143(β <sup>-</sup> )Pr143(β <sup>-</sup> )Nd143(n,γ)_ Nd144(n,γ)Nd145(n,γ)Nd146(n,γ)Nd147(β <sup>-</sup> )_ Pm147 La139(n,γ)Lal140(n,γ)Lal141(n,γ)Lal142(β <sup>-</sup> )_ Ce142(n,γ)Ce143(β <sup>-</sup> )Pr143(β <sup>-</sup> )Nd143(n,γ)_ Nd144(n,γ)Nd145(n,γ)Nd146(n,γ)Nd147(β <sup>-</sup> )_ Pm147 &La139(n,γ)Lal140(n,γ)Lal141(β <sup>-</sup> )Ce141(β <sup>-</sup> )_ Pr141(n,γ)Pr142(n,γ)Pr143(β <sup>-</sup> )Nd143(n,γ)_ Nd144(n,γ)Nd145(n,γ)Nd146(n,γ)Nd147(β <sup>-</sup> )_ Pm147 &La139(n,γ)Lal140(β <sup>-</sup> )Ce140(n,γ)Ce141(β <sup>-</sup> )_ Pr141(n,γ)Pr142(n,γ)Pr143(β <sup>-</sup> )Nd143(n,γ)_ Nd144(n,γ)Nd145(n,γ)Nd146(n,γ)Nd147(β <sup>-</sup> )_ Pm147	88.3	0.1	60.5					
			3.6	47.4	14.9					
			2.3		11.1					
			0.4							
			0.1							
				30.5						
				8.5	0.6					
						3.0				
Eu154	8.593 y	Very long pathways of (n,γ), β <sup>-</sup>	100.0	100.0						
Ba133	10.54 y	&La139(n,2n)Lal138(n,2n)Lal137(n,2n)Lal136_ (β <sup>+</sup> )Ba136(n,2n)Ba135(n,2n)Ba134(n,2n)Ba133 &La139(n,α)Cs136(β <sup>-</sup> )Ba136(n,2n)Ba135_ (n,2n)Ba134(n,2n)Ba133 &La139(n,2n)Lal138(n,2n)Lal137(n,α)_ Cs134(β <sup>-</sup> )Ba134(n,2n)Ba133 &La139(n,2n)Lal138(n,α)Cs135(n,2n)_ Cs134(β <sup>-</sup> )Ba134(n,2n)Ba133 &La139(n,2n)Lal138(n,α)Cs134(β <sup>-</sup> )_ Ba134(n,2n)Ba133				45.2				
						26.6				
						8.2				
						6.6				
						4.9				

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&La139(n,α)Cs136m(β <sup>-</sup> )Ba136(n,2n) Ba135(n,2n)Ba134(n,2n)Ba133 &La139(n,3n)La137(n,3n)La135(β <sup>+</sup> ) Ba135(n,3n)Ba133 &La139(n,4n)La136(β <sup>+</sup> )Ba136(n,4n)Ba133 &La139(n,α)Cs136(β <sup>-</sup> )Ba136(n,2n)Ba135 (n,2n)Ba134(n,2n)Ba133 &La139(n,nt)Ba136(n,4n)Ba133 La139(n,3n)La137(n,5n)La133(β <sup>+</sup> )Ba133 &La139(n,5n)La135(β <sup>+</sup> )Ba135(n,3n)Ba133 &La139(n,t)Ba137(n,5n)Ba133 &La139(n,3n)La137(n,2nt)Ba133				1.6	91.3	1.9	86.1 25.6 2.2 5.8 25.7 25.3 10.8 2.4
H3	12.33 y	La138(n,X)H1(n,γ)H2(n,γ)H3 La139(n,2n)La138(n,X)H3 La139(n,X)H3 La139(n,3n)La137(n,X)H3 La139(n,4n)La136(β <sup>+</sup> )Ba136(n,X)H3 La139(n,5n)La135(β <sup>+</sup> )Ba135(n,X)H3	92.7	94.7	99.3	60.1 38.4	6.8 80.8 10.5	3.1 86.0 4.8 2.1	1.7 87.1 1.9 1.1 4.0
Cs137	30.041 y	La139(n,γ)La140(n,α)Cs137 &La138(n,α)Cs135(n,γ)Cs136(n,γ)Cs137 &La139(n,2n)La138(n,d)Ba137(n,p)Cs137 &La139(n,d)Ba138(n,2n)Ba137(n,p)Cs137 La139(n,d)Ba138(n,d)Cs137 &La139(n,t)Ba137(n,p)Cs137 &La139(n,2n)La138(n,2n)La137(n,p) Ba137(n,p)Cs137 &La139(n,2n)La138(n,p)Ba138(n,2n) Ba137(n,p)Cs137 La139(n,2n)La138(n,p)Ba138(n,d)Cs137 &La139(n,α)Cs136(n,γ)Cs137 La139(n,h)Cs137	99.9	79.6 20.4	100.0	39.1 30.3 14.5 7.2 3.1 2.4 1.5 1.1	0.2 0.2 72.6 4.4 3.9	33.8 3.9	25.7 71.2
Sm151	90.0 y	&La139(n,γ)La140(β <sup>-</sup> )Ce140(n,γ)Ce141 (β <sup>-</sup> )Pr141(n,γ)Pr142(β <sup>-</sup> )Nd142(n,γ)Nd143 (n,γ)Nd144(n,γ)Nd145(n,γ)Nd146(n,γ) Nd147(β <sup>-</sup> )Pm147(n,γ)Pm148(n,γ)Pm149 (β <sup>-</sup> )Sm149(n,γ)Sm150(n,γ)Sm151 &La139(n,γ)La140(β <sup>-</sup> )Ce140(n,γ)Ce141 (β <sup>-</sup> )Pr141(n,γ)Pr142(β <sup>-</sup> )Nd142(n,γ)Nd143 (n,γ)Nd144(n,γ)Nd145(n,γ)Nd146(n,γ) Nd147(β <sup>-</sup> )Pm147(n,γ)Pm148(β <sup>-</sup> )Sm148 (n,γ)Sm149(n,γ)Sm150(n,γ)Sm151 &La139(n,γ)La140(β <sup>-</sup> )Ce140(n,γ)Ce141 (β <sup>-</sup> )Pr141(n,γ)Pr142(β <sup>-</sup> )Nd142(n,γ)Nd143 (n,γ)Nd144(n,γ)Nd145(n,γ)Nd146(n,γ) Nd147(n,γ)Nd148(n,γ)Nd149(β <sup>-</sup> )Pm149 (β <sup>-</sup> )Sm149(n,γ)Sm150(n,γ)Sm151 &La139(n,γ)La140(n,γ)La141(β <sup>-</sup> )Ce141 (β <sup>-</sup> )Pr141(n,γ)Pr142(β <sup>-</sup> )Nd142(n,γ)Nd143 (n,γ)Nd144(n,γ)Nd145(n,γ)Nd146(n,γ) Nd147(β <sup>-</sup> )Pm147(n,γ)Pm148(n,γ)Pm149 (β <sup>-</sup> )Sm149(n,γ)Sm150(n,γ)Sm151 La139(n,γ)La140(n,γ)La141(n,γ)La142(β <sup>-</sup> ) Ce142(n,γ)Ce143(β <sup>-</sup> )Pr143(β <sup>-</sup> )Nd143(n,γ) Nd144(n,γ)Nd145(n,γ)Nd146(n,γ)Nd147(β <sup>-</sup> ) Pm147(n,γ)Pm148(n,γ)Pm149(β <sup>-</sup> )Sm149(n,γ) Sm150(n,γ)Sm151 Other very long pathways of (n,γ), β <sup>-</sup>	12.1 1.1 0.7 0.6 85.5	0.1 0.1 0.1 0.7 98.4					
Ho166m	1200 y	Very long pathways of (n,γ), β <sup>-</sup>	100.0						
La137	6.0 10 <sup>4</sup> y	La139(n,2n)La138(n,2n)La137 La138(n,2n)La137 La139(n,3n)La137				99.3 0.7	98.4	98.7	98.7

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
Cs135	2.3 10 <sup>6</sup> y	La138(n,α)Cs135 &La139(n,2n)La138(n,α)Cs135 &La139(n,α)Cs135 &La139(n,α)Cs136(n,2n)Cs135 &La139(n,4n)La136(β <sup>+</sup> )Ba136(n,d)Cs135 &La139(n,t)Ba137(n,t)Cs135 &La139(n,nt)Ba136(n,d)Cs135 &La139(n,d)Ba138(n,nt)Cs135 &La139(n,5n)La135(β <sup>+</sup> )Ba135(n,p)Cs135	100.0	100.0	100.0	0.5 83.7 12.9 2.1	0.8 94.8	0.2 69.5 25.2 1.7 0.6 0.3	0.5 68.6 15.2 4.9 4.1 3.4 1.5	
La138	1.0 10 <sup>11</sup> y	Nuclide present in starting material La139(n,2n)La138	100.0	100.0	100.0		99.6	98.8	98.1	
Sm147	1.1 10 <sup>11</sup> y	&La139(n,γ)La140(β <sup>-</sup> )Ce140(n,γ)Ce141_ (β <sup>-</sup> )Pr141(n,γ)Pr142(β <sup>-</sup> )Nd142(n,γ)Nd143_ (n,γ)Nd144(n,γ)Nd145(n,γ)Nd146(n,γ)_ Nd147(β <sup>-</sup> )Pm147(β <sup>-</sup> )Sm147 &La139(n,γ)La140(n,γ)La141(β <sup>-</sup> )Ce141_ (β <sup>-</sup> )Pr141(n,γ)Pr142(β <sup>-</sup> )Nd142(n,γ)Nd143_ (n,γ)Nd144(n,γ)Nd145(n,γ)Nd146(n,γ)_ Nd147(β <sup>-</sup> )Pm147(β <sup>-</sup> )Sm147 La139(n,γ)La140(β <sup>-</sup> )Ce140(n,γ)Ce141(n,γ)_ Ce142(n,γ)Ce143(β <sup>-</sup> )Pr143(β <sup>-</sup> )Nd143(n,γ)_ Nd144(n,γ)Nd145(n,γ)Nd146(n,γ)Nd147_ (β <sup>-</sup> )Pm147(β <sup>-</sup> )Sm147 &La139(n,γ)La140(β <sup>-</sup> )Ce140(n,γ)Ce141_ (β <sup>-</sup> )Pr141(n,γ)Pr142(n,γ)Pr143(β <sup>-</sup> )Nd143_ (n,γ)Nd144(n,γ)Nd145(n,γ)Nd146(n,γ)_ Nd147(β <sup>-</sup> )Pm147(β <sup>-</sup> )Sm147 &La139(n,γ)La140(n,γ)La141(β <sup>-</sup> )Ce141_ (β <sup>-</sup> )Pr141(n,γ)Pr142(n,γ)Pr143(β <sup>-</sup> )Nd143_ (n,γ)Nd144(n,γ)Nd145(n,γ)Nd146(n,γ)_ Nd147(β <sup>-</sup> )Pm147(β <sup>-</sup> )Sm147 La139(n,γ)La140(n,γ)La141(β <sup>-</sup> )Ce141(n,γ)_ Ce142(n,γ)Ce143(β <sup>-</sup> )Pr143(β <sup>-</sup> )Nd143(n,γ)_ Nd144(n,γ)Nd145(n,γ)Nd146(n,γ)Nd147_ (β <sup>-</sup> )Pm147(β <sup>-</sup> )Sm147 La139(n,γ)La140(n,γ)La141(n,γ)La142(β <sup>-</sup> )_ Ce142(n,γ)Ce143(β <sup>-</sup> )Pr143(β <sup>-</sup> )Nd143(n,γ)_ Nd144(n,γ)Nd145(n,γ)Nd146(n,γ)Nd147_ (β <sup>-</sup> )Pm147(β <sup>-</sup> )Sm147	87.0	0.1	57.1					
			4.0	45.3	15.8					
			2.4		10.6					
			0.4		3.1					
			0.1	8.7	0.8					
			0.1	8.1	2.6					
				29.7						

# Lanthanum activation characteristics



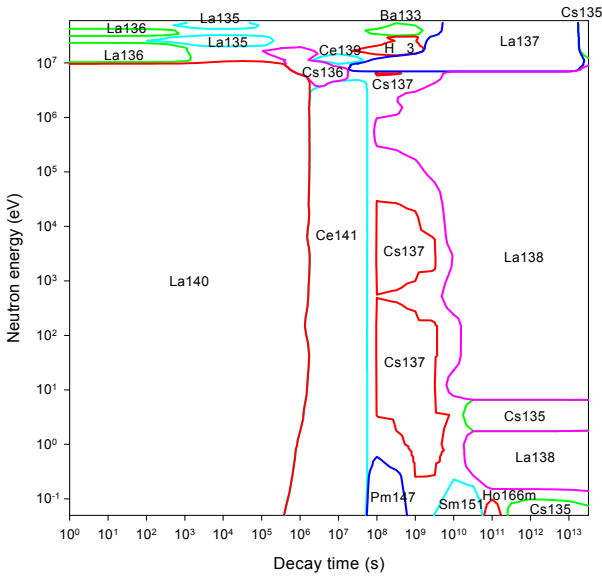
Decay time (years)

Decay time (years)

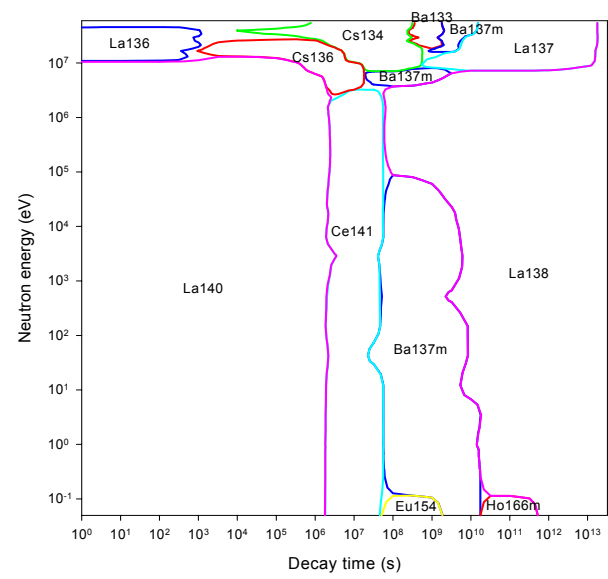


# Lanthanum importance diagrams & transmutation

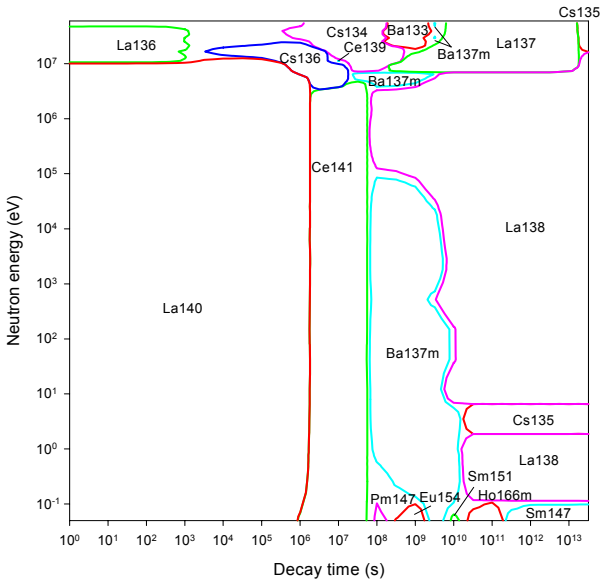
Activity



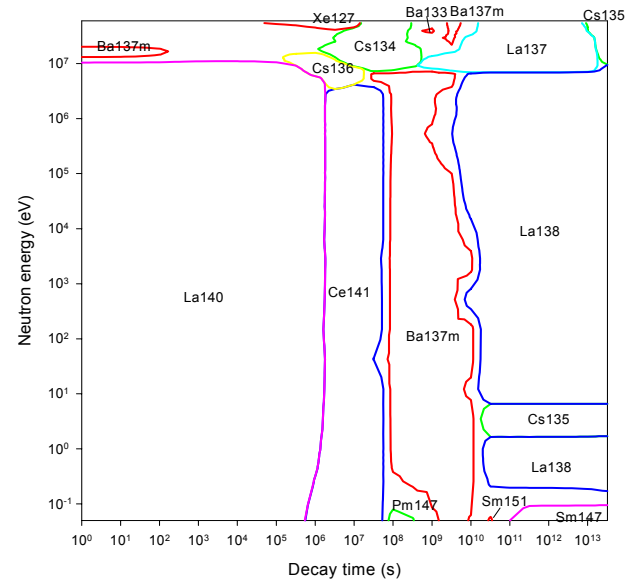
Dose rate



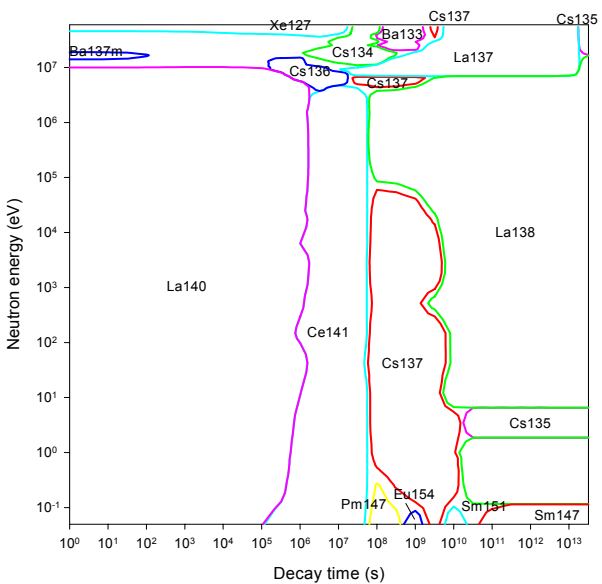
Heat output



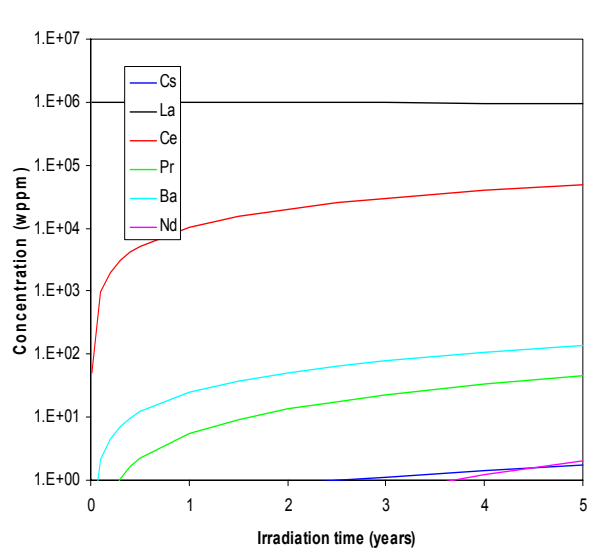
Ingestion dose



Inhalation dose



First wall transmutation





# Cerium

## General properties

Atomic number	58	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	66.5	Ce136	0.185 ( $T_{1/2} = 7.00 \cdot 10^{13}$ y)
Melting point / K	1072	Ce138	0.251
Boiling point / K	3697	Ce140	88.450
Density / $\text{kgm}^{-3}$	6770	Ce142	11.114 ( $T_{1/2} = 5.00 \cdot 10^{16}$ y)
Thermal conductivity / $\text{Wm}^{-1}\text{K}^{-1}$	11.4		
Electrical resistivity / $\Omega\text{m}$	$7.3 \cdot 10^{-7}$		
Coefficient of thermal expansion / $\text{K}^{-1}$	$5.2 \cdot 10^{-6}$		
Crystal structure	FCC		
Number of stable isotopes	2 (4)		
Mean atomic weight	140.115		

## Activation properties

Act	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Heat	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Bq $\text{kg}^{-1}$	1.46E15	1.03E15	9.09E14	1.19E14	7.42E8	2.31E8	kW $\text{kg}^{-1}$	1.05E-1	5.35E-2	3.34E-2	3.67E-3	4.18E-9	1.19E-9
Ce139	51.34	72.64	80.76	99.94			Ce139m	49.33	1.97				
Ce139m	29.45	0.84					Ce139	21.98	43.20	67.82	99.92		
Ce141	10.97	15.53	16.27	0.06			La140	16.49	32.37	11.47			
La140	2.61	3.68	0.93				Ce141	5.97	11.73	17.36	0.07		
Pr142	1.09	1.53	0.07				Pr142	2.09	4.10	0.26			
Ce137	1.07	1.51	0.08				Ce143	1.67	3.29	0.84			
Ce143	1.07	1.50	0.27				Pr143	0.89	0.60				
Pr143	1.06	1.50	1.54				Ba137m	0.14	0.07			5.38	
Pr142m	0.38	0.42					La137					90.24	99.99
La137					98.85	100.0	Ba133					2.70	
H3					0.35		Cs137					1.62	
Dose	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Ing	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{h}^{-1}$	9.39E4	2.97E4	7.64E3	2.96E2	5.33E-4	6.45E-5	Sv $\text{kg}^{-1}$	4.70E5	4.49E5	3.33E5	3.10E4	1.32E-1	1.87E-2
Ce139m	69.24	4.44					Ce139	41.39	43.27	57.24	99.81		
La140	26.55	83.94	72.21				Ce141	24.16	25.26	31.49	0.15		
Ce139	1.98	6.28	23.93	99.91			La140	16.17	16.88	5.04			
Ce143	0.53	1.68	1.04				Pr142	4.38	4.56	0.26			
Pr142	0.31	0.98	0.16				Pr143	3.93	4.11	5.02			
Ce141	0.21	0.66	2.37	0.03			Ce143	3.63	3.79	0.82			
Ba137m	0.19	0.15			51.82		Ba133				0.01	1.77	
Ba133				0.01	9.87		La137					45.10	99.99
La137					38.27	99.71	Cs137					22.29	
Inh	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Clear	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{kg}^{-1}$	2.15E6	2.13E6	2.00E6	2.26E5	6.51E0	2.01E0		1.10E12	7.99E11	7.45E11	1.19E11	4.38E4	6.08E3
Ce139	66.14	66.56	69.67	99.88			Ce139	67.83	93.58	98.62	99.99		
Ce141	28.28	28.45	28.06	0.11			Ce139m	27.80	0.78				
La140	1.95	1.95	0.46				La140	3.45	4.75	1.13			
Pr143	1.72	1.73	1.67				Ce141	0.15	0.20	0.20			
Ce143	0.60	0.60	0.10				Ce143	0.14	0.19	0.03			
Pr142	0.41	0.41	0.02				Ba137m	0.07	0.02			2.86	
Ce137m	0.07	0.07	0.01				Pr142	0.01	0.02				
Ba133				0.01	0.24		Cs137					51.58	
La137					98.01	100.0	La137					44.08	99.99
Cs137					1.35		Ba133					1.42	

# Cerium

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Ce139m	56.1 s	Ce138(n,γ)Ce139m Ce140(n,2n)Ce139m Ce142(n,3n)Ce140(n,2n)Ce139m Ce142(n,4n)Ce139m	100.0	99.9	100.0	98.6 0.3	95.7 2.6 1.1	68.9 29.8	78.9 20.2
Ba137m	2.552 m	Ce140(n,α)Ba137m Ce138(n,γ)Ce139(n,α)Ba136(n,γ)Ba137m &Ce136(n,γ)Ce137(β <sup>+</sup> )La137(n,γ)La138_ (n,α)Cs135(n,γ)Cs136(n,γ)Cs137(β <sup>-</sup> )Ba137m &Ce136(n,γ)Ce137m(β <sup>+</sup> )La137(n,γ)La138_ (n,α)Cs135(n,γ)Cs136(n,γ)Cs137(β <sup>-</sup> )Ba137m &Ce140(n,2n)Ce139(β <sup>+</sup> )La139(n,2n)_ La138(n,d)Ba137m Ce142(n,α)Ba138(n,2n)Ba137m Ce142(n,3n)Ce140(n,α)Ba137m &Ce140(n,2n)Ce139(β <sup>+</sup> )La139(n,t)Ba137m Ce142(n,2nα)Ba137m Ce140(n,d)La139(n,t)Ba137m Ce140(n,t)La138(n,d)Ba137m &Ce142(n,4n)Ce139(β <sup>+</sup> )La139(n,t)Ba137m &Ce140(n,4n)Ce137(β <sup>+</sup> )La137(n,p)Ba137m	96.9 2.4	85.6 13.0	100.0	90.5 2.4 0.3 0.2 0.1	80.0 1.5 1.1 2.1 6.5 1.3 0.8 0.8	34.9 0.5 0.2 22.3 10.8 7.3 7.1 8.1 3.0	40.0 0.1 0.2 0.2 22.1 8.2 9.5 9.9 3.7 1.2
La136	9.87 m	Ce136(β <sup>+</sup> )La136 &Ce140(n,2n)Ce139(β <sup>+</sup> )La139(n,2n)_ La138(n,2n)La137(n,2n)La136 &Ce140(n,2n)Ce139(n,2n)Ce138(n,2n)_ Ce137(β <sup>+</sup> )La137(n,2n)La136 &Ce138(n,2n)Ce137(β <sup>+</sup> )La137(n,2n)La136 &Ce140(n,3n)Ce138(n,2n)Ce137(β <sup>+</sup> )_ La137(n,2n)La136 &Ce140(n,2n)Ce139(β <sup>+</sup> )La139(n,2n)_ La138(n,3n)La136 &Ce140(n,2n)Ce139(β <sup>+</sup> )La139(n,3n)_ La137(n,2n)La136 &Ce140(n,3n)Ce138(n,t)La136 &Ce140(n,t)La138(n,3n)La136 &Ce140(n,nt)La137(n,2n)La136 &Ce140(n,2n)Ce139(β <sup>+</sup> )La139(n,4n)La136 &Ce140(n,4n)Ce137(β <sup>+</sup> )La137(n,2n)La136 &Ce142(n,4n)Ce139(β <sup>+</sup> )La139(n,4n)La136 &Ce140(n,d)La139(n,4n)La136 &Ce140(n,2nt)La136 Other pathways involving (n,2n), (n,α), β <sup>+</sup>	100.0		100.0	53.7 20.7 18.2 0.6 15.2 14.3 12.3 10.7 8.4 0.1 31.3 23.0 11.5 10.2 7.4	0.5 0.3 0.3 9.5 5.3 0.5 38.4	0.5 0.3 0.3 9.5 5.3 0.5 31.3 23.0 11.5 10.2 7.6	5.8 4.8 3.5 13.4 14.4 2.2 5.7 41.9 8.3
Pr144	17.28 m	&Ce142(n,γ)Ce143(β <sup>-</sup> )Pr143(n,γ)Pr144 &Ce140(n,γ)Ce141(n,γ)Ce142(n,γ)Ce143_ (β <sup>-</sup> )Pr143(n,γ)Pr144 &Ce142(n,γ)Ce143(n,γ)Ce144(β <sup>-</sup> )Pr144 Ce142(n,γ)Ce143(β <sup>-</sup> )Pr143(β <sup>-</sup> )Nd143(n,γ)_ Nd144(n,p)Pr144	98.7 0.9 0.7	100.0	97.1 3.0	91.0 9.0	85.7 9.2 4.1	86.5 9.4 3.4	88.3 9.5 2.0
Ba129m	2.14 h	&Ce136(n,α)Ba132(n,2n)Ba131(n,2n)_ Ba130(n,2n)Ba129m &Ce136(n,α)Ba133(n,2n)Ba132(n,2n)_ Ba131(n,2n)Ba130(n,2n)Ba129m Ce140(n,3n)Ce138(n,3n)Ce136(n,α)_ Ba132(n,3n)Ba130(n,2n)Ba129m Ce136(n,α)Ba132(n,3n)Ba130(n,2n)Ba129m Ce140(n,3n)Ce138(n,α)Ba134(n,3n)_ Ba132(n,3n)Ba130(n,2n)Ba129m				45.8 28.1	11.7 10.6 9.5		

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Ce140(n,α)Ba136(n,3n)Ba134(n,3n)_ Ba132(n,3n)Ba130(n,2n)Ba129m &Ce140(n,2nα)Ba135(n,4n)Ba132(n,4n)Ba129m   Ce140(n,5n)Ce136(n,5n)Ce132(β <sup>+</sup> )La132_ (β <sup>+</sup> )Ba132(n,4n)Ba129m Ce140(n,5n)Ce136(n,4n)Ce133m(β <sup>+</sup> )_ La133(β <sup>+</sup> )Ba133(n,5n)Ba129m Ce140(n,5n)Ce136(n,4nα)Ba129m Ce140(n,5n)Ce136(n,nt)La133(β <sup>+</sup> )Ba133_ (n,5n)Ba129m &Ce140(n,4nα)Ba133(n,5n)Ba129m Ce140(n,nt)La137(n,5n)La133(β <sup>+</sup> )Ba133_ (n,5n)Ba129m Other pathways involving (n,2n), (n,α), β <sup>+</sup>					4.5		12.2	0.4
						26.1	63.7	87.8		14.7
										14.0
										8.6
										6.4
										4.2
										4.2
										47.5
Ce137	9.0 h	&Ce136(n,γ)Ce137 &Ce140(n,2n)Ce139(n,2n)Ce138(n,2n)Ce137   &Ce138(n,2n)Ce137 &Ce140(n,3n)Ce138(n,2n)Ce137 &Ce140(n,2n)Ce139(n,3n)Ce137 &Ce142(n,3n)Ce140(n,3n)Ce138(n,2n)Ce137   &Ce140(n,4n)Ce137 &Ce142(n,6n)Ce137	100.0	100.0	100.0	68.7 28.0	0.2 1.5 85.0 8.9 1.0		93.5	94.7 3.0
Pr142	19.12 h	&Ce140(n,γ)Ce141(β <sup>-</sup> )Pr141(n,γ)Pr142 &Ce142(n,2n)Ce141(β <sup>-</sup> )Pr141(n,γ)Pr142 &Ce142(n,γ)Ce143(β <sup>-</sup> )Pr143(β <sup>-</sup> )Nd143(n,d)Pr142   &Ce142(n,d)La141(β <sup>-</sup> )Ce141(β <sup>-</sup> )Pr141(n,γ)Pr142	99.4	99.1	99.2	0.4 98.2	0.4 79.9 8.9 8.8	0.4 69.9 13.6 14.5	0.4 63.2 16.0 19.0	
Ce143	1.379 d	Ce142(n,γ)Ce143 Ce140(n,γ)Ce141(n,γ)Ce142(n,γ)Ce143	99.1 0.9	100.0	100.0	99.9	99.6	99.7	99.8	
La140	1.679 d	&Ce136(n,γ)Ce137(β <sup>+</sup> )La137(n,γ)La138_ (n,γ)La139(n,γ)La140 &Ce138(n,γ)Ce139(β <sup>+</sup> )La139(n,γ)La140 Ce140(n,p)La140 &Ce140(n,2n)Ce139(β <sup>+</sup> )La139(n,γ)La140 Ce142(n,3n)Ce140(n,p)La140 Ce142(n,t)La140	80.0 20.0	94.0 5.9	0.2 99.8	95.8 3.4 0.3	91.4 68.7 49.1	68.7 49.9		
Pr143	13.56 d	Ce142(n,γ)Ce143(β <sup>-</sup> )Pr143 Ce140(n,γ)Ce141(n,γ)Ce142(n,γ)Ce143_ (β <sup>-</sup> )Pr143	99.0 0.8	100.0	100.0	99.4	99.4	99.5	99.7	
Ce141	32.5 d	Ce140(n,γ)Ce141 Ce142(n,2n)Ce141 Ce142(n,d)La141(β <sup>-</sup> )Ce141	100.0	100.0	100.0	0.4 99.4	0.5 88.5 9.7	81.5 17.0	75.9 22.8	
Xe127	36.40 d	Pathways involving (n,α), (n,nα), (n,2n), β <sup>-</sup> , β <sup>+</sup>				100.0	100.0	100.0	100.0	
Ce139	137.64 d	&Ce138(n,γ)Ce139 &Ce140(n,2n)Ce139 &Ce142(n,3n)Ce140(n,2n)Ce139 &Ce142(n,4n)Ce139	100.0	99.9	100.0	99.3 0.2	94.5 2.3 1.5	71.8 25.9	84.6 14.2	
Ce144	285.0 d	Ce142(n,γ)Ce143(n,γ)Ce144 Ce140(n,γ)Ce141(n,γ)Ce142(n,γ)Ce143_ (n,γ)Ce144	99.3 0.7	100.0	100.0	99.9	99.6	99.7	99.8	
Cs134	2.065 y	&Ce136(n,α)Ba133(β <sup>+</sup> )Cs133(n,γ)Cs134 &Ce136(n,γ)Ce137(β <sup>+</sup> )La137(n,α)Cs134 &Ce140(n,2n)Ce139(β <sup>+</sup> )La139(n,2n)_ La138(n,2n)La137(n,α)Cs134 &Ce140(n,2n)Ce139(β <sup>+</sup> )La139(n,2n)_ La138(n,α)Cs135(n,2n)Cs134 &Ce138(n,2n)Ce137(β <sup>+</sup> )La137(n,α)Cs134 &Ce140(n,2n)Ce139(β <sup>+</sup> )La139(n,2n)_ La138(n,α)Cs134 &Ce140(n,2n)Ce139(n,2n)Ce138(n,2n)_ Ce137(β <sup>+</sup> )La137(n,α)Cs134	98.5 1.5	95.2 4.8	94.1 5.9	24.5 20.2 13.5 12.2 10.9	0.2 7.6	0.1		
	▶									

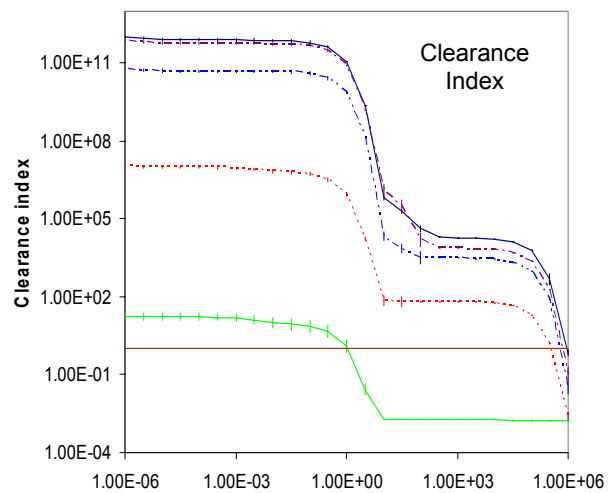
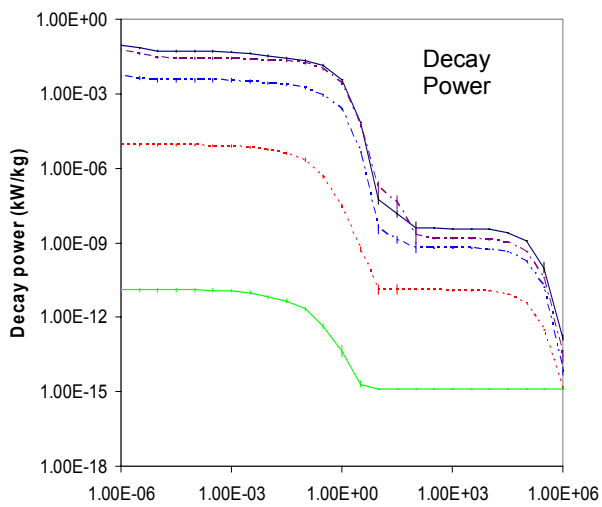
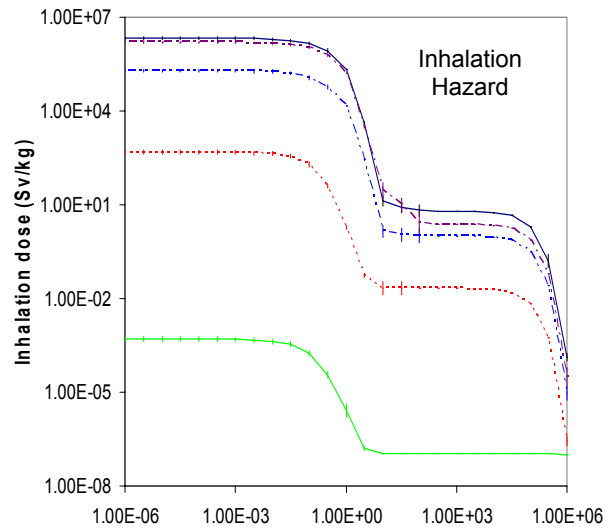
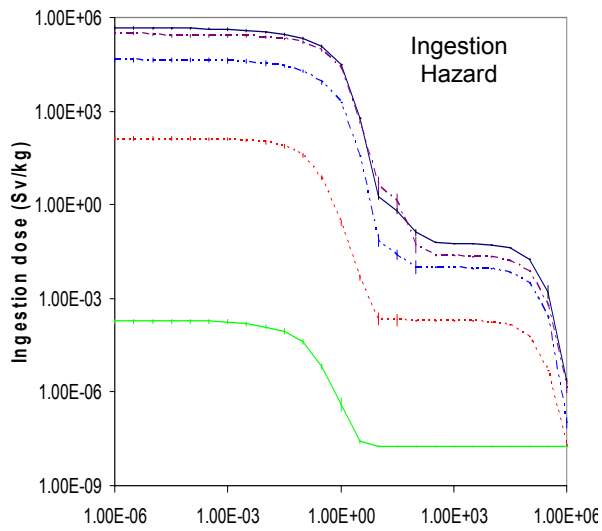
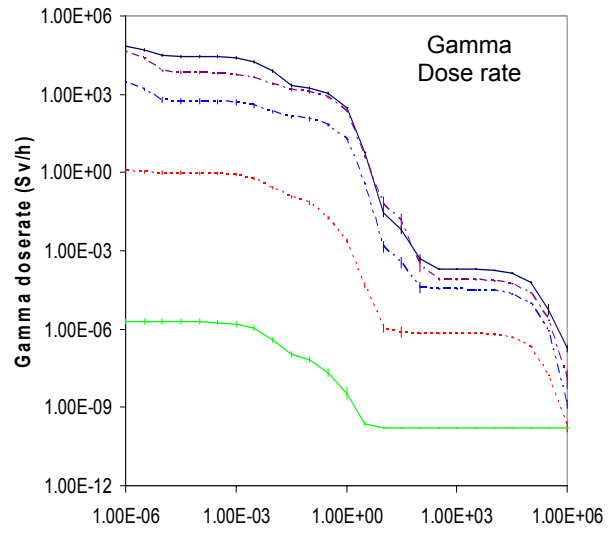
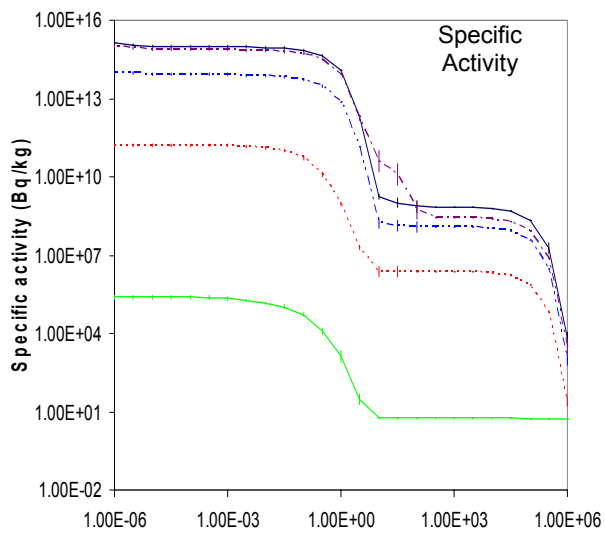
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	&Ce140(n,2n)Ce139(β <sup>+</sup> )La139(n,α) <sub>-</sub> Cs135(n,2n)Cs134 &Ce136(n,2n)Ce135(β <sup>+</sup> )La135(β <sup>+</sup> )Ba135_ (n,d)Cs134 &Ce140(n,t)La138(n,α)Cs134 &Ce140(n,3n)Ce138(n,2n)Ce137(β <sup>+</sup> )_ La137(n,α)Cs134 &Ce140(n,2n)Ce139(β <sup>+</sup> )La139(n,3n)_ La137(n,α)Cs134 &Ce140(n,2n)Ce139(β <sup>+</sup> )La139(n,2nα)Cs134 &Ce140(n,α)Ba136(n,t)Cs134 &Ce140(n,d)La139(n,2nα)Cs134 &Ce140(n,2nα)Ba135(n,d)Cs134 &Ce140(n,4n)Ce137(β <sup>+</sup> )La137(n,α)Cs134 &Ce142(n,4n)Ce139(β <sup>+</sup> )La139(n,2nα)Cs134 Ce140(n,3n)Ce138(n,4n)Ce135(β <sup>+</sup> )La135_ (β <sup>+</sup> )Ba135(n,d)Cs134 &Ce140(n,2nt)La136(β <sup>+</sup> )Ba136(n,t)Cs134 Other pathways involving (n,2n), (n,α), β <sup>+</sup>				6.2	4.2			
						3.7	3.5	0.3		
							6.7	6.3	5.4	
							6.5	0.1		
							4.8			
							4.7	16.1	8.6	
							4.2	5.7	5.1	
							0.6	5.6	4.8	
							0.5	6.0	5.6	
								7.8	10.6	
								5.9	1.8	
								5.1	1.2	
							8.8	56.5	41.0	
									44.3	
Pm147	2.623 y	Ce142(n,γ)Ce143(β <sup>-</sup> )Pr143(β <sup>-</sup> )Nd143(n,γ) <sub>-</sub> Nd144(n,γ)Nd145(n,γ)Nd146(n,γ)Nd147_ (β <sup>-</sup> )Pm147 &Ce140(n,γ)Ce141(β <sup>-</sup> )Pr141(n,γ)Pr142_ (β <sup>-</sup> )Nd142(n,γ)Nd143(n,γ)Nd144(n,γ) <sub>-</sub> Nd145(n,γ)Nd146(n,γ)Nd147(β <sup>-</sup> )Pm147 &Ce142(n,γ)Ce143(β <sup>-</sup> )Pr143(n,γ)Pr144_ (β <sup>-</sup> )Nd144(n,γ)Nd145(n,γ)Nd146(n,γ) <sub>-</sub> Nd147(β <sup>-</sup> )Pm147	87.2	95.3	93.7	87.7	71.3	45.2		
			7.4							
			5.2	4.6	6.1	11.0	24.1	53.9		
Eu154	8.593 y	Very long pathways of (n,γ), β <sup>-</sup>	100.0	100.0	100.0					
Ba133	10.54 y	&Ce136(n,α)Ba133 &Ce136(n,2n)Ce135(β <sup>+</sup> )La135(β <sup>+</sup> )Ba135_ (n,2n)Ba134(n,2n)Ba133 &Ce136(n,2n)Ce135(β <sup>+</sup> )La135(β <sup>+</sup> )Ba135_ (n,3n)Ba133 &Ce136(n,3n)Ce134(β <sup>+</sup> )La134(β <sup>+</sup> )Ba134_ (n,2n)Ba133 &Ce140(n,3n)Ce138(n,2nα)Ba133 &Ce140(n,3n)Ce138(n,3n)Ce136(n,α)Ba133 &Ce140(n,3n)Ce138(n,α)Ba134(n,2n)Ba133 &Ce140(n,2nα)Ba135(n,3n)Ba133 &Ce140(n,α)Ba136(n,4n)Ba133 Ce140(n,3n)Ce138(n,3n)Ce136(n,4n) <sub>-</sub> Ce133m(β <sup>+</sup> )La133(β <sup>+</sup> )Ba133 Ce136(n,4n)Ce133m(β <sup>+</sup> )La133(β <sup>+</sup> )Ba133 Ce140(n,3n)Ce138(n,4n)Ce135(β <sup>+</sup> )La135_ (β <sup>+</sup> )Ba135(n,3n)Ba133 &Ce140(n,4n)Ce137(β <sup>+</sup> )La137(n,5n) <sub>-</sub> La133(β <sup>+</sup> )Ba133 Ce140(n,5n)Ce136(n,4n)Ce133m(β <sup>+</sup> )_ La133(β <sup>+</sup> )Ba133 Ce140(n,5n)Ce136(n,nt)La133(β <sup>+</sup> )Ba133 &Ce140(n,4nα)Ba133 Ce140(n,nt)La137(n,5n)La133(β <sup>+</sup> )Ba133 Ce140(n,5n)Ce136(n,4n)Ce133(β <sup>+</sup> )La133_ (β <sup>+</sup> )Ba133 Other pathways involving (n,2n), (n,α), β <sup>+</sup>	100.0	100.0	100.0	26.3	1.4			
						69.6				
							9.4	0.2		
							5.4	0.5		
							3.5	11.8	0.7	
							3.2			
							3.1	0.1		
							1.5	5.9	0.4	
								11.2	0.5	
								5.1	0.2	
								4.3	1.3	
								3.4		
									29.2	
									23.2	
									10.7	
									7.1	
									7.0	
									3.6	
							4.1	72.5	57.5	
									16.1	
H3	12.33 y	&Ce136(n,γ)Ce137(β <sup>+</sup> )La137(n,γ)La138_ (n,X)H1(n,γ)H2(n,γ)H3 Ce136(n,γ)Ce137m(n,X)H1(n,γ)H2(n,γ)H3 &Ce140(n,2n)Ce139(β <sup>+</sup> )La139(n,X)H3	91.6	91.6						
			2.7	3.5						
						29.7	1.2	0.6		

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&Ce140(n,2n)Ce139(β <sup>+</sup> )La139(n,2n)_ La138(n,X)H3 Ce142(n,2n)Ce141(β <sup>-</sup> )Pr141(n,X)H3 Ce142(n,X)H3 &Ce140(n,2n)Ce139(n,X)H3 Ce140(n,X)H3 Ce142(n,2n)Ce141(n,X)H3 Ce140(n,3n)Ce138(n,X)H3 Ce142(n,3n)Ce140(n,X)H3 Ce140(n,4n)Ce137(β <sup>+</sup> )La137(n,X)H3 Ce140(n,5n)Ce136(n,X)H3				28.2			
La137	6.0 10 <sup>4</sup> y	&Ce136(n,γ)Ce137(β <sup>+</sup> )La137 &Ce140(n,2n)Ce139(β <sup>+</sup> )La139(n,2n)_ La138(n,2n)La137 &Ce138(n,2n)Ce137(β <sup>+</sup> )La137 &Ce140(n,2n)Ce139(n,2n)Ce138(n,2n)_ Ce137(β <sup>+</sup> )La137 &Ce140(n,3n)Ce138(n,2n)Ce137(β <sup>+</sup> )La137 &Ce140(n,2n)Ce139(β <sup>+</sup> )La139(n,3n)La137 &Ce140(n,2n)Ce139(n,3n)Ce137(β <sup>+</sup> )La137 Ce140(n,3n)Ce138(n,d)La137 Ce140(n,d)La139(n,3n)La137 Ce140(n,nt)La137 &Ce140(n,4n)Ce137(β <sup>+</sup> )La137	99.9	99.9	99.9	59.0	0.3		
Cs135	2.3 10 <sup>6</sup> y	&Ce136(n,γ)Ce137(β <sup>+</sup> )La137(n,γ)La138_ (n,α)Cs135 &Ce136(n,α)Ba133(β <sup>+</sup> )Cs133(n,γ)Cs134_ (n,γ)Cs135 &Ce140(n,2n)Ce139(β <sup>+</sup> )La139(n,2n)_ La138(n,α)Cs135 &Ce140(n,2n)Ce139(β <sup>+</sup> )La139(n,α)Cs135 &Ce136(n,2n)Ce135(β <sup>+</sup> )La135(β <sup>+</sup> )Ba135_ (n,p)Cs135 &Ce140(n,2n)Ce139(β <sup>+</sup> )La139(n,α)Cs136_ (n,2n)Cs135 &Ce140(n,α)Ba136(n,d)Cs135 &Ce140(n,d)La139(n,α)Cs135 &Ce142(n,4n)Ce139(β <sup>+</sup> )La139(n,α)Cs135 &Ce140(n,3n)Ce138(n,t)La136(β <sup>+</sup> )Ba136_ (n,d)Cs135 &Ce140(n,t)La138(n,α)Cs135 &Ce140(n,4n)Ce137(β <sup>+</sup> )La137(n,h)Cs135 &Ce140(n,dα)Cs135 &Ce140(n,2nt)La136(β <sup>+</sup> )Ba136(n,d)Cs135 Other pathways involving (n,2n), (n,α), β <sup>+</sup>	77.7	98.5	91.9				
La138	1.0 10 <sup>11</sup> y	&Ce136(n,γ)Ce137(β <sup>+</sup> )La137(n,γ)La138 &Ce140(n,2n)Ce139(β <sup>+</sup> )La139(n,2n)La138 Ce140(n,t)La138 Ce140(n,d)La139(n,2n)La138 Ce140(n,3n)Ce138(n,p)La138 Ce142(n,2nt)La138	99.9	99.9	99.9	99.5	56.6	2.8	
Sm147	1.1 10 <sup>11</sup> y	Ce142(n,γ)Ce143(β <sup>-</sup> )Pr143(β <sup>-</sup> )Nd143(n,γ)_ Nd144(n,γ)Nd145(n,γ)Nd146(n,γ)Nd147_ (β <sup>-</sup> )Pm147(β <sup>-</sup> )Sm147 &Ce140(n,γ)Ce141(β <sup>-</sup> )Pr141(n,γ)Pr142(β <sup>-</sup> )_ Nd142(n,γ)Nd143(n,γ)Nd144(n,γ)Nd145(n,γ)_ Nd146(n,γ)Nd147(β <sup>-</sup> )Pm147(β <sup>-</sup> )Sm147 &Ce142(n,γ)Ce143(β <sup>-</sup> )Pr143(n,γ)Pr144_ (β <sup>-</sup> )Nd144(n,γ)Nd145(n,γ)Nd146(n,γ)_ Nd147(β <sup>-</sup> )Pm147(β <sup>-</sup> )Sm147	88.7	95.2	92.5	87.0	70.9		
Ce136	7.0 10 <sup>13</sup> y ▶	Ce140(n,3n)Ce138(n,3n)Ce136 Ce138(n,3n)Ce136					83.4	68.7	1.0
							2.7	3.4	0.1

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&Ce140(n,2n)Ce139(n,4n)Ce136 Ce140(n,5n)Ce136 Nuclide present in starting material	100.0	100.0	100.0	100.0	13.9	23.7	4.2 0.1 95.3 3.5



# Cerium activation characteristics

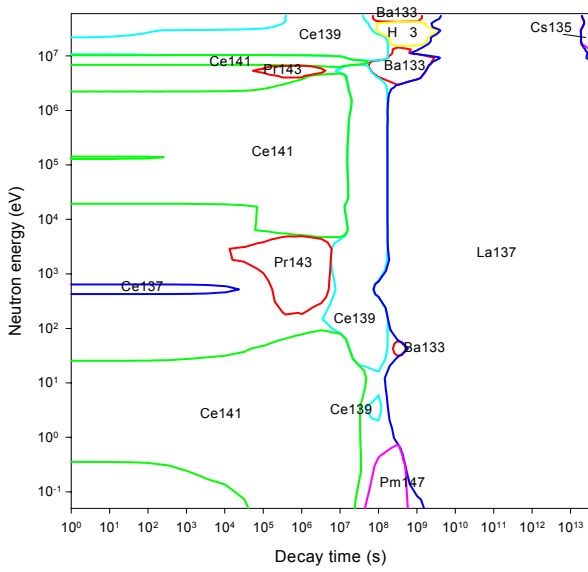


Decay time (years)

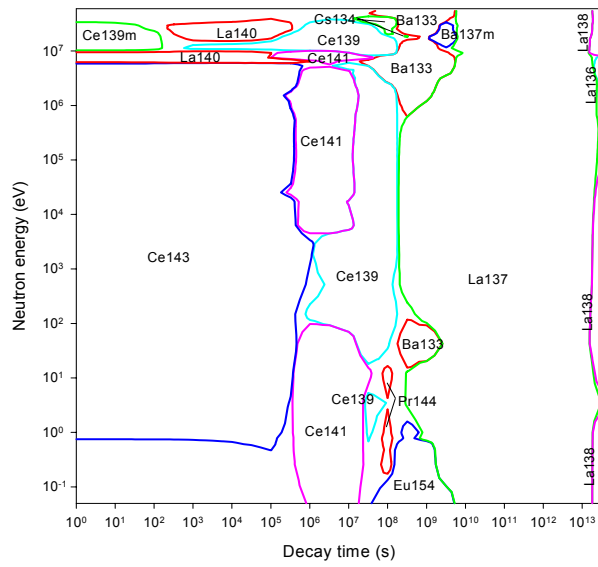
Decay time (years)

# Cerium importance diagrams & transmutation

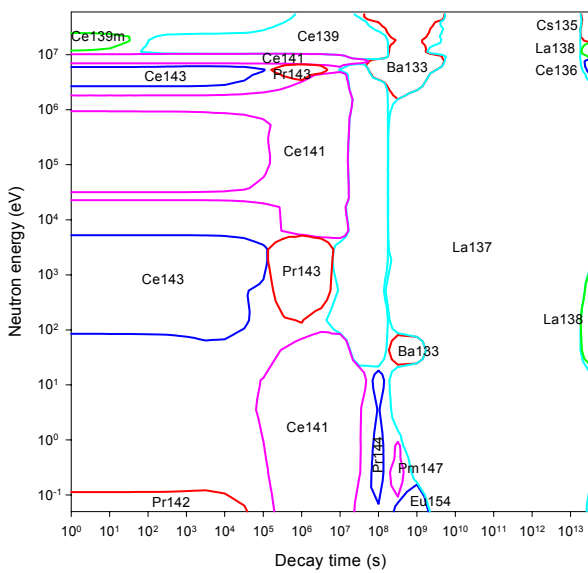
**Activity**



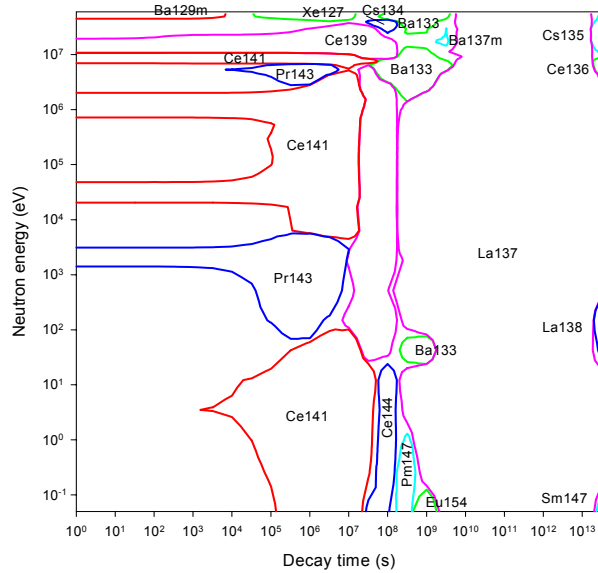
**Dose rate**



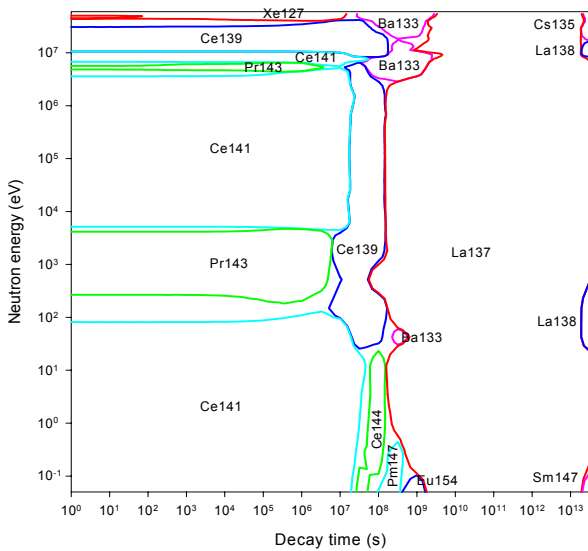
**Heat output**



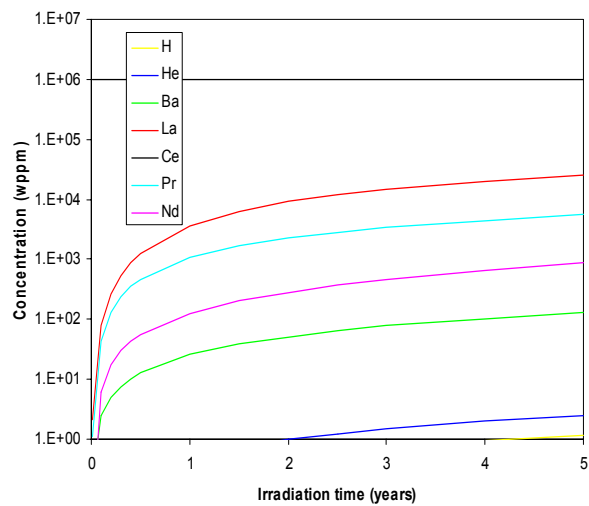
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**



# Praseodymium

## General properties

Atomic number	59	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	9.2	Pr141	100.0
Melting point / K	1204		
Boiling point / K	3783		
Density / kgm <sup>-3</sup>	6773		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	12.5		
Electrical resistivity /Ωm	6.8 10 <sup>-7</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	6.7 10 <sup>-6</sup>		
Crystal structure	HCP		
Number of stable isotopes	1		
Mean atomic weight	140.90765		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	4.39E15	3.58E15	1.36E14	4.27E12	1.33E8	1.04E6	kW kg <sup>-1</sup>	5.04E-1	4.00E-1	1.56E-2	1.31E-4	1.40E-10	5.38E-12
Pr142	56.84	69.44	76.69				Pr142	68.78	86.56	92.96			
Pr142m	19.79	18.88					Pr140	29.27	12.60				
Pr140	19.27	8.05					Nd141m	0.89	0.03				
Nd141	2.23	2.68					Nd141	0.28	0.34				
Nd141m	0.73	0.03					Ce139	0.16	0.21	5.18	99.90		
Ce139	0.61	0.74	19.21	99.15			Ce141	0.05	0.06	1.34	0.07		
Ce141	0.13	0.16	3.92	0.06			H3				0.02	85.04	
H3			0.03	0.80	97.48		La137					12.18	99.81
La137					2.48	99.99	Ba137m					2.14	
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	1.28E5	7.17E4	2.07E3	9.97E0	4.47E-6	2.88E-7	Sv kg <sup>-1</sup>	3.28E6	3.26E6	1.47E5	1.10E3	6.66E-3	8.46E-5
Pr140	56.72	34.49					Pr142	98.95	99.18	92.51			
Pr142	35.27	62.74	91.28				Pr142m	0.45	0.35				
Nd141m	4.62	0.24					Ce139	0.21	0.21	4.64	99.71		
Ce139m	1.94	0.07					Pr140	0.15	0.05				
Nd141	0.80	1.39					Ce141	0.13	0.13	2.58	0.15		
La140	0.40	0.71	5.43				La140	0.05	0.05	0.24			
Ce139	0.05	0.09	2.98	99.97			Ba137m	0.03	0.01			8.07	
Ba137m	0.01				80.31		H3				0.13	82.06	
La137					19.33	94.48	Cs137					5.85	
La138					0.36	5.52	La137					4.02	99.84
							Cs135						0.10
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	1.46E6	1.45E6	1.28E5	8.06E3	6.41E-2	9.08E-3		5.99E11	2.33E11	2.74E10	4.23E9	1.70E3	2.75E1
Pr142	94.18	94.47	44.98				Pr140	82.99	72.83				
Ce139	3.48	3.49	38.92	99.78			Nd141m	4.47	0.34				
Ce141	1.50	1.51	15.87	0.11			Ce139	4.45	11.44	95.36	99.99		
Pr142m	0.42	0.33					Pr142	4.16	10.68	3.81			
Pr140	0.28	0.10					Ce139m	1.99	0.10				
La140	0.06	0.06	0.15				Nd141	1.26	3.17				
Nd141	0.03	0.03					La140	0.13	0.34	0.63			
Pr143	0.01	0.01	0.07				Ce141	0.01	0.03	0.19			
H3			0.01	0.11	52.76		Ba137m	0.01				0.98	
La137					44.88	99.92	H3				0.01	76.33	
Cs137					1.82		Cs137					17.58	
La138					0.01	0.08	La137					5.11	99.83

# Praseodymium

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
Ba137m	2.552 m	&Pr141(n,γ)Pr142(β <sup>-</sup> )Nd142(n,α)Ce139_	81.0							
		(n,α)Ba136(n,γ)Ba137m								
		&Pr141(n,γ)Pr142(β <sup>-</sup> )Nd142(n,γ)Nd143_	11.2							
		(n,α)Ce140(n,α)Ba137m								
		&Pr141(n,γ)Pr142(β <sup>-</sup> )Nd142(n,α)Ce139_	3.5							
		(β <sup>+</sup> )La139(n,γ)La140(n,α)Cs137(β <sup>-</sup> )_								
		Ba137m								
		Pr141(n,α)La138(n,α)Cs135(n,γ)Cs136_	0.1	97.8						
		(n,γ)Cs137(β <sup>-</sup> )Ba137m								
		Pr141(n,2n)Pr140(β <sup>+</sup> )Ce140(n,α)Ba137m					95.9	24.3	2.0	2.5
		Pr141(n,d)Ce140(n,α)Ba137m					0.5	3.5	0.7	1.1
		Pr141(n,3n)Pr139(β <sup>+</sup> )Ce139(β <sup>+</sup> )La139_						43.1	80.8	64.0
		(n,t)Ba137m								
		Pr141(n,3n)Pr139(β <sup>+</sup> )Ce139(β <sup>+</sup> )La139_						11.3		0.8
(n,2n)La138(n,d)Ba137m										
Pr141(n,3n)Pr139(β <sup>+</sup> )Ce139(β <sup>+</sup> )La139_						8.4		0.6		
(n,d)Ba138(n,2n)Ba137m										
Pr141(n,3n)Pr139(β <sup>+</sup> )Ce139(β <sup>+</sup> )La139_						2.3				
(n,3n)La137(n,p)Ba137m										
&Pr141(n,t)Ce139(β <sup>+</sup> )La139(n,t)Ba137m						0.9	7.2	22.6		
Pr141(n,5n)Pr137(β <sup>+</sup> )Ce137(β <sup>+</sup> )La137_								2.5		
(n,p)Ba137m										
Pr140	3.39 m	Pr141(n,2n)Pr140				99.8	99.7	99.8	99.9	
Pr144	17.28 m	&Pr141(n,γ)Pr142(n,γ)Pr143(n,γ)Pr144	99.7	98.5	99.3	4.8	3.7	4.6		
		&Pr141(n,γ)Pr142(β <sup>+</sup> )Ce142(n,γ)Ce143_	0.3	0.4	0.2	0.3		0.1	0.4	
		(β <sup>-</sup> )Pr143(n,γ)Pr144								
		&Pr141(n,γ)Pr142(β <sup>-</sup> )Nd142(n,γ)Nd143_				85.0	84.6	84.6	82.4	
(n,γ)Nd144(n,p)Pr144										
&Pr141(n,γ)Pr142(β <sup>-</sup> )Nd142(n,γ)Nd143_				6.8	4.1	3.8	3.4			
(n,p)Pr143(n,γ)Pr144										
Pr138m	2.12 h	&Pr141(n,γ)Pr142(β <sup>-</sup> )Nd142(n,2n)_				99.9				
		Nd141(n,2n)Nd140(n,t)Pr138m								
		&Pr141(n,γ)Pr142(β <sup>-</sup> )Nd142(n,3n)_					99.7			
Nd140(n,t)Pr138m										
Pr141(n,4n)Pr138m							99.8	99.9		
Ba129m	2.14 h	Pathways involving (n,α), (n,nα), (n,2n), β <sup>-</sup> , β <sup>+</sup>				100.0	100.0	100.0	100.0	
Pr139	4.41 h	&Pr141(n,γ)Pr142(β <sup>-</sup> )Nd142(n,2n)Nd141_				42.2				
		(n,2n)Nd140(n,2n)Nd139m(β <sup>+</sup> )Pr139								
		&Pr141(n,γ)Pr142(β <sup>-</sup> )Nd142(n,2n)_				41.0				
		Nd141(n,2n)Nd140(n,2n)Nd139(β <sup>+</sup> )Pr139								
		&Pr141(n,γ)Pr142(β <sup>-</sup> )Nd142(n,2n)_				9.0				
Nd141(n,t)Pr139										
Pr141(n,3n)Pr139						99.8	99.8	99.9		
Ce135	17.70 h	&Pr141(n,2n)Pr140(β <sup>+</sup> )Ce140(n,2n)_				54.2				
		Ce139(n,2n)Ce138(n,2n)Ce137(n,2n)_								
		Ce136(n,2n)Ce135								
		&Pr141(n,2n)Pr140(β <sup>+</sup> )Ce140(n,2n)_				36.6				
		Ce139(n,2n)Ce138(n,2n)Ce137m(n,2n)_								
		Ce136(n,2n)Ce135								
		Pr141(n,2n)Pr140(β <sup>+</sup> )Ce140(n,3n)Ce138_						55.8		
		(n,3n)Ce136(n,2n)Ce135								
		Pr141(n,3n)Pr139(β <sup>+</sup> )Ce139(n,2n)Ce138_						12.3		
		(n,3n)Ce136(n,2n)Ce135								
&Pr141(n,d)Ce140(n,3n)Ce138(n,3n)_						9.7				
Ce136(n,2n)Ce135										
&Pr141(n,4n)Pr138m(β <sup>+</sup> )Ce138(n,4n)Ce135							49.8	43.0		

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&Pr141(n,4n)Pr138(β <sup>+</sup> )Ce138(n,4n)Ce135 &Pr141(n,nt)Ce138(n,4n)Ce135 Pr141(n,2n)Pr140(β <sup>+</sup> )Ce140(n,3n)Ce138_ (n,4n)Ce135 &Pr141(n,3n)Pr139(β <sup>+</sup> )Ce139(n,5n)Ce135						32.0 4.3 3.3	22.5 19.1 0.6 7.3
Pr142	19.12 h	&Pr141(n,γ)Pr142	100.0	100.0	100.0	100.0	100.0	100.0	100.0
La140	1.679 d	&Pr141(n,γ)Pr142(β <sup>-</sup> )Nd142(n,α)Ce139_ (β <sup>+</sup> )La139(n,γ)La140 Pr141(n,α)La138(n,γ)La139(n,γ)La140 &Pr141(n,γ)Pr142(n,α)La139(n,γ)La140 Pr141(n,2n)Pr140(β <sup>+</sup> )Ce140(n,p)La140 Pr141(n,d)Ce140(n,p)La140 Pr141(n,3n)Pr139(β <sup>+</sup> )Ce139(β <sup>+</sup> )La139(n,γ)La140 Pr141(n,2p)La140	61.2 20.6 17.0	19.3 80.3	41.0 23.5 35.3	97.8 0.5	85.4 12.3 1.9	70.8 24.4 2.2 2.0	55.1 25.3 17.7
Nd147	10.98 d	&Pr141(n,γ)Pr142(β <sup>-</sup> )Nd142(n,γ)Nd143_ (n,γ)Nd144(n,γ)Nd145(n,γ)Nd146(n,γ)_ Nd147 &Pr141(n,γ)Pr142(n,γ)Pr143(β <sup>-</sup> )Nd143_ (n,γ)Nd144(n,γ)Nd145(n,γ)Nd146(n,γ)_ Nd147	99.7 0.2	88.0 11.4	93.7 2.9				
Pr143	13.56 d	&Pr141(n,γ)Pr142(n,γ)Pr143 &Pr141(n,γ)Pr142(β <sup>+</sup> )Ce142(n,γ)Ce143_ (β <sup>-</sup> )Pr143 &Pr141(n,γ)Pr142(β <sup>-</sup> )Nd142(n,γ)Nd143_ (n,p)Pr143	97.9 1.7	98.2 1.8	98.9 1.1	39.8 3.7 55.6	34.5 2.7 62.0	42.3 3.3 53.6	58.4 4.3 36.7
Eu156	15.19 d	Very long pathways of (n,γ), β <sup>-</sup>	100.0	100.0	100.0				
Ce141	32.5 d	&Pr141(n,γ)Pr142(β <sup>-</sup> )Nd142(n,γ)Nd143_ (n,α)Ce140(n,γ)Ce141 &Pr141(n,γ)Pr142(β <sup>-</sup> )Nd142(n,γ)Nd143_ (n,γ)Nd144(n,α)Ce141 &Pr141(n,γ)Pr142(n,α)La139(n,γ)La140_ (n,γ)La141(β <sup>-</sup> )Ce141 &Pr141(n,γ)Pr142(n,γ)Pr143(β <sup>-</sup> )Nd143_ (n,α)Ce140(n,γ)Ce141 Pr141(n,α)La138(n,γ)La139(n,γ)La140_ (n,γ)La141(β <sup>-</sup> )Ce141 Pr141(n,p)Ce141 Pr141(n,2n)Pr140(β <sup>+</sup> )Ce140(n,γ)Ce141	75.6 21.5	59.5 21.6 10.3 4.4 2.4	75.9 21.6 1.5	97.5 1.9	99.1 99.2	99.2 99.3	99.3
Xe127	36.40 d	Pathways involving (n,α), (n,nα), (n,2n), β <sup>-</sup> , β <sup>+</sup>				100.0	100.0	100.0	100.0
Pm148m	41.05 d	&Pr141(n,γ)Pr142(β <sup>-</sup> )Nd142(n,γ)Nd143_ (n,γ)Nd144(n,γ)Nd145(n,γ)Nd146(n,γ)_ Nd147(β <sup>-</sup> )Pm147(n,γ)Pm148m &Pr141(n,γ)Pr142(n,γ)Pr143(β <sup>-</sup> )Nd143_ (n,γ)Nd144(n,γ)Nd145(n,γ)Nd146(n,γ)_ Nd147(β <sup>-</sup> )Pm147(n,γ)Pm148m	97.0 0.3	83.7 12.1	91.4 3.4				
Ce139	137.64 d	&Pr141(n,γ)Pr142(β <sup>-</sup> )Nd142(n,α)Ce139 &Pr141(n,2n)Pr140(β <sup>+</sup> )Ce140(n,2n)Ce139 Pr141(n,3n)Pr139(β <sup>+</sup> )Ce139 &Pr141(n,t)Ce139	100.0	100.0	100.0	99.3	3.9 93.6 1.8	90.1 8.0	72.4 25.6
Ce144	285.0 d	&Pr141(n,γ)Pr142(β <sup>+</sup> )Ce142(n,γ)Ce143_ (n,γ)Ce144 Pr141(n,p)Ce141(n,γ)Ce142(n,γ)Ce143_ (n,γ)Ce144	92.3	100.0	100.0	87.7 11.6	85.9 13.1	89.7 9.6	94.8 4.8
Cs134	2.065 y	&Pr141(n,α)La138(n,2n)La137(n,α)Cs134 &Pr141(n,α)La138(n,α)Cs135(n,2n)Cs134 &Pr141(n,2n)Pr140(β <sup>+</sup> )Ce140(n,2n)_ Ce139(β <sup>+</sup> )La139(n,2n)La138(n,nα)Cs134 Pr141(n,2n)Pr140(β <sup>+</sup> )Ce140(n,2n)Ce139(β <sup>+</sup> )_ La139(n,2n)La138(n,2n)La137(n,α)Cs134 &Pr141(n,nα)La137(n,α)Cs134				13.9 11.4 9.9 8.6 6.0	3.7	0.3	0.5

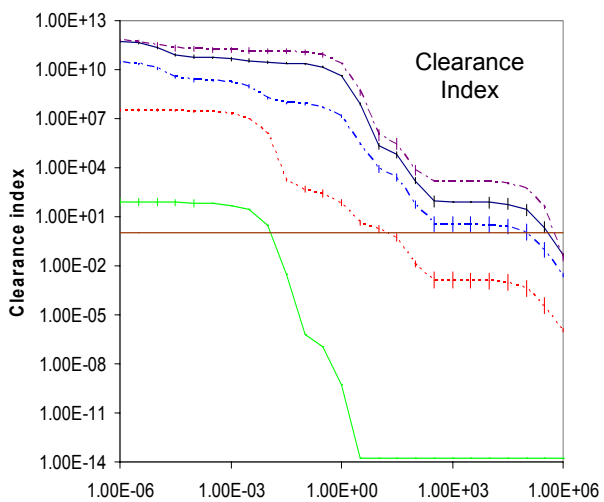
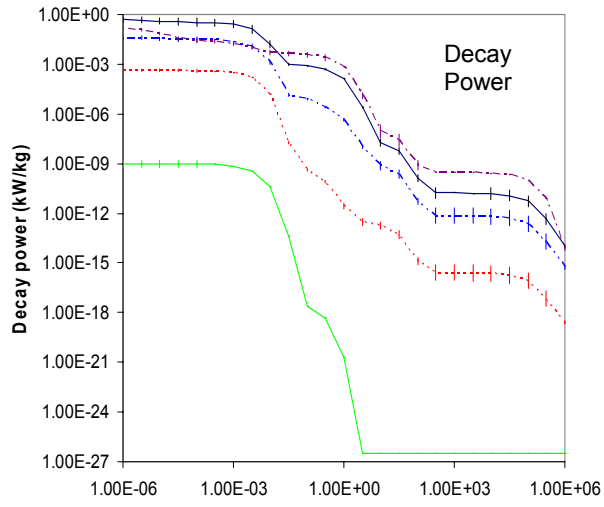
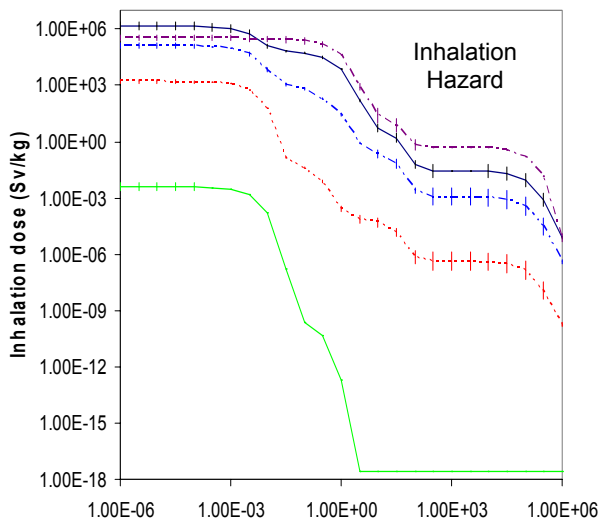
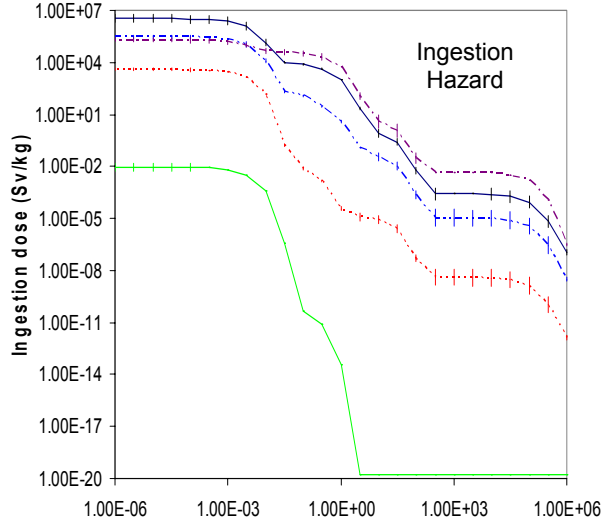
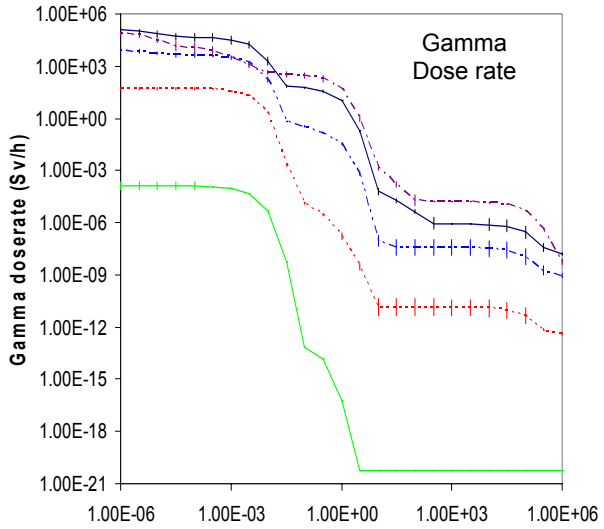
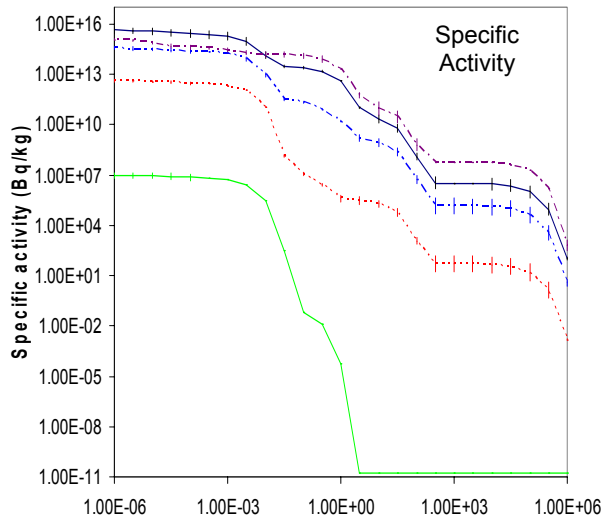
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Pr141(n,2n)Pr140(β <sup>+</sup> )Ce140(n,2n)Ce139(β <sup>+</sup> ) La139(n,2n)La138(n,α)Cs135(n,2n)Cs134 &Pr141(n,2n)Pr140(β <sup>+</sup> )Ce140(n,2n) Ce139(β <sup>+</sup> )La139(n,α)Cs135(n,2n)Cs134 &Pr141(n,α)La138(n,α)Cs134 Pr141(n,2n)Pr140(β <sup>+</sup> )Ce140(n,2n)Ce139(n,2n) Ce138(n,2n)Ce137(β <sup>+</sup> )La137(n,α)Cs134 Pr141(n,3n)Pr139(β <sup>+</sup> )Ce139(β <sup>+</sup> )La139 (n,2n)La138(n,α)Cs134 &Pr141(n,3n)Pr139(β <sup>+</sup> )Ce139(β <sup>+</sup> )La139 (n,2n)Cs134 Pr141(n,3n)Pr139(β <sup>+</sup> )Ce139(β <sup>+</sup> )La139 (n,3n)La137(n,α)Cs134 Pr141(n,3n)Pr139(β <sup>+</sup> )Ce139(β <sup>+</sup> )La139 (n,α)Cs135(n,2n)Cs134 &Pr141(n,α)La137(n,3n)La135(β <sup>+</sup> ) Ba135(n,d)Cs134 &Pr141(n,2nα)La136(β <sup>+</sup> )Ba136(n,t)Cs134 &Pr141(n,t)Ce139(β <sup>+</sup> )La139(n,2nα)Cs134 &Pr141(n,3nα)La135(β <sup>+</sup> )Ba135(n,d)Cs134 &Pr141(n,5n)Pr137(β <sup>+</sup> )Ce137(β <sup>+</sup> )La137 (n,α)Cs134 Other pathways involving (n,2n), (n,α), β <sup>+</sup>				5.7				
						5.2				
						4.6	3.7	0.3	0.5	
						2.0				
							13.6	0.7		
							10.6	56.5	19.6	
							9.6	0.3		
							5.8	0.4		
							3.9	0.4		
								6.0	10.0	
								5.0	6.9	
								0.2	11.0	
									14.8	
						32.7	49.1	29.9	36.7	
Pm147	2.623 y	&Pr141(n,γ)Pr142(β <sup>-</sup> )Nd142(n,γ)Nd143 (n,γ)Nd144(n,γ)Nd145(n,γ)Nd146(n,γ) Nd147(β <sup>-</sup> )Pm147 &Pr141(n,γ)Pr142(n,γ)Pr143(β <sup>-</sup> )Nd143 (n,γ)Nd144(n,γ)Nd145(n,γ)Nd146(n,γ) Nd147(β <sup>-</sup> )Pm147	99.7	87.1	96.3					
			0.3	12.2	3.4					
Eu154	8.593 y	Very long pathways of (n,γ), β <sup>-</sup>	100.0	100.0	100.0					
Ba133	10.54 y	&Pr141(n,α)La137(n,2n)La136(β <sup>+</sup> )Ba136 (n,2n)Ba135(n,2n)Ba134(n,2n)Ba133 &Pr141(n,2n)Pr140(β <sup>+</sup> )Ce140(n,2n)Ce139 (n,2n)Ce138(n,α)Ba134(n,2n)Ba133 &Pr141(n,α)La138(n,2n)La137(n,α) Cs134(β <sup>-</sup> )Ba134(n,2n)Ba133 &Pr141(n,α)La137(n,3n)La135(β <sup>+</sup> ) Ba135(n,3n)Ba133 &Pr141(n,3n)Pr139(β <sup>+</sup> )Ce139(n,α) Ba135(n,3n)Ba133 &Pr141(n,2nα)La136(β <sup>+</sup> )Ba136(n,4n)Ba133 &Pr141(n,4n)Pr138m(β <sup>+</sup> )Ce138(n,2nα)Ba133 &Pr141(n,4n)Pr138(β <sup>+</sup> )Ce138(n,2nα)Ba133 Pr141(n,5n)Pr137(β <sup>+</sup> )Ce137(β <sup>+</sup> )La137 (n,5n)La133(β <sup>+</sup> )Ba133 &Pr141(n,2nt)Ce137(β <sup>+</sup> )La137(n,5n) La133(β <sup>+</sup> )Ba133 &Pr141(n,5n)Pr137(β <sup>+</sup> )Ce137(β <sup>+</sup> )La137 (n,2nt)Ba133 Pr141(n,α)La137(n,5n)La133(β <sup>+</sup> )Ba133 Other pathways involving (n,2n), (n,α), β <sup>+</sup>				6.1				
						3.6				
						2.3				
							18.9	0.6		
							3.6	0.1		
								18.4	1.8	
								6.4	1.4	
								4.2	0.7	
									64.3	
									6.3	
									6.1	
									2.0	
						88.0	77.5	70.3	17.4	
H3	12.33 y	&Pr141(n,γ)Pr142(n,X)H1(n,γ)H2(n,γ)H3 Pr141(n,X)H3	100.0	100.0						
						99.3	92.5	90.1	89.4	
Eu152	13.525 y	Very long pathways of (n,γ), β <sup>-</sup>	100.0	100.0						
Cs137	30.041 y	&Pr141(n,γ)Pr142(β <sup>-</sup> )Nd142(n,α)Ce139 (β <sup>+</sup> )La139(n,γ)La140(n,α)Cs137 &Pr141(n,γ)Pr142(n,α)La139(n,γ)La140 (n,α)Cs137 Pr141(n,α)La138(n,γ)La139(n,γ)La140 (n,α)Cs137	54.2		25.0					
			22.9	0.8	35.0					
			21.2	0.2	15.7					
	▶									

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	&Pr141(n,α)La138(n,α)Cs135(n,γ) Cs136(n,γ)Cs137 &Pr141(n,2n)Pr140(β <sup>+</sup> )Ce140(n,α) Ba137(n,p)Cs137 Pr141(n,3n)Pr139(β <sup>+</sup> )Ce139(β <sup>+</sup> )La139 (n,d)Ba138(n,d)Cs137 Pr141(n,3n)Pr139(β <sup>+</sup> )Ce139(β <sup>+</sup> )La139(n,h)Cs137 &Pr141(n,t)Ce139(β <sup>+</sup> )La139(n,d)Ba138 (n,d)Cs137 &Pr141(n,t)Ce139(β <sup>+</sup> )La139(n,h)Cs137	1.6	99.0	24.1	98.3	2.2	60.0	21.7	12.6
							29.0	66.0	57.9	
							1.1	1.9	4.5	
							0.5	5.8	20.4	
Sm151	90.0 y	&Pr141(n,γ)Pr142(β <sup>-</sup> )Nd142(n,γ)Nd143 (n,γ)Nd144(n,γ)Nd145(n,γ)Nd146(n,γ) Nd147(β <sup>-</sup> )Pm147(n,γ)Pm148(n,γ)Pm149 (β <sup>-</sup> )Sm149(n,γ)Sm150(n,γ)Sm151 &Pr141(n,γ)Pr142(β <sup>-</sup> )Nd142(n,γ)Nd143 (n,γ)Nd144(n,γ)Nd145(n,γ)Nd146(n,γ) Nd147(n,γ)Nd148(n,γ)Nd149(β <sup>-</sup> )Pm149 (β <sup>-</sup> )Sm149(n,γ)Sm150(n,γ)Sm151 &Pr141(n,γ)Pr142(β <sup>-</sup> )Nd142(n,γ)Nd143 (n,γ)Nd144(n,γ)Nd145(n,γ)Nd146(n,γ) Nd147(β <sup>-</sup> )Pm147(β <sup>-</sup> )Sm147(n,γ)Sm148 (n,γ)Sm149(n,γ)Sm150(n,γ)Sm151 &Pr141(n,γ)Pr142(n,γ)Pr143(β <sup>-</sup> )Nd143 (n,γ)Nd144(n,γ)Nd145(n,γ)Nd146(n,γ) Nd147(β <sup>-</sup> )Pm147(β <sup>-</sup> )Sm147(n,γ)Sm148 (n,γ)Sm149(n,γ)Sm150(n,γ)Sm151 Other long pathways of (n,γ), β <sup>-</sup>	13.4	1.2	3.1					
			1.0	10.5	0.8					
			0.2	3.4	4.4					
				0.8	0.3					
			85.4	84.1	91.4					
Ho166m	1200.0 y	Very long pathways of (n,γ), β <sup>-</sup>	100.0							
La137	6.0 10 <sup>4</sup> y	&Pr141(n,2n)Pr140(β <sup>+</sup> )Ce140(n,2n) Ce139(β <sup>+</sup> )La139(n,2n)La138(n,2n)La137 Pr141(n,α)La138(n,2n)La137 &Pr141(n,2n)Pr140(β <sup>+</sup> )Ce140(n,2n) Ce139(n,2n)Ce138(n,2n)Ce137(β <sup>+</sup> )La137 Pr141(n,nα)La137 Pr141(n,3n)Pr139(β <sup>+</sup> )Ce139(β <sup>+</sup> )La139 (n,3n)La137 &Pr141(n,3n)Pr139(β <sup>+</sup> )Ce139(n,3n) Ce137(β <sup>+</sup> )La137 &Pr141(n,t)Ce139(β <sup>+</sup> )La139(n,3n)La137 &Pr141(n,2n)Pr140(β <sup>+</sup> )Ce140(n,4n) Ce137(β <sup>+</sup> )La137 &Pr141(n,4n)Pr138m(β <sup>+</sup> )Ce138(n,2n) Ce137(β <sup>+</sup> )La137 &Pr141(n,d)Ce140(n,4n)Ce137(β <sup>+</sup> )La137 &Pr141(n,4n)Pr138(β <sup>+</sup> )Ce138(n,2n) Ce137(β <sup>+</sup> )La137 &Pr141(n,2nt)Ce137(β <sup>+</sup> )La137 Pr141(n,5n)Pr137(β <sup>+</sup> )Ce137(β <sup>+</sup> )La137				46.5				
						22.5	0.1			
						16.5				
						7.3	12.6	18.2	2.6	
							65.6	35.6		
							15.3	8.8		
							1.3	3.1		
								12.4		
								5.6		
								4.3		
								3.6		
								0.4	8.2	
									82.9	
Cs135	2.3 10 <sup>6</sup> y	&Pr141(n,α)La138(n,α)Cs135 &Pr141(n,2n)Pr140(β <sup>+</sup> )Ce140(n,2n) Ce139(β <sup>+</sup> )La139(n,2n)La138(n,α)Cs135 &Pr141(n,2n)Pr140(β <sup>+</sup> )Ce140(n,2n) Ce139(β <sup>+</sup> )La139(n,nα)Cs135 &Pr141(n,2n)Pr140(β <sup>+</sup> )Ce140(n,2n) Ce139(β <sup>+</sup> )La139(n,α)Cs136(n,2n)Cs135 &Pr141(n,3n)Pr139(β <sup>+</sup> )Ce139(β <sup>+</sup> )La139 (n,nα)Cs135 &Pr141(n,t)Ce139(β <sup>+</sup> )La139(n,nα)Cs135 &Pr141(n,2nα)La136(β <sup>+</sup> )Ba136(n,d)Cs135 &Pr141(n,5n)Pr137(β <sup>+</sup> )Ce137(β <sup>+</sup> )La137 (n,h)Cs135	100.0	100.0	100.0	25.5				0.5
						51.7				
						17.5	0.4			
						2.5				
							92.3	63.6	30.6	
							1.7	5.5	10.9	
							0.1	8.3	20.2	
									9.5	

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&Pr141(n,3nα)La135(β <sup>+</sup> )Ba135(n,p)Cs135							1.4
La138	1.0 10 <sup>11</sup> y	Pr141(n,α)La138 &Pr141(n,2n)Pr140(β <sup>+</sup> )Ce140(n,2n) Ce139(β <sup>+</sup> )La139(n,2n)La138	100.0	100.0	100.0	18.1 80.9	9.1	8.8	45.3
		&Pr141(n,t)Ce139(β <sup>+</sup> )La139(n,2n)La138 Pr141(n,3n)Pr139(β <sup>+</sup> )Ce139(β <sup>+</sup> )La139_ (n,2n)La138 Pr141(n,3n)Pr139(β <sup>+</sup> )Ce139(n,d)La138 Pr141(n,2n)Pr140(β <sup>+</sup> )Ce140(n,t)La138 Pr141(n,d)Ce140(n,t)La138 Pr141(n,4n)Pr138m(β <sup>+</sup> )Ce138(n,p)La138				0.2	1.6 83.4	6.1 69.0	8.7 24.8
Sm147	1.1 10 <sup>11</sup> y	&Pr141(n,γ)Pr142(β <sup>-</sup> )Nd142(n,γ)Nd143_ (n,γ)Nd144(n,γ)Nd145(n,γ)Nd146(n,γ) Nd147(β <sup>-</sup> )Pm147(β <sup>-</sup> )Sm147 &Pr141(n,γ)Pr142(n,γ)Pr143(β <sup>-</sup> )Nd143_ (n,γ)Nd144(n,γ)Nd145(n,γ)Nd146(n,γ) Nd147(β <sup>-</sup> )Pm147(β <sup>-</sup> )Sm147	99.6 0.3	86.2 13.1	95.7 4.0				
Nd144	2.3 10 <sup>15</sup> y	&Pr141(n,γ)Pr142(β <sup>-</sup> )Nd142(n,γ)Nd143_ (n,γ)Nd144 &Pr141(n,γ)Pr142(n,γ)Pr143(β <sup>-</sup> )Nd143_ (n,γ)Nd144	99.8 0.1	92.9 6.7	98.1 1.8	99.6 0.1	99.4 0.1	99.5 0.2	99.6 0.2



# Praseodymium activation characteristics

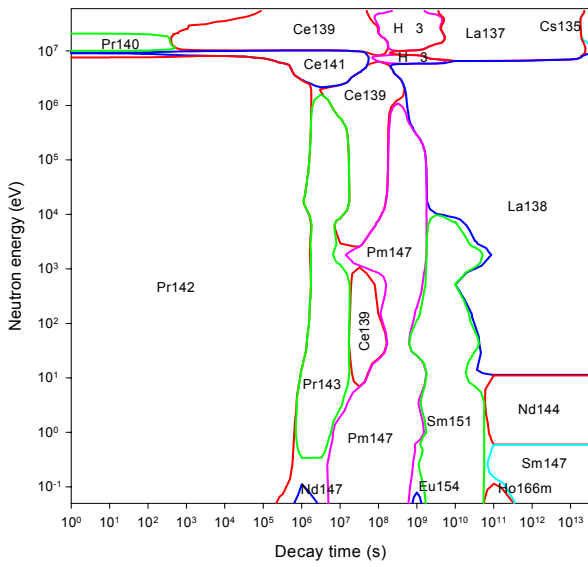


Decay time (years)

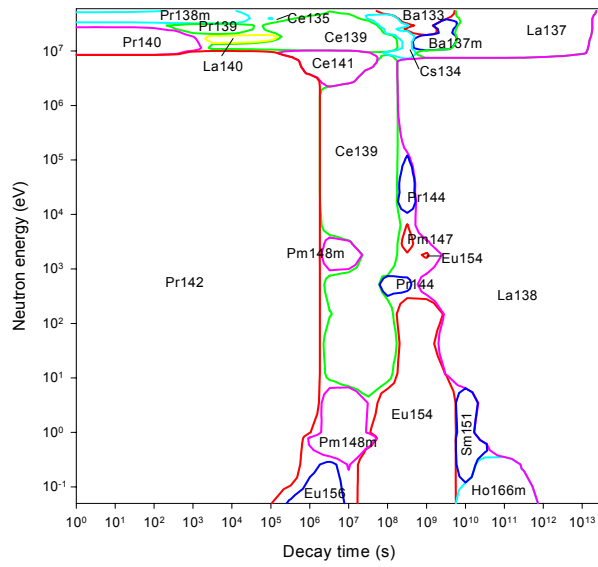
Decay time (years)

# Praseodymium importance diagrams & transmutation

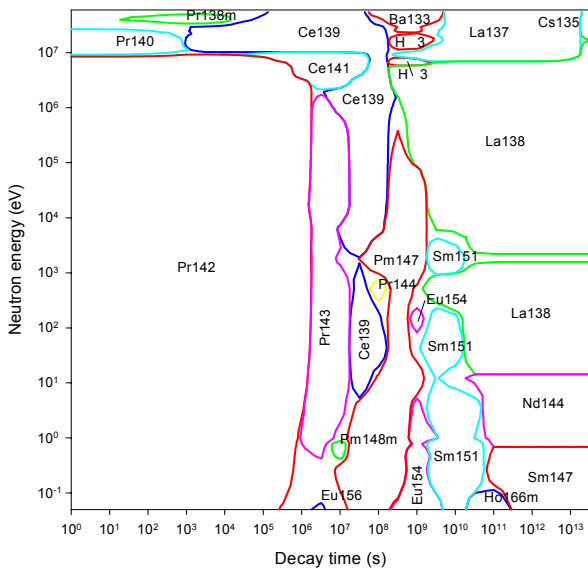
**Activity**



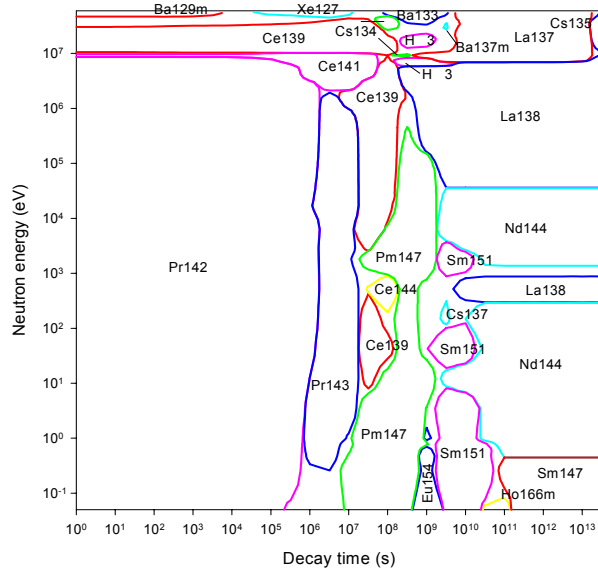
**Dose rate**



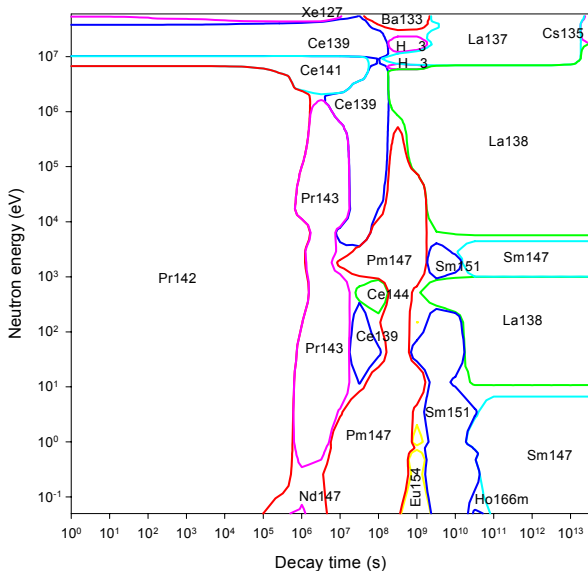
**Heat output**



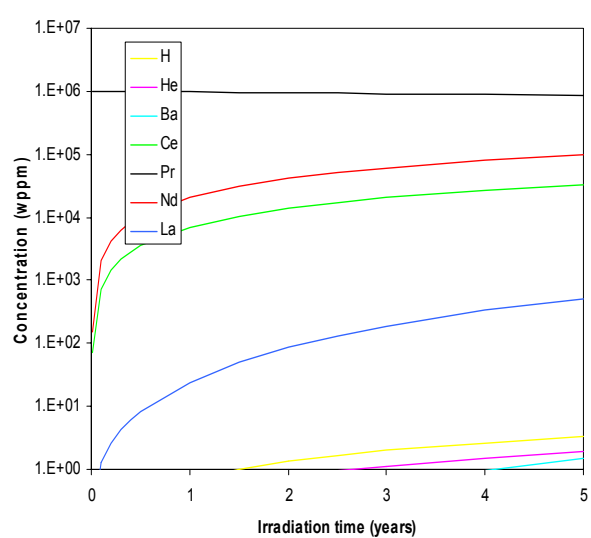
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**



# Neodymium

## General properties

Atomic number	60	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	41.5	Nd142	27.2
Melting point / K	1289	Nd143	12.2
Boiling point / K	3339	Nd144	23.8 (T <sub>1/2</sub> = 2.29 10 <sup>15</sup> y)
Density / kgm <sup>-3</sup>	7008	Nd145	8.3
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	16.5	Nd146	17.2
Electrical resistivity /Ωm	6.4 10 <sup>-7</sup>	Nd148	5.7 (T <sub>1/2</sub> = 2.70 10 <sup>18</sup> y)
Coefficient of thermal expansion / K <sup>-1</sup>	9.6 10 <sup>-6</sup>	Nd150	5.6 (T <sub>1/2</sub> = 2.10 10 <sup>19</sup> y)
Crystal structure	Hexagonal		
Number of stable isotopes	4 (7)		
Mean atomic weight	144.24		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	1.71E15	1.57E15	4.70E14	5.49E13	8.81E11	3.17E4	kW kg <sup>-1</sup>	1.77E-1	1.55E-1	5.52E-2	3.25E-3	3.87E-6	7.80E-12
Nd141	15.39	16.39					Nd149	17.24	18.98				
Pm149	13.34	14.53	15.93				Nd151	16.82	14.31				
Nd149	12.79	13.45					Pm148m	9.25	10.55	27.91	1.06		
Sm153	12.14	13.20	11.88				Pm148	8.03	9.15	16.39	0.03		
Nd147	9.71	10.57	28.04				Pm149	7.80	8.89	8.21			
Nd151	7.51	6.10					Pm151	7.31	8.33	2.78			
Pm151	7.50	8.17	3.24				Nd141m	6.83	0.23				
Nd141m	5.04	0.16					Eu156	6.19	7.06	16.82			
Pm148	3.99	4.34	9.23	0.01			Sm153	6.19	7.04	5.34			
Pm148m	2.78	3.03	9.50	0.18			Nd147	6.10	6.96	15.55			
Eu156	2.38	2.59	7.33				Pr142	2.27	2.59	0.31			
Pm147	2.37	2.58	8.66	59.21			Nd141	2.13	2.37				
Pr142	1.69	1.84	0.26				Eu154	1.63	1.86	5.24	82.09	23.49	
Eu154	0.70	0.76	2.53	19.99	0.42		Pm147	0.23	0.26	0.73	9.92		
Eu155	0.61	0.67	2.23	16.49			Eu155	0.12	0.13	0.38	5.54		
Pr142m	0.61	0.52					Eu152			0.05	0.76	4.02	
Sm151	0.11	0.12	0.40	3.43	99.48		Sm151			0.01	0.18	72.26	
Sm146						43.04	Sm146						72.07
La137						41.25	Gd150						19.76
Gd150						10.85	Sm147						7.26
Sm147						4.82	La137						0.86
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	1.07E5	8.52E4	4.27E4	3.52E3	1.38E0	3.47E-9	Sv kg <sup>-1</sup>	1.12E6	1.12E6	5.82E5	3.39E4	9.45E1	9.93E04
Nd151	21.55	20.27					Pm149	20.11	20.16	12.73			
Pm148m	17.31	21.83	40.94	1.11			Pm148	16.38	16.41	20.11	0.04		
Nd141m	14.70	0.54					Nd147	16.26	16.29	24.88			
Eu156	13.38	16.87	28.50				Sm153	13.67	13.69	7.09			
Pm148	9.67*	12.19*	15.49*	0.02			Pm151	8.34	8.36	1.91			
Nd149	7.95	9.68					Eu156	7.97	7.99	13.00			
Pm151	4.68	5.90	1.40				Pm148m	7.19	7.21	13.03	0.50		
Eu154	3.46	4.37	8.71	97.56	84.35		Pr142	3.35	3.35	0.27			
Nd141	2.53	3.12					Nd149	2.34	2.26				
Nd147	2.23	2.81	4.45				Eu154	2.12	2.12	4.08	64.66	7.89	
Pr140	0.72	0.31					Pm147	0.94	0.94	1.82	24.90		
Pm150	0.48	0.59					Eu155	0.30	0.30	0.57	8.53		
Eu152	0.03	0.04	0.08	0.94	14.93		Sm151			0.03	0.54	90.93	
Eu150					0.66		Sm146						74.25
La137						94.20	Gd150						18.02
La138						5.80	Sm147						7.55

<b>Inh</b>	<b>0</b>	<b>10<sup>-5</sup> y</b>	<b>10<sup>-2</sup> y</b>	<b>1 y</b>	<b>100 y</b>	<b>10<sup>5</sup> y</b>	<b>Clear</b>	<b>0</b>	<b>10<sup>-5</sup> y</b>	<b>10<sup>-2</sup> y</b>	<b>1 y</b>	<b>100 y</b>	<b>10<sup>5</sup> y</b>
Sv kg <sup>-1</sup>	2.28E6	2.28E6	1.81E6	8.21E5	3.74E3	4.51E-1		5.94E11	4.90E11	3.01E11	1.20E11	4.58E7	2.10E0
Eu154	27.61	27.63	34.79	70.81	5.29		Eu154	19.99	24.25	39.44	91.13	81.48	
Nd147	17.44	17.45	17.47				Nd151	19.61	17.74				
Pm148m	11.85	11.86	14.06	0.07			Pm148m	15.97	19.36	29.64	0.17		
Pm147	8.85	8.86	11.24	19.79			Nd141m	12.08	0.43				
Pm149	7.29	7.30	3.02				Eu156	8.77	10.63	14.65			
Pm148	6.56	6.57	5.27				Pm151	7.70	9.34	1.80			
Eu156	6.06	6.06	6.47				Pm148	7.64	9.25	9.60			
Sm153	5.72	5.72	1.94				Nd141	3.40	4.04				
Eu155	3.16	3.17	3.99	7.60			Nd149	0.37	0.43				
Pm151	2.58	2.59	0.39				Sm153	0.35	0.42	0.19			
Nd149	0.85	0.82					Nd147	0.28	0.34	0.44			
Pr142	0.70	0.70	0.04				Eu152	0.21	0.26	0.42	1.00	16.48	
Sm151	0.33	0.33	0.42	0.92	93.80		Pm149		0.05	0.03			
Ce141	0.27	0.27	0.32				Sm151					1.92	
Eu152	0.23	0.23	0.29	0.62	0.85		Eu150					0.12	
Pr143	0.11	0.11	0.12				Sm147						72.68
Gd150					0.01	63.39	La137						16.37
Sm146						33.33	Gd150						6.82
Sm147						3.26	Sm146						3.61

# Neodymium

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Nd141m	1.033 m	Nd142(n,2n)Nd141m Nd143(n,2n)Nd142(n,2n)Nd141m Nd144(n,2n)Nd143(n,2n)Nd142(n,2n)Nd141m   Nd143(n,3n)Nd141m Nd144(n,3n)Nd142(n,2n)Nd141m Nd144(n,2n)Nd143(n,3n)Nd141m Nd145(n,3n)Nd143(n,3n)Nd141m Nd146(n,4n)Nd143(n,3n)Nd141m Nd144(n,4n)Nd141m Nd145(n,5n)Nd141m Nd146(n,6n)Nd141m				85.7 10.9 2.9	42.1 1.7	15.2 0.4	16.6 0.3
Ba137m	2.552 m	Nd142(n,α)Ce139(n,α)Ba136(n,γ) Ba137m Nd142(n,γ)Nd143(n,α)Ce140(n,α) Ba137m Nd143(n,α)Ce140(n,α)Ba137m Nd142(n,α)Ce139(β <sup>+</sup> )La139(n,γ)La140 (n,α)Cs137(β <sup>-</sup> )Ba137m Other pathways involving (n,α), (n,nα), (n,2n), β <sup>-</sup> , β <sup>+</sup>	75.7 10.8 8.1 4.7 0.1						
Pr140	3.39 m	&Nd142(n,2n)Nd141(β <sup>+</sup> )Pr141(n,2n)Pr140 &Nd143(n,2n)Nd142(n,2n)Nd141(β <sup>+</sup> ) Pr141(n,2n)Pr140 Nd142(n,3n)Nd140(β <sup>+</sup> )Pr140 Nd144(n,3n)Nd142(n,3n)Nd140(β <sup>+</sup> )Pr140 Nd143(n,2n)Nd142(n,3n)Nd140(β <sup>+</sup> )Pr140 Nd142(n,t)Pr140 Nd145(n,4n)Nd142(n,3n)Nd140(β <sup>+</sup> )Pr140 Nd143(n,4n)Nd140(β <sup>+</sup> )Pr140 Nd146(n,4n)Nd143(n,4n)Nd140(β <sup>+</sup> )Pr140 Nd143(n,nt)Pr140 Nd144(n,5n)Nd140(β <sup>+</sup> )Pr140 Nd144(n,2nt)Pr140 Nd145(n,6n)Nd140(β <sup>+</sup> )Pr140				90.4 5.8	2.2 69.0 12.4 2.7 0.9 0.8	0.7 57.2 4.4 1.3 4.7 2.5	0.6 20.3 0.8 0.3 8.2 0.3
Nd151	12.44 m	Nd150(n,γ)Nd151	100.0	100.0	100.0	100.0	99.7	99.7	99.9
Nd149	1.728 h	Nd148(n,γ)Nd149 Nd146(n,γ)Nd147(n,γ)Nd148(n,γ)Nd149 Nd145(n,γ)Nd146(n,γ)Nd147(n,γ) Nd148(n,γ)Nd149 Nd150(n,2n)Nd149 Nd150(n,d)Pr149(β <sup>-</sup> )Nd149	95.3 3.4 1.0	97.6 1.7 0.6	100.0		0.2 99.9	0.2 92.4	0.1 78.6 21.3
Nd141	2.49 h	&Nd142(n,2n)Nd141 &Nd143(n,2n)Nd142(n,2n)Nd141 &Nd144(n,2n)Nd143(n,2n)Nd142(n,2n)Nd141   &Nd143(n,3n)Nd141 &Nd144(n,3n)Nd142(n,2n)Nd141 &Nd144(n,2n)Nd143(n,3n)Nd141 &Nd145(n,3n)Nd143(n,3n)Nd141 &Nd146(n,4n)Nd143(n,3n)Nd141 &Nd144(n,4n)Nd141 &Nd145(n,5n)Nd141 &Nd146(n,6n)Nd141				86.7 10.7 2.6	47.7 1.9	26.2 0.6	25.8 0.4
Nd139m	5.50 h	&Nd142(n,2n)Nd141(n,2n)Nd140 (n,2n)Nd139m &Nd143(n,2n)Nd142(n,2n)Nd141 (n,2n)Nd140(n,2n)Nd139m				85.8 10.9			

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&Nd144(n,2n)Nd143(n,2n)Nd142_ (n,2n)Nd141(n,2n)Nd140(n,2n)Nd139m Nd142(n,3n)Nd140(n,2n)Nd139m Nd144(n,3n)Nd142(n,3n)Nd140(n,2n)Nd139m   Nd143(n,2n)Nd142(n,3n)Nd140(n,2n)Nd139m   &Nd142(n,2n)Nd141(n,3n)Nd139m Nd142(n,4n)Nd139m Nd144(n,3n)Nd142(n,4n)Nd139m Nd145(n,4n)Nd142(n,4n)Nd139m Nd143(n,2n)Nd142(n,4n)Nd139m Nd146(n,5n)Nd142(n,4n)Nd139m Nd143(n,5n)Nd139m Nd144(n,6n)Nd139m				2.8	74.5 14.1 3.1 2.2	83.1 6.7 3.9 2.1 1.2	59.3 2.2 0.9 0.9 3.4 23.7 2.0
Nd140	3.37 d	&Nd142(n,2n)Nd141(n,2n)Nd140 &Nd143(n,2n)Nd142(n,2n)Nd141(n,2n)Nd140   Nd144(n,2n)Nd143(n,2n)Nd142(n,2n)_ Nd141(n,2n)Nd140 Nd142(n,3n)Nd140 Nd144(n,3n)Nd142(n,3n)Nd140 Nd143(n,2n)Nd142(n,3n)Nd140 Nd145(n,4n)Nd142(n,3n)Nd140 Nd143(n,4n)Nd140 Nd146(n,4n)Nd143(n,4n)Nd140 Nd144(n,2n)Nd143(n,4n)Nd140 Nd146(n,5n)Nd142(n,3n)Nd140 Nd144(n,5n)Nd140 Nd145(n,6n)Nd140 Nd146(n,3n)Nd144(n,5n)Nd140				88.4 10.2 1.4	77.9 14.8 3.2 0.9	63.5 5.1 1.6 3.0 17.1 3.3 1.6 0.9	25.5 1.0 0.4 0.4 15.7 0.8 0.9 1.5 43.8 3.6 1.1
Nd147	10.98 d	Nd146(n,γ)Nd147 Nd145(n,γ)Nd146(n,γ)Nd147 Nd144(n,γ)Nd145(n,γ)Nd146(n,γ)Nd147 Nd143(n,γ)Nd144(n,γ)Nd145(n,γ)_ Nd146(n,γ)Nd147 Nd142(n,γ)Nd143(n,γ)Nd144(n,γ)_ Nd145(n,γ)Nd146(n,γ)Nd147 Nd148(n,2n)Nd147 Nd150(n,3n)Nd148(n,2n)Nd147 Nd150(n,4n)Nd147 Nd150(n,nt)Pr147(β <sup>-</sup> )Nd147 Nd148(n,d)Pr147(β <sup>-</sup> )Nd147	58.8 25.8 8.8 4.1 2.6	71.1 28.3 0.4 0.2	97.3 2.6	0.2 3.6	0.2 31.9 60.3	28.4 62.0	36.3 37.9 13.5 12.1
Eu156	15.19 d	&Nd148(n,γ)Nd149(β <sup>-</sup> )Pm149(β <sup>-</sup> )_ Sm149(n,γ)Sm150(n,γ)Sm151(n,γ)_ Sm152(n,γ)Sm153(β <sup>-</sup> )Eu153(n,γ)Eu154_ (n,γ)Eu155(n,γ)Eu156 &Nd150(n,γ)Nd151(β <sup>-</sup> )Pm151(β <sup>-</sup> )_ Sm151(n,γ)Sm152(n,γ)Sm153(β <sup>-</sup> )_ Eu153(n,γ)Eu154(n,γ)Eu155(n,γ)Eu156 &Nd146(n,γ)Nd147(β <sup>-</sup> )Pm147(n,γ)_ Pm148m(n,γ)Pm149(β <sup>-</sup> )Sm149(n,γ)_ Sm150(n,γ)Sm151(n,γ)Sm152(n,γ)_ Sm153(β <sup>-</sup> )Eu153(n,γ)Eu154(n,γ)Eu155_ (n,γ)Eu156 &Nd148(n,γ)Nd149(β <sup>-</sup> )Pm149(n,γ)_ Pm150(β <sup>-</sup> )Sm150(n,γ)Sm151(n,γ)_ Sm152(n,γ)Sm153(β <sup>-</sup> )Eu153(n,γ)Eu154_ (n,γ)Eu155(n,γ)Eu156 &Nd145(n,γ)Nd146(n,γ)Nd147(β <sup>-</sup> )_ Pm147(n,γ)Pm148m(n,γ)Pm149(β <sup>-</sup> )_ Sm149(n,γ)Sm150(n,γ)Sm151(n,γ)_ Sm152(n,γ)Sm153(β <sup>-</sup> )Eu153(n,γ)Eu154_ (n,γ)Eu155(n,γ)Eu156	31.3 18.6 18.0 7.1 5.7	99.5 0.3	94.7				

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6		
	◀	&Nd146(n,γ)Nd147(β <sup>-</sup> )Pm147(n,γ) Pm148m(n,γ)Pm149(n,γ)Pm150(β <sup>-</sup> ) Sm150(n,γ)Sm151(n,γ)Sm152(n,γ) Sm153(β <sup>-</sup> )Eu153(n,γ)Eu154(n,γ)Eu155 (n,γ)Eu156 &Nd146(n,γ)Nd147(β <sup>-</sup> )Pm147(n,γ) Pm148(n,γ)Pm149(β <sup>-</sup> )Sm149(n,γ) Sm150(n,γ)Sm151(n,γ)Sm152(n,γ) Sm153(β <sup>-</sup> )Eu153(n,γ)Eu154(n,γ)Eu155 (n,γ)Eu156 &Nd150(n,γ)Nd151(β <sup>-</sup> )Pm151(β <sup>-</sup> ) Sm151(β <sup>-</sup> )Eu151(n,γ)Eu152(n,γ)Eu153 (n,γ)Eu154(n,γ)Eu155(n,γ)Eu156	4.1								
			4.0								
					4.8						
Xe127	36.40 d	Pathways involving (n,α), (n,nα), (n,2n), β <sup>-</sup> , β <sup>+</sup>				100.0	100.0	100.0	100.0		
Pm148m	41.05 d	Nd146(n,γ)Nd147(β <sup>-</sup> )Pm147(n,γ)Pm148m Nd145(n,γ)Nd146(n,γ)Nd147(β <sup>-</sup> )Pm147 (n,γ)Pm148m Nd144(n,γ)Nd145(n,γ)Nd146(n,γ) Nd147(β <sup>-</sup> )Pm147(n,γ)Pm148m Nd143(n,γ)Nd144(n,γ)Nd145(n,γ)Nd146 (n,γ)Nd147(β <sup>-</sup> )Pm147(n,γ)Pm148m Nd142(n,γ)Nd143(n,γ)Nd144(n,γ) Nd145(n,γ)Nd146(n,γ)Nd147(β <sup>-</sup> )Pm147 (n,γ)Pm148m Nd150(n,2n)Nd149(β <sup>-</sup> )Pm149(n,2n)Pm148m Nd150(n,2n)Nd149(β <sup>-</sup> )Pm149(β <sup>-</sup> ) Sm149(n,2n)Sm148(n,p)Pm148m Nd150(n,2n)Nd149(β <sup>-</sup> )Pm149(β <sup>-</sup> ) Sm149(n,d)Pm148m Nd148(n,2n)Nd147(β <sup>-</sup> )Pm147(n,γ)Pm148m Nd150(n,d)Pr149(β <sup>-</sup> )Nd149(β <sup>-</sup> )Pm149 (β <sup>-</sup> )Sm149(n,d)Pm148m Nd150(n,4n)Nd147(β <sup>-</sup> )Pm147(n,γ)Pm148m	60.8 25.7 7.8 3.6 2.1	72.3 27.3 0.3 0.1	98.4 1.6						
						37.6 37.4	0.8 2.5	0.5 1.0	0.3 0.4		
						15.3	86.0	81.7	77.6		
						9.1	1.0 6.6	0.5 14.0	0.4 19.6		
							1.8	1.1	0.4		
Ta182	114.7 d	Very long pathways of (n,γ), β <sup>-</sup>	100.0								
Ce139	137.64 d	&Nd142(n,α)Ce139 &Nd142(n,2n)Nd141(β <sup>+</sup> )Pr141(n,2n) Pr140(β <sup>+</sup> )Ce140(n,2n)Ce139 &Nd143(n,2n)Nd142(n,2n)Nd141(β <sup>+</sup> ) Pr141(n,2n)Pr140(β <sup>+</sup> )Ce140(n,2n)Ce139 &Nd143(n,2n)Nd142(n,α)Ce139 &Nd143(n,nα)Ce139 &Nd142(n,2n)Nd141(β <sup>+</sup> )Pr141(n,2n) Pr140(β <sup>+</sup> )Ce140(n,2n)Ce139 &Nd143(n,3n)Nd141(β <sup>+</sup> )Pr141(n,3n) Pr139(β <sup>+</sup> )Ce139 &Nd142(n,2n)Nd141(β <sup>+</sup> )Pr141(n,3n) Pr139(β <sup>+</sup> )Ce139 &Nd142(n,3n)Nd140(β <sup>+</sup> )Pr140(β <sup>+</sup> ) Ce140(n,2n)Ce139 Nd142(n,2n)Nd141(β <sup>+</sup> )Pr141(n,3n) Pr139(β <sup>+</sup> )Ce139 Nd142(n,d)Pr141(n,3n)Pr139(β <sup>+</sup> )Ce139 &Nd144(n,2nα)Ce139 Nd142(n,4n)Nd139m(β <sup>+</sup> )Pr139(β <sup>+</sup> )Ce139 &Nd144(n,4n)Nd141(β <sup>+</sup> )Pr141(n,3n) Pr139(β <sup>+</sup> )Ce139 &Nd142(n,4n)Nd139(β <sup>+</sup> )Pr139(β <sup>+</sup> )Ce139 Nd142(n,nt)Pr139(β <sup>+</sup> )Ce139 Nd143(n,5n)Nd139m(β <sup>+</sup> )Pr139(β <sup>+</sup> )Ce139 Nd143(n,5n)Nd139(β <sup>+</sup> )Pr139(β <sup>+</sup> )Ce139	100.0	100.0	99.9	10.2 79.3 2.6 1.2 0.6		2.2 3.4 28.6	0.7 1.9 0.7	0.8	
							20.6	5.8	0.5		
							19.8	3.5	0.4		
							18.1	6.6	0.8		
							12.6	5.3	0.7		
							3.4	2.3	0.4		
							0.5	2.7	1.4		
								21.5	31.6		
								13.9	1.1		
								13.3	9.7		
								1.8	10.7		
									12.6		
									4.3		

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6		
	◀	Nd143(n,2nt)Pr139(β <sup>+</sup> )Ce139							2.0		
Pm144	363.0 d	Nd148(n,2n)Nd147(β <sup>-</sup> )Pm147(n,2n) <sub>-</sub> Pm146(n,2n)Pm145(n,2n)Pm144				72.9					
		Nd148(n,2n)Nd147(β <sup>-</sup> )Pm147(β <sup>-</sup> ) <sub>-</sub> Sm147(n,2n)Sm146(n,2n)Sm145(β <sup>+</sup> ) <sub>-</sub> Pm145(n,2n)Pm144				10.5					
		Nd148(n,2n)Nd147(β <sup>-</sup> )Pm147(n,3n) <sub>-</sub> Pm145(n,2n)Pm144				8.7	4.0	0.2	0.3		
		Nd148(n,2n)Nd147(β <sup>-</sup> )Pm147(n,2n) <sub>-</sub> Pm146(n,3n)Pm144				4.8	2.9	0.2	0.2		
		Nd148(n,2n)Nd147(β <sup>-</sup> )Pm147(n,2n) <sub>-</sub> Pm146(β <sup>-</sup> )Sm146(n,2n)Sm145(β <sup>+</sup> ) <sub>-</sub> Pm145(n,2n)Pm144				1.5					
		Nd150(n,4n)Nd147(β <sup>-</sup> )Pm147(n,4n)Pm144					44.9	59.2	27.3		
		Nd148(n,2n)Nd147(β <sup>-</sup> )Pm147(n,4n)Pm144					24.1	27.2	26.1		
		Nd150(n,4n)Nd147(β <sup>-</sup> )Pm147(n,3n) <sub>-</sub> Pm145(n,2n)Pm144					7.4	0.4	0.3		
		Nd150(n,4n)Nd147(β <sup>-</sup> )Pm147(n,2n) <sub>-</sub> Pm146(n,3n)Pm144					5.5	0.3	0.2		
		Nd150(n,3n)Nd148(n,2n)Nd147(β <sup>-</sup> ) <sub>-</sub> Pm147(n,4n)Pm144					1.0	0.4	0.2		
		Nd148(n,d)Pr147(β <sup>-</sup> )Nd147(β <sup>-</sup> )Pm147 <sub>-</sub> (n,4n)Pm144						5.9	8.1		
		Nd150(n,nt)Pr147(β <sup>-</sup> )Nd147(β <sup>-</sup> )Pm147 <sub>-</sub> (n,4n)Pm144						1.5	9.1		
		Nd150(n,4n)Nd147(β <sup>-</sup> )Pm147(β <sup>-</sup> ) <sub>-</sub> Sm147(n,nt)Pm144						1.4	7.2		
		Nd148(n,2n)Nd147(β <sup>-</sup> )Pm147(β <sup>-</sup> ) <sub>-</sub> Sm147(n,nt)Pm144						0.6	6.9		
		Nd148(n,d)Pr147(β <sup>-</sup> )Nd147(β <sup>-</sup> )Pm147 <sub>-</sub> (β <sup>-</sup> )Sm147(n,nt)Pm144						0.1	2.1		
		Nd150(n,2n)Nd149(β <sup>-</sup> )Pm149(β <sup>-</sup> ) <sub>-</sub> Sm149(n,3nt)Pm144							3.2		
		Nd150(n,nt)Pr147(β <sup>-</sup> )Nd147(β <sup>-</sup> )Pm147 <sub>-</sub> (β <sup>-</sup> )Sm147(n,nt)Pm144							2.4		
		Pm147	2.623 y	Nd146(n,γ)Nd147(β <sup>-</sup> )Pm147	60.8	72.1	98.3	0.2	0.2		0.2
				Nd145(n,γ)Nd146(n,γ)Nd147(β <sup>-</sup> )Pm147	25.7	27.5	1.6				
				Nd144(n,γ)Nd145(n,γ)Nd146(n,γ) <sub>-</sub> Nd147(β <sup>-</sup> )Pm147	7.8	0.3					
Nd143(n,γ)Nd144(n,γ)Nd145(n,γ) <sub>-</sub> Nd146(n,γ)Nd147(β <sup>-</sup> )Pm147	3.6			0.1							
Nd142(n,γ)Nd143(n,γ)Nd144(n,γ) <sub>-</sub> Nd145(n,γ)Nd146(n,γ)Nd147(β <sup>-</sup> )Pm147	2.1										
Nd148(n,2n)Nd147(β <sup>-</sup> )Pm147						97.5	32.5	28.5	36.3		
Nd150(n,3n)Nd148(n,2n)Nd147(β <sup>-</sup> )Pm147						2.2			0.4		
Nd150(n,4n)Nd147(β <sup>-</sup> )Pm147							60.9	62.2	37.9		
Nd150(n,nt)Pr147(β <sup>-</sup> )Nd147(β <sup>-</sup> )Pm147									12.6		
Nd148(n,d)Pr147(β <sup>-</sup> )Nd147(β <sup>-</sup> )Pm147									11.3		
Eu155	4.753 y	&Nd148(n,γ)Nd149(β <sup>-</sup> )Pm149(β <sup>-</sup> ) <sub>-</sub> Sm149(n,γ)Sm150(n,γ)Sm151(n,γ) <sub>-</sub> Sm152(n,γ)Sm153(β <sup>-</sup> )Eu153(n,γ)Eu154 <sub>-</sub> (n,γ)Eu155	31.2	99.5							
		&Nd150(n,γ)Nd151(β <sup>-</sup> )Pm151(β <sup>-</sup> ) <sub>-</sub> Sm151(n,γ)Sm152(n,γ)Sm153(β <sup>-</sup> ) <sub>-</sub> Eu153(n,γ)Eu154(n,γ)Eu155	18.5	0.3	94.7	98.6	89.0	97.1			
		&Nd146(n,γ)Nd147(β <sup>-</sup> )Pm147(n,γ) <sub>-</sub> Pm148m(n,γ)Pm149(β <sup>-</sup> )Sm149(n,γ) <sub>-</sub> Sm150(n,γ)Sm151(n,γ)Sm152(n,γ) <sub>-</sub> Sm153(β <sup>-</sup> )Eu153(n,γ)Eu154(n,γ)Eu155	18.0								



Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	&Nd148(n,γ)Nd149(β <sup>-</sup> )Pm149(n,γ) Pm150(β <sup>-</sup> )Sm150(n,γ)Sm151(n,γ) Sm152(n,γ)Sm153(β <sup>-</sup> )Eu153(n,γ) <i>Eu154</i> (n,γ)Eu155 &Nd145(n,γ)Nd146(n,γ)Nd147(β <sup>-</sup> )Pm147 (n,γ)Pm148m(n,γ)Pm149(β <sup>-</sup> )Sm149(n,γ) Sm150(n,γ)Sm151(n,γ)Sm152(n,γ)Sm153 (β <sup>-</sup> )Eu153(n,γ) <i>Eu154</i> (n,γ)Eu155 Nd146(n,γ)Nd147(β <sup>-</sup> )Pm147(n,γ) Pm148m(n,γ)Pm149(n,γ)Pm150(β <sup>-</sup> ) Sm150(n,γ)Sm151(n,γ)Sm152(n,γ) Sm153(β <sup>-</sup> )Eu153(n,γ)Eu154(n,γ)Eu155 &Nd146(n,γ)Nd147(β <sup>-</sup> )Pm147(n,γ) Pm148m(n,γ)Pm149(β <sup>-</sup> )Sm149(n,γ) Sm150(n,γ)Sm151(n,γ)Sm152(n,γ) Sm153(β <sup>-</sup> )Eu153(n,γ) <i>Eu154</i> (n,γ)Eu155 Nd146(n,γ)Nd147(β <sup>-</sup> )Pm147(n,γ) Pm148(n,γ)Pm149(β <sup>-</sup> )Sm149(n,γ) Sm150(n,γ)Sm151(n,γ)Sm152(n,γ) Sm153(β <sup>-</sup> )Eu153(n,γ)Eu154(n,γ)Eu155 Nd150(n,γ)Nd151(β <sup>-</sup> )Pm151(β <sup>-</sup> )Sm151 (n,γ)Sm152(n,γ)Sm153(n,γ)Sm154(n,γ) Sm155(β <sup>-</sup> )Eu155 &Nd150(n,γ)Nd151(β <sup>-</sup> )Pm151(β <sup>-</sup> ) Sm151(β <sup>-</sup> )Eu151(n,γ)Eu152(n,γ)Eu153 (n,γ) <i>Eu154</i> (n,γ)Eu155	7.0							
			5.7							
			4.0							
			3.9							
			3.9							
			0.2			0.3	1.3	2.9		
					4.8	0.3				
Pm146	5.531 y	Nd148(n,2n)Nd147(β <sup>-</sup> )Pm147(n,2n)Pm146 Nd150(n,3n)Nd148(n,2n)Nd147(β <sup>-</sup> ) Pm147(n,2n)Pm146 Nd150(n,4n)Nd147(β <sup>-</sup> )Pm147(n,2n)Pm146 Nd150(n,4n)Nd147(β <sup>-</sup> )Pm147(β <sup>-</sup> ) Sm147(n,d)Pm146 Nd148(n,2n)Nd147(β <sup>-</sup> )Pm147(β <sup>-</sup> ) Sm147(n,d)Pm146 Nd148(n,d)Pr147(β <sup>-</sup> )Nd147(β <sup>-</sup> )Pm147 (n,2n)Pm146 Nd150(n,2n)Nd149(β <sup>-</sup> )Pm149(β <sup>-</sup> ) Sm149(n,nt)Pm146 Nd148(n,d)Pr147(β <sup>-</sup> )Nd147(β <sup>-</sup> )Pm147 (β <sup>-</sup> )Sm147(n,d)Pm146 Nd150(n,nt)Pr147(β <sup>-</sup> )Nd147(β <sup>-</sup> )Pm147 (n,2n)Pm146 Nd150(n,d)Pr149(β <sup>-</sup> )Nd149(β <sup>-</sup> )Pm149 (β <sup>-</sup> )Sm149(n,nt)Pm146 Nd150(n,nt)Pr147(β <sup>-</sup> )Nd147(β <sup>-</sup> )Pm147 (β <sup>-</sup> )Sm147(n,d)Pm146				98.2 1.4	28.9 1.0	22.4 0.3	21.2 0.2	
							53.8	48.8	22.1	
							5.8	8.7	5.3	
							3.1	4.0	5.1	
							3.0	4.8	6.6	
							0.6	4.8	21.0	
							0.3	0.9	1.6	
							0.1	1.2	7.3	
								0.2	5.3	
								0.2	1.8	
Eu154	8.593 y	&Nd148(n,γ)Nd149(β <sup>-</sup> )Pm149(β <sup>-</sup> ) Sm149(n,γ)Sm150(n,γ)Sm151(n,γ) Sm152(n,γ)Sm153(β <sup>-</sup> )Eu153(n,γ) <i>Eu154</i> &Nd150(n,γ)Nd151(β <sup>-</sup> )Pm151(β <sup>-</sup> ) Sm151(n,γ)Sm152(n,γ)Sm153(β <sup>-</sup> ) Eu153(n,γ) <i>Eu154</i> &Nd146(n,γ)Nd147(β <sup>-</sup> )Pm147(n,γ) Pm148m(n,γ)Pm149(β <sup>-</sup> )Sm149(n,γ) Sm150(n,γ)Sm151(n,γ)Sm152(n,γ) Sm153(β <sup>-</sup> )Eu153(n,γ) <i>Eu154</i> &Nd148(n,γ)Nd149(β <sup>-</sup> )Pm149(n,γ) Pm150(β <sup>-</sup> )Sm150(n,γ)Sm151(n,γ) Sm152(n,γ)Sm153(β <sup>-</sup> )Eu153(n,γ) <i>Eu154</i>	31.5	99.5						
			18.7	0.3	93.9	99.0	99.0	99.1	99.3	
			18.2							
			7.1							
	▶	Sm152(n,γ)Sm153(β <sup>-</sup> )Eu153(n,γ) <i>Eu154</i>								

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Nd146(n,γ)Nd147(β <sup>-</sup> )Pm147(n,γ)Pm148_ (n,γ)Pm149(β <sup>-</sup> )Sm149(n,γ)Sm150(n,γ)_ Sm151(n,γ)Sm152(n,γ)Sm153(β <sup>-</sup> )Eu153_ (n,γ)Eu154 &Nd145(n,γ)Nd146(n,γ)Nd147(β <sup>-</sup> )_ Pm147(n,γ)Pm148m(n,γ)Pm149(β <sup>-</sup> )_ Sm149(n,γ)Sm150(n,γ)Sm151(n,γ)_ Sm152(n,γ)Sm153(β <sup>-</sup> )Eu153(n,γ)Eu154 Nd145(n,γ)Nd146(n,γ)Nd147(β <sup>-</sup> )_ Pm147(n,γ)Pm148m(n,γ)Pm149(n,γ)_ Pm150(β <sup>-</sup> )Sm150(n,γ)Sm151(n,γ)_ Sm152(n,γ)Sm153(β <sup>-</sup> )Eu153(n,γ)Eu154 &Nd150(n,γ)Nd151(β <sup>-</sup> )Pm151(β <sup>-</sup> )Sm151_ (β <sup>-</sup> )Eu151(n,γ)Eu152(n,γ)Eu153(n,γ)Eu154	4.0 1.3 1.3							
Ba133	10.54 y	Pathways involving (n,α), (n,nα), (n,2n), β <sup>-</sup> , β <sup>+</sup>				100.0	100.0	100.0	100.0	
H3	12.33 y	Nd150(n,γ)Nd151(β <sup>-</sup> )Pm151(β <sup>-</sup> )Sm151_ (β <sup>-</sup> )Eu151(n,γ)Eu152(n,X)H1(n,γ)H2_ (n,γ)H3 Nd150(n,γ)Nd151(β <sup>-</sup> )Pm151(β <sup>-</sup> )Sm151_ (β <sup>-</sup> )Eu151(n,γ)Eu152m(n,X)H1(n,γ)H2_ (n,γ)H3 Nd143(n,X)H3 Nd145(n,X)H3 Nd144(n,2n)Nd143(n,X)H3 Nd146(n,2n)Nd145(n,X)H3 Nd142(n,2n)Nd141(β <sup>+</sup> )Pr141(n,X)H3 Nd144(n,X)H3 Nd146(n,X)H3 Nd148(n,2n)Nd147(β <sup>-</sup> )Pm147(n,X)H3 Nd142(n,X)H3 Nd148(n,X)H3 Nd150(n,X)H3 Nd144(n,3n)Nd142(n,X)H3 Nd146(n,3n)Nd144(n,X)H3 Nd146(n,4n)Nd143(n,X)H3 &Nd144(n,4n)Nd141(β <sup>+</sup> )Pr141(n,X)H3 Nd142(n,3n)Nd140(β <sup>+</sup> )Pr140(β <sup>+</sup> )Ce140_ (n,X)H3 Other pathways involving (n,γ), β <sup>-</sup> , β <sup>+</sup>	26.0 3.7 70.3	0.4 99.6			41.7 18.4 11.0 5.4 5.3 4.5 2.5 2.3 0.3 0.3 2.7 1.5 1.5 0.5	17.5 10.7 1.1 0.7 1.0 20.2 12.9 0.2 15.7 3.5 2.7 0.8 0.5	14.3 9.1 0.7 0.4 0.6 20.9 13.9 0.1 19.3 4.0 3.3 0.8 1.4	13.0 8.5 0.4 0.3 0.4 21.3 14.3 21.3 4.2 3.7 0.4 0.3 0.3 0.5
Eu152	13.525 y	Nd148(n,γ)Nd149(β <sup>-</sup> )Pm149(β <sup>-</sup> )Sm149_ (n,γ)Sm150(n,γ)Sm151(β <sup>-</sup> )Eu151(n,γ)_ Eu152 Nd146(n,γ)Nd147(β <sup>-</sup> )Pm147(n,γ)_ Pm148m(n,γ)Pm149(β <sup>-</sup> )Sm149(n,γ)_ Sm150(n,γ)Sm151(β <sup>-</sup> )Eu151(n,γ)Eu152 &Nd150(n,γ)Nd151(β <sup>-</sup> )Pm151(β <sup>-</sup> )_ Sm151(β <sup>-</sup> )Eu151(n,γ)Eu152 Nd148(n,γ)Nd149(β <sup>-</sup> )Pm149(n,γ)_ Pm150(β <sup>-</sup> )Sm150(n,γ)Sm151(β <sup>-</sup> )Eu151_ (n,γ)Eu152 Nd145(n,γ)Nd146(n,γ)Nd147(β <sup>-</sup> )Pm147_ (n,γ)Pm148m(n,γ)Pm149(β <sup>-</sup> )Sm149(n,γ)_ Sm150(n,γ)Sm151(β <sup>-</sup> )Eu151(n,γ)Eu152 Nd146(n,γ)Nd147(β <sup>-</sup> )Pm147(n,γ)_ Pm148m(n,γ)Pm149(n,γ)Pm150(β <sup>-</sup> )_ Sm150(n,γ)Sm151(β <sup>-</sup> )Eu151(n,γ)Eu152 Nd146(n,γ)Nd147(β <sup>-</sup> )Pm147(n,γ)_ Pm148(n,γ)Pm149(β <sup>-</sup> )Sm149(n,γ)_ Sm150(n,γ)Sm151(β <sup>-</sup> )Eu151(n,γ)Eu152	29.9 17.8 17.7 6.8 6.6 4.0 3.9	99.6 0.3	99.9	99.9	99.7	99.8	99.9	

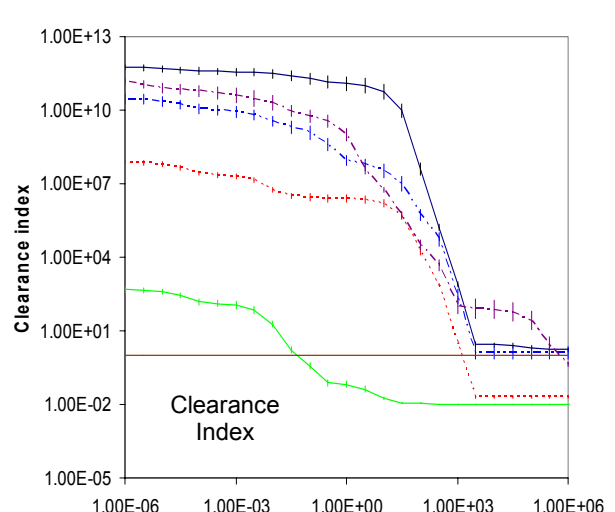
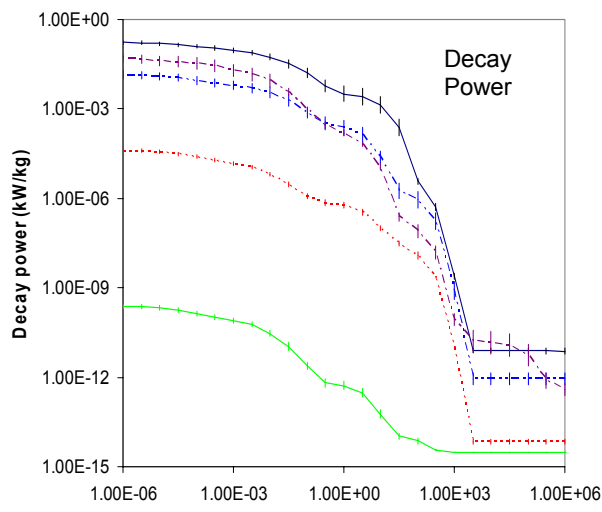
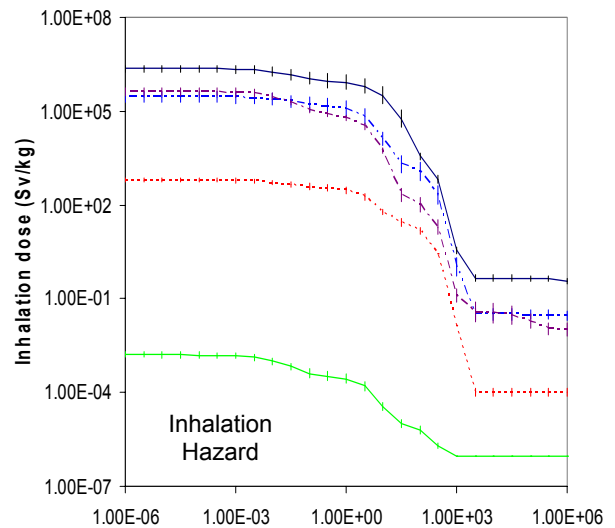
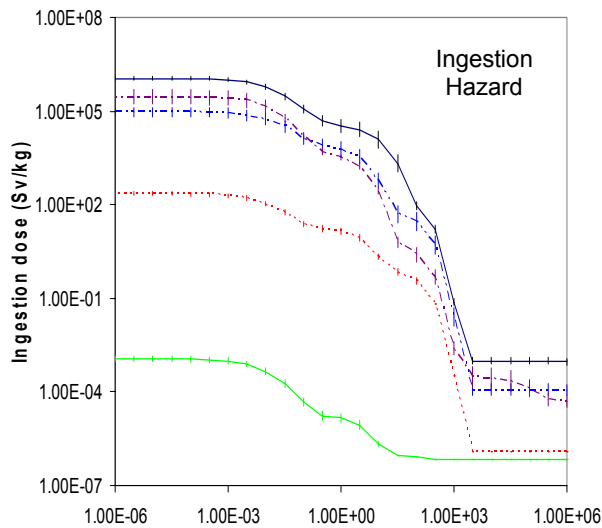
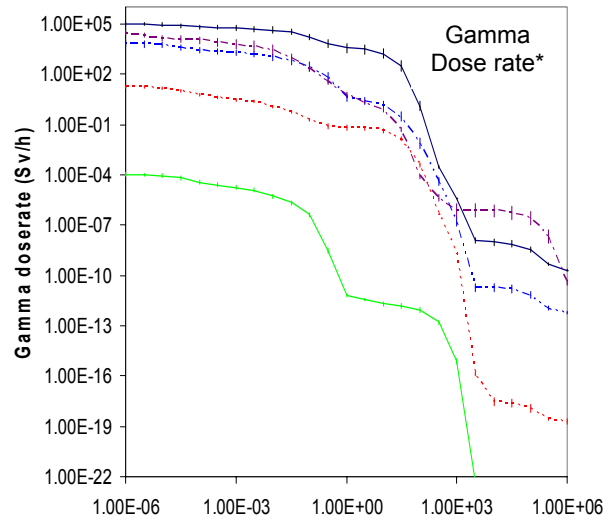
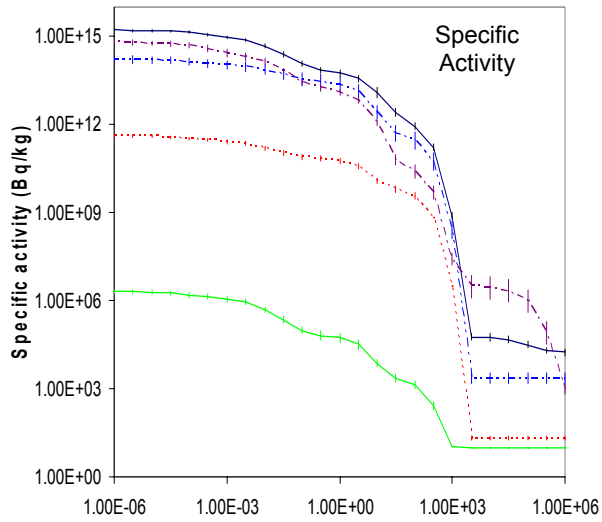
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Nd146(n,γ)Nd147(β <sup>-</sup> )Pm147(n,γ) Pm148(β <sup>-</sup> )Sm148(n,γ)Sm149(n,γ) Sm150(n,γ)Sm151(β <sup>-</sup> )Eu151(n,γ)Eu152 Nd144(n,γ)Nd145(n,γ)Nd146(n,γ) Nd147(β <sup>-</sup> )Pm147(n,γ)Pm148m(n,γ) Pm149(β <sup>-</sup> )Sm149(n,γ)Sm150(n,γ) Sm151(β <sup>-</sup> )Eu151(n,γ)Eu152 Nd145(n,γ)Nd146(n,γ)Nd147(β <sup>-</sup> )Pm147 (n,γ)Pm148(n,γ)Pm149(β <sup>-</sup> )Sm149(n,γ) Sm150(n,γ)Sm151(β <sup>-</sup> )Eu151(n,γ)Eu152 Nd145(n,γ)Nd146(n,γ)Nd147(β <sup>-</sup> )Pm147 (n,γ)Pm148m(n,γ)Pm149(n,γ)Pm150(β <sup>-</sup> ) Sm150(n,γ)Sm151(β <sup>-</sup> )Eu151(n,γ)Eu152	2.0   1.6   1.5   1.5							
Pm145	17.70 y	Nd148(n,2n)Nd147(β <sup>-</sup> )Pm147(n,2n) Pm146(n,2n)Pm145 Nd148(n,2n)Nd147(β <sup>-</sup> )Pm147(β <sup>-</sup> )Sm147 (n,2n)Sm146(n,2n)Sm145(β <sup>+</sup> )Pm145 Nd148(n,2n)Nd147(β <sup>-</sup> )Pm147(n,3n)Pm145 Nd148(n,2n)Nd147(β <sup>-</sup> )Pm147(n,2n) Pm146(β <sup>-</sup> )Sm146(n,2n)Sm145(β <sup>+</sup> )Pm145 Nd150(n,4n)Nd147(β <sup>-</sup> )Pm147(n,3n)Pm145 Nd150(n,4n)Nd147(β <sup>-</sup> )Pm147(β <sup>-</sup> ) Sm147(n,3n)Sm145(β <sup>+</sup> )Pm145 Nd148(n,2n)Nd147(β <sup>-</sup> )Pm147(β <sup>-</sup> ) Sm147(n,3n)Sm145(β <sup>+</sup> )Pm145 Nd150(n,2n)Nd149(β <sup>-</sup> )Pm149(β <sup>-</sup> ) Sm149(n,5n)Sm145(β <sup>+</sup> )Pm145 Nd150(n,4n)Nd147(β <sup>-</sup> )Pm147(β <sup>-</sup> ) Sm147(n,t)Pm145 Nd148(n,d)Pr147(β <sup>-</sup> )Nd147(β <sup>-</sup> )Pm147 (n,3n)Pm145 Nd148(n,2n)Nd147(β <sup>-</sup> )Pm147(β <sup>-</sup> ) Sm147(n,t)Pm145 Nd150(n,nt)Pr147(β <sup>-</sup> )Nd147(β <sup>-</sup> )Pm147 (n,3n)Pm145 Nd150(n,2n)Nd149(β <sup>-</sup> )Pm149(β <sup>-</sup> ) Sm149(n,2nt)Pm145 Nd150(n,d)Pr149(β <sup>-</sup> )Nd149(β <sup>-</sup> )Pm149 (β <sup>-</sup> )Sm149(n,5n)Sm145(β <sup>+</sup> )Pm145				74.8 14.0 7.5 2.0	0.1 25.0 46.7 12.8 6.9	0.2 17.4 38.0 12.1 5.5 5.9 4.7 3.8 2.1 1.0 0.3	12.5 13.0 3.8 3.6 28.7 3.0 3.9 2.9 4.3 7.4 7.2	
Eu150	36.359 y	Nd150(n,γ)Nd151(β <sup>-</sup> )Pm151(β <sup>-</sup> )Sm151 (β <sup>-</sup> )Eu151(n,2n)Eu150				100.0	99.9	99.9	99.9	
Sm151	90.0 y	Nd148(n,γ)Nd149(β <sup>-</sup> )Pm149(β <sup>-</sup> )Sm149 (n,γ)Sm150(n,γ)Sm151 Nd146(n,γ)Nd147(β <sup>-</sup> )Pm147(n,γ) Pm148m(n,γ)Pm149(β <sup>-</sup> )Sm149(n,γ) Sm150(n,γ)Sm151 Nd150(n,γ)Nd151(β <sup>-</sup> )Pm151(β <sup>-</sup> )Sm151 Nd148(n,γ)Nd149(β <sup>-</sup> )Pm149(n,γ) Pm150(β <sup>-</sup> )Sm150(n,γ)Sm151 Nd145(n,γ)Nd146(n,γ)Nd147(β <sup>-</sup> ) Pm147(n,γ)Pm148m(n,γ)Pm149(β <sup>-</sup> ) Sm149(n,γ)Sm150(n,γ)Sm151 Nd146(n,γ)Nd147(β <sup>-</sup> )Pm147(n,γ) Pm148m(n,γ)Pm149(n,γ)Pm150(β <sup>-</sup> ) Sm150(n,γ)Sm151 Nd146(n,γ)Nd147(β <sup>-</sup> )Pm147(n,γ) Pm148(n,γ)Pm149(β <sup>-</sup> )Sm149(n,γ) Sm150(n,γ)Sm151 Nd146(n,γ)Nd147(β <sup>-</sup> )Pm147(n,γ) Pm148(β <sup>-</sup> )Sm148(n,γ)Sm149(n,γ) Sm150(n,γ)Sm151	29.9 17.8 17.7 6.8 6.7 4.0 3.9 2.0	99.6 0.3	0.2 99.8	100.0	99.8	99.9	99.9	
	▶									

Nuclide	T <sub>½</sub>	Pathway	210	186	151	42	30	21	6
	◀	Nd145(n,γ)Nd146(n,γ)Nd147(β <sup>-</sup> ) Pm147(n,γ)Pm148(n,γ)Pm149(β <sup>-</sup> ) Sm149(n,γ)Sm150(n,γ)Sm151 Nd145(n,γ)Nd146(n,γ)Nd147(β <sup>-</sup> ) Pm147(n,γ)Pm148m(n,γ)Pm149(n,γ) Pm150(β <sup>-</sup> )Sm150(n,γ)Sm151	1.5   1.5						
Ho166m	1200.0 y	Very long pathways of (n,γ), β <sup>-</sup>	100.0	100.0					
La137	6.0 10 <sup>4</sup> y	&Nd142(n,α)Ce139(β <sup>+</sup> )La139(n,2n) La138(n,2n)La137 &Nd142(n,2n)Nd141(β <sup>+</sup> )Pr141(n,α) La138(n,2n)La137 &Nd142(n,α)Ce138(n,2n)Ce137(β <sup>+</sup> )La137 &Nd142(n,α)Ce139(n,2n)Ce138(n,2n) Ce137(β <sup>+</sup> )La137 &Nd142(n,2n)Nd141(β <sup>+</sup> )Pr141(n,α)La137 &Nd143(n,α)Ce139(β <sup>+</sup> )La139(n,3n)La137 &Nd143(n,3n)Nd141(β <sup>+</sup> )Pr141(n,α)La137 &Nd142(n,α)Ce139(β <sup>+</sup> )La139(n,3n)La137 &Nd142(n,2n)Ce137(β <sup>+</sup> )La137 Nd142(n,3n)Nd140(β <sup>+</sup> )Pr140(β <sup>+</sup> )Ce140 (n,4n)Ce137(β <sup>+</sup> )La137 Nd142(n,4n)Nd139m(β <sup>+</sup> )Pr139(β <sup>+</sup> ) Ce139(β <sup>+</sup> )La139(n,3n)La137 &Nd142(n,t)Pr140(β <sup>+</sup> )Ce140(n,4n) Ce137(β <sup>+</sup> )La137 &Nd143(n,3n)Ce137(β <sup>+</sup> )La137 &Nd144(n,4n)Ce137(β <sup>+</sup> )La137 Nd142(n,2n)Nd141(β <sup>+</sup> )Pr141(n,5n) Pr137(β <sup>+</sup> )Ce137(β <sup>+</sup> )La137 Other pathways involving (n,2n), (n,α), β <sup>+</sup>				22.1 15.6 9.3 8.3 7.6 3.0 3.0 1.7 8.7 4.9 3.1 0.4 4.5 3.2 37.1	3.9 0.5 0.1 0.1 4.7 4.7 3.0 0.3 0.1 14.0 8.7 4.9 3.1 0.4 7.8 4.5 67.1	0.5 0.1 0.1 0.1 0.5 0.4 0.3 0.1 11.5 0.7 3.1 2.0 7.8 4.5 3.2 67.0	0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 11.5 0.7 3.1 2.0 7.8 4.5 3.2 67.0
Cs135	2.3 10 <sup>6</sup> y	Nd143(n,α)Ce140(n,γ)Ce141(β <sup>-</sup> )Pr141 (n,α)La138(n,α)Cs135 Nd144(n,α)Ce141(β <sup>-</sup> )Pr141(n,α)La138 (n,α)Cs135 Nd142(n,γ)Nd143(n,α)Ce140(n,γ) Ce141(β <sup>-</sup> )Pr141(n,α)La138(n,α)Cs135 Nd143(n,γ)Nd144(n,α)Ce141(β <sup>-</sup> )Pr141 (n,α)La138(n,α)Cs135 Nd142(n,γ)Nd143(n,γ)Nd144(n,α) Ce141(β <sup>-</sup> )Pr141(n,α)La138(n,α)Cs135 Pathways involving (n,α), (n,nα), (n,2n), β <sup>-</sup> , β <sup>+</sup>	38.9 25.1 18.7 11.2 5.4 0.1	42.7 41.7 15.5 0.1		100.0	100.0	100.0	100.0
Sm146	1.0 10 <sup>8</sup> y	Nd148(n,2n)Nd147(β <sup>-</sup> )Pm147(β <sup>-</sup> ) Sm147(n,2n)Sm146 Nd148(n,2n)Nd147(β <sup>-</sup> )Pm147(n,2n) Pm146(β <sup>-</sup> )Sm146 Nd150(n,2n)Nd149(β <sup>-</sup> )Pm149(β <sup>-</sup> )Sm149 (n,2n)Sm148(n,2n)Sm147(n,2n)Sm146 Nd150(n,2n)Nd149(β <sup>-</sup> )Pm149(β <sup>-</sup> ) Sm149(n,3n)Sm147(n,2n)Sm146 Nd150(n,2n)Nd149(β <sup>-</sup> )Pm149(β <sup>-</sup> ) Sm149(n,4n)Sm146 Nd150(n,4n)Nd147(β <sup>-</sup> )Pm147(β <sup>-</sup> ) Sm147(n,2n)Sm146 Nd150(n,2n)Nd149(β <sup>-</sup> )Pm149(β <sup>-</sup> ) Sm149(n,2n)Sm148(n,3n)Sm146 Nd150(n,4n)Nd147(β <sup>-</sup> )Pm147(n,2n) Pm146(β <sup>-</sup> )Sm146 Nd150(n,d)Pr149(β <sup>-</sup> )Nd149(β <sup>-</sup> )Pm149 (β <sup>-</sup> )Sm149(n,4n)Sm146				85.4 11.5 1.6 0.2 33.9 29.8 3.4 3.3 2.6	16.0 1.8 0.7 0.4 64.8 12.3 0.4 1.5 11.1	5.6 0.7 0.4 0.4 51.3 10.7 0.4 1.3 13.0	10.2 1.2 0.4 0.4 51.3 10.7 0.4 1.3 13.0

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Nd148(n,d)Pr147(β <sup>-</sup> )Nd147(β <sup>-</sup> )Pm147_ (β <sup>-</sup> )Sm147(n,2n)Sm146 Nd150(n,nt)Pr147(β <sup>-</sup> )Nd147(β <sup>-</sup> )Pm147_ (β <sup>-</sup> )Sm147(n,2n)Sm146					1.7	1.2	3.2	
								0.3	3.5	
La138	1.010 <sup>11</sup> y	Nd143(n,α)Ce140(n,γ)Ce141(β <sup>-</sup> )Pr141_ (n,α)La138 Nd142(n,γ)Nd143(n,α)Ce140(n,γ)_ Ce141(β <sup>-</sup> )Pr141(n,α)La138 Nd144(n,α)Ce141(β <sup>-</sup> )Pr141(n,α)La138 Nd143(n,γ)Nd144(n,α)Ce141(β <sup>-</sup> )Pr141_ (n,α)La138 Nd142(n,γ)Nd143(n,γ)Nd144(n,α)_ Ce141(β <sup>-</sup> )Pr141(n,α)La138 &Nd142(n,α)Ce139(β <sup>+</sup> )La139(n,2n)La138 &Nd142(n,2n)Nd141(β <sup>+</sup> )Pr141(n,α)La138 &Nd142(n,2n)Nd141(β <sup>+</sup> )Pr141(n,2n)Pr140_ (β <sup>+</sup> )Ce140(n,2n)Ce139(β <sup>+</sup> )La139(n,2n)La138 &Nd143(n,α)Ce139(β <sup>+</sup> )La139(n,2n)La138 &Nd143(n,2n)Nd142(n,α)Ce139(β <sup>+</sup> )_ La139(n,2n)La138 &Nd144(n,α)Ce140(n,2n)Ce139(β <sup>+</sup> )_ La139(n,2n)La138 Nd142(n,3n)Nd140(β <sup>+</sup> )Pr140(β <sup>+</sup> )Ce140_ (n,t)La138 Nd142(n,d)Pr141(n,3n)Pr139(β <sup>+</sup> )Ce139_ (β <sup>+</sup> )La139(n,2n)La138 Nd142(n,t)Pr140(β <sup>+</sup> )Ce140(n,t)La138 Nd142(n,nt)Pr139(β <sup>+</sup> )Ce139(β <sup>+</sup> )La139_ (n,2n)La138 Nd142(n,4n)Nd139m(β <sup>+</sup> )Pr139(β <sup>+</sup> )_ Ce139(β <sup>+</sup> )La139(n,2n)La138 Nd142(n,4n)Nd139(β <sup>+</sup> )Pr139(β <sup>+</sup> )Ce139_ (β <sup>+</sup> )La139(n,2n)La138 Nd143(n,4n)Nd140(β <sup>+</sup> )Pr140(β <sup>+</sup> )Ce140_ (n,t)La138 Nd144(n,5n)Nd140(β <sup>+</sup> )Pr140(β <sup>+</sup> )Ce140_ (n,t)La138 Nd143(n,5n)Nd139m(β <sup>+</sup> )Pr139(β <sup>+</sup> )_ Ce139(β <sup>+</sup> )La139(n,2n)La138 Other pathways involving (n,2n), (n,α), β <sup>+</sup>	36.6 23.8 21.7 10.3 6.8 0.8	43.8 40.2 15.9	2.1 97.2 0.6	0.1	30.5 19.7 13.8	4.4 4.0	0.5 0.5	0.5 0.6
							1.6 1.2	7.0	1.4	0.4
							0.5	0.2		
								8.9	28.7	9.1
								2.3	0.6	
								0.1	2.4	3.7
							0.1	1.4	5.9	
									16.6	17.6
									8.0	3.0
									7.7	5.6
										15.7
										7.0
			0.8	0.1	0.1	32.6	73.0	32.2	30.9	
Sm147	1.1 10 <sup>11</sup> y	Nd146(n,γ)Nd147(β <sup>-</sup> )Pm147(β <sup>-</sup> )Sm147 Nd145(n,γ)Nd146(n,γ)Nd147(β <sup>-</sup> )_ Pm147(β <sup>-</sup> )Sm147 Nd144(n,γ)Nd145(n,γ)Nd146(n,γ)_ Nd147(β <sup>-</sup> )Pm147(β <sup>-</sup> )Sm147 Nd143(n,γ)Nd144(n,γ)Nd145(n,γ)_ Nd146(n,γ)Nd147(β <sup>-</sup> )Pm147(β <sup>-</sup> )Sm147 Nd148(n,2n)Nd147(β <sup>-</sup> )Pm147(β <sup>-</sup> )Sm147 Nd150(n,2n)Nd149(β <sup>-</sup> )Pm149(β <sup>-</sup> )_ Sm149(n,2n)Sm148(n,2n)Sm147 Nd150(n,3n)Nd148(n,2n)Nd147(β <sup>-</sup> )_ Pm147(β <sup>-</sup> )Sm147 Nd150(n,2n)Nd149(β <sup>-</sup> )Pm149(β <sup>-</sup> )_ Sm149(n,3n)Sm147 Nd150(n,4n)Nd147(β <sup>-</sup> )Pm147(β <sup>-</sup> )Sm147 Nd148(n,d)Pr147(β <sup>-</sup> )Nd147(β <sup>-</sup> )Pm147_ (β <sup>-</sup> )Sm147 Nd150(n,nt)Pr147(β <sup>-</sup> )Nd147(β <sup>-</sup> )Pm147_ (β <sup>-</sup> )Sm147	67.6 23.6 5.3 2.4	73.2 26.4 0.3 0.1	99.0 1.0	0.2	95.5 2.7	0.2 30.1	0.2 27.7	0.2 35.4
							1.3	1.0	0.3	0.2
							0.3	7.0	1.9	1.5
								56.1	60.4	37.0
								3.2	6.0	11.0
								0.1	1.5	12.3
Nd144	2.3 10 <sup>15</sup> y ▶	Nd142(n,γ)Nd143(n,γ)Nd144 Nd143(n,γ)Nd144	32.6 23.0	33.9	1.9					

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	Nd145(n,2n)Nd144				8.5	1.6	1.2	0.8
		Nd146(n,2n)Nd145(n,2n)Nd144				2.5	0.1		
		Nd146(n,3n)Nd144				0.9	12.7	4.0	2.4
		Nd148(n,3n)Nd146(n,3n)Nd144					0.3		
		&Nd145(n,d)Pr144(β <sup>-</sup> )Nd144					0.2	0.3	0.3
		Nd148(n,5n)Nd144						1.2	1.2
		&Nd146(n,t)Pr144(β <sup>-</sup> )Nd144						0.6	0.8
		Nd150(n,7n)Nd144							0.4
		Nuclide also present in starting material	44.4	66.1	98.1	88.1	85.1	92.7	94.1

# Neodymium activation characteristics

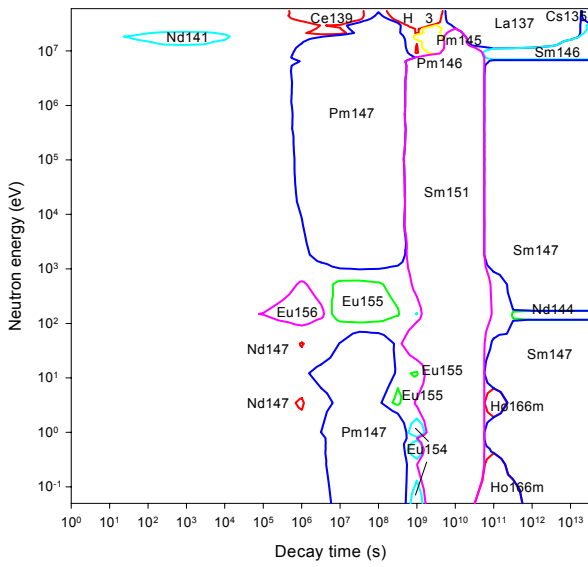


Decay time (years)

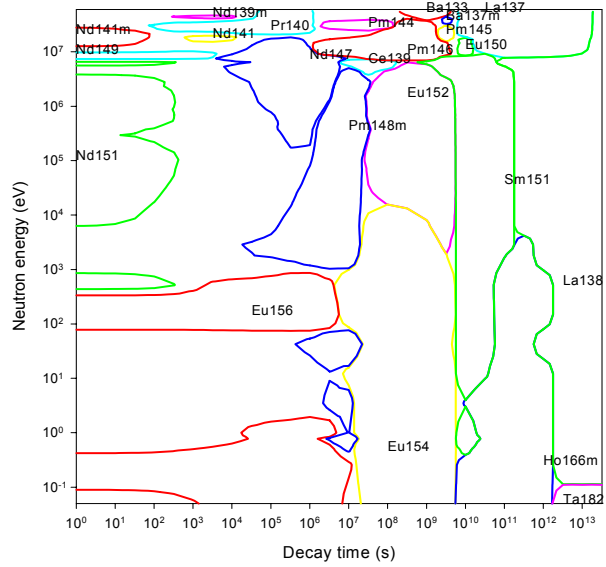
Decay time (years)

# Neodymium importance diagrams & transmutation

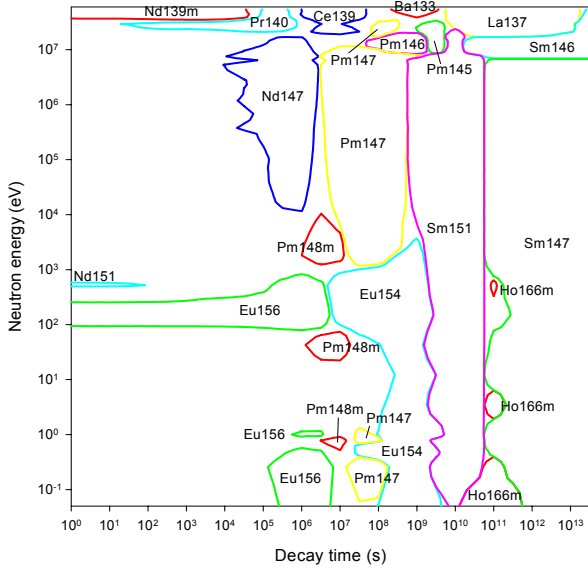
Activity



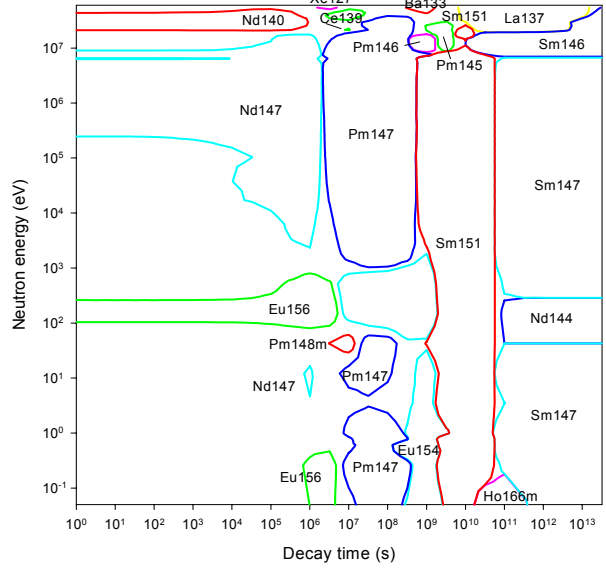
Dose rate



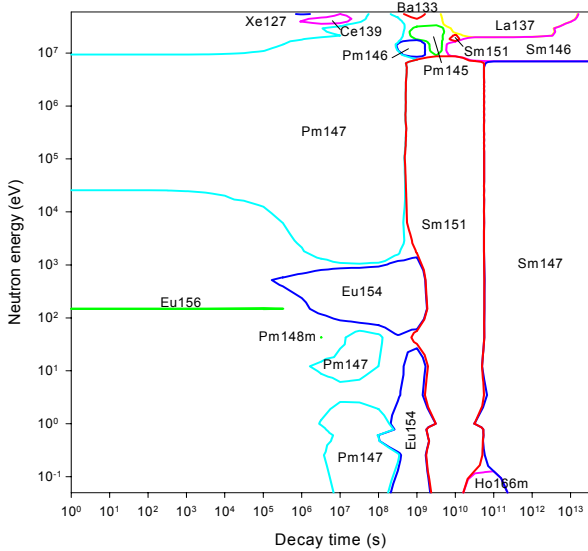
Heat output



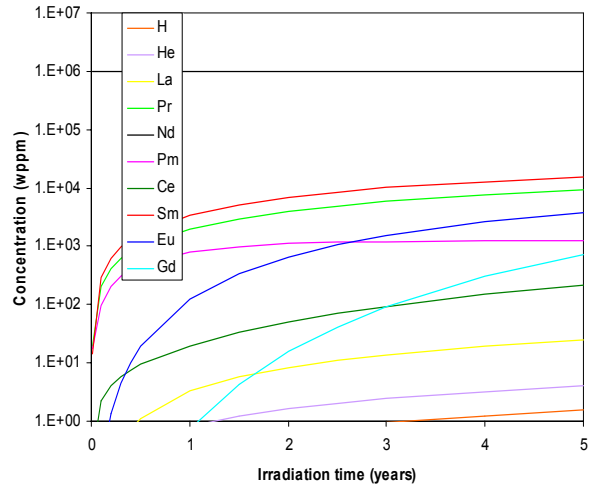
Ingestion dose



Inhalation dose



First wall transmutation





# Samarium

## General properties

Atomic number	62	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	7.05	Sm144	3.07
Melting point / K	1345	Sm147	14.99 ( $T_{1/2} = 1.06 \cdot 10^{11} \text{ y}$ )
Boiling point / K	2063	Sm148	11.24 ( $T_{1/2} = 8.00 \cdot 10^{15} \text{ y}$ )
Density / $\text{kgm}^{-3}$	7520	Sm149	13.82 ( $T_{1/2} = 2.00 \cdot 10^{15} \text{ y}$ )
Thermal conductivity / $\text{Wm}^{-1}\text{K}^{-1}$	13.3	Sm150	7.38
Electrical resistivity / $\Omega\text{m}$	$9.4 \cdot 10^{-7}$	Sm152	26.75
Coefficient of thermal expansion / $\text{K}^{-1}$	$1.27 \cdot 10^{-5}$	Sm154	22.75
Crystal structure	Rhombohedral		
Number of stable isotopes	4 (7)		
Mean atomic weight	150.36		

## Activation properties

Act	0	$10^{-5} \text{ y}$	$10^{-2} \text{ y}$	1 y	100 y	$10^5 \text{ y}$	Heat	0	$10^{-5} \text{ y}$	$10^{-2} \text{ y}$	1 y	100 y	$10^5 \text{ y}$
Bq $\text{kg}^{-1}$	1.18E16	1.17E16	7.36E15	1.83E15	1.11E13	2.28E6	kW $\text{kg}^{-1}$	1.90E0	1.88E0	1.43E0	1.87E-1	9.65E-5	9.40E-10
Eu156	43.34	43.95	59.11				Eu156	73.09	73.76	82.05			
Sm153	28.53	28.90	12.37				Sm153	9.42	9.50	3.36			
Eu155	10.83	10.98	17.42	60.70	0.01		Eu154	9.33	9.42	12.36	87.19	57.51	
Sm155	7.61	6.56					Sm155	5.11	4.38				
Eu154	6.13	6.22	9.87	36.69	2.05		Eu155	1.35	1.36	1.78	11.79	0.01	
Eu157	0.96	0.97	0.03				Eu152	0.05	0.05	0.07	0.52	6.30	
Eu154m	0.90	0.85					Sm151			0.01	0.04	35.69	
Sm151	0.20	0.20	0.32	1.27	97.39		Sm146						96.38
Sm146						96.57	Gd150						3.10
Gd150						2.86	Sm147						0.51
Dose	0	$10^{-5} \text{ y}$	$10^{-2} \text{ y}$	1 y	100 y	$10^5 \text{ y}$	Ing	0	$10^{-5} \text{ y}$	$10^{-2} \text{ y}$	1 y	100 y	$10^5 \text{ y}$
Sv $\text{h}^{-1}$	2.06E6	2.05E6	1.76E6	2.11E5	7.92E1	8.21E-13	Sv $\text{kg}^{-1}$	1.58E7	1.58E7	1.21E7	1.71E6	1.56E3	1.23E-1
Eu156	87.95	88.05	86.77				Eu156	71.31	71.34	78.74			
Eu154	10.98	10.99	12.79	98.76	89.49		Sm153	15.79	15.78	5.54			
Eu157	0.21	0.21					Eu154	9.17	9.18	11.95	78.40	29.19	
Tb160	0.12	0.12	0.14	0.04			Eu155	2.59	2.59	3.38	20.75	0.01	
Eu152	0.07	0.07	0.08	0.61	10.13		Eu152	0.04	0.04	0.06	0.39	2.64	
Eu155	0.03	0.03	0.04	0.26			Sm151	0.01	0.01	0.02	0.13	67.83	
La137						92.24	Sm146					0.01	96.73
La138						7.76	Gd150						2.76
Inh	0	$10^{-5} \text{ y}$	$10^{-2} \text{ y}$	1 y	100 y	$10^5 \text{ y}$	Clear	0	$10^{-5} \text{ y}$	$10^{-2} \text{ y}$	1 y	100 y	$10^5 \text{ y}$
Sv $\text{kg}^{-1}$	6.75E7	6.75E7	6.31E7	4.35E7	5.68E4	2.97E1		1.55E13	1.54E13	1.42E13	7.86E12	2.59E9	2.80E1
Eu154	57.04	57.05	60.93	81.64	21.28		Eu154	47.02	47.12	51.13	85.24	88.06	
Eu156	25.87	25.87	23.41				Eu156	42.62	42.70	39.26			
Eu155	13.11	13.12	14.00	17.58	0.01		Eu155	8.30	8.32	9.02	14.10	0.02	
Sm153	3.16	3.15	0.91				Sm155	0.93	0.79				
Eu152	0.31	0.31	0.33	0.46	2.18		Eu152	0.32	0.32	0.35	0.60	11.40	
Sm151	0.14	0.14	0.15	0.21	76.17		Sm153	0.22	0.22	0.06			
Sm146					0.04	81.40	Sm151					0.42	
Gd150					0.01	18.18	Sm147						46.62
Sm147						0.42	Sm146						43.68
							Gd150						9.69

# Samarium

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Sm155	22.3 m	Sm154(n,γ)Sm155	92.5	97.3	100.0	99.9	99.6	99.7	99.9
		Sm152(n,γ)Sm153(n,γ)Sm154(n,γ)Sm155	3.9	1.9					
		Sm150(n,γ)Sm151(n,γ)Sm152(n,γ)_	1.1	0.2					
		Sm153(n,γ)Sm154(n,γ)Sm155							
Sm153	1.928 d	Sm147(n,γ)Sm148(n,γ)Sm149(n,γ)Sm150_	39.5	27.5					
		(n,γ)Sm151(n,γ)Sm152(n,γ)Sm153							
		Sm148(n,γ)Sm149(n,γ)Sm150(n,γ)_	33.3	21.8					
		Sm151(n,γ)Sm152(n,γ)Sm153							
		Sm150(n,γ)Sm151(n,γ)Sm152(n,γ)Sm153	9.3	16.7	0.3				
		Sm149(n,γ)Sm150(n,γ)Sm151(n,γ)_	2.9	32.4					
		Sm152(n,γ)Sm153							
		Sm152(n,γ)Sm153		1.7	99.7			0.2	0.1
Sm154(n,2n)Sm153					99.8	91.3	83.3	77.6	
Sm154(n,d)Pm153(β <sup>-</sup> )Sm153							16.3	23.7	
Tb161	6.89 d	&Sm152(n,γ)Sm153(β <sup>-</sup> )Eu153(n,γ)_	46.7	0.6					
		Eu154(n,γ)Eu155(n,γ)Eu156(n,γ)Eu157_							
		(β <sup>-</sup> )Gd157(n,γ)Gd158(n,γ)Gd159(β <sup>-</sup> )_							
		Tb159(n,γ)Tb160(n,γ)Tb161							
		Sm154(n,γ)Sm155(β <sup>-</sup> )Eu155(n,γ)Eu156_	10.4		0.4				
		(n,γ)Eu157(β <sup>-</sup> )Gd157(n,γ)Gd158(n,γ)_							
		Gd159(β <sup>-</sup> )Tb159(n,γ)Tb160(n,γ)Tb161							
		&Sm152(n,γ)Sm153(β <sup>-</sup> )Eu153(n,γ)_	5.7	80.5	0.6				
		Eu154(n,γ)Eu155(n,γ)Eu156(β <sup>-</sup> )Gd156_							
		(n,γ)Gd157(n,γ)Gd158(n,γ)Gd159(β <sup>-</sup> )_							
		Tb159(n,γ)Tb160(n,γ)Tb161							
		Sm154(n,γ)Sm155(β <sup>-</sup> )Eu155(n,γ)Eu156_	1.0	0.2	73.1				
		(β <sup>-</sup> )Gd156(n,γ)Gd157(n,γ)Gd158(n,γ)_							
		Gd159(β <sup>-</sup> )Tb159(n,γ)Tb160(n,γ)Tb161							
		Sm152(n,γ)Sm153(n,γ)Sm154(n,γ)_	0.4						
		Sm155(β <sup>-</sup> )Eu155(n,γ)Eu156(n,γ)Eu157_							
		(β <sup>-</sup> )Gd157(n,γ)Gd158(n,γ)Gd159(β <sup>-</sup> )_							
		Tb159(n,γ)Tb160(n,γ)Tb161							
		&Sm152(n,γ)Sm153(β <sup>-</sup> )Eu153(n,γ)_	0.2						
		Eu154(n,γ)Eu155(n,γ)Eu156(n,γ)Eu157_							
(n,γ)Eu158(β <sup>-</sup> )Gd158(n,γ)Gd159(β <sup>-</sup> )_									
Tb159(n,γ)Tb160(n,γ)Tb161									
&Sm152(n,γ)Sm153(β <sup>-</sup> )Eu153(n,γ)_				6.1	0.2				
Eu154(n,γ)Eu155(β <sup>-</sup> )Gd155(n,γ)Gd156_									
(n,γ)Gd157(n,γ)Gd158(n,γ)Gd159(β <sup>-</sup> )_									
Tb159(n,γ)Tb160(n,γ)Tb161									
&Sm152(n,γ)Sm153(β <sup>-</sup> )Eu153(n,γ)_				2.7					
Eu154(β <sup>-</sup> )Gd154(n,γ)Gd155(n,γ)Gd156_									
(n,γ)Gd157(n,γ)Gd158(n,γ)Gd159(β <sup>-</sup> )_									
Tb159(n,γ)Tb160(n,γ)Tb161									
Sm154(n,γ)Sm155(β <sup>-</sup> )Eu155(β <sup>-</sup> )Gd155_					25.7				
(n,γ)Gd156(n,γ)Gd157(n,γ)Gd158(n,γ)_									
Gd159(β <sup>-</sup> )Tb159(n,γ)Tb160(n,γ)Tb161									
Other pathways involving (n,γ), β <sup>-</sup>		35.6	9.9						
Eu156	15.19 d	Sm154(n,γ)Sm155(β <sup>-</sup> )Eu155(n,γ)Eu156	51.5	0.6	94.9	99.9	99.7	99.8	99.9
		&Sm147(n,γ)Sm148(n,γ)Sm149(n,γ)_	12.1	16.6					
		Sm150(n,γ)Sm151(n,γ)Sm152(n,γ)_							
		Sm153(β <sup>-</sup> )Eu153(n,γ)Eu154(n,γ)Eu155_							
		(n,γ)Eu156							

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	&Sm148(n,γ)Sm149(n,γ)Sm150(n,γ) Sm151(n,γ)Sm152(n,γ)Sm153(β <sup>-</sup> ) Eu153(n,γ)Eu154(n,γ)Eu155(n,γ)Eu156 &Sm149(n,γ)Sm150(n,γ)Sm151(n,γ) Sm152(n,γ)Sm153(β <sup>-</sup> )Eu153(n,γ)Eu154 (n,γ)Eu155(n,γ)Eu156 &Sm150(n,γ)Sm151(n,γ)Sm152(n,γ) Sm153(β <sup>-</sup> )Eu153(n,γ)Eu154(n,γ)Eu155 (n,γ)Eu156 Sm152(n,γ)Sm153(n,γ)Sm154(n,γ) Sm155(β <sup>-</sup> )Eu155(n,γ)Eu156 &Sm152(n,γ)Sm153(β <sup>-</sup> )Eu153(n,γ) Eu154(n,γ)Eu155(n,γ)Eu156 Sm150(n,γ)Sm151(n,γ)Sm152(n,γ) Sm153(n,γ)Sm154(n,γ)Sm155(β <sup>-</sup> ) Eu155(n,γ)Eu156	11.0	14.5						
			9.5	31.1						
			7.0	16.5						
			2.1							
			0.8	20.5	5.6					
			0.6							
Tb160	72.3 d	&Sm152(n,γ)Sm153(β <sup>-</sup> )Eu153(n,γ) Eu154(n,γ)Eu155(n,γ)Eu156(n,γ)Eu157 (β <sup>-</sup> )Gd157(n,γ)Gd158(n,γ)Gd159(β <sup>-</sup> ) Tb159(n,γ)Tb160 &Sm149(n,γ)Sm150(n,γ)Sm151(n,γ) Sm152(n,γ)Sm153(β <sup>-</sup> )Eu153(n,γ)Eu154 (n,γ)Eu155(n,γ)Eu156(n,γ)Eu157(β <sup>-</sup> ) Gd157(n,γ)Gd158(n,γ)Gd159(β <sup>-</sup> )Tb159 (n,γ)Tb160 Sm154(n,γ)Sm155(β <sup>-</sup> )Eu155(n,γ)Eu156 (n,γ)Eu157(β <sup>-</sup> )Gd157(n,γ)Gd158(n,γ) Gd159(β <sup>-</sup> )Tb159(n,γ)Tb160 &Sm150(n,γ)Sm151(n,γ)Sm152(n,γ) Sm153(β <sup>-</sup> )Eu153(n,γ)Eu154(n,γ)Eu155 (n,γ)Eu156(n,γ)Eu157(β <sup>-</sup> )Gd157(n,γ) Gd158(n,γ)Gd159(β <sup>-</sup> )Tb159(n,γ)Tb160 &Sm152(n,γ)Sm153(β <sup>-</sup> )Eu153(n,γ) Eu154(n,γ)Eu155(n,γ)Eu156(β <sup>-</sup> )Gd156 (n,γ)Gd157(n,γ)Gd158(n,γ)Gd159(β <sup>-</sup> ) Tb159(n,γ)Tb160 Sm154(n,γ)Sm155(β <sup>-</sup> )Eu155(n,γ)Eu156 (β <sup>-</sup> )Gd156(n,γ)Gd157(n,γ)Gd158(n,γ) Gd159(β <sup>-</sup> )Tb159(n,γ)Tb160 &Sm152(n,γ)Sm153(β <sup>-</sup> )Eu153(n,γ) Eu154(n,γ)Eu155(β <sup>-</sup> )Gd155(n,γ)Gd156 (n,γ)Gd157(n,γ)Gd158(n,γ)Gd159(β <sup>-</sup> ) Tb159(n,γ)Tb160 &Sm152(n,γ)Sm153(β <sup>-</sup> )Eu153(n,γ) Eu154(β <sup>-</sup> )Gd154(n,γ)Gd155(n,γ)Gd156 (n,γ)Gd157(n,γ)Gd158(n,γ)Gd159(β <sup>-</sup> ) Tb159(n,γ)Tb160 Sm154(n,γ)Sm155(β <sup>-</sup> )Eu155(β <sup>-</sup> )Gd155 (n,γ)Gd156(n,γ)Gd157(n,γ)Gd158(n,γ) Gd159(β <sup>-</sup> )Tb159(n,γ)Tb160	47.0	0.6						
			13.8							
			10.4		0.4					
			10.4							
			5.7	81.3	0.6					
			1.0	0.3	73.1					
				6.2	0.2					
				2.7						
					25.7					
Ta182	114.7 d	Very long pathways of (n,γ), β <sup>-</sup>	100.0							
Sm145	340.0 d	Sm144(n,γ)Sm145 Sm147(n,2n)Sm146(n,2n)Sm145 Sm148(n,2n)Sm147(n,2n)Sm146(n,2n)Sm145 Sm147(n,3n)Sm145 Sm149(n,3n)Sm147(n,3n)Sm145 Sm148(n,3n)Sm146(n,2n)Sm145 Sm148(n,2n)Sm147(n,3n)Sm145 Sm148(n,4n)Sm145 Sm149(n,5n)Sm145 Sm152(n,5n)Sm148(n,4n)Sm145	100.0	100.0	100.0	91.4 7.6	1.2 77.3 9.8 3.1 3.0 1.9	0.6 28.5 1.1 0.7 0.8 46.6 6.9	0.3 18.6 0.4 0.3 0.3 16.8 33.3	
	▶							3.2	1.8	

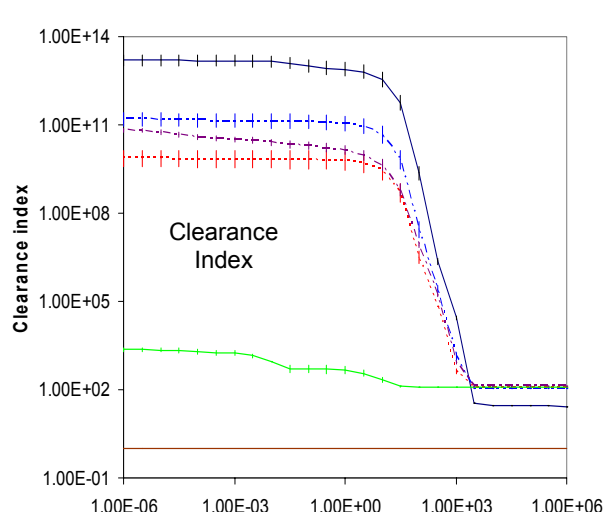
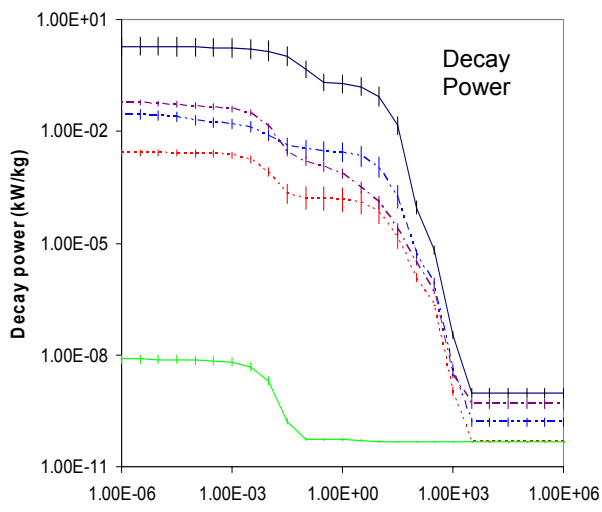
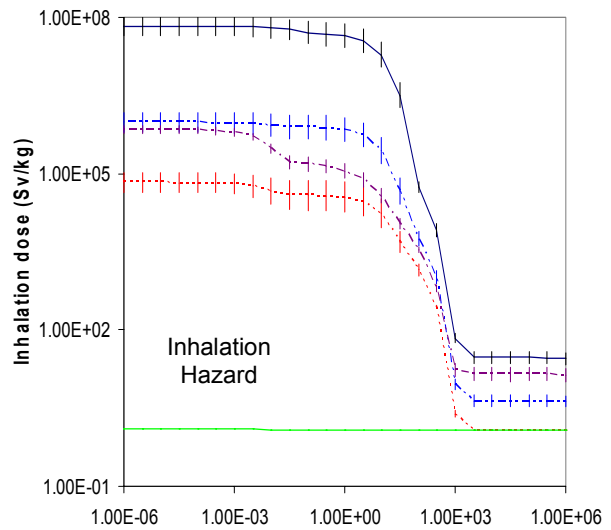
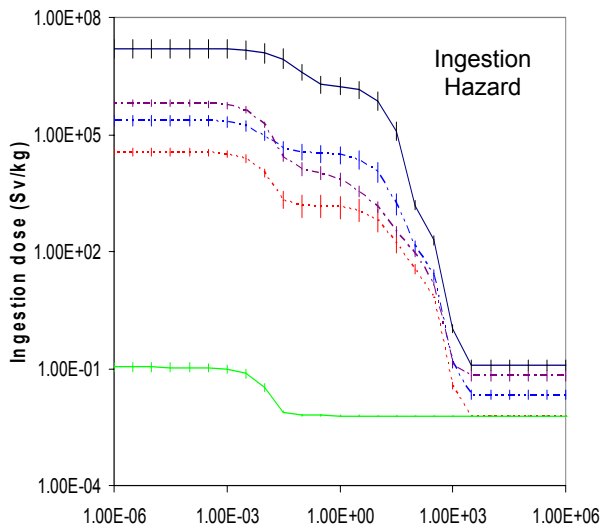
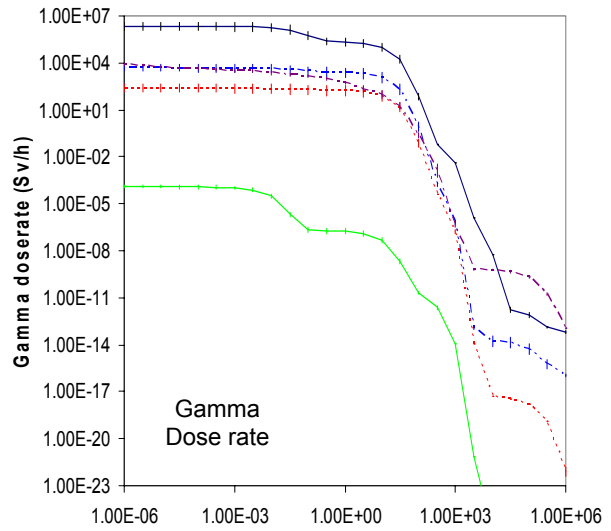
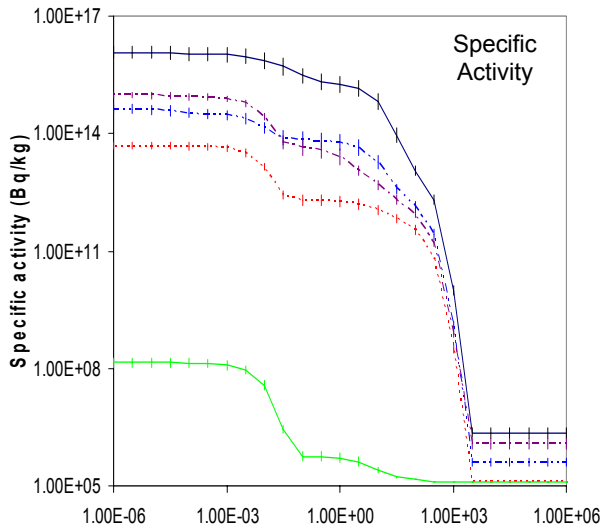
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	Sm150(n,6n)Sm145 Sm154(n,6n)Sm149(n,5n)Sm145 Sm154(n,5n)Sm150(n,6n)Sm145							13.1 3.2 2.0
Pm144	363.0 d	Sm147(n,2n)Sm146(n,2n)Sm145(β <sup>+</sup> ) <sub>-</sub> Pm145(n,2n)Pm144 Sm144(n,p)Pm144 Sm148(n,2n)Sm147(n,2n)Sm146(n,2n) <sub>-</sub> Sm145(β <sup>+</sup> )Pm145(n,2n)Pm144 Sm147(n,3n)Sm145(β <sup>+</sup> )Pm145(n,2n)Pm144   Sm147(n,d)Pm146(n,3n)Pm144 Sm147(n,3n)Sm145(n,d)Pm144 Sm147(n,nt)Pm144 Sm148(n,3n)Sm146(n,t)Pm144 Sm148(n,4n)Sm145(β <sup>+</sup> )Pm145(n,2n)Pm144   Sm148(n,d)Pm147(n,4n)Pm144 Sm149(n,4n)Sm146(n,t)Pm144 Sm149(n,t)Pm147(n,4n)Pm144 Sm148(n,2nt)Pm144 Sm149(n,3nt)Pm144 Sm152(n,6n)Sm147(n,nt)Pm144				78.5 15.7 3.9	10.1	4.6	1.2 1.1 0.6 0.3 42.0 0.8 1.0 0.4 1.1 0.6 20.3 4.2
Tm171	1.917 y	Very long pathways of (n,γ), β <sup>-</sup>	100.0	100.0					
Eu155	4.753 y	Sm154(n,γ)Sm155(β <sup>-</sup> )Eu155 &Sm147(n,γ)Sm148(n,γ)Sm149(n,γ) <sub>-</sub> Sm150(n,γ)Sm151(n,γ)Sm152(n,γ) <sub>-</sub> Sm153(β <sup>-</sup> )Eu153(n,γ)Eu154(n,γ)Eu155 &Sm148(n,γ)Sm149(n,γ)Sm150(n,γ) <sub>-</sub> Sm151(n,γ)Sm152(n,γ)Sm153(β <sup>-</sup> ) <sub>-</sub> Eu153(n,γ)Eu154(n,γ)Eu155 &Sm149(n,γ)Sm150(n,γ)Sm151(n,γ) <sub>-</sub> Sm152(n,γ)Sm153(β <sup>-</sup> )Eu153(n,γ)Eu154 (n,γ)Eu155 &Sm150(n,γ)Sm151(n,γ)Sm152(n,γ) <sub>-</sub> Sm153(β <sup>-</sup> )Eu153(n,γ)Eu154(n,γ)Eu155 Sm152(n,γ)Sm153(n,γ)Sm154(n,γ) <sub>-</sub> Sm155(β <sup>-</sup> )Eu155 &Sm152(n,γ)Sm153(β <sup>-</sup> )Eu153(n,γ) <sub>-</sub> Eu154(n,γ)Eu155 Sm150(n,γ)Sm151(n,γ)Sm152(n,γ) <sub>-</sub> Sm153(n,γ)Sm154(n,γ)Sm155(β <sup>-</sup> )Eu155	51.9 14.4 11.1 9.1 6.8 2.2 0.8 0.6	0.6 17.1 14.9 31.3 16.6 5.8	94.1	100.0	99.8	99.9	99.9
Pm146	5.531 y	Sm144(n,γ)Sm145(β <sup>+</sup> )Pm145(n,γ)Pm146 Sm147(n,2n)Sm146(n,p)Pm146 Sm147(n,d)Pm146 Sm147(n,p)Pm147(n,2n)Pm146 Sm148(n,2n)Sm147(n,d)Pm146 Sm148(n,2n)Sm147(n,2n)Sm146(n,p)Pm146   Sm150(n,α)Nd147(β <sup>-</sup> )Pm147(n,2n)Pm146   Sm148(n,t)Pm146 Sm149(n,3n)Sm147(n,d)Pm146 Sm149(n,nt)Pm146 Sm148(n,3n)Sm146(n,p)Pm146 Sm150(n,2nt)Pm146	100.0	100.0	100.0	36.7 31.3 18.1 3.5 2.6 2.3 0.3	1.3 67.0 0.5 1.9	0.4 43.8 0.1 0.9	25.7 0.3 22.2 0.4 28.2 9.5
Eu154	8.593 y	&Sm147(n,γ)Sm148(n,γ)Sm149(n,γ) <sub>-</sub> Sm150(n,γ)Sm151(n,γ)Sm152(n,γ) <sub>-</sub> Sm153(β <sup>-</sup> )Eu153(n,γ)Eu154 &Sm148(n,γ)Sm149(n,γ)Sm150(n,γ) <sub>-</sub> Sm151(n,γ)Sm152(n,γ)Sm153(β <sup>-</sup> ) <sub>-</sub> Eu153(n,γ)Eu154 &Sm149(n,γ)Sm150(n,γ)Sm151(n,γ) <sub>-</sub> Sm152(n,γ)Sm153(β <sup>-</sup> )Eu153(n,γ)Eu154 &Sm150(n,γ)Sm151(n,γ)Sm152(n,γ) <sub>-</sub> Sm153(β <sup>-</sup> )Eu153(n,γ)Eu154 &Sm152(n,γ)Sm153(β <sup>-</sup> )Eu153(n,γ)Eu154	28.4 25.4 20.7 15.3 1.8	22.4 18.7 33.7 17.5 7.5					

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	&Sm154(n,2n)Sm153(β <sup>-</sup> )Eu153(n,γ)Eu154 &Sm154(n,γ)Sm155(β <sup>-</sup> )Eu155(n,2n)Eu154 &Sm154(n,γ)Sm155(β <sup>-</sup> )Eu155(β <sup>-</sup> ) Gd155(n,d)Eu154 &Sm154(n,d)Pm153(β <sup>-</sup> )Sm153(β <sup>-</sup> ) Eu153(n,γ)Eu154				59.8 40.1	31.4 62.5 3.0	29.6 59.3 5.1	29.0 56.0 6.6	
Eu152	13.525 y	Sm147(n,γ)Sm148(n,γ)Sm149(n,γ) Sm150(n,γ)Sm151(β <sup>-</sup> )Eu151(n,γ)Eu152 Sm148(n,γ)Sm149(n,γ)Sm150(n,γ) Sm151(β <sup>-</sup> )Eu151(n,γ)Eu152 Sm150(n,γ)Sm151(β <sup>-</sup> )Eu151(n,γ)Eu152 Sm149(n,γ)Sm150(n,γ)Sm151(β <sup>-</sup> ) Eu151(n,γ)Eu152 &Sm154(n,2n)Sm153(β <sup>-</sup> )Eu153(n,2n)Eu152 Sm154(n,d)Pm153(β <sup>-</sup> )Sm153(β <sup>-</sup> ) Eu153(n,2n)Eu152	45.6 37.0 5.9 1.8	28.8 22.6 16.5 32.1				99.9 8.1	83.1 16.3	77.5 22.0
Pm145	17.70 y	Sm144(n,γ)Sm145(β <sup>+</sup> )Pm145 Sm147(n,2n)Sm146(n,2n)Sm145(β <sup>+</sup> )Pm145 Sm148(n,2n)Sm147(n,2n)Sm146(n,2n) Sm145(β <sup>+</sup> )Pm145 Sm147(n,t)Pm145 Sm147(n,3n)Sm145(β <sup>+</sup> )Pm145 Sm149(n,3n)Sm147(n,3n)Sm145(β <sup>+</sup> )Pm145 Sm148(n,4n)Sm145(β <sup>+</sup> )Pm145 Sm149(n,5n)Sm145(β <sup>+</sup> )Pm145 Sm149(n,2nt)Pm145 Sm150(n,6n)Sm145(β <sup>+</sup> )Pm145	100.0	100.0	100.0	92.8 5.4	0.7	0.3	0.1	
Eu150	36.359 y	Sm152(n,2n)Sm151(β <sup>-</sup> )Eu151(n,2n)Eu150 &Sm154(n,2n)Sm153(β <sup>-</sup> )Eu153(n,2n) Eu152(n,2n)Eu151(n,2n)Eu150 Sm154(n,2n)Sm153(β <sup>-</sup> )Eu153(n,2n) Eu152m(β <sup>-</sup> )Gd152(n,2n)Gd151(β <sup>+</sup> ) Eu151(n,2n)Eu150 Sm154(n,2n)Sm153(β <sup>-</sup> )Eu153(n,2n) Eu152(n,3n)Eu150 Sm154(n,2n)Sm153(β <sup>-</sup> )Eu153(n,4n)Eu150 Sm154(n,2n)Sm153(β <sup>-</sup> )Eu153(n,3n) Eu151(n,2n)Eu150 Sm154(n,4n)Sm151(β <sup>-</sup> )Eu151(n,2n)Eu150 Sm154(n,d)Pm153(β <sup>-</sup> )Sm153(β <sup>-</sup> ) Eu153(n,4n)Eu150				68.5 26.9 2.8	2.9	0.3	0.8	
Gd148	74.60 y	Sm152(n,2n)Sm151(β <sup>-</sup> )Eu151(n,2n)Eu150m (β <sup>-</sup> )Gd150(n,2n)Gd149(n,2n)Gd148 Sm154(n,2n)Sm153(β <sup>-</sup> )Eu153(n,2n) Eu152(n,2n)Eu151(n,2n)Eu150m(β <sup>-</sup> ) Gd150(n,2n)Gd149(n,2n)Gd148 Sm154(n,2n)Sm153(β <sup>-</sup> )Eu153(n,2n) Eu152m(β <sup>-</sup> )Gd152(n,2n)Gd151(n,2n) Gd150(n,2n)Gd149(n,2n)Gd148 Sm154(n,2n)Sm153(β <sup>-</sup> )Eu153(n,2n)Eu152m (β <sup>-</sup> )Gd152(n,2n)Gd151(β <sup>+</sup> )Eu151(n,2n) Eu150m(β <sup>-</sup> )Gd150(n,2n)Gd149(n,2n)Gd148 Sm154(n,2n)Sm153(β <sup>-</sup> )Eu153(n,2n) Eu152(n,3n)Eu150m(β <sup>-</sup> )Gd150(n,2n) Gd149(n,2n)Gd148 Sm154(n,2n)Sm153(β <sup>-</sup> )Eu153(n,4n) Eu150m(β <sup>-</sup> )Gd150(n,3n)Gd148 Sm154(n,2n)Sm153(β <sup>-</sup> )Eu153(n,3n)Eu151 (n,2n)Eu150m(β <sup>-</sup> )Gd150(n,3n)Gd148 Sm154(n,2n)Sm153(β <sup>-</sup> )Eu153(n,2n)Eu152 (n,3n)Eu150m(β <sup>-</sup> )Gd150(n,3n)Gd148				69.0 21.7 4.3 2.1 1.4		60.2 81.4	45.2	
	▶							11.7 10.2	0.3 0.3	0.2 0.2

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Sm154(n,2n)Sm153(β <sup>-</sup> )Eu153(n,2n)Eu152m <sub>-</sub> (β <sup>-</sup> )Gd152(n,3n)Gd150(n,3n)Gd148 Sm152(n,2n)Sm151(β <sup>-</sup> )Eu151(n,2n) <sub>-</sub> Eu150m(β <sup>-</sup> )Gd150(n,3n)Gd148 Sm154(n,4n)Sm151(β <sup>-</sup> )Eu151(n,2n) <sub>-</sub> Eu150m(β <sup>-</sup> )Gd150(n,3n)Gd148 Sm154(n,d)Pm153(β <sup>-</sup> )Sm153(β <sup>-</sup> )Eu153 (n,4n)Eu150m(β <sup>-</sup> )Gd150(n,3n)Gd148 Sm154(n,2n)Sm153(β <sup>-</sup> )Eu153(n,2n) <sub>-</sub> Eu152m(β <sup>-</sup> )Gd152(n,5n)Gd148 Sm154(n,d)Pm153(β <sup>-</sup> )Sm153(β <sup>-</sup> )Eu153 (n,2n)Eu152m(β <sup>-</sup> )Gd152(n,5n)Gd148 Sm154(n,2n)Sm153(β <sup>-</sup> )Eu153(n,2n) <sub>-</sub> Eu152(β <sup>-</sup> )Gd152(n,5n)Gd148 Sm154(n,d)Pm153(β <sup>-</sup> )Sm153(β <sup>-</sup> )Eu153 (n,2n)Eu152(β <sup>-</sup> )Gd152(n,5n)Gd148					4.6	0.1		
							2.0	0.2	0.3	
							1.1	0.5	0.2	
								15.9	12.9	
								0.2	26.6	
									7.6	
									4.0	
									1.1	
Sm151	90.0 y	Sm147(n,γ)Sm148(n,γ)Sm149(n,γ) <sub>-</sub> Sm150(n,γ)Sm151 Sm148(n,γ)Sm149(n,γ)Sm150(n,γ)Sm151 Sm150(n,γ)Sm151 Sm149(n,γ)Sm150(n,γ)Sm151 Sm152(n,2n)Sm151 Sm154(n,3n)Sm152(n,2n)Sm151 Sm154(n,4n)Sm151 Sm152(n,d)Pm151(β <sup>-</sup> )Sm151 Sm154(n,nt)Pm151(β <sup>-</sup> )Sm151	46.0	30.7						
			37.2	23.6	0.3					
			5.7	15.5	78.9					
			1.6	30.2	20.8					
						99.5	56.2	25.6	37.3	
						0.2	4.7			
							30.4	65.5	34.4	
							7.1		13.8	
									13.0	
Ho166m	1200 y	Very long pathways of (n,γ), β <sup>-</sup>	100.0	100.0	100.0					
La137	6.0 10 <sup>4</sup> y	Very long pathways of (n,2n), β <sup>+</sup> , (n,α)				100.0	100.0	100.0	100.0	
Gd150	1.8 10 <sup>6</sup> y	Sm152(n,2n)Sm151(β <sup>-</sup> )Eu151(n,2n) <sub>-</sub> Eu150m(β <sup>-</sup> )Gd150 Sm154(n,2n)Sm153(β <sup>-</sup> )Eu153(n,2n)Eu152 (n,2n)Eu151(n,2n)Eu150m(β <sup>-</sup> )Gd150 Sm154(n,2n)Sm153(β <sup>-</sup> )Eu153(n,2n)Eu152m (β <sup>-</sup> )Gd152(n,2n)Gd151(n,2n)Gd150 Sm154(n,2n)Sm153(β <sup>-</sup> )Eu153(n,2n) <sub>-</sub> Eu152m(β <sup>-</sup> )Gd152(n,2n)Gd151(β <sup>+</sup> ) Eu151(n,2n)Eu150m(β <sup>-</sup> )Gd150 Sm154(n,2n)Sm153(β <sup>-</sup> )Eu153(n,2n) <sub>-</sub> Eu152(n,3n)Eu150m(β <sup>-</sup> )Gd150 Sm154(n,2n)Sm153(β <sup>-</sup> )Eu153(n,4n) <sub>-</sub> Eu150m(β <sup>-</sup> )Gd150 Sm154(n,2n)Sm153(β <sup>-</sup> )Eu153(n,3n) <sub>-</sub> Eu151(n,2n)Eu150m(β <sup>-</sup> )Gd150 Sm154(n,2n)Sm153(β <sup>-</sup> )Eu153(n,2n) <sub>-</sub> Eu152m(β <sup>-</sup> )Gd152(n,3n)Gd150 Sm154(n,d)Pm153(β <sup>-</sup> )Sm153(β <sup>-</sup> ) Eu153(n,4n)Eu150m(β <sup>-</sup> )Gd150 Sm154(n,4n)Sm151(β <sup>-</sup> )Eu151(n,2n) <sub>-</sub> Eu150m(β <sup>-</sup> )Gd150 Sm154(n,2n)Sm153(β <sup>-</sup> )Eu153(n,2n) <sub>-</sub> Eu152(β <sup>-</sup> )Gd152(n,3n)Gd150				64.7	2.3	0.2	0.6	
						25.2				
						4.3				
						2.6				
							1.3	12.1	0.4	0.5
								54.0	81.2	74.8
								13.9	0.4	0.5
								5.4	0.2	0.2
								4.8	15.9	21.3
								1.3	0.6	0.5
								1.1		
Sm146	1.0 10 <sup>8</sup> y	Sm144(n,γ)Sm145(n,γ)Sm146 Sm144(n,γ)Sm145(β <sup>+</sup> )Pm145(n,γ) <sub>-</sub> Pm146(β <sup>-</sup> )Sm146 Sm147(n,2n)Sm146 Sm148(n,2n)Sm147(n,2n)Sm146 Sm148(n,3n)Sm146 Sm149(n,4n)Sm146 Sm150(n,3n)Sm148(n,3n)Sm146 Sm152(n,4n)Sm149(n,4n)Sm146 Sm150(n,5n)Sm146	100.0	95.2	84.2					
				4.8	15.8					
						89.5	22.0	16.5	17.9	
						9.1	0.6	0.3	0.2	
							54.7	19.0	17.0	
							12.2	48.7	22.8	
							3.6	0.3	0.2	
							0.4	6.3	0.7	
								3.1	23.1	

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	Sm154(n,5n)Sm150(n,5n)Sm146						0.2	2.4
Lu176	4.0 10 <sup>10</sup> y	Very long pathways of (n,γ), β <sup>-</sup>	100.0	100.0					
La138	1.0 10 <sup>11</sup> y	&Sm144(n,α)Nd141(β <sup>+</sup> )Pr141(n,α)La138	99.9	99.9	99.9	7.7	1.0		
		&Sm144(n,α)Nd140(β <sup>+</sup> )Pr140(β <sup>+</sup> )_				23.5			
		Ce140(n,2n)Ce139(β <sup>+</sup> )La139(n,2n)La138				6.2			
		&Sm144(n,2n)Sm143(β <sup>+</sup> )Pm143(β <sup>+</sup> )_				5.4			
		Nd143(n,α)Ce139(β <sup>+</sup> )La139(n,2n)La138				4.7			
		&Sm144(n,2n)Sm143(β <sup>+</sup> )Pm143(n,α)_				1.6			
		Pr139(β <sup>+</sup> )Ce139(β <sup>+</sup> )La139(n,2n)La138				1.6			
		&Sm144(n,α)Nd141(β <sup>+</sup> )Pr141(n,2n)Pr140_				1.2			
		(β <sup>+</sup> )Ce140(n,2n)Ce139(β <sup>+</sup> )La139(n,2n)La138				1.2			
		&Sm144(n,2n)Sm143(β <sup>+</sup> )Pm143(n,α)_				1.0			
		Pr140(β <sup>+</sup> )Ce140(n,2n)Ce139(β <sup>+</sup> )La139_							
		(n,2n)La138							
		&Sm144(n,2n)Sm143(β <sup>+</sup> )Pm143(β <sup>+</sup> )_							
		Nd143(n,2n)Nd142(n,2n)Nd141(β <sup>+</sup> )_							
		Pr141(n,α)La138							
		&Sm144(n,2n)Sm143(β <sup>+</sup> )Pm143(β <sup>+</sup> )_							
		Nd143(n,α)Ce140(n,2n)Ce139(β <sup>+</sup> )_							
		La139(n,2n)La138							
		&Sm144(n,2n)Sm143(β <sup>+</sup> )Pm143_							
		(n,2n)Pm142(β <sup>+</sup> )Nd142(n,2n)Nd141_							
		(β <sup>+</sup> )Pr141(n,α)La138							
		&Sm144(n,2n)Sm143(β <sup>+</sup> )Pm143(β <sup>+</sup> )_							
		Nd143(n,2n)Nd142(n,α)Ce139(β <sup>+</sup> )_							
		La139(n,2n)La138							
		Sm144(n,α)Nd140(β <sup>+</sup> )Pr140(β <sup>+</sup> )_					3.5	6.2	2.0
		Ce140(n,t)La138					2.4	12.9	3.0
		Sm144(n,2n)Nd139m(β <sup>+</sup> )Pr139(β <sup>+</sup> )_					1.8	4.1	0.5
		Ce139(β <sup>+</sup> )La139(n,2n)La138							
		Sm144(n,2n)Nd139(β <sup>+</sup> )Pr139(β <sup>+</sup> )_							
		Ce139(β <sup>+</sup> )La139(n,2n)La138							
		Sm144(n,4n)Sm141m(β <sup>+</sup> )Pm141(β <sup>+</sup> )_						0.2	2.4
		Nd141(β <sup>+</sup> )Pr141(n,α)La138							
		Sm147(n,4n)Nd140(β <sup>+</sup> )Pr140(β <sup>+</sup> )_							7.7
		Ce140(n,t)La138							
		Sm144(n,2n)Pm140(β <sup>+</sup> )Nd140(β <sup>+</sup> )_							3.0
		Pr140(β <sup>+</sup> )Ce140(n,t)La138							
		Sm144(n,2n)Pm140m(β <sup>+</sup> )Nd140(β <sup>+</sup> )_							1.9
		Pr140(β <sup>+</sup> )Ce140(n,t)La138							
		Other long pathways	0.1	0.1	0.1	45.9	91.3	76.6	79.5
Sm147	1.1 10 <sup>11</sup> y	Sm144(n,γ)Sm145(n,γ)Sm146(n,γ)Sm147	3.3	9.0					
		Sm144(n,γ)Sm145(β <sup>+</sup> )Pm145(n,γ)_	0.1	10.3					
		Pm146(n,γ)Pm147(β <sup>-</sup> )Sm147							
		Sm148(n,2n)Sm147				16.4	4.0	3.0	1.8
		Sm149(n,2n)Sm148(n,2n)Sm147				2.9	0.1		
		Sm149(n,3n)Sm147				0.2	13.3	4.1	2.4
		Sm150(n,4n)Sm147					1.0	6.0	1.5
		Sm152(n,6n)Sm147							10.8
		Nuclide also present in starting material	96.6	80.7	100.0	80.5	81.6	86.9	83.5

# Samarium activation characteristics



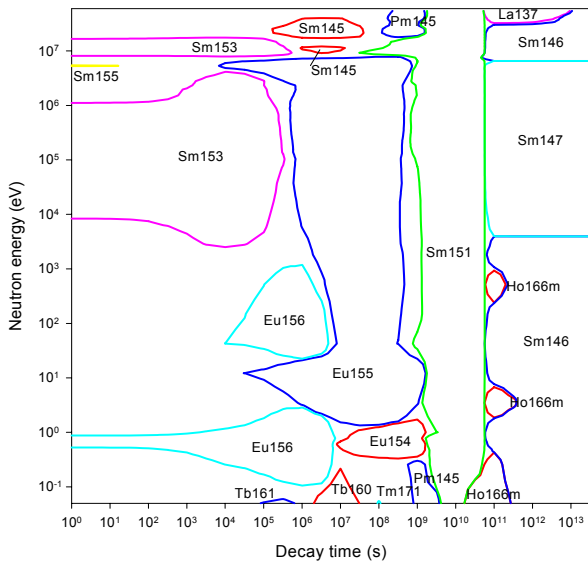
Decay time (years)

Decay time (years)

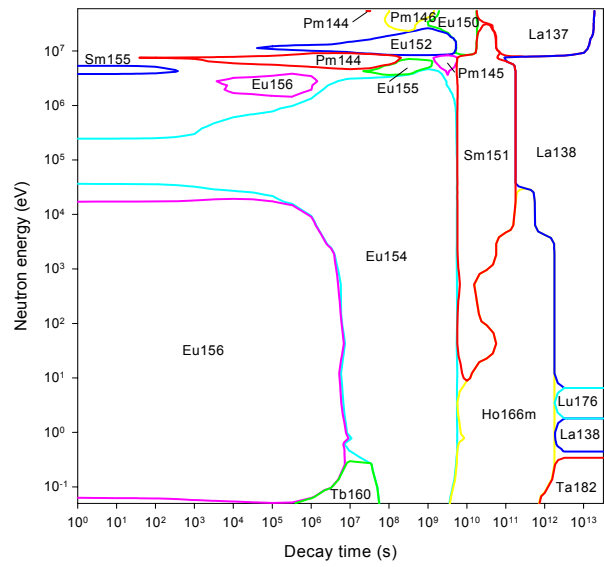


# Samarium importance diagrams & transmutation

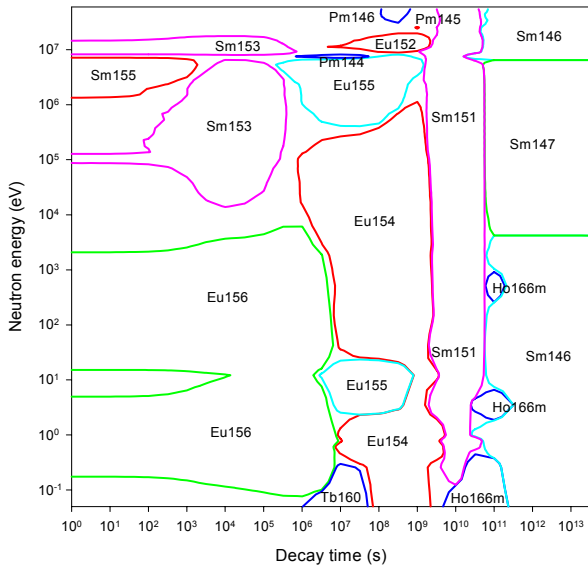
Activity



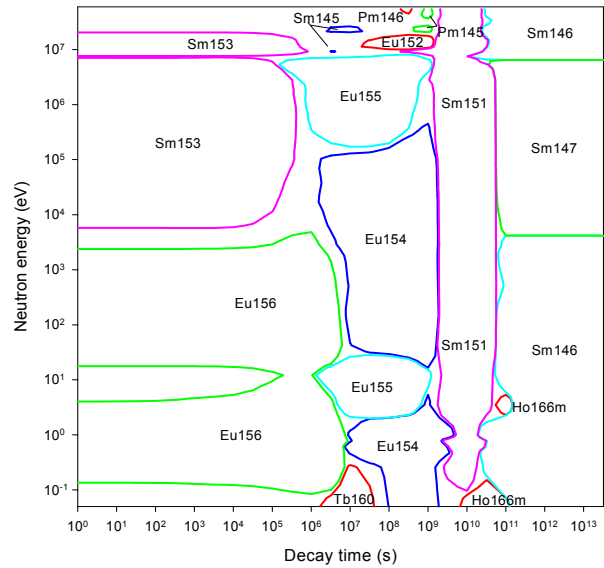
Dose rate



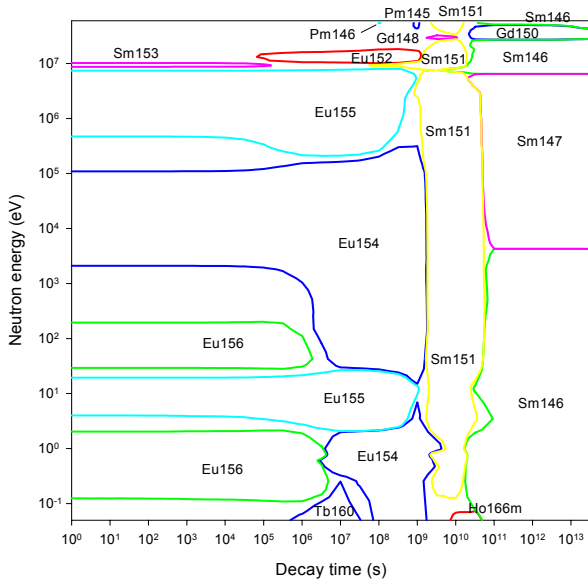
Heat output



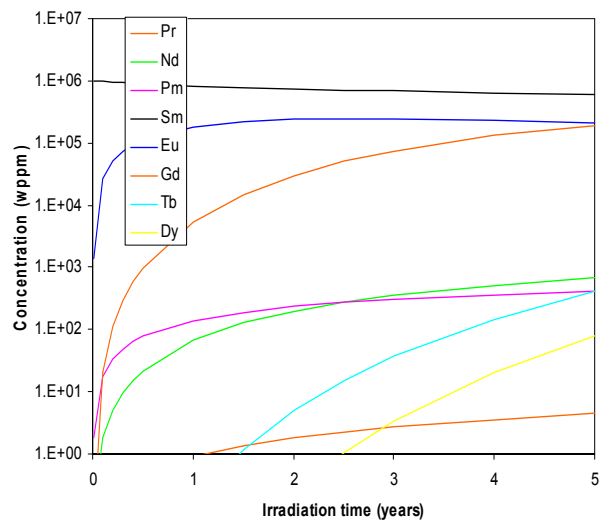
Ingestion dose



Inhalation dose



First wall transmutation





# Europium

## General properties

Atomic number	63	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	2	Eu151	47.81
Melting point / K	1095	Eu153	52.19
Boiling point / K	1869		
Density / kgm <sup>-3</sup>	5244		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	13.9		
Electrical resistivity /Ωm	9.0 10 <sup>-7</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	3.5 10 <sup>-5</sup>		
Crystal structure	BCC		
Number of stable isotopes	2		
Mean atomic weight	151.965		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	1.69E16	1.68E16	1.41E16	4.00E15	1.29E12	3.86E7	kW kg <sup>-1</sup>	3.47E0	3.46E0	2.93E0	4.15E-1	2.80E-4	1.73E-8
Eu156	63.94	64.00	64.78				Eu156	83.89	83.90	83.91			
Eu155	15.88	15.90	18.98	57.86	0.10		Eu154	10.77	10.77	12.71	82.94	41.81	
Eu154	9.09	9.10	10.88	35.36	37.41		Eu155	1.54	1.54	1.81	11.10	0.01	
Gd153	2.82	2.83	3.35	4.15			Eu152m	0.90	0.89				
Sm153	2.27	2.27	0.73				Eu157	0.75	0.75	0.02			
Eu157	1.41	1.41	0.03				Eu152	0.62	0.62	0.73	4.91	45.58	
Eu152m	1.41	1.41					Sm153	0.58	0.58	0.19			
Eu154m	1.11	1.03					Gd153	0.32	0.32	0.37	0.93		
Gd159	0.97	0.96	0.04				Gd159	0.28	0.27	0.01			
Eu152	0.62	0.62	0.74	2.48	48.19		Tb160	0.18	0.18	0.21	0.05		
Eu150	0.01	0.01	0.01	0.02	10.86		Eu154m	0.14	0.13				
Sm151					3.25		Eu150	0.01	0.01	0.01	0.06	12.43	
Gd150						99.93	Gd150					0.01	99.94
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	4.29E6	4.28E6	3.68E6	4.62E5	3.49E2	2.03E-20	Sv kg <sup>-1</sup>	2.86E7	2.86E7	2.44E7	3.75E6	2.02E3	2.01E0
Eu156	87.52	87.52	86.22				Eu156	82.92	82.93	82.26			
Eu154	10.98	10.98	12.77	93.89	42.25		Eu154	10.72	10.73	12.56	75.31	47.62	
Eu152	0.65	0.65	0.76	5.75	47.56		Eu155	3.00	3.00	3.51	19.71	0.02	
Eu152m	0.39	0.39					Sm153	0.99	0.99	0.31			
Tb160	0.18	0.18	0.20	0.05			Eu152	0.51	0.51	0.60	3.69	42.94	
Eu150	0.01	0.01	0.01	0.05	10.08		Gd153	0.45	0.45	0.52	1.19		
La137						91.00	Eu150			0.01	0.03	8.99	
La138						9.00	Gd150					0.10	99.93
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	1.42E8	1.42E8	1.36E8	9.54E7	6.25E4	3.20E3		3.30E13	3.30E13	3.08E13	1.75E13	1.12E10	1.61E3
Eu154	57.04	57.04	59.54	78.49	40.77		Eu154	46.38	46.38	49.71	80.97	42.85	
Eu156	25.73	25.72	22.75				Eu156	41.81	41.80	37.96			
Eu155	12.97	12.97	13.53	16.72	0.01		Eu155	8.10	8.10	8.68	13.25	0.01	
Eu152	3.07	3.07	3.21	4.36	41.62		Eu152	3.15	3.15	3.38	5.67	55.20	
Gd153	0.70	0.70	0.73	0.37			Gd153	0.14	0.14	0.15	0.10		
Eu150	0.04	0.04	0.04	0.05	11.84		Eu150			0.01	0.01	1.92	
Gd150					5.32	99.99	Gd150						99.99

# Europium

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
Eu152m	9.275 h	Eu151(n,γ)Eu152m Eu153(n,2n)Eu152m &Eu153(n,2n)Eu152(n,n')Eu152m	100.0	100.0	100.0	90.0 9.8	90.2 9.2	93.6	95.7	
Tb161	6.89 d	&Eu153(n,γ)Eu154(n,γ)Eu155(n,γ)Eu156_ (n,γ)Eu157(β <sup>-</sup> )Gd157(n,γ)Gd158(n,γ)_ Gd159(β <sup>-</sup> )Tb159(n,γ)Tb160(n,γ)Tb161 &Eu151(n,γ)Eu152(n,γ)Eu153(n,γ)_ Eu154(n,γ)Eu155(n,γ)Eu156(n,γ)Eu157_ (β <sup>-</sup> )Gd157(n,γ)Gd158(n,γ)Gd159(β <sup>-</sup> )_ Tb159(n,γ)Tb160(n,γ)Tb161 &Eu153(n,γ)Eu154(n,γ)Eu155(n,γ)Eu156_ (β <sup>-</sup> )Gd156(n,γ)Gd157(n,γ)Gd158(n,γ)_ Gd159(β <sup>-</sup> )Tb159(n,γ)Tb160(n,γ)Tb161 &Eu151(n,γ)Eu152(n,γ)Eu153(n,γ)_ Eu154(n,γ)Eu155(n,γ)Eu156(β <sup>-</sup> )Gd156_ (n,γ)Gd157(n,γ)Gd158(n,γ)Gd159(β <sup>-</sup> )_ Tb159(n,γ)Tb160(n,γ)Tb161 Eu151(n,γ)Eu152m(β <sup>-</sup> )Gd152(n,γ)_ Gd153(n,γ)Gd154(n,γ)Gd155(n,γ)_ Gd156(n,γ)Gd157(n,γ)Gd158(n,γ)_ Gd159(β <sup>-</sup> )Tb159(n,γ)Tb160(n,γ)Tb161 &Eu153(n,γ)Eu154(n,γ)Eu155(β <sup>-</sup> )Gd155_ (n,γ)Gd156(n,γ)Gd157(n,γ)Gd158(n,γ)_ Gd159(β <sup>-</sup> )Tb159(n,γ)Tb160(n,γ)Tb161 &Eu151(n,γ)Eu152(n,γ)Eu153(n,γ)_ Eu154(n,γ)Eu155(β <sup>-</sup> )Gd155(n,γ)Gd156_ (n,γ)Gd157(n,γ)Gd158(n,γ)Gd159(β <sup>-</sup> )_ Tb159(n,γ)Tb160(n,γ)Tb161 &Eu153(n,γ)Eu154(β <sup>-</sup> )Gd154(n,γ)Gd155_ (n,γ)Gd156(n,γ)Gd157(n,γ)Gd158(n,γ)_ Gd159(β <sup>-</sup> )Tb159(n,γ)Tb160(n,γ)Tb161	50.1 29.4 6.8 4.0	0.3 0.2 53.0 25.4	0.5  72.8 0.3	   4.7 4.2 2.0	   3.6			
Eu156	15.19 d	&Eu153(n,γ)Eu154(n,γ)Eu155(n,γ)Eu156_ Eu151(n,γ)Eu152m(β <sup>+</sup> )Sm152(n,γ)_ Sm153(n,γ)Sm154(n,γ)Sm155(β <sup>-</sup> )_ Eu155(n,γ)Eu156 &Eu151(n,γ)Eu152(n,γ)Eu153(n,γ)_ Eu154(n,γ)Eu155(n,γ)Eu156 &Eu151(n,γ)Eu152m(β <sup>+</sup> )Sm152(n,γ)_ Sm153(β <sup>-</sup> )Eu153(n,γ)Eu154(n,γ)Eu155_ (n,γ)Eu156 Eu151(n,γ)Eu152m(n,γ)Eu153(n,γ)_ Eu154(n,γ)Eu155(n,γ)Eu156 &Eu151(n,γ)Eu152(β <sup>+</sup> )Sm152(n,γ)_ Sm153(β <sup>-</sup> )Eu153(n,γ)Eu154(n,γ)Eu155_ (n,γ)Eu156 &Eu151(n,γ)Eu152m(β <sup>-</sup> )Gd152(n,γ)_ Gd153(β <sup>+</sup> )Eu153(n,γ)Eu154(n,γ)Eu155_ (n,γ)Eu156	34.0 28.9 22.0 12.1 2.3 0.1	14.4 29.9 13.5 1.7	97.9 2.0	99.7  39.8	99.5	99.6	99.8	
Eu148	54.50 d	Eu151(n,2n)Eu150(n,2n)Eu149(n,2n)Eu148 Eu151(n,2n)Eu150m(β <sup>-</sup> )Gd150(n,2n)_ Gd149(β <sup>+</sup> )Eu149(n,2n)Eu148 Eu151(n,3n)Eu149(n,2n)Eu148 Eu151(n,4n)Eu148 Eu151(n,2n)Eu150(n,3n)Eu148 Eu153(n,3n)Eu151(n,4n)Eu148				70.6 26.8 0.8	4.3 39.3 31.9 8.7	89.2 1.0 5.2	36.4	

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6		
	◀	Eu153(n,4n)Eu150(n,3n)Eu148 Eu153(n,3n)Eu151(n,2n)Eu150(n,3n)Eu148 Eu153(n,2n)Eu152(n,3n)Eu150(n,3n)Eu148 Eu153(n,6n)Eu148					8.1 3.6 3.4	3.5	59.0		
Tb160	72.30 d	&Eu153(n,γ)Eu154(n,γ)Eu155(n,γ) Eu156(n,γ)Eu157(β <sup>-</sup> )Gd157(n,γ)Gd158 (n,γ)Gd159(β <sup>-</sup> )Tb159(n,γ)Tb160 &Eu151(n,γ)Eu152(n,γ)Eu153(n,γ) Eu154(n,γ)Eu155(n,γ)Eu156(n,γ)Eu157 (β <sup>-</sup> )Gd157(n,γ)Gd158(n,γ)Gd159(β <sup>-</sup> ) Tb159(n,γ)Tb160 &Eu153(n,γ)Eu154(n,γ)Eu155(n,γ) Eu156(β <sup>-</sup> )Gd156(n,γ)Gd157(n,γ)Gd158 (n,γ)Gd159(β <sup>-</sup> )Tb159(n,γ)Tb160 &Eu151(n,γ)Eu152(n,γ)Eu153(n,γ) Eu154(n,γ)Eu155(n,γ)Eu156(β <sup>-</sup> )Gd156 (n,γ)Gd157(n,γ)Gd158(n,γ)Gd159(β <sup>-</sup> ) Tb159(n,γ)Tb160 Eu151(n,γ)Eu152m(β <sup>-</sup> )Gd152(n,γ)Gd153 (n,γ)Gd154(n,γ)Gd155(n,γ)Gd156(n,γ)Gd157 (n,γ)Gd158(n,γ)Gd159(β <sup>-</sup> )Tb159(n,γ)Tb160 &Eu153(n,γ)Eu154(n,γ)Eu155(β <sup>-</sup> ) Gd155(n,γ)Gd156(n,γ)Gd157(n,γ) Gd158(n,γ)Gd159(β <sup>-</sup> )Tb159(n,γ)Tb160 &Eu151(n,γ)Eu152(n,γ)Eu153(n,γ)Eu154 (n,γ)Eu155(β <sup>-</sup> )Gd155(n,γ)Gd156(n,γ)Gd157 (n,γ)Gd158(n,γ)Gd159(β <sup>-</sup> )Tb159(n,γ)Tb160 &Eu153(n,γ)Eu154(β <sup>-</sup> )Gd154(n,γ) Gd155(n,γ)Gd156(n,γ)Gd157(n,γ) Gd158(n,γ)Gd159(β <sup>-</sup> )Tb159(n,γ)Tb160	50.1 29.4 6.8 4.0	0.3 0.2 53.0 25.4	0.5  72.8 0.3						
Eu149	93.10 d	Eu151(n,2n)Eu150(n,2n)Eu149 Eu151(n,2n)Eu150m(β <sup>-</sup> )Gd150(n,2n) Gd149(β <sup>+</sup> )Eu149 Eu151(n,3n)Eu149 Eu153(n,3n)Eu151(n,3n)Eu149 Eu153(n,2n)Eu152(n,4n)Eu149 Eu153(n,4n)Eu150(n,2n)Eu149 Eu153(n,5n)Eu149				70.6 26.8 0.8	0.8 80.0 17.2 1.0 0.2	1.1 64.3 3.5 4.8 3.9	31.5 65.1		
Ta182	114.7 d	Very long pathways of (n,γ), β <sup>-</sup>	100.0								
Gd153	240.4 d	Eu151(n,γ)Eu152m(β <sup>-</sup> )Gd152(n,γ)Gd153 Eu151(n,γ)Eu152(β <sup>-</sup> )Gd152(n,γ)Gd153 &Eu153(n,γ)Eu154(β <sup>-</sup> )Gd154(n,2n)Gd153 Eu153(n,2n)Eu152m(β <sup>-</sup> )Gd152(n,γ)Gd153 &Eu153(n,2n)Eu152(β <sup>-</sup> )Gd152(n,γ)Gd153 Eu153(n,2n)Eu152(n,n')Eu152m(β <sup>-</sup> ) Gd152(n,γ)Gd153	93.6 6.4	98.2 1.8	93.6 6.4	52.1 38.3 7.7 1.8	29.9 50.4 17.1 2.3	27.5 55.0 15.7 1.6	28.2 56.2 14.4 1.1		
Tm171	1.917 y	Very long pathways of (n,γ), β <sup>-</sup>	100.0	100.0							
Eu155	4.753 y	&Eu153(n,γ)Eu154(n,γ)Eu155 Eu151(n,γ)Eu152m(β <sup>+</sup> )Sm152(n,γ) Sm153(n,γ)Sm154(n,γ)Sm155(β <sup>-</sup> )Eu155 &Eu151(n,γ)Eu152(n,γ)Eu153(n,γ) Eu154(n,γ)Eu155 &Eu151(n,γ)Eu152m(β <sup>+</sup> )Sm152(n,γ) Sm153(β <sup>-</sup> )Eu153(n,γ)Eu154(n,γ)Eu155 Eu151(n,γ)Eu152m(n,γ)Eu153(n,γ) Eu154(n,γ)Eu155 &Eu151(n,γ)Eu152(β <sup>+</sup> )Sm152(n,γ) Sm153(β <sup>-</sup> )Eu153(n,γ)Eu154(n,γ)Eu155 &Eu151(n,γ)Eu152m(β <sup>-</sup> )Gd152(n,γ) Gd153(β <sup>+</sup> )Eu153(n,γ)Eu154(n,γ)Eu155	33.1 30.7 21.4 11.9 2.2 0.1	14.0 29.2 13.6 1.7 40.9	97.8 2.0	99.9 99.9 99.6 99.7 99.8					
Eu154	8.593 y▶	&Eu153(n,γ)Eu154	48.3	2.6	95.9	100.0	99.9	99.9	100.0		

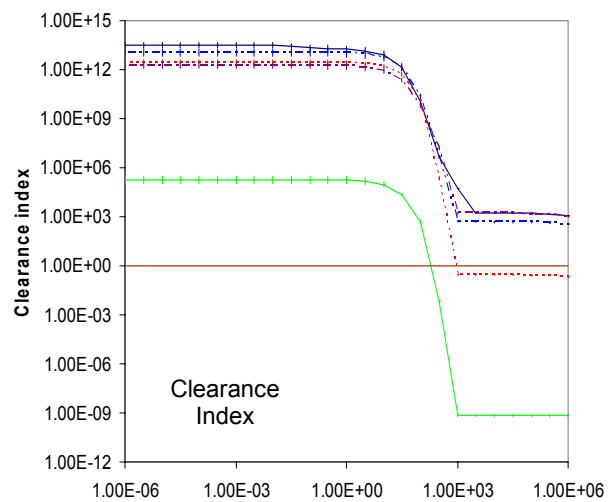
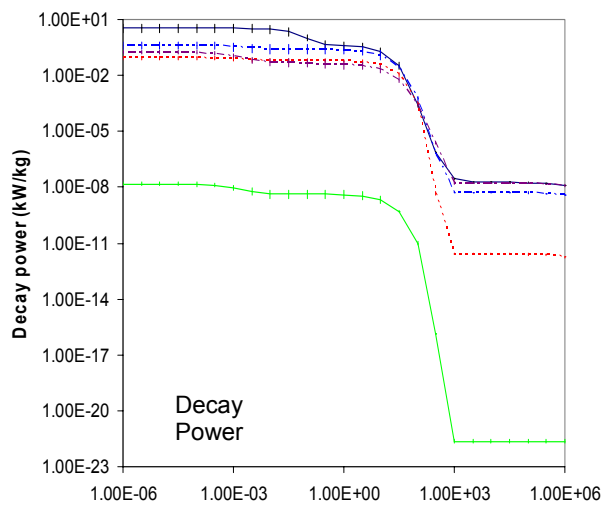
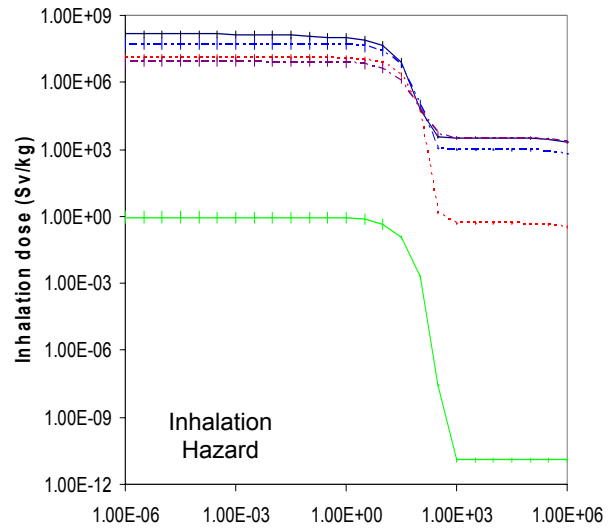
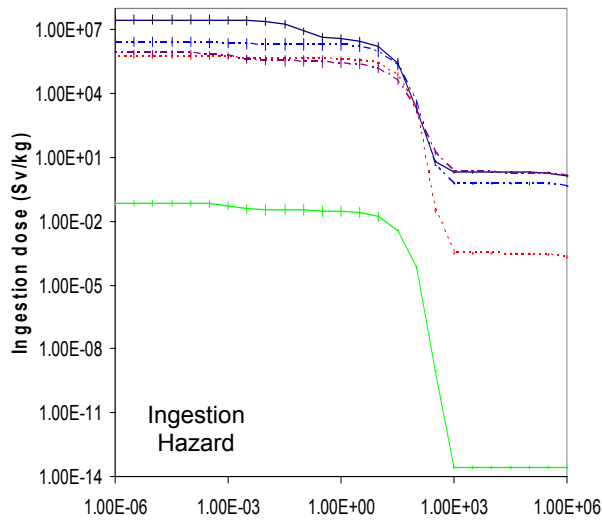
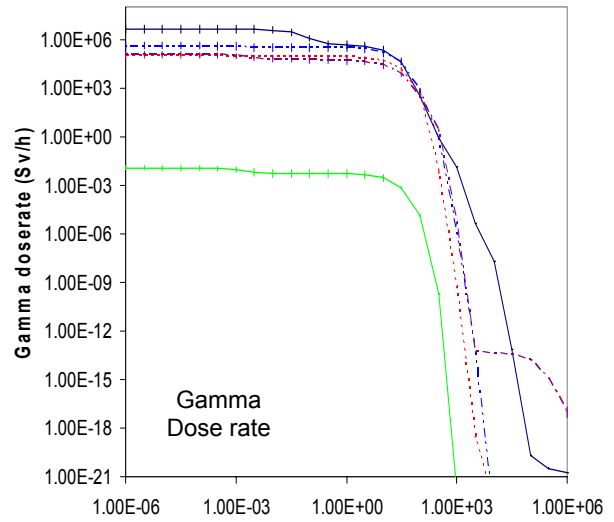
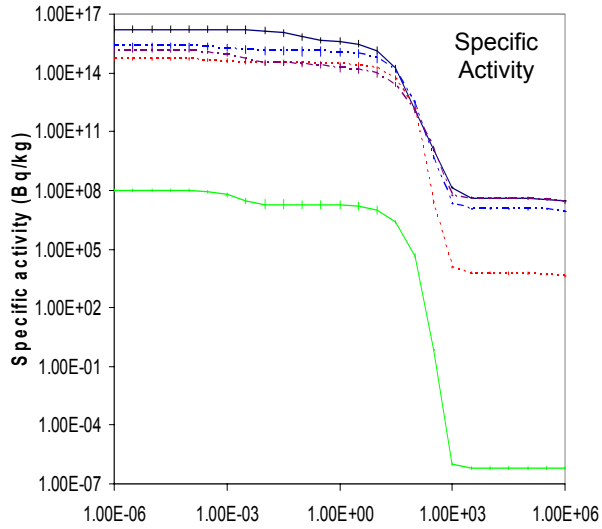
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	&Eu151(n,γ)Eu152(n,γ)Eu153(n,γ)Eu154 Eu151(n,γ)Eu152m(β <sup>+</sup> )Sm152(n,γ) Sm153(β <sup>-</sup> )Eu153(n,γ)Eu154 Eu151(n,γ)Eu152m(n,γ)Eu153(n,γ)Eu154 Eu151(n,γ)Eu152(β <sup>+</sup> )Sm152(n,γ)Sm153 (β <sup>-</sup> )Eu153(n,γ)Eu154 Eu151(n,γ)Eu152m(β <sup>-</sup> )Gd152(n,γ) Gd153(β <sup>+</sup> )Eu153(n,γ)Eu154 Eu151(n,γ)Eu152(β <sup>-</sup> )Gd152(n,γ)Gd153 (β <sup>+</sup> )Eu153(n,γ)Eu154	31.1 16.6	10.8 14.6	3.7					
Eu152	13.525 y	&Eu151(n,γ)Eu152 &Eu153(n,2n)Eu152	100.0	99.8	100.0	99.8	99.9	97.0	97.0	
Eu150	36.359 y	Eu151(n,2n)Eu150 Eu153(n,2n)Eu152(n,2n)Eu151(n,2n)Eu150 Eu153(n,4n)Eu150 Eu153(n,3n)Eu151(n,2n)Eu150 Eu153(n,2n)Eu152(n,3n)Eu150				98.5 1.2	68.8 17.4	21.2 77.5	44.0 54.5	
Gd148	74.602 y	Eu151(n,2n)Eu150m(β <sup>-</sup> )Gd150(n,2n) Gd149(n,2n)Gd148 Eu151(n,2n)Eu150(n,n')Eu150m(β <sup>-</sup> ) Gd150(n,2n)Gd149(n,2n)Gd148 Eu151(n,2n)Eu150m(β <sup>-</sup> )Gd150(n,3n)Gd148 Eu153(n,4n)Eu150m(β <sup>-</sup> )Gd150(n,3n)Gd148 Eu153(n,3n)Eu151(n,2n)Eu150m(β <sup>-</sup> ) Gd150(n,3n)Gd148 Eu153(n,2n)Eu152(n,3n)Eu150m(β <sup>-</sup> ) Gd150(n,3n)Gd148 Eu153(n,2n)Eu152m(β <sup>-</sup> )Gd152(n,3n) Gd150(n,3n)Gd148 Eu153(n,2n)Eu152m(β <sup>-</sup> )Gd152(n,5n)Gd148 Eu153(n,2n)Eu152(β <sup>-</sup> )Gd152(n,5n)Gd148				98.1 1.0	66.9 19.9	18.4 79.6	24.9 43.1	
Sm151	90.0 y	Eu151(n,γ)Eu152(n,α)Pm149(β <sup>-</sup> ) Sm149(n,γ)Sm150(n,γ)Sm151 Eu151(n,γ)Eu152m(β <sup>-</sup> )Gd152(n,γ) Gd153(n,γ)Gd154(n,α)Sm151 Eu151(n,γ)Eu152m(β <sup>-</sup> )Gd152(n,α) Sm149(n,γ)Sm150(n,γ)Sm151 Eu151(n,γ)Eu152(n,α)Pm149(n,γ) Pm150(β <sup>-</sup> )Sm150(n,γ)Sm151 Eu151(n,γ)Eu152m(β <sup>-</sup> )Gd152(n,γ) Gd153(n,α)Sm150(n,γ)Sm151 &Eu153(n,γ)Eu154(β <sup>-</sup> )Gd154(n,α)Sm151 Eu151(n,γ)Eu152(n,γ)Eu153(n,γ)Eu154 (β <sup>-</sup> )Gd154(n,α)Sm151 &Eu153(n,γ)Eu154(n,α)Pm151(β <sup>-</sup> )Sm151 &Eu153(n,2n)Eu152(β <sup>+</sup> )Sm152(n,2n)Sm151 Eu153(n,2n)Eu152m(β <sup>+</sup> )Sm152(n,2n)Sm151 Eu151(n,p)Sm151 Eu153(n,2n)Eu152(n,d)Sm151 Eu153(n,d)Sm152(n,2n)Sm151 Eu153(n,2n)Eu152(n,n')Eu152m(β <sup>+</sup> ) Sm152(n,2n)Sm151 Eu153(n,t)Sm151 Eu153(n,3n)Eu151(n,p)Sm151	35.8 35.3 16.0 8.1 2.5 0.5 0.3	36.9 1.7 56.9 3.4	0.8 0.5 3.0 0.2	86.3 1.0 7.8	35.7 33.7 24.7 1.8 1.6 1.2 0.4	1.7 1.0 38.0 4.7 5.5	13.3	6.6 88.5
Ho166m	1200 y	Very long pathways of (n,γ), β <sup>-</sup>	100.0	100.0	100.0					
La137	6.0 10 <sup>4</sup> y	Long pathways of (n,2n), (n,α), (n,α)				100.0	100.0	100.0	100.0	
Gd150	1.8 10 <sup>6</sup> y	Eu151(n,2n)Eu150m(β <sup>-</sup> )Gd150 Eu151(n,2n)Eu150(n,n')Eu150m(β <sup>-</sup> )Gd150 Eu153(n,2n)Eu152(n,2n)Eu151(n,2n) Eu150m(β <sup>-</sup> )Gd150 Eu153(n,4n)Eu150m(β <sup>-</sup> )Gd150				96.9 1.5 1.1	62.7 0.9	18.3	35.8 62.0	

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6		
		Eu153(n,3n)Eu151(n,2n)Eu150m(β <sup>-</sup> )Gd150 Eu153(n,2n)Eu152(n,3n)Eu150m(β <sup>-</sup> )Gd150 Eu153(n,2n)Eu152m(β <sup>-</sup> )Gd152(n,3n)Gd150					7.2 6.1 2.8				
Hf182	9.0 10 <sup>6</sup> y	Very long pathways of (n,γ), β <sup>-</sup>	100.0								
Sm146	1.0 10 <sup>8</sup> y	Eu151(n,2n)Eu150m(β <sup>-</sup> )Gd150(n,α)Sm146 Eu151(n,α)Pm147(β <sup>-</sup> )Sm147(n,2n)Sm146 Eu151(n,2n)Eu150(n,2n)Eu149(β <sup>+</sup> )Sm149_ (n,2n)Sm148(n,2n)Sm147(n,2n)Sm146 Eu151(n,α)Pm148m(β <sup>-</sup> )Sm148(n,2n)_ Sm147(n,2n)Sm146 &Eu151(n,α)Pm148(β <sup>-</sup> )Sm148(n,2n)_ Sm147(n,2n)Sm146 Eu151(n,2n)Eu150m(β <sup>-</sup> )Gd150(n,α)_ Sm147(n,2n)Sm146 Eu151(n,2n)Eu150(n,α)Pm146(β <sup>-</sup> )Sm146 Eu151(n,2n)Eu150(n,2n)Eu149(n,2n)_ Eu148(β <sup>+</sup> )Sm148(n,2n)Sm147(n,2n)Sm146 Eu151(n,α)Pm147(n,2n)Pm146(β <sup>-</sup> )Sm146 Eu151(n,3n)Eu149(β <sup>+</sup> )Sm149(n,4n)Sm146 Eu151(n,4n)Eu148(β <sup>+</sup> )Sm148(n,3n)Sm146 Eu151(n,3n)Eu149(β <sup>+</sup> )Sm149(n,2n)_ Sm148(n,3n)Sm146 Eu151(n,3n)Eu149(β <sup>+</sup> )Sm149(n,3n)_ Sm147(n,2n)Sm146 Eu153(n,3n)Eu151(n,3n)Eu149(β <sup>+</sup> )_ Sm149(n,4n)Sm146 Eu151(n,2n)Eu150(n,3n)Eu148(β <sup>+</sup> )_ Sm148(n,3n)Sm146 Eu151(n,t)Sm149(n,4n)Sm146 Eu151(n,3n)Eu149(n,4n)Eu146(β <sup>+</sup> )Sm146 Eu153(n,5n)Eu149(β <sup>+</sup> )Sm149(n,4n)Sm146 Eu153(n,4n)Eu150(n,5n)Eu146(β <sup>+</sup> )Sm146 Eu151(n,6n)Eu146(β <sup>+</sup> )Sm146 Eu151(n,3nt)Sm146 Pathways involving (n,α), (n,nα), (n,2n), β <sup>-</sup> , β <sup>+</sup>				29.9 16.4 10.6 6.0 5.8 5.0 4.1 3.3 2.2 51.7 11.2 4.9 4.9 3.7 3.1 1.0 0.8 8.0 3.5 74.8 4.9 16.7	0.4 0.5 27.6 26.9 0.2 0.1 0.5 5.2 4.2 8.0 3.5 0.4 0.2 2.3 1.3 0.8 23.8		1.1 0.9		
Lu176	4.0 10 <sup>10</sup> y	Very long pathways of (n,γ), β <sup>-</sup>	100.0	100.0							
La138	1.0 10 <sup>11</sup> y	Long pathways of (n,2n), (n,α), (n,α)				100.0	100.0	100.0	100.0		
Sm147	1.1 10 <sup>11</sup> y	Eu151(n,γ)Eu152(n,α)Pm149(β <sup>-</sup> )_ Sm149(n,γ)Sm150(n,α)Nd147(β <sup>-</sup> )_ Pm147(β <sup>-</sup> )Sm147 Eu151(n,γ)Eu152(n,α)Pm149(β <sup>-</sup> )_ Sm149(n,α)Nd146(n,γ)Nd147(β <sup>-</sup> )_ Pm147(β <sup>-</sup> )Sm147 Eu151(n,γ)Eu152m(β <sup>-</sup> )Gd152(n,α)_ Sm149(n,γ)Sm150(n,α)Nd147(β <sup>-</sup> )_ Pm147(β <sup>-</sup> )Sm147 Eu151(n,γ)Eu152m(β <sup>-</sup> )Gd152(n,α)_ Sm149(n,α)Nd146(n,γ)Nd147(β <sup>-</sup> )_ Pm147(β <sup>-</sup> )Sm147 Eu151(n,γ)Eu152(n,α)Pm149(n,γ)_ Pm150(β <sup>-</sup> )Sm150(n,α)Nd147(β <sup>-</sup> )_ Pm147(β <sup>-</sup> )Sm147 Eu151(n,γ)Eu152m(β <sup>-</sup> )Gd152(n,γ)_ Gd153(n,α)Sm150(n,α)Nd147(β <sup>-</sup> )_ Pm147(β <sup>-</sup> )Sm147 Eu151(n,γ)Eu152m(β <sup>-</sup> )Gd152(n,α)Sm149_ (n,α)Nd146(n,γ)Nd147(β <sup>-</sup> )Pm147(β <sup>-</sup> )Sm147 Eu151(n,2n)Eu150(n,2n)Eu149(β <sup>+</sup> )_ Sm149(n,2n)Sm148(n,2n)Sm147 Eu151(n,α)Pm147(β <sup>-</sup> )Sm147	33.9 28.8 14.6 12.0 7.7 2.3 2.1 24.0 19.2	38.8 0.2 56.8 0.3 3.4 3.4 0.1 2.1	0.5 18.5 1.8 72.9 0.1						

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Eu151(n,2n)Eu150m(β <sup>-</sup> )Gd150(n,2n) Gd149(β <sup>+</sup> )Eu149(β <sup>+</sup> )Sm149(n,2n) Sm148(n,2n)Sm147 Eu151(n,α)Pm148m(β <sup>-</sup> )Sm148(n,2n)Sm147 &Eu151(n,α)Pm148(β <sup>-</sup> )Sm148(n,2n)Sm147 Eu151(n,2n)Eu150m(β <sup>-</sup> )Gd150(n,α)Sm147 Eu151(n,2n)Eu150(n,2n)Eu149(n,2n) Eu148(β <sup>+</sup> )Sm148(n,2n)Sm147 Eu151(n,2n)Eu150(n,2n)Eu149(β <sup>+</sup> ) Sm149(n,3n)Sm147 Eu151(n,2n)Eu150(n,α)Pm147(β <sup>-</sup> )Sm147 Eu151(n,2n)Eu150m(β <sup>-</sup> )Gd150(n,2n) Gd149(β <sup>+</sup> )Eu149(n,2n)Eu148(β <sup>+</sup> ) Sm148(n,2n)Sm147 Eu151(n,3n)Eu149(β <sup>+</sup> )Sm149(n,3n)Sm147 Eu151(n,3n)Eu149(n,3n)Eu147(β <sup>+</sup> )Sm147 Eu153(n,3n)Eu151(n,3n)Eu149(β <sup>+</sup> ) Sm149(n,3n)Sm147 Eu151(n,2n)Eu150(n,4n)Eu147(β <sup>+</sup> )Sm147 Eu151(n,4n)Eu148(β <sup>+</sup> )Sm148(n,2n)Sm147 Eu151(n,d)Sm150(n,4n)Sm147 Eu153(n,4n)Eu150(n,4n)Eu147(β <sup>+</sup> )Sm147 Eu151(n,5n)Eu147(β <sup>+</sup> )Sm147 Eu151(n,2nt)Sm147 Eu153(n,4n)Eu150m(β <sup>-</sup> )Gd150(n,4n) Gd147(β <sup>+</sup> )Eu147(β <sup>+</sup> )Sm147				8.5				
						7.9				
						7.5				
						6.5				
						6.2				
						3.4	0.2			
						3.2				
						2.2				
						0.1	66.1	4.4	0.6	
							11.3	0.8		
							4.7			
							1.7	5.1	0.4	
							1.0	8.1	0.5	
							0.6	2.8	0.3	
							0.4	18.7	0.4	
								32.1	72.6	
								1.8	13.2	
									6.6	
Gd152	1.1 10 <sup>14</sup> y	Eu151(n,γ)Eu152m(β <sup>-</sup> )Gd152 Eu151(n,γ)Eu152(β <sup>-</sup> )Gd152 Eu153(n,2n)Eu152m(β <sup>-</sup> )Gd152 &Eu153(n,2n)Eu152(β <sup>-</sup> )Gd152 &Eu153(n,2n)Eu152(n,n')Eu152m(β <sup>-</sup> )Gd152	93.5 6.5	98.2 1.8	92.8 7.2					
						77.5	68.9	73.2	75.7	
						18.0	27.1	24.1	22.6	
						4.4	3.8	2.4	1.7	
Gd160	1.3 10 <sup>17</sup> y	&Eu153(n,γ)Eu154(n,γ)Eu155(n,γ) Eu156(n,γ)Eu157(β <sup>-</sup> )Gd157(n,γ)Gd158 (n,γ)Gd159(n,γ)Gd160 &Eu151(n,γ)Eu152(n,γ)Eu153(n,γ)Eu154 (n,γ)Eu155(n,γ)Eu156(n,γ)Eu157(β <sup>-</sup> ) Gd157(n,γ)Gd158(n,γ)Gd159(n,γ)Gd160 &Eu153(n,γ)Eu154(n,γ)Eu155(n,γ) Eu156(β <sup>-</sup> )Gd156(n,γ)Gd157(n,γ)Gd158 (n,γ)Gd159(n,γ)Gd160 Eu151(n,γ)Eu152m(β <sup>-</sup> )Gd152(n,γ)Gd153 (n,γ)Gd154(n,γ)Gd155(n,γ)Gd156(n,γ) Gd157(n,γ)Gd158(n,γ)Gd159(n,γ)Gd160 &Eu151(n,γ)Eu152(n,γ)Eu153(n,γ)Eu154 (n,γ)Eu155(n,γ)Eu156(β <sup>-</sup> )Gd156(n,γ) Gd157(n,γ)Gd158(n,γ)Gd159(n,γ)Gd160 &Eu153(n,γ)Eu154(n,γ)Eu155(β <sup>-</sup> ) Gd155(n,γ)Gd156(n,γ)Gd157(n,γ) Gd158(n,γ)Gd159(n,γ)Gd160 Eu153(n,γ)Eu154(β <sup>-</sup> )Gd154(n,γ) Gd155(n,γ)Gd156(n,γ)Gd157(n,γ) Gd158(n,γ)Gd159(n,γ)Gd160 Eu151(n,γ)Eu152(n,γ)Eu153(n,γ)Eu154 (n,γ)Eu155(β <sup>-</sup> )Gd155(n,γ)Gd156(n,γ) Gd157(n,γ)Gd158(n,γ)Gd159(n,γ)Gd160	51.0 30.3 6.0 4.3 3.5	0.5 0.2 56.0	0.5 72.1					
							4.1	23.2		
							1.8	3.7		
							1.7			



# Europium activation characteristics

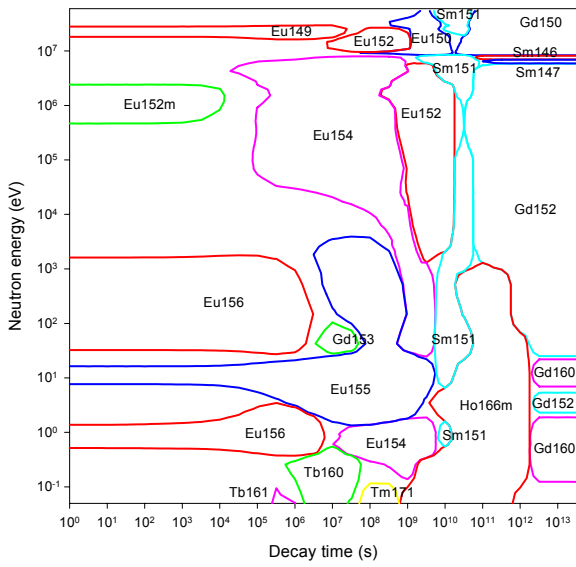


Decay time (years)

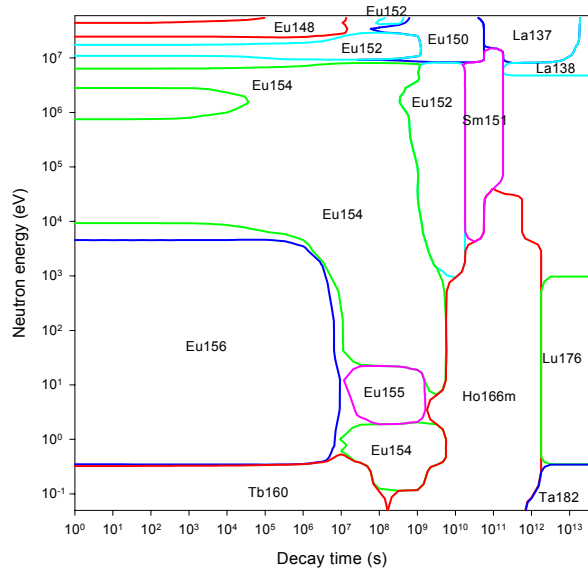
Decay time (years)

# Europium importance diagrams & transmutation

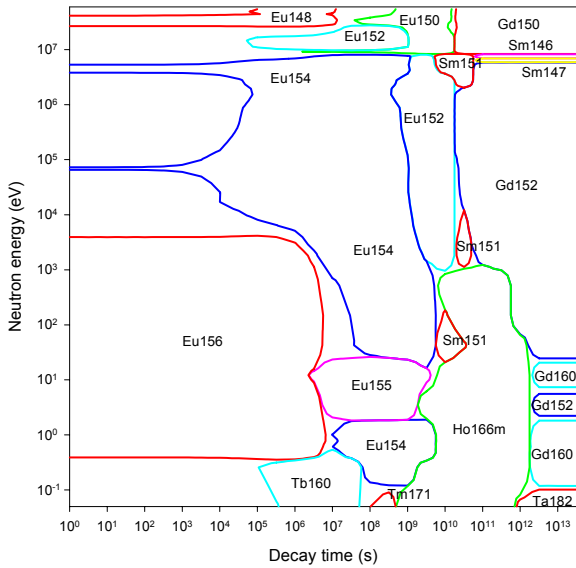
**Activity**



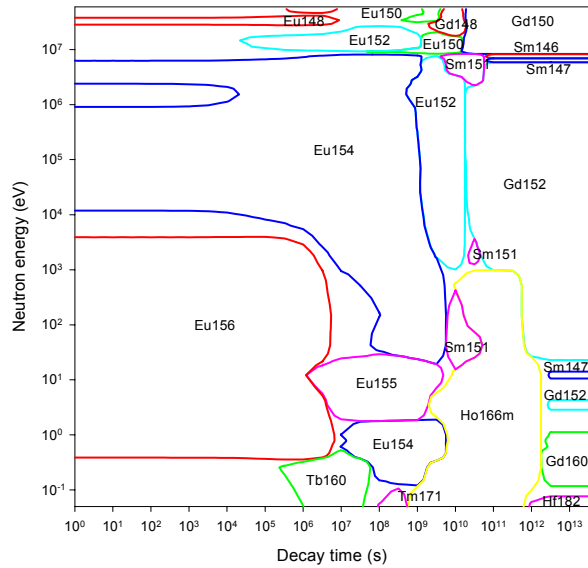
**Dose rate**



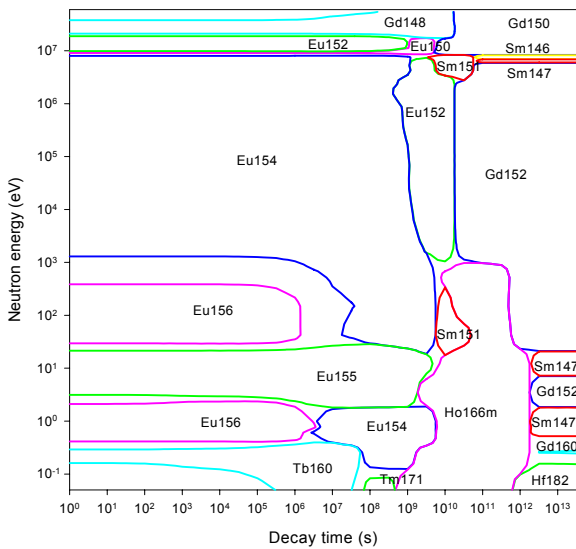
**Heat output**



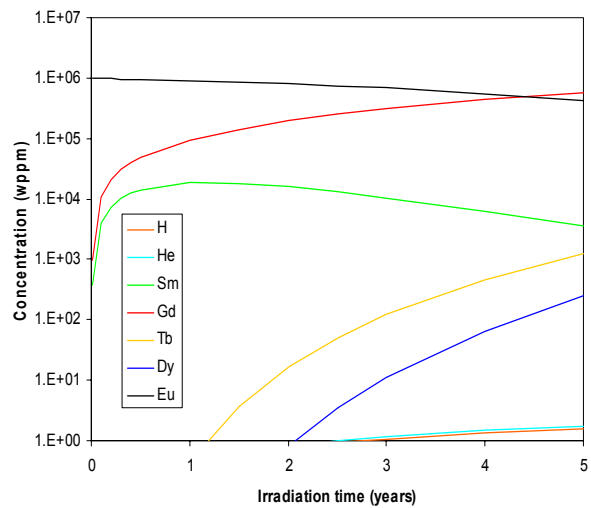
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**



# Gadolinium

## General properties

Atomic number	64	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	6.2	Gd152	0.20 ( $T_{1/2}=1.08 \cdot 10^{14}$ y)
Melting point / K	1587	Gd154	2.18
Boiling point / K	3537	Gd155	14.80
Density / $\text{kgm}^{-3}$	7901	Gd156	20.47
Thermal conductivity / $\text{Wm}^{-1}\text{K}^{-1}$	10.6	Gd157	15.65
Electrical resistivity / $\Omega\text{m}$	$1.34 \cdot 10^{-6}$	Gd158	24.84
Coefficient of thermal expansion / $\text{K}^{-1}$	$9.0 \cdot 10^{-6}$	Gd160	21.86 ( $T_{1/2}=1.30 \cdot 10^{17}$ y)
Crystal structure	HCP		
Number of stable isotopes	5 (7)		
Mean atomic weight	157.25		

## Activation properties

Act	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Heat	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Bq $\text{kg}^{-1}$	4.66E15	4.42E15	1.79E15	4.82E13	1.90E11	6.31E3	kW $\text{kg}^{-1}$	5.15E-1	4.83E-1	3.12E-1	9.59E-3	2.78E-5	2.83E-12
Gd159	50.51	53.07	4.90				Tb160	58.17	62.05	92.83	94.24		
Tb160	28.97	30.53	72.75	84.33			Gd159	26.71	28.40	1.65			
Tb161	11.56	12.18	20.83				Gd161	9.35	3.68				
Gd161	6.60	2.57					Tb161	3.93	4.19	4.49			
Gd153	0.15	0.16	0.39	5.09			Eu156	0.54	0.57	0.75			
Dy159	0.12	0.13	0.32	2.07			Dy165	0.42	0.44				
Eu155	0.05	0.06	0.14	4.42			Tb162	0.31	0.20				
Eu154	0.04	0.04	0.10	3.38	0.29		Eu154	0.08	0.09	0.14	4.14	0.49	
Tb158		0.01	0.02	0.57	97.92		Gd153	0.03	0.03	0.05	0.60		
Tb157				0.01	1.54		Tb158	0.01	0.01	0.01	0.42	99.20	
Gd150						99.92	Gd150						99.93
Dose	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Ing	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{h}^{-1}$	3.85E5	3.78E5	3.51E5	1.14E4	3.42E1	6.62E-21	Sv $\text{kg}^{-1}$	3.87E6	3.82E6	2.42E6	7.01E4	2.07E2	3.28E-4
Tb160	93.33	94.99	98.81	95.02			Tb160	55.80	56.55	86.00	92.80		
Gd159	2.54	2.58	0.10				Gd159	29.80	30.10	1.78			
Gd161	2.53	0.95					Tb161	10.02	10.15	11.08			
Eu156	0.94	0.96	0.87				Eu154	0.09	0.09	0.15	4.65	0.54	
Eu154	0.14	0.15	0.16	4.44	0.50		Eu155	0.02	0.02	0.03	0.97		
Tb158	0.01	0.01	0.01	0.44	99.22		Tb158	0.01	0.01	0.01	0.43	99.14	
Lu176						99.75	Gd150						99.92
Inh	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Clear	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{kg}^{-1}$	1.11E7	1.10E7	9.80E6	4.05E5	8.63E3	5.23E01		1.59E12	1.49E12	1.36E12	5.99E10	1.63E8	2.63E-1
Tb160	85.04	85.47	93.06	70.28			Tb160	85.10	90.37	96.07	67.89		
Tb161	6.30	6.33	4.95				Gd161	8.81	3.46				
Gd159	5.72	5.73	0.24				Tb161	1.79	1.90	1.45			
Eu154	0.84	0.85	0.96	21.32	0.34		Gd159	1.48	1.57	0.07			
Eu155	0.15	0.15	0.17	3.63			Eu154	1.11	1.18	1.30	27.20	3.40	
Gd153	0.13	0.13	0.15	1.27			Eu156	0.83	0.88	0.82			
Tb158	0.11	0.11	0.13	3.10	99.32		Tb158	0.01	0.02	0.02	0.38	95.32	
Gd150					0.01	99.99	Gd150						99.93

# Gadolinium

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Gd161	3.66 m	Gd160(n,γ)Gd161	100.0	100.0	100.0	100.0	99.8	99.8	99.9
Tb162	7.60 m	Gd160(n,γ)Gd161(β <sup>-</sup> )Tb161(n,γ)Tb162 Gd158(n,γ)Gd159(β <sup>-</sup> )Tb159(n,γ)Tb160_ (n,γ)Tb161(n,γ)Tb162 Gd157(n,γ)Gd158(n,γ)Gd159(β <sup>-</sup> )Tb159_ (n,γ)Tb160(n,γ)Tb161(n,γ)Tb162 Gd156(n,γ)Gd157(n,γ)Gd158(n,γ)Gd159_ (β <sup>-</sup> )Tb159(n,γ)Tb160(n,γ)Tb161(n,γ)Tb162 Gd155(n,γ)Gd156(n,γ)Gd157(n,γ)_ Gd158(n,γ)Gd159(β <sup>-</sup> )Tb159(n,γ)Tb160_ (n,γ)Tb161(n,γ)Tb162 Gd154(n,γ)Gd155(n,γ)Gd156(n,γ)_ Gd157(n,γ)Gd158(n,γ)Gd159(β <sup>-</sup> )Tb159_ (n,γ)Tb160(n,γ)Tb161(n,γ)Tb162 Gd160(n,γ)Gd161(β <sup>-</sup> )Tb161(β <sup>-</sup> )Dy161_ (n,γ)Dy162(n,p)Tb162	99.1 0.5 0.4 16.2 11.1 1.6	34.2 22.4 14.5 16.2 11.1 1.6	100.0	84.0	41.8	47.2	61.8
Tb154m	9.00 h	&Gd160(n,2n)Gd159(β <sup>-</sup> )Tb159(n,2n)_ <i>Tb158(n,2n)Tb157(n,2n)Tb156(n,2n)_</i> Tb155(n,2n)Tb154m &Gd160(n,2n)Gd159(β <sup>-</sup> )Tb159(n,2n)_ <i>Tb158(n,2n)Tb157(n,2n)Tb156m(n,2n)_</i> Tb155(n,2n)Tb154m Gd160(n,2n)Gd159(β <sup>-</sup> )Tb159(n,3n)_ Tb157(n,4n)Tb154m Gd160(n,2n)Gd159(β <sup>-</sup> )Tb159(n,3n)_ Tb157(n,3n)Tb155(n,2n)Tb154m &Gd160(n,2n)Gd159(β <sup>-</sup> )Tb159(n,2n)_ <i>Tb158(n,3n)Tb156(n,3n)Tb154m</i> &Gd160(n,2n)Gd159(β <sup>-</sup> )Tb159(n,3n)_ Tb157(n,2n)Tb156(n,3n)Tb154m Gd160(n,d)Eu159(β <sup>-</sup> )Gd159(β <sup>-</sup> )Tb159_ (n,3n)Tb157(n,4n)Tb154m &Gd160(n,2n)Gd159(β <sup>-</sup> )Tb159(n,4n)_ <i>Tb156(n,3n)Tb154m</i> Gd160(n,d)Eu159(β <sup>-</sup> )Gd159(β <sup>-</sup> )Tb159_ (n,3n)Tb157(n,3n)Tb155(n,2n)Tb154m &Gd160(n,2n)Gd159(β <sup>-</sup> )Tb159(n,2n)_ <i>Tb158(n,5n)Tb154m</i> Gd160(n,2n)Gd159(β <sup>-</sup> )Tb159(n,6n)Tb154m   Gd160(n,d)Eu159(β <sup>-</sup> )Gd159(β <sup>-</sup> )Tb159_ (n,6n)Tb154m				88.2 6.7	48.3 13.8 11.9 11.3 3.8 3.8 1.1	82.1 14.2 0.3	1.4 0.3 3.9 74.0 18.7
Gd159	18.479 h	Gd158(n,γ)Gd159 Gd157(n,γ)Gd158(n,γ)Gd159 Gd156(n,γ)Gd157(n,γ)Gd158(n,γ)Gd159 Gd155(n,γ)Gd156(n,γ)Gd157(n,γ)_ Gd158(n,γ)Gd159 Gd154(n,γ)Gd155(n,γ)Gd156(n,γ)_ Gd157(n,γ)Gd158(n,γ)Gd159 Gd160(n,2n)Gd159 Gd160(n,d)Eu159(β <sup>-</sup> )Gd159	61.2 38.6 0.1 17.9 2.6	33.0 20.8 25.6 17.9 2.6	87.8 11.5 0.7	0.2	0.6	0.5	
Tb161	6.89 d	Gd160(n,γ)Gd161(β <sup>-</sup> )Tb161 Gd158(n,γ)Gd159(β <sup>-</sup> )Tb159(n,γ)Tb160_ (n,γ)Tb161 Gd157(n,γ)Gd158(n,γ)Gd159(β <sup>-</sup> )Tb159_ (n,γ)Tb160(n,γ)Tb161	99.1 0.6 0.3	34.5 22.5 14.1	99.5 0.5	100.0	99.5	99.6	99.8

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Gd156(n,γ)Gd157(n,γ)Gd158(n,γ) Gd159(β <sup>-</sup> )Tb159(n,γ)Tb160(n,γ)Tb161 Gd155(n,γ)Gd156(n,γ)Gd157(n,γ)Gd158 (n,γ)Gd159(β <sup>-</sup> )Tb159(n,γ)Tb160(n,γ)Tb161 Gd154(n,γ)Gd155(n,γ)Gd156(n,γ) Gd157(n,γ)Gd158(n,γ)Gd159(β <sup>-</sup> )Tb159 (n,γ)Tb160(n,γ)Tb161		16.3 11.1 1.5						
Eu156	15.19 d	Gd152(n,γ)Gd153(β <sup>+</sup> )Eu153(n,γ)Eu154 (n,γ)Eu155(n,γ)Eu156 Gd156(n,p)Eu156 Gd157(n,2n)Gd156(n,p)Eu156 Gd160(n,2n)Gd159(β <sup>-</sup> )Tb159(n,α)Eu156 Gd157(n,d)Eu156 Gd158(n,2n)Gd157(n,2n)Gd156(n,p)Eu156 Gd158(n,2n)Gd157(n,d)Eu156 Gd160(n,nα)Sm156(β <sup>-</sup> )Eu156 Gd158(n,t)Eu156 Gd160(n,4n)Gd157(n,d)Eu156 Gd158(n,3n)Gd156(n,p)Eu156 Gd160(n,3n)Gd158(n,t)Eu156 Gd160(n,2nt)Eu156	98.4	98.4	98.3					
						62.4 13.2 12.6 5.9 2.9 2.6 0.2	13.4 0.6	5.5 35.6 1.4 4.3 40.5 7.0 3.6 1.7 1.0	2.3 24.5 44.3 21.1	
Tb160	72.30 d	Gd158(n,γ)Gd159(β <sup>-</sup> )Tb159(n,γ)Tb160 Gd157(n,γ)Gd158(n,γ)Gd159(β <sup>-</sup> )Tb159 (n,γ)Tb160 Gd156(n,γ)Gd157(n,γ)Gd158(n,γ) Gd159(β <sup>-</sup> )Tb159(n,γ)Tb160 Gd155(n,γ)Gd156(n,γ)Gd157(n,γ) Gd158(n,γ)Gd159(β <sup>-</sup> )Tb159(n,γ)Tb160 Gd154(n,γ)Gd155(n,γ)Gd156(n,γ)Gd157 (n,γ)Gd158(n,γ)Gd159(β <sup>-</sup> )Tb159(n,γ)Tb160 Gd160(n,2n)Gd159(β <sup>-</sup> )Tb159(n,γ)Tb160 Gd160(n,γ)Gd161(β <sup>-</sup> )Tb161(n,2n)Tb160 Gd160(n,d)Eu159(β <sup>-</sup> )Gd159(β <sup>-</sup> )Tb159 (n,γ)Tb160 Gd160(n,γ)Gd161(β <sup>-</sup> )Tb161(β <sup>-</sup> )Dy161 (n,d)Tb160	61.9 38.0	34.2 21.5 24.8 16.9 2.4	93.5 6.2 0.2	0.2	0.6	0.5	0.5	
						99.2 0.4	89.0 0.1 6.9	79.9 13.9	73.2 18.5	
							3.4	5.5	7.6	
Ta182	114.7 d	Very long pathways of (n,γ), β <sup>-</sup>	100.0	100.0						
Tm170	128.6 d	Very long pathways of (n,γ), β <sup>-</sup>	100.0	100.0	100.0					
Gd153	240.4 d	Gd152(n,γ)Gd153 Gd155(n,2n)Gd154(n,2n)Gd153 Gd154(n,2n)Gd153 Gd156(n,2n)Gd155(n,2n)Gd154(n,2n)Gd153 Gd155(n,3n)Gd153 Gd157(n,3n)Gd155(n,3n)Gd153 Gd156(n,3n)Gd154(n,2n)Gd153 Gd156(n,2n)Gd155(n,3n)Gd153 Gd158(n,4n)Gd155(n,3n)Gd153 Gd156(n,4n)Gd153 Gd157(n,4n)Gd154(n,2n)Gd153 Gd158(n,3n)Gd156(n,4n)Gd153 Gd157(n,5n)Gd153 Gd160(n,5n)Gd156(n,4n)Gd153 Gd157(n,2n)Gd156(n,4n)Gd153 Gd160(n,4n)Gd157(n,5n)Gd153 Gd158(n,6n)Gd153 Gd158(n,5n)Gd154(n,2n)Gd153 Gd160(n,6n)Gd155(n,3n)Gd153	100.0	100.0	100.0					
						55.8 34.5 9.1	1.2 3.9	0.5 2.2 10.3 0.6 0.5 0.2 0.5 17.5 0.5 0.6 24.6 1.0 0.3 1.0 1.5 1.0	0.3 1.9	
Tm171	1.917 y	Very long pathways of (n,γ), β <sup>-</sup>	100.0	100.0	100.0					
Eu155	4.753 y	&Gd152(n,γ)Gd153(β <sup>+</sup> )Eu153(n,γ) Eu154(n,γ)Eu155 Gd155(n,p)Eu155 Gd158(n,α)Sm155(β <sup>-</sup> )Eu155	100.0	100.0	100.0					
	▶					51.1 28.0	10.3 7.9	4.2 1.4	1.5	



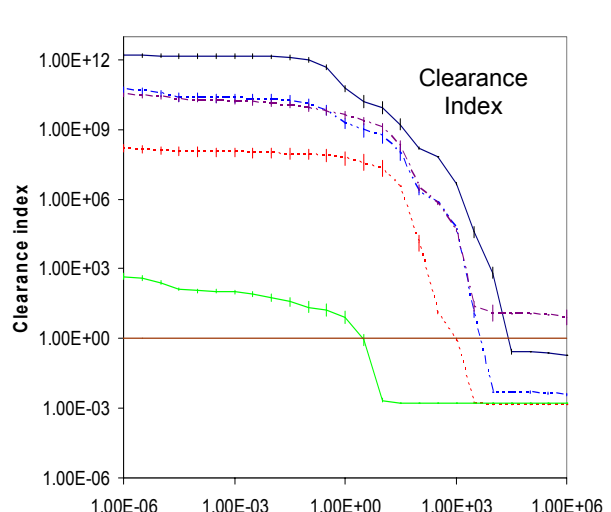
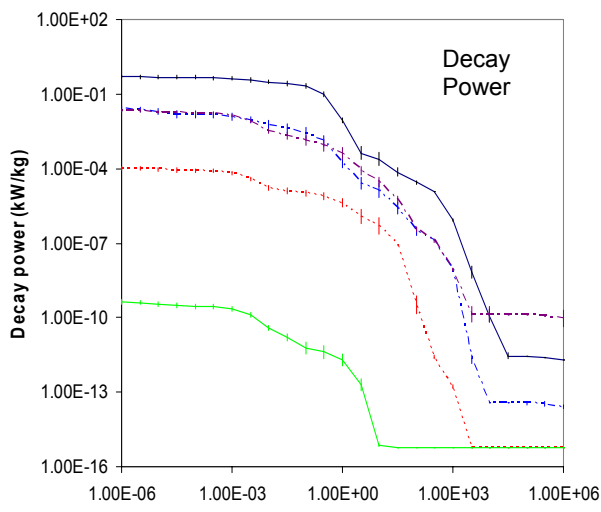
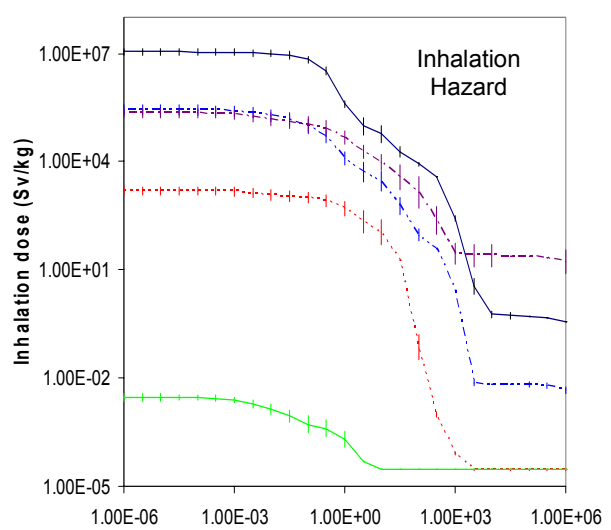
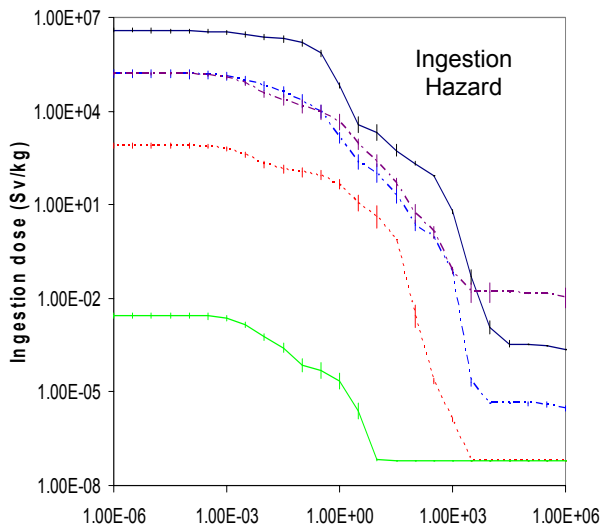
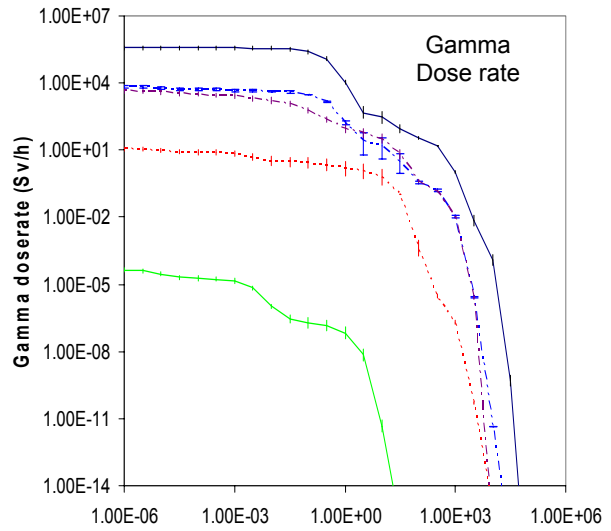
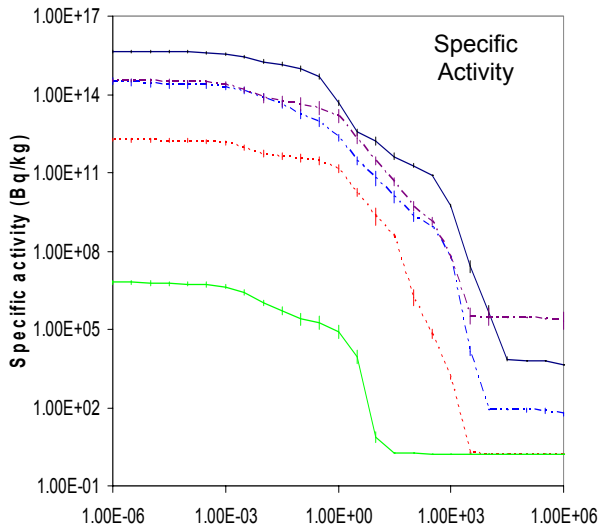
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Gd156(n,4n)Gd153(β <sup>+</sup> )Eu153(n,4n)Eu150 Gd155(n,4n)Gd152(n,t)Eu150 Gd155(n,t)Eu153(n,4n)Eu150 Gd157(n,5n)Gd153(β <sup>+</sup> )Eu153(n,4n)Eu150 Gd155(n,5n)Gd151(β <sup>+</sup> )Eu151(n,2n)Eu150 Gd156(n,5n)Gd152(n,t)Eu150 Gd154(n,2nt)Eu150 Gd155(n,3nt)Eu150 Gd158(n,6n)Gd153(β <sup>+</sup> )Eu153(n,4n)Eu150 Gd156(n,6n)Gd151(β <sup>+</sup> )Eu151(n,2n)Eu150 Gd158(n,nt)Eu155(n,6n)Eu150 Gd158(n,5n)Gd154(n,2nt)Eu150					1.1 1.1 0.9	51.9 3.2 4.2 3.8 0.9 0.2 0.1	3.7 1.3 1.6 5.2 5.1 4.0 7.4 8.8 7.3 5.0 3.8 3.6	
Gd148	74.602 y	Gd152(n,2n)Gd151(n,2n)Gd150(n,2n) Gd149(n,2n)Gd148 Gd152(n,2n)Gd151(β <sup>+</sup> )Eu151(n,2n) Eu150m(β <sup>-</sup> )Gd150(n,2n)Gd149(n,2n)Gd148 Gd152(n,3n)Gd150(n,3n)Gd148 Gd154(n,3n)Gd152(n,3n)Gd150(n,3n)Gd148 Gd155(n,4n)Gd152(n,3n)Gd150(n,3n)Gd148 Gd156(n,3n)Gd154(n,3n)Gd152(n,3n) Gd150(n,3n)Gd148 Gd155(n,3n)Gd153(n,4n)Gd150(n,3n)Gd148 Gd156(n,4n)Gd153(n,4n)Gd150(n,3n)Gd148 Gd154(n,4n)Gd151(n,4n)Gd148 Gd155(n,4n)Gd152(n,5n)Gd148 Gd157(n,4n)Gd154(n,4n)Gd151(n,4n)Gd148 Gd155(n,5n)Gd151(n,4n)Gd148 Gd156(n,3n)Gd154(n,4n)Gd151(n,4n)Gd148 Gd156(n,4n)Gd153(β <sup>+</sup> )Eu153(n,4n) Eu150m(β <sup>-</sup> )Gd150(n,3n)Gd148 Gd155(n,4n)Gd152(n,2n)Gd151(n,4n)Gd148 Gd152(n,5n)Gd148 Gd156(n,5n)Gd152(n,5n)Gd148 Gd157(n,6n)Gd152(n,5n)Gd148 Gd155(n,6n)Gd150(n,3n)Gd148 Gd158(n,6n)Gd153(n,6n)Gd148 Gd157(n,5n)Gd153(n,6n)Gd148				51.4 40.7	27.4 21.8 19.4 12.1	2.0 0.5 7.7	10.4 8.1 7.4 4.3 3.9 2.9 1.7 0.8	7.2 32.0 18.7 6.3 4.2 2.9
Sm151	90.0 y	Gd154(n,α)Sm151 Gd152(n,α)Sm149(n,γ)Sm150(n,γ)Sm151 Gd152(n,γ)Gd153(n,γ)Gd154(n,α)Sm151 Gd152(n,γ)Gd153(n,α)Sm150(n,γ)Sm151 Gd155(n,2n)Gd154(n,α)Sm151 Gd155(n,α)Sm152(n,2n)Sm151 Gd155(n,α)Sm151 Gd154(n,2n)Gd153(β <sup>+</sup> )Eu153(n,2n) Eu152m(β <sup>+</sup> )Sm152(n,2n)Sm151 Gd156(n,2n)Gd155(n,2n)Gd154(n,α)Sm151 &Gd154(n,2n)Gd153(β <sup>+</sup> )Eu153(n,2n) Eu152(β <sup>+</sup> )Sm152(n,2n)Sm151 Gd156(n,2n)Gd155(n,α)Sm152(n,2n)Sm151 Gd156(n,2n)Gd155(n,α)Sm151 Gd156(n,α)Sm152(n,2n)Sm151 Gd157(n,3n)Gd155(n,α)Sm151 Gd156(n,3n)Gd154(n,α)Sm151 Gd156(n,2α)Sm151 Gd158(n,4n)Gd155(n,α)Sm151 Gd158(n,α)Sm154(n,4n)Sm151 Gd158(n,3n)Gd156(n,2α)Sm151 Gd156(n,4n)Gd153(β <sup>+</sup> )Eu153(n,t)Sm151 Gd157(n,3α)Sm151 Gd155(n,3n)Gd153(β <sup>+</sup> )Eu153(n,t)Sm151 Gd160(n,5n)Gd156(n,2α)Sm151	88.2 5.7 5.3 0.8	92.2 2.1 5.5	99.7 0.2	27.8 27.8 15.4 7.4 4.7 3.5 3.2 1.9 1.4 0.4	3.1 0.6 0.3 66.0 28.7 0.1 13.5	0.8 0.1 13.5	1.0 0.1 0.3 0.2 0.2 17.7 0.4 0.2 0.4 1.9 1.1 21.6 1.1 0.6	

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Gd157(n,5n)Gd153(β <sup>+</sup> )Eu153(n,t)Sm151 Gd156(n,nt)Eu153(n,t)Sm151 Gd158(n,4nα)Sm151 Gd158(n,6n)Gd153(β <sup>+</sup> )Eu153(n,t)Sm151						0.8 0.2	2.7 1.1 17.3 3.8	
Tb157	99.0 y	&Gd160(n,2n)Gd159(β <sup>-</sup> )Tb159(n,2n) <i>Tb158</i> (n,2n)Tb157 Gd160(n,2n)Gd159(β <sup>-</sup> )Tb159(n,3n)Tb157 Gd160(n,d)Eu159(β <sup>-</sup> )Gd159(β <sup>-</sup> ) (n,3n)Tb157				99.7		1.5 83.2 14.4	1.2 78.1 19.7	
Tb158	180.0 y	&Gd160(n,2n)Gd159(β <sup>-</sup> )Tb159(n,2n) <i>Tb158</i> &Gd158(n,γ)Gd159(β <sup>-</sup> )Tb159(n,2n) <i>Tb158</i> &Gd160(n,d)Eu159(β <sup>-</sup> )Gd159(β <sup>-</sup> ) Tb159(n,2n) <i>Tb158</i>				99.8 0.1	92.0 0.6	84.7 0.5 14.7	79.3 0.6 20.1	
Ho166m	1200 y	&Gd160(n,γ)Gd161(β <sup>-</sup> )Tb161(β <sup>-</sup> ) Dy161(n,γ)Dy162(n,γ)Dy163(n,γ)Dy164 (n,γ)Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166m &Gd160(n,γ)Gd161(β <sup>-</sup> )Tb161(n,γ)Tb162 (β <sup>-</sup> )Dy162(n,γ)Dy163(n,γ)Dy164(n,γ) Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166m &Gd158(n,γ)Gd159(β <sup>-</sup> )Tb159(n,γ) Tb160(n,γ)Tb161(β <sup>-</sup> )Dy161(n,γ)Dy162 (n,γ)Dy163(n,γ)Dy164(n,γ)Dy165(β <sup>-</sup> ) Ho165(n,γ)Ho166m &Gd158(n,γ)Gd159(β <sup>-</sup> )Tb159(n,γ) Tb160(β <sup>-</sup> )Dy160(n,γ)Dy161(n,γ)Dy162 (n,γ)Dy163(n,γ)Dy164(n,γ)Dy165(β <sup>-</sup> ) Ho165(n,γ)Ho166m &Gd157(n,γ)Gd158(n,γ)Gd159(β <sup>-</sup> )Tb159 (n,γ)Tb160(β <sup>-</sup> )Dy160(n,γ)Dy161(n,γ) Dy162(n,γ)Dy163(n,γ)Dy164(n,γ)Dy165 (β <sup>-</sup> )Ho165(n,γ)Ho166m &Gd157(n,γ)Gd158(n,γ)Gd159(β <sup>-</sup> )Tb159 (n,γ)Tb160(n,γ)Tb161(β <sup>-</sup> )Dy161(n,γ) Dy162(n,γ)Dy163(n,γ)Dy164(n,γ)Dy165 (β <sup>-</sup> )Ho165(n,γ)Ho166m &Gd156(n,γ)Gd157(n,γ)Gd158(n,γ)Gd159 (β <sup>-</sup> )Tb159(n,γ)Tb160(β <sup>-</sup> )Dy160(n,γ)Dy161 (n,γ)Dy162(n,γ)Dy163(n,γ)Dy164(n,γ) Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166m &Gd156(n,γ)Gd157(n,γ)Gd158(n,γ)Gd159 (β <sup>-</sup> )Tb159(n,γ)Tb160(n,γ)Tb161(β <sup>-</sup> )Dy161 (n,γ)Dy162(n,γ)Dy163(n,γ)Dy164(n,γ) Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166m &Gd155(n,γ)Gd156(n,γ)Gd157(n,γ)Gd158 (n,γ)Gd159(β <sup>-</sup> )Tb159(n,γ)Tb160(β <sup>-</sup> )Dy160 (n,γ)Dy161(n,γ)Dy162(n,γ)Dy163(n,γ) Dy164(n,γ)Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166m Gd155(n,γ)Gd156(n,γ)Gd157(n,γ)Gd158(n,γ) Gd159(β <sup>-</sup> )Tb159(n,γ)Tb160(n,γ)Tb161(β <sup>-</sup> ) Dy161(n,γ)Dy162(n,γ)Dy163(n,γ)Dy164(n,γ) Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166m	95.6 0.3 0.1	33.6 1.3 14.1 20.4 8.8 6.4 4.5 3.5 2.1 1.7	93.1 2.3 0.1					
La137	6.0 10 <sup>4</sup> y	Very long pathways of (n,α), (n,nα), β <sup>-</sup>				100.0	100.0	100.0	100.0	
Gd150	1.8 10 <sup>6</sup> y	Gd152(n,2n)Gd151(β <sup>+</sup> )Eu151(n,2n) Eu150m(β <sup>-</sup> )Gd150 Gd152(n,2n)Gd151(n,2n)Gd150 Gd154(n,2n)Gd153(n,2n)Gd152(n,2n) Gd151(n,2n)Gd150 Gd154(n,3n)Gd152(n,3n)Gd150 Gd155(n,4n)Gd152(n,3n)Gd150 Gd152(n,3n)Gd150 Gd156(n,3n)Gd154(n,3n)Gd152(n,3n)Gd150				48.5 40.9 2.3		22.6 20.1 19.0 16.7	1.3 22.0 3.9 0.3	



Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Gd155(n,3n)Gd153(n,4n)Gd150 Gd155(n,2n)Gd154(n,3n)Gd152(n,3n)Gd150 Gd157(n,4n)Gd154(n,3n)Gd152(n,3n)Gd150 Gd156(n,4n)Gd153(n,4n)Gd150 Gd156(n,4n)Gd153(β <sup>+</sup> )Eu153(n,4n) <sub>-</sub> Eu150m(β <sup>-</sup> )Gd150 Gd154(n,5n)Gd150 Gd155(n,3n)Gd153(β <sup>+</sup> )Eu153(n,4n) <sub>-</sub> Eu150m(β <sup>-</sup> )Gd150 Gd156(n,5n)Gd152(n,3n)Gd150 Gd156(n,3n)Gd154(n,5n)Gd150 Gd158(n,5n)Gd154(n,5n)Gd150 Gd155(n,6n)Gd150 Gd160(n,6n)Gd155(n,6n)Gd150					4.7 2.9 2.7 0.1	5.0 0.1 0.5 21.7 12.9	0.2   0.3 0.2  12.6 0.1  2.1 2.1 6.1 55.5 3.5	
Hf182	9.0 10 <sup>6</sup> y	Very long pathways of (n,γ), β <sup>-</sup>	100.0							
Lu176	4.0 10 <sup>10</sup> y	Very long pathways of (n,γ), β <sup>-</sup>	100.0							
La138	1.0 10 <sup>11</sup> y	Very long pathways of (n,α), (n,nα), β <sup>-</sup>				100.0	100.0	100.0	100.0	
Gd152	1.1 10 <sup>14</sup> y	Gd154(n,α)Sm151(β <sup>-</sup> )Eu151(n,γ) <sub>-</sub> Eu152m(β <sup>-</sup> )Gd152 Gd154(n,2n)Gd153(n,2n)Gd152 Gd155(n,2n)Gd154(n,2n)Gd153(n,2n)Gd152 Gd154(n,2n)Gd153(β <sup>+</sup> )Eu153(n,2n) <sub>-</sub> Eu152m(β <sup>-</sup> )Gd152 Gd155(n,2n)Gd154(n,2n)Gd153(β <sup>+</sup> ) <sub>-</sub> Eu153(n,2n)Eu152m(β <sup>-</sup> )Gd152 Gd156(n,2n)Gd155(n,2n)Gd154(n,2n) <sub>-</sub> Gd153(n,2n)Gd152 Gd156(n,3n)Gd154(n,3n)Gd152 Gd154(n,3n)Gd152 Gd155(n,4n)Gd152 Gd155(n,2n)Gd154(n,3n)Gd152 Gd157(n,4n)Gd154(n,3n)Gd152 Gd158(n,3n)Gd156(n,3n)Gd154(n,3n)Gd152 Gd157(n,3n)Gd155(n,4n)Gd152 Gd155(n,3n)Gd153(n,2n)Gd152 Gd156(n,2n)Gd155(n,4n)Gd152 Gd158(n,4n)Gd155(n,4n)Gd152 Gd156(n,5n)Gd152 Gd160(n,5n)Gd156(n,5n)Gd152 Gd157(n,6n)Gd152 Nuclide present in starting material	86.5				10.7 9.1 2.9  1.7 1.0	26.6 23.8 21.3 4.6 4.3 2.4 2.1 1.3 0.5 0.4	1.2 4.0 65.9 0.6 2.3  1.8 0.1 1.1 8.7 5.2 0.2	0.3 1.8 14.2 0.2 0.3  0.2 0.2 0.4 43.7 1.6 25.5 11.6
Gd160	1.3 10 <sup>17</sup> y	Nuclide present in starting material	100.0	100.0	100.0	100.0	100.0	100.0	100.0	

# Gadolinium activation characteristics

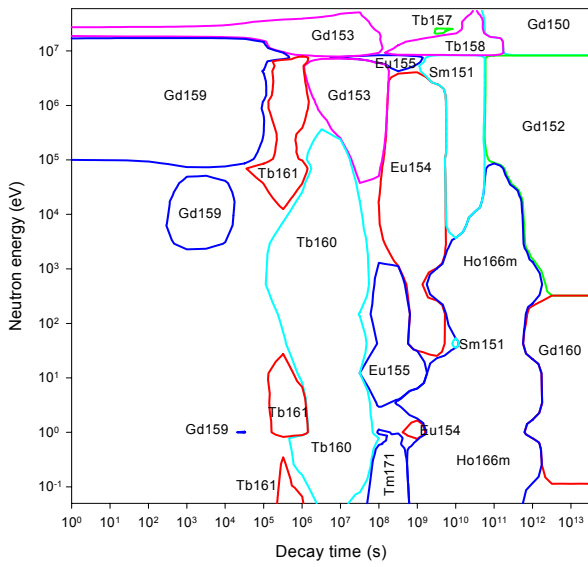


Decay time (years)

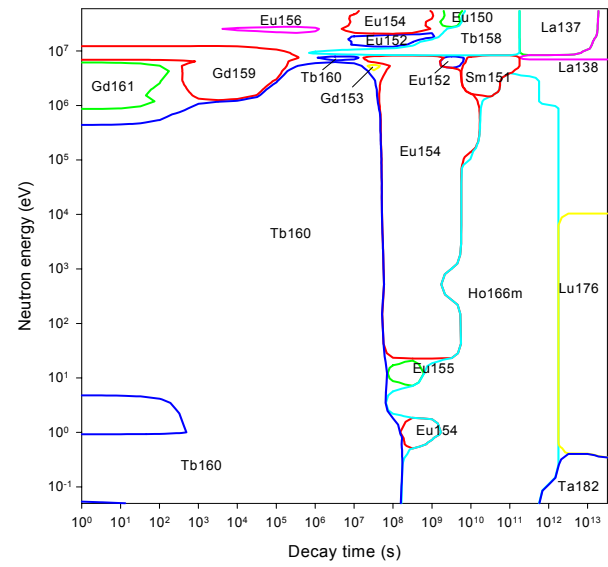
Decay time (years)

# Gadolinium importance diagrams & transmutation

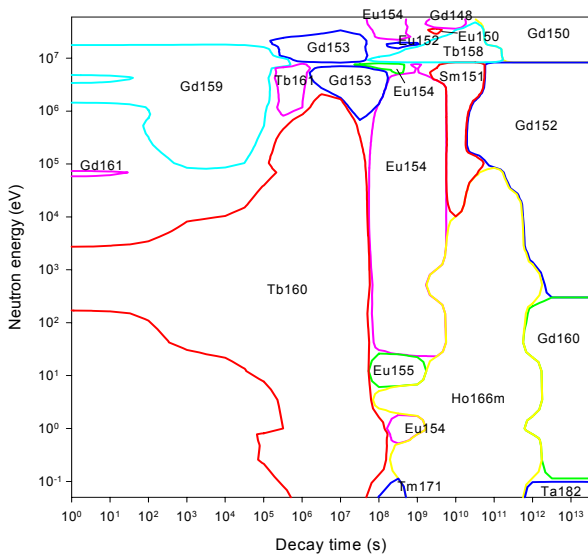
**Activity**



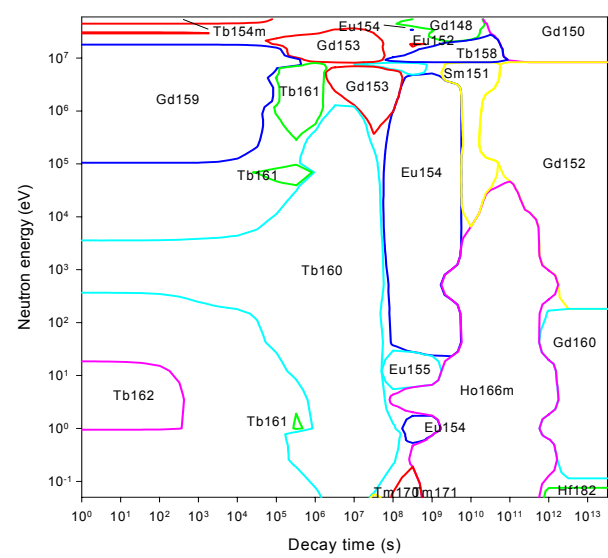
**Dose rate**



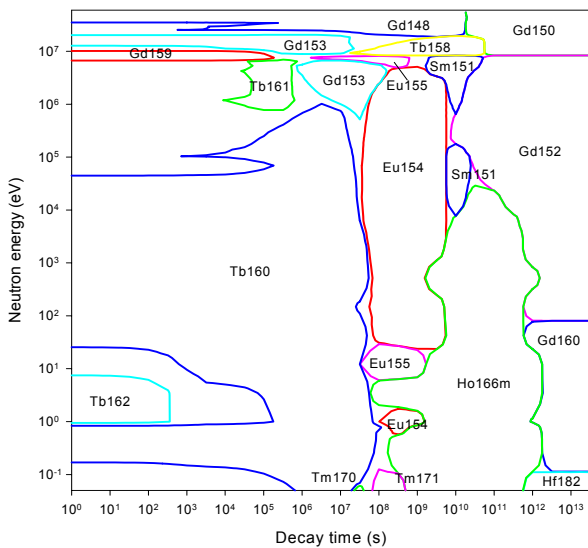
**Heat output**



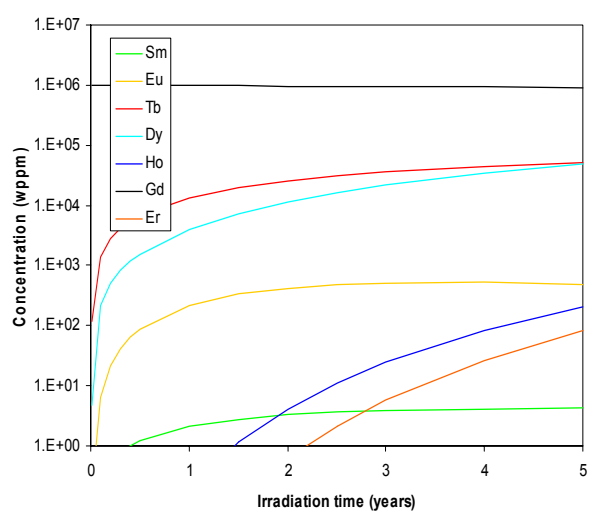
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**





# Terbium

## General properties

Atomic number	65	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	1.2	Tb159	100.0
Melting point / K	1632		
Boiling point / K	3494		
Density / kgm <sup>-3</sup>	8230		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	11.1		
Electrical resistivity /Ωm	1.14 10 <sup>-6</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	1.03 10 <sup>-5</sup>		
Crystal structure	Rhombic		
Number of stable isotopes	1		
Mean atomic weight	158.92534		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	1.03E16	9.78E15	8.22E15	2.40E14	2.11E12	5.68E-1	kW kg <sup>-1</sup>	1.80E0	1.79E0	1.64E0	5.07E-2	3.05E-4	2.45E-19
Tb160	72.58	76.45	87.89	93.85			Tb160	92.09	92.74	97.70	98.90		
Tb161	12.63	13.30	10.97				Dy165	2.80	2.77				
Dy165	6.46	6.67					Tb161	2.71	2.73	2.06			
Dy165m	4.14	0.24					Ho166	1.47	1.48	0.17			
Ho166	2.22	2.33	0.29				Dy165m	0.47	0.03				
Dy159	0.65	0.69	0.80	4.83			Tb162	0.22	0.13				
Tb158	0.03	0.03	0.04	1.25	97.18		Tb158	0.03	0.03	0.03	0.88	99.65	
Tb157				0.05	2.65		Ho163						98.61
Ho163						100.0	Gd150						1.05
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	1.98E6	1.97E6	1.90E6	5.98E4	3.69E2	1.00E-19	Sv kg <sup>-1</sup>	1.36E7	1.35E7	1.22E7	3.65E5	2.26E3	1.34E-11
Tb160	99.56	99.66	99.94	99.09			Tb160	87.86	88.65	94.33	98.77		
Tb162	0.16	0.10					Tb161	6.88	6.94	5.30			
Dy165	0.10	0.10					Ho166	2.35	2.37	0.28			
Tb158	0.03	0.03	0.03	0.90	99.73		Tb158	0.02	0.03	0.03	0.90	99.62	
Ho166m					0.27		Ho163						97.61
Lu176						99.94	Gd150						2.23
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	5.48E7	5.46E7	5.19E7	1.72E6	9.46E4	5.08E-10		7.60E12	7.57E12	7.28E12	2.29E11	1.71E9	1.50E-7
Tb160	95.61	95.85	97.39	91.70			Tb160	98.47	98.78	99.26	98.66		
Tb161	3.09	3.10	2.26				Tb161	0.90	0.90	0.65			
Ho166	0.27	0.27	0.03				Tb158	0.03	0.03	0.03	1.09	99.65	
Tb158	0.25	0.25	0.27	8.01	99.51		Ho166	0.03	0.03				
Gd150						93.96	Dy165	0.01	0.01				
Ho163						5.93	Ho163						99.50

# Terbium

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Tb158m	10.8 s	Tb159(n,2n)Tb158m				99.6	99.7	99.8	99.9
Tb162	7.60 m	Tb159(n,γ)Tb160(n,γ)Tb161(n,γ)Tb162 Tb159(n,γ)Tb160(β <sup>-</sup> )Dy160(n,γ)Dy161_ (n,γ)Dy162(n,p)Tb162 Tb159(n,γ)Tb160(n,γ)Tb161(β <sup>-</sup> )Dy161_ (n,γ)Dy162(n,p)Tb162	100.0	100.0	100.0	47.8 43.5	7.7 82.2	10.0 79.9	16.5 74.1
Tb154m	9.00 h	&Tb159(n,2n)Tb158(n,2n)Tb157(n,2n)_ Tb156(n,2n)Tb155(n,2n)Tb154m &Tb159(n,2n)Tb158(n,2n)Tb157(n,2n)_ Tb156m(n,2n)Tb155(n,2n)Tb154m Tb159(n,3n)Tb157(n,4n)Tb154m Tb159(n,3n)Tb157(n,3n)Tb155(n,2n)Tb154m   &Tb159(n,2n)Tb158(n,3n)Tb156(n,3n)_ Tb154m &Tb159(n,3n)Tb157(n,2n)Tb156(n,3n)_ Tb154m &Tb159(n,4n)Tb156(n,3n)Tb154m &Tb159(n,2n)Tb158(n,5n)Tb154m Tb159(n,6n)Tb154m				91.5 6.7		53.2 14.2 12.8 11.2 2.6	94.5 3.2 6.4 87.3
Ho166	1.117 d	&Tb159(n,γ)Tb160(n,γ)Tb161(β <sup>-</sup> )_ Dy161(n,γ)Dy162(n,γ)Dy163(n,γ)_ Dy164(n,γ)Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166 &Tb159(n,γ)Tb160(β <sup>-</sup> )Dy160(n,γ)_ Dy161(n,γ)Dy162(n,γ)Dy163(n,γ)_ Dy164(n,γ)Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166	60.0 35.1	61.8 35.4	46.8 50.7				
Tm172	2.65 d	&Tb159(n,γ)Tb160(n,γ)Tb161(β <sup>-</sup> )Dy161_ (n,γ)Dy162(n,γ)Dy163(n,γ)Dy164(n,γ)_ Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166(β <sup>-</sup> )Er166_ (n,γ)Er167(n,γ)Er168(n,γ)Er169(β <sup>-</sup> )_ Tm169(n,γ)Tm170(n,γ)Tm171(n,γ)Tm172 &Tb159(n,γ)Tb160(n,γ)Tb161(β <sup>-</sup> )Dy161_ (n,γ)Dy162(n,γ)Dy163(n,γ)Dy164(n,γ)_ Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166m(n,γ)Ho167_ (β <sup>-</sup> )Er167(n,γ)Er168(n,γ)Er169(β <sup>-</sup> )_ Tm169(n,γ)Tm170(n,γ)Tm171(n,γ)Tm172 &Tb159(n,γ)Tb160(β <sup>-</sup> )Dy160(n,γ)Dy161_ (n,γ)Dy162(n,γ)Dy163(n,γ)Dy164(n,γ)_ Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166(β <sup>-</sup> )Er166_ (n,γ)Er167(n,γ)Er168(n,γ)Er169(β <sup>-</sup> )_ Tm169(n,γ)Tm170(n,γ)Tm171(n,γ)Tm172 &Tb159(n,γ)Tb160(β <sup>-</sup> )Dy160(n,γ)Dy161_ (n,γ)Dy162(n,γ)Dy163(n,γ)Dy164(n,γ)_ Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166m(n,γ)Ho167_ (β <sup>-</sup> )Er167(n,γ)Er168(n,γ)Er169(β <sup>-</sup> )_ Tm169(n,γ)Tm170(n,γ)Tm171(n,γ)Tm172	49.4 27.3 13.4 8.8	33.4 8.8 38.4 10.5	52.2 8.6 31.2 5.2				
Tb156	5.17 d	&Tb159(n,2n)Tb158(n,2n)Tb157(n,2n)Tb156   &Tb159(n,2n)Tb158(n,3n)Tb156 &Tb159(n,3n)Tb157(n,2n)Tb156 &Tb159(n,4n)Tb156				93.4	0.5 48.2 41.8 7.5	1.6 1.4 95.2	2.4 2.0 92.7
Tb155	5.32 d	&Tb159(n,2n)Tb158(n,2n)Tb157(n,2n)_ Tb156(n,2n)Tb155 &Tb159(n,2n)Tb158(n,2n)Tb157(n,2n)_ Tb156m(n,2n)Tb155 Tb159(n,3n)Tb157(n,3n)Tb155 &Tb159(n,2n)Tb158(n,4n)Tb155 Tb159(n,5n)Tb155				91.5 6.7		94.3 4.1 32.7	20.2 46.3 96.1

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
Tb161	6.89 d	Tb159(n,γ)Tb160(n,γ)Tb161 Tb159(n,γ)Tb160(β <sup>-</sup> )Dy160(n,γ)Dy161_(n,p)Tb161	100.0	100.0	99.0	99.0 0.7	96.5 2.9	97.4 2.2	98.6 1.2	
Tb160	72.3 d	Tb159(n,γ)Tb160	100.0	100.0	100.0	99.8	99.7	99.8	99.9	
Ta182	114.7 d	Very long pathways of (n,γ), β <sup>-</sup>	100.0							
Tm170	128.6 d	&Tb159(n,γ)Tb160(n,γ)Tb161(β <sup>-</sup> )_Dy161(n,γ)Dy162(n,γ)Dy163(n,γ)_Dy164(n,γ)Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166_(β <sup>-</sup> )Er166(n,γ)Er167(n,γ)Er168(n,γ)_Er169(β <sup>-</sup> )Tm169(n,γ)Tm170 &Tb159(n,γ)Tb160(β <sup>-</sup> )Dy160(n,γ)_Dy161(n,γ)Dy162(n,γ)Dy163(n,γ)_Dy164(n,γ)Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166_(β <sup>-</sup> )Er166(n,γ)Er167(n,γ)Er168(n,γ)_Er169(β <sup>-</sup> )Tm169(n,γ)Tm170 &Tb159(n,γ)Tb160(n,γ)Tb161(β <sup>-</sup> )_Dy161(n,γ)Dy162(n,γ)Dy163(n,γ)_Dy164(n,γ)Dy165(β <sup>-</sup> )Ho165(n,γ)_Ho166m(n,γ)Ho167(β <sup>-</sup> )Er167(n,γ)Er168_(n,γ)Er169(β <sup>-</sup> )Tm169(n,γ)Tm170 &Tb159(n,γ)Tb160(β <sup>-</sup> )Dy160(n,γ)_Dy161(n,γ)Dy162(n,γ)Dy163(n,γ)_Dy164(n,γ)Dy165(β <sup>-</sup> )Ho165(n,γ)_Ho166m(n,γ)Ho167(β <sup>-</sup> )Er167(n,γ)Er168_(n,γ)Er169(β <sup>-</sup> )Tm169(n,γ)Tm170 &Tb159(n,γ)Tb160(n,γ)Tb161(n,γ)_Tb162(β <sup>-</sup> )Dy162(n,γ)Dy163(n,γ)Dy164_(n,γ)Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166(β <sup>-</sup> )_Er166(n,γ)Er167(n,γ)Er168(n,γ)(β <sup>-</sup> )_Tm169(n,γ)Tm170	53.6 15.7 15.3 5.3 0.8	32.7 40.5 6.8 8.7 1.4	47.2 30.6 4.5 2.9 1.9					
Gd153	240.4 d	&Tb159(n,2n)Tb158(n,2n)Tb157(n,2n)_Tb156(β <sup>+</sup> )Gd156(n,2n)Gd155(n,2n)_Gd154(n,2n)Gd153 Tb159(n,α)Eu156(β <sup>-</sup> )Gd156(n,2n)_Gd155(n,2n)Gd154(n,2n)Gd153 Tb159(n,2n)Tb158(n,α)Eu155(β <sup>-</sup> )_Gd155(n,2n)Gd154(n,2n)Gd153 Tb159(n,3n)Tb157(n,3n)Tb155(β <sup>+</sup> )_Gd155(n,3n)Gd153 &Tb159(n,2n)Tb158(n,4n)Tb155(β <sup>+</sup> )_Gd155(n,3n)Gd153 &Tb159(n,4n)Tb156(β <sup>+</sup> )Gd156(n,4n)Gd153   Tb159(n,nt)Gd156(n,4n)Gd153   Tb159(n,5n)Tb155(β <sup>+</sup> )Gd155(n,3n)Gd153   Tb159(n,3n)Tb157(n,5n)Tb153(β <sup>+</sup> )Gd153   Tb159(n,t)Gd157(n,5n)Gd153   &Tb159(n,2n)Tb158(n,6n)Tb153(β <sup>+</sup> )Gd153   Tb159(n,6n)Tb154m(β <sup>+</sup> )Gd154(n,2n)Gd153   Tb159(n,d)Gd158(n,6n)Gd153   Tb159(n,3n)Tb157(n,2nt)Gd153				52.8 23.8 2.2	84.4 3.6 0.1	0.6 1.1 82.2 3.3 2.4 1.1 0.8	0.1 0.1 5.8 3.6 19.6 24.7 5.8 17.2 4.7 4.4 2.2	
Tm171	1.917 y	&Tb159(n,γ)Tb160(n,γ)Tb161(β <sup>-</sup> )Dy161_(n,γ)Dy162(n,γ)Dy163(n,γ)Dy164(n,γ)_Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166(β <sup>-</sup> )Er166_(n,γ)Er167(n,γ)Er168(n,γ)Er169(β <sup>-</sup> )_Tm169(n,γ)Tm170(n,γ)Tm171 &Tb159(n,γ)Tb160(n,γ)Tb161(β <sup>-</sup> )Dy161_(n,γ)Dy162(n,γ)Dy163(n,γ)Dy164(n,γ)_Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166m(n,γ)Ho167_(β <sup>-</sup> )Er167(n,γ)Er168(n,γ)Er169(β <sup>-</sup> )_Tm169(n,γ)Tm170(n,γ)Tm171	52.4 16.7	32.8 7.1	32.8 7.1					

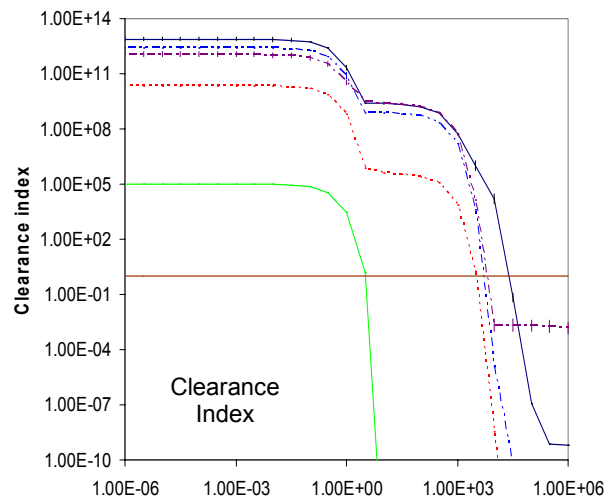
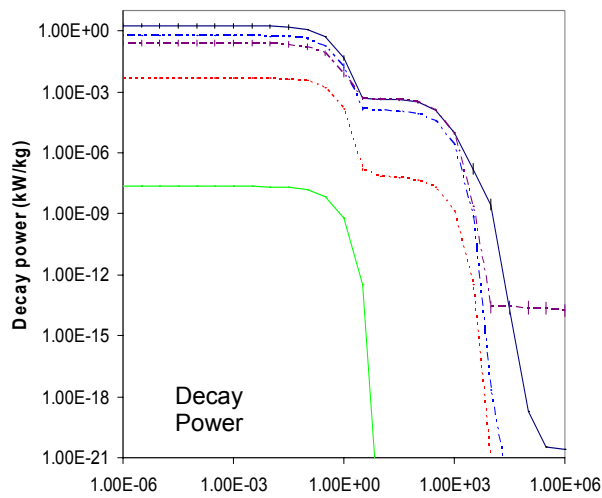
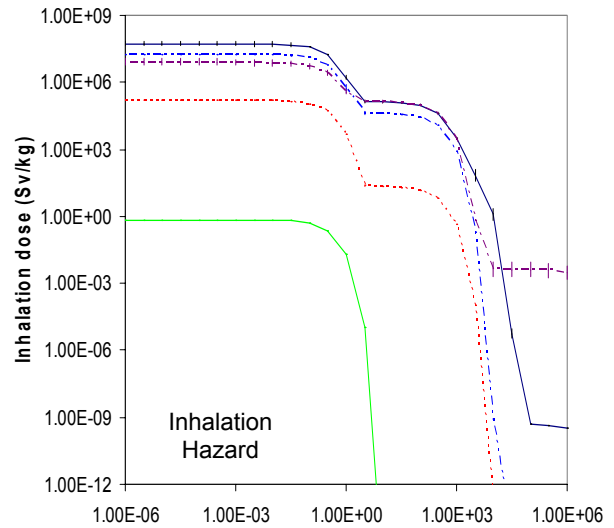
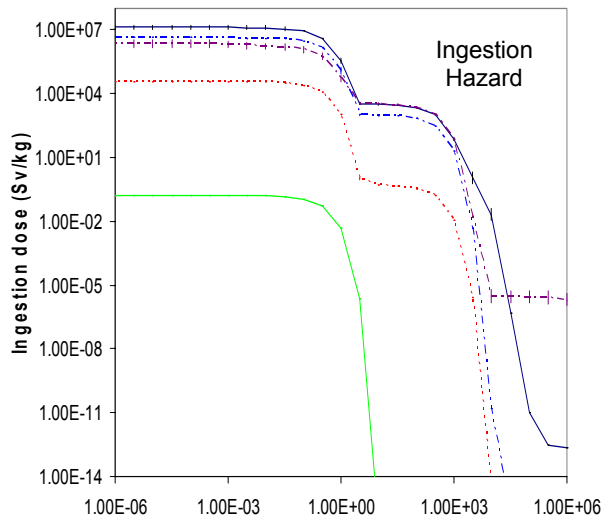
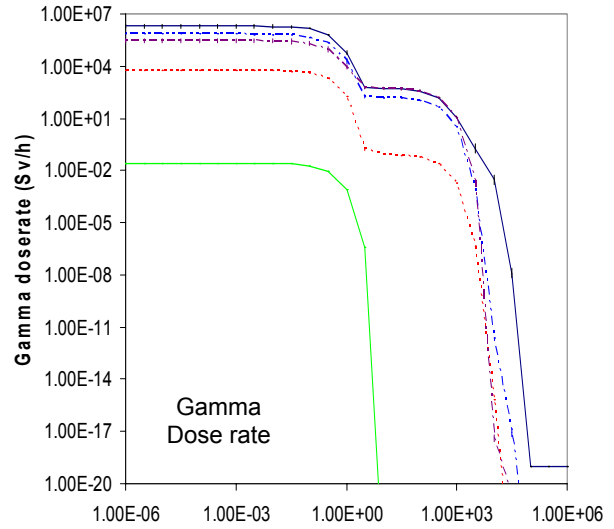
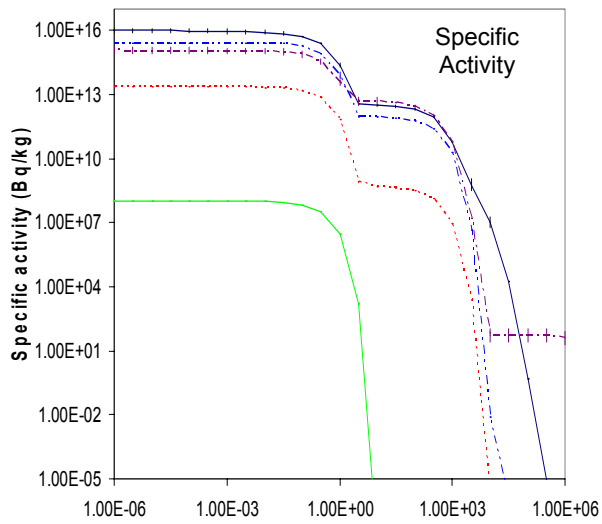
Nuclide	$T_{1/2}$	Pathway	210	186	151	42	30	21	6
	◀	&Tb159(n, $\gamma$ )Tb160( $\beta^-$ )Dy160(n, $\gamma$ )Dy161_ (n, $\gamma$ )Dy162(n, $\gamma$ )Dy163(n, $\gamma$ )Dy164(n, $\gamma$ )_ Dy165( $\beta^-$ )Ho165(n, $\gamma$ )Ho166( $\beta^-$ )Er166_ (n, $\gamma$ )Er167(n, $\gamma$ )Er168(n, $\gamma$ )Er169( $\beta^-$ )_ Tm169(n, $\gamma$ )Tm170(n, $\gamma$ )Tm171 &Tb159(n, $\gamma$ )Tb160( $\beta^-$ )Dy160(n, $\gamma$ )Dy161_ (n, $\gamma$ )Dy162(n, $\gamma$ )Dy163(n, $\gamma$ )Dy164(n, $\gamma$ )_ Dy165( $\beta^-$ )Ho165(n, $\gamma$ )Ho166m(n, $\gamma$ )Ho167_ ( $\beta^-$ )Er167(n, $\gamma$ )Er168(n, $\gamma$ )Er169( $\beta^-$ )_ Tm169(n, $\gamma$ )Tm170(n, $\gamma$ )Tm171	14.3	39.1	39.1				
			5.4	8.7	8.7				
Eu155	4.753 y	Tb159(n, $\gamma$ )Tb160( $\beta^-$ )Dy160(n, $\alpha$ )Gd157_ (n, $\alpha$ )Sm154(n, $\gamma$ )Sm155( $\beta^-$ )Eu155 Tb159(n, $\gamma$ )Tb160(n, $\alpha$ )Eu157( $\beta^-$ )Gd157_ (n, $\alpha$ )Sm154(n, $\gamma$ )Sm155( $\beta^-$ )Eu155 &Tb159(n, $\alpha$ )Eu156( $\beta^-$ )Gd156(n, $\alpha$ )_ Sm153( $\beta^-$ )Eu153(n, $\gamma$ )Eu154(n, $\gamma$ )Eu155 &Tb159(n,2n)Tb158(n, $\alpha$ )Eu155 Tb159(n, $\alpha$ )Eu155 Tb159(n, $\alpha$ )Eu156(n,2n)Eu155 &Tb159(n,4n)Tb156( $\beta^+$ )Gd156(n,d)Eu155   Tb159(n,t)Gd157(n,t)Eu155 Tb159(n,nt)Gd156(n,d)Eu155 Tb159(n,d)Gd158(n,nt)Eu155 Tb159(n,5n)Tb155( $\beta^+$ )Gd155(n,p)Eu155	99.2	39.8	54.2				
			0.8	45.8	38.1				
				12.4	2.1				
						83.2	1.6		
						13.3	92.2	64.5	69.0
						2.3			
							0.5	27.8	7.8
							0.2	2.4	5.6
							0.1	1.1	5.7
								0.6	4.5
									2.8
Eu154	8.593 y	Tb159(n, $\alpha$ )Eu156( $\beta^-$ )Gd156(n, $\alpha$ )_ Sm153( $\beta^-$ )Eu153(n, $\gamma$ )Eu154 Tb159(n, $\alpha$ )Eu156(n, $\alpha$ )Pm153( $\beta^-$ )_ Sm153( $\beta^-$ )Eu153(n, $\gamma$ )Eu154 &Tb159(n,2n)Tb158(n,2n)Tb157(n, $\alpha$ )Eu154   &Tb159(n,2n)Tb158(n, $\alpha$ )Eu155(n,2n)Eu154   &Tb159(n,2n)Tb158(n, $\alpha$ )Eu154 &Tb159(n, $\alpha$ )Eu155(n,2n)Eu154 &Tb159(n,3n)Tb157(n, $\alpha$ )Eu154 &Tb159(n,2n $\alpha$ )Eu154 &Tb159(n,3n)Tb157(n,3n)Tb155( $\beta^+$ )_ Gd155(n,d)Eu154 &Tb159(n,4n)Tb156( $\beta^+$ )Gd156(n,t)Eu154   &Tb159(n,5n)Tb155( $\beta^+$ )Gd155(n,d)Eu154   &Tb159(n,nt)Gd156(n,t)Eu154 &Tb159(n,t)Gd157(n,nt)Eu154 &Tb159(n,2nt)Gd155(n,d)Eu154 &Tb159(n,d)Gd158(n,2nt)Eu154	63.7	95.0	87.2				
			34.7	3.4	11.2				
						44.9	0.2		
						30.2			
						15.7	28.1	3.2	1.5
						7.4	7.5	0.8	0.4
							25.3	0.6	0.5
							16.8	68.5	57.1
							16.8		
								0.2	17.6
								2.3	21.5
								0.5	3.6
									3.2
									1.8
									1.4
H3	12.33 y	Tb159(n,X)H3 &Tb159(n,2n)Tb158(n,X)H3 &Tb159(n,2n)Tb158(n,2n)Tb157(n,X)H3   Tb159(n,3n)Tb157(n,X)H3 Tb159(n,4n)Tb156( $\beta^+$ )Gd156(n,X)H3 Tb159(n,5n)Tb155( $\beta^+$ )Gd155(n,X)H3				85.9	82.6	86.3	85.7
						9.8	4.7	3.2	1.9
						4.1	1.7	1.3	
							9.1	3.2	1.7
								2.6	
									4.1
Gd148	74.60 y	Tb159(n,3n)Tb157(n,3n)Tb155( $\beta^+$ )Gd155_ (n,4n)Gd152(n,3n)Gd150(n,3n)Gd148 Tb159(n,3n)Tb157(n,3n)Tb155( $\beta^+$ )Gd155_ (n,3n)Gd153(n,4n)Gd150(n,3n)Gd148 &Tb159(n,4n)Tb156( $\beta^+$ )Gd156(n,4n)_ Gd153(n,4n)Gd150(n,3n)Gd148 Tb159(n,4n)Tb156( $\beta^+$ )Gd156(n,3n)_ Gd154(n,4n)Gd151(n,4n)Gd148 Tb159(n,3n)Tb157(n,4n)Tb154m( $\beta^+$ )_ Gd154(n,4n)Gd151(n,4n)Gd148 &Tb159(n,3n)Tb157(n,4n)Tb154( $\beta^+$ )_ Gd154(n,4n)Gd151(n,4n)Gd148					41.5	0.2	
							16.2		
								21.3	
								8.6	
								7.8	
								4.3	



Nuclide	T <sub>½</sub>	Pathway	210	186	151	42	30	21	6
	◀	Tb159(n,5n)Tb155(β <sup>+</sup> )Gd155(n,4n) Gd152(n,5n)Gd148 Tb159(n,5n)Tb155(β <sup>+</sup> )Gd155(n,5n) Gd151(n,4n)Gd148 Tb159(n,4n)Tb156(β <sup>+</sup> )Gd156(n,5n) Gd152(n,5n)Gd148 Tb159(n,5n)Tb155(β <sup>+</sup> )Gd155(n,6n) Gd150(n,3n)Gd148 Tb159(n,nt)Gd156(n,5n)Gd152(n,5n)Gd148 Tb159(n,t)Gd157(n,6n)Gd152(n,5n)Gd148 Tb159(n,3n)Tb157(n,5n)Tb153(β <sup>+</sup> ) Gd153(n,6n)Gd148 Tb159(n,6n)Tb154m(β <sup>+</sup> )Gd154(n,5n) Gd150(n,3n)Gd148 Tb159(n,6n)Tb154m(β <sup>+</sup> )Gd154(n,3n) Gd152(n,5n)Gd148 Many other similar pathways						3.3	19.2
								3.3	4.0
								1.7	8.6
									11.6
									6.3
									4.2
									3.7
									3.5
									3.2
						100.0	42.3	49.5	35.7
Sm151	90.0 y	&Tb159(n,2n)Tb158(n,2n)Tb157(n,2n)Tb156 (β <sup>+</sup> )Gd156(n,2n)Gd155(n,2n)Gd154(n,α)Sm151 &Tb159(n,2n)Tb158(n,2n)Tb157(n,2n) Tb156(β <sup>+</sup> )Gd156(n,2n)Gd155(n,α)Sm151 Tb159(n,α)Eu156(β <sup>-</sup> )Gd156(n,2n) Gd155(n,2n)Gd154(n,α)Sm151 &Tb159(n,2n)Tb158(n,2n)Tb157(n,2n)Tb156 (β <sup>+</sup> )Gd156(n,2n)Gd155(n,α)Sm152(n,2n)Sm151 Tb159(n,α)Eu156(β <sup>-</sup> )Gd156(n,2n) Gd155(n,α)Sm152(n,2n)Sm151 Tb159(n,α)Eu156(β <sup>-</sup> )Gd156(n,2n) Gd155(n,α)Sm151 &Tb159(n,2n)Tb158(n,2n)Tb157(n,α) Eu154(n,α)Pm151(β <sup>-</sup> )Sm151 &Tb159(n,2n)Tb158(n,2n)Tb157(n,2n) Tb156(β <sup>+</sup> )Gd156(n,α)Sm152(n,2n)Sm151 Tb159(n,α)Eu155(n,α)Pm151(β <sup>-</sup> )Sm151 Tb159(n,3n)Tb157(n,3n)Tb155(β <sup>+</sup> ) Gd155(n,α)Sm151 Tb159(n,2n)Tb158(n,4n)Tb155(β <sup>+</sup> ) Gd155(n,α)Sm151 Tb159(n,4n)Tb156(β <sup>+</sup> )Gd156(n,2nα)Sm151 Tb159(n,4n)Tb156(β <sup>+</sup> )Gd156(n,4n) Gd153(β <sup>+</sup> )Eu153(n,t)Sm151 Tb159(n,5n)Tb155(β <sup>+</sup> )Gd155(n,α)Sm151 Tb159(n,nt)Gd156(n,2nα)Sm151 Tb159(n,2nα)Eu154(n,nt)Sm151 Tb159(n,3nα)Eu153(n,t)Sm151 Tb159(n,t)Gd157(n,3nα)Sm151 Tb159(n,2nt)Gd155(n,α)Sm151 Tb159(n,3n)Tb157(n,5n)Tb153(β <sup>+</sup> ) Gd153(β <sup>+</sup> )Eu153(n,t)Sm151 Tb159(n,6n)Tb154m(β <sup>+</sup> )Gd154(n,α)Sm151 Tb159(n,d)Gd158(n,4nα)Sm151 Many other similar long pathways				16.8			
									15.5
									9.1
									8.6
									5.0
									4.9
									3.8
									3.0
									0.1
							3.8	0.7	0.2
							75.3	1.4	0.2
								2.4	0.2
								0.2	55.6
								9.2	0.4
									6.6
									33.1
									2.2
									4.6
									1.6
									2.7
									0.8
									6.9
									0.8
									6.5
									0.2
									2.7
									0.1
									2.1
									3.1
									2.8
									27.1
Tb157	99.0 y	&Tb159(n,2n)Tb158(n,2n)Tb157 Tb159(n,3n)Tb157				99.9		1.9	
							98.4	97.3	97.8
Tb158	180.0 y	&Tb159(n,2n)Tb158				99.9	99.9	99.9	99.9
Hol66m	1200 y	&Tb159(n,γ)Tb160(n,γ)Tb161(β <sup>-</sup> )Dy161 (n,γ)Dy162(n,γ)Dy163(n,γ)Dy164(n,γ) Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166m &Tb159(n,γ)Tb160(β <sup>-</sup> )Dy160(n,γ)Dy161 (n,γ)Dy162(n,γ)Dy163(n,γ)Dy164(n,γ) Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166m	61.2	36.4	48.7				
			36.6	60.5	46.9				

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
La137	6.0 10 <sup>4</sup> y	Pathways involving (n,α), (n,nα), (n,2n), β <sup>+</sup>				100.0	100.0	100.0	100.0	
Gd150	1.8 10 <sup>6</sup> y	&Tb159(n,2n)Tb158(n,2n)Tb157(n,nα) Eu153(n,2n)Eu152(n,2n)Eu151(n,2n) Eu150m(β <sup>-</sup> )Gd150				8.0				
		Tb159(n,α)Eu156(β <sup>-</sup> )Gd156(n,2n) Gd155(n,2n)Gd154(n,2n)Gd153(n,2n) Gd152(n,2n)Gd151(n,2n)Gd150				7.5				
		&Tb159(n,2n)Tb158(n,2n)Tb157(n,α) Eu154(n,2n)Eu153(n,2n)Eu152(n,2n) Eu151(n,2n)Eu150m(β <sup>-</sup> )Gd150				4.7				
		&Tb159(n,2n)Tb158(n,nα)Eu154(n,2n) Eu153(n,2n)Eu152(n,2n)Eu151(n,2n) Eu150m(β <sup>-</sup> )Gd150				4.5				
		Tb159(n,α)Eu156(β <sup>-</sup> )Gd156(n,α) Sm153(β <sup>-</sup> )Eu153(n,2n)Eu152(n,2n) Eu151(n,2n)Eu150m(β <sup>-</sup> )Gd150				4.0				
		&Tb159(n,2n)Tb158(n,α)Eu155(n,2n) Eu154(n,2n)Eu153(n,2n)Eu152(n,2n) Eu151(n,2n)Eu150m(β <sup>-</sup> )Gd150				2.8				
		&Tb159(n,nα)Eu155(n,2n)Eu154(n,2n) Eu153(n,2n)Eu152(n,2n)Eu151(n,2n) Eu150m(β <sup>-</sup> )Gd150				2.4				
		Tb159(n,3n)Tb157(n,3n)Tb155(β <sup>+</sup> ) Gd155(n,4n)Gd152(n,3n)Gd150						42.3	0.7	
		Tb159(n,3n)Tb157(n,3n)Tb155(β <sup>+</sup> ) Gd155(n,3n)Gd153(n,4n)Gd150						14.8	0.2	
		Tb159(n,3n)Tb157(n,3n)Tb155(β <sup>+</sup> ) (n,2n)Gd154(n,3n)Gd152(n,3n)Gd150						3.7		
		&Tb159(n,2n)Tb158(n,3n)Tb156(β <sup>+</sup> )Gd156 (n,3n)Gd154(n,3n)Gd152(n,3n)Gd150						2.9		
		Tb159(n,4n)Tb156(β <sup>+</sup> )Gd156(n,3n) Gd154(n,3n)Gd152(n,3n)Gd150						2.7	0.3	
		Tb159(n,3n)Tb157(n,3n)Tb155(β <sup>+</sup> ) Gd155(n,3n)Gd153(β <sup>+</sup> )Eu153(n,4n) Eu150m(β <sup>-</sup> )Gd150						2.5		
		Tb159(n,3n)Tb157(n,2n)Tb156(β <sup>+</sup> )Gd156 (n,3n)Gd154(n,3n)Gd152(n,3n)Gd150						2.0		
		&Tb159(n,4n)Tb156(β <sup>+</sup> )Gd156(n,4n) Gd153(n,4n)Gd150							41.8	0.4
		Tb159(n,4n)Tb156(β <sup>+</sup> )Gd156(n,4n)Gd153 (β <sup>+</sup> )Eu153(n,4n)Eu150m(β <sup>-</sup> )Gd150							15.1	
		Tb159(n,4n)Tb156(β <sup>+</sup> )Gd156(n,5n) Gd152(n,3n)Gd150							2.3	0.2
		Tb159(n,5n)Tb155(β <sup>+</sup> )Gd155(n,6n)Gd150 Tb159(n,6n)Tb154m(β <sup>+</sup> )Gd154(n,5n)Gd150								52.1
&Tb159(n,6n)Tb154(β <sup>+</sup> )Gd154(n,5n)Gd150 Tb159(n,6n)Tb154n(β <sup>+</sup> )Gd154(n,5n)Gd150 Tb159(n,2nt)Gd155(n,6n)Gd150								15.7		
Many other similar pathways						66.1	29.1	39.6	12.1	
Hf182	9.0 10 <sup>6</sup> y	Very long pathways of (n,γ), β <sup>-</sup>	100.0	100.0						
Lu176	4.0 10 <sup>10</sup> y	Very long pathways of (n,γ), β <sup>-</sup>	100.0	100.0						
La138	1.0 10 <sup>11</sup> y	Pathways involving (n,α), (n,nα), (n,2n), β <sup>+</sup>				100.0	100.0	100.0	100.0	
Gd160	1.3 10 <sup>17</sup> y	Tb159(n,γ)Tb160(n,γ)Tb161(β <sup>-</sup> )Dy161 (n,γ)Dy162(n,γ)Dy163(n,α)Gd160	67.2	37.4	42.0					
		Tb159(n,γ)Tb160(β <sup>-</sup> )Dy160(n,γ)Dy161 (n,γ)Dy162(n,γ)Dy163(n,α)Gd160	31.5	60.8	55.8					
		Tb159(n,γ)Tb160(n,γ)Tb161(n,γ)Tb162 (β <sup>-</sup> )Dy162(n,γ)Dy163(n,α)Gd160	0.9	1.4	0.7					
		Tb159(n,γ)Tb160(n,p)Gd160				99.0	99.2	99.3	99.4	

# Terbium activation characteristics

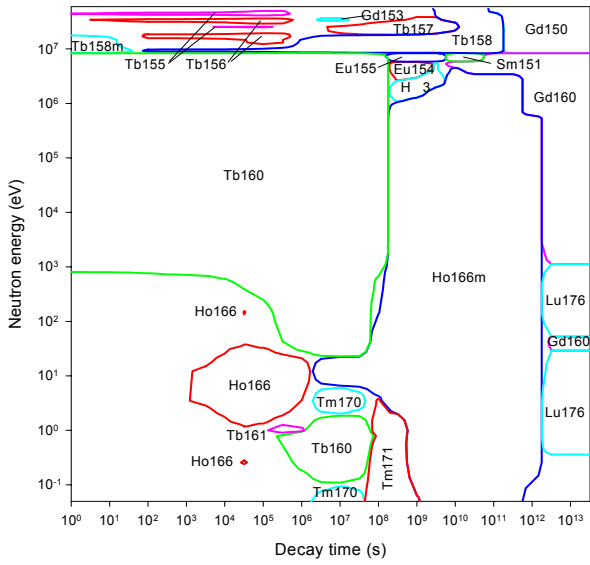


Decay time (years)

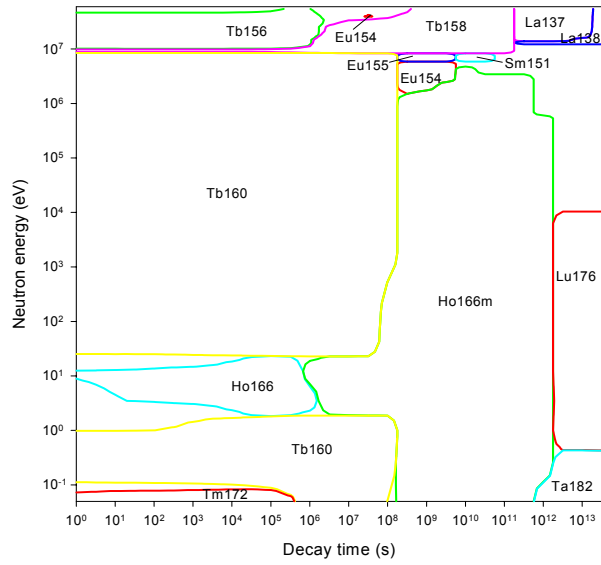
Decay time (years)

# Terbium importance diagrams & transmutation

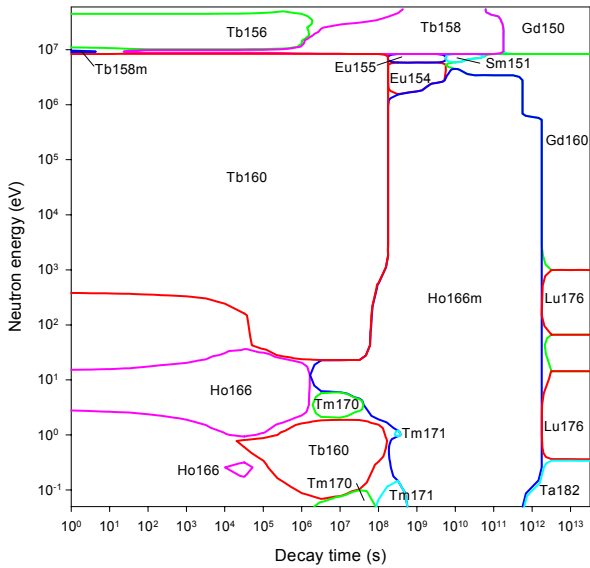
Activity



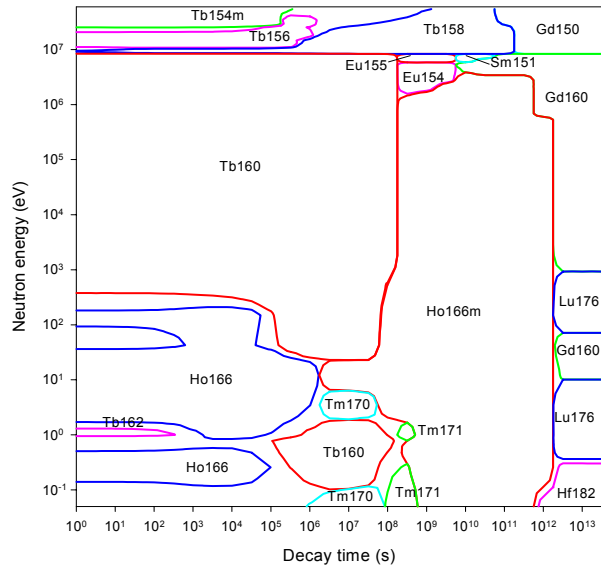
Dose rate



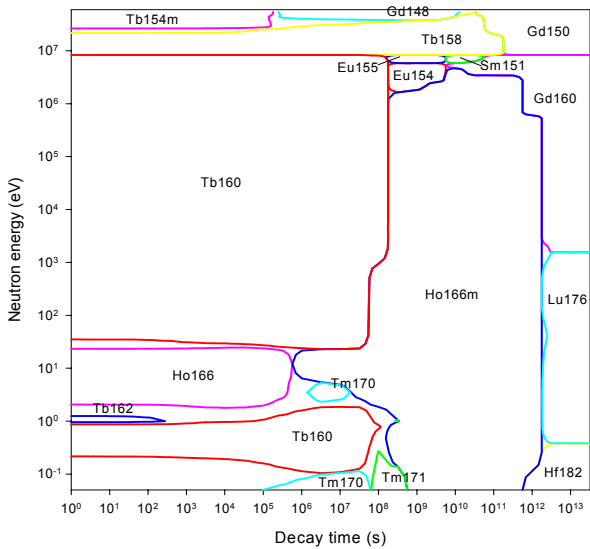
Heat output



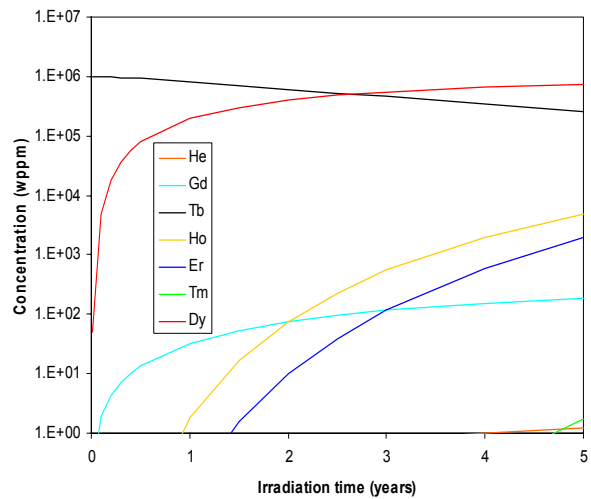
Ingestion dose



Inhalation dose



First wall transmutation



# Dysprosium

## General properties

Atomic number	66	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	5.2	Dy156	0.06 ( $T_{1/2}=1.00 \cdot 10^{18}$ y)
Melting point / K	1684	Dy158	0.10
Boiling point / K	2834	Dy160	2.34
Density / $\text{kgm}^{-3}$	8551	Dy161	18.91
Thermal conductivity / $\text{Wm}^{-1}\text{K}^{-1}$	10.7	Dy162	25.51
Electrical resistivity / $\Omega\text{m}$	$5.7 \cdot 10^{-7}$	Dy163	24.90
Coefficient of thermal expansion / $\text{K}^{-1}$	$9.9 \cdot 10^{-6}$	Dy164	28.18
Crystal structure	Rhombic		
Number of stable isotopes	6 (7)		
Mean atomic weight	162.5		

## Activation properties

Act	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Heat	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Bq $\text{kg}^{-1}$	1.05E16	7.38E15	3.62E14	2.78E12	1.64E11	3.18E1	kW $\text{kg}^{-1}$	7.36E-1	6.62E-1	3.88E-2	1.71E-4	2.56E-5	7.98E-16
Dy165	38.52	53.44					Ho166	46.13	51.20	91.37			
Ho166	27.95	39.51	84.36				Dy165	41.58	45.30				
Dy165m	24.64	1.92					Dy165m	6.99	0.43				
Er167m	5.28	0.22					Er167m	2.50	0.08				
Ho167	1.30	1.80					Ho167	1.74	1.90				
Er169	0.37	0.53	8.19				Tb160	0.30	0.34	5.53	39.18		
Tb160	0.10	0.14	2.67	10.85			Er169	0.09	0.10	1.25			
Tm170	0.08	0.12	2.29	42.51			Tm170	0.06	0.07	1.14	36.70		
Dy159	0.04	0.06	1.22	27.91			Dy159	0.01	0.01	0.11	4.24		
Tm171		0.01	0.10	9.29			Tm168	0.01	0.01	0.11	1.67		
Tb157			0.03	3.76	31.74		Ho166m			0.05	11.44	72.26	
Ho166m			0.02	2.49	39.65		Tb158			0.03	5.96	27.22	
Tb158			0.02	2.47	28.53		Dy154						94.55
Ho163					0.07	94.76	Gd150						3.85
Dy154						5.02	Ho163						1.60
Dose	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Ing	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{h}^{-1}$	4.23E4	3.63E4	4.42E3	1.16E2	2.78E1	1.44E-15	Sv $\text{kg}^{-1}$	4.63E6	4.60E6	4.69E5	2.35E3	1.84E2	9.69E-8
Ho166	39.57	46.03	39.55				Ho166	88.49	88.87	90.97			
Dy165	29.19	33.33					Dy165	9.58	9.45				
Ho167	9.89	11.31					Tb160	0.35	0.35	3.29	20.49		
Dy165m	8.31	0.53					Er169	0.31	0.31	2.34			
Tb160	6.20	7.23	57.34	68.52			Tm170	0.24	0.24	2.30	65.21		
Er167m	5.00	0.17					Ho167	0.24	0.24				
Tb164	0.82	0.28					Dy159	0.01	0.01	0.09	3.29		
Tm168	0.11	0.13	1.05	2.72		2.60	Ho166m			0.03	5.87	70.95	
Ho166m	0.05	0.06	0.47	17.81	69.73		Tb158			0.02	3.21	28.08	
Tb158	0.03	0.03	0.28	10.68	30.24		Tm171			0.01	1.21		
Tm170				0.02*			Dy154						95.61
Tb156						80.07	Gd150						3.67
Lu176						17.28							

Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	2.37E6	2.35E6	3.74E5	2.26E4	1.00E4	4.24E-5		2.45E11	1.11E11	1.38E10	5.40E8	1.47E8	2.92E-5
Ho166	80.07	80.59	53.07				Dy165m	31.83	3.88				
Dy165	10.19	10.06					Er167m	24.21	1.54				
Tb160	2.95	2.98	18.09	9.32			Ho167	21.30	46.19				
Tm170	2.49	2.52	15.54	36.50			Ho166	11.92	26.29	22.09			
Er169	1.63	1.65	7.93	0.82	0.28		Tb160	4.08	9.01	69.93	55.77		
Ho167	0.41	0.40					Dy165	1.64	3.56				
Ho166m	0.35	0.35	2.22	36.58	77.89		Dy165m	1.64	3.56				
Dy166	0.31	0.31	0.93				Er167m	1.31	2.67				
Tb158	0.13	0.14	0.85	13.95	21.49		Ho167	1.12	2.45	0.06			
Dy159	0.07	0.07	0.44	1.27			Ho166	0.63	0.41				
Tm171	0.02	0.02	0.14	1.60			Tb160	0.59	1.19				
Tb157			0.03	0.55	0.62		Dy165	0.54	1.19	0.01			
Dy154						86.60	Ho164	0.11	0.21				
Gd150						13.39	Er165	0.10	0.23	1.80	3.12		
							Tm168	0.10	0.23	1.80	3.12		
							Tb164	0.10	0.23	1.20			0.02
							Dy159	0.09	0.19	1.52	6.83		
							Ho166m	0.05	0.10	0.82	20.94	72.93	
							Tm170		0.08	0.60	2.19		
							Tb158			0.42	10.59	26.68	
							Dy154						62.97
							Ho163						27.20
							Gd150						9.78

# Dysprosium

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6		
Er167m	2.269 s	&Dy162(n,γ)Dy163(n,γ)Dy164(n,γ) Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166(β <sup>-</sup> )Er166_ (n,γ)Er167m	25.6	0.5							
		&Dy164(n,γ)Dy165(β <sup>-</sup> )Ho165(n,γ) Ho166(β <sup>-</sup> )Er166(n,γ)Er167m	25.4	48.9	94.1	91.7	94.2	94.0	93.6		
		&Dy163(n,γ)Dy164(n,γ)Dy165(β <sup>-</sup> ) Ho165(n,γ)Ho166(β <sup>-</sup> )Er166(n,γ)Er167m	24.1	48.1	2.9						
		&Dy161(n,γ)Dy162(n,γ)Dy163(n,γ) Dy164(n,γ)Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166_ (β <sup>-</sup> )Er166(n,γ)Er167m	19.2								
		&Dy160(n,γ)Dy161(n,γ)Dy162(n,γ) Dy163(n,γ)Dy164(n,γ)Dy165(β <sup>-</sup> )Ho165_ (n,γ)Ho166(β <sup>-</sup> )Er166(n,γ)Er167m	2.2								
		Dy164(n,γ)Dy165m(β <sup>-</sup> )Ho165(n,γ) Ho166(β <sup>-</sup> )Er166(n,γ)Er167m	0.4	0.8	1.4	0.5	0.5	0.5	0.5		
		&Dy164(n,γ)Dy165(β <sup>-</sup> )Ho165(n,γ) Ho166m(n,γ)Ho167(β <sup>-</sup> )Er167m		0.1	1.0	5.7	3.9	4.2	4.7		
Tb163	19.5 m	&Dy162(n,γ)Dy163(n,γ)Dy164(n,γ) Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166(n,α)Tb163	24.1	0.1							
		&Dy161(n,γ)Dy162(n,γ)Dy163(n,γ) Dy164(n,γ)Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166_ (n,α)Tb163	20.8	0.1							
		&Dy163(n,γ)Dy164(n,γ)Dy165(β <sup>-</sup> ) Ho165(n,γ)Ho166(n,α)Tb163	16.6	3.5							
		&Dy164(n,γ)Dy165(β <sup>-</sup> )Ho165(n,γ) Ho166(n,α)Tb163	11.2	1.0	3.1						
		&Dy162(n,γ)Dy163(n,γ)Dy164(n,γ) Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166m(n,α)Tb163	7.4	1.9							
		&Dy161(n,γ)Dy162(n,γ)Dy163(n,γ) Dy164(n,γ)Dy165(β <sup>-</sup> )Ho165(n,γ) Ho166m(n,α)Tb163	6.3	1.3							
		&Dy163(n,γ)Dy164(n,γ)Dy165(β <sup>-</sup> ) Ho165(n,γ)Ho166m(n,α)Tb163	5.0	62.3	2.9						
		&Dy164(n,γ)Dy165(β <sup>-</sup> )Ho165(n,γ) Ho166m(n,α)Tb163	3.2	28.2	91.8						
		Dy160(n,γ)Dy161(n,γ)Dy162(n,γ) Dy163(n,γ)Dy164(n,γ)Dy165(β <sup>-</sup> )Ho165_ (n,γ)Ho166(n,α)Tb163	2.1								
		Dy163(n,γ)Dy164(n,γ)Dy165m(β <sup>-</sup> ) Ho165(n,γ)Ho166m(n,α)Tb163			1.0						
		Dy164(n,γ)Dy165m(β <sup>-</sup> )Ho165(n,γ) Ho166m(n,α)Tb163		0.4	1.4						
		Dy163(n,p)Tb163					71.0	16.2	8.5	5.0	
		Dy164(n,2n)Dy163(n,p)Tb163					25.2				
		Dy164(n,d)Tb163					3.7	82.6	90.9	94.7	
		Dy165	2.334 h	&Dy160(n,γ)Dy161(n,γ)Dy162(n,γ) Dy163(n,γ)Dy164(n,γ)Dy165	50.0	0.8					
				&Dy161(n,γ)Dy162(n,γ)Dy163(n,γ) Dy164(n,γ)Dy165	20.2	17.1					
&Dy162(n,γ)Dy163(n,γ)Dy164(n,γ)Dy165	19.0			22.2	0.1						
&Dy163(n,γ)Dy164(n,γ)Dy165	5.9			59.8	7.9						
&Dy158(n,γ)Dy159(n,γ)Dy160(n,γ) Dy161(n,γ)Dy162(n,γ)Dy163(n,γ) Dy164(n,γ)Dy165	4.9										
&Dy164(n,γ)Dy165				0.1	91.8	100.0	100.0	100.0	100.0		

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
Dy157	8.14 h	Dy156(n,γ)Dy157	100.0	100.0	100.0					
		Dy158(n,2n)Dy157				64.9	2.2			
		Dy161(n,2n)Dy160(n,2n)Dy159(n,2n)_				17.4				
		Dy158(n,2n)Dy157								
		Dy160(n,2n)Dy159(n,2n)Dy158(n,2n)Dy157				15.1				
		Dy162(n,2n)Dy161(n,2n)Dy160(n,2n)_				2.2				
		Dy159(n,2n)Dy158(n,2n)Dy157								
		Dy161(n,3n)Dy159(n,3n)Dy157						24.2		
		Dy162(n,3n)Dy160(n,3n)Dy158(n,2n)Dy157						15.3		
		Dy161(n,4n)Dy158(n,2n)Dy157						12.9	8.4	
		Dy160(n,3n)Dy158(n,2n)Dy157						11.8		
		Dy163(n,3n)Dy161(n,3n)Dy159(n,3n)Dy157						4.9		
		Dy163(n,4n)Dy160(n,3n)Dy158(n,2n)Dy157						4.7		
		Dy162(n,3n)Dy160(n,4n)Dy157						1.2	10.6	
		Dy160(n,4n)Dy157						0.5	16.2	2.6
		Dy163(n,4n)Dy160(n,4n)Dy157						0.4	27.9	1.1
		Dy161(n,2n)Dy160(n,4n)Dy157						0.2	5.6	
		Dy164(n,5n)Dy160(n,4n)Dy157							8.8	2.3
Dy161(n,5n)Dy157							6.8	40.1		
Dy162(n,6n)Dy157								34.3		
Tb154m	9.0 h	Dy156(n,2n)Dy155(β <sup>+</sup> )Tb155(n,2n)Tb154m				100.0	0.1			
		Dy161(n,4n)Dy158(n,3n)Dy156(n,t)Tb154m					11.5	0.7		
		Dy156(n,t)Tb154m					10.8	0.3	0.2	
		Dy160(n,3n)Dy158(n,3n)Dy156(n,t)Tb154m					10.6			
		Dy162(n,3n)Dy160(n,3n)Dy158(n,3n)_					9.1			
		Dy156(n,t)Tb154m								
		Dy156(n,3n)Dy154(n,p)Tb154m					9.1			
		Dy161(n,3n)Dy159(β <sup>+</sup> )Tb159(n,3n)_					6.2	1.9		
		Tb157(n,4n)Tb154m								
		Dy162(n,4n)Dy159(β <sup>+</sup> )Tb159(n,3n)_					0.6	7.4	0.1	
		Tb157(n,4n)Tb154m								
		Dy161(n,4n)Dy158(n,2n)Dy157(β <sup>+</sup> )_					0.4	5.4	0.1	
		Tb157(n,4n)Tb154m								
		Dy160(n,4n)Dy157(β <sup>+</sup> )Tb157(n,4n)Tb154m							21.0	0.7
		Dy163(n,4n)Dy160(n,4n)Dy157(β <sup>+</sup> )_							18.1	0.2
		Tb157(n,4n)Tb154m								
		Dy161(n,5n)Dy157(β <sup>+</sup> )Tb157(n,4n)Tb154m							8.8	11.1
		Dy162(n,3n)Dy160(n,4n)Dy157(β <sup>+</sup> )_							6.9	0.1
		Tb157(n,4n)Tb154m								
		Dy164(n,5n)Dy160(n,4n)Dy157(β <sup>+</sup> )_							5.7	0.3
Tb157(n,4n)Tb154m										
Dy164(n,6n)Dy159(β <sup>+</sup> )Tb159(n,6n)Tb154m								15.4		
Dy163(n,5n)Dy159(β <sup>+</sup> )Tb159(n,6n)Tb154m								12.0		
Dy162(n,6n)Dy157(β <sup>+</sup> )Tb157(n,4n)Tb154m								9.5		
Dy162(n,4n)Dy159(β <sup>+</sup> )Tb159(n,6n)Tb154m								6.7		
Many other similar long pathways							41.6	23.8	43.6	
Ho166	1.117 d	&Dy162(n,γ)Dy163(n,γ)Dy164(n,γ)_	30.8	4.8						
		Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166								
		&Dy161(n,γ)Dy162(n,γ)Dy163(n,γ)_	26.1	3.5						
		Dy164(n,γ)Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166								
		&Dy163(n,γ)Dy164(n,γ)Dy165(β <sup>-</sup> )_	20.8	69.7	4.3					
		Ho165(n,γ)Ho166								
		&Dy164(n,γ)Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166	13.0	20.1	94.1	99.2	99.1	99.2	99.4	
		&Dy160(n,γ)Dy161(n,γ)Dy162(n,γ)Dy163_	7.1	0.5						
		(n,γ)Dy164(n,γ)Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166								
		Dy163(n,γ)Dy164(n,γ)Dy165m(β <sup>-</sup> )_	0.3	1.1						
Ho165(n,γ)Ho166										
Dy164(n,γ)Dy165m(β <sup>-</sup> )Ho165(n,γ)Ho166	0.2	0.3	1.4	0.6	0.5	0.5	0.5			
Tm172	2.650 d	&Dy164(n,γ)Dy165(β <sup>-</sup> )Ho165(n,γ)_	29.3	51.5	82.8					
		Ho166(β <sup>-</sup> )Er166(n,γ)Er167(n,γ)Er168_								
		(n,γ)Er169(β <sup>-</sup> )Tm169(n,γ)Tm170(n,γ)_								
		Tm171(n,γ)Tm172								



Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	&Dy163(n,γ)Dy164(n,γ)Dy165(β <sup>-</sup> ) Ho165(n,γ)Ho166(β <sup>-</sup> )Er166(n,γ)Er167 (n,γ)Er168(n,γ)Er169(β <sup>-</sup> )Tm169(n,γ) Tm170(n,γ)Tm171(n,γ)Tm172 &Dy162(n,γ)Dy163(n,γ)Dy164(n,γ) Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166(β <sup>-</sup> )Er166 (n,γ)Er167(n,γ)Er168(n,γ)Er169(β <sup>-</sup> ) Tm169(n,γ)Tm170(n,γ)Tm171(n,γ)Tm172 &Dy161(n,γ)Dy162(n,γ)Dy163(n,γ) Dy164(n,γ)Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166 (β <sup>-</sup> )Er166(n,γ)Er167(n,γ)Er168(n,γ) Er169(β <sup>-</sup> )Tm169(n,γ)Tm170(n,γ) Tm171(n,γ)Tm172 &Dy164(n,γ)Dy165(β <sup>-</sup> )Ho165(n,γ) Ho166m(n,γ)Ho167(β <sup>-</sup> )Er167(n,γ) Er168(n,γ)Er169(β <sup>-</sup> )Tm169(n,γ)Tm170 (n,γ)Tm171(n,γ)Tm172 &Dy163(n,γ)Dy164(n,γ)Dy165(β <sup>-</sup> ) Ho165(n,γ)Ho166m(n,γ)Ho167(β <sup>-</sup> ) Er167(n,γ)Er168(n,γ)Er169(β <sup>-</sup> )Tm169 (n,γ)Tm170(n,γ)Tm171(n,γ)Tm172 &Dy162(n,γ)Dy163(n,γ)Dy164(n,γ) Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166m(n,γ)Ho167 (β <sup>-</sup> )Er167(n,γ)Er168(n,γ)Er169(β <sup>-</sup> ) Tm169(n,γ)Tm170(n,γ)Tm171(n,γ)Tm172 &Dy161(n,γ)Dy162(n,γ)Dy163(n,γ)Dy164 (n,γ)Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166m(n,γ) Ho167(β <sup>-</sup> )Er167(n,γ)Er168(n,γ)Er169(β <sup>-</sup> ) Tm169(n,γ)Tm170(n,γ)Tm171(n,γ)Tm172	20.2	29.9	1.1					
			16.8	0.1						
			11.3							
			4.8	7.8	7.9					
			3.8	5.1	0.1					
			3.6							
			2.5							
Tb156	5.17 d	Dy156(β <sup>+</sup> )Tb156 &Dy158(n,2n)Dy157(β <sup>+</sup> )Tb157(n,2n)Tb156 &Dy160(n,2n)Dy159(β <sup>+</sup> )Tb159(n,2n) Tb158(n,2n)Tb157(n,2n)Tb156 &Dy161(n,2n)Dy160(n,2n)Dy159(β <sup>+</sup> ) Tb159(n,2n)Tb158(n,2n)Tb157(n,2n)Tb156 &Dy160(n,2n)Dy159(n,2n)Dy158 (n,2n)Dy157(β <sup>+</sup> )Tb157(n,2n)Tb156 &Dy161(n,2n)Dy160(n,2n)Dy159(n,2n) Dy158(n,2n)Dy157(β <sup>+</sup> )Tb157(n,2n)Tb156 &Dy161(n,3n)Dy159(β <sup>+</sup> )Tb159(n,2n) Tb158(n,3n)Tb156 &Dy161(n,3n)Dy159(β <sup>+</sup> )Tb159(n,3n) Tb157(n,2n)Tb156 &Dy161(n,3n)Dy159(β <sup>+</sup> )Tb159(n,4n)Tb156 &Dy161(n,3n)Dy159(n,3n)Dy157(β <sup>+</sup> ) Tb157(n,2n)Tb156 &Dy162(n,4n)Dy159(β <sup>+</sup> )Tb159(n,4n)Tb156 &Dy163(n,5n)Dy159(β <sup>+</sup> )Tb159(n,4n)Tb156 &Dy161(n,5n)Dy157(β <sup>+</sup> )Tb157(n,2n)Tb156 &Dy162(n,5n)Dy158(n,t)Tb156 &Dy164(n,6n)Dy159(β <sup>+</sup> )Tb159(n,4n)Tb156 &Dy162(n,6n)Dy157(β <sup>+</sup> )Tb157(n,2n)Tb156 &Dy163(n,6n)Dy158(n,t)Tb156 Many other similar long pathways	100.0		100.0	59.7 15.3 6.8 6.3 4.8	0.5 23.8 21.4 8.4 5.0 0.8 8.6 0.7 0.2	12.6 3.4	5.6 10.0 11.1 5.4 12.9 9.5 4.2 37.9	
Tb161	6.89 d	&Dy156(n,γ)Dy157(β <sup>+</sup> )Tb157(n,γ) Tb158(n,γ)Tb159(n,γ)Tb160(n,γ)Tb161 Dy158(n,γ)Dy159(β <sup>+</sup> )Tb159(n,γ)Tb160 (n,γ)Tb161 Dy161(n,p)Tb161 Dy162(n,2n)Dy161(n,p)Tb161 Dy164(n,α)Gd161(β <sup>-</sup> )Tb161	98.3	60.3	2.3					
			1.9	41.8	97.7					
						52.1 22.1 13.7	11.5 0.8 4.2	5.1 0.8 0.8	1.9	

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
		Dy162(n,d)Tb161 Dy163(n,2n)Dy162(n,2n)Dy161(n,p)Tb161   Dy163(n,2n)Dy162(n,d)Tb161 Dy163(n,t)Tb161 Dy164(n,2n)Dy163(n,t)Tb161 Dy164(n,3n)Dy162(n,d)Tb161 Dy163(n,3n)Dy161(n,p)Tb161 Dy164(n,nt)Tb161 Dy164(n,4n)Dy161(n,p)Tb161				5.4 3.4 1.7 0.9 0.3 11.4 2.7 1.3 1.0	50.5 2.8 12.2 0.7 2.6 8.7 1.2	43.4 1.7 32.7 1.3 2.6 8.7 1.2	28.5 31.4 33.3
Er169	9.4 d	&Dy164(n,γ)Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166 <sub>-</sub> (β <sup>-</sup> )Er166(n,γ)Er167(n,γ)Er168(n,γ)Er169 &Dy163(n,γ)Dy164(n,γ)Dy165(β <sup>-</sup> ) Ho165(n,γ)Ho166(β <sup>-</sup> )Er166(n,γ)Er167 <sub>-</sub> (n,γ)Er168(n,γ)Er169 &Dy162(n,γ)Dy163(n,γ)Dy164(n,γ) Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166(β <sup>-</sup> )Er166 <sub>-</sub> (n,γ)Er167(n,γ)Er168(n,γ)Er169 &Dy161(n,γ)Dy162(n,γ)Dy163(n,γ) Dy164(n,γ)Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166 <sub>-</sub> (β <sup>-</sup> )Er166(n,γ)Er167(n,γ)Er168(n,γ)Er169 &Dy164(n,γ)Dy165(β <sup>-</sup> )Ho165(n,γ) Ho166m(n,γ)Ho167(β <sup>-</sup> )Er167(n,γ) Er168(n,γ)Er169 &Dy163(n,γ)Dy164(n,γ)Dy165(β <sup>-</sup> ) Ho165(n,γ)Ho166m(n,γ)Ho167(β <sup>-</sup> ) Er167(n,γ)Er168(n,γ)Er169 &Dy162(n,γ)Dy163(n,γ)Dy164(n,γ) Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166m(n,γ) Ho167(β <sup>-</sup> )Er167(n,γ)Er168(n,γ)Er169 &Dy161(n,γ)Dy162(n,γ)Dy163(n,γ) Dy164(n,γ)Dy165(β <sup>-</sup> )Ho165(n,γ) Ho166m(n,γ)Ho167(β <sup>-</sup> )Er167(n,γ) Er168(n,γ)Er169 &Dy160(n,γ)Dy161(n,γ)Dy162(n,γ) Dy163(n,γ)Dy164(n,γ)Dy165(β <sup>-</sup> )Ho165 <sub>-</sub> (n,γ)Ho166(β <sup>-</sup> )Er166(n,γ)Er167(n,γ) Er168(n,γ)Er169	28.2 21.6 19.7 13.8 3.2 2.8 2.8 2.0 1.1	50.7 35.1 0.2 0.1 5.8 4.6 0.2	85.3 1.6 8.1 8.1 0.2	79.4 11.9	88.1 8.3	87.3 9.2	86.0 10.6
Tb160	72.3 d	&Dy156(n,γ)Dy157(β <sup>+</sup> )Tb157(n,γ) Tb158(n,γ)Tb159(n,γ)Tb160 Dy158(n,γ)Dy159(β <sup>+</sup> )Tb159(n,γ)Tb160 Dy161(n,2n)Dy160(n,p)Tb160 Dy161(n,d)Tb160 Dy160(n,p)Tb160 Dy162(n,2n)Dy161(n,2n)Dy160(n,p)Tb160   Dy162(n,2n)Dy161(n,d)Tb160 Dy162(n,t)Tb160 Dy161(n,2n)Dy160(n,2n)Dy159(β <sup>+</sup> ) Tb159(n,γ)Tb160 Dy160(n,2n)Dy159(β <sup>+</sup> )Tb159(n,γ)Tb160   Dy163(n,2n)Dy162(n,2n)Dy161(n,d)Tb160   Dy163(n,2n)Dy162(n,t)Tb160 Dy163(n,3n)Dy161(n,d)Tb160 Dy162(n,3n)Dy160(n,p)Tb160 Dy164(n,4n)Dy161(n,d)Tb160 Dy164(n,3n)Dy162(n,t)Tb160 Dy163(n,nt)Tb160 Dy163(n,4n)Dy160(n,p)Tb160 Dy164(n,2nt)Tb160	98.1 1.9	59.0 40.9	1.3 97.7	41.2 18.0 17.1 8.3 7.2 2.2 1.3 1.2 1.1 0.6	0.8 52.2 1.7 0.7 3.4 12.2 34.0 1.3 2.2 0.6 11.4 4.2 4.1 2.6 2.1 1.3	34.8 0.7 1.7 34.0 1.3 2.2 7.5 1.9 10.1 1.1 0.8	19.2 28.8 27.9 16.7
Ta182	114.7 d	Very long pathways of (n,γ), β <sup>-</sup>	100.0	100.0					
Tm170	128.6 d	&Dy164(n,γ)Dy165(β <sup>-</sup> )Ho165(n,γ) Ho166(β <sup>-</sup> )Er166(n,γ)Er167(n,γ)Er168 <sub>-</sub> (n,γ)Er169(β <sup>-</sup> )Tm169(n,γ)Tm170	29.1	51.5	87.9				

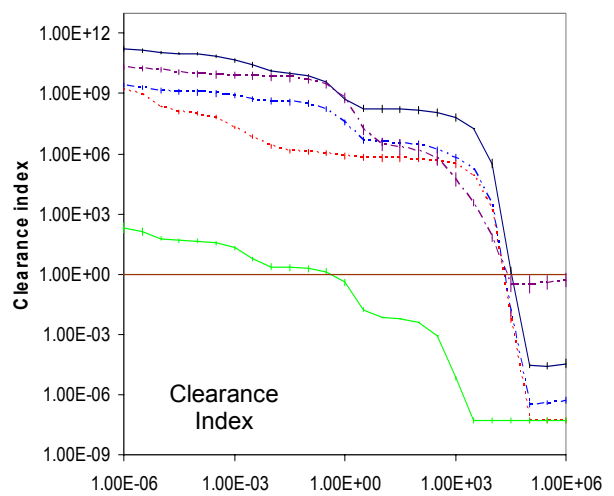
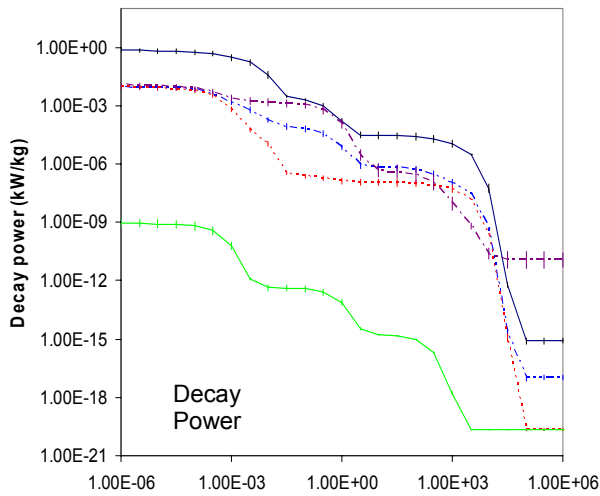
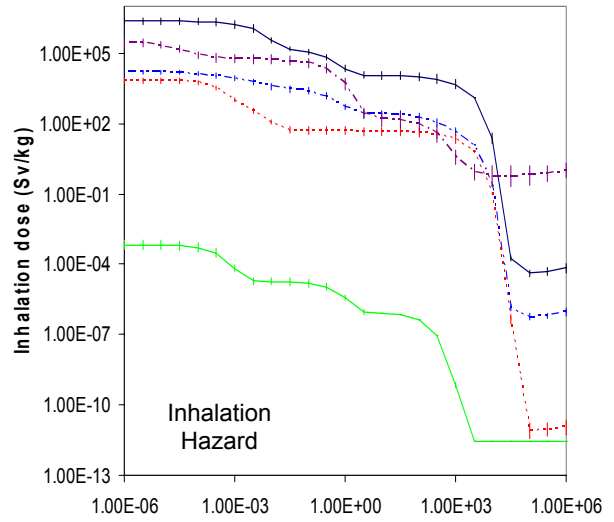
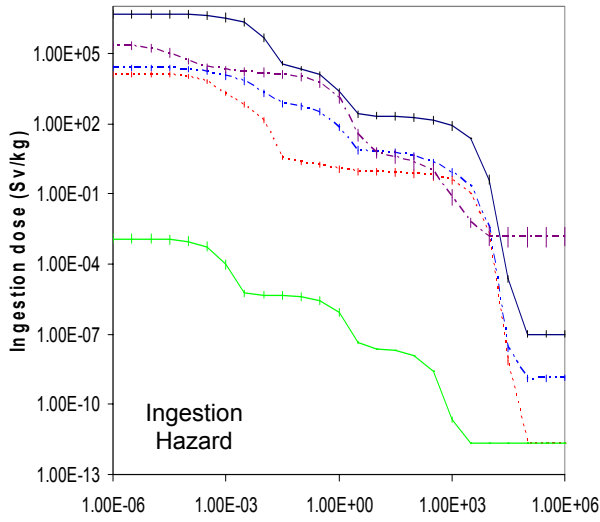
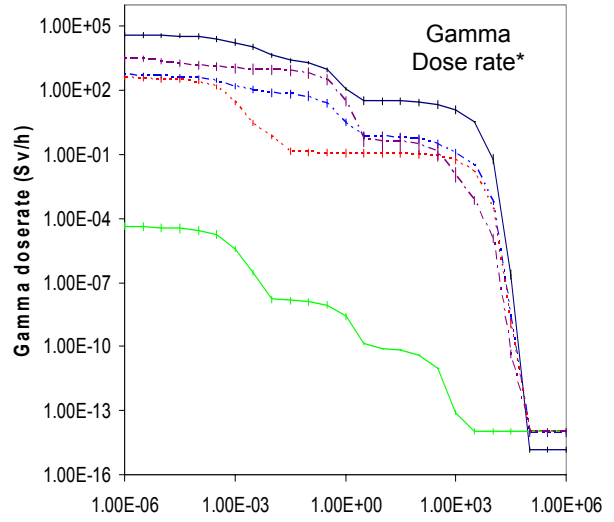
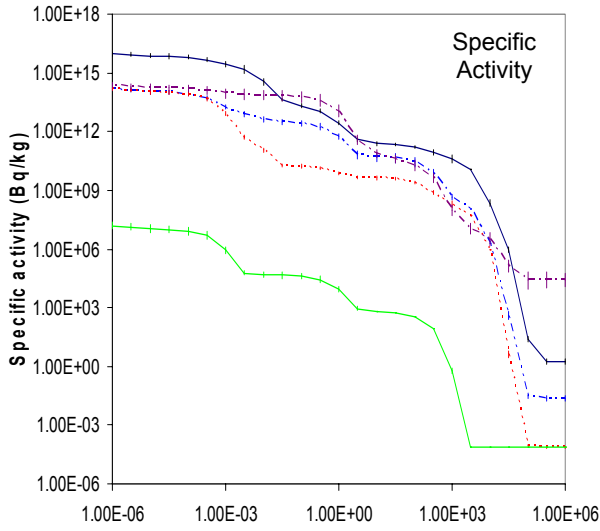


Nuclide	T <sub>½</sub>	Pathway	210	186	151	42	30	21	6	
	◀	&Dy164(n,γ)Dy165(β <sup>-</sup> )Ho165(n,γ)_ Ho166m(n,γ)Ho167(β <sup>-</sup> )Er167(n,γ)_ Er168(n,γ)Er169(β <sup>-</sup> )Tm169(n,γ)Tm170_ (n,γ)Tm171 &Dy163(n,γ)Dy164(n,γ)Dy165(β <sup>-</sup> )_ Ho165(n,γ)Ho166m(n,γ)Ho167(β <sup>-</sup> )_ Er167(n,γ)Er168(n,γ)Er169(β <sup>-</sup> )Tm169_ (n,γ)Tm170(n,γ)Tm171 &Dy162(n,γ)Dy163(n,γ)Dy164(n,γ)_ Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166m(n,γ)_ Ho167(β <sup>-</sup> )Er167(n,γ)Er168(n,γ)Er169_ (β <sup>-</sup> )Tm169(n,γ)Tm170(n,γ)Tm171 &Dy161(n,γ)Dy162(n,γ)Dy163(n,γ)_ Dy164(n,γ)Dy165(β <sup>-</sup> )Ho165(n,γ)_ Ho166m(n,γ)Ho167(β <sup>-</sup> )Er167(n,γ)_ Er168(n,γ)Er169(β <sup>-</sup> )Tm169(n,γ)Tm170_ (n,γ)Tm171	4.8	7.9						
Gd148	74.602 y	Dy156(n,α)Gd152(n,2n)Gd151(n,2n)_ Gd150(n,2n)Gd149(n,2n)Gd148 Dy156(n,α)Gd152(n,2n)Gd151(β <sup>+</sup> )_ Eu151(n,2n)Eu150m(β <sup>-</sup> )Gd150(n,2n)_ Gd149(n,2n)Gd148 Dy156(n,α)Gd153(n,2n)Gd152(n,2n)Gd151_ (n,2n)Gd150(n,2n)Gd149(n,2n)Gd148 Dy156(n,3n)Dy154(n,3nα)Gd148 Dy156(n,3n)Dy154(n,α)Gd150(n,3n)Gd148 Dy156(n,α)Gd152(n,3n)Gd150(n,3n)Gd148 Dy156(n,3n)Dy154(n,3n)Dy152(α)Gd148 Dy161(n,4n)Dy158(n,3n)Dy156(n,3n)_ Dy154(n,3nα)Gd148 Dy161(n,6n)Dy156(n,5n)Dy152(β <sup>+</sup> )_ Tb152(β <sup>+</sup> )Gd152(n,5n)Gd148 Dy161(n,5n)Dy157(β <sup>+</sup> )Tb157(n,5n)_ Tb153(β <sup>+</sup> )Gd153(n,6n)Gd148 Dy162(n,6n)Dy157(β <sup>+</sup> )Tb157(n,5n)_ Tb153(β <sup>+</sup> )Gd153(n,6n)Gd148 Dy160(n,5n)Dy156(n,5n)Dy152(β <sup>+</sup> )_ Tb152(β <sup>+</sup> )Gd152(n,5n)Gd148 Many other similar long pathways				28.8				
							17.2			
							12.5			
								17.8	3.8	
								8.7	0.1	
								6.4		
								5.2	0.2	
								3.2	1.5	
									13.4	
									5.0	
									4.2	
									3.4	
							41.5	58.7	94.4	
									74.0	
Tb157	99.0 y	Dy156(n,γ)Dy157(β <sup>+</sup> )Tb157 Dy158(n,2n)Dy157(β <sup>+</sup> )Tb157 &Dy160(n,2n)Dy159(β <sup>+</sup> )Tb159(n,2n)_ Tb158(n,2n)Tb157 &Dy161(n,2n)Dy160(n,2n)Dy159(β <sup>+</sup> )_ Tb159(n,2n)Tb158(n,2n)Tb157 Dy160(n,2n)Dy159(n,2n)Dy158(n,2n)_ Dy157(β <sup>+</sup> )Tb157 Dy161(n,2n)Dy160(n,2n)Dy159(n,2n)_ Dy158(n,2n)Dy157(β <sup>+</sup> )Tb157 Dy161(n,3n)Dy159(β <sup>+</sup> )Tb159(n,3n)Tb157 Dy161(n,3n)Dy159(n,3n)Dy157(β <sup>+</sup> )Tb157 Dy162(n,4n)Dy159(β <sup>+</sup> )Tb159(n,3n)Tb157 Dy161(n,4n)Dy158(n,2n)Dy157(β <sup>+</sup> )Tb157 Dy163(n,3n)Dy161(n,3n)Dy159(β <sup>+</sup> )_ Tb159(n,3n)Tb157 Dy162(n,3n)Dy160(n,4n)Dy157(β <sup>+</sup> )Tb157 Dy160(n,4n)Dy157(β <sup>+</sup> )Tb157 Dy163(n,4n)Dy160(n,4n)Dy157(β <sup>+</sup> )Tb157 Dy161(n,5n)Dy157(β <sup>+</sup> )Tb157 Dy164(n,5n)Dy160(n,4n)Dy157(β <sup>+</sup> )Tb157 Dy161(n,2n)Dy160(n,4n)Dy157(β <sup>+</sup> )Tb157	99.2	100.0	100.0					
							60.5	1.2	0.4	
							16.6			
							6.9			
							6.4			
							4.9			
								48.4	2.0	
								11.2	0.4	
								4.6	7.6	
								3.4	5.6	
								3.4		
								0.3	7.1	
								0.2	21.6	
									18.7	
									9.0	
									39.7	
									5.9	
									1.1	
									3.8	
									0.3	

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Dy161(n,2nt)Tb157 Dy162(n,6n)Dy157(β <sup>+</sup> )Tb157						0.3	4.4 33.9	
Tb158	180.0 y	&Dy156(n,γ)Dy157(β <sup>+</sup> )Tb157(n,γ) <i>Tb158</i> &Dy160(n,2n)Dy159(β <sup>+</sup> )Tb159(n,2n) <i>Tb158</i>   &Dy161(n,2n)Dy160(n,2n)Dy159(β <sup>+</sup> ) Tb159(n,2n) <i>Tb158</i> &Dy162(n,2n)Dy161(n,2n)Dy160 (n,2n)Dy159(β <sup>+</sup> )Tb159(n,2n) <i>Tb158</i> &Dy161(n,3n)Dy159(β <sup>+</sup> )Tb159(n,2n) <i>Tb158</i>   &Dy162(n,4n)Dy159(β <sup>+</sup> )Tb159(n,2n) <i>Tb158</i>   &Dy163(n,3n)Dy161(n,3n)Dy159(β <sup>+</sup> ) Tb159(n,2n) <i>Tb158</i> &Dy161(n,nt) <i>Tb158</i> &Dy160(n,t) <i>Tb158</i> &Dy163(n,4n)Dy160(n,t) <i>Tb158</i> &Dy163(n,5n)Dy159(β <sup>+</sup> )Tb159(n,2n) <i>Tb158</i>   &Dy162(n,2nt) <i>Tb158</i> &Dy164(n,6n)Dy159(β <sup>+</sup> )Tb159(n,2n) <i>Tb158</i>   &Dy163(n,3nt) <i>Tb158</i>	100.0	100.0	100.0	53.1 41.3 2.9	3.0 0.4	1.1	0.2 1.9 3.0 0.1 34.6 4.4 0.9 5.3 23.9 6.8 4.3	
Ho166m	1200 y	&Dy162(n,γ)Dy163(n,γ)Dy164(n,γ) <i>Dy165</i> (β <sup>-</sup> )Ho165(n,γ)Ho166m &Dy161(n,γ)Dy162(n,γ)Dy163(n,γ) Dy164(n,γ) <i>Dy165</i> (β <sup>-</sup> )Ho165(n,γ)Ho166m   &Dy163(n,γ)Dy164(n,γ) <i>Dy165</i> (β <sup>-</sup> ) Ho165(n,γ)Ho166m &Dy164(n,γ)Dy165(β <sup>-</sup> )Ho165(n,γ) Ho166m &Dy160(n,γ)Dy161(n,γ)Dy162(n,γ) Dy163(n,γ)Dy164(n,γ) <i>Dy165</i> (β <sup>-</sup> )Ho165 (n,γ)Ho166m Dy164(n,γ)Dy165m(β <sup>-</sup> )Ho165(n,γ) Ho166m Dy163(n,γ)Dy164(n,γ)Dy165m(β <sup>-</sup> ) Ho165(n,γ)Ho166m	30.8 26.2 20.9 13.1 7.1 0.2	2.0 1.4 65.4 29.5 1.0	3.0	99.4 99.4	99.2 99.4	99.4 99.4	99.4	
Ho163	4570.1 y	&Dy164(n,γ) <i>Dy165</i> (β <sup>-</sup> )Ho165(n,2n) <i>Ho164</i> (β <sup>-</sup> )Er164(n,2n)Er163(β <sup>+</sup> )Ho163 &Dy164(n,γ) <i>Dy165</i> (β <sup>-</sup> )Ho165(n,3n)Ho163				99.1	97.3	98.9	98.6	
La137	6.0 10 <sup>4</sup> y	Very long pathways of (n,α), β <sup>+</sup> , (n,α)				100.0	100.0	100.0	100.0	
Gd150	1.8 10 <sup>6</sup> y	Dy156(n,α)Gd152(n,2n)Gd151(n,2n)Gd150   Dy156(n,α)Gd152(n,2n)Gd151(β <sup>+</sup> ) Eu151(n,2n)Eu150m(β <sup>-</sup> )Gd150 Dy156(n,α)Gd153(n,2n)Gd152(n,2n) Gd151(n,2n)Gd150 &Dy156(n,α)Gd153(β <sup>+</sup> )Eu153(n,2n) <i>Eu152</i> (n,2n)Eu151(n,2n)Eu150m(β <sup>-</sup> )Gd150 Dy156(n,α)Gd153(n,2n)Gd152(n,2n) Gd151(β <sup>+</sup> )Eu151(n,2n)Eu150m(β <sup>-</sup> )Gd150 Dy156(n,3n)Dy154(n,3n)Dy152(β <sup>+</sup> ) Tb152(β <sup>+</sup> )Gd152(n,3n)Gd150 Dy156(n,3n)Dy154(n,α)Gd150 Dy156(n,α)Gd152(n,3n)Gd150 Dy156(n,4n)Dy153(β <sup>+</sup> )Tb153(β <sup>+</sup> ) Gd153(n,4n)Gd150 Dy161(n,6n)Dy156(n,3nα)Gd150 Dy162(n,5n)Dy158(n,5n)Dy154(n,5n) Dy150(β <sup>+</sup> )Tb150(β <sup>+</sup> )Gd150 Dy161(n,4nα)Gd154(n,5n)Gd150 Dy164(n,6n)Dy159(β <sup>+</sup> )Tb159(n,5n) Tb155(β <sup>+</sup> )Gd155(n,6n)Gd150				21.8 17.4 10.9 9.5 7.6	26.7	0.2 9.9 7.3 5.5	0.4 0.2 5.5	4.3 3.5 3.4 3.2

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	Dy160(n,6n)Dy155(β <sup>+</sup> )Tb155(β <sup>+</sup> ) <sub>-</sub> Gd155(n,6n)Gd150 Dy161(n,3nα)Gd155(n,6n)Gd150 Many other similar long pathways				32.8	63.4	93.7	3.2 3.1 79.3
Dy154	3.0 10 <sup>6</sup> y	Dy156(n,2n)Dy155(n,2n)Dy154 Dy156(n,3n)Dy154 Dy161(n,4n)Dy158(n,3n)Dy156(n,3n)Dy154 Dy160(n,3n)Dy158(n,3n)Dy156(n,3n)Dy154 Dy162(n,3n)Dy160(n,3n)Dy158(n,3n) <sub>-</sub> Dy156(n,3n)Dy154 Dy158(n,3n)Dy156(n,3n)Dy154 Dy161(n,3n)Dy159(n,4n)Dy156(n,3n)Dy154 Dy162(n,4n)Dy159(n,4n)Dy156(n,3n)Dy154 Dy161(n,4n)Dy158(n,5n)Dy154 Dy162(n,5n)Dy158(n,5n)Dy154 Dy163(n,6n)Dy158(n,5n)Dy154 Dy161(n,6n)Dy156(n,3n)Dy154				100.0	43.7 15.5 14.3 9.2 7.9 1.2 0.1	30.9 24.4 1.4 2.3 4.1 15.8 4.1	12.7 35.7 27.8 5.6
Hf182	9.0 10 <sup>6</sup> y	Very long pathways of (n,γ), β <sup>-</sup>	100.0	100.0					
Lu176	4.0 10 <sup>10</sup> y	Very long pathways of (n,γ), β <sup>-</sup>	100.0	100.0	100.0				
La138	1.0 10 <sup>11</sup> y	Very long pathways of (n,α), β <sup>+</sup> , (n,nα)				100.0	100.0	100.0	100.0
Gd152	1.1 10 <sup>14</sup> y	Dy156(n,α)Gd153(n,γ)Gd154(n,α) <sub>-</sub> Sm151(β <sup>-</sup> )Eu151(n,γ)Eu152m(β <sup>-</sup> )Gd152 Dy156(n,α)Gd153(n,α)Sm150(n,γ) <sub>-</sub> Sm151(β <sup>-</sup> )Eu151(n,γ)Eu152m(β <sup>-</sup> )Gd152 Dy156(n,α)Gd153(β <sup>+</sup> )Eu153(n,γ)Eu154 (β <sup>-</sup> )Gd154(n,α)Sm151(β <sup>-</sup> )Eu151(n,γ) <sub>-</sub> Eu152m(β <sup>-</sup> )Gd152 Dy156(n,2n)Dy155(β <sup>+</sup> )Tb155(β <sup>+</sup> )Gd155 (n,2n)Gd154(n,2n)Gd153(n,2n)Gd152 Dy156(n,nα)Gd152 Dy156(n,α)Gd153(n,2n)Gd152 Dy156(n,α)Gd153(β <sup>+</sup> )Eu153(n,2n) <sub>-</sub> Eu152m(β <sup>-</sup> )Gd152 Dy156(n,3n)Dy154(n,3n)Dy152(β <sup>+</sup> ) <sub>-</sub> Tb152(β <sup>+</sup> )Gd152 Dy161(n,4n)Dy158(n,4n)Dy155(β <sup>+</sup> ) <sub>-</sub> Tb155(β <sup>+</sup> )Gd155(n,4n)Gd152 Dy162(n,5n)Dy158(n,4n)Dy155(β <sup>+</sup> ) <sub>-</sub> Tb155(β <sup>+</sup> )Gd155(n,4n)Gd152 Dy158(n,4n)Dy155(β <sup>+</sup> )Tb155(β <sup>+</sup> ) <sub>-</sub> Gd155(n,4n)Gd152 Dy161(n,6n)Dy156(n,5n)Dy152(β <sup>+</sup> ) <sub>-</sub> Tb152(β <sup>+</sup> )Gd152 &Dy161(n,5n)Dy157(β <sup>+</sup> )Tb157(n,6n) <sub>-</sub> Tb152(β <sup>+</sup> )Gd152 &Dy162(n,6n)Dy157(β <sup>+</sup> )Tb157(n,6n) <sub>-</sub> Tb152(β <sup>+</sup> )Gd152 Dy160(n,5n)Dy156(n,5n)Dy152(β <sup>+</sup> ) <sub>-</sub> Tb152(β <sup>+</sup> )Gd152 Many other similar long pathways	88.9 10.7 0.4	50.6 45.4 1.5	63.6 28.9 3.6 41.3 27.8 16.8 4.5 3.9	43.7 27.8 16.8 4.5 28.9 35.5 4.1 3.4 65.9	5.2 0.5 1.0 35.5 4.1 3.4 55.5	0.5 0.1 0.4 22.2 8.3 7.1 5.6 56.3	
Dy156	1.0 10 <sup>18</sup> y	Dy161(n,4n)Dy158(n,3n)Dy156 Dy160(n,3n)Dy158(n,3n)Dy156 Dy162(n,3n)Dy160(n,3n)Dy158(n,3n)Dy156 Dy158(n,3n)Dy156 Dy163(n,4n)Dy160(n,3n)Dy158(n,3n)Dy156 Dy161(n,3n)Dy159(n,4n)Dy156 Dy162(n,4n)Dy159(n,4n)Dy156 Dy160(n,5n)Dy156 Dy164(n,5n)Dy160(n,5n)Dy156 Dy161(n,6n)Dy156 Nuclide present in starting material					21.0 19.4 16.6 7.2 5.1 1.2 0.1	36.2 2.0 0.4 2.3 1.2 4.5 17.4 1.6 0.4	0.9 0.2 0.2 0.3 13.7 6.1 54.1 24.5

# Dysprosium activation characteristics

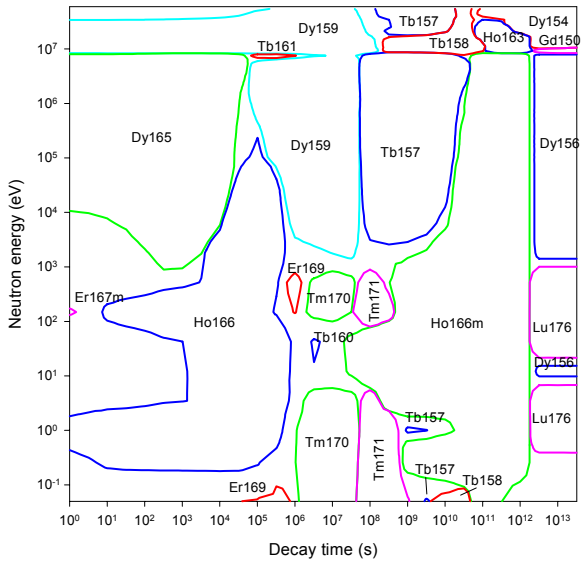


Decay time (years)

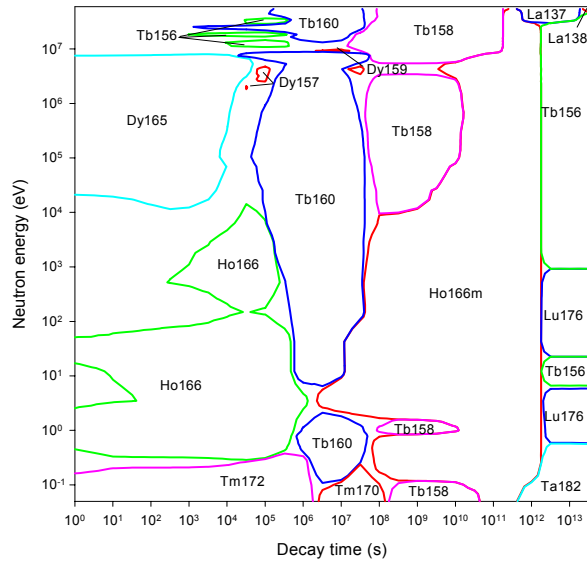
Decay time (years)

# Dysprosium importance diagrams & transmutation

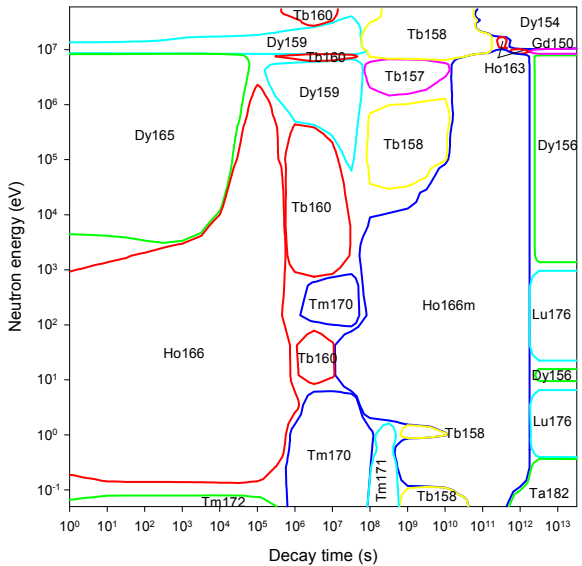
Activity



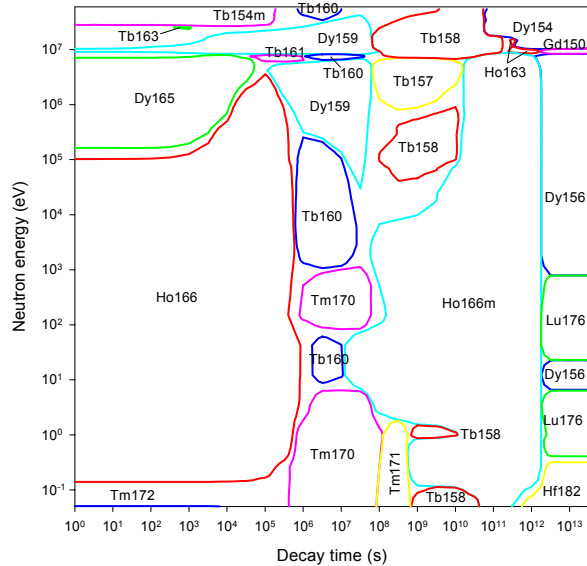
Dose rate



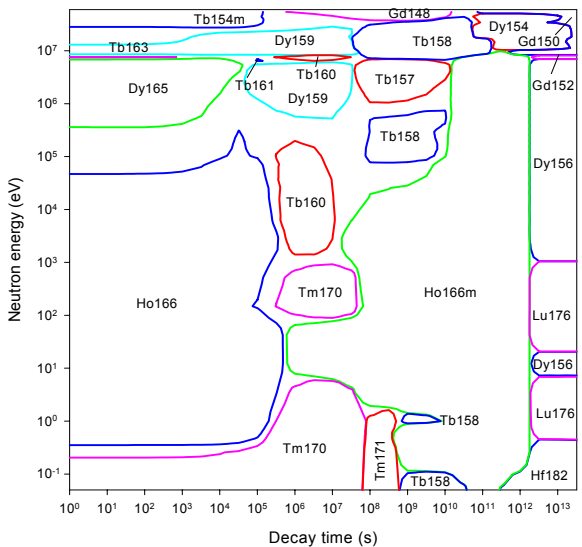
Heat output



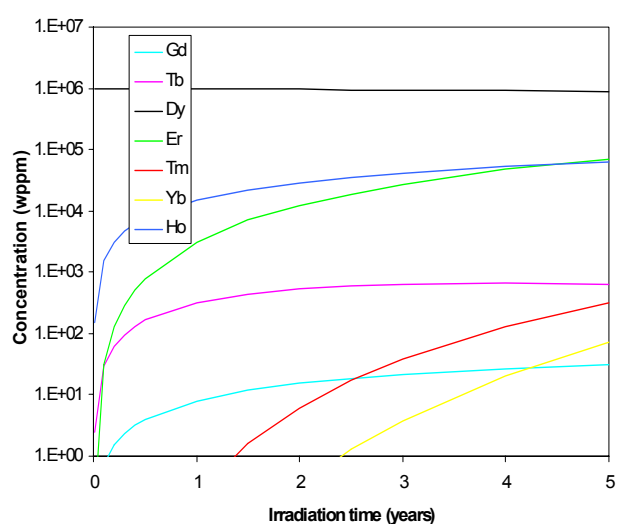
Ingestion dose



Inhalation dose



First wall transmutation





# Holmium

## General properties

Atomic number	67	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	1.3	Ho165	100.0
Melting point / K	1745		
Boiling point / K	2967		
Density / kgm <sup>-3</sup>	8795		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	16.2		
Electrical resistivity /Ωm	8.70 10 <sup>-7</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	1.12 10 <sup>-5</sup>		
Crystal structure	HCP		
Number of stable isotopes	1		
Mean atomic weight	164.93032		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	1.43E16	8.71E15	1.73E15	5.86E13	2.35E11	4.85E2	kW kg <sup>-1</sup>	9.67E-1	7.80E-1	1.03E-1	2.65E-3	6.61E-5	2.06E-16
Ho166	41.19	67.40	35.29				Ho166	70.67	87.40	68.69			
Er167m	38.90	0.64					Er167m	19.13	0.24				
Er169	6.99	11.46	44.15				Ho167	4.68	5.68				
Er165	5.04	8.22	0.12				Tm170	1.79	2.22	16.47	91.34		
Ho167	3.35	5.39					Er169	1.68	2.09	12.07			
Tm170	2.28	3.74	18.49	77.71			Er165	0.51	0.63	0.01			
Ho164	0.98	1.48					Tm168	0.17	0.21	1.54	4.06		
Tm171	0.12	0.20	1.02	20.94			Ho166m	0.01	0.01	0.07	2.64	100.0	
Ho166m			0.01	0.42	99.16		Tm171	0.01	0.01	0.07	1.95		
Ho163					0.78	100.0	Ho163						99.94
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	7.29E4	5.22E4	6.14E3	2.00E2	6.85E1	3.30E-14	Sv kg <sup>-1</sup>	9.13E6	9.11E6	1.57E6	6.15E4	4.66E2	1.11E-8
Ho166	45.93	64.12	57.10				Ho166	90.22	90.22	54.28			
Er167m	28.20	0.40					Tm170	4.64	4.65	26.41	96.21		
Ho167	19.73	27.08					Er169	4.05	4.05	17.95			
Tm172	2.80	3.92	12.94				Ho167	0.44	0.43				
Tm168	2.43	3.40	28.41	61.36		6.27	Tm172	0.28	0.28	0.62			
Ho166m	0.10	0.14	1.20	38.10	100.0		Tm168	0.08	0.08	0.46	0.79		
Tm170	0.01*	0.01*	0.12*	0.52*			Tm171	0.02	0.02	0.12	2.19		
Lu176						83.31	Ho166m	0.01	0.01	0.03	0.80	99.99	
Ta182						10.14	Ho163					0.01	99.97
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	7.25E6	7.24E6	3.49E6	3.67E5	2.80E4	2.58E-8		9.03E11	3.05E11	2.38E10	1.51E9	3.82E8	1.29E-4
Ho166	52.74	52.69	11.37				Er167m	66.22	1.98	0.01			
Tm170	31.44	31.49	64.13	86.82			Ho167	20.39	59.13				
Er169	13.77	13.78	21.87				Ho166	6.52	19.24	25.61			
Ho167	0.47	0.46					Er165	3.07	9.02	0.33			
Ho166m	0.41	0.41	0.85	8.08	100.0		Tm168	1.07	3.16	39.42	42.14		0.01
Tm171	0.34	0.34	0.70	4.68			Tm172	0.88	2.59	12.76			
Tm168	0.33	0.33	0.67	0.43			Tm170	0.36	1.07	13.42	30.17		
Tm172	0.23	0.23	0.18				Er169	0.11	0.33	3.20			
Yb169	0.11	0.11	0.22				Ho166m	0.05	0.13	1.70	26.84	100.0	
Ho163						99.74	Tm171		0.01	0.07	0.81		
Lu176						0.24	Ho163						99.21

# Holmium

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6		
Er167m	2.269 s	Ho165(n,γ)Ho166(β <sup>-</sup> )Er166(n,γ)Er167m	99.8	99.8	98.5	91.8	94.5	94.3	94.0		
		Ho165(n,γ)Ho166m(n,γ)Ho167(β <sup>-</sup> )Er167m				6.1	4.2	4.6	5.1		
Tb162	7.6 m	Ho165(n,α)Tb162	100.0	100.0	100.0	96.8	78.0	20.4	48.9		
		&Ho165(n,2n)Ho164(β <sup>+</sup> )Dy164(n,t)Tb162					6.2	19.2	16.7		
		Ho165(n,t)Dy163(n,d)Tb162					3.5	12.3	13.0		
		&Ho165(n,4n)Ho162(β <sup>+</sup> )Dy162(n,p)Tb162					2.1	25.1	3.3		
		Ho165(n,d)Dy164(n,t)Tb162					2.0	11.5	14.2		
		&Ho165(n,3n)Ho163(n,2n)Ho162(β <sup>+</sup> )_Dy162(n,p)Tb162					2.0				
		Ho165(n,4n)Ho162m(β <sup>+</sup> )Dy162(n,p)Tb162 Ho165(n,nt)Dy162(n,p)Tb162						0.5	8.5	1.2	
						0.2	0.8	1.5			
Ho162	15.0 m	&Ho165(n,2n)Ho164(β <sup>-</sup> )Er164(n,2n)_ Er163(β <sup>+</sup> )Ho163(n,2n)Ho162				94.0					
		&Ho165(n,3n)Ho163(n,2n)Ho162					64.2	0.8	1.0		
		&Ho165(n,4n)Ho162					32.8	99.2	99.0		
Ho164	28.6 m	&Ho165(n,2n)Ho164				100.0	100.0	100.0			
Ho162m	1.117 h	&Ho165(n,2n)Ho164(β <sup>-</sup> )Er164(n,2n)_ Er163(β <sup>+</sup> )Ho163(n,2n)Ho162m				99.5					
		&Ho165(n,3n)Ho163(n,2n)Ho162m					72.9	1.6			
		Ho165(n,4n)Ho162m					26.3	98.0	97.3		
Ho161	2.48 h	&Ho165(n,3n)Ho163(n,3n)Ho161 &Ho165(n,5n)Ho161					98.0	31.3			
		Ho165(n,2n)Ho164(β <sup>-</sup> )Er164(n,4n)_ Er161(β <sup>+</sup> )Ho161						50.5	91.5		
								9.2			
Ho167	3.10 h	Ho165(n,γ)Ho166m(n,γ)Ho167	95.0	96.7	98.3	99.4	98.8	99.1	99.5		
		Ho165(n,γ)Ho166(n,γ)Ho167	5.0	3.3	1.7	0.3	0.3	0.3	0.2		
Tb154m	9.00 h	Ho165(n,nα)Tb161(β <sup>-</sup> )Dy161(n,4n)_ Dy158(n,3n)Dy156(n,t)Tb154m					2.7				
		Ho165(n,3n)Ho163(n,nα)Tb159(n,3n)_ Tb157(n,4n)Tb154m					2.5	0.1			
		Ho165(n,2nα)Tb160(β <sup>-</sup> )Dy160(n,4n)_ Dy157(β <sup>+</sup> )Tb157(n,4n)Tb154m							8.2		
		Ho165(n,t)Dy163(n,4n)Dy160(n,4n)_ Dy157(β <sup>+</sup> )Tb157(n,4n)Tb154m							3.0		
		Ho165(n,5n)Ho161(β <sup>+</sup> )Dy161(n,5n)_ Dy157(β <sup>+</sup> )Tb157(n,4n)Tb154m							2.5	15.2	
		&Ho165(n,4nα)Tb158(n,5n)Tb154m								9.5	
		Ho165(n,3nα)Tb159(n,6n)Tb154m								8.7	
		Ho165(n,3n)Ho163(n,5n)Ho159(β <sup>+</sup> )_ Dy159(β <sup>+</sup> )Tb159(n,6n)Tb154m								5.4	
		Ho165(n,5n)Ho161(β <sup>+</sup> )Dy161(n,3n)_ Dy159(β <sup>+</sup> )Tb159(n,6n)Tb154m								5.1	
		&Ho165(n,5n)Ho161(β <sup>+</sup> )Dy161(n,nt)_ Tb158(n,5n)Tb154m								5.1	
		Ho165(n,5n)Ho161(β <sup>+</sup> )Dy161(n,6n)_ Dy156(n,t)Tb154m								3.7	
		&Ho165(n,5n)Ho161(β <sup>+</sup> )Dy161(n,t)_ Tb159(n,6n)Tb154m								2.9	
		Plus many other similar long pathways					100.0	94.8	86.2	44.4	
		Ho166	1.117 d	Ho165(n,γ)Ho166	100.0	100.0	100.0	99.6	99.6	99.7	99.8
		Tm172	2.650 d	&Ho165(n,γ)Ho166(β <sup>-</sup> )Er166(n,γ)_ Er167(n,γ)Er168(n,γ)Er169(β <sup>-</sup> )Tm169_ (n,γ)Tm170(n,γ)Tm171(n,γ)Tm172	83.9	84.6	86.1				
				&Ho165(n,γ)Ho166m(n,γ)Ho167(β <sup>-</sup> )_ Er167(n,γ)Er168(n,γ)Er169(β <sup>-</sup> )Tm169_ (n,γ)Tm170(n,γ)Tm171(n,γ)Tm172	13.5	12.0	8.2				

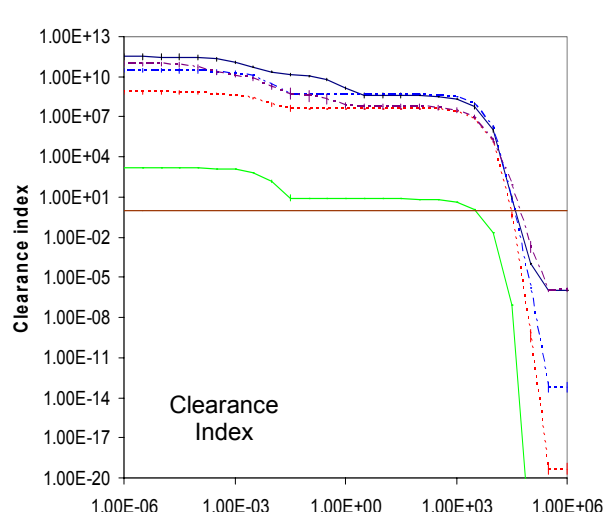
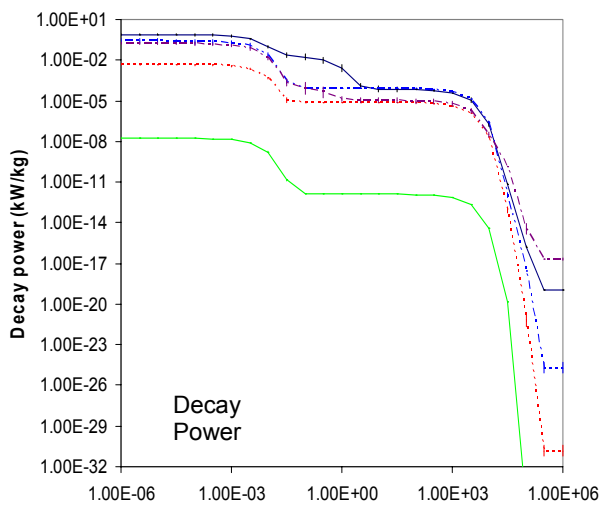
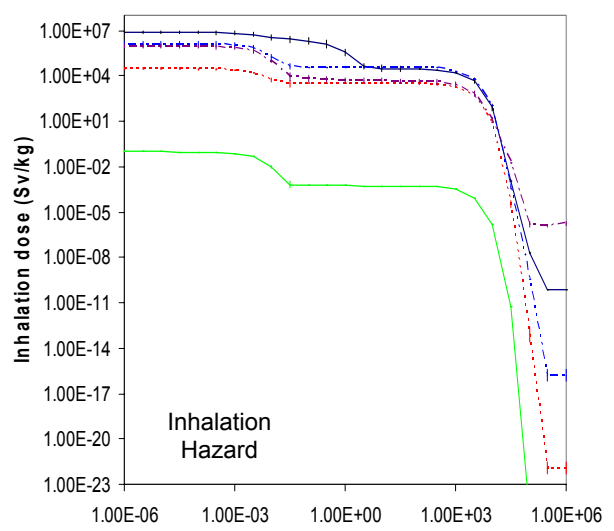
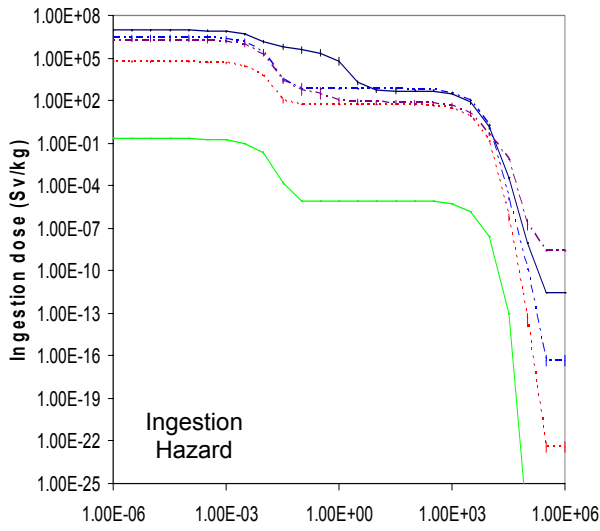
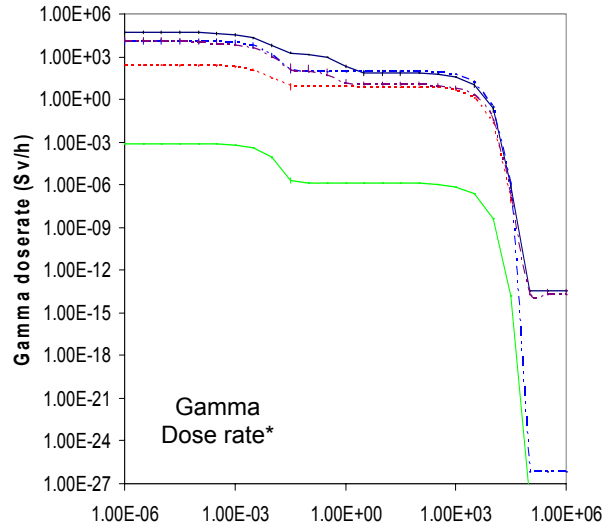
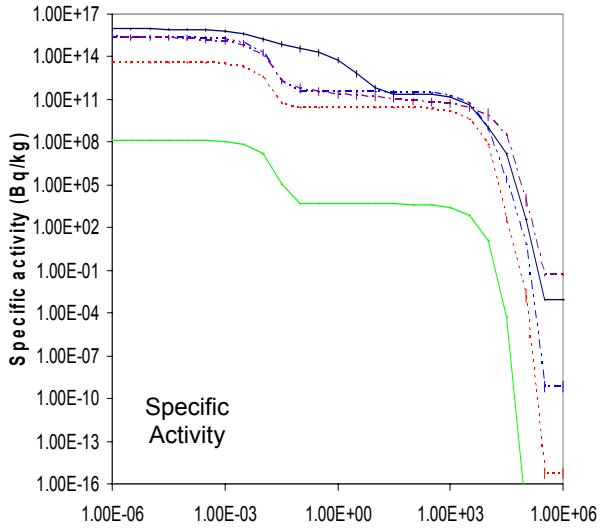
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&Ho165(n,γ)Ho166(n,γ)Ho167(β <sup>-</sup> ) Er167(n,γ)Er168(n,γ)Er169(β <sup>-</sup> )Tm169 (n,γ)Tm170(n,γ)Tm171(n,γ)Tm172	0.6	1.5	0.7				
Er169	9.40 d	&Ho165(n,γ)Ho166(β <sup>-</sup> )Er166(n,γ) Er167(n,γ)Er168(n,γ)Er169 &Ho165(n,γ)Ho166(n,γ)Ho167(β <sup>-</sup> ) Er167(n,γ)Er168(n,γ)Er169 &Ho165(n,γ)Ho166m(n,γ)Ho167(β <sup>-</sup> ) Er167(n,γ)Er168(n,γ)Er169	90.0 0.5	89.5 1.0	91.0 0.4	86.7 0.1	90.8 8.5	89.9 9.4	88.5 10.9
Tb160	72.3 d	Ho165(n,α)Tb162(β <sup>-</sup> )Dy162(n,α) Gd159(β <sup>-</sup> )Tb159(n,γ)Tb160 &Ho165(n,2n)Ho164(β <sup>-</sup> )Er164(n,2n) Er163(β <sup>+</sup> )Ho163(n,α)Tb160 &Ho165(n,3n)Ho163(n,3n)Ho161(β <sup>+</sup> ) Dy161(n,d)Tb160 &Ho165(n,3n)Ho163(n,α)Tb160 Ho165(n,2nα)Tb160 Ho165(n,α)Tb161(β <sup>-</sup> )Dy161(n,d)Tb160 &Ho165(n,4n)Ho162(β <sup>+</sup> )Dy162(n,t)Tb160 Ho165(n,4n)Ho162m(β <sup>+</sup> )Dy162(n,t)Tb160 Ho165(n,nt)Dy162(n,t)Tb160 Ho165(n,t)Dy163(n,nt)Tb160 &Ho165(n,5n)Ho161(β <sup>+</sup> )Dy161(n,d)Tb160 &Ho165(n,2n)Ho164(β <sup>+</sup> )Dy164(n,2nt)Tb160 Ho165(n,2nt)Dy161(n,d)Tb160 Ho165(n,d)Dy164(n,2nt)Tb160	100.0	100.0	100.0	96.6	0.1 37.6 36.3 13.8 2.4 1.2 0.3 0.1 0.1	0.8 0.8 47.4 0.5 30.2 10.3 0.9 0.7 2.8	0.2 0.6 39.2 0.3 9.8 3.5 4.5 3.7 28.7 2.2 2.2 1.9
Ta182	114.7 d	Very long pathways of (n,γ), β <sup>-</sup>	100.0	100.0					
Tm170	128.6 d	&Ho165(n,γ)Ho166(β <sup>-</sup> )Er166(n,γ)Er167 (n,γ)Er168(n,γ)Er169(β <sup>-</sup> )Tm169(n,γ)Tm170 &Ho165(n,γ)Ho166m(n,γ)Ho167(β <sup>-</sup> ) Er167(n,γ)Er168(n,γ)Er169(β <sup>-</sup> )Tm169 (n,γ)Tm170 &Ho165(n,γ)Ho166(n,γ)Ho167(β <sup>-</sup> ) Er167(n,γ)Er168(n,γ)Er169(β <sup>-</sup> )Tm169 (n,γ)Tm170	86.3 12.3 0.5	86.3 11.3 1.4	88.0 8.4 0.5	84.5 12.3 0.1	88.5 8.3	87.6 9.2	86.2 10.6
Dy159	144.4 d	&Ho165(n,2n)Ho164(β <sup>+</sup> )Dy164(n,2n) Dy163(n,2n)Dy162(n,2n)Dy161(n,2n) Dy160(n,2n)Dy159 &Ho165(n,2n)Ho164(β <sup>-</sup> )Er164(n,α) Dy161(n,2n)Dy160(n,2n)Dy159 &Ho165(n,2n)Ho164(β <sup>-</sup> )Er164(n,α) Dy160(n,2n)Dy159 &Ho165(n,2n)Ho164(β <sup>+</sup> )Dy164(n,3n)Dy162 (n,2n)Dy161(n,2n)Dy160(n,2n)Dy159 Ho165(n,α)Tb162(β <sup>-</sup> )Dy162(n,2n) Dy161(n,2n)Dy160(n,2n)Dy159 &Ho165(n,2n)Ho164(β <sup>-</sup> )Er164(n,2n)Er163 (β <sup>+</sup> )Ho163(n,α)Tb160(β <sup>-</sup> )Dy160(n,2n)Dy159 &Ho165(n,2n)Ho164(β <sup>+</sup> )Dy164(n,α) Gd161(β <sup>-</sup> )Tb161(β <sup>-</sup> )Dy161(n,2n) Dy160(n,2n)Dy159 Ho165(n,α)Tb161(β <sup>-</sup> )Dy161(n,2n) Dy160(n,2n)Dy159 &Ho165(n,3n)Ho163(n,3n)Ho161(β <sup>+</sup> ) Dy161(n,3n)Dy159 Ho165(n,α)Tb161(β <sup>-</sup> )Dy161(n,3n)Dy159 &Ho165(n,4n)Ho162(β <sup>+</sup> )Dy162(n,4n)Dy159 Ho165(n,4n)Ho162m(β <sup>+</sup> )Dy162(n,4n)Dy159 Ho165(n,nt)Dy162(n,4n)Dy159 &Ho165(n,5n)Ho161(β <sup>+</sup> )Dy161(n,3n)Dy159 &Ho165(n,3n)Ho163(n,5n)Ho159(β <sup>+</sup> )Dy159				27.8 9.7 8.2 8.0 7.1 5.4 3.2 2.7	79.6 5.4 1.1 0.3 0.1	0.1 0.2 8.3 2.9 3.8 23.4 27.6	

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	Ho165(n,t)Dy163(n,5n)Dy159 &Ho165(n,2n)Ho164(β <sup>+</sup> )Dy164(n,6n)Dy159   Ho165(n,d)Dy164(n,6n)Dy159   &Ho165(n,6n)Ho160(β <sup>+</sup> )Dy160(n,2n)Dy159   Ho165(n,3n)Ho163(n,2nt)Dy159 Ho165(n,2nt)Dy161(n,3n)Dy159 Many other similar long pathways						0.9	5.7 7.3 6.2 4.0 2.2 1.7 6.6
Tm171	1.917 y	&Ho165(n,γ)Ho166(β <sup>-</sup> )Er166(n,γ) Er167(n,γ)Er168(n,γ)Er169(β <sup>-</sup> )Tm169_ (n,γ)Tm170(n,γ)Tm171 &Ho165(n,γ)Ho166m(n,γ)Ho167(β <sup>-</sup> ) Er167(n,γ)Er168(n,γ)Er169(β <sup>-</sup> )Tm169_ (n,γ)Tm170(n,γ)Tm171 &Ho165(n,γ)Ho166(n,γ)Ho167(β <sup>-</sup> ) Er167(n,γ)Er168(n,γ)Er169(β <sup>-</sup> )Tm169_ (n,γ)Tm170(n,γ)Tm171	84.2 13.5 0.6	85.0 12.1 1.5	87.0 8.3 0.7				
H3	12.33 y	Ho165(n,X)H3 &Ho165(n,3n)Ho163(n,X)H3 Ho165(n,4n)Ho162(β <sup>+</sup> )Dy162(n,X)H3 Ho165(n,4n)Ho162m(β <sup>+</sup> )Dy162(n,X)H3 Ho165(n,5n)Ho161(β <sup>+</sup> )Dy161(n,X)H3				99.6	86.7 9.9	86.9 3.2	87.4 1.7 1.4 4.1
Gd148	74.602 y	Very long pathways				100.0	100.0	100.0	100.0
Tb157	99.0 y	&Ho165(n,2n)Ho164(β <sup>-</sup> )Er164(n,nα) Dy160(n,2n)Dy159(β <sup>+</sup> )Tb159(n,2n) Tb158(n,2n)Tb157 &Ho165(n,2n)Ho164(β <sup>-</sup> )Er164(n,2n) Er163(β <sup>+</sup> )Ho163(n,nα)Tb159(n,2n) Tb158(n,2n)Tb157 &Ho165(n,2n)Ho164(β <sup>-</sup> )Er164(n,nα) Dy160(n,2n)Dy159(n,2n)Dy158(n,2n) Dy157(β <sup>+</sup> )Tb157 Ho165(n,3n)Ho163(n,3n)Ho161(β <sup>+</sup> )Dy161_ (n,3n)Dy159(β <sup>+</sup> )Tb159(n,3n)Tb157 Ho165(n,3n)Ho163(n,3n)Ho161(β <sup>+</sup> )Dy161_ (n,3n)Dy159(n,3n)Dy157(β <sup>+</sup> )Tb157 Ho165(n,3n)Ho163(n,nα)Tb159(n,3n)Tb157 Ho165(n,nα)Tb161(β <sup>-</sup> )Dy161(n,3n) Dy159(β <sup>+</sup> )Tb159(n,3n)Tb157 &Ho165(n,4n)Ho162(β <sup>+</sup> )Dy162(n,4n) Dy159(β <sup>+</sup> )Tb159(n,3n)Tb157 &Ho165(n,4n)Ho162(β <sup>+</sup> )Dy162(n,4n) Dy159(n,3n)Dy157(β <sup>+</sup> )Tb157 Ho165(n,4n)Ho162m(β <sup>+</sup> )Dy162(n,4n) Dy159(β <sup>+</sup> )Tb159(n,3n)Tb157 &Ho165(n,4n)Ho162(β <sup>+</sup> )Dy162(n,3n) Dy160(n,4n)Dy157(β <sup>+</sup> )Tb157 &Ho165(n,3n)Ho163(n,4n)Ho160(β <sup>+</sup> ) Dy160(n,4n)Dy157(β <sup>+</sup> )Tb157 Ho165(n,2nα)Tb160(β <sup>-</sup> )Dy160(n,4n) Dy157(β <sup>+</sup> )Tb157 Ho165(n,4n)Ho162m(β <sup>+</sup> )Dy162(n,3n) Dy160(n,4n)Dy157(β <sup>+</sup> )Tb157 Ho165(n,t)Dy163(n,4n)Dy160(n,4n) Dy157(β <sup>+</sup> )Tb157 &Ho165(n,5n)Ho161(β <sup>+</sup> )Dy161(n,5n) Dy157(β <sup>+</sup> )Tb157 Ho165(n,2nt)Dy161(n,5n)Dy157(β <sup>+</sup> )Tb157   &Ho165(n,4n)Ho162(β <sup>+</sup> )Dy162(n,6n) Dy157(β <sup>+</sup> )Tb157 Ho165(n,5n)Ho161(β <sup>+</sup> )Dy161(n,2nt)Tb157   Ho165(n,nt)Dy162(n,6n)Dy157(β <sup>+</sup> )Tb157				7.5 5.4 5.3		34.1 15.5 10.4 5.3 1.1 0.4 0.3 14.9 8.8 8.5 5.1 3.1 2.9	0.1 14.6 4.7 5.0 14.9 8.8 0.3 5.1 3.1 53.7 4.0 10.1 5.5 4.6

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
		&Ho165(n,6n)Ho160(β <sup>+</sup> )Dy160(n,4n) Dy157(β <sup>+</sup> )Tb157							3.7
		Ho165(n,4n)Ho162m(β <sup>+</sup> )Dy162(n,6n) Dy157(β <sup>+</sup> )Tb157							3.6
		Many other similar long pathways				81.8	32.9	32.2	14.5
Tb158	180.0 y	&Ho165(n,2n)Ho164(β <sup>-</sup> )Er164(n,nα) Dy160(n,2n)Dy159(β <sup>+</sup> )Tb159(n,2n)Tb158				10.5			
		&Ho165(n,2n)Ho164(β <sup>+</sup> )Dy164(n,2n) Dy163(n,2n)Dy162(n,α)Gd159(β <sup>-</sup> ) Tb159(n,2n)Tb158				8.0			
		&Ho165(n,2n)Ho164(β <sup>-</sup> )Er164(n,2n) Er163(β <sup>+</sup> )Ho163(n,nα)Tb159(n,2n)Tb158				6.9			
		&Ho165(n,2n)Ho164(β <sup>-</sup> )Er164(n,α) Dy161(n,2n)Dy160(n,2n)Dy159(β <sup>+</sup> ) Tb159(n,2n)Tb158				6.8			
		&Ho165(n,α)Tb162(β <sup>-</sup> )Dy162(n,2n) Dy161(n,2n)Dy160(n,2n)Dy159(β <sup>+</sup> ) Tb159(n,2n)Tb158				5.6			
		&Ho165(n,2n)Ho164(β <sup>+</sup> )Dy164(n,2n) Dy163(n,α)Gd160(n,2n)Gd159(β <sup>-</sup> ) Tb159(n,2n)Tb158				4.9			
		&Ho165(n,nα)Tb161(β <sup>-</sup> )Dy161(n,2n) Dy160(n,2n)Dy159(β <sup>+</sup> )Tb159(n,2n)Tb158				3.5			
		Ho165(n,3n)Ho163(n,3n)Ho161(β <sup>+</sup> ) Dy161(n,3n)Dy159(β <sup>+</sup> )Tb159(n,2n)Tb158					25.3		
		&Ho165(n,3n)Ho163(n,2nα)Tb158					20.1	14.9	1.2
		&Ho165(n,3n)Ho163(n,nα)Tb159(n,2n)Tb158					10.5	0.2	
		&Ho165(n,nα)Tb161(β <sup>-</sup> )Dy161(n,3n) Dy159(β <sup>+</sup> )Tb159(n,2n)Tb158					5.3	0.1	
		Ho165(n,3n)Ho163(n,3n)Ho161(β <sup>+</sup> ) Dy161(n,nt)Tb158					2.5	0.5	0.1
		&Ho165(n,4n)Ho162(β <sup>+</sup> )Dy162(n,4n) Dy159(β <sup>+</sup> )Tb159(n,2n)Tb158					1.0	33.0	
		&Ho165(n,4n)Ho162m(β <sup>+</sup> )Dy162 (n,4n)Dy159(β <sup>+</sup> )Tb159(n,2n)Tb158					0.2	13.4	
		&Ho165(n,5n)Ho161(β <sup>+</sup> )Dy161(n,nt)Tb158						2.7	26.7
		&Ho165(n,4nα)Tb158							47.0
		&Ho165(n,6n)Ho160(β <sup>+</sup> )Dy160(n,t)Tb158							4.3
		Many other similar long pathways				51.9	35.1	35.2	20.7
Ho166m	1200 y	Ho165(n,γ)Ho166m	100.0	100.0	100.0	99.9	99.8	99.8	99.9
Ho163	4570 y	&Ho165(n,2n)Ho164(β <sup>-</sup> )Er164(n,2n) Er163(β <sup>+</sup> )Ho163				99.8			
		&Ho165(n,3n)Ho163					99.4	98.9	91.4
La137	6.0 10 <sup>4</sup> y	Very long pathways of (n,α), β <sup>+</sup> , (n,nα)				100.0	100.0	100.0	100.0
Gd150	1.8 10 <sup>6</sup> y	Very long pathways of (n,α), β <sup>+</sup> , (n,nα)				100.0	100.0	100.0	100.0
Dy154	3.0 10 <sup>6</sup> y	&Ho165(n,3n)Ho163(n,3n)Ho161(β <sup>+</sup> )Dy161 (n,4n)Dy158(n,3n)Dy156(n,3n)Dy154					48.6	0.6	
		&Ho165(n,4n)Ho162(β <sup>+</sup> )Dy162(n,3n)Dy160 (n,3n)Dy158(n,3n)Dy156(n,3n)Dy154					7.7	0.2	
		Ho165(n,nα)Tb161(β <sup>-</sup> )Dy161(n,4n) Dy158(n,3n)Dy156(n,3n)Dy154					7.3	1.0	
		Ho165(n,3n)Ho163(n,3n)Ho161(β <sup>+</sup> )Dy161 (n,3n)Dy159(n,4n)Dy156(n,3n)Dy154					4.5	0.2	
		&Ho165(n,4n)Ho162(β <sup>+</sup> )Dy162(n,4n) Dy159(n,4n)Dy156(n,3n)Dy154						46.8	
		Ho165(n,4n)Ho162m(β <sup>+</sup> )Dy162(n,4n) Dy159(n,4n)Dy156(n,3n)Dy154						15.9	
		&Ho165(n,4n)Ho162(β <sup>+</sup> )Dy162(n,5n) Dy158(n,3n)Dy156(n,3n)Dy154						6.8	
		Ho165(n,5n)Ho161(β <sup>+</sup> )Dy161(n,4n) Dy158(n,3n)Dy156(n,3n)Dy154						5.3	

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
		&Ho165(n,4n)Ho162(β <sup>+</sup> )Dy162(n,5n) Dy158(n,5n)Dy154						1.5	16.2
		Ho165(n,5n)Ho161(β <sup>+</sup> )Dy161(n,4n) Dy158(n,5n)Dy154						1.2	24.3
		Ho165(n,4n)Ho162m(β <sup>+</sup> )Dy162(n,5n) Dy158(n,5n)Dy154						0.5	5.7
		Ho165(n,5n)Ho161(β <sup>+</sup> )Dy161(n,6n) Dy156(n,3n)Dy154							10.7
		Ho165(n,nt)Dy162(n,5n)Dy158(n,5n)Dy154							7.3
		Ho165(n,t)Dy163(n,6n)Dy158(n,5n)Dy154							4.8
		Many other similar long pathways				100.0	31.9	20.0	31.0
Hf182	9.0 10 <sup>6</sup> y	Very long pathways of (n,γ), β <sup>-</sup>	100.0	100.0					
Lu176	4.0 10 <sup>10</sup> y	&Ho165(n,γ)Ho166(β <sup>-</sup> )Er166(n,γ) Er167(n,γ)Er168(n,γ)Er169(β <sup>-</sup> )Tm169 (n,γ)Tm170(n,γ)Tm171(n,γ)Tm172(β <sup>-</sup> ) Yb172(n,γ)Yb173(n,γ)Yb174(n,γ) Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176	36.7	62.9	44.2				
		&Ho165(n,γ)Ho166(β <sup>-</sup> )Er166(n,γ) Er167(n,γ)Er168(n,γ)Er169(β <sup>-</sup> )Tm169 (n,γ)Tm170(n,γ)Tm171(n,γ)Tm172(n,γ) Tm173(β <sup>-</sup> )Yb173(n,γ)Yb174(n,γ) Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176	23.2	1.6	2.3				
		&Ho165(n,γ)Ho166m(n,γ)Ho167(β <sup>-</sup> ) Er167(n,γ)Er168(n,γ)Er169(β <sup>-</sup> )Tm169 (n,γ)Tm170(n,γ)Tm171(n,γ)Tm172(β <sup>-</sup> ) Yb172(n,γ)Yb173(n,γ)Yb174(n,γ) Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176	16.0	14.2	4.2				
		&Ho165(n,γ)Ho166m(n,γ)Ho167(β <sup>-</sup> ) Er167(n,γ)Er168(n,γ)Er169(β <sup>-</sup> )Tm169 (n,γ)Tm170(n,γ)Tm171(n,γ)Tm172(n,γ) Tm173(β <sup>-</sup> )Yb173(n,γ)Yb174(n,γ) Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176	8.3	0.3	0.2				
		&Ho165(n,γ)Ho166(β <sup>-</sup> )Er166(n,γ) Er167(n,γ)Er168(n,γ)Er169(β <sup>-</sup> )Tm169 (n,γ)Tm170(β <sup>-</sup> )Yb170(n,γ)Yb171(n,γ) Yb172(n,γ)Yb173(n,γ)Yb174(n,γ) Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176	3.0	0.3	22.1				
		&Ho165(n,γ)Ho166(β <sup>-</sup> )Er166(n,γ) Er167(n,γ)Er168(n,γ)Er169(β <sup>-</sup> )Tm169 (n,γ)Tm170(n,γ)Tm171(β <sup>-</sup> )Yb171(n,γ) Yb172(n,γ)Yb173(n,γ)Yb174(n,γ) Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176	2.1	7.4	10.5				
		&Ho165(n,γ)Ho166(n,γ)Ho167(β <sup>-</sup> )Er167(n,γ) Er168(n,γ)Er169(β <sup>-</sup> )Tm169(n,γ)Tm170(n,γ) Tm171(n,γ)Tm172(β <sup>-</sup> )Yb172(n,γ)Yb173 (n,γ)Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176	0.7	3.0	0.7				
Er162	1.4 10 <sup>14</sup> y	&Ho165(n,2n)Ho164(β <sup>-</sup> )Er164(n,3n)Er162 Ho165(n,γ)Ho166(β <sup>-</sup> )Er166(n,5n)Er162					99.8	99.9	97.6
									2.3
Gd160	1.3 10 <sup>17</sup> y	Ho165(n,γ)Ho166(β <sup>-</sup> )Er166(n,α)Dy163 (n,α)Gd160	85.0	99.9	99.8				
		Ho165(n,α)Tb162(β <sup>-</sup> )Dy162(n,γ) Dy163(n,α)Gd160	14.9		0.2				
		&Ho165(n,2n)Ho164(β <sup>+</sup> )Dy164(n,2n) Dy163(n,α)Gd160				91.4	0.3		
		&Ho165(n,2n)Ho164(β <sup>+</sup> )Dy164(n,α)Gd160				7.3	73.5	41.4	41.6
		Ho165(n,t)Dy163(n,α)Gd160				0.9	1.6	2.7	12.7
		Ho165(n,d)Dy164(n,α)Gd160					23.5	24.8	26.7
		&Ho165(n,4n)Ho162(β <sup>+</sup> )Dy162(n,h)Gd160						21.3	12.3
		Ho165(n,4n)Ho162m(β <sup>+</sup> )Dy162(n,h)Gd160						7.3	4.3
		Ho165(n,nt)Dy162(n,h)Gd160						0.7	5.6
		&Ho165(n,5n)Ho161(β <sup>+</sup> )Dy161(n,2p)Gd160							2.8

# Holmium activation characteristics

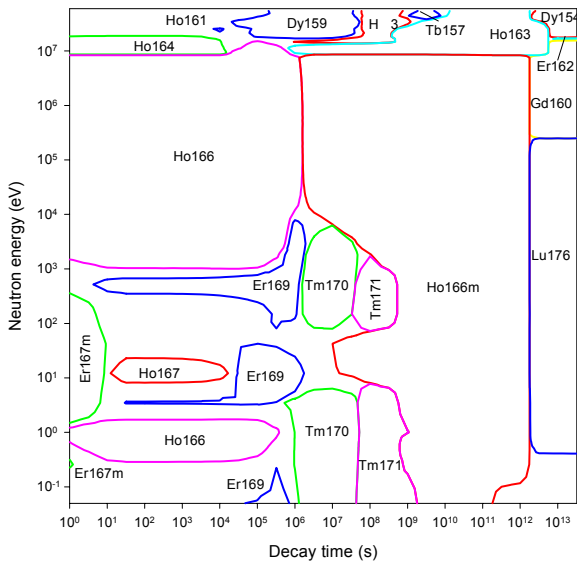


Decay time (years)

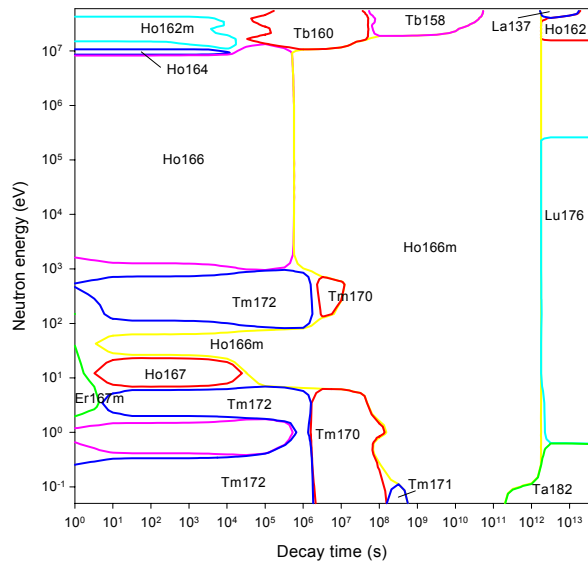
Decay time (years)

# Holmium importance diagrams & transmutation

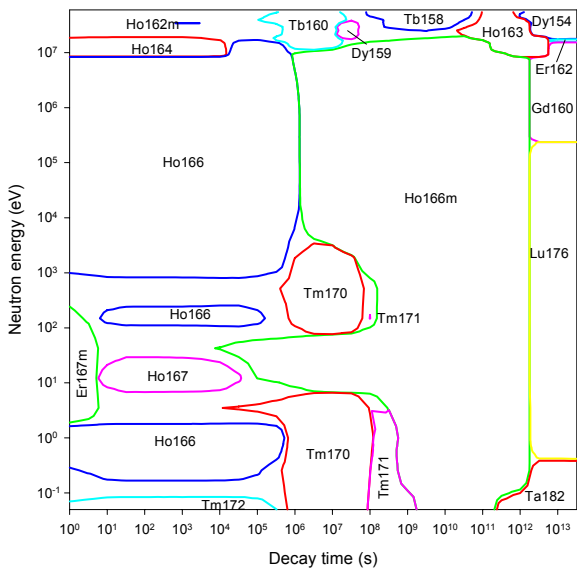
Activity



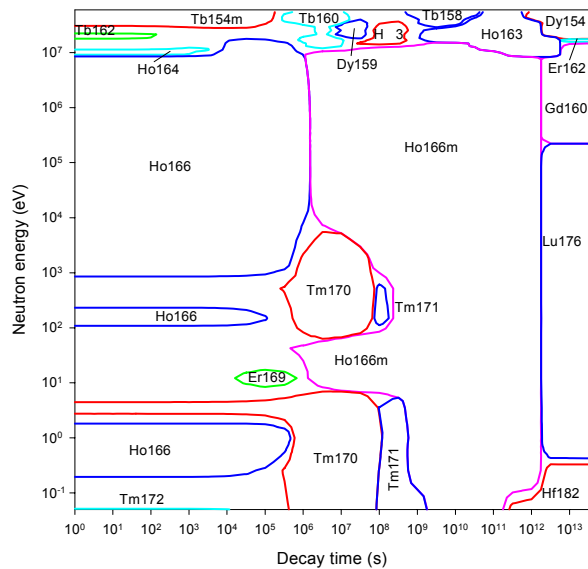
Dose rate



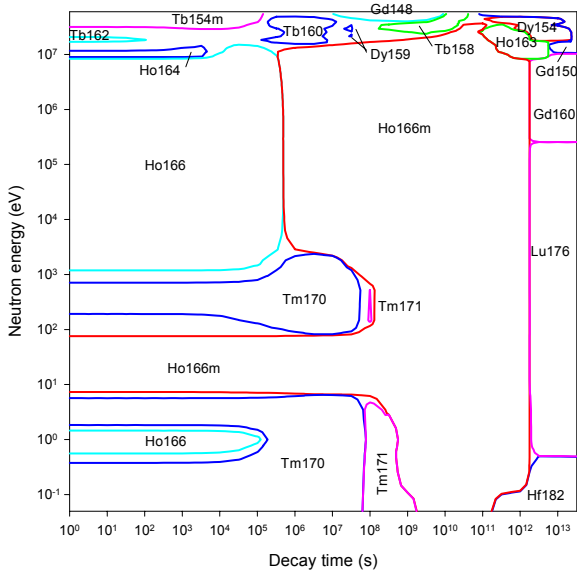
Heat output



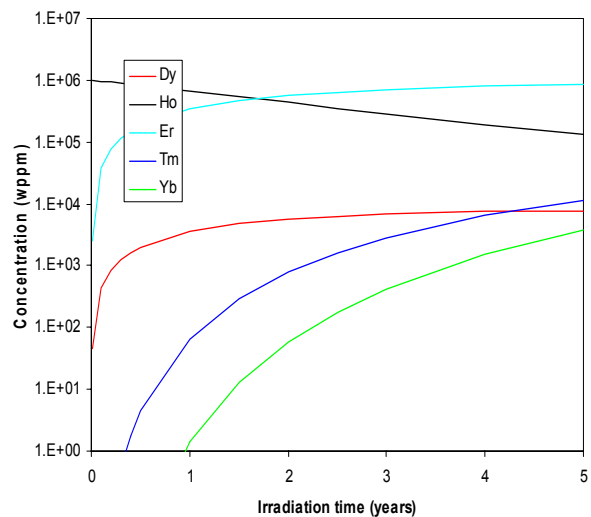
Ingestion dose



Inhalation dose



First wall transmutation





# Erbium

## General properties

Atomic number	68	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	3.5	Er162	0.139 ( $T_{1/2}=1.40 \cdot 10^{14}$ y)
Melting point / K	1802	Er164	1.601
Boiling point / K	3135	Er166	33.503
Density / kgm <sup>-3</sup>	9066	Er167	22.869
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	14.3	Er168	26.978
Electrical resistivity /Ωm	8.7 · 10 <sup>-7</sup>	Er170	14.910
Coefficient of thermal expansion / K <sup>-1</sup>	1.22 · 10 <sup>-5</sup>		
Crystal structure	HCP		
Number of stable isotopes	5 (6)		
Mean atomic weight	167.259		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	9.20E15	7.14E15	4.80E15	6.28E14	1.85E10	2.53E3	kW kg <sup>-1</sup>	4.27E-1	3.58E-1	1.78E-1	1.61E-2	2.52E-6	1.21E-15
Er169	30.66	39.47	44.89				Tm170	23.47	27.98	55.21	86.85		
Er167m	22.06	0.03					Er171	19.29	22.81	0.01			
Tm170	20.51	26.41	38.54	41.95			Tm172	16.74	19.93	15.45			
Er171	7.09	9.05					Er167m	15.82	0.02				
Tm171	5.64	7.26	10.78	57.59			Er169	10.77	12.84	19.74			
Tm172	4.81	6.19	3.55				Ho166	9.29	11.05	2.31			
Ho166	3.71	4.77	0.74				Tm168	2.12	2.53	4.95	3.70		
Er165	3.69	4.72	0.02				Tm171	0.51	0.61	1.22	9.43		
Tm168	0.47	0.60	0.87	0.45			Yb169	0.50	0.59	1.10	0.01		
Ho164	0.35	0.40					Ho166m				0.02	99.84	
Yb169	0.34	0.44	0.60				Ho163					0.16	88.67
Ho163					51.97	99.96	Lu176						6.77
Ho166m					47.96		Ta182						1.09
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	9.64E4	8.88E4	3.32E4	7.01E2	2.57E0	3.94E-11	Sv kg <sup>-1</sup>	5.09E6	5.09E6	3.66E6	3.85E5	1.80E1	6.88E-8
Tm172	62.29	67.53	70.03				Tm170	48.17	48.21	65.73	88.96		
Er171	16.83	18.12	0.02				Er169	20.50	20.51	21.79			
Tm168	10.12	10.98	28.77	98.55		0.08	Tm172	14.78	14.77	7.91			
Er167m	7.54	0.01					Ho166	9.39	9.38	1.35			
Ho166	2.01	2.18	0.61				Er171	4.61	4.58				
Ho167	0.56	0.60					Tm171	1.12	1.12	1.56	10.33		
Tm170	0.04*	0.05*	0.12*	0.85*			Tm168	0.81	0.81	1.09	0.70		
Ho166m			0.01	0.42	100.0		Yb169	0.43	0.43	0.56			
Lu176						49.80	Ho166m				0.01	98.76	
Ta182						45.35	Ho163					1.23	84.41
Hf182						1.24	Er162						13.49
							Lu176						1.72
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	1.78E7	1.78E7	1.62E7	2.36E6	1.06E3	2.27E-7		5.71E11	3.52E11	1.73E11	6.54E9	1.45E7	1.91E-3
Tm170	74.04	74.04	79.66	78.13			Tm172	40.74	66.05	51.93			
Er169	15.81	15.81	13.26				Er167m	38.17	0.07	0.01			
Tm171	4.07	4.07	4.46	21.45			Tm168	9.36	15.18	30.17	53.90		0.01
Tm172	2.73	2.73	1.15				Tm170	3.30	5.36	10.72	40.27		
Ho166	1.25	1.24	0.14				Er165	2.28	3.68	0.02			
Er171	0.80	0.80					Yb169	1.75	2.85	5.37	0.06		
Tm168	0.74	0.74	0.79	0.37			Ho167	1.28	1.98				
Yb169	0.52	0.52	0.53				Er171	1.14	1.84				
Ho166m	0.01	0.01	0.01	0.05	99.95		Ho166	0.60	0.97	0.21			
Ho163					0.05	59.06	Er169	0.49	0.80	1.25			
Lu176						20.28	Tm171	0.09	0.15	0.30	5.53		
Er162						12.87	Ho166m			0.01	0.24	99.97	
Hf182						7.53	Ho163					0.02	34.83
Ta182						0.24	Lu176						34.41
							Ta182						28.84
							Hf182						0.70
							Er162						0.63
							Ho162						0.56

# Erbium

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
Er167m	2.269 s	Er166(n,γ)Er167m	97.0	93.9	100.0		0.2	0.2	0.2	
		Er164(n,γ)Er165(β <sup>+</sup> )Ho165(n,γ)Ho166 <sub>-</sub>	2.8	5.5						
		(β <sup>-</sup> )Er166(n,γ)Er167m								
		Er168(n,2n)Er167m				87.1	40.5	47.5	53.1	
		Er167(n,n')Er167m				5.5	7.6	7.8	7.3	
		Er170(n,3n)Er168(n,2n)Er167m				1.9	3.7	1.3	0.9	
		Er170(n,2n)Er169(β <sup>-</sup> )Tm169(n,2n) <sub>-</sub>				1.9				
		Tm168(β <sup>+</sup> )Er168(n,2n)Er167m								
		Er170(n,2n)Er169(β <sup>-</sup> )Tm169(n,3n) <sub>-</sub>					23.8	11.5	5.4	
		Tm167(β <sup>+</sup> )Er167m								
		Er170(n,4n)Er167m					16.7	20.8	17.6	
		Er168(n,d)Ho167(β <sup>-</sup> )Er167m					2.4	5.6	7.6	
		Er170(n,d)Ho169(β <sup>-</sup> )Er169(β <sup>-</sup> )Tm169 <sub>-</sub>						2.2	1.5	
		(n,3n)Tm167(β <sup>+</sup> )Er167m								
Er170(n,nt)Ho167(β <sup>-</sup> )Er167m						0.7	4.7			
Ho158	11.0 m	&Er162(n,2n)Er161(n,2n)Er160(n,t)Ho158				100.0				
		Er166(n,3n)Er164(n,3n)Er162(n,3n) <sub>-</sub>					42.5	0.9		
		Er160(n,3n)Er158(β <sup>+</sup> )Ho158								
		Er164(n,3n)Er162(n,3n)Er160(n,3n) <sub>-</sub>					18.6	1.3		
		Er158(β <sup>+</sup> )Ho158								
		Er162(n,3n)Er160(n,3n)Er158(β <sup>+</sup> )Ho158					9.2	1.8		
		Er167(n,4n)Er164(n,3n)Er162(n,3n) <sub>-</sub>					5.0	1.5		
		Er160(n,3n)Er158(β <sup>+</sup> )Ho158								
		Er166(n,5n)Er162(n,5n)Er158(β <sup>+</sup> )Ho158						14.6	48.2	
		Er162(n,5n)Er158(β <sup>+</sup> )Ho158						10.5	2.3	
		Er167(n,4n)Er164(n,3n)Er162(n,5n) <sub>-</sub>						9.9	0.2	
		Er158(β <sup>+</sup> )Ho158								
		Er164(n,3n)Er162(n,5n)Er158(β <sup>+</sup> )Ho158							8.9	0.9
		Er166(n,3n)Er164(n,3n)Er162(n,5n) <sub>-</sub>							5.9	0.3
		Er158(β <sup>+</sup> )Ho158								
		Er167(n,4n)Er164(n,4n)Er161(n,4n) <sub>-</sub>							5.3	
		Er158(β <sup>+</sup> )Ho158								
		&Er166(n,5n)Er162(n,2nt)Ho158							3.6	2.4
		Er166(n,3n)Er164(n,4n)Er161(n,4n) <sub>-</sub>							3.2	
		Er158(β <sup>+</sup> )Ho158								
		Er167(n,6n)Er162(n,5n)Er158(β <sup>+</sup> )Ho158								19.9
&Er167(n,5n)Er163(β <sup>+</sup> )Ho163(n,6n)Ho158								4.2		
&Er168(n,6n)Er163(β <sup>+</sup> )Ho163(n,6n)Ho158								4.1		
Many other similar long pathways						24.7	32.6	17.5		
Ho162	15.0 m	Er162(β <sup>+</sup> )Ho162	100.0		100.0					
		&Er164(n,2n)Er163(β <sup>+</sup> )Ho163(n,2n)Ho162				83.1	3.9	0.1		
		&Er166(n,2n)Er165(β <sup>+</sup> )Ho165(n,2n)Ho164 <sub>-</sub>				11.3				
		(β <sup>-</sup> )Er164(n,2n)Er163(β <sup>+</sup> )Ho163(n,2n)Ho162								
		&Er167(n,3n)Er165(β <sup>+</sup> )Ho165(n,4n)Ho162					15.0	11.2	3.6	
		&Er167(n,3n)Er165(β <sup>+</sup> )Ho165(n,3n) <sub>-</sub>					14.2			
		Ho163(n,2n)Ho162								
		&Er166(n,3n)Er164(n,2n)Er163(β <sup>+</sup> ) <sub>-</sub>					9.3			
		Ho163(n,2n)Ho162								
		&Er166(n,2n)Er165(β <sup>+</sup> )Ho165(n,4n)Ho162					8.4	15.4	5.8	
		&Er166(n,2n)Er165(β <sup>+</sup> )Ho165(n,3n) <sub>-</sub>					8.0			
		Ho163(n,2n)Ho162								
		&Er166(n,3n)Er164(n,t)Ho162					7.1	1.3	1.9	
		&Er166(n,4n)Er163(β <sup>+</sup> )Ho163(n,2n)Ho162					3.7	12.4	4.4	
&Er168(n,4n)Er165(β <sup>+</sup> )Ho165(n,4n)Ho162					2.7	38.6	5.2			
&Er168(n,4n)Er165(β <sup>+</sup> )Ho165(n,3n) <sub>-</sub>					2.6	0.2				
▶ Ho163(n,2n)Ho162										

Nuclide	T <sub>½</sub>	Pathway	210	186	151	42	30	21	6
	◀	&Er166(n,3n)Er164(n,3n)Er162(n,p)Ho162 &Er164(n,t)Ho162 &Er166(n,d)Ho165(n,4n)Ho162 &Er167(n,4n)Er164(n,t)Ho162 &Er167(n,t)Ho165(n,4n)Ho162 &Er167(n,5n)Er163(β <sup>+</sup> )Ho163(n,2n)Ho162 &Er168(n,nt)Ho165(n,4n)Ho162 &Er168(n,5n)Er164(n,t)Ho162 &Er168(n,t)Ho166m(n,5n)Ho162 &Er166(n,2nt)Ho162 &Er170(n,6n)Er165(β <sup>+</sup> )Ho165(n,4n)Ho162 &Er168(n,6n)Er163(β <sup>+</sup> )Ho163(n,2n)Ho162 &Er167(n,3nt)Ho162 Many other similar long pathways					2.3 1.5 1.0 0.9 0.1	1.0 3.7 2.1 2.1	2.9 1.9 1.6 1.5
						15.6	19.3	9.8	13.8
Ho160	25.3 m	&Er162(n,2n)Er161(n,2n)Er160(β <sup>+</sup> )Ho160 &Er162(n,t)Ho160 &Er166(n,3n)Er164(n,3n)Er162(n,3n) Er160(β <sup>+</sup> )Ho160 &Er164(n,3n)Er162(n,3n)Er160(β <sup>+</sup> )Ho160 &Er162(n,3n)Er160(β <sup>+</sup> )Ho160 &Er167(n,4n)Er164(n,3n)Er162(n,3n) Er160(β <sup>+</sup> )Ho160 &Er168(n,3n)Er166(n,3n)Er164(n,3n) Er162(n,3n)Er160(β <sup>+</sup> )Ho160 &Er166(n,4n)Er163(β <sup>+</sup> )Ho163(n,4n)Ho160 &Er167(n,5n)Er163(β <sup>+</sup> )Ho163(n,4n)Ho160 &Er166(n,5n)Er162(n,3n)Er160(β <sup>+</sup> )Ho160 &Er168(n,4n)Er165(β <sup>+</sup> )Ho165(n,3n) Ho163(n,4n)Ho160 &Er168(n,3n)Er166(n,4n)Er163(β <sup>+</sup> ) Ho163(n,4n)Ho160 &Er167(n,4n)Er164(n,2n)Er163(β <sup>+</sup> ) Ho163(n,4n)Ho160 &Er167(n,4n)Er164(n,5n)Er160(β <sup>+</sup> )Ho160 &Er164(n,5n)Er160(β <sup>+</sup> )Ho160 &Er166(n,3n)Er164(n,5n)Er160(β <sup>+</sup> )Ho160 &Er166(n,5n)Er162(n,t)Ho160 &Er168(n,5n)Er164(n,5n)Er160(β <sup>+</sup> )Ho160 &Er168(n,6n)Er163(β <sup>+</sup> )Ho163(n,4n)Ho160 &Er167(n,6n)Er162(n,3n)Er160(β <sup>+</sup> )Ho160 &Er170(n,6n)Er165(β <sup>+</sup> )Ho165(n,6n)Ho160 &Er166(n,2n)Er165(β <sup>+</sup> )Ho165(n,6n)Ho160 &Er168(n,4n)Er165(β <sup>+</sup> )Ho165(n,6n)Ho160 &Er167(n,3n)Er165(β <sup>+</sup> )Ho165(n,6n)Ho160 Many other similar long pathways				93.4 6.6	42.3	0.9	0.2 0.4
							2.6		2.8 3.7 9.3
								67.6 3.8 2.3 1.8	2.8 3.7 9.3
								1.5 1.3	
								0.4 0.2 0.2 0.1	7.2 12.8 8.6 2.5
								20.1	20.4
Er171	7.516 h	Er170(n,γ)Er171	99.2	99.8	100.0	99.9	99.7	99.8	99.9
Tb154m	9.00 h	&Er162(n,α)Dy158(n,2n)Dy157(β <sup>+</sup> )Tb157 (n,2n)Tb156(n,2n)Tb155(n,2n)Tb154m Er162(n,α)Dy159(β <sup>+</sup> )Tb159(n,2n) Tb158(n,2n)Tb157(n,2n)Tb156(n,2n) Tb155(n,2n)Tb154m Er162(n,α)Dy159(n,2n)Dy158(n,2n) Dy157(β <sup>+</sup> )Tb157(n,2n)Tb156(n,2n) Tb155(n,2n)Tb154m Er166(n,3n)Er164(n,3n)Er162(n,α) Dy158(n,3n)Dy156(n,t)Tb154m Er162(n,α)Dy158(n,3n)Dy156(n,t)Tb154m Er166(n,3n)Er164(n,α)Dy160(n,3n) Dy158(n,3n)Dy156(n,t)Tb154m Er164(n,3n)Er162(n,α)Dy158(n,3n) Dy156(n,t)Tb154m				15.5 9.8 5.3			
								3.1	
								2.8 2.7	
								2.5	
	▶								

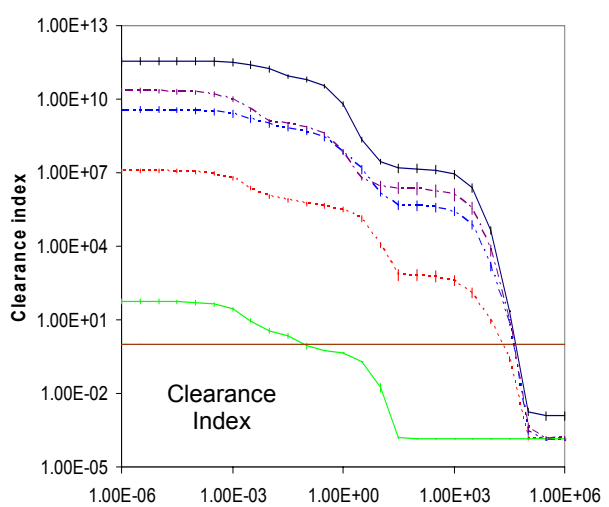
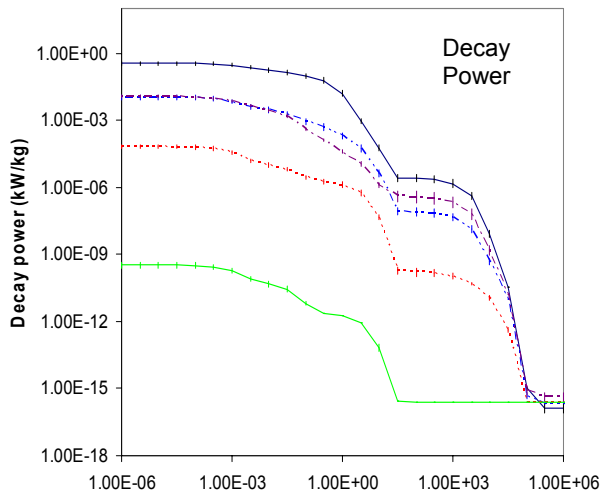
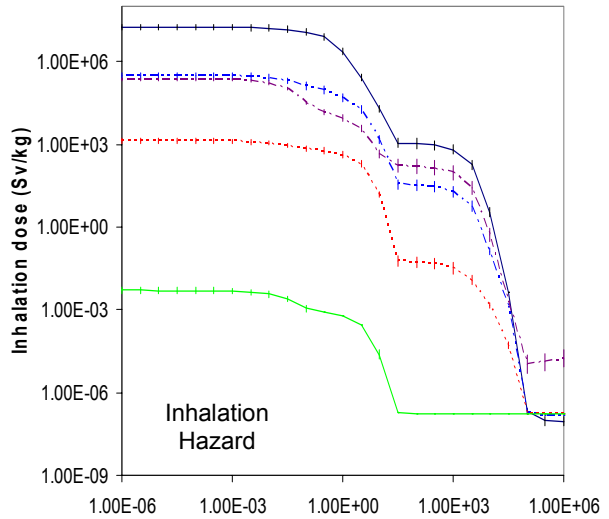
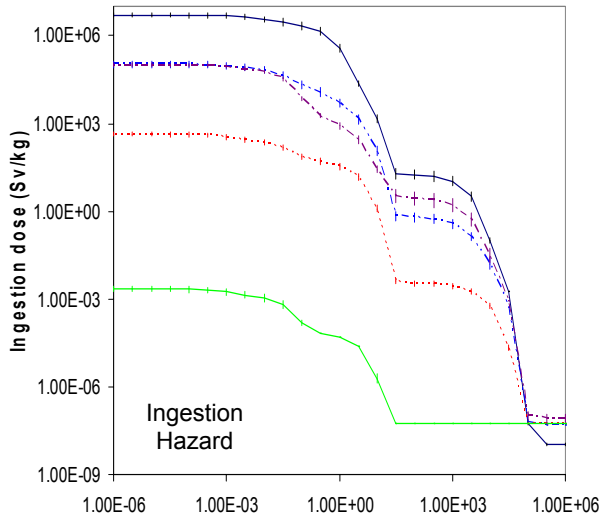
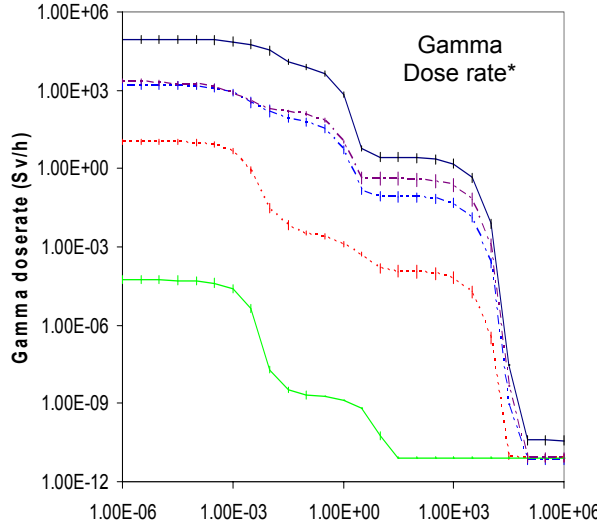
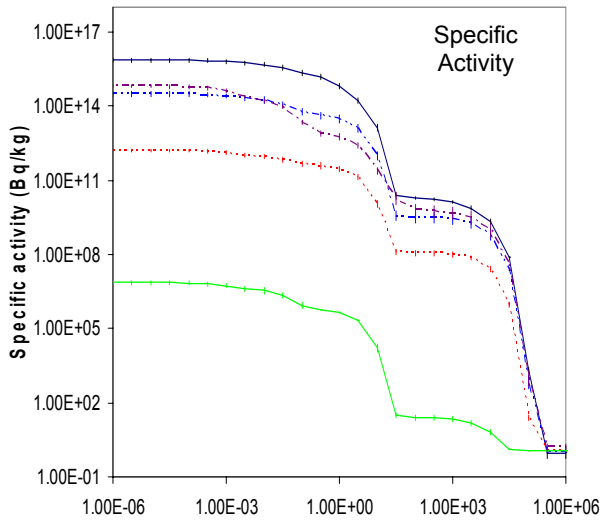
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Er164(n,α)Dy160(n,3n)Dy158(n,3n)_ Dy156(n,t)Tb154m Er166(n,4n)Er163(β <sup>+</sup> )Ho163(n,3nα)_ Tb157(n,4n)Tb154m Er166(n,3nα)Dy160(n,4n)Dy157(β <sup>+</sup> )_ Tb157(n,4n)Tb154m Er166(n,4nα)Dy159(β <sup>+</sup> )Tb159(n,6n)Tb154m   Er166(n,5n)Er162(n,5n)Er158(β <sup>+</sup> )_ Ho158(β <sup>+</sup> )Dy158(n,2nt)Tb154m Many other similar long pathways					2.2	2.4	0.2	
								2.1	0.2	
									4.5	
									2.9	
						69.4	86.7	95.5	92.2	
Er165	10.360 h	Er164(n,γ)Er165 &Er162(n,γ)Er163(β <sup>+</sup> )Ho163(n,γ)_ Ho164(β <sup>-</sup> )Er164(n,γ)Er165 Er166(n,2n)Er165 Er167(n,2n)Er166(n,2n)Er165 Er168(n,2n)Er167(n,2n)Er166(n,2n)Er165   Er168(n,3n)Er166(n,2n)Er165 Er167(n,3n)Er165 Er168(n,4n)Er165 Er170(n,4n)Er167(n,3n)Er165 Er168(n,2n)Er167(n,3n)Er165 Er170(n,6n)Er165	96.9 2.8	1.4 89.2	99.9					
						79.3	27.1	22.1	25.3	
						17.2	1.1			
						2.4				
						0.1	5.0			
							48.9	16.3	16.2	
							9.0	54.5	22.7	
							3.0			
							2.4			
									30.1	
Tm172	2.650 d	Er170(n,γ)Er171(β <sup>-</sup> )Tm171(n,γ)Tm172 Er168(n,γ)Er169(β <sup>-</sup> )Tm169(n,γ)Tm170_ (n,γ)Tm171(n,γ)Tm172 Er167(n,γ)Er168(n,γ)Er169(β <sup>-</sup> )Tm169_ (n,γ)Tm170(n,γ)Tm171(n,γ)Tm172 &Er166(n,γ)Er167(n,γ)Er168(n,γ)_ Er169(β <sup>-</sup> )Tm169(n,γ)Tm170(n,γ)_ Tm171(n,γ)Tm172	56.0 18.0	58.6 17.6	99.2 0.7	99.8	99.5	99.6	99.8	
Er169	9.40 d	Er168(n,γ)Er169 Er167(n,γ)Er168(n,γ)Er169 &Er166(n,γ)Er167(n,γ)Er168(n,γ)Er169 Er170(n,2n)Er169 Er170(n,d)Ho169(β <sup>-</sup> )Er169	38.1 32.4 29.3	38.3 32.5 28.0	87.8 11.3 0.9		0.2	0.1		
						99.8	91.4	83.8	76.8	
								15.8	23.2	
Hf181	42.38 d	Very long pathways of (n,γ), β <sup>-</sup>	100.0	100.0	100.0					
Tb160	72.3 d	Er162(n,α)Dy159(β <sup>+</sup> )Tb159(n,γ)Tb160 Er164(n,2n)Er163(β <sup>+</sup> )Ho163(n,α)Tb160 Er166(n,2n)Er165(β <sup>+</sup> )Ho165(n,2n)Ho164_ (β <sup>-</sup> )Er164(n,2n)Er163(β <sup>+</sup> )Ho163(n,α)Tb160 Er162(n,2n)Er161(β <sup>+</sup> )Ho161(β <sup>+</sup> )Dy161_ (n,2n)Dy160(n,p)Tb160 &Er167(n,3n)Er165(β <sup>+</sup> )Ho165(n,3n)_ Ho163(n,α)Tb160 Er167(n,3n)Er165(β <sup>+</sup> )Ho165(n,2nα)Tb160   Er166(n,3n)Er164(n,2n)Er163(β <sup>+</sup> )_ Ho163(n,α)Tb160 Er167(n,3n)Er165(β <sup>+</sup> )Ho165(n,3n)Ho163_ (n,3n)Ho161(β <sup>+</sup> )Dy161(n,d)Tb160 Er166(n,2n)Er165(β <sup>+</sup> )Ho165(n,3n)_ Ho163(n,α)Tb160 Er166(n,3n)Er164(n,3n)Er162(n,2n)_ Er161(β <sup>+</sup> )Ho161(β <sup>+</sup> )Dy161(n,d)Tb160 Er166(n,2n)Er165(β <sup>+</sup> )Ho165(n,2nα)Tb160 Er166(n,3n)Er164(n,2n)Er163(β <sup>+</sup> )Ho163_ (n,3n)Ho161(β <sup>+</sup> )Dy161(n,d)Tb160 Er166(n,4n)Er163(β <sup>+</sup> )Ho163(n,α)Tb160 Er166(n,4n)Er163(β <sup>+</sup> )Ho163(n,3n)_ Ho161(β <sup>+</sup> )Dy161(n,d)Tb160 ▶ Er168(n,4n)Er165(β <sup>+</sup> )Ho165(n,2nα)Tb160	99.0	100.0	99.2					
						78.7	2.4			
						7.3				
						3.5				
							9.2			
							7.0	4.9	2.0	
							5.8			
							5.4			
							4.8			
							4.2			
							3.9	6.7	3.1	
							3.7			
							2.4	5.6	1.6	
							2.3	5.4	0.5	
							1.3	16.5	2.7	

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	Er167(n,4n)Er164(n,4n)Er161(β <sup>+</sup> )_Ho161(β <sup>+</sup> )Dy161(n,d)Tb160 Er164(n,4n)Er161(β <sup>+</sup> )Ho161(β <sup>+</sup> )Dy161_(n,d)Tb160 Er166(n,3n)Er164(n,4n)Er161(β <sup>+</sup> )_Ho161(β <sup>+</sup> )Dy161(n,d)Tb160 Er166(n,6n)Er161(β <sup>+</sup> )Ho161(β <sup>+</sup> )Dy161_(n,d)Tb160 Er170(n,6n)Er165(β <sup>+</sup> )Ho165(n,2nα)Tb160 Many other similar long pathways	1.0		0.8	10.5	47.6	42.3	58.8
Tm168	93.10 d	Er170(n,2n)Er169(β <sup>-</sup> )Tm169(n,2n)Tm168 Er170(n,d)Ho169(β <sup>-</sup> )Er169(β <sup>-</sup> )Tm169_(n,2n)Tm168				99.9	91.6	83.4	77.5
Ta182	114.7 d	Very long pathways of (n,γ), β <sup>-</sup>	100.0	100.0	100.0				
Tm170	128.6 d	Er168(n,γ)Er169(β <sup>-</sup> )Tm169(n,γ)Tm170 Er167(n,γ)Er168(n,γ)Er169(β <sup>-</sup> )Tm169_(n,γ)Tm170 &Er166(n,γ)Er167(n,γ)Er168(n,γ)_Er169(β <sup>-</sup> )Tm169(n,γ)Tm170 Er170(n,2n)Er169(β <sup>-</sup> )Tm169(n,γ)Tm170 Er170(n,γ)Er171(β <sup>-</sup> )Tm171(n,2n)Tm170 Er170(n,d)Ho169(β <sup>-</sup> )Er169(β <sup>-</sup> )Tm169_(n,γ)Tm170 Er170(n,γ)Er171(β <sup>-</sup> )Tm171(β <sup>-</sup> )Yb171_(n,d)Tm170	40.4 34.3 25.2	41.2 34.7 23.2	94.0 5.7 0.2		0.1 65.5 34.3	59.2 21.4 11.2	54.6 19.9 15.3
Dy159	144.4 d	Er162(n,α)Dy159 Er162(n,2n)Er161(β <sup>+</sup> )Ho161(β <sup>+</sup> )Dy161_(n,2n)Dy160(n,2n)Dy159 &Er167(n,3n)Er165(β <sup>+</sup> )Ho165(n,3n)_Ho163(n,3n)Ho161(β <sup>+</sup> )Dy161(n,3n)Dy159 Er166(n,3n)Er164(n,3n)Er162(n,2n)_Er161(β <sup>+</sup> )Ho161(β <sup>+</sup> )Dy161(n,3n)Dy159 &Er166(n,3n)Er164(n,2n)Er163(β <sup>+</sup> )_Ho163(n,3n)Ho161(β <sup>+</sup> )Dy161(n,3n)Dy159 &Er166(n,2n)Er165(β <sup>+</sup> )Ho165(n,3n)_Ho163(n,3n)Ho161(β <sup>+</sup> )Dy161(n,3n)Dy159 Er164(n,3n)Er162(n,2n)Er161(β <sup>+</sup> )_Ho161(β <sup>+</sup> )Dy161(n,3n)Dy159 &Er164(n,2n)Er163(β <sup>+</sup> )Ho163(n,3n)_Ho161(β <sup>+</sup> )Dy161(n,3n)Dy159 &Er166(n,4n)Er163(β <sup>+</sup> )Ho163(n,3n)_Ho161(β <sup>+</sup> )Dy161(n,3n)Dy159 &Er168(n,4n)Er165(β <sup>+</sup> )Ho165(n,4n)_Ho162(β <sup>+</sup> )Dy162(n,4n)Dy159 &Er166(n,4n)Er163(β <sup>+</sup> )Ho163(n,5n)_Ho159(β <sup>+</sup> )Dy159 &Er166(n,5n)Er162(n,4n)Er159(β <sup>+</sup> )_Ho159(β <sup>+</sup> )Dy159 &Er166(n,2n)Er165(β <sup>+</sup> )Ho165(n,4n)_Ho162(β <sup>+</sup> )Dy162(n,4n)Dy159 &Er167(n,5n)Er163(β <sup>+</sup> )Ho163(n,5n)_Ho159(β <sup>+</sup> )Dy159 &Er166(n,5n)Er162(n,nt)Ho159(β <sup>+</sup> )Dy159 &Er168(n,6n)Er163(β <sup>+</sup> )Ho163(n,5n)_Ho159(β <sup>+</sup> )Dy159 &Er167(n,6n)Er162(n,4n)Er159(β <sup>+</sup> )_Ho159(β <sup>+</sup> )Dy159 Er166(n,4nα)Dy159 Many other similar long pathways	99.9	100.0	100.0	9.9 80.0	0.4 10.1 7.1 6.8 5.6 4.6 4.4 4.3	2.8 10.1	10.1 11.1 13.4 4.4 13.0 4.6
Tm171	1.917 y▶	Er170(n,γ)Er171(β <sup>-</sup> )Tm171	56.1	58.6	99.2	100.0	99.8	99.9	99.9

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	Er168(n,γ)Er169(β <sup>-</sup> )Tm169(n,γ)Tm170_ (n,γ)Tm171 Er167(n,γ)Er168(n,γ)Er169(β <sup>-</sup> )Tm169_ (n,γ)Tm170(n,γ)Tm171 &Er166(n,γ)Er167(n,γ)Er168(n,γ)_ Er169(β <sup>-</sup> )Tm169(n,γ)Tm170(n,γ)Tm171	18.0	17.6	0.7				
H3	12.33 y	Er166(n,2n)Er165(β <sup>+</sup> )Ho165(n,X)H3 Er167(n,X)H3 &Er168(n,2n)Er167(n,X)H3 Er170(n,2n)Er169(β <sup>-</sup> )Tm169(n,X)H3 Er166(n,X)H3 Er168(n,X)H3 Er170(n,X)H3 Er164(n,X)H3 Er166(n,3n)Er164(n,X)H3 Er167(n,3n)Er165(β <sup>+</sup> )Ho165(n,X)H3 Er168(n,3n)Er166(n,X)H3 Er170(n,4n)Er167(n,X)H3 Er168(n,4n)Er165(β <sup>+</sup> )Ho165(n,X)H3 Er167(n,4n)Er164(n,X)H3 Er166(n,4n)Er163(β <sup>+</sup> )Ho163(n,X)H3 Er166(n,5n)Er162(n,X)H3 Er167(n,5n)Er163(β <sup>+</sup> )Ho163(n,X)H3				47.5 30.4 5.9 4.4 2.5 2.1 1.7 0.1	1.7 27.0 0.8 0.7 26.2 20.1 6.7 1.4 3.4 3.1 2.4 0.8 0.6 0.4	0.9 23.2 0.3 0.2 27.7 21.1 9.0 1.4 1.0 0.7 0.7 1.0 2.3 1.7 3.1	0.6 22.0 0.3 0.2 28.8 21.9 10.7 1.2 0.4 0.4 0.2 0.5 0.4 0.7 1.5 1.0
Gd148	74.602 y	Very long pathways				100.0	100.0	100.0	100.0
Ho166m	1200 y	Er164(n,γ)Er165(β <sup>+</sup> )Ho165(n,γ)Ho166m &Er162(n,γ)Er163(β <sup>+</sup> )Ho163(n,γ)Ho164_ (β <sup>-</sup> )Er164(n,γ)Er165(β <sup>+</sup> )Ho165(n,γ)Ho166m &Er162(n,γ)Er163(β <sup>+</sup> )Ho163(n,γ)Ho164(β <sup>+</sup> )_ Dy164(n,γ)Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166m Er166(n,p)Ho166m Er167(n,d)Ho166m Er170(n,2n)Er169(β <sup>-</sup> )Tm169(n,α)Ho166m Er167(n,2n)Er166(n,p)Ho166m Er166(n,2n)Er165(β <sup>+</sup> )Ho165(n,γ)Ho166m Er168(n,2n)Er167(n,d)Ho166m Er168(n,t)Ho166m Er170(n,2nt)Ho166m	93.2	74.2 13.3	100.0				
Ho163	4570 y	Er162(n,γ)Er163(β <sup>+</sup> )Ho163 Er164(n,2n)Er163(β <sup>+</sup> )Ho163 &Er166(n,2n)Er165(β <sup>+</sup> )Ho165(n,2n)_ Ho164(β <sup>-</sup> )Er164(n,2n)Er163(β <sup>+</sup> )Ho163 Er167(n,3n)Er165(β <sup>+</sup> )Ho165(n,3n)Ho163 Er166(n,3n)Er164(n,2n)Er163(β <sup>+</sup> )Ho163 Er166(n,2n)Er165(β <sup>+</sup> )Ho165(n,3n)Ho163 Er166(n,4n)Er163(β <sup>+</sup> )Ho163 Er168(n,4n)Er165(β <sup>+</sup> )Ho165(n,3n)Ho163 &Er166(n,3n)Er164(n,d)Ho163 Er167(n,4n)Er164(n,2n)Er163(β <sup>+</sup> )Ho163 &Er166(n,nt)Ho163 Er167(n,5n)Er163(β <sup>+</sup> )Ho163 Er168(n,6n)Er163(β <sup>+</sup> )Ho163 Er167(n,2nt)Ho163	100.0	100.0	100.0	84.6 14.0	7.4	1.3	
Gd150	1.8 10 <sup>6</sup> y	Very long pathways				100.0	100.0	100.0	100.0
Dy154	3.0 10 <sup>6</sup> y	Er162(n,α)Dy158(n,2n)Dy157(n,2n)_ Dy156(n,2n)Dy155(n,2n)Dy154 Er162(n,α)Dy159(n,2n)Dy158(n,2n)Dy157_ (n,2n)Dy156(n,2n)Dy155(n,2n)Dy154 Er164(n,4n)Er161(β <sup>+</sup> )Ho161(β <sup>+</sup> )Dy161_ (n,4n)Dy158(n,3n)Dy156(n,3n)Dy154 &Er162(n,4n)Er159(β <sup>+</sup> )Ho159(β <sup>+</sup> )_ Dy159(n,4n)Dy156(n,3n)Dy154				47.5 26.7			9.6 6.7

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Er167(n,4n)Er164(n,4n)Er161(β <sup>+</sup> )_Ho161(β <sup>+</sup> )Dy161(n,4n)Dy158(n,3n)_Dy156(n,3n)Dy154 Er166(n,4n)Er163(β <sup>+</sup> )Ho163(n,3n)_Ho161(β <sup>+</sup> )Dy161(n,4n)Dy158(n,3n)_Dy156(n,3n)Dy154 Er166(n,4n)Er163(β <sup>+</sup> )Ho163(n,5n)Ho159_ (β <sup>+</sup> )Dy159(n,4n)Dy156(n,3n)Dy154 Er166(n,5n)Er162(n,5n)Er158(β <sup>+</sup> )_Ho158(β <sup>+</sup> )Dy158(n,5n)Dy154 Er167(n,6n)Er162(n,5n)Er158(β <sup>+</sup> )_Ho158(β <sup>+</sup> )Dy158(n,5n)Dy154 Er166(n,6n)Er161(β <sup>+</sup> )Ho161(β <sup>+</sup> )_Dy161(n,4n)Dy158(n,5n)Dy154 Er162(n,5n)Er158(β <sup>+</sup> )Ho158(β <sup>+</sup> )_Dy158(n,5n)Dy154 Many other similar long pathways							4.6 3.3 3.1 27.3 11.2 4.9 3.4	
Hf182	9.0 10 <sup>6</sup> y	Very long pathways of (n,γ), β <sup>-</sup>	100.0	100.0	100.0					
Lu176	4.0 10 <sup>10</sup> y	Er170(n,γ)Er171(β <sup>-</sup> )Tm171(n,γ)Tm172_ (β <sup>-</sup> )Yb172(n,γ)Yb173(n,γ)Yb174(n,γ)_Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176 Er170(n,γ)Er171(β <sup>-</sup> )Tm171(n,γ)Tm172_ (n,γ)Tm173(β <sup>-</sup> )Yb173(n,γ)Yb174(n,γ)_Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176 Er168(n,γ)Er169(β <sup>-</sup> )Tm169(n,γ)Tm170_ (n,γ)Tm171(n,γ)Tm172(β <sup>-</sup> )Yb172(n,γ)_Yb173(n,γ)Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175_ (n,γ)Lu176 Er167(n,γ)Er168(n,γ)Er169(β <sup>-</sup> )Tm169_ (n,γ)Tm170(n,γ)Tm171(n,γ)Tm172(β <sup>-</sup> )_Yb172(n,γ)Yb173(n,γ)Yb174(n,γ)_Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176 Er170(n,γ)Er171(β <sup>-</sup> )Tm171(β <sup>-</sup> )Yb171_ (n,γ)Yb172(n,γ)Yb173(n,γ)Yb174(n,γ)_Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176 Er168(n,γ)Er169(β <sup>-</sup> )Tm169(n,γ)Tm170_ (n,γ)Tm171(n,γ)Tm172(n,γ)Tm173(β <sup>-</sup> )_Yb173(n,γ)Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175_ (n,γ)Lu176 Er167(n,γ)Er168(n,γ)Er169(β <sup>-</sup> )Tm169_ (n,γ)Tm170(n,γ)Tm171(n,γ)Tm172(n,γ)_Tm173(β <sup>-</sup> )Yb173(n,γ)Yb174(n,γ)_Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176 Er168(n,γ)Er169(β <sup>-</sup> )Tm169(n,γ)Tm170_ (n,γ)Tm171(β <sup>-</sup> )Yb171(n,γ)Yb172(n,γ)_Yb173(n,γ)Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175_ (n,γ)Lu176	54.2 18.1 7.1 5.9 4.4 3.0 2.5 0.5	70.0 1.3 8.6 5.5 10.9 0.2 0.1 1.2	70.2 2.0 27.6					
Er162	1.4 10 <sup>14</sup> y	Er166(n,3n)Er164(n,3n)Er162 Er164(n,3n)Er162 Er167(n,4n)Er164(n,3n)Er162 Er168(n,3n)Er166(n,3n)Er164(n,3n)Er162 Er166(n,5n)Er162 Er168(n,5n)Er164(n,3n)Er162 Er168(n,3n)Er166(n,5n)Er162 Er170(n,5n)Er166(n,5n)Er162 Er167(n,6n)Er162 Nuclide present in starting material					56.6 22.5 6.7 3.5 26.8 3.5 0.6 0.5	11.8 16.3 19.7 0.2 26.8 3.5 0.9 1.0	0.4 1.2 0.4 0.4 64.0 0.8 0.9 1.0 26.4 4.9	

# Erbium activation characteristics



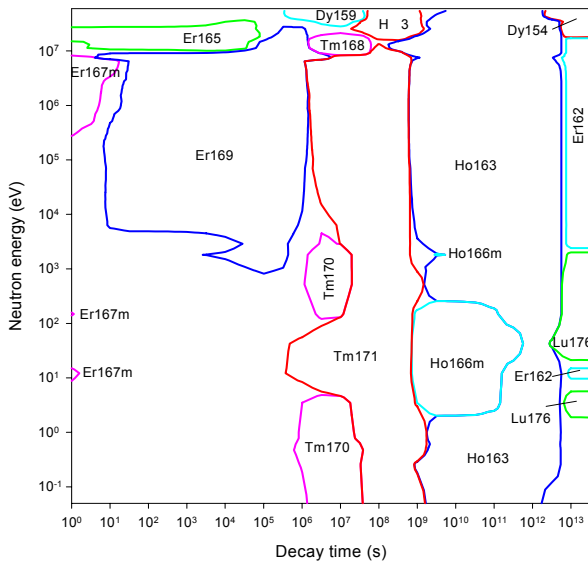
Decay time (years)

Decay time (years)

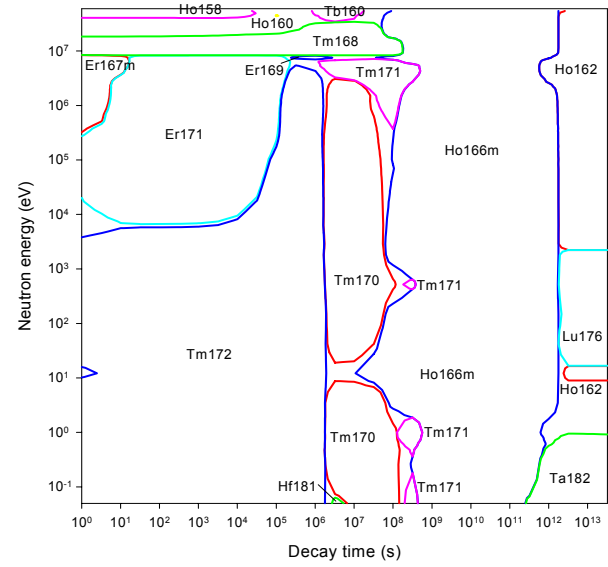


# Erbium importance diagrams & transmutation

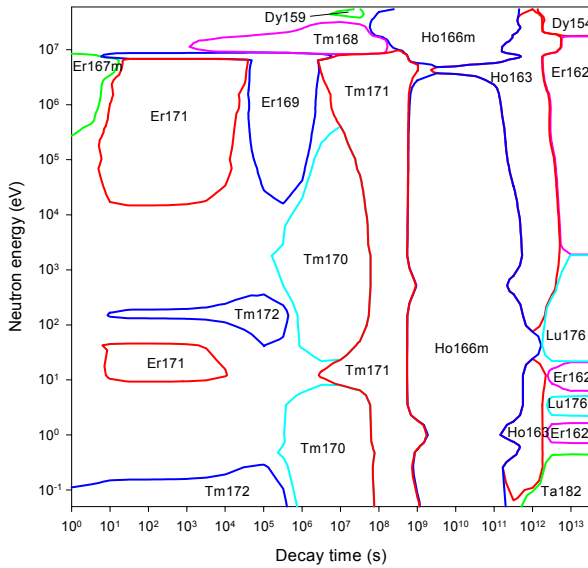
**Activity**



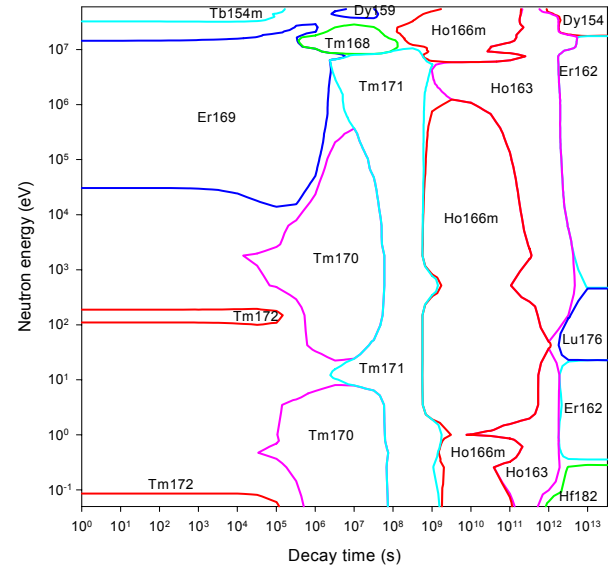
**Dose rate**



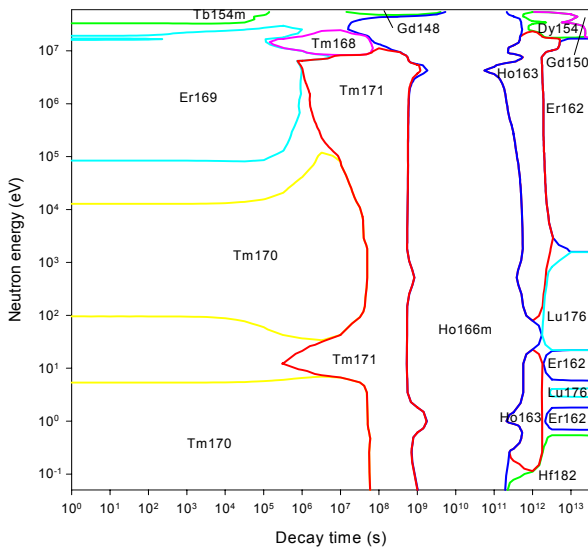
**Heat output**



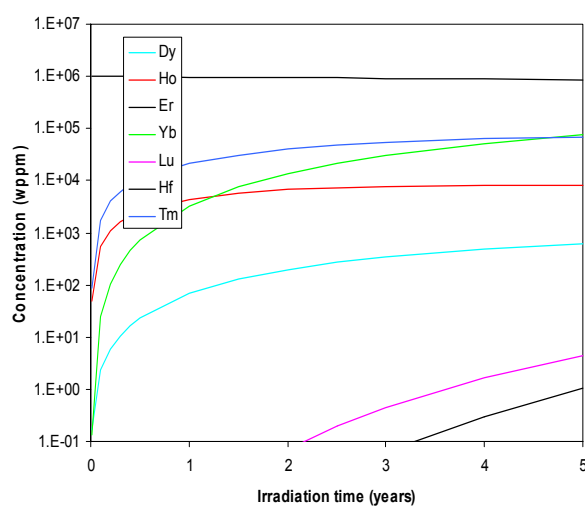
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**





# Thulium

## General properties

Atomic number	69	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	0.52	Tm169	100.0
Melting point / K	1818		
Boiling point / K	2219		
Density / kgm <sup>-3</sup>	9321		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	16.8		
Electrical resistivity /Ωm	7.9 10 <sup>-7</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	1.33 10 <sup>-5</sup>		
Crystal structure	HCP		
Number of stable isotopes	1		
Mean atomic weight	168.93421		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	8.62E15	8.49E15	7.73E15	1.61E15	1.71E8	5.51E0	kW kg <sup>-1</sup>	5.24E-1	5.23E-1	4.18E-1	4.83E-2	3.49E-8	6.98E-16
Tm170	67.67	68.67	74.04	50.71			Tm170	59.20	59.28	72.79	89.58		
Tm171	13.05	13.24	14.51	48.77			Tm172	29.59	29.61	14.28			
Tm172	11.13	11.28	4.78				Tm168	5.02	5.03	6.13	3.59		0.07
Yb169	4.18	4.24	4.31	0.01			Yb169	4.68	4.69	5.42	0.02		
Tm168	1.44	1.46	1.57	0.51		0.04	Tm171	0.90	0.90	1.13	6.82		
Er169	0.90	0.91	0.77				Er169	0.24	0.24	0.23			
Ho166m					72.00		Ho166m					99.85	
H3					27.98		Hf178n					0.01	
Lu176						88.81	Lu176						87.38
Ta182						5.53	Ta182						10.48
Hf182						5.53	Hf182						1.90
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	1.59E5	1.59E5	7.91E4	2.00E3	3.50E-2	2.42E-10	Sv kg <sup>-1</sup>	9.75E6	9.75E6	8.56E6	1.15E6	2.48E-1	1.04E-8
Tm172	81.10	81.09	63.19				Tm170	77.80	77.81	86.85	91.84		
Tm168	17.56	17.58	34.62	98.95		0.21	Tm172	16.73	16.72	7.33			
Yb169	1.08	1.08	2.02	0.03			Yb169	2.62	2.62	2.76	0.01		
Tm170	0.08*	0.08*	0.15*	0.89*			Tm171	1.27	1.27	1.44	7.48		
Er171	0.07	0.07					Tm168	1.22	1.22	1.36	0.68		0.02
Ho166m					99.99		Ho166m					99.16	
Hf178n					0.01		H3					0.81	
Lu176						58.37	Hf178n					0.03	
Ta182						40.34	Lu176						84.40
Hf182						1.08	Hf182						8.76
							Ta182						4.38
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	4.50E7	4.50E7	4.34E7	6.82E6	1.48E1	4.40E-7		8.39E11	8.37E11	5.11E11	1.92E10	2.02E5	8.01E-3
Tm170	90.72	90.72	92.15	83.55			Tm172	60.20	60.24	38.00			
Tm171	3.50	3.50	3.61	16.07			Tm168	18.53	18.56	29.58	53.30		0.04
Yb169	2.40	2.40	2.30	0.01			Yb169	13.84	13.86	20.99	0.22		
Tm172	2.35	2.34	0.93				Tm170	6.96	6.97	11.19	42.39		
Tm168	0.86	0.86	0.86	0.37			Tm171	0.13	0.13	0.22	4.08		
Ho166m					99.89		Ho166m					99.74	
Hf178n					0.03		Hf178n					0.01	
Lu176						77.73	Lu176						61.04
Hf182						21.43	Ta182						38.00
Ta182						0.69	Hf182						0.93

# Thulium

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
Ho162	15.0 m	&Tm169(n,α)Ho166m(n,2n)Ho165_				15.7				
		(n,2n)Ho164(β <sup>-</sup> )Er164(n,2n)Er163(β <sup>+</sup> )_								
		Ho163(n,2n)Ho162								
		&Tm169(n,nα)Ho165(n,2n)Ho164(β <sup>-</sup> )_				9.6				
		Er164(n,2n)Er163(β <sup>+</sup> )Ho163(n,2n)Ho162								
		&Tm169(n,2n)Tm168(n,nα)Ho164(β <sup>-</sup> )_				2.7				
		Er164(n,2n)Er163(β <sup>+</sup> )Ho163(n,2n)Ho162								
		&Tm169(n,2n)Tm168(n,α)Ho165_				1.7				
		(n,2n)Ho164(β <sup>-</sup> )Er164(n,2n)Er163(β <sup>+</sup> )_								
		Ho163(n,2n)Ho162								
		&Tm169(n,3n)Tm167(β <sup>+</sup> )Er167(n,3n)_					26.4	5.2		
		Er165(β <sup>+</sup> )Ho165(n,4n)Ho162								
		&Tm169(n,nα)Ho165(n,4n)Ho162					3.6	7.1	0.7	
		&Tm169(n,nα)Ho165(n,3n)Ho163_					3.5			
		(n,2n)Ho162								
		&Tm169(n,3n)Tm167(β <sup>+</sup> )Er167(n,4n)_					2.4	2.2		
		Er164(n,t)Ho162								
		&Tm169(n,2n)Tm168(β <sup>+</sup> )Er168(n,4n)_					1.5	12.4	0.1	
		Er165(β <sup>+</sup> )Ho165(n,4n)Ho162								
		&Tm169(n,3n)Tm167(β <sup>+</sup> )Er167(n,t)_					0.5	2.1		
Ho165(n,4n)Ho162										
&Tm169(n,d)Er168(n,4n)Er165(β <sup>+</sup> )_					0.2	3.9				
Ho165(n,4n)Ho162										
&Tm169(n,2n)Tm168(n,4n)Tm165(β <sup>+</sup> )_					0.1	2.1				
Er165(β <sup>+</sup> )Ho165(n,4n)Ho162										
&Tm169(n,5n)Tm165(β <sup>+</sup> )Er165(β <sup>+</sup> )_						14.7	57.6			
Ho165(n,4n)Ho162										
&Tm169(n,4n)Tm166(β <sup>+</sup> )Er166(n,2n)_						13.2	0.2			
Er165(β <sup>+</sup> )Ho165(n,4n)Ho162										
&Tm169(n,4n)Tm166(β <sup>+</sup> )Er166(n,4n)_						10.6	0.1			
Er163(β <sup>+</sup> )Ho163(n,2n)Ho162										
&Tm169(n,4n)Tm166(β <sup>+</sup> )Er166(n,d)_							3.2			
Ho165(n,4n)Ho162										
&Tm169(n,2nt)Er165(β <sup>+</sup> )Ho165(n,4n)Ho162							1.1	3.9		
&Tm169(n,4n)Tm166(β <sup>+</sup> )Er166(n,2nt)Ho162							0.4	3.5		
&Tm169(n,4nα)Ho162								16.9		
&Tm169(n,6n)Tm164(β <sup>+</sup> )Er164(n,t)Ho162								1.6		
Many other similar long pathways						70.3	61.8	21.8	15.4	
Tm166	7.70 h	Tm169(n,2n)Tm168(n,2n)Tm167(n,2n)Tm166				100.0				
		Tm169(n,2n)Tm168(n,3n)Tm166					61.0			
		Tm169(n,4n)Tm166					32.7	99.7	99.8	
		Tm169(n,3n)Tm167(n,2n)Tm166					6.1			
Tb154m	9.00 h	Pathways involving (n,2n), β <sup>+</sup> , (n,α)				100.0	100.0	100.0	100.0	
Tm172	2.650 d	Tm169(n,γ)Tm170(n,γ)Tm171(n,γ)Tm172	98.9	99.9	99.9	98.6	97.7	98.0	98.6	
		Tm169(n,γ)Tm170(β <sup>+</sup> )Er170(n,γ)Er171_	1.1			0.7	07	0.7	0.7	
Yb175	4.185 d	(β <sup>-</sup> )Tm171(n,γ)Tm172								
		Tm169(n,γ)Tm170(n,γ)Tm171(n,γ)_	66.1	82.1	36.0					
		Tm172(β <sup>-</sup> )Yb172(n,γ)Yb173(n,γ)_								
		Yb174(n,γ)Yb175								
		Tm169(n,γ)Tm170(β <sup>-</sup> )Yb170(n,γ)_	15.2	1.3	44.5					
Yb175	4.185 d	Yb171(n,γ)Yb172(n,γ)Yb173(n,γ)_								
		Yb174(n,γ)Yb175								
		Tm169(n,γ)Tm170(n,γ)Tm171(n,γ)_	11.6	1.2	0.7					
Tm172(n,γ)Tm173(β <sup>-</sup> )Yb173(n,γ)_										
Yb174(n,γ)Yb175										

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	Tm169(n,γ)Tm170(n,γ)Tm171(β <sup>-</sup> )_Yb171(n,γ)Yb172(n,γ)Yb173(n,γ)_Yb174(n,γ)Yb175	7.0	15.5	18.8				
Tm167	9.25 d	Tm169(n,2n)Tm168(n,2n)Tm167 Tm169(n,3n)Tm167				99.8	99.7	99.7	99.8
Hf181	42.38 d	&Tm169(n,γ)Tm170(n,γ)Tm171(n,γ)_Tm172(β <sup>-</sup> )Yb172(n,γ)Yb173(n,γ)_Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176_(n,γ)Lu177(β <sup>-</sup> )Hf177(n,γ)Hf178(n,γ)_Hf179(n,γ)Hf180(n,γ)Hf181 &Tm169(n,γ)Tm170(n,γ)Tm171(n,γ)_Tm172(n,γ)Tm173(β <sup>-</sup> )Yb173(n,γ)_Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176_(n,γ)Lu177(β <sup>-</sup> )Hf177(n,γ)Hf178(n,γ)_Hf179(n,γ)Hf180(n,γ)Hf181 &Tm169(n,γ)Tm170(n,γ)Tm171(n,γ)_Tm172(β <sup>-</sup> )Yb172(n,γ)Yb173(n,γ)_Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176_(n,γ)Lu177(n,γ)Lu178(β <sup>-</sup> )Hf178(n,γ)_Hf179(n,γ)Hf180(n,γ)Hf181 &Tm169(n,γ)Tm170(n,γ)Tm171(n,γ)_Tm172(β <sup>-</sup> )Yb172(n,γ)Yb173(n,γ)_Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)_Lu176m(β <sup>-</sup> )Hf176(n,γ)Hf177(n,γ)_Hf178(n,γ)Hf179(n,γ)Hf180(n,γ)Hf181 &Tm169(n,γ)Tm170(n,γ)Tm171(n,γ)_Tm172(n,γ)Tm173(β <sup>-</sup> )Yb173(n,γ)_Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176_(n,γ)Lu177(n,γ)Lu178(β <sup>-</sup> )Hf178(n,γ)_Hf179(n,γ)Hf180(n,γ)Hf181 &Tm169(n,γ)Tm170(n,γ)Tm171(n,γ)_Tm172(n,γ)Tm173(β <sup>-</sup> )Yb173(n,γ)_Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)_Lu176m(β <sup>-</sup> )Hf176(n,γ)Hf177(n,γ)_Hf178(n,γ)Hf179(n,γ)Hf180(n,γ)Hf181 &Tm169(n,γ)Tm170(β <sup>-</sup> )Yb170(n,γ)_Yb171(n,γ)Yb172(n,γ)Yb173(n,γ)_Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176_(n,γ)Lu177(β <sup>-</sup> )Hf177(n,γ)Hf178(n,γ)_Hf179(n,γ)Hf180(n,γ)Hf181 &Tm169(n,γ)Tm170(n,γ)Tm171(β <sup>-</sup> )_Yb171(n,γ)Yb172(n,γ)Yb173(n,γ)_Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176_(n,γ)Lu177(β <sup>-</sup> )Hf177(n,γ)Hf178(n,γ)_Hf179(n,γ)Hf180(n,γ)Hf181 &Tm169(n,γ)Tm170(n,γ)Tm171(β <sup>-</sup> )_Yb171(n,γ)Yb172(n,γ)Yb173(n,γ)_Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)_Lu176m(β <sup>-</sup> )Hf176(n,γ)Hf177(n,γ)_Hf178(n,γ)_Hf179(n,γ)Hf180(n,γ)Hf181 &Tm169(n,γ)Tm170(β <sup>-</sup> )Yb170(n,γ)_Yb171(n,γ)Yb172(n,γ)Yb173(n,γ)_Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)_Lu176m(β <sup>-</sup> )Hf176(n,γ)Hf177(n,γ)_Hf178(n,γ)Hf179(n,γ)Hf180(n,γ)Hf181	31.6	74.5	29.4				
			20.6	1.9	1.6				
			12.7	3.7	1.0				
			7.9	0.8	20.8				
			7.9	0.1					
			6.1		1.1				
			2.5	0.4	14.3				
			1.7	8.6	6.9				
			0.6	0.1	4.9				
			0.5		10.2				
Tm168	93.10 d	Tm169(n,2n)Tm168				99.9	99.9	99.9	99.9

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Ta182	114.7 d	&Tm169(n,γ)Tm170(n,γ)Tm171(n,γ)_ Tm172(β <sup>-</sup> )Yb172(n,γ)Yb173(n,γ)Yb174_ (n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176(n,γ)_ Lu177(β <sup>-</sup> )Hf177(n,γ)Hf178(n,γ)Hf179_ (n,γ)Hf180(n,γ)Hf181(β <sup>-</sup> )Ta181(n,γ)Ta182	32.7	81.6	33.0				
		&Tm169(n,γ)Tm170(n,γ)Tm171(n,γ)_ Tm172(n,γ)Tm173(β <sup>-</sup> )Yb173(n,γ)Yb174_ (n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176(n,γ)_ Lu177(β <sup>-</sup> )Hf177(n,γ)Hf178(n,γ)Hf179_ (n,γ)Hf180(n,γ)Hf181(β <sup>-</sup> )Ta181(n,γ)Ta182	24.9	2.4	2.0				
		&Tm169(n,γ)Tm170(n,γ)Tm171(n,γ)_ Tm172(β <sup>-</sup> )Yb172(n,γ)Yb173(n,γ)Yb174_ (n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176(n,γ)_ Lu177(n,γ)Lu178(β <sup>-</sup> )Hf178(n,γ)Hf179_ (n,γ)Hf180(n,γ)Hf181(β <sup>-</sup> )Ta181(n,γ)Ta182	13.6	4.5	3.5				
		&Tm169(n,γ)Tm170(n,γ)Tm171(n,γ)_ Tm172(n,γ)Tm173(β <sup>-</sup> )Yb173(n,γ)Yb174_ (n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176(n,γ)_ Lu177(n,γ)Lu178(β <sup>-</sup> )Hf178(n,γ)Hf179_ (n,γ)Hf180(n,γ)Hf181(β <sup>-</sup> )Ta181(n,γ)Ta182	9.9	0.1	0.1				
		&Tm169(n,γ)Tm170(n,γ)Tm171(n,γ)_ Tm172(β <sup>-</sup> )Yb172(n,γ)Yb173(n,γ)Yb174_ (n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176m(β <sup>-</sup> )_ Hf176(n,γ)Hf177(n,γ)Hf178(n,γ)Hf179_ (n,γ)Hf180(n,γ)Hf181(β <sup>-</sup> )Ta181(n,γ)Ta182	7.3	2.4	23.5				
		&Tm169(n,γ)Tm170(n,γ)Tm171(n,γ)_ Tm172(n,γ)Tm173(β <sup>-</sup> )Yb173(n,γ)Yb174_ (n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176m(β <sup>-</sup> )_ Hf176(n,γ)Hf177(n,γ)Hf178(n,γ)Hf179_ (n,γ)Hf180(n,γ)Hf181(β <sup>-</sup> )Ta181(n,γ)Ta182	6.4		1.4				
		&Tm169(n,γ)Tm170(β <sup>-</sup> )Yb170(n,γ)_ Yb171(n,γ)Yb172(n,γ)Yb173(n,γ)Yb174_ (n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176(n,γ)_ Lu177(β <sup>-</sup> )Hf177(n,γ)Hf178(n,γ)Hf179_ (n,γ)Hf180(n,γ)Hf181(β <sup>-</sup> )Ta181(n,γ)Ta182	2.0	0.3	14.0				
		&Tm169(n,γ)Tm170(n,γ)Tm171(β <sup>-</sup> )_ Yb171(n,γ)Yb172(n,γ)Yb173(n,γ)Yb174_ (n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176(n,γ)_ Lu177(β <sup>-</sup> )Hf177(n,γ)Hf178(n,γ)Hf179_ (n,γ)Hf180(n,γ)Hf181(β <sup>-</sup> )Ta181(n,γ)Ta182	1.7	8.6	6.9				
		&Tm169(n,γ)Tm170(β <sup>-</sup> )Yb170(n,γ)_ Yb171(n,γ)Yb172(n,γ)Yb173(n,γ)Yb174_ (n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176(n,γ)_ Lu177(n,γ)Lu178(β <sup>-</sup> )Hf178(n,γ)Hf179_ (n,γ)Hf180(n,γ)Hf181(β <sup>-</sup> )Ta181(n,γ)Ta182	0.9		0.6				
		&Tm169(n,γ)Tm170(β <sup>-</sup> )Yb170(n,γ)_ Yb171(n,γ)Yb172(n,γ)Yb173(n,γ)Yb174_ (n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176m(β <sup>-</sup> )_ Hf176(n,γ)Hf177(n,γ)Hf178(n,γ)Hf179_ (n,γ)Hf180(n,γ)Hf181(β <sup>-</sup> )Ta181(n,γ)Ta182	0.3		10.1				
&Tm169(n,γ)Tm170(n,γ)Tm171(β <sup>-</sup> )_ Yb171(n,γ)Yb172(n,γ)Yb173(n,γ)Yb174_ (n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176m(β <sup>-</sup> )_ Hf176(n,γ)Hf177(n,γ)Hf178(n,γ)Hf179_ (n,γ)Hf180(n,γ)Hf181(β <sup>-</sup> )Ta181(n,γ)Ta182	0.3	0.1	4.9						
Tm170	128.6 d	Tm169(n,γ)Tm170	100.0	100.0	100.0	99.8	99.6	99.7	99.9
Tm171	1.917 y	Tm169(n,γ)Tm170(n,γ)Tm171	98.9	99.9	99.9	98.9	98.5	98.7	99.0
		Tm169(n,γ)Tm170(β <sup>+</sup> )Er170(n,γ)Er171_ (β <sup>-</sup> )Tm171	1.1			0.7	0.7	0.7	0.7
H3	12.33 y▶	Tm169(n,X)H3				87.8	86.2	87.3	86.7

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Tm169(n,2n)Tm168(n,X)H3 Tm169(n,2n)Tm168(β <sup>+</sup> )Er168(n,X)H3 &Tm169(n,3n)Tm167(β <sup>+</sup> )Er167(n,X)H3 Tm169(n,4n)Tm166(β <sup>+</sup> )Er166(n,X)H3 Tm169(n,5n)Tm165(β <sup>+</sup> )Er165(β <sup>+</sup> ) Ho165(n,X)H3				10.5 0.5	0.6 1.4 9.5	0.3 1.2 3.9 4.3 0.2	0.2 0.8 1.9 1.5 4.6	
Gd148	74.602 y	Pathways involving (n,2n), β <sup>+</sup> , (n,α)				100.0	100.0	100.0	100.0	
Tb158	180.0 y	&Tm169(n,α)Ho165(n,3n)Ho163_ (n,2nα)Tb158 &Tm169(n,4n)Tm166(β <sup>+</sup> )Er166(n,4n) Er163(β <sup>+</sup> )Ho163(n,2nα)Tb158 &Tm169(n,3n)Tm167(β <sup>+</sup> )Er167(n,5n) Er163(β <sup>+</sup> )Ho163(n,2nα)Tb158 Tm169(n,3nα)Ho163(n,2nα)Tb158 Tm169(n,nt)Er166(n,4n)Er163(β <sup>+</sup> ) Ho163(n,2nα)Tb158 &Tm169(n,5n)Tm165(β <sup>+</sup> )Er165(β <sup>+</sup> ) Ho165(n,4nα)Tb158 Tm169(n,5n)Tm165(β <sup>+</sup> )Er165(β <sup>+</sup> )Ho165_ (n,5n)Ho161(β <sup>+</sup> )Dy161(n,nt)Tb158 &Tm169(n,2nt)Er165(β <sup>+</sup> )Ho165(n,4nα)Tb158   Tm169(n,4n)Tm166(β <sup>+</sup> )Er166(n,6n) Er161(β <sup>+</sup> )Ho161(β <sup>+</sup> )Dy161(n,nt)Tb158 &Tm169(n,4nα)Ho162(β <sup>+</sup> )Dy162_ (n,2nt)Tb158 Tm169(n,5n)Tm165(β <sup>+</sup> )Er165(β <sup>+</sup> ) Ho165(n,6n)Ho160(β <sup>+</sup> )Dy160(n,t)Tb158 Tm169(n,5n)Tm165(β <sup>+</sup> )Er165(β <sup>+</sup> ) Ho165(n,2nt)Dy161(n,nt)Tb158 Tm169(n,5n)Tm165(β <sup>+</sup> )Er165(β <sup>+</sup> ) Ho165(n,nt)Dy162(n,2nt)Tb158 Many other similar long pathways						2.9 49.4 3.0 1.5 1.4	0.3 0.3 0.6 1.3 0.1	39.6 13.4 2.6 1.9 1.8 1.6 1.1 1.0
Ho166m	1200 y	Tm169(n,α)Ho166m &Tm169(n,3n)Tm167(β <sup>+</sup> )Er167(n,d)Ho166m   Tm169(n,2n)Tm168(β <sup>+</sup> )Er168(n,t)Ho166m   &Tm169(n,t)Er167(n,d)Ho166m Tm169(n,d)Er168(n,t)Ho166m Tm169(n,4n)Tm166(β <sup>+</sup> )Er166(n,p)Ho166m	100.0	100.0	100.0	99.7	59.7 37.6 1.4 0.3 0.2	45.5 32.4 10.0 3.3 3.2 4.8	56.6 18.5 11.6 5.1 5.5 1.3	
Ho163	4570 y	&Tm169(n,α)Ho166m(n,2n)Ho165(n,2n) Ho164(β <sup>-</sup> )Er164(n,2n)Er163(β <sup>+</sup> )Ho163 &Tm169(n,α)Ho165(n,2n)Ho164(β <sup>-</sup> ) Er164(n,2n)Er163(β <sup>+</sup> )Ho163 &Tm169(n,α)Ho166(β <sup>-</sup> )Er166(n,2n) Er165(β <sup>+</sup> )Ho165(n,2n)Ho164(β <sup>-</sup> ) Er164(n,2n)Er163(β <sup>+</sup> )Ho163 &Tm169(n,2n)Tm168(β <sup>+</sup> )Er168(n,α) Dy165(β <sup>-</sup> )Ho165(n,2n)Ho164(β <sup>-</sup> ) Er164(n,2n)Er163(β <sup>+</sup> )Ho163 &Tm169(n,2n)Tm168(n,α)Ho165(n,2n) Ho164(β <sup>-</sup> )Er164(n,2n)Er163(β <sup>+</sup> )Ho163 &Tm169(n,2n)Tm168(n,α)Ho164(β <sup>-</sup> ) Er164(n,2n)Er163(β <sup>+</sup> )Ho163 &Tm169(n,3n)Tm167(β <sup>+</sup> )Er167(n,3n) Er165(β <sup>+</sup> )Ho165(n,3n)Ho163 &Tm169(n,α)Ho165(n,3n)Ho163 &Tm169(n,3n)Tm167(β <sup>+</sup> )Er167(n,4n) Er164(n,2n)Er163(β <sup>+</sup> )Ho163 &Tm169(n,2n)Tm168(β <sup>+</sup> )Er168(n,4n) Er165(β <sup>+</sup> )Ho165(n,3n)Ho163 &Tm169(n,3n)Tm167(n,3n)Tm165(β <sup>+</sup> ) Er165(β <sup>+</sup> )Ho165(n,3n)Ho163				20.0 10.2 5.8 3.3 2.9 2.8	64.3 9.0 5.0 2.4 1.8	0.4 0.2 0.5	0.2	

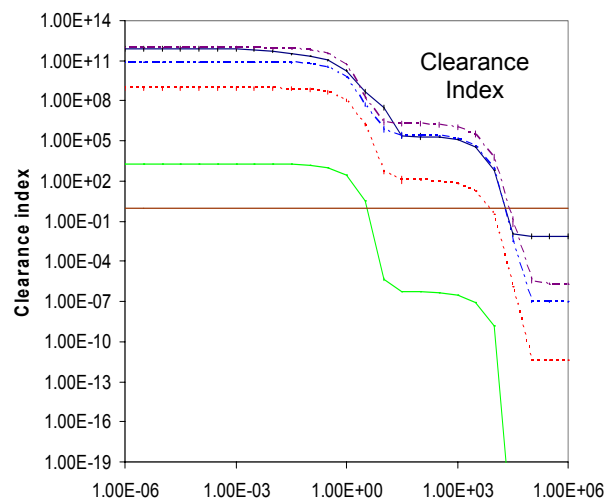
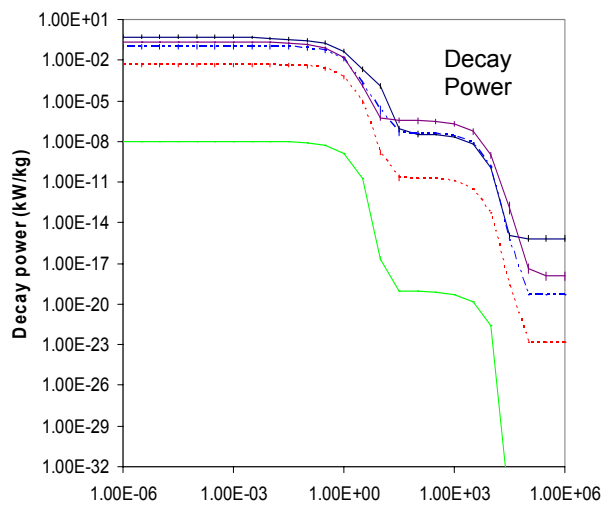
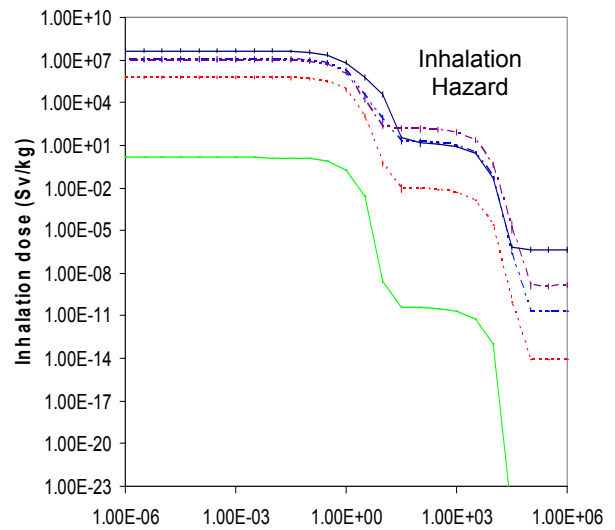
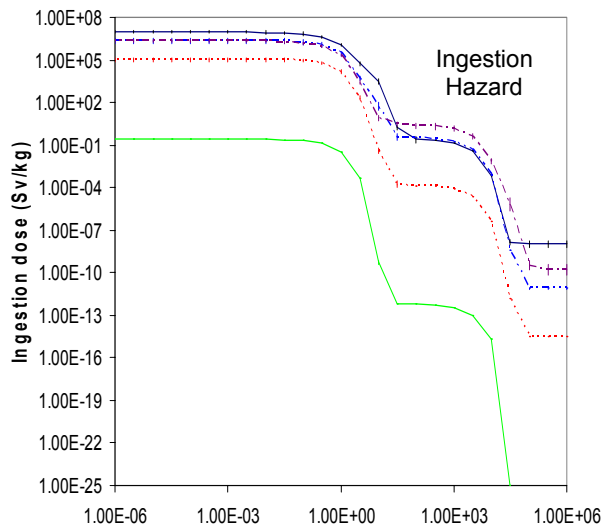
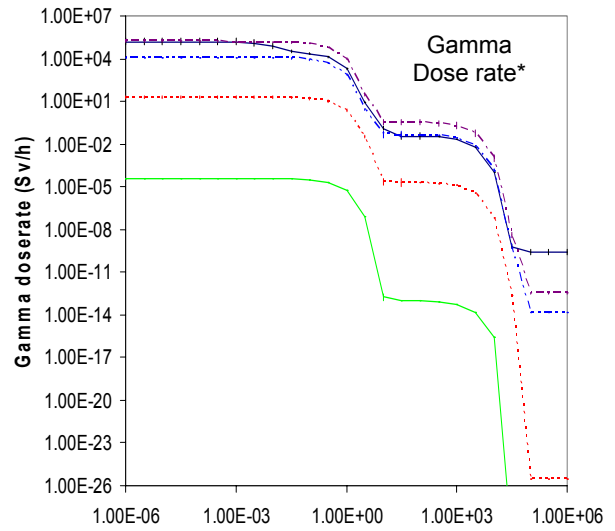
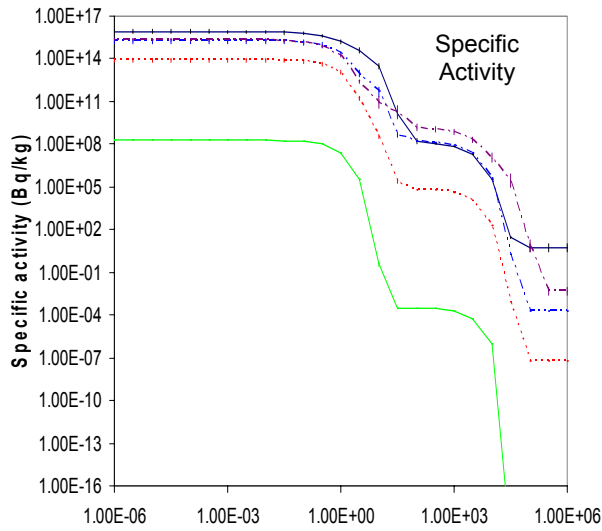
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Tm169(n,α)Ho166m(n,4n)Ho163 Tm169(n,4n)Tm166(β <sup>+</sup> )Er166(n,4n) Er163(β <sup>+</sup> )Ho163 &Tm169(n,3n)Tm167(β <sup>+</sup> )Er167(n,5n) Er163(β <sup>+</sup> )Ho163 Tm169(n,nt)Er166(n,4n)Er163(β <sup>+</sup> )Ho163 &Tm169(n,3nα)Ho163 &Tm169(n,4n)Tm166(β <sup>+</sup> )Er166(n,nt)Ho163 &Tm169(n,5n)Tm165(β <sup>+</sup> )Er165(β <sup>+</sup> ) Ho165(n,3n)Ho163 &Tm169(n,t)Er167(n,5n)Er163(β <sup>+</sup> )Ho163 Tm169(n,2n)Tm168(β <sup>+</sup> )Er168(n,6n) Er163(β <sup>+</sup> )Ho163 Tm169(n,d)Er168(n,6n)Er163(β <sup>+</sup> )Ho163 &Tm169(n,6n)Tm164(β <sup>+</sup> )Er164(n,2n) Er163(β <sup>+</sup> )Ho163 &Tm169(n,3n)Tm167(β <sup>+</sup> )Er167(n,2nt)Ho163 Tm169(n,2nt)Er165(β <sup>+</sup> )Ho165(n,3n)Ho163 Many other similar long pathways					1.6	0.3	78.8	7.5
								5.1	16.6	
								2.4	2.7	
								1.9	23.4	
								1.3	2.8	
								0.9	19.0	
								0.5	4.5	
									6.9	
									3.2	
									2.8	
									1.7	
									1.2	
						55.0	15.9	7.9	7.5	
Gd150	1.8 10 <sup>6</sup> y	Pathways involving (n,2n), β <sup>+</sup> , (n,α)				100.0	100.0	100.0	100.0	
Dy154	3.0 10 <sup>6</sup> y	Pathways involving (n,2n), β <sup>+</sup> , (n,α)				100.0	100.0	100.0	100.0	
Hf182	9.0 10 <sup>6</sup> y	&Tm169(n,γ)Tm170(n,γ)Tm171(n,γ) Tm172(β <sup>-</sup> )Yb172(n,γ)Yb173(n,γ) Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176 (n,γ)Lu177(β <sup>-</sup> )Hf177(n,γ)Hf178(n,γ) Hf179(n,γ)Hf180(n,γ)Hf181(n,γ)Hf182 &Tm169(n,γ)Tm170(n,γ)Tm171(n,γ) Tm172(n,γ)Tm173(β <sup>-</sup> )Yb173(n,γ) Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176 (n,γ)Lu177(β <sup>-</sup> )Hf177(n,γ)Hf178(n,γ) Hf179(n,γ)Hf180(n,γ)Hf181(n,γ)Hf182 &Tm169(n,γ)Tm170(n,γ)Tm171(n,γ) Tm172(β <sup>-</sup> )Yb172(n,γ)Yb173(n,γ) Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176 (n,γ)Lu177(n,γ)Lu178(β <sup>-</sup> )Hf178(n,γ) Hf179(n,γ)Hf180(n,γ)Hf181(n,γ)Hf182 &Tm169(n,γ)Tm170(n,γ)Tm171(n,γ) Tm172(n,γ)Tm173(β <sup>-</sup> )Yb173(n,γ) Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176 (n,γ)Lu177(n,γ)Lu178(β <sup>-</sup> )Hf178(n,γ) Hf179(n,γ)Hf180(n,γ)Hf181(n,γ)Hf182 &Tm169(n,γ)Tm170(n,γ)Tm171(n,γ) Tm172(β <sup>-</sup> )Yb172(n,γ)Yb173(n,γ)Yb174 (n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176m(β <sup>-</sup> ) Hf176(n,γ)Hf177(n,γ)Hf178(n,γ)Hf179 (n,γ)Hf180(n,γ)Hf181(n,γ)Hf182 &Tm169(n,γ)Tm170(n,γ)Tm171(n,γ) Tm172(n,γ)Tm173(β <sup>-</sup> )Yb173(n,γ) Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176m (β <sup>-</sup> )Hf176(n,γ)Hf177(n,γ)Hf178(n,γ) Hf179(n,γ)Hf180(n,γ)Hf181(n,γ)Hf182 &Tm169(n,γ)Tm170(β <sup>-</sup> )Yb170(n,γ) Yb171(n,γ)Yb172(n,γ)Yb173(n,γ) Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176 (n,γ)Lu177(β <sup>-</sup> )Hf177(n,γ)Hf178(n,γ) Hf179(n,γ)Hf180(n,γ)Hf181(n,γ)Hf182	29.7	73.2	33.3					
			22.9	2.1	1.9					
			12.4	4.0	1.2					
			9.1	0.1	0.1					
			6.6	0.7	23.7					
			5.8		1.4					
			2.0	0.3	14.8					
	▶									



Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&Tm169(n,γ)Tm170(n,γ)Tm171(β <sup>-</sup> ) Yb171(n,γ)Yb172(n,γ)Yb173(n,γ) Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176 (n,γ)Lu177(β <sup>-</sup> )Hf177(n,γ)Hf178(n,γ) Hf179(n,γ)Hf180(n,γ)Hf181(n,γ)Hf182 &Tm169(n,γ)Tm170(β <sup>-</sup> )Yb170(n,γ) Yb171(n,γ)Yb172(n,γ)Yb173(n,γ)Yb174 (n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176m(β <sup>-</sup> ) Hf176(n,γ)Hf177(n,γ)Hf178(n,γ)Hf179 (n,γ)Hf180(n,γ)Hf181(n,γ)Hf182 &Tm169(n,γ)Tm170(n,γ)Tm171(β <sup>-</sup> ) Yb171(n,γ)Yb172(n,γ)Yb173(n,γ)Yb174 (n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176m(β <sup>-</sup> ) Hf176(n,γ)Hf177(n,γ)Hf178(n,γ)Hf179 (n,γ)Hf180(n,γ)Hf181(n,γ)Hf182	1.5	7.8	7.2				
		&Tm169(n,γ)Tm170(β <sup>-</sup> )Yb170(n,γ) Yb171(n,γ)Yb172(n,γ)Yb173(n,γ)Yb174 (n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176m(β <sup>-</sup> ) Hf176(n,γ)Hf177(n,γ)Hf178(n,γ)Hf179 (n,γ)Hf180(n,γ)Hf181(n,γ)Hf182	0.4		10.6				
		&Tm169(n,γ)Tm170(n,γ)Tm171(β <sup>-</sup> ) Yb171(n,γ)Yb172(n,γ)Yb173(n,γ)Yb174 (n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176m(β <sup>-</sup> ) Hf176(n,γ)Hf177(n,γ)Hf178(n,γ)Hf179 (n,γ)Hf180(n,γ)Hf181(n,γ)Hf182	0.3	0.1	5.2				
Lu176	4.0 10 <sup>10</sup> y	Tm169(n,γ)Tm170(n,γ)Tm171(n,γ) Tm172(β <sup>-</sup> )Yb172(n,γ)Yb173(n,γ) Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176 Tm169(n,γ)Tm170(n,γ)Tm171(n,γ) Tm172(n,γ)Tm173(β <sup>-</sup> )Yb173(n,γ) Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176 Tm169(n,γ)Tm170(β <sup>-</sup> )Yb170(n,γ) Yb171(n,γ)Yb172(n,γ)Yb173(n,γ) Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176 Tm169(n,γ)Tm170(n,γ)Tm171(β <sup>-</sup> ) Yb171(n,γ)Yb172(n,γ)Yb173(n,γ) Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176	65.0	84.1	44.9				
		Tm169(n,γ)Tm170(n,γ)Tm171(n,γ) Tm172(β <sup>-</sup> )Yb172(n,γ)Yb173(n,γ) Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176	18.8	1.4	1.4				
		Tm169(n,γ)Tm170(β <sup>-</sup> )Yb170(n,γ) Yb171(n,γ)Yb172(n,γ)Yb173(n,γ) Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176	10.5	0.9	37.1				
		Tm169(n,γ)Tm170(n,γ)Tm171(β <sup>-</sup> ) Yb171(n,γ)Yb172(n,γ)Yb173(n,γ) Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176	5.6	13.6	16.6				
Yb168	1.3 10 <sup>14</sup> y	Tm169(n,2n)Tm168(β <sup>-</sup> )Yb168 &Tm169(n,γ)Tm170(β <sup>-</sup> )Yb170(n,2n) Yb169(n,2n)Yb168 Tm169(n,γ)Tm170(β <sup>-</sup> )Yb170(n,3n)Yb168				99.4	48.6	75.0	83.9
						0.6			
							51.3	25.0	16.1
Gd160	1.3 10 <sup>17</sup> y	Tm169(n,α)Ho166(β <sup>-</sup> )Er166(n,α) Dy163(n,α)Gd160 &Tm169(n,α)Ho166m(n,2n)Ho165(n,2n) Ho164(β <sup>+</sup> )Dy164(n,2n)Dy163(n,α)Gd160 Tm169(n,2n)Tm168(β <sup>+</sup> )Er168(n,2n) Er167(n,2n)Er166(n,α)Dy163(n,α)Gd160 Tm169(n,2n)Tm168(β <sup>+</sup> )Er168(n,2n) Er167(n,α)Dy163(n,α)Gd160 Tm169(n,2n)Tm168(β <sup>+</sup> )Er168(n,2n) Er167(n,α)Dy164(n,2n)Dy163(n,α)Gd160 Tm169(n,α)Ho165(n,2n)Ho164(β <sup>+</sup> ) Dy164(n,2n)Dy163(n,α)Gd160 Tm169(n,2n)Tm168(β <sup>+</sup> )Er168(n,α) Dy164(n,2n)Dy163(n,α)Gd160 &Tm169(n,2n)Tm168(n,2n)Tm167(β <sup>+</sup> ) Er167(n,2n)Er166(n,α)Dy163(n,α)Gd160 Tm169(n,α)Ho166(β <sup>-</sup> )Er166(n,2n) Er165(β <sup>+</sup> )Ho165(n,2n)Ho164(β <sup>+</sup> ) Dy164(n,2n)Dy163(n,α)Gd160 Tm169(n,2n)Tm168(β <sup>+</sup> )Er168(n,α) Dy164(n,α)Gd160 &Tm169(n,2nα)Ho164(β <sup>+</sup> )Dy164(n,α)Gd160 &Tm169(n,3n)Tm167(β <sup>+</sup> )Er167(n,α) Dy163(n,α)Gd160 &Tm169(n,α)Ho166m(n,3n)Ho164(β <sup>+</sup> ) Dy164(n,α)Gd160 &Tm169(n,3n)Tm167(β <sup>+</sup> )Er167(n,α) Dy164(n,α)Gd160	99.6	97.6		2.0			
							10.7		
							6.7		
							5.4		
							5.3		
							4.3		
							3.2		
							3.2		
							3.1		
							0.4	6.7	1.1
								6.7	1.1
								13.4	60.9
								10.7	0.5
								7.2	0.3
								4.9	0.4
									0.2
	▶								

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&Tm169(n,4n)Tm166(β <sup>+</sup> )Er166(n,t) Ho164(β <sup>+</sup> )Dy164(n,nα)Gd160 Tm169(n,5n)Tm165(β <sup>+</sup> )Er165(β <sup>+</sup> ) Ho165(n,d)Dy164(n,nα)Gd160 Tm169(n,5n)Tm165(β <sup>+</sup> )Er165(β <sup>+</sup> )Ho165 (n,2n)Ho164(β <sup>+</sup> )Dy164(n,nα)Gd160 Tm169(n,5n)Tm165(β <sup>+</sup> )Er165(β <sup>+</sup> ) Ho165(n,t)Dy163(n,α)Gd160 Plus many other similar long pathways	0.4	2.4		55.7	57.1	13.5 1.0 1.0 0.1 21.2	2.7 13.1 9.1 6.2 43.3

# Thulium activation characteristics

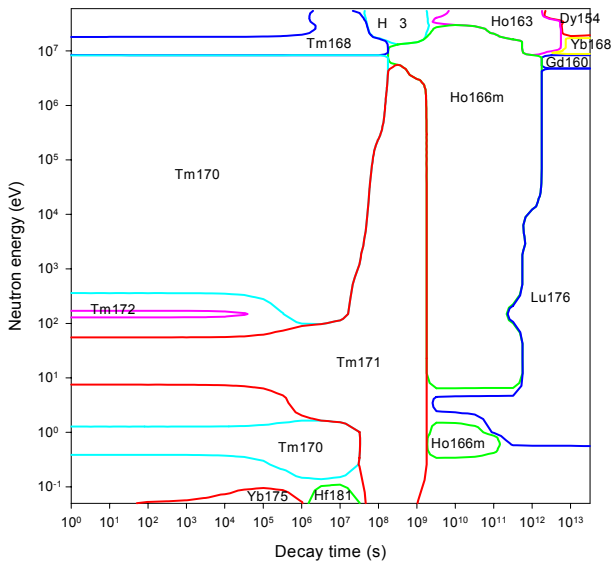


Decay time (years)

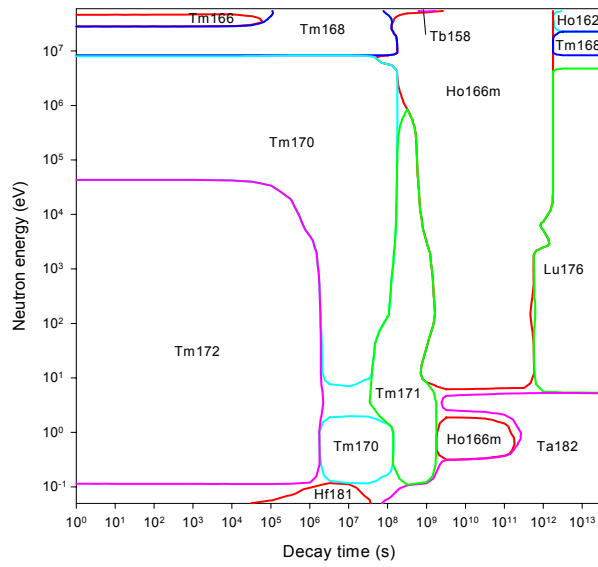
Decay time (years)

# Thulium importance diagrams & transmutation

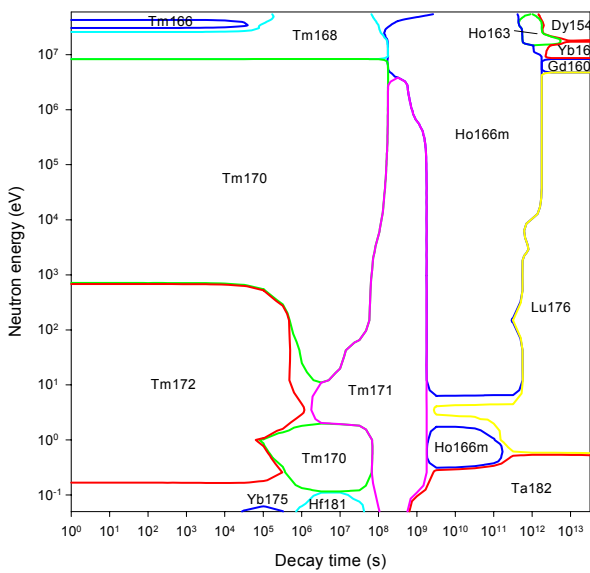
Activity



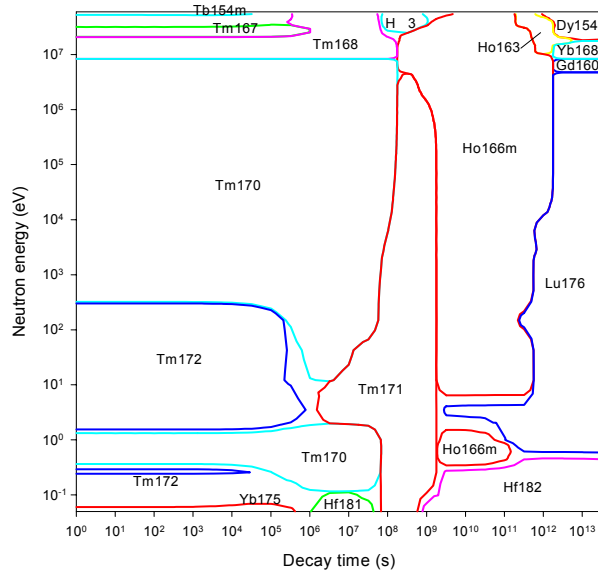
Dose rate



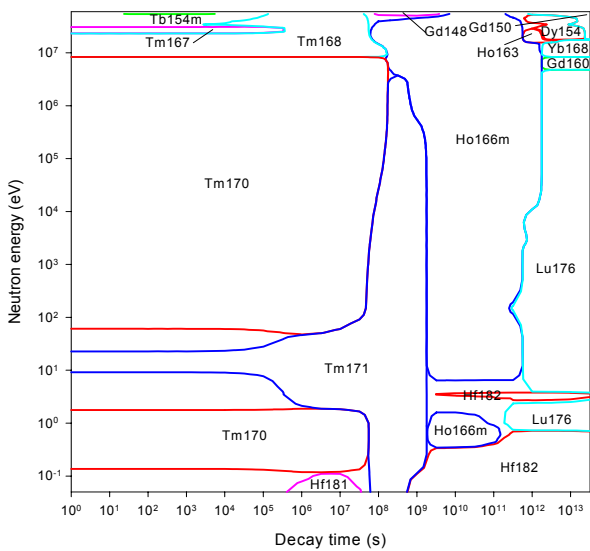
Heat output



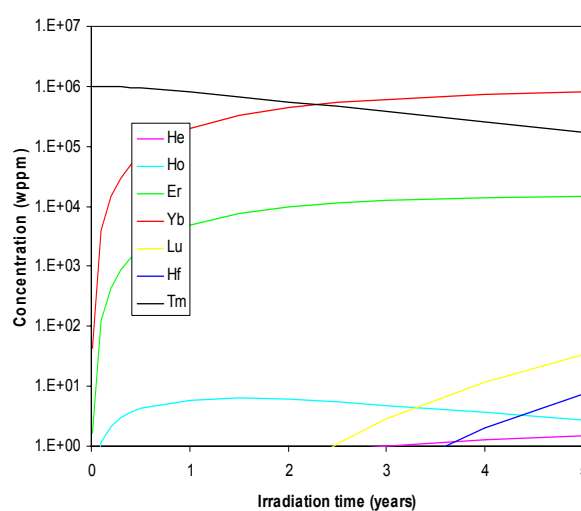
Ingestion dose



Inhalation dose



First wall transmutation



# Ytterbium

## General properties

Atomic number	70	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	3.2	Yb168	0.13 ( $T_{1/2}=1.30 \cdot 10^{14}$ y)
Melting point / K	1097	Yb170	3.04
Boiling point / K	1467	Yb171	14.28
Density / kgm <sup>-3</sup>	6903	Yb172	21.83
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	34.9	Yb173	16.13
Electrical resistivity /Ωm	2.9 10 <sup>-7</sup>	Yb174	31.83
Coefficient of thermal expansion / K <sup>-1</sup>	2.63 10 <sup>-5</sup>	Yb176	12.76
Crystal structure	FCC		
Number of stable isotopes	6 (7)		
Mean atomic weight	173.04		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	1.69E15	1.45E15	5.89E14	9.61E12	4.68E8	7.90E4	kW kg <sup>-1</sup>	8.81E-2	7.32E-2	2.08E-2	3.46E-4	8.97E-8	1.11E-11
Yb175	40.06	46.78	62.78				Lu176m	31.68	37.51				
Lu176m	21.45	24.64					Yb175	24.83	29.87	57.48			
Lu177	13.15	15.37	25.95	0.05			Yb177	12.95	15.11				
Hf179m	9.69						Hf179m	11.16					
Yb177	6.74	7.63					Lu177	7.31	8.80	21.31	0.04		
Yb177m	3.37						Yb177m	3.40					
Tm170	1.53	1.79	4.31	37.64			Tm170	1.56	1.88	6.49	55.47		
Yb169	1.01	1.18	2.68	0.07			Yb169	1.32	1.59	5.17	0.12		
Lu178	0.48	0.49					Lu178	1.30	1.37				
Hf181	0.35	0.41	0.95	0.16			Hf181	0.79	0.95	3.16	0.51		
Hf175	0.34	0.39	0.93	1.60			Hf175	0.42	0.51	1.73	2.90		
Lu174m	0.20	0.23	0.56	5.87			Hf178m	0.36			0.11	46.87	
Tm171	0.19	0.22	0.53	22.68			Ta182	0.30	0.36	1.25	8.43	0.01	80.02
Lu174	0.18	0.21	0.53	29.29			Tm168	0.14	0.17	0.57	2.31		
Hf178m	0.10			0.02	48.85		Lu174m		0.13	0.45	4.65		
Ta182		0.08	0.18	1.27	0.01	46.90	Lu174		0.11	0.39	21.02		
Lu173			0.02	0.56			Tm171			0.06	2.64		
Hf178n				0.02	48.85		Hf178n				0.13	52.97	
Hf182					0.01	46.90	Hf182						14.49
Lu176						6.20	Lu176						5.49
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	1.22E4	1.02E4	3.21E3	1.08E2	5.17E-2	1.24E-5	Sv kg <sup>-1</sup>	5.57E5	5.54E5	3.05E5	6.36E3	1.08E0	1.76E-4
Yb177	39.71	46.05					Yb175	53.56	53.73	53.33			
Yb175	26.21	31.34	54.59				Lu177	21.18	21.26	26.55	0.04		
Hf179m	10.51						Lu176m	11.08	10.94				
Tm172	3.53	4.22	5.18				Tm170	6.05	6.07	10.82	73.90		
Ta182	2.91	3.48	10.84	36.02	0.02	96.37	Yb169	2.18	2.19	3.67	0.07		
Hf181	2.80	3.34	10.04	0.80			Yb177	1.80	1.75				
Lu178	2.17	2.29					Hf181	1.17	1.18	2.01	0.26		
Lu177	1.79	2.14	4.69				Tm172	0.98	0.99	0.69			
Hf178m	1.22		0.01	0.17	37.98		Hf175	0.42	0.42	0.74	0.99		
Hf175	1.13	1.35	4.14	3.41			Lu174m	0.32	0.32	0.57	4.70		
Tm174	1.12	0.68					Ta182	0.30	0.30	0.53	2.87	0.01	31.66
Tm168	1.05	1.25	3.89	7.78			Hf179n	0.21	0.21	0.35			
Hf177m	0.94	0.07	0.12	0.77			Lu174	0.15	0.15	0.27	11.95		
Yb169	0.65	0.77	2.28	0.03			Tm168	0.10	0.10	0.18	0.57		
Hf179n	0.60	0.72	2.07				Tm171	0.06	0.06	0.11	3.77		
Lu174	0.48	0.58	1.83	49.29			Lu177m			0.05	0.52		
Hf178n			0.01	0.27	61.74		Hf178n				0.16	99.86	
Hf182						2.51	Hf182					0.01	63.32
Lu176						1.12	Lu176						5.02

<b>Inh</b>	<b>0</b>	<b>10<sup>-5</sup> y</b>	<b>10<sup>-2</sup> y</b>	<b>1 y</b>	<b>100 y</b>	<b>10<sup>5</sup> y</b>	<b>Clear</b>	<b>0</b>	<b>10<sup>-5</sup> y</b>	<b>10<sup>-2</sup> y</b>	<b>1 y</b>	<b>100 y</b>	<b>10<sup>5</sup> y</b>
Sv kg <sup>-1</sup>	1.14E6	1.14E6	7.65E5	4.52E4	5.95E1	1.22E-2		1.49E11	9.06E10	3.19E10	1.79E9	5.17E5	3.85E2
Yb175	43.46	43.50	35.32				Hf179m	28.10					
Lu177	23.45	23.49	24.00	0.01			Yb177	18.60	29.73				
Tm170	15.93	15.96	23.25	56.07			Lu176m	15.17	24.60				
Yb169	4.50	4.51	6.19	0.04			Ta182	7.39	12.19	33.83	67.96	0.07	96.38
Lu176m	3.83	3.77					Yb177m	6.35					
Hf181	2.60	2.61	3.65	0.17			Yb175	4.53	7.47	11.58			
Lu174m	1.24	1.24	1.81	5.24			Hf181	3.97	6.54	17.47	0.84		
Lu174	1.14	1.14	1.70	26.18			Yb169	3.69	6.08	15.94	0.11		
Ta182	0.97	0.97	1.41	2.69		3.04	Hf177m	1.50	0.15	0.24	0.91		
Yb177	0.69	0.67					Lu177	1.49	2.45	4.79			
Hf175	0.60	0.60	0.86	0.41			Hf175	1.41	2.33	6.38	3.18		
Tm171	0.39	0.39	0.57	6.76			Hf178m	1.18			0.12	45.14	
Hf179n	0.33	0.33	0.44				Tm172	1.13	1.87	2.04			
Tm172	0.31	0.31	0.18				Lu178	1.09	1.57				
Tm168	0.16	0.16	0.23	0.26			Hf179n	0.60	0.99	2.54			
Lu177m	0.13	0.13	0.19	0.69			Tm168	0.48	0.79	2.19	2.65		
Hf178n	0.05	0.05	0.07	1.20	99.88		Lu174	0.25	0.41	1.17	18.96		
Er169	0.04	0.04	0.05				Tm170		0.29	0.80	2.02		
Ta183	0.04	0.04	0.03				Lu174m		0.26	0.74	2.25		
Lu173			0.03	0.29			Lu173			0.05	0.53		
Hf182					0.02	94.16	Hf178n			0.01	0.14	54.62	
Lu176						2.81	Hf182						2.35
							Lu176						1.27

# Ytterbium

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
Hf177m	1.08 s	Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ) <sub>-</sub>	48.6	1.5	53.9					
		Lu176m(β <sup>-</sup> )Hf176(n,γ)Hf177m								
		Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176 <sub>-</sub>	31.7	56.4	44.0					
		(n,γ)Lu177m(β <sup>-</sup> )Hf177m								
		Yb173(n,γ)Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175 <sub>-</sub>	10.0	16.1	0.8					
		(n,γ)Lu176(n,γ)Lu177m(β <sup>-</sup> )Hf177m								
		Yb173(n,γ)Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175 <sub>-</sub>	8.9	0.3	1.1					
		(n,γ)Lu176m(β <sup>-</sup> )Hf176(n,γ)Hf177m								
		Yb172(n,γ)Yb173(n,γ)Yb174(n,γ) <sub>-</sub>	0.3	16.8						
		Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176(n,γ) <sub>-</sub>								
		Lu177m(β <sup>-</sup> )Hf177m								
		Yb171(n,γ)Yb172(n,γ)Yb173(n,γ) <sub>-</sub>			8.4					
Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ) <sub>-</sub>										
Lu176(n,γ)Lu177m(β <sup>-</sup> )Hf177m										
&Yb176(n,γ)Yb177(β <sup>-</sup> )Lu177(β <sup>-</sup> ) <sub>-</sub>						99.4	96.5	96.4	96.5	
Hf177(n,n')Hf177m										
Yb176m	11.4 s	Yb173(n,γ)Yb174(n,γ)Yb175(n,γ)Yb176m	65.8	18.6	4.9					
		Yb174(n,γ)Yb175(n,γ)Yb176m	28.9	44.7	94.8					
		Yb172(n,γ)Yb173(n,γ)Yb174(n,γ) <sub>-</sub>	3.8	23.0	0.2					
		Yb175(n,γ)Yb176m								
		Yb171(n,γ)Yb172(n,γ)Yb173(n,γ) <sub>-</sub>	1.5	13.6						
		Yb174(n,γ)Yb175(n,γ)Yb176m								
Yb176(n,n')Yb176m						100.0	99.8	99.8	99.9	
Yb177	1.911 h	&Yb176(n,γ)Yb177	98.5	100.0	100.0	100.0	100.0	100.0	100.0	
		&Yb174(n,γ)Yb175(n,γ)Yb176(n,γ)Yb177	1.3							
Lu176m	3.635 h	Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176m	72.9	50.3	97.0	0.1	0.2	0.2	0.2	
		Yb173(n,γ)Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175 <sub>-</sub>	26.0	17.8	3.0					
		(n,γ)Lu176m								
		Yb172(n,γ)Yb173(n,γ)Yb174(n,γ) <sub>-</sub>	0.8	20.6						
		Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176m								
		Yb171(n,γ)Yb172(n,γ)Yb173(n,γ)Yb174 <sub>-</sub>	0.3	11.3						
		(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176m								
		Yb176(n,2n)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176m					95.3	82.8	73.2	65.3
		Yb176(n,2n)Yb175(β <sup>-</sup> )Lu175(n,γ) <sub>-</sub>					3.9	2.1	1.5	0.9
		Lu176(n,n')Lu176m								
Yb176(n,d)Tm175(β <sup>-</sup> )Yb175(β <sup>-</sup> )Lu175 <sub>-</sub>						7.7	13.9	18.1		
(n,γ)Lu176m										
&Yb176(n,γ)Yb177(β <sup>-</sup> )Lu177(β <sup>-</sup> ) <sub>-</sub>						6.3	10.3	14.6		
Hf177(n,d)Lu176m										
Tm166	7.70 h	Yb168(n,2n)Yb167(β <sup>+</sup> )Tm167(n,2n)Tm166				71.7				
		&Yb170(n,2n)Yb169(β <sup>+</sup> )Tm169(n,2n) <sub>-</sub>				11.2				
		Tm168(n,2n)Tm167(n,2n)Tm166								
		&Yb171(n,2n)Yb170(n,2n)Yb169(β <sup>+</sup> )Tm169 <sub>-</sub>				7.7				
		(n,2n)Tm168(n,2n)Tm167(n,2n)Tm166								
		&Yb170(n,2n)Yb169(n,2n)Yb168(n,2n) <sub>-</sub>				4.1				
		Yb167(β <sup>+</sup> )Tm167(n,2n)Tm166								
		&Yb171(n,2n)Yb170(n,2n)Yb169(n,2n) <sub>-</sub>				2.9				
		Yb168(n,2n)Yb167(β <sup>+</sup> )Tm167(n,2n)Tm166								
		Yb170(n,3n)Yb168(n,3n)Yb166(β <sup>+</sup> )Tm166						28.5	1.7	0.2
		Yb172(n,3n)Yb170(n,3n)Yb168(n,3n) <sub>-</sub>						24.8	0.4	
		Yb166(β <sup>+</sup> )Tm166								
		Yb171(n,4n)Yb168(n,3n)Yb166(β <sup>+</sup> )Tm166						20.2	18.9	1.0
		Yb173(n,4n)Yb170(n,3n)Yb168(n,3n) <sub>-</sub>						5.3	0.8	
Yb166(β <sup>+</sup> )Tm166										
▶ Yb168(n,3n)Yb166(β <sup>+</sup> )Tm166						4.9	1.0	0.2		

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Yb171(n,2n)Yb170(n,3n)Yb168(n,3n)_ Yb166(β <sup>+</sup> )Tm166 Yb174(n,3n)Yb172(n,3n)Yb170(n,3n)_ Yb168(n,3n)Yb166(β <sup>+</sup> )Tm166 Yb173(n,3n)Yb171(n,4n)Yb168(n,3n)_ Yb166(β <sup>+</sup> )Tm166 Yb174(n,4n)Yb171(n,4n)Yb168(n,3n)_ Yb166(β <sup>+</sup> )Tm166 &Yb171(n,3n)Yb169(β <sup>+</sup> )Tm169(n,4n)Tm166 &Yb172(n,4n)Yb169(β <sup>+</sup> )Tm169(n,4n)Tm166 &Yb173(n,5n)Yb169(β <sup>+</sup> )Tm169(n,4n)Tm166 Yb172(n,5n)Yb168(n,3n)Yb166(β <sup>+</sup> )Tm166 Yb170(n,5n)Yb166(β <sup>+</sup> )Tm166 Yb173(n,4n)Yb170(n,5n)Yb166(β <sup>+</sup> )Tm166 Yb174(n,5n)Yb170(n,5n)Yb166(β <sup>+</sup> )Tm166 Yb171(n,6n)Yb166(β <sup>+</sup> )Tm166 &Yb174(n,6n)Yb169(β <sup>+</sup> )Tm169(n,4n)Tm166 Yb176(n,6n)Yb171(n,6n)Yb166(β <sup>+</sup> )Tm166 Yb174(n,4n)Yb171(n,6n)Yb166(β <sup>+</sup> )Tm166						4.1 2.5 2.2 1.4 0.2 35.7 4.5 2.7 0.7 0.6 0.3 28.7 4.1 2.8 2.5	0.2  0.6 3.5 7.9 1.4 1.9 3.4 13.1 3.0 11.2 28.7 4.1 2.8 2.5	0.7     1.4 1.9 3.4 13.1 3.0 11.2 28.7 4.1 2.8 2.5
Yb175	4.185 d	Yb173(n,γ)Yb174(n,γ)Yb175 Yb174(n,γ)Yb175 Yb172(n,γ)Yb173(n,γ)Yb174(n,γ)Yb175 Yb171(n,γ)Yb172(n,γ)Yb173(n,γ)_ Yb174(n,γ)Yb175 Yb176(n,2n)Yb175 Yb176(n,d)Tm175(β <sup>-</sup> )Yb175	65.8 28.8 3.8 1.5	18.6 44.7 23.0 13.6	5.5 94.2 0.2	0.2	0.3	83.6 17.3	77.9 21.6	
Lu177	6.647 d	Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176_ (n,γ)Lu177 Yb173(n,γ)Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175_ (n,γ)Lu176(n,γ)Lu177 &Yb176(n,γ)Yb177(β <sup>-</sup> )Lu177	59.1 21.1 18.7	100.0	2.1 97.9 100.0	100.0	99.4	99.6	99.8	
Yb169	32.018 d	&Yb168(n,γ)Yb169 &Yb171(n,2n)Yb170(n,2n)Yb169 &Yb170(n,2n)Yb169 &Yb172(n,2n)Yb171(n,2n)Yb170(n,2n)Yb169   &Yb171(n,3n)Yb169 &Yb173(n,3n)Yb171(n,3n)Yb169 &Yb174(n,4n)Yb171(n,3n)Yb169 &Yb172(n,4n)Yb169 &Yb172(n,3n)Yb170(n,2n)Yb169 &Yb172(n,2n)Yb171(n,3n)Yb169 &Yb174(n,3n)Yb172(n,4n)Yb169 Yb173(n,2n)Yb172(n,4n)Yb169 &Yb173(n,5n)Yb169 &Yb176(n,5n)Yb172(n,4n)Yb169 &Yb174(n,6n)Yb169		100.0	99.7	51.5 34.7 12.3	0.8 3.1 1.8	1.8 8.1 0.2 0.7 14.9 0.3 0.2 0.7 0.2 20.8 0.6 44.2	0.1 1.4  8.1 0.2 0.7 14.9 0.3 0.2 0.7 0.2 20.8 0.6 44.2	
Hf181	42.38 d	&Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)_ Lu176(n,γ)Lu177(β <sup>-</sup> )Hf177(n,γ)Hf178_ (n,γ)Hf179(n,γ)Hf180(n,γ)Hf181 &Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)_ Lu176m(β <sup>-</sup> )Hf176(n,γ)Hf177(n,γ)_ Hf178(n,γ)Hf179(n,γ)Hf180(n,γ)Hf181 &Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)_ Lu176(n,γ)Lu177(n,γ)Lu178(β <sup>-</sup> )Hf178_ (n,γ)Hf179(n,γ)Hf180(n,γ)Hf181 &Yb176(n,γ)Yb177(β <sup>-</sup> )Lu177(β <sup>-</sup> )Hf177_ (n,γ)Hf178(n,γ)Hf179(n,γ)Hf180(n,γ)Hf181 &Yb176(n,γ)Yb177(β <sup>-</sup> )Lu177(n,γ)Lu178_ (β <sup>-</sup> )Hf178(n,γ)Hf179(n,γ)Hf180(n,γ)Hf181	40.6 19.5 14.1 6.4 4.4	0.1	0.1	95.0	2.0			



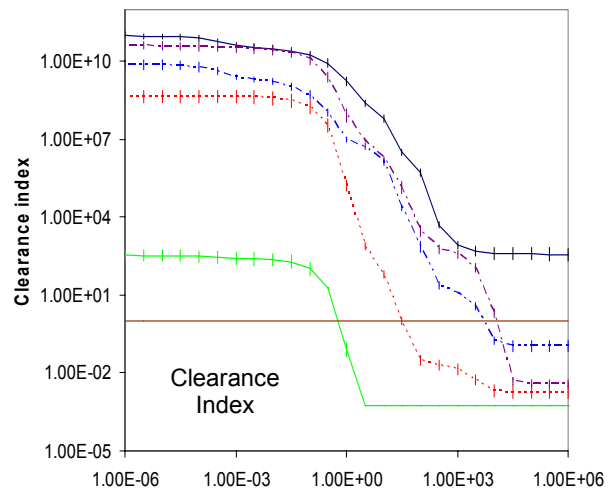
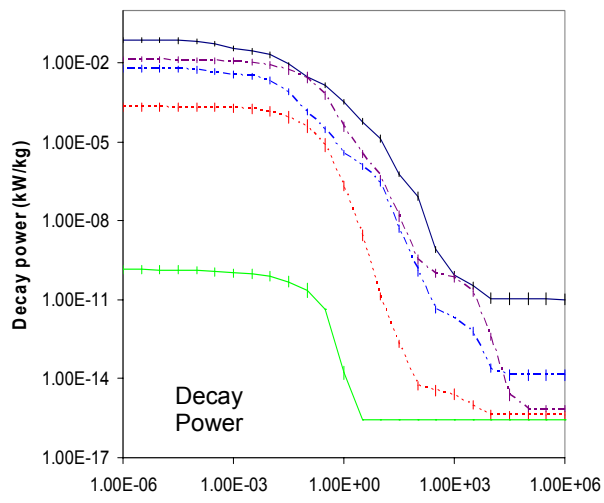
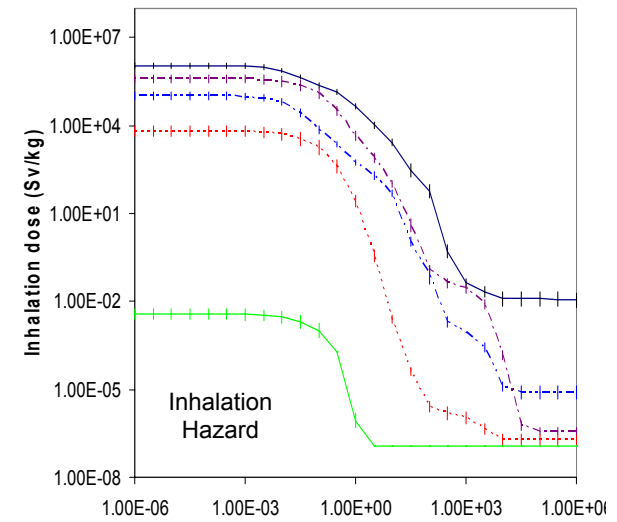
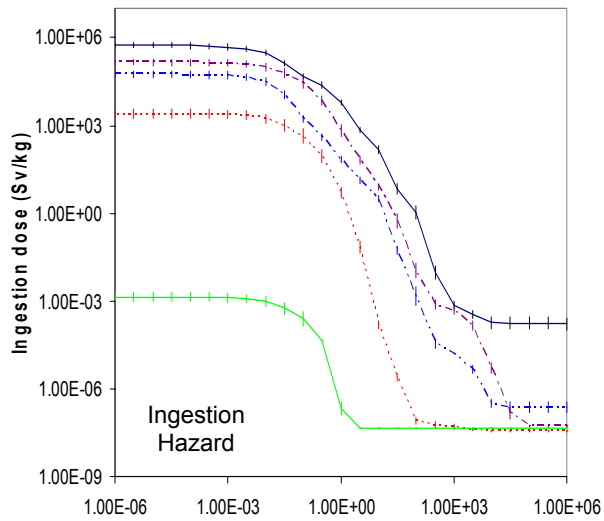
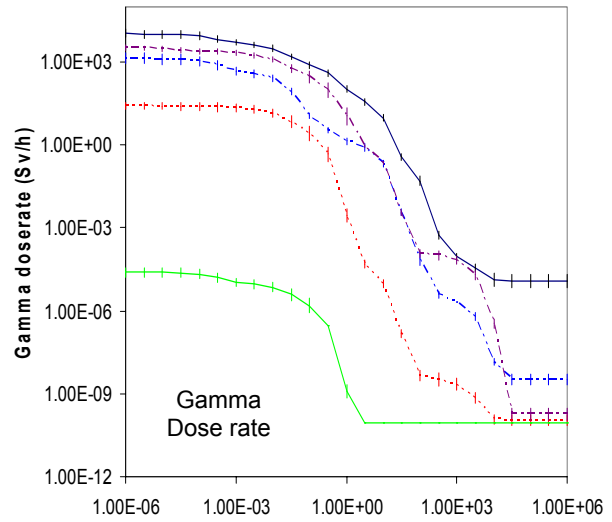
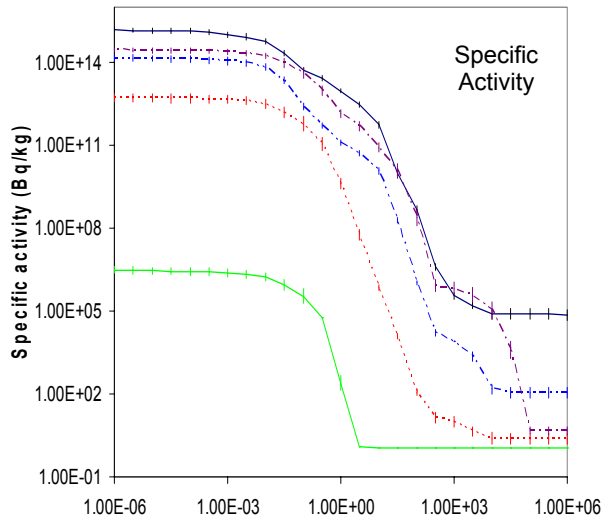
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&Yb173(n,γ)Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175 <sub>-</sub> (n,γ)Lu176(n,γ)Lu177(β <sup>-</sup> )Hf177(n,γ) <sub>-</sub> Hf178(n,γ)Hf179(n,γ)Hf180(n,γ)Hf181 &Yb173(n,γ)Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175 <sub>-</sub> (n,γ)Lu176m(β <sup>-</sup> )Hf176(n,γ)Hf177(n,γ) <sub>-</sub> Hf178(n,γ)Hf179(n,γ)Hf180(n,γ)Hf181 &Yb173(n,γ)Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175 <sub>-</sub> (n,γ)Lu176(n,γ)Lu177(n,γ)Lu178(β <sup>-</sup> ) <sub>-</sub> Hf178(n,γ)Hf179(n,γ)Hf180(n,γ)Hf181	4.2						
Tm168	93.10 d	Yb168(β <sup>+</sup> )Tm168 &Yb170(n,2n)Yb169(β <sup>+</sup> )Tm169(n,2n)Tm168   &Yb171(n,2n)Yb170(n,2n)Yb169(β <sup>+</sup> ) <sub>-</sub> Tm169(n,2n)Tm168 &Yb172(n,2n)Yb171(n,2n)Yb170 <sub>-</sub> (n,2n)Yb169(β <sup>+</sup> )Tm169(n,2n)Tm168 &Yb171(n,3n)Yb169(β <sup>+</sup> )Tm169(n,2n)Tm168   &Yb172(n,4n)Yb169(β <sup>+</sup> )Tm169(n,2n)Tm168   &Yb173(n,3n)Yb171(n,3n)Yb169(β <sup>+</sup> ) <sub>-</sub> Tm169(n,2n)Tm168 &Yb174(n,4n)Yb171(n,3n)Yb169(β <sup>+</sup> ) <sub>-</sub> Tm169(n,2n)Tm168 Yb172(n,3n)Yb170(n,t)Tm168 &Yb172(n,3n)Yb170(n,2n)Yb169(β <sup>+</sup> ) <sub>-</sub> Tm169(n,2n)Tm168 &Yb172(n,2n)Yb171(n,3n)Yb169(β <sup>+</sup> ) <sub>-</sub> Tm169(n,2n)Tm168 Yb170(n,t)Tm168 Yb171(n,nt)Tm168 Yb172(n,d)Tm171(n,4n)Tm168 Yb173(n,4n)Yb170(n,t)Tm168 Yb173(n,t)Tm171(n,4n)Tm168 Yb174(n,4n)Yb171(n,nt)Tm168 &Yb173(n,5n)Yb169(β <sup>+</sup> )Tm169(n,2n)Tm168   Yb174(n,5n)Yb170(n,t)Tm168 Yb172(n,2nt)Tm168 &Yb174(n,6n)Yb169(β <sup>+</sup> )Tm169(n,2n)Tm168   Yb173(n,3nt)Tm168 Yb176(n,6n)Yb171(n,nt)Tm168		100.0	100.0	55.1 37.9 3.9	3.1 0.4	1.0	0.2
							54.1 6.8 5.2 3.3 2.9 2.5 2.0 1.8 1.4 1.3 0.6 0.3 0.2	6.7 30.5 0.1 1.1 2.7 0.1 0.1 6.4 10.0 3.9 5.4 2.3 3.4	1.5 2.8 1.3
Ta182	114.7 d	&Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ) <sub>-</sub> Lu176(n,γ)Lu177(β <sup>-</sup> )Hf177(n,γ)Hf178 <sub>-</sub> (n,γ)Hf179(n,γ)Hf180(n,γ)Hf181(β <sup>-</sup> ) <sub>-</sub> Ta181(n,γ)Ta182 &Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ) <sub>-</sub> Lu176m(β <sup>-</sup> )Hf176(n,γ)Hf177(n,γ) <sub>-</sub> Hf178(n,γ)Hf179(n,γ)Hf180(n,γ)Hf181 <sub>-</sub> (β <sup>-</sup> )Ta181(n,γ)Ta182 &Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ) <sub>-</sub> Lu176(n,γ)Lu177(n,γ)Lu178(β <sup>-</sup> )Hf178 <sub>-</sub> (n,γ)Hf179(n,γ)Hf180(n,γ)Hf181(β <sup>-</sup> ) <sub>-</sub> Ta181(n,γ)Ta182 &Yb176(n,γ)Yb177(β <sup>-</sup> )Lu177(β <sup>-</sup> ) <sub>-</sub> Hf177(n,γ)Hf178(n,γ)Hf179(n,γ)Hf180 <sub>-</sub> (n,γ)Hf181(β <sup>-</sup> )Ta181(n,γ)Ta182 &Yb176(n,γ)Yb177(β <sup>-</sup> )Lu177(n,γ) <sub>-</sub> Lu178(β <sup>-</sup> )Hf178(n,γ)Hf179(n,γ)Hf180 <sub>-</sub> (n,γ)Hf181(β <sup>-</sup> )Ta181(n,γ)Ta182 &Yb173(n,γ)Yb174(n,γ)Yb175(β <sup>-</sup> ) <sub>-</sub> Lu175(n,γ)Lu176(n,γ)Lu177(β <sup>-</sup> )Hf177 <sub>-</sub> (n,γ)Hf178(n,γ)Hf179(n,γ)Hf180(n,γ) <sub>-</sub> Hf181(β <sup>-</sup> )Ta181(n,γ)Ta182	41.5						
			15.9						
			15.1						
			14.8	96.0	97.7				
			5.4	3.4	1.6				
			1.3						
Tm170	128.6 d▶	&Yb168(n,γ)Yb169(β <sup>+</sup> )Tm169(n,γ)Tm170	100.0	98.2	100.0				

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	Yb171(n,2n)Yb170(n,p)Tm170 Yb170(n,p)Tm170 Yb171(n,d)Tm170 Yb171(n,p)Tm171(n,2n)Tm170 Yb172(n,2n)Yb171(n,d)Tm170 Yb172(n,2n)Yb171(n,2n)Yb170(n,p)Tm170   Yb174(n,α)Er171(β <sup>-</sup> )Tm171(n,2n)Tm170   Yb172(n,2n)Yb171(n,p)Tm171(n,2n)Tm170   Yb172(n,t)Tm170 Yb173(n,3n)Yb171(n,d)Tm170 Yb174(n,4n)Yb171(n,d)Tm170 Yb172(n,3n)Yb170(n,p)Tm170 Yb174(n,3n)Yb172(n,t)Tm170 Yb173(n,nt)Tm170 Yb174(n,2nt)Tm170				26.6 19.5 16.1 10.2 7.1 5.9 5.6 2.9 0.3 8.9 5.7 5.0 3.4 1.8	0.8 3.2 46.8 0.2 3.4 0.2 12.4 1.6 9.6 2.5 8.1	1.2 29.4 1.6 34.3 1.6 9.6 2.5 8.1	0.4 16.2 0.6 27.8 0.5 1.3 1.2 20.5 23.2
Lu177m	160.3 d	Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176_ (n,γ)Lu177m Yb173(n,γ)Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175_ (n,γ)Lu176(n,γ)Lu177m Yb172(n,γ)Yb173(n,γ)Yb174(n,γ)_ Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176(n,γ)Lu177m Yb171(n,γ)Yb172(n,γ)Yb173(n,γ)Yb174_ (n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176(n,γ)Lu177m   &Yb176(n,γ)Yb177(β <sup>-</sup> )Lu177(n,n')Lu177m   &Yb176(n,γ)Yb177(β <sup>-</sup> )Lu177(β <sup>-</sup> )_ Hf177(n,p)Lu177m	75.3 23.7 0.6 0.2	57.7 16.5 17.2 8.6	98.1 1.8	72.3 24.8	47.9 50.9	54.3 44.9	68.7 30.7
Lu173	1.336 y	&Yb176(n,2n)Yb175(β <sup>-</sup> )Lu175(n,2n)_ Lu174(n,2n)Lu173 Yb176(n,2n)Yb175(β <sup>-</sup> )Lu175(n,2n)_ Lu174m(n,2n)Lu173 Yb176(n,2n)Yb175(β <sup>-</sup> )Lu175(n,3n)Lu173   Yb176(n,d)Tm175(β <sup>-</sup> )Yb175(β <sup>-</sup> )Lu175_ (n,3n)Lu173				88.4 9.7 1.4	0.4 90.7	0.7 83.0 15.7	0.4 77.3 21.5
Tm171	1.917 y	&Yb168(n,γ)Yb169(β <sup>+</sup> )Tm169(n,γ)_ Tm170(n,γ)Tm171 Yb174(n,α)Er171(β <sup>-</sup> )Tm171 Yb171(n,γ)Yb172(n,α)Er169(β <sup>-</sup> )Tm169_ (n,γ)Tm170(n,γ)Tm171 Yb171(n,p)Tm171 Yb172(n,2n)Yb171(n,p)Tm171 Yb172(n,d)Tm171 Yb173(n,2n)Yb172(n,2n)Yb171(n,p)Tm171   Yb173(n,2n)Yb172(n,d)Tm171 Yb173(n,t)Tm171 Yb174(n,2n)Yb173(n,t)Tm171 Yb174(n,3n)Yb172(n,d)Tm171 Yb174(n,nt)Tm171 Yb173(n,3n)Yb171(n,p)Tm171 Yb176(n,4n)Yb173(n,t)Tm171 Yb176(n,2nα)Er171(β <sup>-</sup> )Tm171 Yb176(n,5n)Yb172(n,d)Tm171 Yb176(n,3nt)Tm171	99.4 0.2	97.2 1.4	99.9	25.5 46.4 14.7 7.8 1.3 1.2 0.9 0.4	6.4 8.7 0.5 54.0 1.5 10.5 0.7 10.5 2.2 1.2 0.8 0.4	1.2 3.5 43.2 0.8 25.9 1.2 2.2 13.4 1.6	1.2 26.2 22.0 41.2 2.4
Lu174	3.559 y	&Yb176(n,2n)Yb175(β <sup>-</sup> )Lu175(n,2n)Lu174   &Yb176(n,d)Tm175(β <sup>-</sup> )Yb175(β <sup>-</sup> )_ Lu175(n,2n)Lu174				99.6	9.0	83.6 15.9	77.9 21.7
H3	12.33 y	&Yb168(n,γ)Yb169(n,X)H1(n,γ)H2(n,γ)H3   Yb171(n,X)H3 Yb173(n,X)H3 Yb172(n,2n)Yb171(n,X)H3 Yb174(n,2n)Yb173(n,X)H3 Yb176(n,2n)Yb175(β <sup>-</sup> )Lu175(n,X)H3 Yb174(n,X)H3 Yb172(n,X)H3	92.6			34.8 23.9 8.5 7.5 6.0 5.2 4.6	16.7 16.3 0.7 0.8 0.5 22.1 16.7	14.8 15.0 0.3 0.5 0.2 23.8 17.7	14.1 14.6 0.3 0.3 0.2 24.9 18.4

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Yb176(n,X)H3 Yb170(n,X)H3 Yb174(n,3n)Yb172(n,X)H3 Yb172(n,3n)Yb170(n,X)H3 Yb173(n,3n)Yb171(n,X)H3 Yb171(n,3n)Yb169(β <sup>+</sup> )Tm169(n,X)H3 Yb174(n,4n)Yb171(n,X)H3 Yb173(n,4n)Yb170(n,X)H3 &Yb172(n,4n)Yb169(β <sup>+</sup> )Tm169(n,X)H3 Yb174(n,5n)Yb170(n,X)H3				1.7 0.6	8.1 2.5 2.5 2.1 1.8 1.3 1.1 0.5 0.2	8.8 2.6 0.7 0.6  2.7 1.2 1.4 0.6	9.3 2.7 0.4 0.3 0.3 0.2 0.6 0.3 0.4 1.2	
Hf178n	31.00 y	Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176m_   (β <sup>-</sup> )Hf176(n,γ)Hf177(n,γ)Hf178n Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176_   (n,γ)Lu177(β <sup>-</sup> )Hf177(n,γ)Hf178n &Yb176(n,γ)Yb177(β <sup>-</sup> )Lu177(β <sup>-</sup> )_   Hf177(n,γ)Hf178n Yb173(n,γ)Yb174(n,γ)Yb175(β <sup>-</sup> )Lu175_   (n,γ)Lu176(n,γ)Lu177(β <sup>-</sup> )Hf177(n,γ)Hf178n   &Yb176(n,γ)Yb177(β <sup>-</sup> )Lu177(β <sup>-</sup> )_   Hf177(n,γ)Hf178(n,n')Hf178n &Yb176(n,γ)Yb177(β <sup>-</sup> )Lu177(n,γ)_   Lu178(β <sup>-</sup> )Hf178(n,n')Hf178n	39.9 35.5 9.6 8.6		0.3 0.4 99.4 98.8			1.4 5.5 6.8 9.4		
Ho166m	1200 y	Yb168(n,α)Er165(β <sup>+</sup> )Ho165(n,γ)Ho166m   &Yb168(n,γ)Yb169(β <sup>+</sup> )Tm169(n,α)_   Ho166m &Yb170(n,2n)Yb169(β <sup>+</sup> )Tm169(n,α)Ho166m   &Yb171(n,2n)Yb170(n,2n)Yb169(β <sup>+</sup> )_   Tm169(n,α)Ho166m &Yb172(n,2n)Yb171(n,2n)Yb170_   (n,2n)Yb169(β <sup>+</sup> )Tm169(n,α)Ho166m &Yb171(n,3n)Yb169(β <sup>+</sup> )Tm169(n,α)Ho166m   &Yb171(n,3n)Yb169(β <sup>+</sup> )Tm169(n,3n)_   Tm167(β <sup>+</sup> )Er167(n,d)Ho166m &Yb172(n,4n)Yb169(β <sup>+</sup> )Tm169(n,α)Ho166m   &Yb171(n,nα)Er167(n,d)Ho166m &Yb173(n,3n)Yb171(n,3n)Yb169(β <sup>+</sup> )_   Tm169(n,α)Ho166m &Yb172(n,4n)Yb169(β <sup>+</sup> )Tm169(n,3n)_   Tm167(β <sup>+</sup> )Er167(n,d)Ho166m &Yb170(n,4n)Yb167(β <sup>+</sup> )Tm167(β <sup>+</sup> )_   Er167(n,d)Ho166m &Yb172(n,3n)Yb170(n,4n)Yb167(β <sup>+</sup> )_   Tm167(β <sup>+</sup> )Er167(n,d)Ho166m &Yb173(n,4n)Yb170(n,4n)Yb167(β <sup>+</sup> )_   Tm167(β <sup>+</sup> )Er167(n,d)Ho166m &Yb171(n,5n)Yb167(β <sup>+</sup> )Tm167(β <sup>+</sup> )_   Er167(n,d)Ho166m &Yb174(n,5n)Yb170(n,4n)Yb167(β <sup>+</sup> )_   Tm167(β <sup>+</sup> )Er167(n,d)Ho166m Yb171(n,nt)Tm168(β <sup>+</sup> )Er168(n,t)Ho166m   &Yb171(n,2nt)Tm167(β <sup>+</sup> )Er167(n,d)Ho166m   Yb172(n,2nt)Tm168(β <sup>+</sup> )Er168(n,t)Ho166m   &Yb172(n,6n)Yb167(β <sup>+</sup> )Tm167(β <sup>+</sup> )_   Er167(n,d)Ho166m &Yb174(n,6n)Yb169(β <sup>+</sup> )Tm169(n,α)Ho166m	52.0 48.0	41.1 56.8	28.3 71.7		63.2 31.3 2.6	2.3 0.2	0.4	
Ho163	4570 y	Yb168(n,α)Er164(n,2n)Er163(β <sup>+</sup> )Ho163   &Yb168(n,α)Er165(β <sup>+</sup> )Ho165(n,2n)_   Ho164(β <sup>-</sup> )Er164(n,2n)Er163(β <sup>+</sup> )Ho163 &Yb171(n,nα)Er167(n,3n)Er165(β <sup>+</sup> )_   Ho165(n,3n)Ho163				28.8 20.0	0.3	4.2		

Nuclide	$T_{1/2}$	Pathway	210	186	151	42	30	21	6
	◀	&Yb171(n,3n)Yb169( $\beta^+$ )Tm169(n, $\alpha$ )_ Ho165(n,3n)Ho163 Yb171(n,2n $\alpha$ )Er166(n,4n)Er163( $\beta^+$ )Ho163 Yb171(n,6n)Yb166( $\beta^+$ )Tm166( $\beta^+$ )_ Er166(n,4n)Er163( $\beta^+$ )Ho163 Yb172(n,5n)Yb168(n,6n)Yb163( $\beta^+$ )_ Tm163( $\beta^+$ )Er163( $\beta^+$ )Ho163 Many other similar long pathways				51.2	91.4	95.6	91.7
Gd150	$1.8 \cdot 10^6$ y	Very long pathways of (n, $\alpha$ ), (n,2n), $\beta^+$				100.0	100.0	100.0	100.0
Dy154	$3.0 \cdot 10^6$ y	Very long pathways of (n, $\alpha$ ), (n,2n), $\beta^+$				100.0	100.0	100.0	100.0
Hf182	$9.0 \cdot 10^6$ y	&Yb174(n, $\gamma$ )Yb175( $\beta^-$ )Lu175(n, $\gamma$ )Lu176_ (n, $\gamma$ )Lu177( $\beta^-$ )Hf177(n, $\gamma$ )Hf178(n, $\gamma$ )_ Hf179(n, $\gamma$ )Hf180(n, $\gamma$ )Hf181(n, $\gamma$ )Hf182 &Yb174(n, $\gamma$ )Yb175( $\beta^-$ )Lu175(n, $\gamma$ )_ Lu176m( $\beta^-$ )Hf176(n, $\gamma$ )Hf177(n, $\gamma$ )_ Hf178(n, $\gamma$ )Hf179(n, $\gamma$ )Hf180(n, $\gamma$ )Hf181_ (n, $\gamma$ )Hf182 &Yb174(n, $\gamma$ )Yb175( $\beta^-$ )Lu175(n, $\gamma$ )Lu176_ (n, $\gamma$ )Lu177(n, $\gamma$ )Lu178( $\beta^-$ )Hf178(n, $\gamma$ )_ Hf179(n, $\gamma$ )Hf180(n, $\gamma$ )Hf181(n, $\gamma$ )Hf182 &Yb176(n, $\gamma$ )Yb177( $\beta^-$ )Lu177( $\beta^-$ )_ Hf177(n, $\gamma$ )Hf178(n, $\gamma$ )Hf179(n, $\gamma$ )Hf180_ (n, $\gamma$ )Hf181(n, $\gamma$ )Hf182 &Yb176(n, $\gamma$ )Yb177( $\beta^-$ )Lu177(n, $\gamma$ )_ Lu178( $\beta^-$ )Hf178(n, $\gamma$ )Hf179(n, $\gamma$ )Hf180_ (n, $\gamma$ )Hf181(n, $\gamma$ )Hf182 &Yb173(n, $\gamma$ )Yb174(n, $\gamma$ )Yb175( $\beta^-$ )_ Lu175(n, $\gamma$ )Lu176(n, $\gamma$ )Lu177( $\beta^-$ )Hf177_ (n, $\gamma$ )Hf178(n, $\gamma$ )Hf179(n, $\gamma$ )Hf180(n, $\gamma$ )_ Hf181(n, $\gamma$ )Hf182 &Yb173(n, $\gamma$ )Yb174(n, $\gamma$ )Yb175( $\beta^-$ )_ Lu175(n, $\gamma$ )Lu176(n, $\gamma$ )Lu177(n, $\gamma$ )Lu178_ ( $\beta^-$ )Hf178(n, $\gamma$ )Hf179(n, $\gamma$ )Hf180(n, $\gamma$ )_ Hf181(n, $\gamma$ )Hf182	41.8 15.5 15.1 13.0 5.4 3.4 1.3	96.2 3.6	98.1 1.6				
Lu176	$4.0 \cdot 10^{10}$ y	Yb174(n, $\gamma$ )Yb175( $\beta^-$ )Lu175(n, $\gamma$ )Lu176_ Yb173(n, $\gamma$ )Yb174(n, $\gamma$ )Yb175( $\beta^-$ )Lu175_ (n, $\gamma$ )Lu176 Yb172(n, $\gamma$ )Yb173(n, $\gamma$ )Yb174(n, $\gamma$ )_ Yb175( $\beta^-$ )Lu175(n, $\gamma$ )Lu176 Yb171(n, $\gamma$ )Yb172(n, $\gamma$ )Yb173(n, $\gamma$ )_ Yb174(n, $\gamma$ )Yb175( $\beta^-$ )Lu175(n, $\gamma$ )Lu176 Yb176(n,2n)Yb175( $\beta^-$ )Lu175(n, $\gamma$ )Lu176 Yb176(n,d)Tm175( $\beta^-$ )Yb175( $\beta^-$ )Lu175_ (n, $\gamma$ )Lu176 &Yb176(n, $\gamma$ )Yb177( $\beta^-$ )Lu177( $\beta^-$ )_ Hf177(n,d)Lu176	73.1 25.9 0.8 0.2	54.1 17.1 18.8 9.8	97.9 2.0	0.1 99.3	0.2 85.3 7.9 5.9	0.2 75.7 14.4 9.2	0.2 68.8 19.1 11.6
Yb168	$1.3 \cdot 10^{14}$ y	&Yb170(n,2n)Yb169(n,2n)Yb168 &Yb171(n,2n)Yb170(n,2n)Yb169(n,2n)Yb168   Yb170(n,3n)Yb168 Yb172(n,3n)Yb170(n,3n)Yb168 Yb171(n,4n)Yb168 Yb173(n,4n)Yb170(n,3n)Yb168 Yb171(n,2n)Yb170(n,3n)Yb168 Yb174(n,3n)Yb172(n,3n)Yb170(n,3n)Yb168   Yb173(n,3n)Yb171(n,4n)Yb168 Yb174(n,4n)Yb171(n,4n)Yb168 Yb172(n,2n)Yb171(n,4n)Yb168 Yb172(n,5n)Yb168 Yb173(n,6n)Yb168 Nuclide present in starting material				5.1 3.8	29.2 25.3 20.7 5.4 4.2 2.6 2.2 1.4 0.8	5.5 1.2 60.1 2.5 0.6 1.9 11.0 1.8 8.5	2.4 0.3 13.7 0.3 0.2 0.3 0.6 0.3 45.3 26.0
			100.0	100.0	91.1	8.2	5.3	7.4	

# Ytterbium activation characteristics

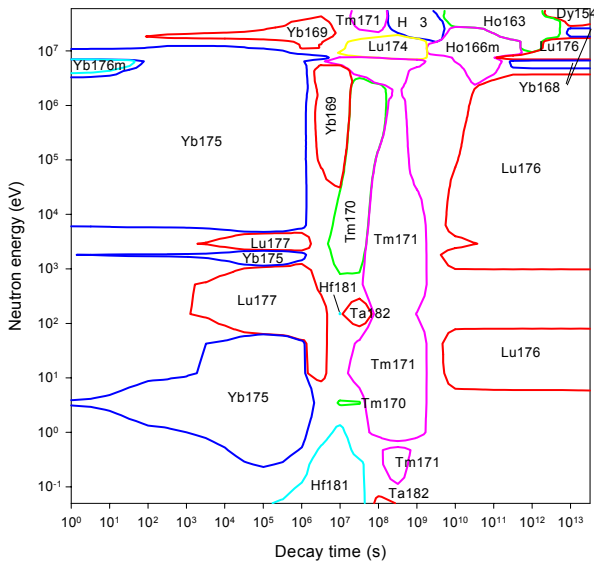


Decay time (years)

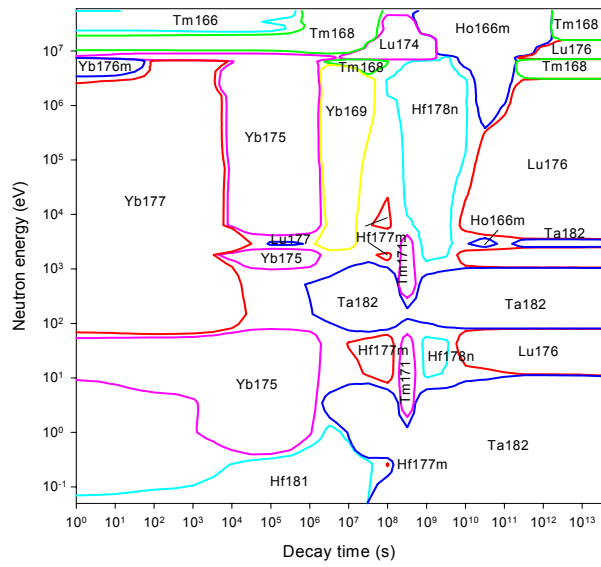
Decay time (years)

# Ytterbium importance diagrams & transmutation

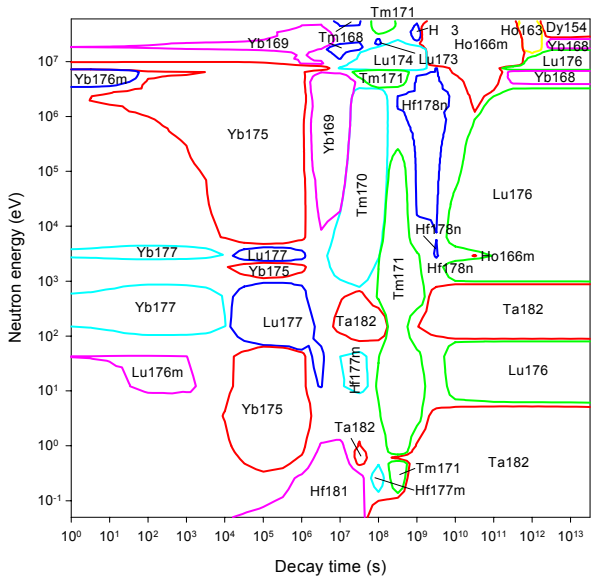
Activity



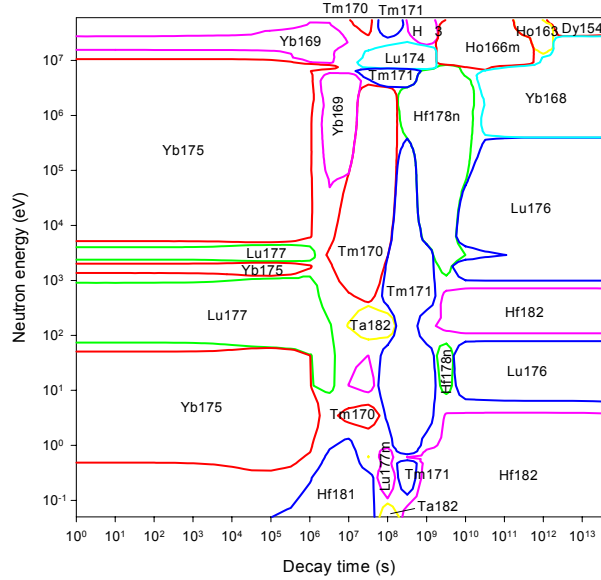
Dose rate



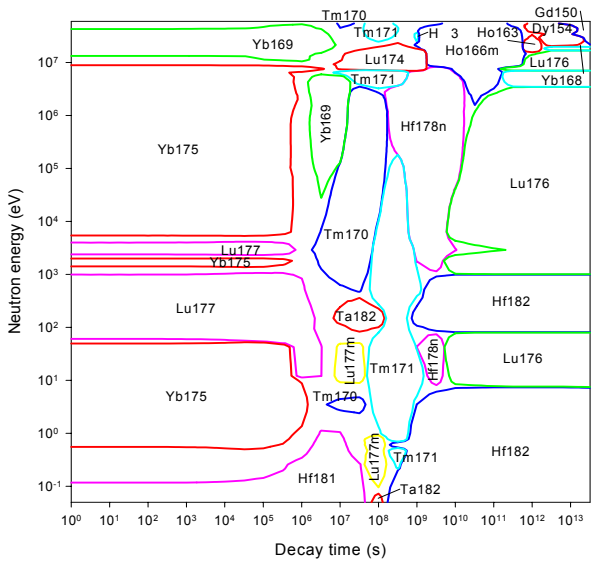
Heat output



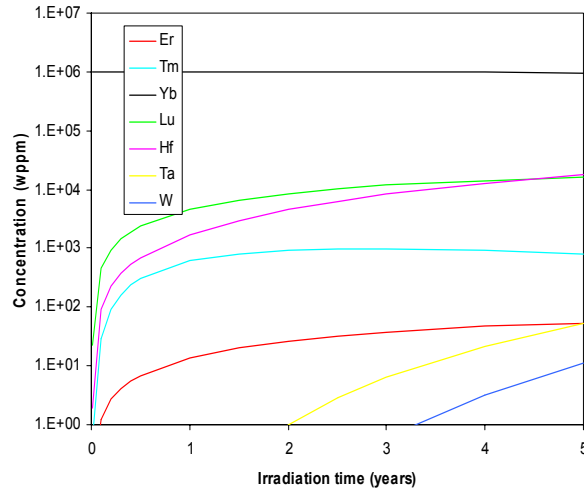
Ingestion dose



Inhalation dose



First wall transmutation



# Lutetium

## General properties

Atomic number	71	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	0.8	Lu175	97.41
Melting point / K	1936	Lu176	2.59 ( $T_{1/2} = 4.00 \cdot 10^{10} \text{ y}$ )
Boiling point / K	3666		
Density / $\text{kgm}^{-3}$	9841		
Thermal conductivity / $\text{Wm}^{-1}\text{K}^{-1}$	16.4		
Electrical resistivity / $\Omega\text{m}$	$7.9 \cdot 10^{-7}$		
Coefficient of thermal expansion / $\text{K}^{-1}$	$9.9 \cdot 10^{-6}$		
Crystal structure	HCP		
Number of stable isotopes	1 (2)		
Mean atomic weight	174.967		

## Activation properties

Act	0	$10^{-5} \text{ y}$	$10^{-2} \text{ y}$	1 y	100 y	$10^5 \text{ y}$	Heat	0	$10^{-5} \text{ y}$	$10^{-2} \text{ y}$	1 y	100 y	$10^5 \text{ y}$
Bq $\text{kg}^{-1}$	1.63E16	8.98E15	3.28E15	9.51E13	2.30E10	4.01E6	kW $\text{kg}^{-1}$	1.01E0	5.47E-1	1.49E-1	4.34E-3	4.49E-6	5.66E-10
Hf179m	43.53						Hf179m	42.19					
Lu176m	26.83	48.01					Lu176m	33.34	60.68				
Lu177	22.50	40.93	76.56	0.19			Lu177	10.52	19.47	48.90	0.12		
Hf181	1.93	3.52	9.08	0.84			Hf181	3.68	6.81	23.58	2.19		
Hf175	1.40	2.54	6.72	6.46			Lu178	1.87	3.04				
Lu178	0.82	1.31					Hf178m	1.56		0.01	0.45	46.94	
Hf178m	0.52			0.11	49.85		Hf177m	1.50	0.18	0.42	3.02		
Lu174	0.48	0.88	2.42	73.16			Hf175	1.48	2.74	9.70	9.28		
Ta182	0.35	0.64	1.71	6.64	0.01	48.00	Ta182	1.36	2.52	9.07	35.03	0.01	81.68
Hf180m	0.34	0.62					Hf180m	1.02	1.87				
Lu174m	0.30	0.55	1.48	8.78			Hf179n	0.85	1.57	5.23	0.01		
Hf179n	0.29	0.54	1.34				Lu174	0.20	0.37	1.38	41.52		
Lu177m	0.02	0.04	0.11	0.85			Lu174m	0.14	0.26	0.93	5.50		
Lu173	0.02	0.03	0.10	2.10			Lu173	0.01	0.02	0.07	1.60		
Hf178n				0.11	49.85		Hf178n			0.01	0.50	53.04	
Hf182					0.01	48.00	Hf182						14.79
Lu176						3.99	Lu176						3.52
Dose	0	$10^{-5} \text{ y}$	$10^{-2} \text{ y}$	1 y	100 y	$10^5 \text{ y}$	Ing	0	$10^{-5} \text{ y}$	$10^{-2} \text{ y}$	1 y	100 y	$10^5 \text{ y}$
Sv $\text{h}^{-1}$	1.25E5	6.00E4	4.74E4	3.60E3	2.52E0	6.32E-4	Sv $\text{kg}^{-1}$	3.37E6	3.36E6	1.95E6	3.86E4	5.39E1	8.95E-3
Hf179m	42.97						Lu177	57.81	58.04	68.19	0.25		
Ta182	14.58	30.46	37.75	55.84	0.02	96.84	Lu176m	22.11	21.84				
Hf181	14.21	29.69	35.44	1.25			Hf181	10.33	10.37	16.79	2.29		
Hf178m	5.73		0.01	0.24	38.05		Hf175	2.78	2.80	4.63	6.53		
Hf175	4.28	8.95	10.93	4.00			Ta182	2.56	2.57	4.32	24.57	0.01	32.26
Hf180m	3.95	8.16					Hf179n	1.73	1.74	2.71	0.01		
Lu178	3.47	6.38					Lu174m	0.78	0.78	1.32	11.47		
Hf177m	3.13	0.43	0.34	0.94			Lu174	0.64	0.64	1.10	48.67		
Hf179n	2.81	5.88	6.73				Lu177m	0.19	0.19	0.33	3.56		
Lu177	2.78*	5.81*	5.03*	0.01			Lu173	0.02	0.02	0.04	1.35		
Lu174	1.19	2.49	3.16	36.34			Hf178n	0.01	0.01	0.02	1.27	99.87	
Hf178n			0.03	0.39	61.92		Hf182					0.01	64.52
Hf182						2.46	Lu176						3.21

<b>Inh</b>	<b>0</b>	<b>10<sup>-5</sup> y</b>	<b>10<sup>-2</sup> y</b>	<b>1 y</b>	<b>100 y</b>	<b>10<sup>5</sup> y</b>	<b>Clear</b>	<b>0</b>	<b>10<sup>-5</sup> y</b>	<b>10<sup>-2</sup> y</b>	<b>1 y</b>	<b>100 y</b>	<b>10<sup>5</sup> y</b>
Sv kg <sup>-1</sup>	8.24E6	8.22E6	6.15E6	4.47E5	2.98E3	6.27E-1		3.43E12	1.43E12	1.03E12	7.67E10	2.59E7	1.99E4
Lu177	53.56	53.62	49.00	0.05			Hf179m	53.19					
Hf181	19.20	19.23	24.22	0.90			Ta182	16.76	40.07	54.73	82.42	0.08	96.83
Ta182	6.98	6.99	9.14	14.14		3.07	Hf181	9.23	22.06	29.01	1.05		
Lu176m	6.39	6.29					Lu176m	7.99	18.78				
Lu174	4.07	4.07	5.44	65.35			Hf178m	2.55		0.01	0.14	45.22	
Hf175	3.33	3.34	4.30	1.65			Hf175	2.47	5.90	7.95	2.96		
Lu174m	2.53	2.54	3.33	7.84			Hf177m	2.30	0.36	0.31	0.88		
Hf179n	2.25	2.25	2.72				Hf180m	1.67	3.94				
Lu177m	0.76	0.76	1.01	2.89			Hf179n	1.29	3.08	3.89			
Hf178n	0.33	0.33	0.45	6.09	99.97		Lu177	1.07	2.56	2.44			
Ta183	0.26	0.26	0.21				Lu178	0.78	1.64				
Lu173	0.09	0.09	0.13	1.07			Lu174	0.28	0.67	0.93	10.92		
Hf180m	0.08	0.08					Lu174m	0.10	0.24	0.33	0.77		
Hf182					0.02	95.15	Lu173	0.01	0.04	0.05	0.45		
Lu176						1.78	Hf178n		0.01	0.01	0.16	54.70	
							Hf182						2.36
							Lu176						0.80



# Lutetium

## Pathway analysis

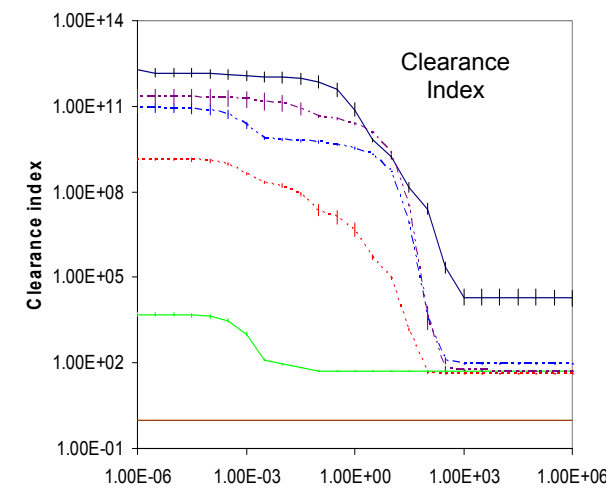
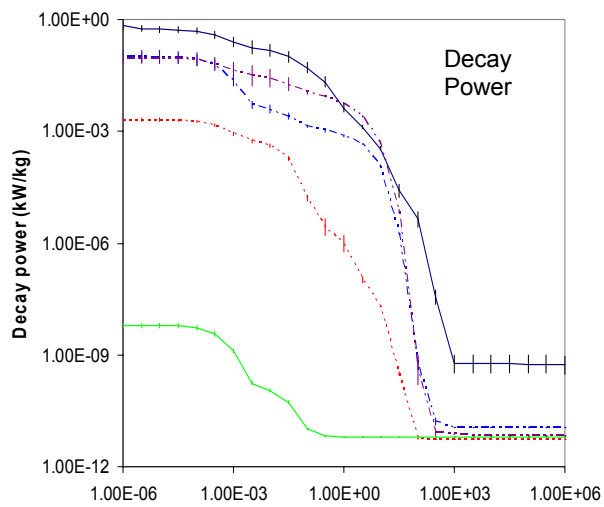
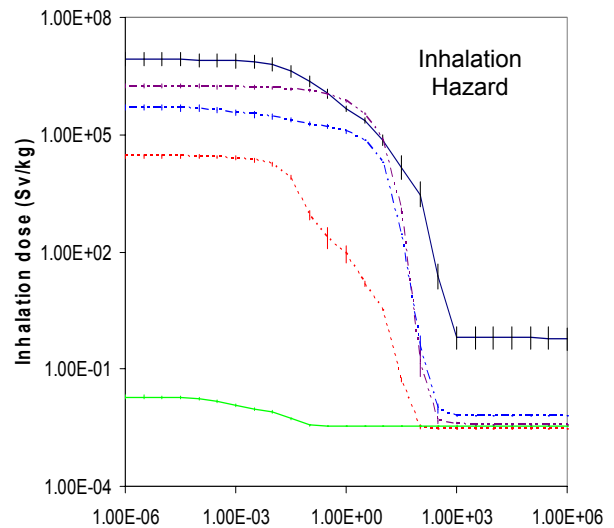
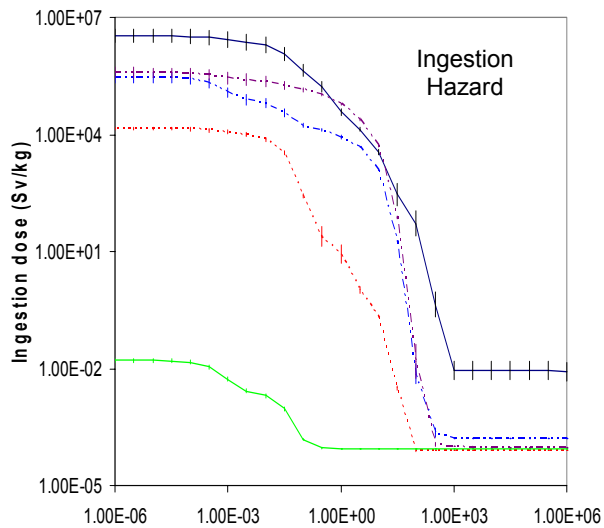
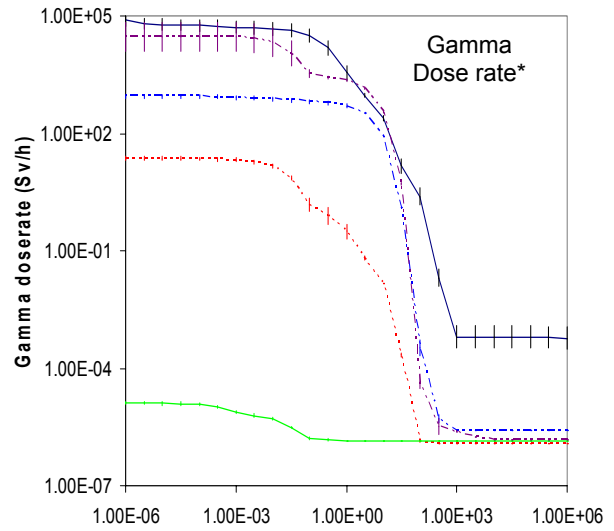
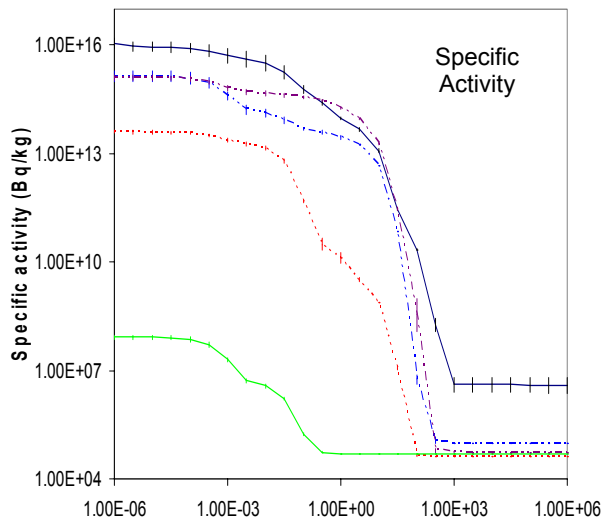
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Hf177m	1.08 s	Lu175(n,γ)Lu176(n,γ)Lu177m(β <sup>-</sup> )_Hf177m	94.9	90.8	38.2	0.2	0.1		
		Lu175(n,γ)Lu176m(β <sup>-</sup> )Hf176(n,γ)_Hf177m	3.8	8.5	42.4				
		Lu176(n,γ)Lu177m(β <sup>-</sup> )Hf177m	1.3	0.7	19.4	26.4	40.4	41.2	42.8
		&Lu176(n,γ)Lu177(β <sup>-</sup> )Hf177(n,n')Hf177m				71.5	58.3	57.6	56.1
Hf179m	18.67 s	&Lu176(n,γ)Lu177(β <sup>-</sup> )Hf177(n,γ)_Hf178(n,γ)Hf179m	77.6		44.2	95.9	96.9	96.9	96.5
		&Lu175(n,γ)Lu176(n,γ)Lu177(β <sup>-</sup> )_Hf177(n,γ)Hf178(n,γ)Hf179m	19.5	88.3	32.6	0.2			
		Lu176(n,γ)Lu177(n,γ)Lu178(β <sup>-</sup> )Hf178_(n,γ)Hf179m	1.3		0.3	1.0	1.0	1.3	1.9
		Lu175(n,γ)Lu176(n,γ)Lu177(n,γ)Lu178_(β <sup>-</sup> )Hf178(n,γ)Hf179m	0.6	2.2	0.3				
		&Lu175(n,γ)Lu176m(β <sup>-</sup> )Hf176(n,γ)_Hf177(n,γ)Hf178(n,γ)Hf179m	0.4	2.5	22.4				
Lu178	28.4 m	Lu175(n,γ)Lu176(n,γ)Lu177(n,γ)Lu178	100.0	99.6	62.9	0.7	0.3	0.2	0.1
		&Lu176(n,γ)Lu177(n,γ)Lu178		0.4	32.2	84.0	81.3	84.6	87.7
		Lu176(n,γ)Lu177m(n,γ)Lu178				11.8	10.3	10.0	10.1
		&Lu176(n,γ)Lu177(β <sup>-</sup> )Hf177(n,γ)_Hf178(n,p)Lu178				3.3	7.6	4.9	1.8
Lu176m	3.635 h	Lu175(n,γ)Lu176m	100.0	100.0	100.0	9.3	6.4	5.7	5.6
		Lu176(n,n')Lu176m				89.8	93.2	94.0	94.2
Lu170	2.002 d	&Lu175(n,2n)Lu174(n,2n)Lu173(n,2n)_Lu172(n,2n)Lu171(n,2n)Lu170				89.4			
		&Lu175(n,2n)Lu174m(n,2n)Lu173_(n,2n)Lu172(n,2n)Lu171(n,2n)Lu170				7.0			
		&Lu175(n,3n)Lu173(n,4n)Lu170					79.4	86.9	
		&Lu175(n,4n)Lu172(n,3n)Lu170					9.8	0.8	
		&Lu175(n,3n)Lu173(n,3n)Lu171(n,2n)Lu170					3.3		
		&Lu175(n,2n)Lu174(n,3n)Lu172(n,3n)Lu170					2.9		
		&Lu175(n,3n)Lu173(n,2n)Lu172(n,3n)Lu170					2.1		
		&Lu176(n,4n)Lu173(n,4n)Lu170					0.6	5.7	
		&Lu175(n,2n)Lu174(n,5n)Lu170						4.4	1.5
		&Lu175(n,6n)Lu170							97.0
Tm172	2.650 d	Lu175(n,α)Tm172	100.0	100.0	100.0	94.7	17.0	9.9	37.0
		Lu176(n,2n)Lu175(n,α)Tm172				0.8			
		Lu176(n,nα)Tm172				0.2	3.3	2.8	2.3
		Lu175(n,3n)Lu173(β <sup>+</sup> )Yb173(n,d)Tm172					68.4	33.7	20.9
		&Lu175(n,4n)Lu172(β <sup>+</sup> )Yb172(n,p)Tm172					2.9	24.4	3.0
		Lu175(n,t)Yb173(n,d)Tm172					1.4	8.2	11.2
		&Lu175(n,2n)Lu174(β <sup>+</sup> )Yb174(n,t)Tm172					1.3	7.1	9.7
		Lu175(n,d)Yb174(n,t)Tm172					0.7	6.5	10.2
		Lu176(n,4n)Lu173(β <sup>+</sup> )Yb173(n,d)Tm172					0.5	2.2	
Lu175(n,nt)Yb172(n,p)Tm172						0.6	1.4		
Lu177	6.647 d	Lu175(n,γ)Lu176(n,γ)Lu177	100.0	99.2	69.4	0.8	0.3	0.2	0.2
		&Lu176(n,γ)Lu177		0.3	30.6	99.0	99.4	99.6	99.7
Lu172	6.70 d	&Lu175(n,2n)Lu174(n,2n)Lu173(n,2n)Lu172				90.5			
		&Lu175(n,2n)Lu174m(n,2n)Lu173_(n,2n)Lu172				7.0			
		&Lu175(n,3n)Lu173(n,2n)Lu172				0.9	14.1	98.6	94.3
		&Lu175(n,4n)Lu172					59.8		
		&Lu175(n,2n)Lu174(n,3n)Lu172					22.0		
		&Lu176(n,3n)Lu174(n,3n)Lu172					1.7		
		&Lu175(n,2n)Lu174m(n,3n)Lu172					1.3		
		Lu176(n,5n)Lu172							4.0

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Hf181	42.38 d	&Lu176(n,γ)Lu177(β <sup>-</sup> )Hf177(n,γ) Hf178(n,γ)Hf179(n,γ)Hf180(n,γ)Hf181 &Lu175(n,γ)Lu176(n,γ)Lu177(β <sup>-</sup> ) Hf177(n,γ)Hf178(n,γ)Hf179(n,γ)Hf180 (n,γ)Hf181 &Lu176(n,γ)Lu177(n,γ)Lu178(β <sup>-</sup> ) Hf178(n,γ)Hf179(n,γ)Hf180(n,γ)Hf181 &Lu175(n,γ)Lu176(n,γ)Lu177(n,γ) Lu178(β <sup>-</sup> )Hf178(n,γ)Hf179(n,γ)Hf180 (n,γ)Hf181 &Lu175(n,γ)Lu176m(β <sup>-</sup> )Hf176(n,γ)Hf177 (n,γ)Hf178(n,γ)Hf179(n,γ)Hf180(n,γ)Hf181	85.6	10.7	57.2	94.0			
			9.5	84.5	24.5				
			2.8	0.3	0.7	1.9			
			0.5	2.7	0.3				
				1.3	16.5				
Tm168	93.10 d	&Lu175(n,2n)Lu174(n,2n)Lu173(n,α) Tm169(n,2n)Tm168 &Lu175(n,2n)Lu174(n,α)Tm170(β <sup>-</sup> ) Yb170(n,2n)Yb169(β <sup>+</sup> )Tm169(n,2n)Tm168 &Lu175(n,α)Tm172(β <sup>-</sup> )Yb172(n,2n) Yb171(n,2n)Yb170(n,2n)Yb169(β <sup>+</sup> ) Tm169(n,2n)Tm168 Lu175(n,2n)Lu174(n,2n)Lu173(β <sup>+</sup> ) Yb173(n,α)Er170(n,2n)Er169(β <sup>-</sup> ) Tm169(n,2n)Tm168 &Lu175(n,2n)Lu174(n,2n)Lu173(n,2n) Lu172(β <sup>+</sup> )Yb172(n,α)Er169(β <sup>-</sup> )Tm169 (n,2n)Tm168 &Lu175(n,α)Tm171(n,2n)Tm170(β <sup>-</sup> ) Yb170(n,2n)Yb169(β <sup>+</sup> )Tm169(n,2n)Tm168 Lu175(n,α)Tm171(n,4n)Tm168 Lu175(n,3n)Lu173(n,3n)Lu171(β <sup>+</sup> )Yb171 (n,3n)Yb169(β <sup>+</sup> )Tm169(n,2n)Tm168 Lu175(n,3n)Lu173(n,2nα)Tm168 Lu175(n,3n)Lu173(β <sup>+</sup> )Yb173(n,3n)Yb171 (n,3n)Yb169(β <sup>+</sup> )Tm169(n,2n)Tm168 &Lu175(n,4n)Lu172(β <sup>+</sup> )Yb172(n,4n) Yb169(β <sup>+</sup> )Tm169(n,2n)Tm168 &Lu175(n,4n)Lu172(β <sup>+</sup> )Yb172(n,d) Tm171(n,4n)Tm168 &Lu175(n,5n)Lu171(β <sup>+</sup> )Yb171(n,nt)Tm168 Lu175(n,4n)Lu172(β <sup>+</sup> )Yb172(n,2nt)Tm168 Lu175(n,4nα)Tm168 &Lu175(n,6n)Lu170(β <sup>+</sup> )Yb170(n,t)Tm168 Plus many other similar long pathways				7.6			
						7.0			
						4.7			
						4.5			
						4.5			
						3.5			
							17.4	8.2	0.4
							9.9		
							8.0	4.2	0.5
							8.0		
							2.9	38.5	0.2
							0.8	6.7	
								4.8	26.6
								1.8	4.5
									34.1
									14.5
						68.2	53.0	35.8	19.2
Ta182	114.7 d	&Lu176(n,γ)Lu177(β <sup>-</sup> )Hf177(n,γ) Hf178(n,γ)Hf179(n,γ)Hf180(n,γ)Hf181 (β <sup>-</sup> )Ta181(n,γ)Ta182 &Lu175(n,γ)Lu176(n,γ)Lu177(β <sup>-</sup> ) Hf177(n,γ)Hf178(n,γ)Hf179(n,γ)Hf180 (n,γ)Hf181(β <sup>-</sup> )Ta181(n,γ)Ta182 &Lu176(n,γ)Lu177(n,γ)Lu178(β <sup>-</sup> ) Hf178(n,γ)Hf179(n,γ)Hf180(n,γ)Hf181 (β <sup>-</sup> )Ta181(n,γ)Ta182 &Lu175(n,γ)Lu176(n,γ)Lu177(n,γ) Lu178(β <sup>-</sup> )Hf178(n,γ)Hf179(n,γ)Hf180 (n,γ)Hf181(β <sup>-</sup> )Ta181(n,γ)Ta182 &Lu175(n,γ)Lu176m(β <sup>-</sup> )Hf176(n,γ) Hf177(n,γ)Hf178(n,γ)Hf179(n,γ)Hf180 (n,γ)Hf181(β <sup>-</sup> )Ta181(n,γ)Ta182	86.1	12.6	62.6				
			7.5	82.0	21.0				
			5.0	0.5	1.1				
			0.5	3.0	0.5				
				1.1	14.1				
Lu177m	160.3 d	Lu175(n,γ)Lu176(n,γ)Lu177m Lu176(n,γ)Lu177m	98.7	99.2	66.3	0.7	0.3	0.2	0.1
			1.3	0.8	33.6	99.0	99.4	99.5	99.7
Lu173	1.336 y	&Lu175(n,2n)Lu174(n,2n)Lu173 Lu175(n,2n)Lu174m(n,2n)Lu173				91.4			
						6.9			

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Lu175(n,3n)Lu173 Lu176(n,4n)Lu173				0.9	98.1	92.3	95.7	
							0.7	6.0	3.1	
Tm171	1.917 y	Lu176(n,γ)Lu177(β <sup>-</sup> )Hf177(n,α)Yb174_ (n,α)Er171(β <sup>-</sup> )Tm171 Lu176(n,α)Tm173(β <sup>-</sup> )Yb173(n,γ)_ Yb174(n,α)Er171(β <sup>-</sup> )Tm171 Lu175(n,γ)Lu176(n,γ)Lu177(β <sup>-</sup> )Hf177_ (n,α)Yb174(n,α)Er171(β <sup>-</sup> )Tm171 Lu175(n,γ)Lu176(n,α)Tm173(β <sup>-</sup> )_ Yb173(n,γ)Yb174(n,α)Er171(β <sup>-</sup> )Tm171 Lu176(n,α)Tm173(β <sup>-</sup> )Yb173(n,α)_ Er170(n,γ)Er171(β <sup>-</sup> )Tm171 Lu175(n,α)Tm172(β <sup>-</sup> )Yb172(n,α)_ Er169(β <sup>-</sup> )Tm169(n,γ)Tm170(n,γ)Tm171 Lu175(n,α)Tm172(β <sup>-</sup> )Yb172(n,γ)_ Yb173(n,α)Er170(n,γ)Er171(β <sup>-</sup> )Tm171 Lu175(n,γ)Lu176m(β <sup>-</sup> )Hf176(n,α)_ Yb173(n,α)Er170(n,γ)Er171(β <sup>-</sup> )Tm171 &Lu175(n,2n)Lu174(n,α)Tm171 Lu175(n,α)Tm171 &Lu175(n,2n)Lu174(β <sup>+</sup> )Yb174(n,α)_ Er171(β <sup>-</sup> )Tm171 Lu175(n,2n)Lu174m(n,α)Tm171 Lu175(n,3n)Lu173(β <sup>+</sup> )Yb173(n,t)Tm171 &Lu175(n,4n)Lu172(β <sup>+</sup> )Yb172(n,d)Tm171 Lu176(n,2nα)Tm171 Lu175(n,t)Yb173(n,t)Tm171 Lu175(n,nt)Yb172(n,d)Tm171 Lu175(n,d)Yb174(n,nt)Tm171 Lu175(n,2n)Lu174(β <sup>+</sup> )Yb174(n,nt)Tm171 Lu175(n,5n)Lu171(β <sup>+</sup> )Yb171(n,p)Tm171	47.1 36.2 8.5 6.1 0.7 0.2 0.2 0.6 59.0 53.3 23.8 17.2 3.9 4.1 0.3 0.2 0.1 0.6 2.3 1.4			23.7 99.4 0.7 2.1 59.0			44.3 52.3	
Lu174	3.559 y	&Lu175(n,2n)Lu174 &Lu176(n,3n)Lu174				99.1	92.1	96.2	96.6	
							7.3	3.4	2.2	
H3	12.33 y	Lu175(n,X)H3 &Lu175(n,2n)Lu174(n,X)H3 Lu176(n,X)H3 Lu175(n,2n)Lu174m(n,X)H3 Lu175(n,3n)Lu173(n,X)H3 Lu175(n,3n)Lu173(β <sup>+</sup> )Yb173(n,X)H3 Lu175(n,4n)Lu172(β <sup>+</sup> )Yb172(n,X)H3 Lu175(n,5n)Lu171(β <sup>+</sup> )Yb171(n,X)H3 Lu175(n,6n)Lu170(β <sup>+</sup> )Yb170(n,X)H3				61.4 29.1 5.8 2.1 4.9 3.9 0.3	82.5 2.5 2.8 0.2 1.5 1.3 4.4 0.5	83.3 1.2 2.5 2.4 1.5 1.3 4.4 2.2 1.6		
Hf178n	31.0 y	Lu176(n,γ)Lu177(β <sup>-</sup> )Hf177(n,γ)Hf178n Lu175(n,γ)Lu176(n,γ)Lu177(β <sup>-</sup> )Hf177_ (n,γ)Hf178n Lu175(n,γ)Lu176m(β <sup>-</sup> )Hf176(n,γ)_ Hf177(n,γ)Hf178n &Lu176(n,γ)Lu177(β <sup>-</sup> )Hf177(n,γ)_ Hf178(n,n')Hf178n Lu176(n,γ)Lu177(n,γ)Lu178(β <sup>-</sup> )Hf178_ (n,n')Hf178n	79.1 20.4 0.4	6.6 90.6 2.6	44.2 33.0 22.7	5.5 5.5 90.5 1.3	5.6 5.6 90.7 1.4	6.8 6.8 90.3 1.8	9.3 9.3 87.0 2.6	
Ho166m	1200 y	Lu175(n,α)Tm172(β <sup>-</sup> )Yb172(n,α)_ Er169(β <sup>-</sup> )Tm169(n,α)Ho166m &Lu175(n,2n)Lu174(n,2n)Lu173(n,α)_ Tm169(n,α)Ho166m &Lu175(n,2n)Lu174(n,α)Tm170(β <sup>-</sup> )_ Yb170(n,2n)Yb169(β <sup>+</sup> )Tm169(n,α)_ Ho166m &Lu175(n,2n)Lu174(n,2n)Lu173(β <sup>+</sup> )_ Yb173(n,α)Er170(n,2n)Er169(β <sup>-</sup> )_ Tm169(n,α)Ho166m		100.0		1.0 7.4 4.1 4.1				

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	&Lu175(n,α)Tm172(β <sup>-</sup> )Yb172(n,2n) Yb171(n,2n)Yb170(n,2n)Yb169(β <sup>+</sup> ) Tm169(n,α)Ho166m &Lu175(n,2n)Lu174(n,nα)Tm170 (n,2n)Tm169(n,α)Ho166m &Lu175(n,nα)Tm171(n,2n)Tm170(β <sup>-</sup> ) Yb170(n,2n)Yb169(β <sup>+</sup> )Tm169(n,α) Ho166m &Lu175(n,2n)Lu174(n,2n)Lu173(n,2n) Lu172(β <sup>+</sup> )Yb172(n,α)Er169(β <sup>-</sup> )Tm169 (n,α)Ho166m Lu175(n,2n)Lu174(β <sup>+</sup> )Yb174(n,2n) Yb173(n,α)Er170(n,2n)Er169(β <sup>-</sup> ) Tm169(n,α)Ho166m Lu175(n,nα)Tm171(n,3n)Tm169(n,α) Ho166m Lu175(n,3n)Lu173(n,nα)Tm169(n,α)Ho166m Lu175(n,nα)Tm171(n,2nα)Ho166m Lu175(n,3n)Lu173(β <sup>+</sup> )Yb173(n,nα) Er169(β <sup>-</sup> )Tm169(n,α)Ho166m Lu175(n,4n)Lu172(β <sup>+</sup> )Yb172(n,4n) Yb169(β <sup>+</sup> )Tm169(n,α)Ho166m Lu175(n,4n)Lu172(β <sup>+</sup> )Yb172(n,2nα) Er167(n,d)Ho166m Lu175(n,5n)Lu171(β <sup>+</sup> )Yb171(n,nt) Tm168(β <sup>+</sup> )Er168(n,t)Ho166m Lu175(n,4nα)Tm168(β <sup>+</sup> )Er168(n,t)Ho166m Other similar long pathways				3.1				
						2.8				
						2.7				
						2.5				
						2.2				
						0.7	4.0			
						0.2	4.7			
							3.5	4.5	0.8	
							2.4			
							2.0	14.2	0.2	
							0.1	2.6	0.1	
								0.4	2.3	
									16.4	
						69.2	83.3	78.3	80.2	
Ho163	4570 y	Very long pathways of (n,α), (n,2n), β <sup>+</sup>				100.0	100.0	100.0	100.0	
Gd150	1.8 10 <sup>6</sup> y	Very long pathways of (n,α), (n,2n), β <sup>+</sup>					100.0	100.0	100.0	
Dy154	3.0 10 <sup>6</sup> y	Very long pathways of (n,α), (n,2n), β <sup>+</sup>					100.0	100.0	100.0	
Hf182	9.0 10 <sup>6</sup> y	&Lu176(n,γ)Lu177(β <sup>-</sup> )Hf177(n,γ) Hf178(n,γ)Hf179(n,γ)Hf180(n,γ)Hf181 (n,γ)Hf182 &Lu175(n,γ)Lu176(n,γ)Lu177(β <sup>-</sup> ) Hf177(n,γ)Hf178(n,γ)Hf179(n,γ)Hf180 (n,γ)Hf181(n,γ)Hf182 &Lu176(n,γ)Lu177(n,γ)Lu178(β <sup>-</sup> ) Hf178(n,γ)Hf179(n,γ)Hf180(n,γ)Hf181 (n,γ)Hf182 &Lu175(n,γ)Lu176(n,γ)Lu177(n,γ) Lu178(β <sup>-</sup> )Hf178(n,γ)Hf179(n,γ)Hf180 (n,γ)Hf181(n,γ)Hf182 &Lu175(n,γ)Lu176m(β <sup>-</sup> )Hf176(n,γ) Hf177(n,γ)Hf178(n,γ)Hf179(n,γ)Hf180 (n,γ)Hf181(n,γ)Hf182	86.4	12.8	61.5					
			7.5	82.1	21.9					
			5.0	0.5	1.0					
			0.5	3.0	0.5					
				1.1	14.6					
Lu176	4.0 10 <sup>10</sup> y	Lu175(n,γ)Lu176 Nuclide also present in starting material	100.0	99.7 0.3	69.4 30.6	0.8 99.2	0.3 99.7	0.2 99.8	0.2 99.8	

# Lutetium activation characteristics

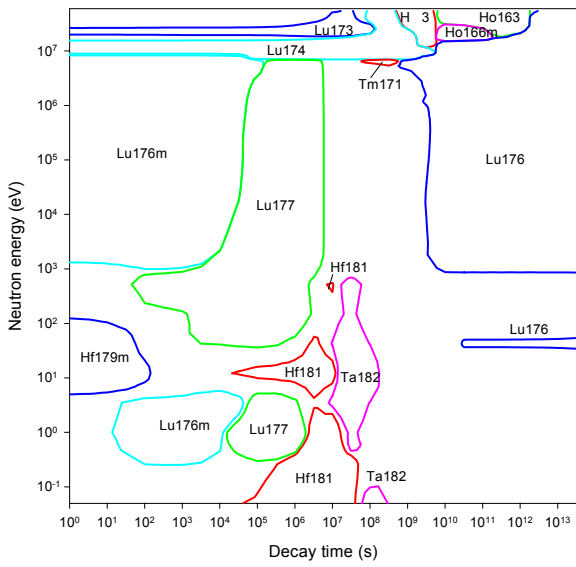


Decay time (years)

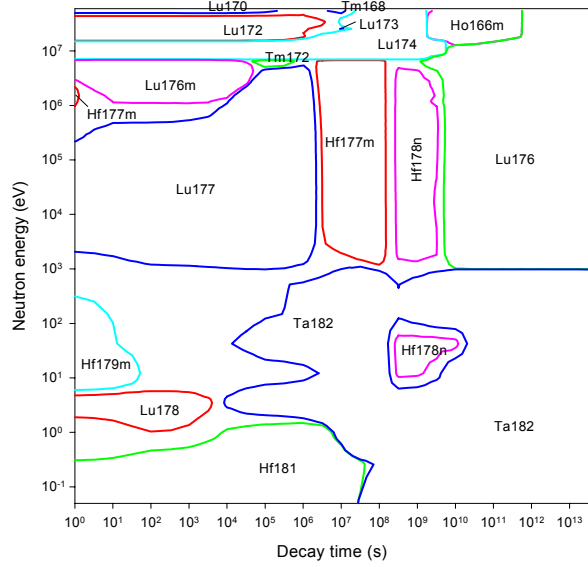
Decay time (years)

# Lutetium importance diagrams & transmutation

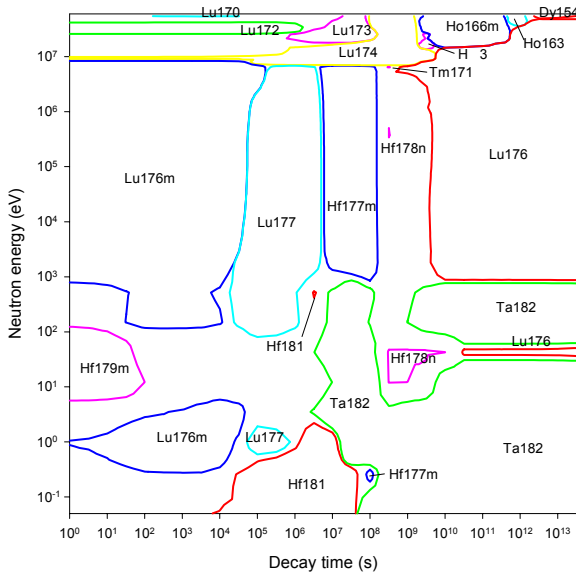
Activity



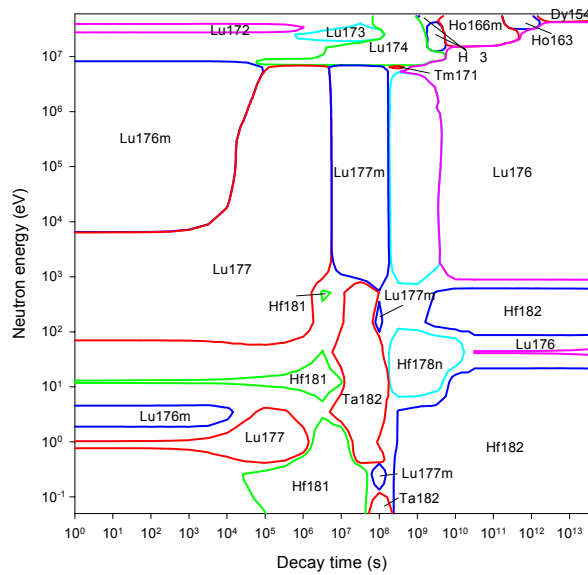
Dose rate



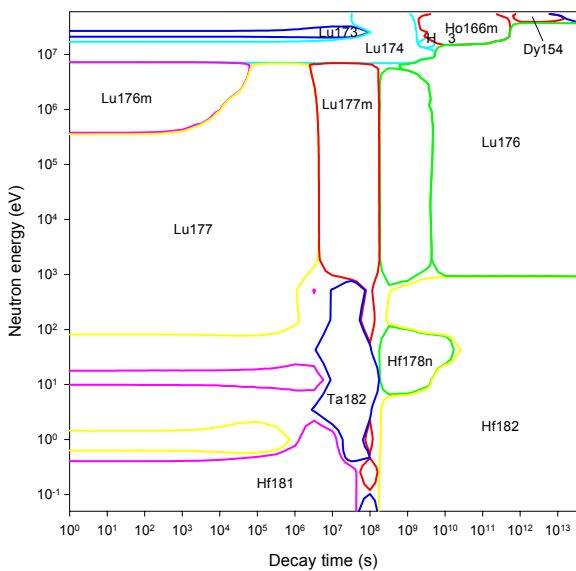
Heat output



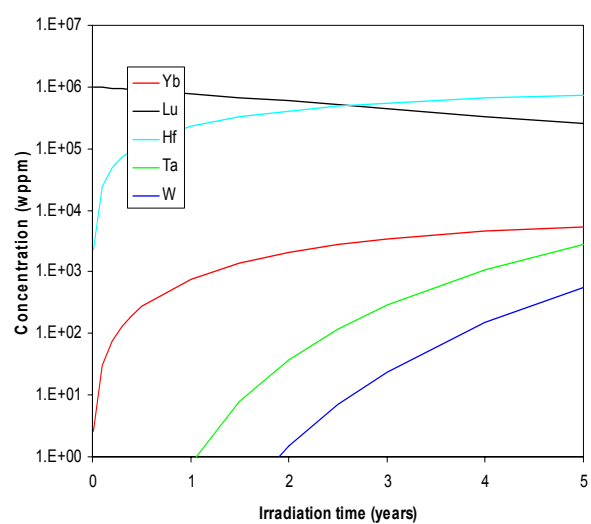
Ingestion dose



Inhalation dose



First wall transmutation



# Hafnium

## General properties

Atomic number	72	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	3.0	Hf174	0.16 ( $T_{1/2} = 2.00 \cdot 10^{15} \text{ y}$ )
Melting point / K	2506	Hf176	5.26
Boiling point / K	4876	Hf177	18.60
Density / $\text{kgm}^{-3}$	13310	Hf178	27.28
Thermal conductivity / $\text{Wm}^{-1}\text{K}^{-1}$	23.0	Hf179	13.62
Electrical resistivity / $\Omega\text{m}$	$3.51 \cdot 10^{-7}$	Hf180	35.08
Coefficient of thermal expansion / $\text{K}^{-1}$	$5.9 \cdot 10^{-6}$		
Crystal structure	HCP		
Number of stable isotopes	5 (6)		
Mean atomic weight	178.49		

## Activation properties

Act	0	$10^{-5} \text{ y}$	$10^{-2} \text{ y}$	1 y	100 y	$10^5 \text{ y}$	Heat	0	$10^{-5} \text{ y}$	$10^{-2} \text{ y}$	1 y	100 y	$10^5 \text{ y}$
Bq $\text{kg}^{-1}$	6.49E15	4.27E15	3.84E15	1.53E14	1.77E10	9.59E7	kW $\text{kg}^{-1}$	8.03E-1	6.57E-1	6.03E-1	3.50E-2	3.46E-6	1.36E-8
Hf181	37.89	57.60	60.36	4.11			Ta182	38.70	47.28	50.39	97.56	0.34	84.67
Hf179m	31.47						Hf181	36.11	44.11	45.28	2.11		
Ta182	19.91	30.25	32.92	93.25	0.27	49.99	Hf179m	15.29					
Ta183	3.65	5.54	3.75				Ta183	3.01	3.67	2.43			
Hf178m	1.51			0.05	49.69		Hf178m	2.25			0.04	46.76	
Hf180m	1.24	1.86					Hf180m	1.83	2.21				
W 183m	1.12	0.19	0.13				Hf179n	1.24	1.52	1.49			
Hf179n	0.87	1.32	1.32				Lu176m	0.23	0.27				
Hf175	0.38	0.58	0.62	0.44			Hf175	0.20	0.25	0.26	0.13		
W181	0.29	0.43	0.47	1.50			Hf182m	0.07	0.08				
Hf178n				0.05	49.69		Hf178n				0.05	52.85	
Hf182					0.27	49.99	Hf182					0.06	15.33
Dose	0	$10^{-5} \text{ y}$	$10^{-2} \text{ y}$	1 y	100 y	$10^5 \text{ y}$	Ing	0	$10^{-5} \text{ y}$	$10^{-2} \text{ y}$	1 y	100 y	$10^5 \text{ y}$
Sv $\text{h}^{-1}$	5.86E5	5.62E5	5.35E5	4.55E4	1.92E0	1.56E-2	Sv $\text{kg}^{-1}$	5.07E6	5.07E6	4.72E6	2.21E5	4.15E1	2.16E-1
Ta182	70.05	73.00	74.95	99.15	0.80	97.58	Hf181	53.41	53.43	54.08	3.11		
Hf181	23.29	24.27	24.00	0.76			Ta182	38.26	38.27	40.22	96.39	0.17	33.33
Hf179m	2.57						Ta183	6.07	6.07	3.97			
Hf178m	1.38			0.02	37.70		Hf179n	1.33	1.33	1.29			
Hf180m	1.18	1.21					Hf180m	0.27	0.27				
Hf179n	0.68	0.71	0.68				Hf175	0.20	0.20	0.21	0.12		
Hf178n				0.02	61.48		Hf178n	0.01	0.01	0.01	0.17	99.48	
Hf182					0.02	2.42	Hf182					0.35	66.66
Inh	0	$10^{-5} \text{ y}$	$10^{-2} \text{ y}$	1 y	100 y	$10^5 \text{ y}$	Clear	0	$10^{-5} \text{ y}$	$10^{-2} \text{ y}$	1 y	100 y	$10^5 \text{ y}$
Sv $\text{kg}^{-1}$	2.60E7	2.60E7	2.48E7	1.48E6	2.30E3	1.53E1		1.63E13	1.56E13	1.51E13	1.43E12	2.03E7	4.91E5
Ta182	49.66	49.66	50.99	96.27	0.02	3.13	Ta182	79.48	82.74	83.92	99.51	2.38	97.62
Hf181	47.27	47.27	46.75	2.12			Hf181	15.13	15.75	15.39	0.44		
Ta183	1.91	1.91	1.22				Hf179m	3.22					
Hf179n	0.82	0.82	0.78				Hf178m	0.62			0.01	44.15	
Hf175	0.11	0.11	0.12	0.05			Hf180m	0.50	0.51				
Hf178n	0.08	0.08	0.09	1.42	99.33		Ta183	0.47	0.49	0.31			
Lu177	0.04	0.04	0.03				Hf179n	0.31	0.33	0.31			
Hf182					0.65	96.88	Hf178n				0.01	53.42	
							Hf182					0.06	2.38

# Hafnium

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
Hf177m	1.08 s	&Hf176(n,γ)Hf177m	97.0	75.2	99.2					
		Hf174(n,γ)Hf175(β <sup>+</sup> )Lu175(n,γ) <sub>-</sub>	1.7	1.2						
		Lu176m(β <sup>-</sup> )Hf176(n,γ)Hf177m								
		Hf174(n,γ)Hf175(β <sup>+</sup> )Lu175(n,γ) <sub>-</sub>	0.8	23.2						
		Lu176(n,γ)Lu177m(β <sup>-</sup> )Hf177m								
		&Hf178(n,2n)Hf177m				48.6	11.9	8.9	11.0	
		&Hf177(n,n')Hf177m				26.1	22.5	22.1	39.8	
		&Hf178(n,2n)Hf177(n,n')Hf177m				11.8	1.5	1.0	1.2	
		&Hf179(n,2n)Hf178(n,2n)Hf177m				7.2	0.3			
		&Hf180(n,2n)Hf179(n,2n)Hf178(n,2n)Hf177m				3.0				
		&Hf180(n,3n)Hf178(n,2n)Hf177m				0.8	1.9			
		&Hf179(n,3n)Hf177(n,n')Hf177m				0.2	2.8	0.7		
		Hf180(n,4n)Hf177m					28.4	48.3	22.7	
		Hf179(n,3n)Hf177m					20.6	6.3	7.2	
		&Hf180(n,4n)Hf177(n,n')Hf177m					3.6	6.2	2.5	
		&Hf180(n,2n)Hf179(n,3n)Hf177m					2.6			
		Hf178(n,d)Lu177m(β <sup>-</sup> )Hf177m					1.1	1.7	3.1	
		Hf179(n,t)Lu177m(β <sup>-</sup> )Hf177m					0.1	0.8	2.0	
Hf180(n,nt)Lu177m(β <sup>-</sup> )Hf177m						0.6	5.2			
Hf178m	4.00 s	Hf176(n,γ)Hf177(n,γ)Hf178m	97.1	52.0	2.0					
		Hf177(n,γ)Hf178m		32.2	98.0					
		Hf174(n,γ)Hf175(β <sup>+</sup> )Lu175(n,γ)Lu176 <sub>-</sub> (n,γ)Lu177(β <sup>-</sup> )Hf177(n,γ)Hf178m		14.8						
		Hf179(n,2n)Hf178m				51.8	36.0	49.1	49.0	
		&Hf180(n,2n)Hf179(n,2n)Hf178m				42.3	4.7	4.6		
		&Hf178(n,n')Hf178m				4.2	14.8	21.4	21.4	
		Hf180(n,3n)Hf178m					40.6	21.3	21.4	
		Hf180(n,3n)Hf178(n,n')Hf178m					1.9	0.7		
		Hf180(n,d)Lu179(β <sup>-</sup> )Hf179(n,2n)Hf178m					0.6	1.2		
		Hf179m	18.67 s	Hf176(n,γ)Hf177(n,γ)Hf178(n,γ)Hf179m	44.0	0.3	0.1			
Hf178(n,γ)Hf179m	30.3			56.6	89.2					
Hf177(n,γ)Hf178(n,γ)Hf179m	24.4			42.9	10.7					
Hf180(n,2n)Hf179m						93.9	86.7	87.8	89.2	
Hf179(n,n')Hf179m						3.3	11.4	10.7	9.8	
Hf180(n,2n)Hf179(n,n')Hf179m						1.9			0.4	
Hf171	12.11 h	Hf174(n,2n)Hf173(n,2n)Hf172(n,2n)Hf171				86.3				
		Hf176(n,2n)Hf175(n,2n)Hf174(n,2n) <sub>-</sub>				9.3				
		Hf173(n,2n)Hf172(n,2n)Hf171								
		Hf176(n,3n)Hf174(n,3n)Hf172(n,2n)Hf171						34.1		
		Hf177(n,4n)Hf174(n,3n)Hf172(n,2n)Hf171						23.8		
		Hf178(n,3n)Hf176(n,3n)Hf174(n,3n) <sub>-</sub>						15.3		
		Hf172(n,2n)Hf171								
		Hf174(n,3n)Hf172(n,2n)Hf171						6.6		
		Hf179(n,4n)Hf176(n,3n)Hf174(n,3n) <sub>-</sub>						3.0		
		Hf172(n,2n)Hf171								
		Hf177(n,2n)Hf176(n,3n)Hf174(n,3n) <sub>-</sub>						2.7		
		Hf172(n,2n)Hf171								
		Hf176(n,3n)Hf174(n,4n)Hf171						2.5	6.5	1.3
		Hf177(n,4n)Hf174(n,4n)Hf171						1.8	57.2	5.8
		Hf174(n,4n)Hf171						0.3	2.8	1.1
		Hf180(n,4n)Hf177(n,4n)Hf174(n,4n)Hf171						0.1	8.1	
		Hf178(n,5n)Hf174(n,4n)Hf171							14.4	17.1
		Hf176(n,6n)Hf171								27.0
		Hf180(n,5n)Hf176(n,6n)Hf171								13.5
		Hf179(n,6n)Hf174(n,4n)Hf171								8.3
Hf178(n,3n)Hf176(n,6n)Hf171								4.8		
Hf179(n,4n)Hf176(n,6n)Hf171								2.9		



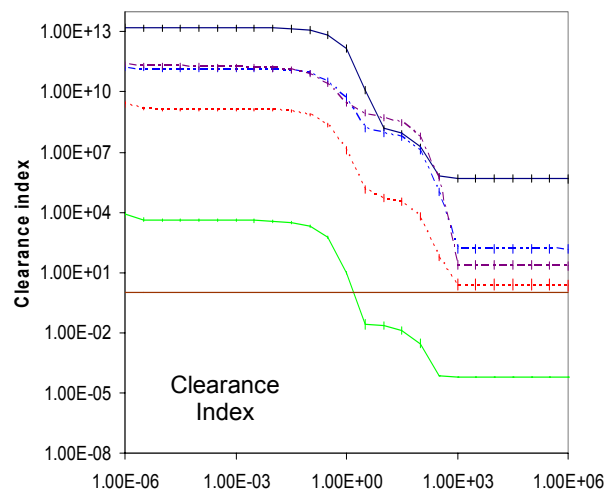
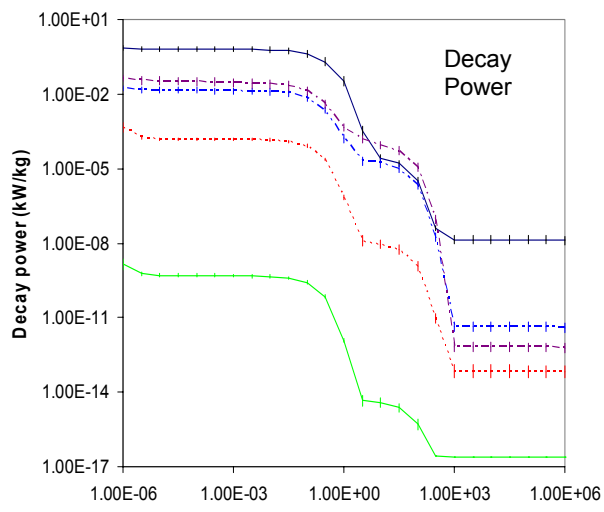
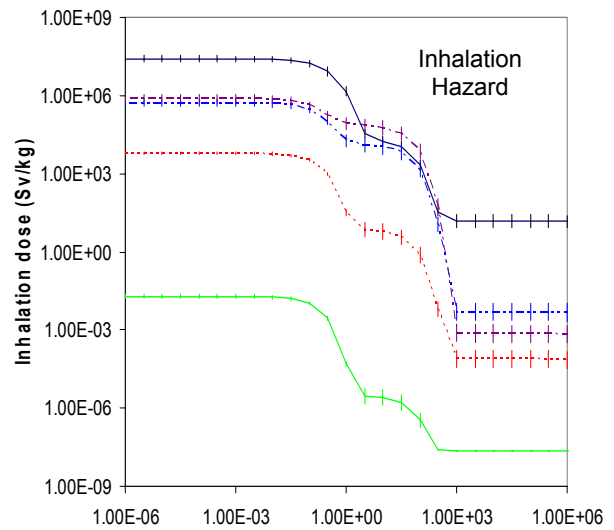
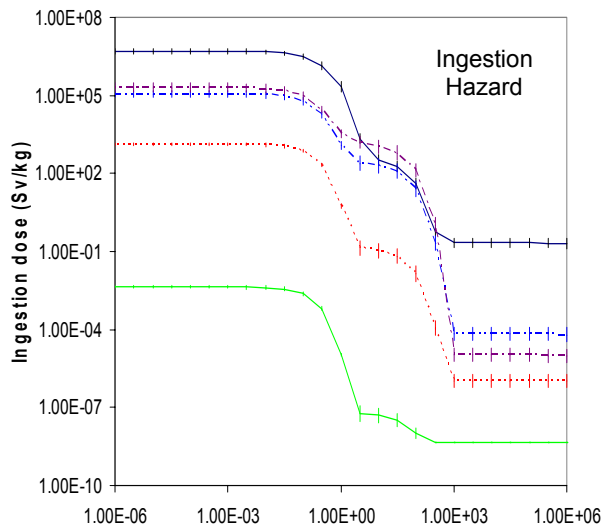
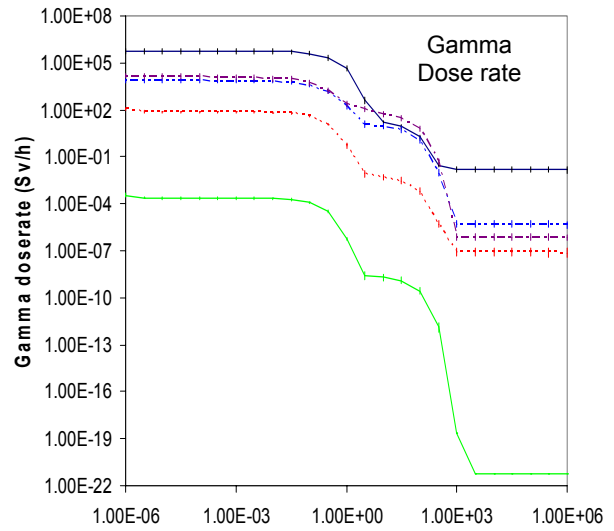
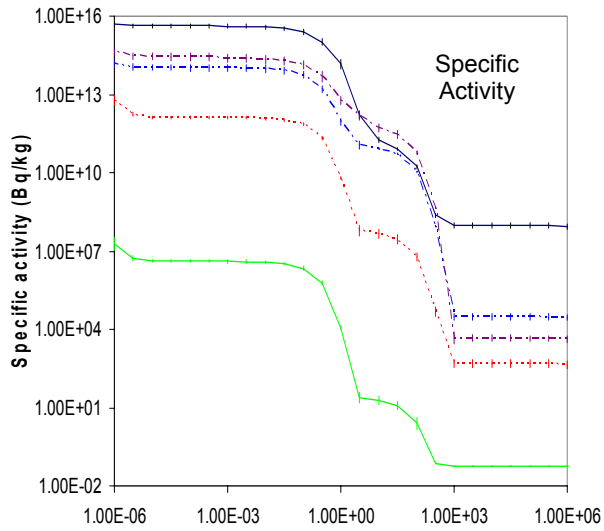
Nuclide	T <sub>½</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Hf177(n,2n)Hf176(n,6n)Hf171 Hf180(n,6n)Hf175(n,5n)Hf171 Hf177(n,6n)Hf172(n,2n)Hf171							2.6 2.5 2.3	
Ta183	5.09 d	&Hf180(n,γ)Hf181(β <sup>-</sup> )Ta181(n,γ)Ta182_ (n,γ)Ta183 &Hf178(n,γ)Hf179(n,γ)Hf180(n,γ)Hf181_ (β <sup>-</sup> )Ta181(n,γ)Ta182(n,γ)Ta183 &Hf177(n,γ)Hf178(n,γ)Hf179(n,γ)Hf180_ (n,γ)Hf181(β <sup>-</sup> )Ta181(n,γ)Ta182(n,γ)Ta183 &Hf179(n,γ)Hf180(n,γ)Hf181(β <sup>-</sup> )Ta181_ (n,γ)Ta182(n,γ)Ta183 &Hf180(n,γ)Hf181(n,γ)Hf182(n,γ)Hf183_ (β <sup>-</sup> )Ta183	49.0 19.8 12.7 13.1 2.5	55.0 13.2 7.2 20.1 2.5	95.3  2.2	96.9  2.2	96.8  0.9	97.0  0.9	97.3  0.9	
Lu172	6.70 d	&Hf174(n,2n)Hf173(β <sup>+</sup> )Lu173(n,2n)Lu172 &Hf176(n,2n)Hf175(β <sup>+</sup> )Lu175(n,2n)_ Lu174(n,2n)Lu173(n,2n)Lu172 &Hf177(n,2n)Hf176(n,2n)Hf175(β <sup>+</sup> )Lu175_ (n,2n)Lu174(n,2n)Lu173(n,2n)Lu172 &Hf176(n,3n)Hf174(n,3n)Hf172(β <sup>+</sup> )Lu172 &Hf177(n,4n)Hf174(n,3n)Hf172(β <sup>+</sup> )Lu172 &Hf178(n,3n)Hf176(n,3n)Hf174(n,3n)_ Hf172(β <sup>+</sup> )Lu172 &Hf177(n,3n)Hf175(β <sup>+</sup> )Lu175(n,4n)Lu172 &Hf174(n,3n)Hf172(β <sup>+</sup> )Lu172 &Hf178(n,4n)Hf175(β <sup>+</sup> )Lu175(n,4n)Lu172 &Hf179(n,5n)Hf175(β <sup>+</sup> )Lu175(n,4n)Lu172 &Hf176(n,5n)Hf172(β <sup>+</sup> )Lu172 &Hf180(n,5n)Hf176(n,5n)Hf172(β <sup>+</sup> )Lu172 &Hf177(n,6n)Hf172(β <sup>+</sup> )Lu172 &Hf180(n,6n)Hf175(β <sup>+</sup> )Lu175(n,4n)Lu172				48.4 27.3 7.8				
Hf179n	25.10 d	Hf176(n,γ)Hf177(n,γ)Hf178(n,γ)Hf179n Hf178(n,γ)Hf179n Hf177(n,γ)Hf178(n,γ)Hf179n Hf180(n,2n)Hf179n Hf179(n,n')Hf179n &Hf180(n,2n)Hf179(n,n')Hf179n Hf180(n,d)Lu179(β <sup>-</sup> )Hf179(n,n')Hf179n	42.2 31.3 25.2	0.3 56.7 43.0	89.3 10.7					
Hf181	42.38 d	Hf180(n,γ)Hf181 &Hf178(n,γ)Hf179(n,γ)Hf180(n,γ)Hf181 &Hf177(n,γ)Hf178(n,γ)Hf179(n,γ)_ Hf180(n,γ)Hf181 &Hf179(n,γ)Hf180(n,γ)Hf181	35.9 28.2 18.9 14.9	50.3 18.7 11.2 19.6	95.2 0.1 4.6	99.1	98.8	98.8	99.0	
Hf175	70.0 d	Hf174(n,γ)Hf175 Hf177(n,2n)Hf176(n,2n)Hf175 Hf176(n,2n)Hf175 &Hf178(n,2n)Hf177(n,2n)Hf176(n,2n)Hf175   Hf178(n,3n)Hf176(n,2n)Hf175 Hf177(n,3n)Hf175 Hf178(n,4n)Hf175 &Hf180(n,4n)Hf177(n,3n)Hf175 &Hf179(n,3n)Hf177(n,3n)Hf175 &Hf178(n,2n)Hf177(n,3n)Hf175 &Hf180(n,3n)Hf178(n,4n)Hf175 Hf179(n,4n)Hf176(n,2n)Hf175 Hf179(n,5n)Hf175 Hf180(n,5n)Hf176(n,2n)Hf175 Hf180(n,6n)Hf175	100.0	100.0	100.0	45.7 42.1 10.3 0.8	1.3 6.2 7.1 47.9 13.8 7.8 5.9 3.4 2.0 1.4	0.6 4.4 1.3 13.4 57.5 3.6 0.7 2.0 1.8	3.5  9.2 15.9  14.3	50.3
W185	75.1 d ▶	&Hf180(n,γ)Hf181(β <sup>-</sup> )Ta181(n,γ)Ta182_ (n,γ)Ta183(β <sup>-</sup> )W183(n,γ)W184(n,γ)W185	66.7	59.3	56.2	32.0	30.5	31.1		

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	&Hf178(n,γ)Hf179(n,γ)Hf180(n,γ) Hf181(β <sup>-</sup> )Ta181(n,γ)Ta182(n,γ)Ta183 (β <sup>-</sup> )W183(n,γ)W184(n,γ)W185 &Hf179(n,γ)Hf180(n,γ)Hf181(β <sup>-</sup> )Ta181 (n,γ)Ta182(n,γ)Ta183(β <sup>-</sup> )W183(n,γ) W184(n,γ)W185 &Hf177(n,γ)Hf178(n,γ)Hf179(n,γ)Hf180 (n,γ)Hf181(β <sup>-</sup> )Ta181(n,γ)Ta182(n,γ) Ta183(β <sup>-</sup> )W183(n,γ)W184(n,γ)W185 &Hf180(n,γ)Hf181(n,γ)Hf182(n,γ)Hf183 (β <sup>-</sup> )Ta183(β <sup>-</sup> )W183(n,γ)W184(n,γ)W185 Hf180(n,γ)Hf181(β <sup>-</sup> )Ta181(n,γ)Ta182 (n,γ)Ta183(n,γ)Ta184(β <sup>-</sup> )W184(n,γ)W185 &Hf180(n,γ)Hf181(β <sup>-</sup> )Ta181(n,γ)Ta182 (β <sup>-</sup> )W182(n,γ)W183(n,γ)W184(n,γ)W185	9.3	5.8						
			9.1	16.8	0.6					
			5.4	2.5						
			2.6	2.0	1.5	0.8	0.4	0.4		
			2.3	1.4	1.0					
				0.7	39.8	63.0	64.8	64.7		
Ta182	114.7 d	&Hf180(n,γ)Hf181(β <sup>-</sup> )Ta181(n,γ)Ta182 &Hf178(n,γ)Hf179(n,γ)Hf180(n,γ) Hf181(β <sup>-</sup> )Ta181(n,γ)Ta182 &Hf179(n,γ)Hf180(n,γ)Hf181(β <sup>-</sup> ) Ta181(n,γ)Ta182 &Hf177(n,γ)Hf178(n,γ)Hf179(n,γ) Hf180(n,γ)Hf181(β <sup>-</sup> )Ta181(n,γ)Ta182 &Hf176(n,γ)Hf177(n,γ)Hf178(n,γ)Hf179 (n,γ)Hf180(n,γ)Hf181(β <sup>-</sup> )Ta181(n,γ)Ta182	51.2	57.4	97.5	99.8	99.5	99.6	99.8	
			20.6	13.8						
			13.7	21.0	2.2					
			13.3	7.4						
			0.8							
Lu173	1.336 y	Hf174(n,2n)Hf173(β <sup>+</sup> )Lu173 &Hf176(n,2n)Hf175(β <sup>+</sup> )Lu175(n,2n) Lu174(n,2n)Lu173 Hf177(n,2n)Hf176(n,2n)Hf175(β <sup>+</sup> ) Lu175(n,2n)Lu174(n,2n)Lu173 Hf176(n,2n)Hf175(n,2n)Hf174(n,2n) Hf173(β <sup>+</sup> )Lu173 Hf176(n,2n)Hf175(β <sup>+</sup> )Lu175(n,2n) Lu174m(n,2n)Lu173 Hf177(n,2n)Hf176(n,2n)Hf175(n,2n) Hf174(n,2n)Hf173(β <sup>+</sup> )Lu173 Hf176(n,2n)Hf175(β <sup>+</sup> )Lu175(n,3n)Lu173 Hf177(n,3n)Hf175(β <sup>+</sup> )Lu175(n,3n)Lu173 Hf178(n,4n)Hf175(β <sup>+</sup> )Lu175(n,3n)Lu173 Hf176(n,3n)Hf174(n,2n)Hf173(β <sup>+</sup> )Lu173 Hf177(n,3n)Hf175(n,3n)Hf173(β <sup>+</sup> )Lu173 Hf177(n,4n)Hf174(n,2n)Hf173(β <sup>+</sup> )Lu173 Hf178(n,3n)Hf176(n,2n)Hf175(β <sup>+</sup> ) Lu175(n,3n)Lu173 Hf180(n,4n)Hf177(n,3n)Hf175(β <sup>+</sup> ) Lu175(n,3n)Lu173 Hf176(n,4n)Hf173(β <sup>+</sup> )Lu173 Hf178(n,3n)Hf176(n,4n)Hf173(β <sup>+</sup> )Lu173 Hf179(n,4n)Hf176(n,4n)Hf173(β <sup>+</sup> )Lu173 Hf177(n,2n)Hf176(n,4n)Hf173(β <sup>+</sup> )Lu173 Hf177(n,5n)Hf173(β <sup>+</sup> )Lu173 Hf180(n,5n)Hf176(n,4n)Hf173(β <sup>+</sup> )Lu173 Hf178(n,6n)Hf173(β <sup>+</sup> )Lu173 Hf177(n,2nt)Lu173				48.5	0.7			
							27.5			
							6.6			
							5.7			
							3.1			
							2.4			
							0.5	5.6	0.6	
								42.2	1.7	
								12.2	7.3	
								4.1	0.5	
								3.5		
								2.9	3.2	
								2.5	0.3	
								2.5		
								2.4	31.5	
								2.0	6.7	
								0.4	9.2	
								0.4	3.3	
									10.4	
									32.4	
									9.2	
									1.6	
									38.2	
									3.5	
Hf172	1.870 y	Hf174(n,2n)Hf173(n,2n)Hf172 Hf176(n,2n)Hf175(n,2n)Hf174(n,2n) Hf173(n,2n)Hf172 Hf177(n,2n)Hf176(n,2n)Hf175(n,2n) Hf174(n,2n)Hf173(n,2n)Hf172 Hf176(n,3n)Hf174(n,3n)Hf172 Hf177(n,4n)Hf174(n,3n)Hf172 Hf178(n,3n)Hf176(n,3n)Hf174(n,3n)Hf172				86.3				
							9.3			
							3.8			
								36.9	4.6	
								25.7	40.0	
								16.5	0.5	



Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	&Hf179(n,2n)Hf178(n,n')Hf178n &Hf180(n,2n)Hf179(n,2n)Hf178n &Hf180(n,2n)Hf179(n,2n)Hf178(n,n')Hf178n   Hf180(n,3n)Hf178(n,n')Hf178n Hf180(n,3n)Hf178n				6.1 3.2 1.7 0.7	0.5 0.3	1.7 0.8		
Pt193	50.0 y	Very long pathways of (n,γ), β <sup>-</sup>	100.0	100.0						
Ho166m	1200 y	&Hf174(n,α)Yb171(n,α)Er168(n,α) <sub>-</sub> Dy165(β <sup>-</sup> )Ho165(n,γ)Ho166m Hf174(n,α)Yb171(n,γ)Yb172(n,α) <sub>-</sub> Er169(β <sup>-</sup> )Tm169(n,α)Ho166m Hf174(n,γ)Hf175(n,α)Yb172(n,α) <sub>-</sub> Er169(β <sup>-</sup> )Tm169(n,α)Ho166m Hf174(n,γ)Hf175(β <sup>+</sup> )Lu175(n,α)Tm172 <sub>-</sub> (β <sup>-</sup> )Yb172(n,α)Er169(β <sup>-</sup> )Tm169(n,α) <sub>-</sub> Ho166m Hf174(n,α)Yb171(n,α)Er168(n,γ) <sub>-</sub> Er169(β <sup>-</sup> )Tm169(n,α)Ho166m &Hf174(n,α)Yb170(n,2n)Yb169(β <sup>+</sup> ) <sub>-</sub> Tm169(n,α)Ho166m Hf174(n,2n)Hf173(β <sup>+</sup> )Lu173(n,α) <sub>-</sub> Tm169(n,α)Ho166m &Hf174(n,α)Yb171(n,2n)Yb170(n,2n) <sub>-</sub> Yb169(β <sup>+</sup> )Tm169(n,α)Ho166m Hf174(n,2n)Hf173(β <sup>+</sup> )Lu173(n,α) <sub>-</sub> Tm170(n,2n)Tm169(n,α)Ho166m &Hf176(n,3n)Hf174(n,2nα)Yb169(β <sup>+</sup> ) <sub>-</sub> Tm169(n,α)Ho166m Hf177(n,α)Yb173(n,3n)Yb171(n,3n) <sub>-</sub> Yb169(β <sup>+</sup> )Tm169(n,α)Ho166m Hf177(n,3n)Hf175(β <sup>+</sup> )Lu175(n,α) <sub>-</sub> Tm171(n,2nα)Ho166m &Hf176(n,2nα)Yb171(n,3n)Yb169(β <sup>+</sup> ) <sub>-</sub> Tm169(n,α)Ho166m Hf177(n,3n)Hf175(β <sup>+</sup> )Lu175(n,α) <sub>-</sub> Tm171(n,3n)Tm169(n,α)Ho166m Hf178(n,4n)Hf175(β <sup>+</sup> )Lu175(n,α) <sub>-</sub> Tm171(n,2nα)Ho166m Other similar long pathways	59.4 28.2 5.2 4.0 2.3  22.1 7.4 6.4 1.4  2.0 1.6 1.5 1.3 1.2 0.4 0.9							
Ho163	4570 y	Very long pathways of (n,α), (n,2n), β <sup>-</sup>				100.0	100.0	100.0	100.0	
Gd150	1.8 10 <sup>6</sup> y	Very long pathways of (n,α), (n,2n), β <sup>+</sup>					100.0	100.0	100.0	
Dy154	3.0 10 <sup>6</sup> y	Very long pathways of (n,α), (n,2n), β <sup>+</sup>					100.0	100.0	100.0	
Hf182	9.0 10 <sup>6</sup> y	&Hf180(n,γ)Hf181(n,γ)Hf182 &Hf178(n,γ)Hf179(n,γ)Hf180(n,γ) <sub>-</sub> Hf181(n,γ)Hf182 &Hf179(n,γ)Hf180(n,γ)Hf181(n,γ)Hf182 Hf177(n,γ)Hf178(n,γ)Hf179(n,γ)Hf180 <sub>-</sub> (n,γ)Hf181(n,γ)Hf182	53.1 19.6 13.3 4.7	61.5 11.5 20.6 2.3	97.5 2.4	99.8 99.1	99.3	99.6		
Lu176	4.0 10 <sup>10</sup> y	Hf174(n,γ)Hf175(β <sup>+</sup> )Lu175(n,γ)Lu176 Hf176(n,p)Lu176 Hf177(n,2n)Hf176(n,p)Lu176 Hf177(n,d)Lu176 &Hf178(n,2n)Hf177(n,d)Lu176 &Hf178(n,2n)Hf177(n,2n)Hf176(n,p)Lu176   Hf176(n,2n)Hf175(β <sup>+</sup> )Lu175(n,γ)Lu176 Hf178(n,t)Lu176 Hf178(n,3n)Hf176(n,p)Lu176 &Hf180(n,4n)Hf177(n,d)Lu176 &Hf179(n,3n)Hf177(n,d)Lu176 Hf179(n,nt)Lu176 &Hf180(n,3n)Hf178(n,t)Lu176 Hf180(n,2nt)Lu176	100.0	100.0	100.0	42.5 24.6 19.2 4.6 3.9 2.0 0.5 0.4	6.8 0.7 56.0 2.1 0.9 16.0 4.0	2.5 34.7 0.9 43.1	19.7 35.5 14.8 25.2	

# Hafnium activation characteristics

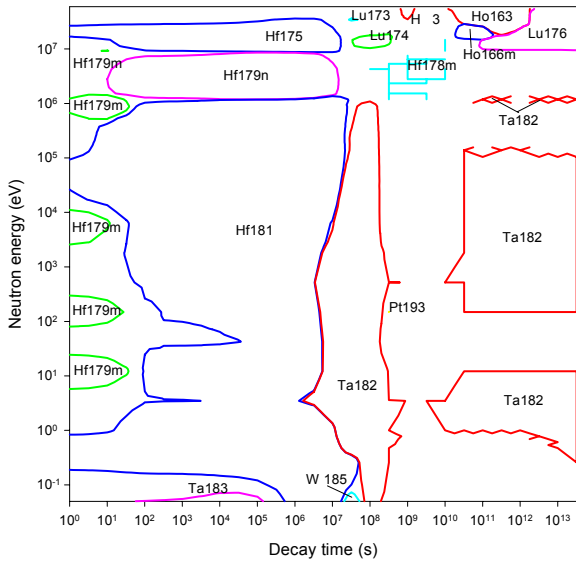


Decay time (years)

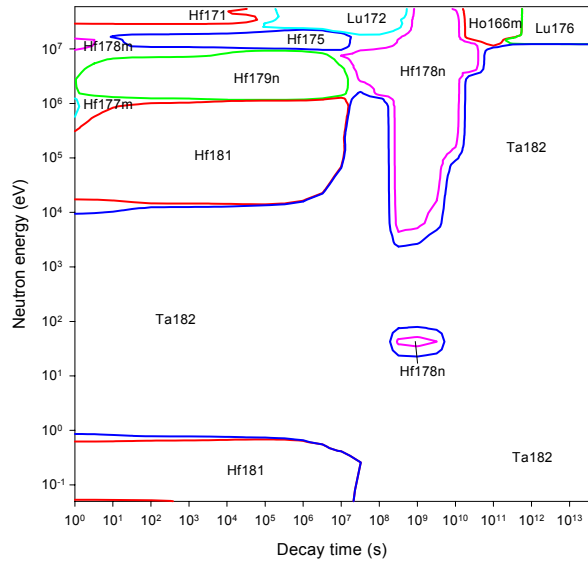
Decay time (years)

# Hafnium importance diagrams & transmutation

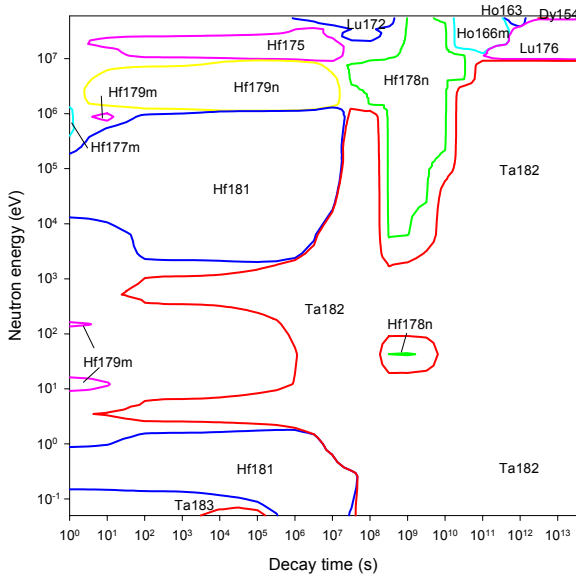
Activity



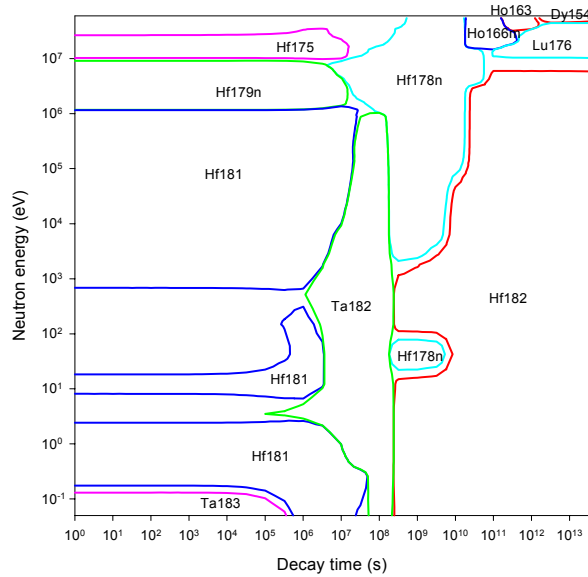
Dose rate



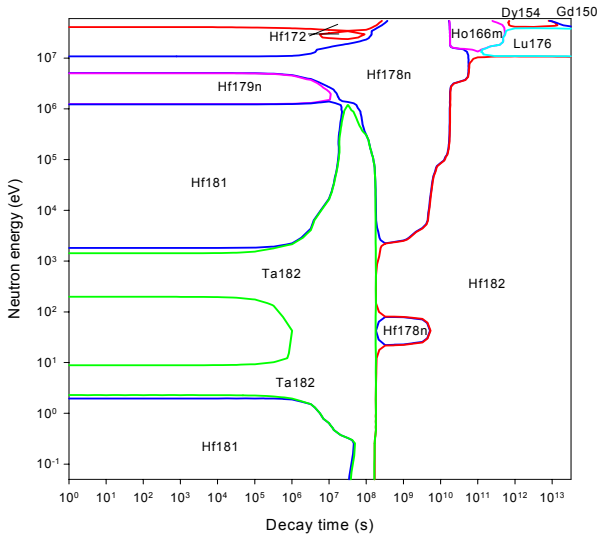
Heat output



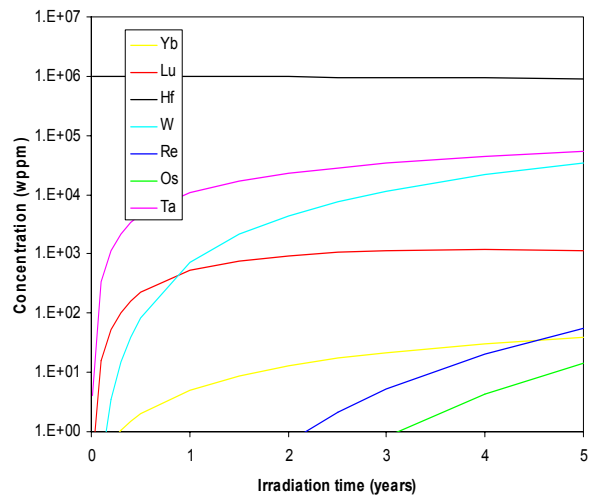
Ingestion dose



Inhalation dose



First wall transmutation



# Tantalum

## General properties

Atomic number	73	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	2	Ta180m	0.012 ( $T_{1/2} = 1.80 \cdot 10^{15}$ y)
Melting point / K	3290	Ta181	99.988
Boiling point / K	5731		
Density / $\text{kgm}^{-3}$	16654		
Thermal conductivity / $\text{Wm}^{-1}\text{K}^{-1}$	57.5		
Electrical resistivity / $\Omega\text{m}$	$1.245 \cdot 10^{-7}$		
Coefficient of thermal expansion / $\text{K}^{-1}$	$6.3 \cdot 10^{-6}$		
Crystal structure	BCC		
Number of stable isotopes	1 (2)		
Mean atomic weight	180.9479		

## Activation properties

Act	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Heat	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Bq $\text{kg}^{-1}$	1.00E16	8.83E15	7.94E15	7.79E14	4.24E7	2.54E6	kW $\text{kg}^{-1}$	1.78E0	1.72E0	1.63E0	1.73E-1	3.28E-9	2.44E-10
Ta182	65.10	73.98	80.48	92.34	1.67	27.67	Ta182	88.18	91.18	94.31	99.61	5.19	69.33
W183m	11.97	0.45	0.30				Ta183	6.67	6.89	4.43			
W181	3.67	4.17	4.55	5.84			W183m	3.35	0.11	0.07			
W185	3.47	3.95	4.24	1.54			Re186	0.47	0.49	0.27		1.40	13.34
Re186	1.47	1.67	0.95		1.89	22.33	W185	0.40	0.41	0.42	0.14		
Ta180	1.25	1.41					Hf181	0.27	0.28	0.28	0.01		
H3					56.70		W181	0.18	0.19	0.19	0.23		
Hf178m					18.02		Hf178n					48.43	
Hf178n					18.02		Hf178m					42.85	
Re186m					1.89	22.33	Hf182					0.94	12.55
Hf182					1.67	27.67	H3					0.67	
							Re186m					0.50	4.78
Dose	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Ing	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{h}^{-1}$	2.07E6	2.07E6	2.02E6	2.26E5	1.85E-3	2.27E-4	Sv $\text{kg}^{-1}$	1.18E7	1.18E7	1.08E7	1.09E6	4.31E-2	5.26E-3
Ta182	99.19	99.23	99.54	99.98	12.09	97.49	Ta182	83.17	83.18	88.42	99.15	2.47	20.04
Ta183	0.53	0.53	0.33				Ta183	12.85	12.84	8.49			
Hf181	0.11	0.11	0.10				Re186	1.88	1.88	1.04		2.79	16.17
Hf178n					54.34		W185	1.30	1.30	1.37	0.48		
Hf178m					33.25		Hf178n					83.37	
Hf182					0.29	2.36	Hf182					4.93	40.07
Re186m					0.02	0.09	Re186m					4.10	23.72
Re186					0.01*	0.06*	H3					2.35	
Inh	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Clear	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{kg}^{-1}$	6.82E7	6.82E7	6.57E7	7.19E6	2.23E0	2.32E-1		6.60E13	6.58E13	6.42E13	7.19E12	2.48E4	7.24E3
Ta182	95.78	95.78	97.23	99.93	0.32	3.03	Ta182	99.01	99.26	99.52	99.93	28.57	97.10
Ta183	3.59	3.58	2.26				Ta183	0.57	0.57	0.36			
Hf181	0.30	0.30	0.29	0.01			W183m	0.26	0.01	0.01			
Re186	0.24	0.24	0.13		0.04	0.27	Hf178n					38.07	
Hf178n					89.09		Hf178m					31.47	
Hf182					9.84	93.77	Hf182					0.70	2.37
Re186m					0.43	2.93	Re186m					0.22	0.52

# Tantalum

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Ta178m	2.361 h	Ta181(n,2n)Ta180m(n,2n)Ta179(n,2n)Ta178m   Ta181(n,2n)Ta180(β <sup>-</sup> )W180(n,2n) W179(β <sup>+</sup> )Ta179(n,2n)Ta178m Ta181(n,2n)Ta180m(n,3n)Ta178m Ta181(n,3n)Ta179(n,2n)Ta178m Ta181(n,4n)Ta178m				76.8 8.8 8.6 2.5 34.1	39.2 26.2 34.1	3.5 2.4 93.9	91.0
Ta180	8.08 h	Ta180m(n,n')Ta180 Ta181(n,2n)Ta180 Ta181(n,2n)Ta180m(n,n')Ta180			100.0	98.9 1.0	99.1	99.5	99.7
Ta176	8.09 h	Ta181(n,2n)Ta180m(n,2n)Ta179(n,3n) Ta177(n,2n)Ta176 &Ta181(n,2n)Ta180(β <sup>-</sup> )W180(n,2n) W179(β <sup>+</sup> )Ta179(n,3n)Ta177(n,2n)Ta176 Ta181(n,3n)Ta179(n,3n)Ta177(n,2n)Ta176   Ta181(n,3n)Ta179(n,4n)Ta176 Ta181(n,2n)Ta180m(n,5n)Ta176 Ta181(n,6n)Ta176				84.1 13.1 2.7	0.4 98.0	91.9 6.5	96.9
Hf171	12.11 h	Ta181(n,α)Lu177(β <sup>-</sup> )Hf177(n,2n) Hf176(n,2n)Hf175(n,2n)Hf174(n,2n) Hf173(n,2n)Hf172(n,2n)Hf171 Ta181(n,2n)Ta180m(n,α)Lu176m(β <sup>-</sup> ) Hf176(n,2n)Hf175(n,2n)Hf174(n,2n) Hf173(n,2n)Hf172(n,2n)Hf171 Ta181(n,2n)Ta180(β <sup>-</sup> )W180(n,α) Hf176(n,2n)Hf175(n,2n)Hf174(n,2n) Hf173(n,2n)Hf172(n,2n)Hf171 Ta181(n,3n)Ta179(n,3n)Ta177(β <sup>+</sup> )Hf177 (n,4n)Hf174(n,3n)Hf172(n,2n)Hf171 Ta181(n,3n)Ta179(β <sup>+</sup> )Hf179(n,4n)Hf176 (n,3n)Hf174(n,3n)Hf172(n,2n)Hf171 Ta181(n,4n)Ta178(β <sup>+</sup> )Hf178(n,3n)Hf176 (n,3n)Hf174(n,3n)Hf172(n,2n)Hf171 Ta181(n,3n)Ta179(β <sup>+</sup> )Hf179(n,3n)Hf177 (n,4n)Hf174(n,3n)Hf172(n,2n)Hf171 Ta181(n,3n)Ta179(n,4n)Ta176(β <sup>+</sup> )Hf176 (n,3n)Hf174(n,3n)Hf172(n,2n)Hf171 Ta181(n,α)Lu177(β <sup>-</sup> )Hf177(n,4n) Hf174(n,3n)Hf172(n,2n)Hf171 Ta181(n,3n)Ta179(β <sup>+</sup> )Hf179(n,4n) Hf176(n,3n)Hf174(n,4n)Hf171 Ta181(n,3n)Ta179(n,3n)Ta177(β <sup>+</sup> ) Hf177(n,4n)Hf174(n,4n)Hf171 Ta181(n,2n)Ta180m(n,4n)Ta177(β <sup>+</sup> ) Hf177(n,4n)Hf174(n,4n)Hf171 Ta181(n,5n)Ta177(β <sup>+</sup> )Hf177(n,4n) Hf174(n,4n)Hf171 Ta181(n,4n)Ta178(β <sup>+</sup> )Hf178(n,5n) Hf174(n,4n)Hf171 Ta181(n,4n)Ta178m(β <sup>+</sup> )Hf178(n,5n) Hf174(n,4n)Hf171 Ta181(n,6n)Ta176(β <sup>+</sup> )Hf176(n,6n)Hf171 Other similar long pathways				4.2 2.4 2.2 21.1 18.7 16.5 6.9 3.1 3.1 2.5 2.4 0.1 46.7 27.0 4.1 76.2 91.2	21.1 18.7 16.5 6.9 3.1 3.1 2.5 2.4 0.1	0.8 1.4 2.3 46.7 27.0 4.1	2.7 1.5 0.2 76.2 19.4
Ir194	19.30 h	Very long pathways of (n,γ), β <sup>-</sup>	100.0	100.0					
Re186	3.775 d	► &Ta181(n,γ)Ta182(n,γ)Ta183(β <sup>-</sup> )W183 (n,γ)W184(n,γ)W185(β <sup>-</sup> )Re185(n,γ)Re186 &Ta181(n,γ)Ta182(n,γ)Ta183(n,γ)Ta184 (β <sup>-</sup> )W184(n,γ)W185(β <sup>-</sup> )Re185(n,γ)Re186	95.0 2.4	91.6 1.2	56.9 0.9	37.4 0.1	30.7	31.2	



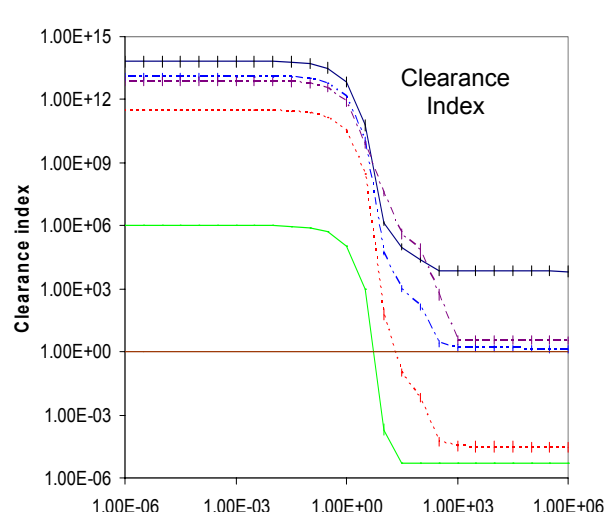
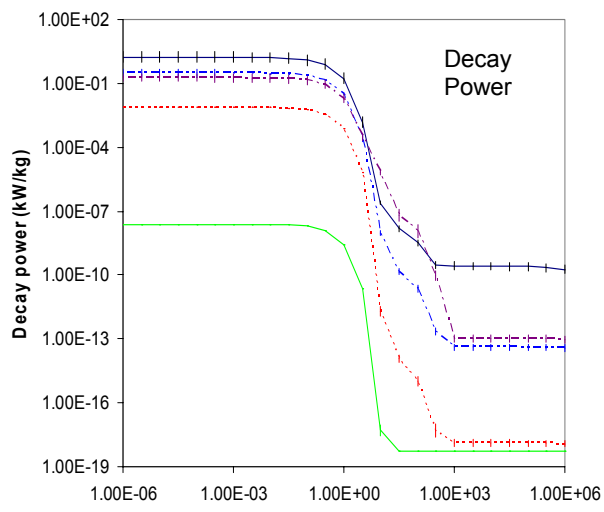
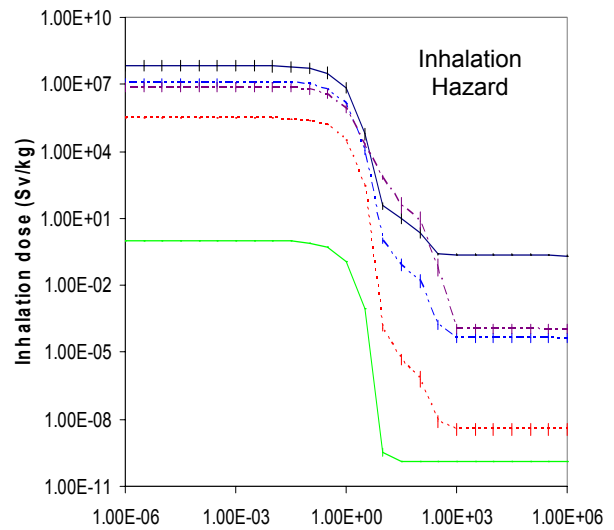
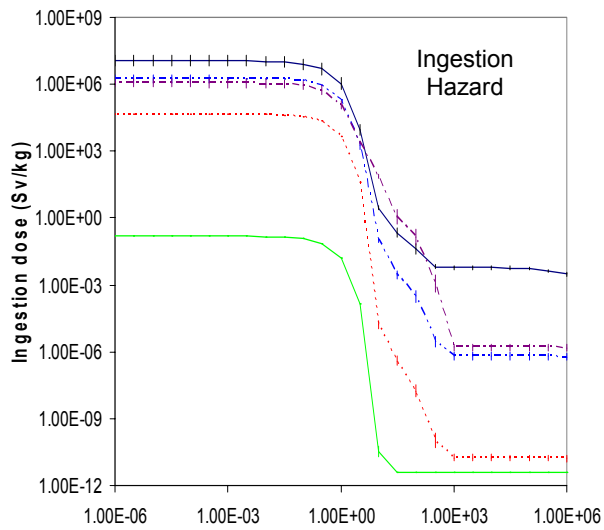
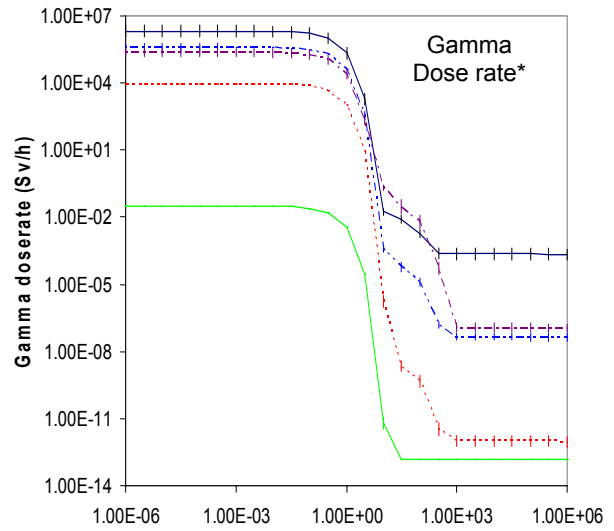
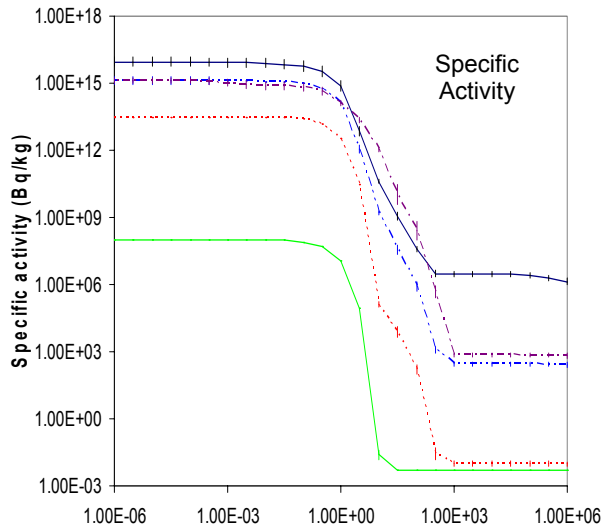
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&Ta181(n, $\gamma$ )Ta182( $\beta^-$ )W182(n, $\gamma$ )W183_ (n, $\gamma$ )W184(n, $\gamma$ )W185( $\beta^-$ )Re185(n, $\gamma$ )Re186	0.1	1.4	42.0	62.5	69.3	68.8	
Ta183	5.09 d	&Ta181(n, $\gamma$ )Ta182(n, $\gamma$ )Ta183	99.9	99.9	99.9	99.2	98.3	98.7	99.3
Lu172	6.70 d	Ta181(n,3n)Ta179(n,3n)Ta177( $\beta^+$ )Hf177_ (n,3n)Hf175( $\beta^+$ )Lu175(n,4n)Lu172 &Ta181(n,4n)Ta178( $\beta^+$ )Hf178(n,4n)_ Hf175( $\beta^+$ )Lu175(n,4n)Lu172 Ta181(n,4n)Ta178( $\beta^+$ )Hf178(n,4n)Hf175_ (n,4n)Hf172( $\beta^+$ )Lu172m(IT)Lu172 &Ta181(n,5n)Ta177( $\beta^+$ )Hf177(n,3n)_ Hf175( $\beta^+$ )Lu175(n,4n)Lu172 &Ta181(n,3n)Ta179( $\beta^+$ )Hf179(n,5n)_ Hf175( $\beta^+$ )Lu175(n,4n)Lu172 Ta181(n,5n)Ta177( $\beta^+$ )Hf177(n,4n)Hf174_ (n,3n)Hf172( $\beta^+$ )Lu172m(IT)Lu172 Ta181(n,6n)Ta176( $\beta^+$ )Hf176(n,5n)_ Hf172( $\beta^+$ )Lu172m(IT)Lu172 Ta181(n,5n)Ta177( $\beta^+$ )Hf177(n,6n)_ Hf172( $\beta^+$ )Lu172m(IT)Lu172 &Ta181(n,6n)Ta176( $\beta^+$ )Hf176(n,2nt)Lu172 Other similar long pathways					7.1	0.1	
							4.6	49.9	0.1
							0.3	3.1	
								5.1	0.4
								3.7	0.2
								3.6	
									43.2
									30.3
									5.9
						100.0	88.0	34.5	19.9
Hf175	70.0 d	&Ta181(n,2n)Ta180( $\beta^+$ )Hf180(n,2n)_ Hf179(n,2n)Hf178(n,2n)Hf177(n,2n)_ Hf176(n,2n)Hf175 &Ta181(n,2n)Ta180( $\beta^+$ )Hf180(n,3n)Hf178_ (n,2n)Hf177(n,2n)Hf176(n,2n)Hf175 Ta181(n,2n)Ta180m(n,2n)Ta179(n,2n)_ Ta178( $\beta^+$ )Hf178(n,2n)Hf177(n,2n)_ Hf176(n,2n)Hf175 &Ta181(n,2n)Ta180( $\beta^+$ )Hf180(n,2n)Hf179_ (n,3n)Hf177(n,2n)Hf176(n,2n)Hf175 Ta181(n,2n)Ta180m(n,2n)Ta179(n,2n)_ Ta178m( $\beta^+$ )Hf178(n,2n)Hf177(n,2n)_ Hf176(n,2n)Hf175 &Ta181(n,2n)Ta180m(n,2n)Ta179( $\beta^+$ )_ Hf179(n,2n)Hf178(n,2n)Hf177(n,2n)_ Hf176(n,2n)Hf175 Ta181(n,2n)Ta180m(n,2n)Ta179( $\beta^+$ )Hf179_ (n,3n)Hf177(n,2n)Hf176(n,2n)Hf175 Ta181(n,2n)Ta180m(n, $\alpha$ )Lu177( $\beta^-$ )_ Hf177(n,2n)Hf176(n,2n)Hf175 Ta181(n,3n)Ta179(n,3n)Ta177( $\beta^+$ )_ Hf177(n,3n)Hf175 &Ta181(n,3n)Ta179( $\beta^+$ )Hf179(n,3n)_ Hf177(n,3n)Hf175 Ta181(n,4n)Ta178( $\beta^+$ )Hf178(n,4n)Hf175 Ta181(n,3n)Ta179( $\beta^+$ )Hf179(n,4n)_ Hf176(n,2n)Hf175 Ta181(n, $\alpha$ )Lu177( $\beta^-$ )Hf177(n,3n)Hf175 Ta181(n,4n)Ta178m( $\beta^+$ )Hf178(n,4n)Hf175 Ta181(n,5n)Ta177( $\beta^+$ )Hf177(n,3n)Hf175 Ta181(n,3n)Ta179( $\beta^+$ )Hf179(n,5n)Hf175 Ta181(n,3n)Ta179(n,5n)Ta175( $\beta^+$ )Hf175 Ta181(n,t)Hf179(n,5n)Hf175 Ta181(n,6n)Ta176( $\beta^+$ )Hf176(n,2n)Hf175 Ta181(n,2n)Ta180( $\beta^+$ )Hf180(n,6n)Hf175 Ta181(n,2n)Ta180m(n,6n)Ta175( $\beta^+$ )Hf175 Ta181(n,7n)Ta175( $\beta^+$ )Hf175 &Ta181(n,d)Hf180(n,6n)Hf175 Other similar long pathways				13.1			
							12.0		
							10.1		
							9.6		
							6.5		
							5.4		
							3.9		
							3.4		
								36.2	
								19.9	
								12.1	65.4
								4.8	0.5
								3.7	
								1.2	10.0
									6.6
									17.4
									6.1
									8.8
									1.2
									10.5
									1.1
									3.5
									19.8
									6.9
									6.3
									5.4
									5.3
						36.0	22.1	9.1	10.3
Ir192	73.822 d	Very long pathways of (n, $\gamma$ ), $\beta^-$	100.0	100.0	100.0				

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
W185	75.10 d	&Ta181(n,γ)Ta182(n,γ)Ta183(β <sup>-</sup> )W183_ (n,γ)W184(n,γ)W185	94.6	90.3	50.3	26.5	24.8	25.3	26.1
		&Ta181(n,γ)Ta182(n,γ)Ta183(n,γ)_ Ta184(β <sup>-</sup> )W184(n,γ)W185	2.1	1.0	0.6	0.1			
		&Ta181(n,γ)Ta182(β <sup>-</sup> )W182(n,γ)W183_ (n,γ)W184(n,γ)W185	0.2	1.7	48.9	73.0	71.8	71.7	71.4
Ta182	114.7 d	&Ta181(n,γ)Ta182	99.9	99.9	99.9	99.7	98.5	98.7	98.7
Ta179	1.61 y	Ta181(n,2n)Ta180m(n,2n)Ta179				84.1			
		&Ta181(n,2n)Ta180(β <sup>-</sup> )W180(n,2n)_ W179(β <sup>+</sup> )Ta179 Ta181(n,3n)Ta179				13.1			
Hf172	1.87 y	Ta181(n,2n)Ta180m(n,α)Lu177(β <sup>-</sup> )_				4.9			
		Hf177(n,2n)Hf176(n,2n)Hf175(n,2n)_							
		Hf174(n,2n)Hf173(n,2n)Hf172							
		Ta181(n,nα)Lu177(β <sup>-</sup> )Hf177(n,2n)_				4.2			
		Hf176(n,2n)Hf175(n,2n)Hf174(n,2n)_							
		Hf173(n,2n)Hf172							
		Ta181(n,3n)Ta179(n,3n)Ta177(β <sup>+</sup> )_					23.8	0.7	
		Hf177(n,4n)Hf174(n,3n)Hf172							
		Ta181(n,3n)Ta179(β <sup>+</sup> )Hf179(n,4n)_					21.1	0.3	
		Hf176(n,3n)Hf174(n,3n)Hf172							
		Ta181(n,4n)Ta178(β <sup>+</sup> )Hf178(n,3n)_					18.6	0.6	
		Hf176(n,3n)Hf174(n,3n)Hf172							
		Ta181(n,3n)Ta179(β <sup>+</sup> )Hf179(n,3n)_					7.7	0.2	
		Hf177(n,4n)Hf174(n,3n)Hf172							
		Ta181(n,nα)Lu177(β <sup>-</sup> )Hf177(n,4n)_					3.5	0.9	
		Hf174(n,3n)Hf172							
		Ta181(n,3n)Ta179(n,4n)Ta176(β <sup>+</sup> )_					3.5	0.7	
		Hf176(n,3n)Hf174(n,3n)Hf172							
		Ta181(n,4n)Ta178(β <sup>+</sup> )Hf178(n,4n)_					0.6	23.1	
		Hf175(n,4n)Hf172							
Ta181(n,5n)Ta177(β <sup>+</sup> )Hf177(n,4n)_						26.5			
Hf174(n,3n)Hf172									
Ta181(n,4n)Ta178(β <sup>+</sup> )Hf178(n,5n)_							15.3		
Hf174(n,3n)Hf172									
Ta181(n,4n)Ta178m(β <sup>+</sup> )Hf178(n,4n)_							3.5		
Hf175(n,4n)Hf172									
Ta181(n,6n)Ta176(β <sup>+</sup> )Hf176(n,5n)Hf172								52.1	
Ta181(n,5n)Ta177(β <sup>+</sup> )Hf177(n,6n)Hf172								36.9	
Ta181(n,2nt)Hf177(n,6n)Hf172								3.2	
Other similar long pathways						90.9	21.2	28.2	7.8
Os194	5.989 y	Very long pathways of (n,γ), β <sup>-</sup>	100.0	100.0					
H3	12.33 y	Ta181(n,X)H3				68.0	78.6	82.0	83.5
		Ta181(n,2n)Ta180m(n,X)H3				28.3	2.3	1.6	
		Ta181(n,2n)Ta180m(n,2n)Ta179(n,X)H3				1.2			
		Ta181(n,2n)Ta180(β <sup>+</sup> )Hf180(n,X)H3				0.6	0.9	0.8	
		Ta181(n,3n)Ta179(n,X)H3					8.3	2.3	1.1
		Ta181(n,3n)Ta179(β <sup>+</sup> )Hf179(n,X)H3					5.5	1.6	
		Ta181(n,4n)Ta178(β <sup>+</sup> )Hf178(n,X)H3					1.1	5.3	1.1
		Ta181(n,5n)Ta177(β <sup>+</sup> )Hf177(n,X)H3						2.0	4.6
		Ta181(n,6n)Ta176(β <sup>+</sup> )Hf176(n,X)H3							3.5
Hf178n	31.0 y	&Ta180m(n,α)Lu177(β <sup>-</sup> )Hf177(n,γ)Hf178n	94.7	99.4	99.6				
		&Ta181(n,2n)Ta180(β <sup>+</sup> )Hf180(n,2n)_				32.8			
		Hf179(n,2n)Hf178n							
		Ta181(n,2n)Ta180m(n,2n)Ta179(β <sup>+</sup> )_				16.3			
		Hf179(n,2n)Hf178n							
		&Ta181(n,2n)Ta180(β <sup>+</sup> )Hf180(n,2n)_				13.1			
		Hf179(n,2n)Hf178(n,n')Hf178n							
Ta181(n,2n)Ta180m(n,2n)Ta179(n,2n)_				8.1					
Ta178(β <sup>+</sup> )Hf178(n,n')Hf178n									
&Ta181(n,2n)Ta180(β <sup>+</sup> )Hf180(n,3n)_				7.6	1.7				
► Hf178(n,n')Hf178n									

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	&Ta181(n,2n)Ta180m(n,2n)Ta179(β <sup>+</sup> ) Hf179(n,2n)Hf178(n,n')Hf178n Ta181(n,2n)Ta180m(n,2n)Ta179(n,2n) Ta178m(β <sup>+</sup> )Hf178(n,n')Hf178n &Ta181(n,2n)Ta180(β <sup>-</sup> )W180(n,2n) W179(β <sup>+</sup> )Ta179(β <sup>+</sup> )Hf179(n,2n)Hf178n Ta181(n,3n)Ta179(β <sup>+</sup> )Hf179(n,2n)Hf178n Ta181(n,2n)Ta180m(n,3n)Ta178m(β <sup>+</sup> ) Hf178(n,n')Hf178n Ta181(n,3n)Ta179(n,2n)Ta178(β <sup>+</sup> ) Hf178(n,n')Hf178n &Ta181(n,3n)Ta179(β <sup>+</sup> )Hf179(n,2n) Hf178(n,n')Hf178n Ta181(n,3n)Ta179(n,2n)Ta178m(β <sup>+</sup> ) Hf178(n,n')Hf178n Ta181(n,2n)Ta180m(n,3n)Ta178(β <sup>+</sup> ) Hf178(n,n')Hf178n Ta181(n,4n)Ta178(β <sup>+</sup> )Hf178(n,n')Hf178n Ta181(n,4n)Ta178m(β <sup>+</sup> )Hf178(n,n')Hf178n Ta181(n,2n)Ta180(β <sup>+</sup> )Hf180(n,3n)Hf178n &Ta181(n,nt)Hf178(n,n')Hf178n Ta181(n,t)Hf179(n,2n)Hf178n Ta181(n,nt)Hf178n				5.5				
						5.2				
						2.5				
						1.3	25.4	2.6	3.8	
						0.9	1.9			
						0.6	3.1			
						0.6	2.8			
						0.4	2.0			
						0.1	3.0			
							48.3	80.0	54.9	
							5.0	12.2	8.7	
							1.0			
							0.5	1.5	17.0	
							0.4	0.6	1.9	
							0.2	0.7	9.9	
Pt193	50.0 y	Very long pathways of (n,γ), β <sup>-</sup>	100.0	100.0	100.0					
Ir192n	241.0 y	Very long pathways of (n,γ), β <sup>-</sup>	100.0	100.0	100.0					
Ho166m	1200 y	Very long pathways of (n,α), (n,2n), β <sup>-</sup>				100.0	100.0	100.0	100.0	
Ho163	4570 y	Very long pathways of (n,α), (n,2n), β <sup>-</sup>				100.0	100.0	100.0	100.0	
Re186m	2.0 10 <sup>3</sup> y	&Ta181(n,γ)Ta182(n,γ)Ta183(β <sup>-</sup> )W183 (n,γ)W184(n,γ)W185(β <sup>-</sup> )Re185(n,γ) Re186m &Ta181(n,γ)Ta182(n,γ)Ta183(n,γ) Ta184(β <sup>-</sup> )W184(n,γ)W185(β <sup>-</sup> )Re185 (n,γ)Re186m &Ta181(n,γ)Ta182(β <sup>-</sup> )W182(n,γ)W183 (n,γ)W184(n,γ)W185(β <sup>-</sup> )Re185(n,γ) Re186m	93.8	93.0	60.6	36.3	34.5	35.4	36.7	
			3.5	1.3	1.3	0.2	0.1	0.1	0.1	
			0.1	1.3	36.7	61.7	63.7	63.5	63.2	
Gd150	1.8 10 <sup>6</sup> y	Very long pathways of (n,α), (n,2n), β <sup>-</sup>					100.0	100.0	100.0	
Dy154	3.0 10 <sup>6</sup> y	Very long pathways of (n,α), (n,2n), β <sup>-</sup>					100.0	100.0	100.0	
Hf182	9.0 10 <sup>6</sup> y	&Ta181(n,γ)Ta182(n,γ)Ta183(β <sup>-</sup> )W183 (n,α)Hf180(n,γ)Hf181(n,γ)Hf182 Ta181(n,γ)Ta182(n,α)Lu179(β <sup>-</sup> )Hf179 (n,γ)Hf180(n,γ)Hf181(n,γ)Hf182 &Ta181(n,α)Lu178(β <sup>-</sup> )Hf178(n,γ) Hf179(n,γ)Hf180(n,γ)Hf181(n,γ)Hf182 &Ta181(n,α)Lu178m(β <sup>-</sup> )Hf178(n,γ) Hf179(n,γ)Hf180(n,γ)Hf181(n,γ)Hf182 Ta181(n,γ)Ta182(n,γ)Ta183(β <sup>-</sup> )W183 (n,γ)W184(n,α)Hf181(n,γ)Hf182 &Ta181(n,γ)Ta182(β <sup>-</sup> )W182(n,γ)W183 (n,α)Hf180(n,γ)Hf181(n,γ)Hf182 &Ta181(n,γ)Ta182(n,γ)Ta183(β <sup>-</sup> )W183 (n,γ)W184(n,γ)W185(n,α)Hf182 &Ta181(n,γ)Ta182(β <sup>-</sup> )W182(n,γ)W183 (n,γ)W184(n,γ)W185(n,α)Hf182 &Ta181(n,γ)Ta182(β <sup>-</sup> )W182(n,α) Hf179(n,γ)Hf180(n,γ)Hf181(n,γ)Hf182 &Ta181(n,γ)Ta182(β <sup>-</sup> )W182(n,γ)W183 (n,γ)W184(n,α)Hf181(n,γ)Hf182 &Ta181(n,γ)Ta182(n,p)Hf182 &Ta181(n,p)Hf181(n,γ)Hf182	87.2	78.5	38.3					
			6.5	3.3	7.3					
			3.2	1.3	0.1					
			1.6	0.6						
			0.2	1.5	1.3					
			0.1	1.2	29.1					
				10.7	10.1					
				0.1	7.6					
					3.7					
					1.0					
						88.0	88.6	88.1	87.7	
						10.6	11.0	11.6	12.1	

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Lu176	4.0 10 <sup>10</sup> y	Ta181(n,α)Lu178(β <sup>-</sup> )Hf178(n,α)Yb175 <sub>-</sub> (β <sup>-</sup> )Lu175(n,γ)Lu176	65.9	66.0	85.0				
		Ta181(n,α)Lu178m(β <sup>-</sup> )Hf178(n,α) <sub>-</sub> Yb175(β <sup>-</sup> )Lu175(n,γ)Lu176 Ta181(n,2n)Ta180m(n,nα)Lu176 Ta181(n,2n)Ta180m(n,2n)Ta179(n,α)Lu176   Ta181(n,2n)Ta180(β <sup>-</sup> )W180(n,2n) <sub>-</sub> W179(β <sup>+</sup> )Ta179(n,α)Lu176 Ta181(n,3n)Ta179(n,α)Lu176 Ta181(n,2nα)Lu176 Ta181(n,3n)Ta179(n,3n)Ta177(β <sup>+</sup> ) <sub>-</sub> Hf177(n,d)Lu176 Ta181(n,4n)Ta178(β <sup>+</sup> )Hf178(n,t)Lu176 Ta181(n,3n)Ta179(β <sup>+</sup> )Hf179(n,3n) <sub>-</sub> Hf177(n,d)Lu176 Ta181(n,3n)Ta179(β <sup>+</sup> )Hf179(n,nt)Lu176 Ta181(n,nα)Lu177(β <sup>-</sup> )Hf177(n,d)Lu176 Ta181(n,3n)Ta179(β <sup>+</sup> )Hf179(n,4n) <sub>-</sub> Hf176(n,p)Lu176 Ta181(n,5n)Ta177(β <sup>+</sup> )Hf177(n,d)Lu176 Ta181(n,4n)Ta178(β <sup>+</sup> )Hf178(n,3n) <sub>-</sub> Hf176(n,p)Lu176 Ta181(n,4n)Ta178m(β <sup>+</sup> )Hf178(n,t)Lu176   Ta181(n,6n)Ta176(β <sup>+</sup> )Hf176(n,p)Lu176   Ta181(n,t)Hf179(n,nt)Lu176   Ta181(n,2n)Ta180(β <sup>+</sup> )Hf180(n,2nt)Lu176   Ta181(n,nt)Hf178(n,t)Lu176   Ta181(n,2nt)Hf177(n,d)Lu176   Ta181(n,d)Hf180(n,2nt)Lu176	34.0	34.0	14.7	49.3 39.5 4.5 2.2	9.1 11.6 38.2 13.6 5.7 5.3 4.9 1.8 1.2	0.6 59.4 22.2 1.8 7.8 1.0 0.6	48.2 7.9 4.3 22.7 3.4 2.2 2.1 2.1 2.0 1.2
Ta180m	1.8 10 <sup>15</sup> y	&Ta181(n,γ)Ta182(n,γ)Ta183(β <sup>-</sup> )W183 <sub>-</sub> (n,α)Hf180m(β <sup>-</sup> )Ta180m Ta181(n,γ)Ta182(n,α)Lu179(β <sup>-</sup> )Hf179 <sub>-</sub> (n,γ)Hf180m(β <sup>-</sup> )Ta180m &Ta181(n,α)Lu178(β <sup>-</sup> )Hf178(n,γ) <sub>-</sub> Hf179(n,γ)Hf180m(β <sup>-</sup> )Ta180m &Ta181(n,α)Lu178m(β <sup>-</sup> )Hf178(n,γ) <sub>-</sub> Hf179(n,γ)Hf180m(β <sup>-</sup> )Ta180m Ta181(n,2n)Ta180m Nuclide also present in starting material	34.9 29.1 23.4 12.0 0.6	100.0	100.0	99.9 0.1	99.6 0.4	99.4 0.6	99.2 0.8
W183	1.1 10 <sup>17</sup> y	&Ta181(n,γ)Ta182(n,γ)Ta183(β <sup>-</sup> )W183 &Ta181(n,γ)Ta182(β <sup>-</sup> )W182(n,γ)W183	99.3 0.3	84.4 10.5	39.2 60.5	18.7 81.0	17.7 81.7	18.1 81.3	18.7 80.8

# Tantalum activation characteristics

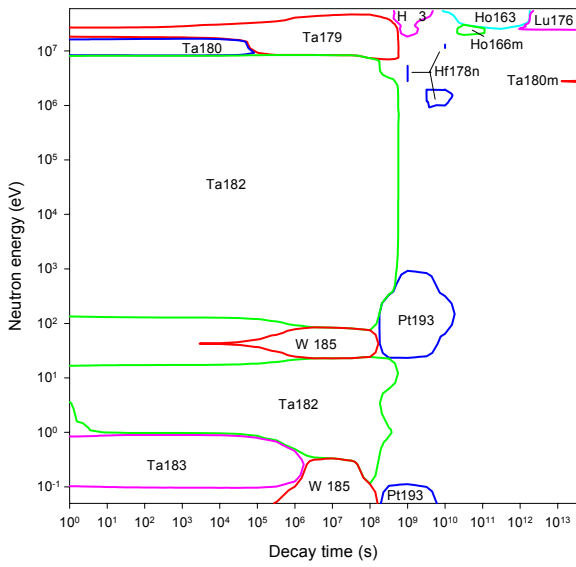


Decay time (years)

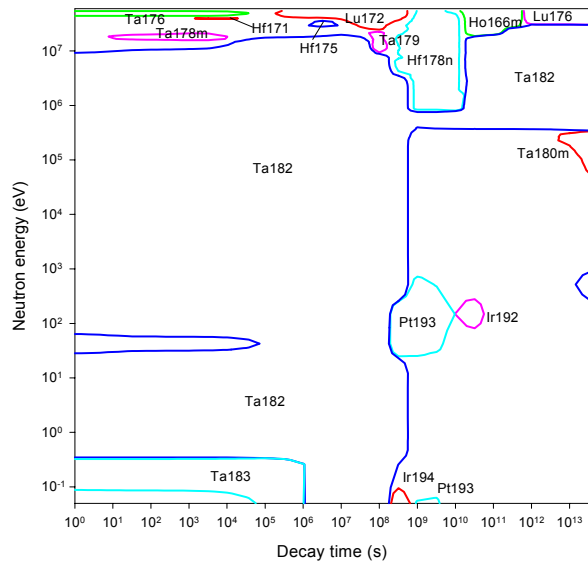
Decay time (years)

# Tantalum importance diagrams & transmutation

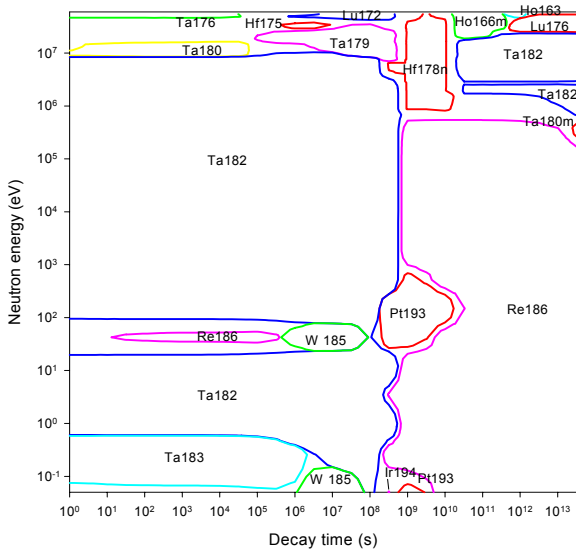
Activity



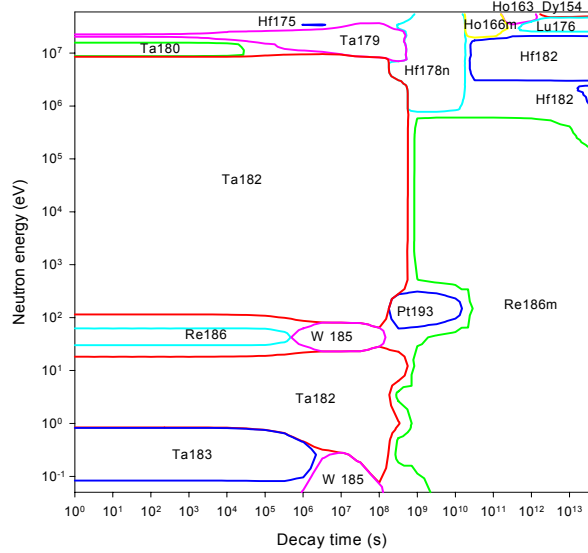
Dose rate



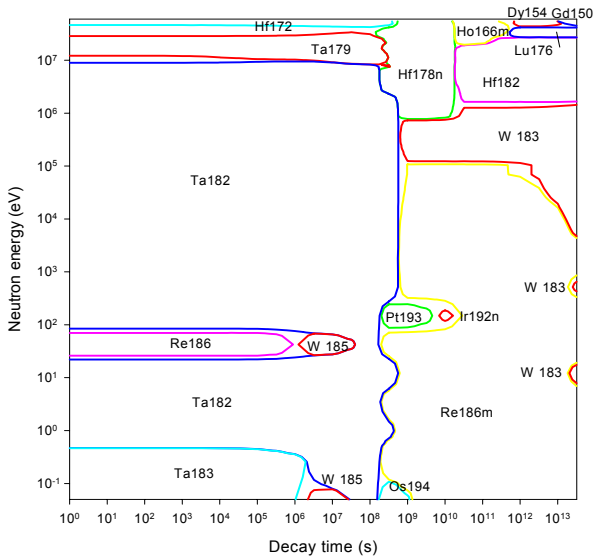
Heat output



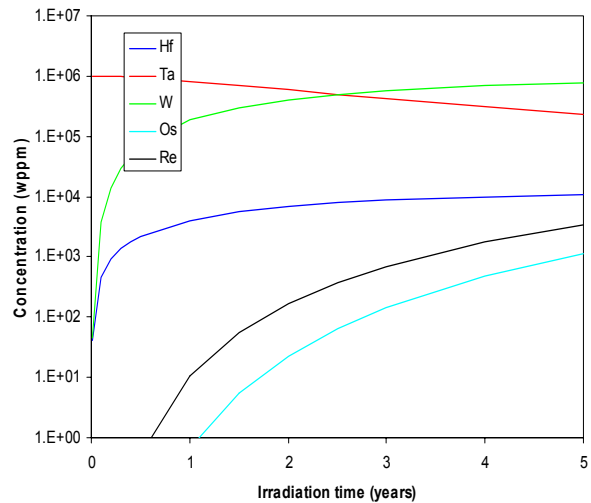
Ingestion dose



Inhalation dose



First wall transmutation



# Tungsten

## General properties

Atomic number	74	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	1.25	W180	0.12
Melting point / K	3695	W182	26.50
Boiling point / K	5828	W183	14.31 ( $T_{1/2} = 1.10 \cdot 10^{17}$ y)
Density / $\text{kgm}^{-3}$	$1.93 \cdot 10^4$	W184	30.64 ( $T_{1/2} = 4.00 \cdot 10^{17}$ y)
Thermal conductivity / $\text{Wm}^{-1}\text{K}^{-1}$	174	W186	28.43 ( $T_{1/2} = 5.90 \cdot 10^{17}$ y)
Electrical resistivity / $\Omega\text{m}$	$5.65 \cdot 10^{-8}$		
Coefficient of thermal expansion / $\text{K}^{-1}$	$4.5 \cdot 10^{-6}$		
Crystal structure	BCC		
Number of stable isotopes	2 (5)		
Mean atomic weight	183.84		

## Activation properties

Act	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Heat	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Bq $\text{kg}^{-1}$	1.33E16	1.08E16	4.75E15	1.36E14	2.64E9	1.43E8	kW $\text{kg}^{-1}$	9.37E-1	8.36E-1	1.92E-1	5.41E-3	2.58E-8	5.57E-9
W185	23.55	29.05	64.00	79.30			Re188	36.91	41.24	5.36	0.33		
Re188	19.31	23.73	1.61	0.10			W187	27.20	30.42	10.40			
Re186	16.94	20.88	24.35		3.83	49.94	Re186	13.82	15.48	34.51		22.43	73.58
W187	16.04	19.74	3.53				W185	6.82	7.64	32.18	40.56		
W183m	8.42		0.01				W183m	5.94		0.01			
Os189m	1.00	1.22					Ta182	2.52	2.83	12.05	48.07	0.01	0.03
W181	0.78	0.97	2.16	9.47			Re184	0.47	0.53	2.19	3.64		
Ta182	0.74	0.91	2.03	7.95		0.01	Os185	0.23	0.25	1.07	2.63		
Re188m	0.52	0.53					Ir192	0.11	0.12	0.52	0.61	3.50	
Re184	0.22	0.27	0.58	0.94			W181	0.10	0.11	0.46	2.06		
Os191	0.16	0.19	0.38				Re184m	0.05	0.06	0.26	2.04		
Os185	0.13	0.17	0.37	0.89			Pt193					62.30	
Ir192	0.05	0.06	0.13	0.15	0.21		Re186m					8.04	26.38
Pt193				0.01	91.44		Hf178n					1.65	
Re186m					3.83	49.94	Hf178m					1.46	
Dose	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Ing	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{h}^{-1}$	2.02E5	2.00E5	5.01E4	3.84E3	1.32E-3	5.69E-5	Sv $\text{kg}^{-1}$	1.00E7	9.98E6	3.53E6	6.93E4	4.68E-1	2.65E-1
W187	70.90	71.31	22.25				Re188	36.08	36.03	3.04	0.27		
Ta182	15.42	15.55	60.48	88.09	0.17	4.92	Re186	33.92	33.96	49.20		32.39	40.54
Re188	8.52*	8.56*	1.02*	0.02			W185	13.83	13.86	37.93	68.53		
Re184	2.50	2.52	9.47	5.76			W187	13.49	13.48	3.00			
Os185	1.13	1.14	4.41	3.95			Ta182	1.48	1.48	4.10	23.42		
Re186	0.25*	0.25*	0.51*		1.72*	35.84*	Re184	0.29	0.29	0.77	1.85		
Ir192	0.24	0.24	0.93	0.40	32.27		Os191	0.12	0.12	0.29			
Re184m	0.15	0.15	0.59	1.71			Re184m	0.09	0.09	0.25	2.81		
Ta183	0.08	0.08	0.20				Os185	0.09	0.09	0.25	0.89		
Pt193					30.41		Ir192	0.09	0.09	0.24	0.41	1.63	
Hf178n					20.21		W181	0.08	0.08	0.22	1.41		
Hf178m					12.35		Re186m					47.51	59.45
Re186m					2.83	59.13	Pt193					15.97	
Ir192n					0.04		Hf178n					2.06	

<b>Inh</b>	<b>0</b>	<b>10<sup>-5</sup> y</b>	<b>10<sup>-2</sup> y</b>	<b>1 y</b>	<b>100 y</b>	<b>10<sup>5</sup> y</b>	<b>Clear</b>	<b>0</b>	<b>10<sup>-5</sup> y</b>	<b>10<sup>-2</sup> y</b>	<b>1 y</b>	<b>100 y</b>	<b>10<sup>5</sup> y</b>
Sv kg <sup>-1</sup>	5.90E6	5.89E6	2.90E6	1.36E5	2.16E0	9.39E-1		1.54E12	1.32E12	1.05E12	1.13E11	1.01E5	5.07E3
Re186	42.13	42.17	43.93		5.14	8.38	Ta182	64.02	74.83	91.59	96.01	0.07	1.37
Re188	23.57	23.53	1.43	0.05			W187	13.93	16.24	1.59			
Ta182	16.67	16.70	33.25	79.63		0.01	W183m	10.44		0.01			
W187	6.89	6.89	1.10				Re184	1.71	2.00	2.36	1.03		
W185	6.39	6.40	12.60	9.53			Re188	1.68	1.95	0.07			
Re184	0.93	0.93	1.79	1.79			Os185	1.17	1.36	1.66	1.07		
Ir192	0.69	0.69	1.36	0.97	1.67		W181	0.68	0.80	0.97	1.14		
Os191	0.67	0.67	1.19				Ir192	0.40	0.47	0.57	0.18	5.43	
Re184m	0.64	0.65	1.29	6.20			Ta183	0.38	0.44	0.33			
Ta183	0.64	0.64	0.79				W185	0.20	0.24	0.29	0.10		
Os185	0.49	0.49	0.96	1.42			Re184m	0.15	0.18	0.22	0.46		
W181	0.05	0.05	0.10	0.26			Re186	0.15	0.17	0.11		0.10	1.41
Os191m	0.04	0.04					Pt193					82.73	
Re186m					56.12	91.39	Re186m					6.71	94.01
Hf178n					24.69		Hf178n					2.52	
Ir192n					9.84		Hf178m					2.08	
Pt193					2.34		Ir192n					0.11	



# Tungsten

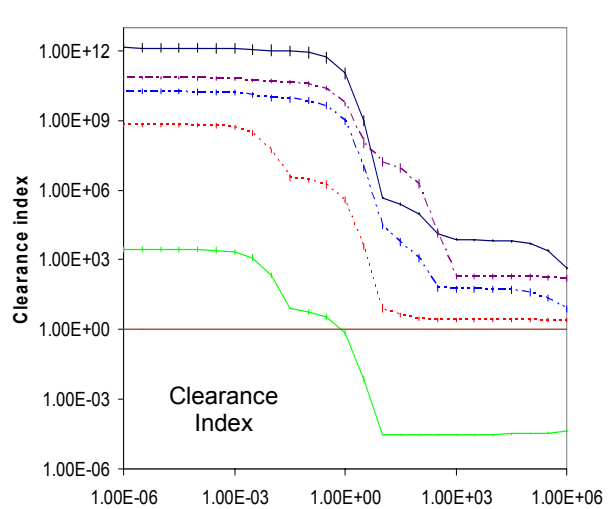
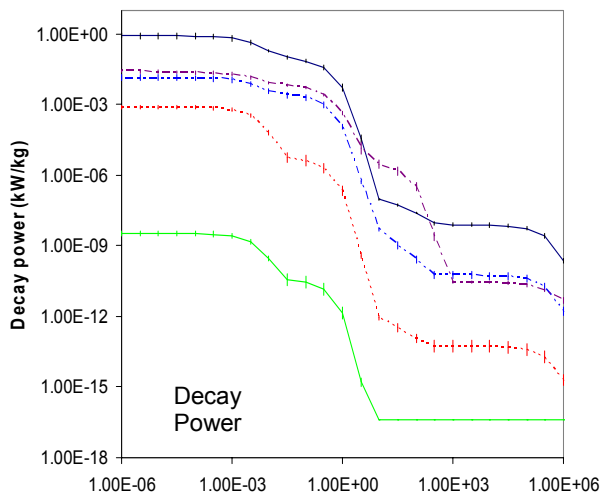
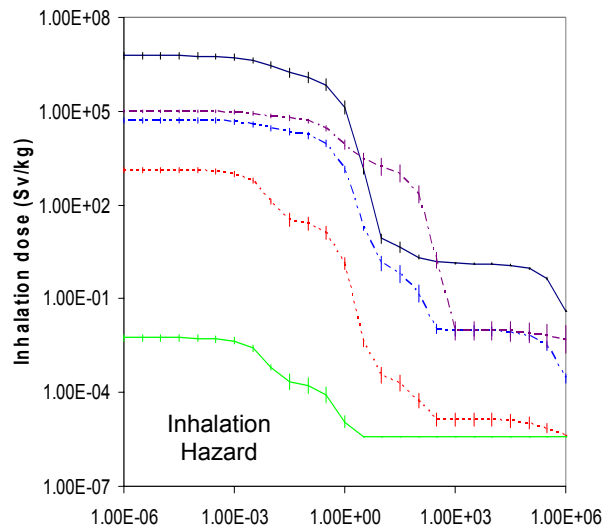
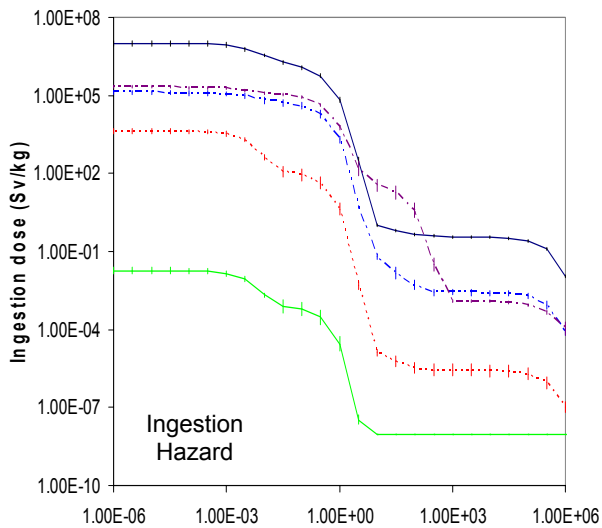
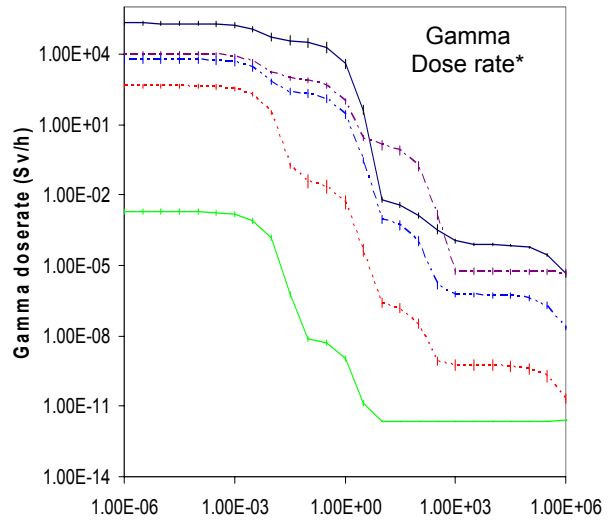
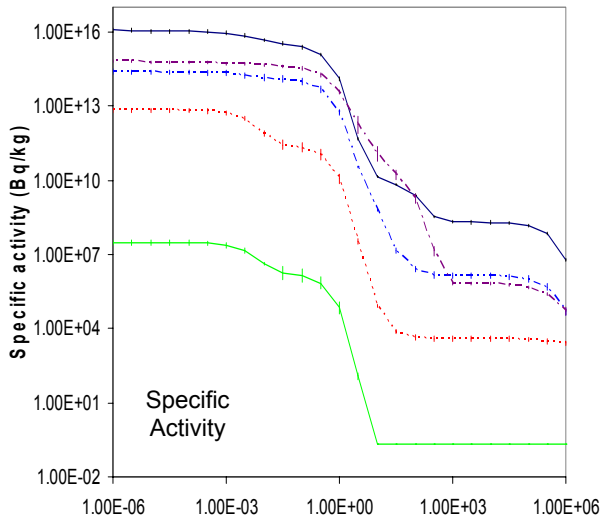
## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
W183m	5.25 s	W182(n,γ)W183m W184(n,γ)W185(β <sup>-</sup> )Re185(n,γ)Re186_ (β <sup>-</sup> )Os186(n,α)W183m W184(n,2n)W183m W186(n,3n)W184(n,2n)W183m W183(n,n')W183m W184(n,2n)W183(n,n')W183m W186(n,4n)W183m	99.9 0.1	93.4 6.6	100.0	0.2	0.2		
						90.5	38.7	31.9	53.1
						2.6			
						2.0	1.6	1.3	2.2
						0.9			
							52.6	63.3	38.4
Re188	16.98 h	&W186(n,γ)W187(β <sup>-</sup> )Re187(n,γ)Re188 &W184(n,γ)W185(β <sup>-</sup> )Re185(n,γ)Re186_ (n,γ)Re187(n,γ)Re188 &W183(n,γ)W184(n,γ)W185(β <sup>-</sup> )Re185_ (n,γ)Re186(n,γ)Re187(n,γ)Re188	97.1	78.3 9.7 4.4	99.7	97.4	88.1	97.8	97.9
Ir194	19.30 h	Very long pathways of (n,γ), β <sup>-</sup>	100.0	100.0	100.0				
W187	23.85 h	W186(n,γ)W187 W184(n,γ)W185(β <sup>-</sup> )Re185(n,γ)Re186_ (β <sup>+</sup> )W186(n,γ)W187	91.8 1.7	98.5 0.3	100.0	99.9	99.5	99.5	99.7
Re186	3.775 d	&W184(n,γ)W185(β <sup>-</sup> )Re185(n,γ)Re186 W183(n,γ)W184(n,γ)W185(β <sup>-</sup> )Re185_ (n,γ)Re186 W186(n,γ)W187(β <sup>-</sup> )Re187(n,2n)Re186 &W186(n,2n)W185(β <sup>-</sup> )Re185(n,γ)Re186 W186(n,d)Ta185(β <sup>-</sup> )W185(β <sup>-</sup> )_ Re185(n,γ)Re186	99.8 0.1	98.4 1.5	98.1 1.6				
						86.9	92.1	90.7	89.6
						12.8	6.3	6.1	5.8
							1.2	2.9	4.3
Lu172	6.70 d	Very long pathways of (n,α), (n,2n), β <sup>-</sup>				100.0	100.0	100.0	100.0
Re184	37.90 d	&W186(n,2n)W185(β <sup>-</sup> )Re185(n,2n)Re184 &186(n,d)Ta185(β <sup>-</sup> )W185(β <sup>-</sup> )Re185_ (n,2n)Re184 &186(n,γ)W187(β <sup>-</sup> )Re187(n,4n)Re184				99.9	82.7 15.5	65.2 30.5	56.6 41.7
							1.3	4.1	1.4
Ir192	73.82 d	&W186(n,γ)W187(β <sup>-</sup> )Re187(n,γ)Re188_ (β <sup>-</sup> )Os188(n,γ)Os189(n,γ)Os190(n,γ)_ Os191(β <sup>-</sup> )Ir191(n,γ)Ir192 &W184(n,γ)W185(β <sup>-</sup> )Re185(n,γ)Re186_ (β <sup>-</sup> )Os186(n,γ)Os187(n,γ)Os188(n,γ)_ Os189(n,γ)Os190(n,γ)Os191(β <sup>-</sup> )Ir191_ (n,γ)Ir192 &W184(n,γ)W185(β <sup>-</sup> )Re185(n,γ)Re186(n,γ)_ Re187(n,γ)Re188(β <sup>-</sup> )Os188(n,γ)Os189(n,γ)_ Os190(n,γ)Os191(β <sup>-</sup> )Ir191(n,γ)Ir192	99.9 0.1	96.6 3.1 0.3	100.0				
W185	75.10 d	&184(n,γ)W185 W183(n,γ)W184(n,γ)W185 &186(n,2n)W185 W186(n,d)Ta185(β <sup>-</sup> )W185	99.5 0.2	96.8 2.9	96.1 3.0				
						99.8	83.7 15.7	67.7 31.8	57.5 42.3
Ta182	114.7 d	&180(n,γ)W181(β <sup>+</sup> )Ta181(n,γ)Ta182 &W182(n,p)Ta182 &W182(n,2n)W181(β <sup>+</sup> )Ta181(n,γ)Ta182 &W183(n,2n)W182(n,p)Ta182 &W186(n,2n)W185(β <sup>-</sup> )Re185(n,α)Ta182 &W184(n,2n)W183(n,2n)W182(n,p)Ta182 &W183(n,d)Ta182 &W184(n,2n)W183(n,d)Ta182 W184(n,3n)W182(n,p)Ta182 &184(n,t)Ta182 W186(n,α)Hf182m(β <sup>-</sup> )Ta182 &186(n,2nt)Ta182	99.9	99.9	99.9				
						63.0	45.6	20.1	7.3
						14.2			
						9.7	0.1		
						4.0			
						2.7			
						1.7	33.8	27.9	17.3
						1.0			
						0.4	1.1		
							12.0	44.0	42.4
							1.8		
								1.1	23.3

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
W181	120.98 d	W180(n,γ)W181 W182(n,2n)W181 W183(n,2n)W182(n,2n)W181 W183(n,3n)W181 W184(n,4n)W181 W186(n,6n)W181	100.0	100.0	100.0	82.6 12.6 0.2	36.4 41.6 19.3	22.2 10.8 66.0	17.5 7.9 19.5 49.6
Re184m	168.0 d	&W186(n,2n)W185(β <sup>-</sup> )Re185(n,2n)Re184m W186(n,d)Ta185(β <sup>-</sup> )W185(β <sup>-</sup> )Re185 (n,2n)Re184m W186(n,γ)W187(β <sup>-</sup> )Re187(n,4n)Re184m				99.8	81.2 15.2 3.0	59.6 28.0 12.1	55.2 40.7 3.9
Ta179	1.610 y	W182(n,2n)W181(β <sup>+</sup> )Ta181(n,2n) Ta180m(n,2n)Ta179 &W182(n,2n)W181(n,2n)W180(n,2n) W179(β <sup>+</sup> )Ta179 &W180(n,2n)W179(β <sup>+</sup> )Ta179 W182(n,2n)W181(β <sup>+</sup> )Ta181(n,3n)Ta179 W183(n,2n)W182(n,2n)W181(β <sup>+</sup> ) Ta181(n,2n)Ta180m(n,2n)Ta179 &W182(n,4n)W179(β <sup>+</sup> )Ta179 W183(n,3n)W181(β <sup>+</sup> )Ta181(n,3n)Ta179 &W182(n,3n)W180(n,2n)W179(β <sup>+</sup> )Ta179 W184(n,4n)W181(β <sup>+</sup> )Ta181(n,3n)Ta179 W183(n,3n)W181(n,3n)W179(β <sup>+</sup> )Ta179 W182(n,2n)W181(n,3n)W179(β <sup>+</sup> )Ta179 W182(n,nt)Ta179 W182(n,3n)W180(n,d)Ta179 W184(n,3n)W182(n,4n)W179(β <sup>+</sup> )Ta179 &W183(n,5n)W179(β <sup>+</sup> )Ta179 &W186(n,5n)W182(n,4n)W179(β <sup>+</sup> )Ta179 W184(n,6n)W179(β <sup>+</sup> )Ta179 W183(n,2nt)Ta179				48.2 20.5 16.0 3.0 2.1  57.9 9.5 6.0 4.4 1.5 1.3 1.2 1.0 1.0  6.0 4.1	2.1 8.3 1.0  71.8 0.5 0.9  19.3 0.2 1.0 0.2  18.2 41.6	19.3 6.4 18.2 2.1	
Hf172	1.870 y	W180(n,α)Hf176(n,2n)Hf175(n,2n) Hf174(n,2n)Hf173(n,2n)Hf172 W180(n,α)Hf177(n,2n)Hf176(n,2n)Hf175 (n,2n)Hf174(n,2n)Hf173(n,2n)Hf172 W182(n,3n)W180(n,α)Hf176(n,3n) Hf174(n,3n)Hf172 W182(n,4n)W179(β <sup>+</sup> )Ta179(n,4n) Ta176(β <sup>+</sup> )Hf176(n,5n)Hf172 W182(n,4n)W179(β <sup>+</sup> )Ta179(β <sup>+</sup> )Hf179 (n,4n)Hf176(n,5n)Hf172 W182(n,4n)W179(β <sup>+</sup> )Ta179(β <sup>+</sup> )Hf179 (n,5n)Hf175(n,4n)Hf172 W182(n,6n)W177(β <sup>+</sup> )Ta177(β <sup>+</sup> )Hf177 (n,6n)Hf172 Other similar long pathways				9.5 7.4  5.9  11.4 6.9 6.9  34.6 93.1	94.1 74.8 64.6	0.5 0.3 34.6 64.6	
Os194	5.989 y	&W186(n,γ)W187(β <sup>-</sup> )Re187(n,γ)Re188 (β <sup>-</sup> )Os188(n,γ)Os189(n,γ)Os190(n,γ) Os191(n,γ)Os192(n,γ)Os193(n,γ)Os194	100.0	100.0	100.0				
H3	12.33 y	W183(n,X)H3 W182(n,X)H3 W184(n,X)H3 W186(n,X)H3 &W184(n,2n)W183(n,X)H3 &W186(n,2n)W185(β <sup>-</sup> )Re185(n,X)H3 W182(n,2n)W181(β <sup>+</sup> )Ta181(n,X)H3				70.8 10.4 6.4 4.8 2.4 1.8 1.4	22.7 29.1 20.6 25.2 0.1	18.5 28.6 27.0 23.6	17.0 28.7 30.2 22.0
Hf178n	31.0 y	W180(n,γ)W181(n,α)Hf178n W180(n,α)Hf177(n,γ)Hf178n W182(n,α)Hf178n &W182(n,2n)W181(β <sup>+</sup> )Ta181(n,2n)Ta180 (β <sup>+</sup> )Hf180(n,2n)Hf179(n,2n)Hf178n	100.0	100.0	98.9 1.1	51.2 7.9	98.4	85.0	59.7

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
		&W180(n,2n)W179(β <sup>+</sup> )Ta179(β <sup>+</sup> )Hf179_ (n,2n)Hf178n W183(n,2n)W182(n,nα)Hf178n W182(n,2n)W181(β <sup>+</sup> )Ta181(n,2n)Ta180m_ (n,2n)Ta179(β <sup>+</sup> )Hf179(n,2n)Hf178n &W180(n,2n)W179(β <sup>+</sup> )Ta179(n,2n)_ Ta178(β <sup>+</sup> )Hf178(n,n')Hf178n &W182(n,2n)W181(n,2n)W180(n,2n)_ W179(β <sup>+</sup> )Ta179(β <sup>+</sup> )Hf179(n,2n)Hf178n &W180(n,2n)W179(β <sup>+</sup> )Ta179(β <sup>+</sup> )_ Hf179(n,2n)Hf178(n,n')Hf178n &W182(n,α)Hf179(n,2n)Hf178n &W180(n,2n)W179(β <sup>+</sup> )Ta179(n,2n)_ Ta178m(β <sup>+</sup> )Hf178(n,n')Hf178n W186(n,5n)W182(n,nα)Hf178n &W182(n,4n)W179(β <sup>+</sup> )Ta179(β <sup>+</sup> )_ Hf179(n,2n)Hf178n W182(n,5n)W178(β <sup>+</sup> )Ta178(β <sup>+</sup> )Hf178_ (n,n')Hf178n W183(n,6n)W178(β <sup>+</sup> )Ta178(β <sup>+</sup> )Hf178_ (n,n')Hf178n				5.2 4.4 3.2 2.6 2.3 2.3 1.9 1.7		3.7 1.2 1.1	2.1 0.4 19.7 8.2
Pt193	50.0 y	Very long pathways of (n,γ), β <sup>-</sup>	100.0	100.0	100.0				
Ir192n	241.0 y	&W186(n,γ)W187(β <sup>-</sup> )Re187(n,γ)Re188_ (β <sup>-</sup> )Os188(n,γ)Os189(n,γ)Os190(n,γ)_ Os191(β <sup>-</sup> )Ir191(n,γ)Ir192n &W186(n,γ)W187(β <sup>-</sup> )Re187(n,γ)Re188_ (β <sup>-</sup> )Os188(n,γ)Os189(n,γ)Os190(n,γ)_ Os191(n,γ)Os192m(β <sup>-</sup> )Ir192n	94.7 3.0	93.6 4.2	88.4 8.1				
Ho166m	1200 y	Very long pathways of (n,α), (n,2n), β <sup>-</sup>				100.0	100.0	100.0	100.0
Ho163	4570 y	Very long pathways of (n,α), (n,2n), β <sup>-</sup>				100.0	100.0	100.0	100.0
Re186m	2.0 10 <sup>5</sup> y	&W184(n,γ)W185(β <sup>-</sup> )Re185(n,γ)Re186m W183(n,γ)W184(n,γ)W185(β <sup>-</sup> )Re185_ (n,γ)Re186m W186(n,γ)W187(β <sup>-</sup> )Re187(n,2n)Re186m &W186(n,2n)W185(β <sup>-</sup> )Re185(n,γ)Re186m W186(n,d)Ta185(β <sup>-</sup> )W185(β <sup>-</sup> )Re185_ (n,γ)Re186m	99.9 3.0	98.9 1.0 4.2	98.8 1.1 8.1		73.1 26.9	78.3 18.1 3.4	73.6 17.8 8.4 12.2
Hf182	9.0 10 <sup>6</sup> y	&W183(n,α)Hf180(n,γ)Hf181(n,γ)Hf182 &W182(n,γ)W183(n,α)Hf180(n,γ)_ Hf181(n,γ)Hf182 &W182(n,α)Hf179(n,γ)Hf180(n,γ)_ Hf181(n,γ)Hf182 W184(n,α)Hf181(n,γ)Hf182 &W184(n,γ)W185(n,α)Hf182 W183(n,γ)W184(n,α)Hf181(n,γ)Hf182 W183(n,γ)W184(n,γ)W185(n,α)Hf182 &W186(n,2n)W185(n,α)Hf182 &W186(n,nα)Hf182 W184(n,h)Hf182	57.7 34.8 2.4 1.0 0.2 0.1	56.9 1.1 2.8 19.2 1.2 7.8	4.7 10.1 83.1 0.2 1.3		52.4 45.5	89.0 0.1 82.9 7.0	77.2 13.5
Re187	4.3 10 <sup>10</sup> y	W186(n,γ)W187(β <sup>-</sup> )Re187 W184(n,γ)W185(β <sup>-</sup> )Re185(n,γ)Re186_ (n,γ)Re187 W183(n,γ)W184(n,γ)W185(β <sup>-</sup> )Re185_ (n,γ)Re186(n,γ)Re187	97.1	78.4 9.6 4.4	100.0	100.0	99.8	99.8	99.9
W183	1.1 10 <sup>17</sup> y	&W182(n,γ)W183 W184(n,γ)W185(β <sup>-</sup> )Re185(n,γ)Re186_ (β <sup>-</sup> )Os186(n,α)W183 &W186(n,4n)W183 W186(n,nt)Ta183(β <sup>-</sup> )W183 Nuclide also present in starting material	52.9 1.2 45.9	26.6 10.3 63.1	7.0			15.7 0.3 79.4	6.5 1.7 91.8

# Tungsten activation characteristics

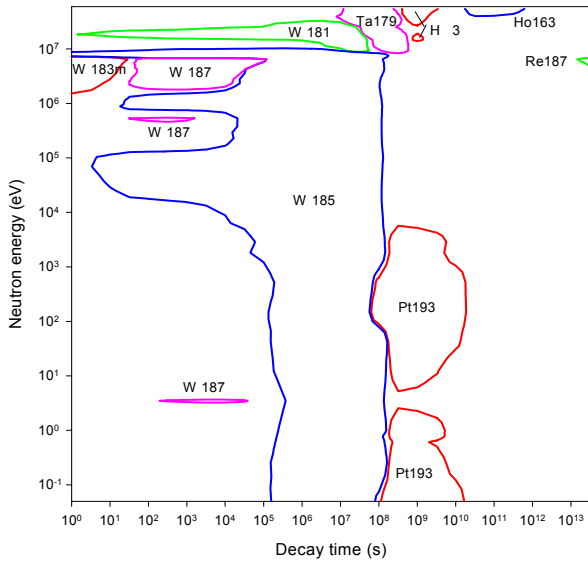


Decay time (years)

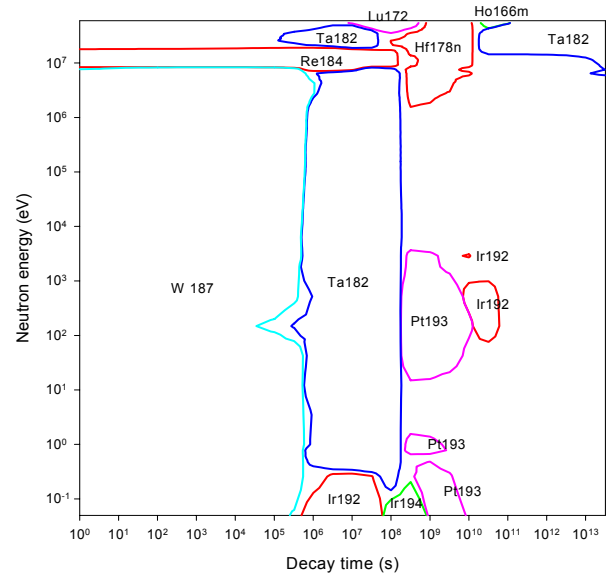
Decay time (years)

# Tungsten importance diagrams & transmutation

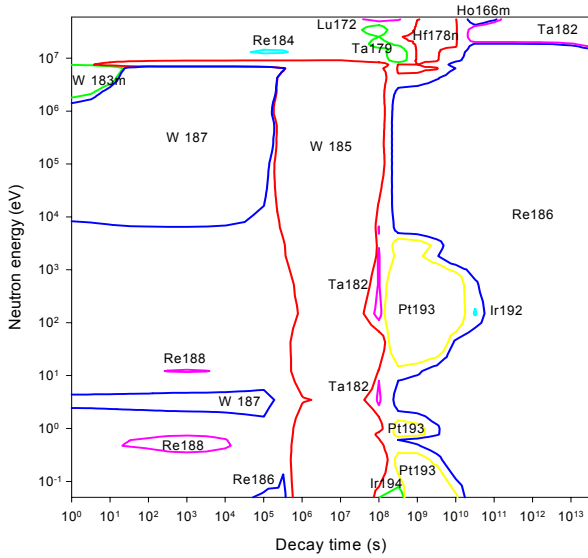
**Activity**



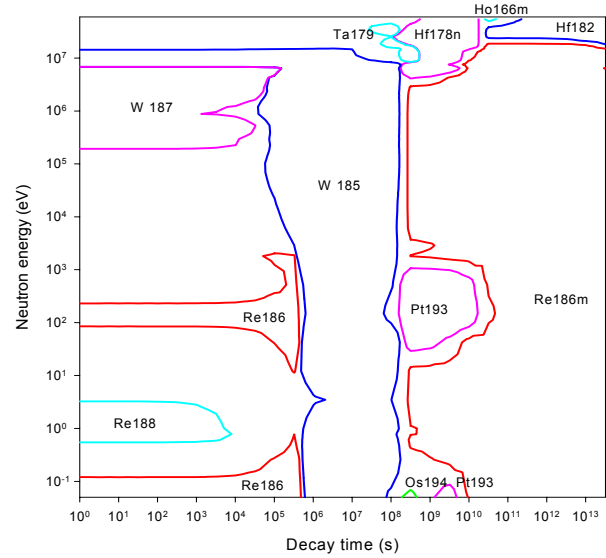
**Dose rate**



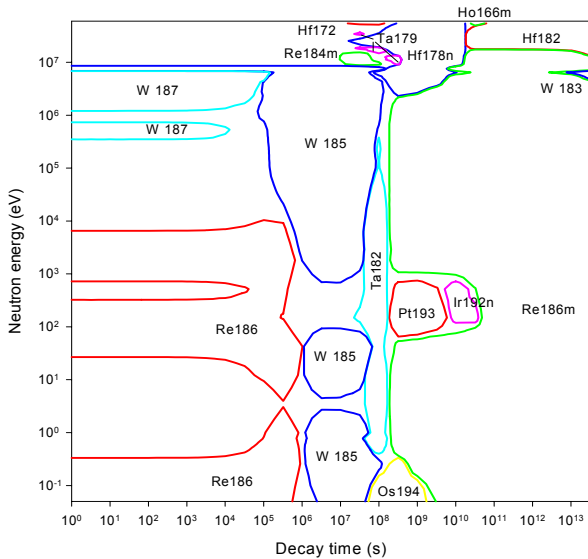
**Heat output**



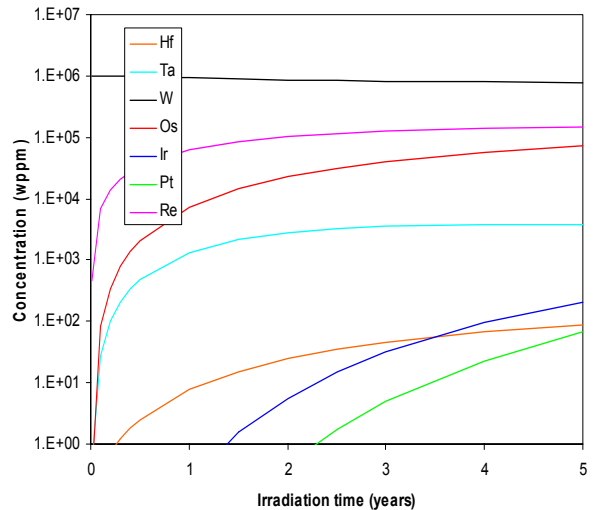
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**





# Rhenium

## General properties

Atomic number	75	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	7.0 10 <sup>-4</sup>	Re185	37.4
Melting point / K	3459	Re187	62.6 (T <sub>1/2</sub> = 4.35 10 <sup>10</sup> y)
Boiling point / K	5869		
Density / kgm <sup>-3</sup>	21020		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	47.9		
Electrical resistivity /Ωm	1.93 10 <sup>-7</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	6.2 10 <sup>-6</sup>		
Crystal structure	HCP		
Number of stable isotopes	1 (2)		
Mean atomic weight	186.207		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	3.00E16	2.19E16	1.13E16	2.50E14	3.04E10	4.08E8	kW kg <sup>-1</sup>	1.71E0	1.38E0	4.36E-1	7.12E-3	2.32E-7	1.59E-8
Re186	26.92	36.81	36.49		0.95	49.96	Re188	37.62	46.29	4.16	0.07		
W185	22.27	30.47	57.06	91.84			Re186	27.05	33.38	54.29		7.14	73.61
Re188	15.97	21.78	1.19	0.01			W185	7.94	9.80	30.12	65.47		
W187	2.13	2.90	0.44				W187	4.44	5.47	1.37			
Os189m	1.43	1.93					Re184	0.99	1.22	3.68	11.54		
Os191	0.48	0.65	1.10				Os185	0.75	0.93	2.87	12.15		
Re188m	0.44	0.49					Ir192	0.51	0.63	1.93	3.96	4.07	
Re184	0.37	0.50	0.92	2.14			Re188m	0.19	0.19				
Os185	0.36	0.50	0.94	2.93			Re184m	0.12	0.15	0.47	6.47		
Os191m	0.34	0.46	0.01				Os189m	0.11	0.13				
Ir192m	0.20	0.02					Os191	0.05	0.06	0.17			
Ir192	0.18	0.24	0.45	0.68	0.19		Ir190	0.02	0.02	0.06			
Re184m	0.08	0.11	0.21	2.17			Pt193					85.55	
Pt193				0.05	97.65		Re186m					2.56	26.39
Re186m					0.95	49.96	Ir192n					0.66	
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	1.22E5	1.18E5	4.23E4	2.25E3	9.20E-3	1.51E-4	Sv kg <sup>-1</sup>	2.26E7	2.25E7	9.60E6	1.21E5	2.09E0	7.55E-1
W187	35.39	36.63	7.83				Re186	53.67	53.73	64.52		20.75	40.54
Re188	26.65*	27.56*	2.12	0.01			Re188	29.73	29.68	1.97	0.04		
Re184	16.03	16.64	42.85	40.58			W185	13.02	13.05	29.60	83.55		
Os185	11.54	11.97	31.73	40.46			W187	1.78	1.78	0.33			
Ir192	3.37	3.50	9.21	5.70	46.78		Re184	0.49	0.49	1.08	4.42		
Re186	1.48*	1.53*	2.14*		0.68*	37.76*	Os191	0.36	0.36	0.74			
Re184m	1.04	1.08	2.91	12.06			Ir192	0.33	0.33	0.74	1.97	3.82	
Os190m	0.36	0.27					Os185	0.25	0.25	0.56	3.09		
Ta182	0.21	0.21	0.57	1.18	0.01	0.67	Re184m	0.16	0.16	0.38	6.73		
Ir190	0.20	0.21	0.46				Pt193					44.11	
Pt193					51.32		Re186m					30.43	59.46
Re186m					1.10	61.55	Ir192n					0.84	
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	1.36E7	1.36E7	6.51E6	9.68E4	7.01E0	2.67E0		1.19E12	4.57E11	2.99E11	1.72E10	1.10E6	1.41E4
Re186	65.18	65.36	69.77		4.53	8.39	W183m	46.08					
Re188	18.99	18.99	1.12	0.02			W185m	16.96	4.96				
W185	5.88	5.90	11.90	28.44			Os185	9.15	23.83	35.49	42.65		
Ir192	2.54	2.55	5.15	11.61	5.36		Re184	8.40	21.88	31.67	28.27		
Os191	1.99	1.99	3.62				W187	5.36	13.93	1.67			
Re184	1.53	1.54	3.04	10.48			Ir192	4.41	11.49	16.99	9.91	5.16	
Os185	1.28	1.28	2.61	12.11			Re188	4.03	10.45	0.45			
Re184m	1.17	1.17	2.40	36.38			Ir191m1	1.01	2.56	3.46			
W187	0.89	0.89	0.15				Re188m	0.91	1.95				
Ta182	0.06	0.06	0.12	0.88			Re184m	0.82	2.14	3.23	12.62		
Re186m					49.41	91.58	Re186	0.68	1.77	1.38		0.03	1.44
Ir192n					31.62		Ta182	0.65	1.70	2.55	4.99		0.18
Pt193					8.90		W185	0.56	1.46	2.16	1.34		
							Os191	0.12	0.31	0.42			
							Ir190	0.11	0.28	0.35			
							Pt193				0.02	92.92	
							Re186m					1.75	96.26

# Rhenium

## Pathway analysis

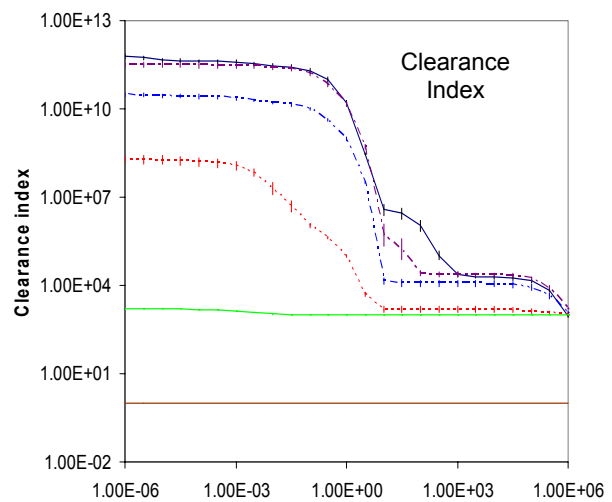
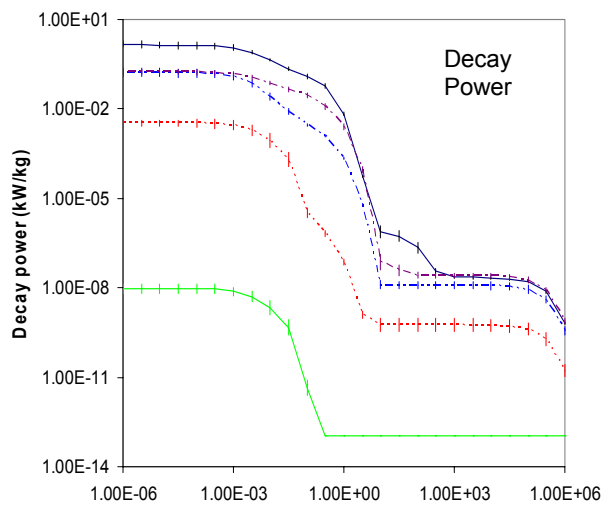
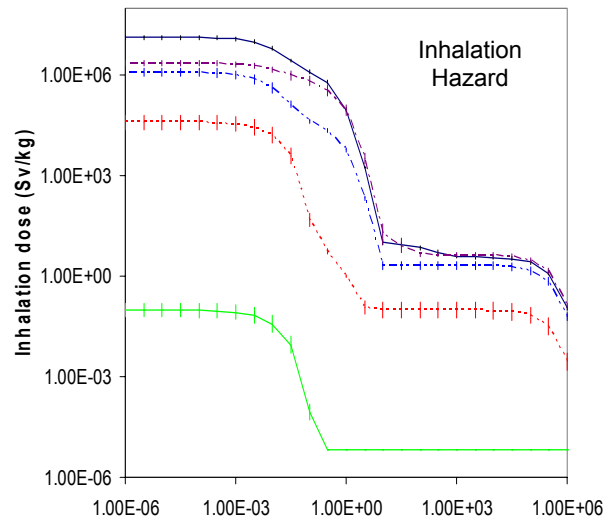
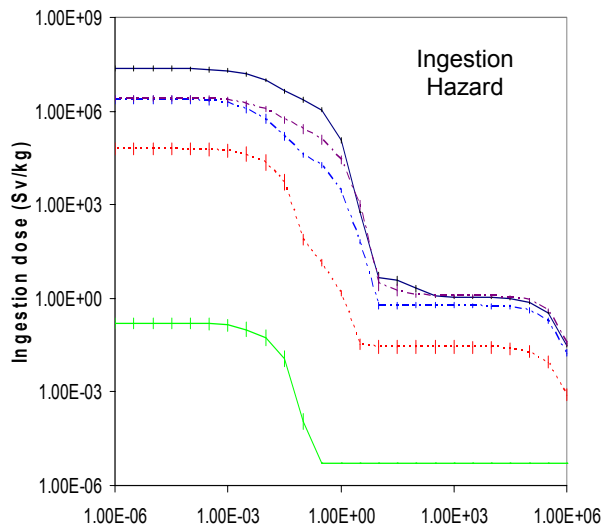
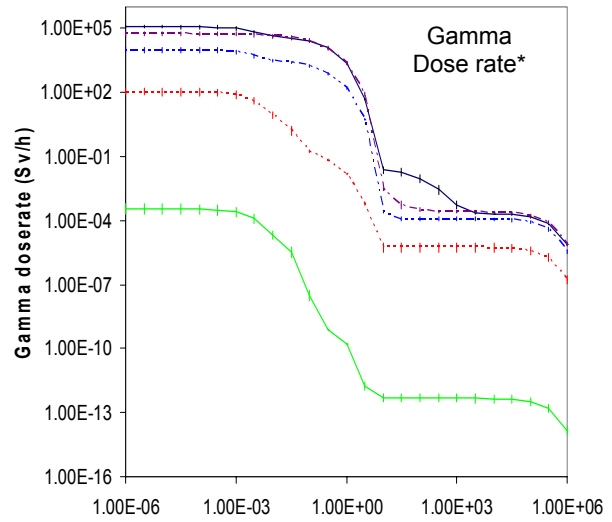
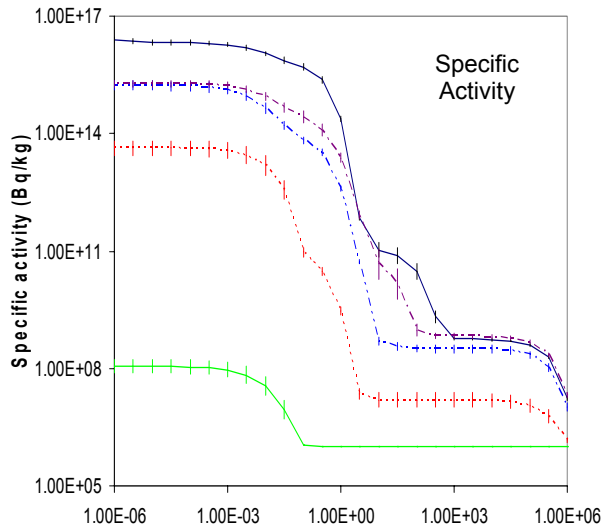
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Re188	16.98 h	&Re187(n,γ)Re188	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Ir194	19.30 h	&Re187(n,γ)Re188(β <sup>-</sup> )Os188(n,γ) Os189(n,γ)Os190(n,γ)Os191(β <sup>-</sup> )Ir191 (n,γ)Ir192(n,γ)Ir193(n,γ)Ir194 &Re185(n,γ)Re186(β <sup>-</sup> )Os186(n,γ) Os187(n,γ)Os188(n,γ)Os189(n,γ)Os190 (n,γ)Os191(β <sup>-</sup> )Ir191(n,γ)Ir192(n,γ)Ir193 (n,γ)Ir194 &Re187(n,γ)Re188(β <sup>-</sup> )Os188(n,γ) Os189(n,γ)Os190(n,γ)Os191(n,γ)Os192 (n,γ)Os193(β <sup>-</sup> )Ir193(n,γ)Ir194	98.5  1.0  0.5	98.7  1.3	96.6   3.4				
W187	23.85 h	Re185(n,γ)Re186(β <sup>+</sup> )W186(n,γ)W187 Re187(n,p)W187 Re187(n,2n)Re186(β <sup>+</sup> )W186(n,γ)W187	100.0	99.2	98.8	97.9 2.1	99.7	99.7	99.7
Re186	3.775 d	Re185(n,γ)Re186 Re187(n,2n)Re186	100.0	98.6	97.8	99.5	99.3	99.5	99.6
Lu172	6.70 d	Very long pathways of (n,α), (n,2n), β <sup>-</sup>				100.0	100.0	100.0	100.0
Re184	37.90 d	&Re185(n,2n)Re184 Re187(n,2n)Re186(β <sup>-</sup> )Os186(n,2n) Os185(β <sup>+</sup> )Re185(n,2n)Re184 &Re187(n,2n)Re186m(n,2n)Re185 (n,2n)Re184 &Re187(n,3n)Re185(n,2n)Re184 &Re187(n,2n)Re186m(n,3n)Re184 &Re187(n,4n)Re184				90.2 4.7  1.7  1.6 0.1	33.9    12.2 2.7	13.5    1.1	30.5    1.5 65.8
Re183	70.00 d	&Re185(n,2n)Re184(n,2n)Re183 Re185(n,2n)Re184m(n,2n)Re183 Re185(n,3n)Re183 Re187(n,2n)Re186(β <sup>-</sup> )Os186(n,2n) Os185(β <sup>+</sup> )Re185(n,3n)Re183 Re187(n,3n)Re185(n,3n)Re183 Re187(n,2n)Re186m(n,4n)Re183 Re187(n,5n)Re183 Re187(n,2n)Re186(β <sup>-</sup> )Os186(n,4n) Os183(β <sup>+</sup> )Re183				36.6 33.1 17.1 1.0  0.3	72.4    25.8 0.5	45.1    4.1 2.3	18.4    78.7
Ir192	73.82 d	&Re187(n,γ)Re188(β <sup>-</sup> )Os188(n,γ) Os189(n,γ)Os190(n,γ)Os191(β <sup>-</sup> )Ir191 (n,γ)Ir192	99.8	99.8	99.6	90.3	93.3	95.6	96.8
W185	75.10 d	&Re187(n,γ)Re188(β <sup>-</sup> )Os188(n,α)W185 Re187(n,γ)Re188(β <sup>-</sup> )Os188(n,α)W185 &Re187(n,2n)Re186(β <sup>+</sup> )W186(n,2n)W185 &Re185(n,p)W185 &Re187(n,d)W186(n,2n)W185 &Re187(n,2n)Re186m(n,d)W185 &Re187(n,t)W185 &Re187(n,3n)Re185(n,p)W185 Re187(n,d)W186(n,d)Ta185(β <sup>-</sup> )W185	72.3 27.6	72.3 27.6	72.3 27.6	89.3 8.6 0.8 0.3 0.2	1.7 30.2 5.3 3.2 46.3 10.8 1.0	9.4 2.1 1.3	4.4   91.7
Ta182	114.7 d	&Re185(n,α)Ta182 Re187(n,2n)Re186(β <sup>-</sup> )Os186(n,2n) Os185(β <sup>+</sup> )Re185(n,α)Ta182 &Re187(n,3n)Re185(n,α)Ta182 &Re187(n,2n)Re186m(n,2n)Re185(n,α)Ta182 &Re185(n,3n)Re183(β <sup>+</sup> )W183(n,d)Ta182 &Re187(n,3n)Re185(n,3n)Re183(β <sup>+</sup> ) W183(n,d)Ta182 &Re187(n,2nα)Ta182	99.7	98.9	98.1	89.3 2.3  1.5 1.5	34.8   11.9 32.6 5.2	8.1   0.7 9.1 0.3	8.4   0.5 5.4 27.9



Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&Re187(n,4n)Re184(β <sup>+</sup> )W184(n,t)Ta182 &Re185(n,2n)Re184(β <sup>+</sup> )W184(n,t)Ta182 &Re185(n,4n)Re182m(β <sup>+</sup> )W182(n,p)Ta182 &Re185(n,4n)Re182(β <sup>+</sup> )W182(n,p)Ta182 &Re187(n,4n)Re184m(β <sup>+</sup> )W184(n,t)Ta182 &Re185(n,d)W184(n,t)Ta182 &Re187(n,5n)Re183(β <sup>+</sup> )W183(n,d)Ta182 &Re187(n,nt)W184(n,t)Ta182 Re187(n,6n)Re182m(β <sup>+</sup> )W182(n,p)Ta182 &Re187(n,2nt)W183(n,d)Ta182 Re187(n,6n)Re182(β <sup>+</sup> )W182(n,p)Ta182 &Re187(n,d)W186(n,2nt)Ta182					1.5 1.0 0.3 0.2 0.1 0.1	21.0 3.1 5.3 3.5 2.7 1.1	9.0 3.8 0.8 0.6 0.9 1.6
Re184m	168.0 d	Re185(n,2n)Re184m Re187(n,2n)Re186(β <sup>-</sup> )Os186(n,2n) Os185(β <sup>+</sup> )Re185(n,2n)Re184m Re187(n,3n)Re185(n,2n)Re184m Re187(n,2n)Re186m(n,2n)Re185(n,2n)Re184m Re187(n,2n)Re186m(n,3n)Re184m Re187(n,4n)Re184m				91.6 4.5 1.5 1.4 0.4	19.9 6.5 4.7	4.9 94.0	13.9 84.0
Ta179	1.610 y	Re185(n,α)Ta181(n,2n)Ta180m(n,2n)Ta179 Re185(n,2n)Re184(β <sup>+</sup> )W184(n,3n) W182(n,2n)W181(β <sup>+</sup> )Ta181(n,2n) Ta180m(n,2n)Ta179 Re185(n,α)Ta181(n,3n)Ta179 Re185(n,3n)Re183(β <sup>+</sup> )W183(n,3n) W181(β <sup>+</sup> )Ta181(n,3n)Ta179 Re185(n,3n)Re183(β <sup>+</sup> )W183(n,3n) W181(n,3n)W179(β <sup>+</sup> )Ta179 Re185(n,3n)Re183(n,3n)Re181(β <sup>+</sup> ) W181(β <sup>+</sup> )Ta181(n,3n)Ta179 &Re185(n,4n)Re182m(β <sup>+</sup> )W182(n,4n) W179(β <sup>+</sup> )Ta179 &Re185(n,4n)Re182(β <sup>+</sup> )W182(n,4n) W179(β <sup>+</sup> )Ta179 &Re185(n,3n)Re183(β <sup>+</sup> )W183(n,5n) W179(β <sup>+</sup> )Ta179 &Re187(n,5n)Re183(β <sup>+</sup> )W183(n,5n) W179(β <sup>+</sup> )Ta179 Re185(n,5n)Re181(β <sup>+</sup> )W181(β <sup>+</sup> )Ta181 (n,3n)Ta179 Re185(n,3nα)Ta179 &Re187(n,6n)Re182m(β <sup>+</sup> )W182(n,4n) W179(β <sup>+</sup> )Ta179 &Re187(n,4n)Re184(β <sup>+</sup> )W184(n,6n) W179(β <sup>+</sup> )Ta179 Other similar long pathways				7.0 5.9 0.4 39.0 10.9 7.9 0.4 0.2 4.2 3.8 1.3 1.0 6.0 5.7 86.7	5.4 0.2 27.0 40.5 21.8	0.2 0.2 2.1 1.4 5.2 22.2 6.4 5.8 6.0 5.7 45.2	
Hf172	1.870 y	Very long pathways of (n,α), (n,2n), β <sup>-</sup>				100.0	100.0	100.0	100.0
Os194	5.989 y	&Re187(n,γ)Re188(β <sup>-</sup> )Os188(n,γ) Os189(n,γ)Os190(n,γ)Os191(n,γ)Os192 (n,γ)Os193(n,γ)Os194 &Re185(n,γ)Re186(β <sup>-</sup> )Os186(n,γ)Os187 (n,γ)Os188(n,γ)Os189(n,γ)Os190(n,γ) Os191(n,γ)Os192(n,γ)Os193(n,γ)Os194 &Re185(n,γ)Re186(n,γ)Re187(n,γ)Re188 (β <sup>-</sup> )Os188(n,γ)Os189(n,γ)Os190(n,γ) Os191(n,γ)Os192(n,γ)Os193(n,γ)Os194 &Re187(n,γ)Re188(n,γ)Re189(β <sup>-</sup> ) Os189(n,γ)Os190(n,γ)Os191(n,γ)Os192 (n,γ)Os193(n,γ)Os194	85.3 12.2	86.3 11.2	100.0 1.6 0.9				
H3	12.33 y	Re185(n,X)H3 Re187(n,X)H3				45.4 39.3	34.7 49.5	34.2 51.2	33.7 51.5

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	Re187(n,2n)Re186m(n,X)H3 &Re185(n,2n)Re184(n,X)H3 Re185(n,2n)Re184m(n,X)H3 Re187(n,3n)Re185(n,X)H3 Re185(n,3n)Re183(β <sup>+</sup> )W183(n,X)H3 &Re187(n,4n)Re184(β <sup>+</sup> )W184(n,X)H3 Re185(n,4n)Re182m(β <sup>+</sup> )W182(n,X)H3 Re187(n,5n)Re183(β <sup>+</sup> )W183(n,X)H3 Re185(n,5n)Re181(β <sup>+</sup> )W181(β <sup>+</sup> )Ta181_ (n,X)H3 Re187(n,6n)Re182m(β <sup>+</sup> )W182(n,X)H3				8.2 1.7 1.2 0.4 3.7 0.4 1.4 1.0	0.6 4.6 1.1 1.6 1.4 1.0	4.6 1.1 1.6 1.4 1.0	1.0 0.6 0.7 0.4 2.4 1.3 1.1
Hf178n	31.0 y	Re185(n,γ)Re186(β <sup>-</sup> )Os186(n,α)W183_ (n,α)Hf180(n,α)Yb177(β <sup>-</sup> )Lu177(β <sup>-</sup> )_ Hf177(n,γ)Hf178n &Re185(n,2n)Re184(β <sup>+</sup> )W184(n,2n)_ W183(n,2n)W182(n,nα)Hf178n &Re185(n,2n)Re184(β <sup>+</sup> )W184(n,3n)_ W182(n,nα)Hf178n &Re185(n,α)Ta182(β <sup>-</sup> )W182(n,nα)Hf178n   &Re185(n,2n)Re184(n,2n)Re183(β <sup>+</sup> )_ W183(n,2n)W182(n,nα)Hf178n Re185(n,2n)Re184m(n,2n)Re183(β <sup>+</sup> )_ W183(n,2n)W182(n,nα)Hf178n Re185(n,3n)Re183(β <sup>+</sup> )W183(n,2n)_ W182(n,nα)Hf178n Re185(n,3n)Re183(β <sup>+</sup> )W183(n,2n)_ W182(n,nα)Hf178n &Re187(n,4n)Re184(β <sup>+</sup> )W184(n,3n)_ W182(n,nα)Hf178n Re185(n,4n)Re182m(β <sup>+</sup> )W182(n,nα)Hf178n   Re185(n,4n)Re182(β <sup>+</sup> )W182(n,nα)Hf178n   Re185(n,nt)W182(n,nα)Hf178n   Re187(n,6n)Re182m(β <sup>+</sup> )W182(n,nα)Hf178n   Re187(n,6n)Re182(β <sup>+</sup> )W182(n,nα)Hf178n   Other similar long pathways	15.3			49.4 12.7 5.2 4.9 3.9 2.9 2.9 18.0 12.1 8.1 1.6 23.5 15.7	12.8 2.5 12.2 12.2 18.0	0.3 0.4 0.4 2.0	0.1 8.2 5.5 4.4 23.5 15.7
Pt193	50.0 y	&Re187(n,γ)Re188(β <sup>-</sup> )Os188(n,γ)_ Os189(n,γ)Os190(n,γ)Os191(β <sup>-</sup> )Ir191_ (n,γ)Ir192(β <sup>-</sup> )Pt192(n,γ)Pt193 &Re185(n,γ)Re186(β <sup>-</sup> )Os186(n,γ)_ Os187(n,γ)Os188(n,γ)Os189(n,γ)Os190_ (n,γ)Os191(β <sup>-</sup> )Ir191(n,γ)Ir192(β <sup>-</sup> )Pt192_ (n,γ)Pt193	99.1 0.9	98.7 1.3	100.0				
Ir192n	241.0 y	&Re187(n,γ)Re188(β <sup>-</sup> )Os188(n,γ)Os189_ (n,γ)Os190(n,γ)Os191(β <sup>-</sup> )Ir191(n,γ)Ir192n   &Re187(n,γ)Re188(β <sup>-</sup> )Os188(n,γ)_ Os189(n,γ)Os190(n,γ)Os191(n,γ)_ Os192m(β <sup>-</sup> )Ir192n &Re187(n,γ)Re188(β <sup>-</sup> )Os188(n,γ)_ Os189(n,γ)Os190(n,γ)Os191(β <sup>-</sup> )Ir191_ (n,γ)Ir192(n,n')Ir192n	96.6 2.5	95.0 3.6	90.6 6.8	95.8 2.2			
Re186m	2.0 10 <sup>5</sup> y	Re185(n,γ)Re186m Re187(n,2n)Re186m	100.0	99.5	99.2	99.9	0.3 99.5	99.5	99.6
Re187	4.3 10 <sup>10</sup> y	Re185(n,γ)Re186(β <sup>+</sup> )W186(n,γ)W187_ (β <sup>-</sup> )Re187 Re185(n,γ)Re186(n,γ)Re187 Nuclide also present in starting material	12.7 0.2 87.1	2.4 2.1 95.5					

# Rhenium activation characteristics

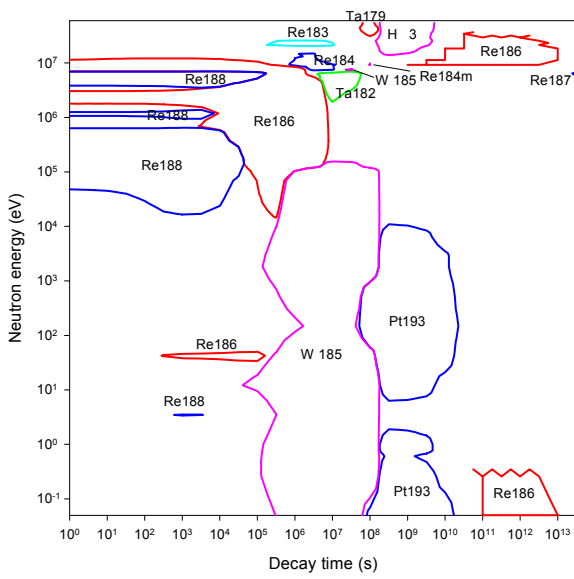


Decay time (years)

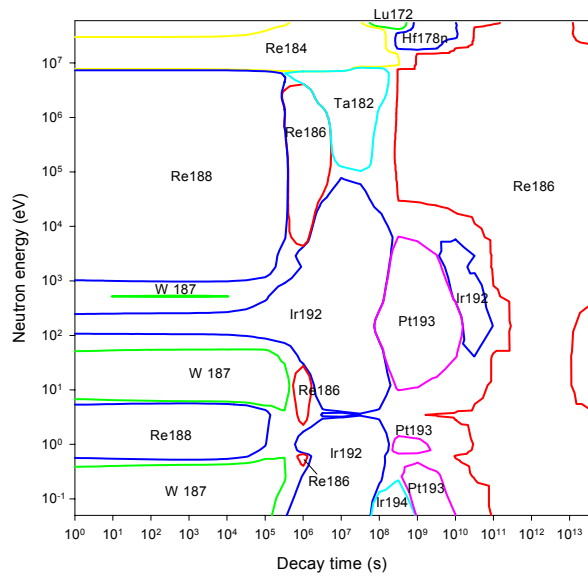
Decay time (years)

# Rhenium importance diagrams & transmutation

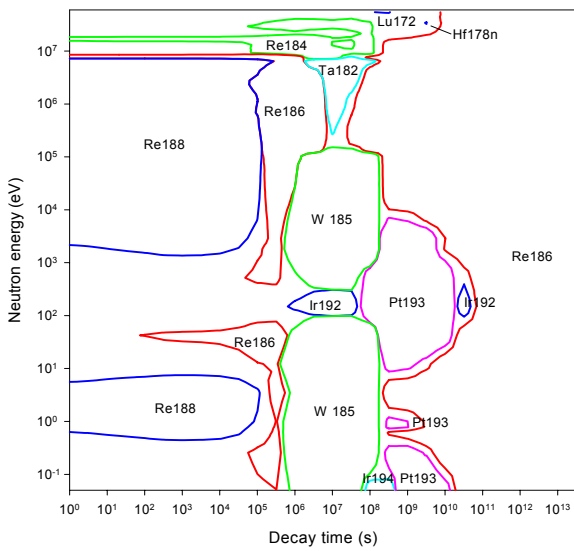
**Activity**



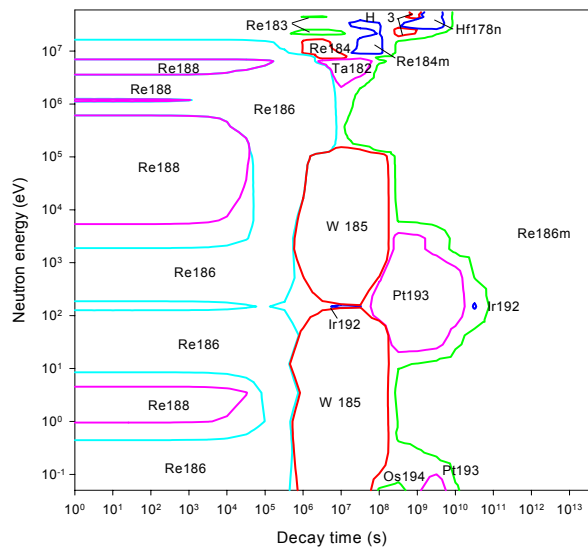
**Dose rate**



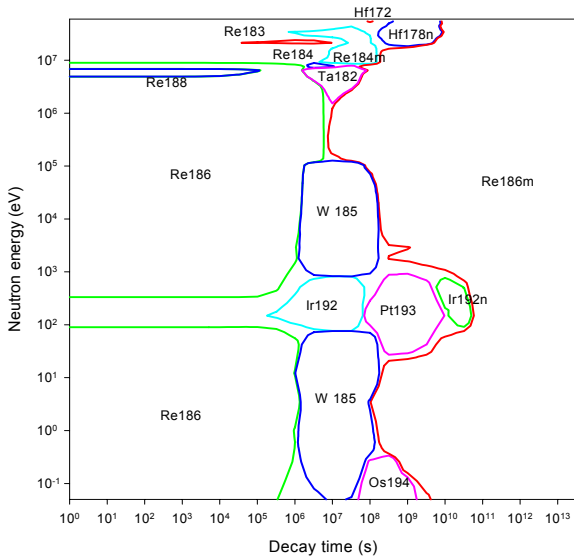
**Heat output**



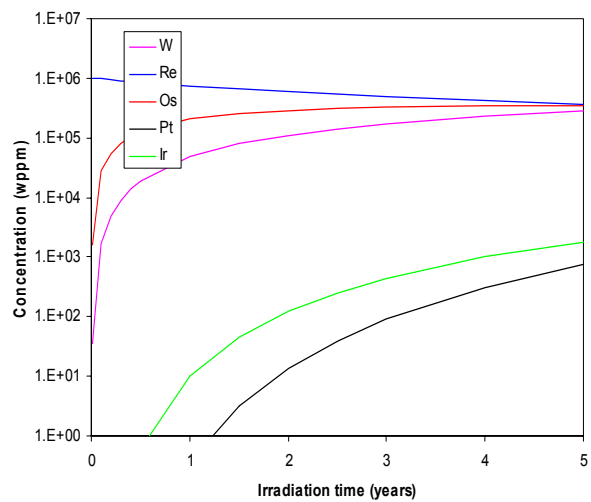
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**



# Osmium

## General properties

Atomic number	76	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	1.5 10 <sup>-3</sup>	Os184	0.02 (T <sub>1/2</sub> = 5.60 10 <sup>13</sup> y)
Melting point / K	3306	Os186	1.59 (T <sub>1/2</sub> = 2.00 10 <sup>15</sup> y)
Boiling point / K	5285	Os187	1.60
Density / kgm <sup>-3</sup>	22570	Os188	13.29
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	87.6	Os189	16.21
Electrical resistivity /Ωm	8.12 10 <sup>-8</sup>	Os190	26.36
Coefficient of thermal expansion / K <sup>-1</sup>	5.1 10 <sup>-6</sup>	Os192	40.93
Crystal structure	HCP		
Number of stable isotopes	5 (7)		
Mean atomic weight	190.23		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	1.17E16	9.30E15	5.30E15	6.79E13	2.11E12	2.50E7	kW kg <sup>-1</sup>	5.98E-1	5.27E-1	2.84E-1	6.35E-3	1.53E-5	9.71E-10
Ir191m	13.13	16.27	24.75				Ir192	27.79	31.56	56.58	84.88	7.03	
Os191	12.91	16.26	24.75				Ir194	18.16	20.56	1.64	0.04		
Re186	11.72	14.76	13.26			49.98	Re186	13.16	14.94	14.18		0.01	73.59
Ir192m	8.80	0.88					Os193	7.66	8.68	2.15			
Ir192	8.56	10.79	18.30	47.92	0.31		Ir191m	7.05	7.88	12.66			
Os191m	8.04	10.08	0.17				W183m	6.22					
Ir194	6.42	8.06	0.61	0.03			W187	2.61	2.96	0.43			
W183m	6.41						W185m	2.37	0.30				
W185	5.81	7.32	12.42	34.45			W185	2.31	2.63	4.71	7.49		
Os193	5.47	6.87	1.61				Re188	2.14	2.42	0.14	0.02		
W185m	3.81	0.54					Os191m	1.88	2.12	0.04			
Ir194m	2.25						Ir192m	1.57	0.14				
Os189m	1.92	2.38					Os191	1.52	1.73	2.78			
W187	1.12	1.41	0.19				Os191m	1.52	1.73	2.78			
Pt193m	0.99	1.24	1.22				Ir194m	1.04					
Ir193m	0.62	0.77	1.08				Ir190	0.93	1.06	1.59			
Os185	0.19	0.24	0.42	2.25			Os190m	0.81	0.66				
Pt193			0.16	12.20	99.39		Ir191n	0.60					
Re186m						49.98	Re184	0.50	0.57	1.01	2.43		
							Os185	0.49	0.51	0.92	2.84		
							Pt193m	0.47	0.53	0.55			
							Re184m			0.14	1.36		
							Pt193			0.02	0.87	91.81	
							Re186m						26.39
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	1.16E5	1.11E5	8.39E4	2.83E3	8.03E-1	9.26E-6	Sv kg <sup>-1</sup>	7.14E6	6.58E6	3.68E6	5.95E4	7.62E1	4.62E-2
Ir192	64.58	67.52	85.81	85.31	59.76		Re186	28.87	31.31	28.64		0.04	40.54
Ir194	7.97*	8.31*	0.47*	0.01*			Ir192	19.68	21.36	36.90	76.51	11.90	
W187	7.33	7.65	0.79				Ir194	13.70	14.82	1.14	0.04		
Ir190	3.47	3.63	3.87				Os191	12.08	13.11	20.31			
Os190m	2.94	2.19					Os193	7.27	7.87	1.87			
Re184	2.89	3.02	3.76	6.01			Os191m	1.27	1.37	0.02			
Os193	2.67	2.78	0.49				Pt193m	0.73	0.79	0.79			
Os185	2.43	2.54	3.25	6.66			Ir190	0.38	0.41	0.59			
Ir191n	2.25						Ir193m	0.27	0.30	0.42			
Ir191m	0.70	0.72	0.82				Pt193			0.01	0.43	85.38	
Re188	0.54	0.59	0.02				Ir192n					2.63	
Ir194m	0.50						Re186m					0.05	59.45
Pt191	0.38	0.39	0.21										
Re186	0.25*	0.26*	0.18*			36.81*							
Ta182		0.04	0.06	0.18		3.76							
Pt193				0.05	40.16								
Re186m						59.32							

<b>Inh</b>	<b>0</b>	<b>10<sup>-5</sup> y</b>	<b>10<sup>-2</sup> y</b>	<b>1 y</b>	<b>100 y</b>	<b>10<sup>5</sup> y</b>	<b>Clear</b>	<b>0</b>	<b>10<sup>-5</sup> y</b>	<b>10<sup>-2</sup> y</b>	<b>1 y</b>	<b>100 y</b>	<b>10<sup>5</sup> y</b>
Sv kg <sup>-1</sup>	1.58E7	1.23E7	1.00E7	2.31E5	3.40E2	1.64E-1		1.48E12	1.27E12	1.16E12	3.59E10	7.90E7	8.59E2
Ir192	41.98	53.66	63.73	93.04	12.59		Ir192	67.99	78.96	83.72	90.72	8.20	
Ir194m	21.75						Ir191m	8.69	9.92	9.44			
Os191	18.22	23.29	24.81				W183m	7.27					
Re186	9.58	12.24	7.70		0.01	8.38	Ir194m	2.63					
Ir194	2.67	3.40	0.18	0.01			Os190m	1.94	1.61				
Os193	2.11	2.69	0.44				Os185	1.54	1.79	1.91	4.26		
Os191m	0.96	1.22	0.02				Ir190	1.52	1.77	1.57			
Ir193m	0.59	0.76	0.74				Ir191n	1.49					
W185	0.52	0.66	0.79	1.22			W185m	1.32	0.17				
Ir190	0.34	0.44	0.44				Re184	1.21	1.40	1.46	2.54		
Re188	0.33	0.42	0.44				Os191	1.03	1.19	1.13			
Re184	0.24	0.30	0.35	0.82			W187	0.89	1.03	0.09			
Os185	0.23	0.29	0.35	1.06			Ir192m	0.54					
Re184m	0.19	0.24	0.29	2.86			Ir194	0.51	0.59	0.03			
Os194	0.01	0.02	0.02	0.70	0.01		Os193	0.43	0.50	0.07			
Ir192n				0.15	74.35		Pt191	0.15	0.17	0.08			
Pt193				0.08	12.99		Re184m	0.12	0.14	0.16	1.33		
Re186m					0.06	91.44	Ta182	0.10	0.12	0.13	0.47		1.02
							Re186	0.09	0.11	0.06			1.45
							Os191m		0.07				
							Pt193			0.03	0.80	91.64	
							Re186m						96.82
							Re187						0.69

# Osmium

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Ir191m	4.90 s	&Os190(n,γ)Os191(β <sup>-</sup> )Ir191m	59.7	93.5	89.3		0.5	0.3	0.2
		&Os189(n,γ)Os190(n,γ)Os191(β <sup>-</sup> )Ir191m &Os188(n,γ)Os189(n,γ)Os190(n,γ) Os191(β <sup>-</sup> )Ir191m	36.0 3.4	6.4	10.5 0.1				
Ir191n	5.50 s	&Os192(n,2n)Os191(β <sup>-</sup> )Ir191(n,n')Ir191n &Os192(n,d)Re191(β <sup>-</sup> )Os191(β <sup>-</sup> )Ir191 (n,n')Ir191n &Os190(n,γ)Os191(β <sup>-</sup> )Ir191(n,n')Ir191n				98.7	69.7 29.8	46.3 53.4	32.4 67.3
						0.5	0.3	0.3	
Os190m	9.90 m	Os189(n,γ)Os190m &Os188(n,γ)Os189(n,γ)Os190m &Os187(n,γ)Os188(n,γ)Os189(n,γ)Os190m &Os186(n,γ)Os187(n,γ)Os188(n,γ) Os189(n,γ)Os190m &Os192(n,2n)Os191(β <sup>-</sup> )Ir191m(IT) Ir191(n,2n)Ir190n(β <sup>+</sup> )Os190m Os190(n,n')Os190m &Os192(n,2n)Os191(n,2n)Os190m Os192(n,3n)Os190(n,n')Os190m Os192(n,3n)Os190m	78.6 16.7 2.0 0.7	95.7 4.3 15.0	95.6 4.3				
					72.9	16.5 1.8 0.3	5.6	17.8 1.4	25.5 1.2
Os189m	4.806 h	Os188(n,γ)Os189m Os187(n,γ)Os188(n,γ)Os189m Os189(n,n')Os189m Os190(n,2n)Os189m Os192(n,3n)Os190(n,2n)Os189m Os190(n,2n)Os189(n,n')Os189m Os192(n,4n)Os189m	98.6 1.4	98.7 1.2	95.6 1.5 2.8	4.7 84.2 1.4 1.2	5.4 25.4 7.9 0.2	2.3 12.2	4.5 19.2
						56.7	81.1	66.4	
Ir194	19.30 h	&Os190(n,γ)Os191(β <sup>-</sup> )Ir191(n,γ)Ir192 (n,γ)Ir193(n,γ)Ir194 &Os189(n,γ)Os190(n,γ)Os191(β <sup>-</sup> )Ir191 (n,γ)Ir192(n,γ)Ir193(n,γ)Ir194 &Os192(n,γ)Os193(β <sup>-</sup> )Ir193(n,γ)Ir194 &Os190(n,γ)Os191(n,γ)Os192(n,γ) Os193(β <sup>-</sup> )Ir193(n,γ)Ir194 &Os188(n,γ)Os189(n,γ)Os190(n,γ)Os191 (β <sup>-</sup> )Ir191(n,γ)Ir192(n,γ)Ir193(n,γ)Ir194 &Os187(n,γ)Os188(n,γ)Os189(n,γ) Os190(n,γ)Os191(β <sup>-</sup> )Ir191(n,γ)Ir192 (n,γ)Ir193(n,γ)Ir194	47.2 24.6 23.6 1.3 1.1	47.5 38.5 1.2 0.4	97.7	94.0	93.2	93.8	94.5
Os193	1.255 d	Os192(n,γ)Os193 &Os190(n,γ)Os191(n,γ)Os192(n,γ)Os193 &Os189(n,γ)Os190(n,γ)Os191(n,γ) Os192(n,γ)Os193	92.2 5.8 1.7	91.9 3.5 2.1	100.0	99.9	99.2	99.3	99.6
Re186	3.775 d	&Os188(n,α)W185(β <sup>-</sup> )Re185(n,γ)Re186 Os184(n,γ)Os185(β <sup>+</sup> )Re185(n,γ)Re186 &Os187(n,γ)Os188(n,α)W185(β <sup>-</sup> ) Re185(n,γ)Re186 Os186(n,p)Re186 Os190(n,α)W187(β <sup>-</sup> )Re187(n,2n)Re186 Os188(n,2n)Os187(n,2n)Os186(n,p)Re186 Os188(n,2n)Os187(n,p)Re187(n,2n)Re186 Os187(n,2n)Os186(n,p)Re186 Os187(n,p)Re187(n,2n)Re186 Os188(n,2n)Os187(n,d)Re186 Os188(n,d)Re187(n,2n)Re186	89.0 10.4 0.6	99.5 0.6	99.2 0.7				
					23.0 20.5 9.4 9.3 7.3 7.2 6.7 3.5	3.6 2.0 0.2	1.1 0.2	0.4	



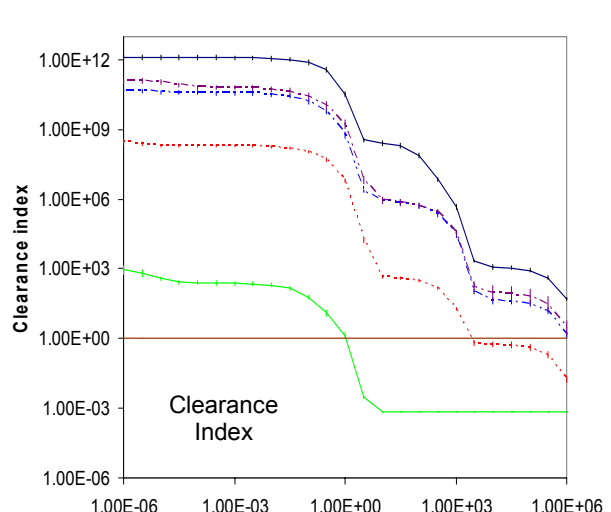
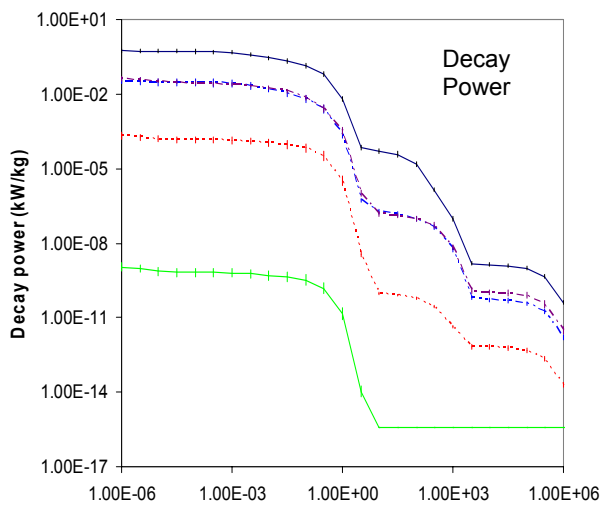
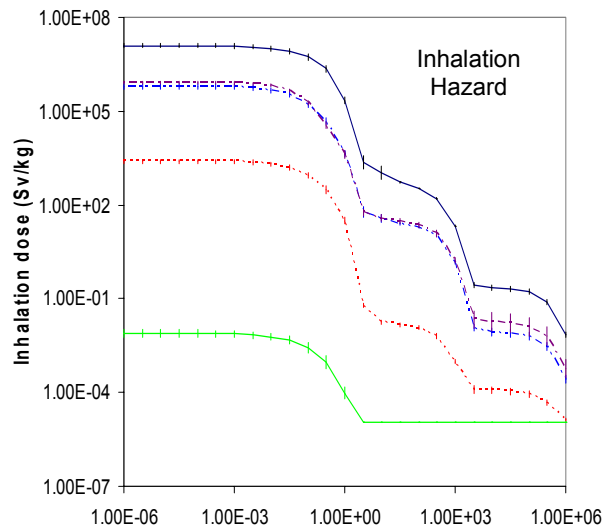
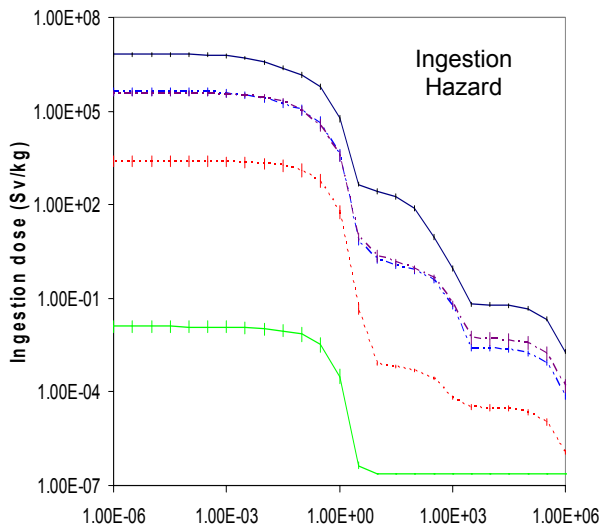
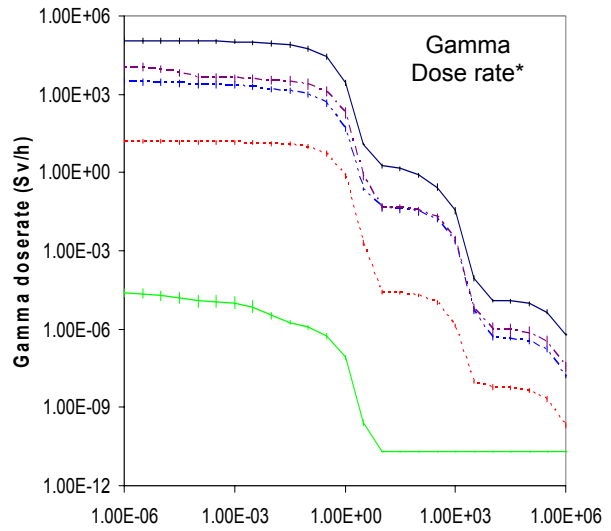
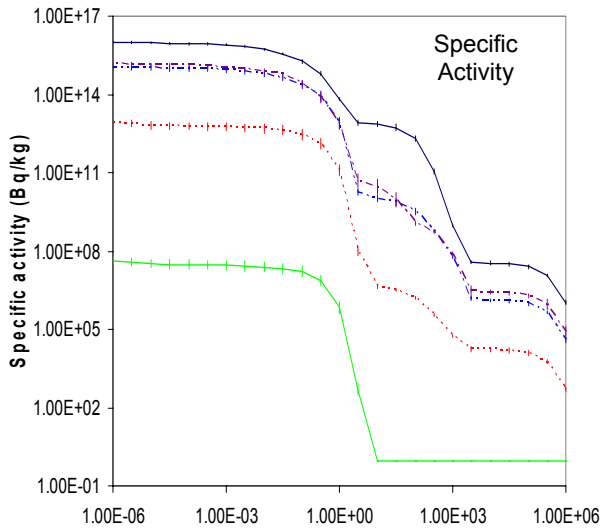


Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&Os192(n,6n)Os187(n,nt)Re184 &Os189(n,3nt)Re184 &Os192(n,5n)Os188(n,2nt)Re184							10.2 4.3 4.0
Ir192	73.82 d	&Os190(n,γ)Os191(β <sup>-</sup> )Ir191(n,γ)Ir192 &Os189(n,γ)Os190(n,γ)Os191(β <sup>-</sup> )Ir191_ (n,γ)Ir192 &Os188(n,γ)Os189(n,γ)Os190(n,γ)_ Os191(β <sup>-</sup> )Ir191(n,γ)Ir192 &Os192(n,γ)Os193(β <sup>-</sup> )Ir193(n,2n)Ir192 &Os192(n,2n)Os191(β <sup>-</sup> )Ir191(n,γ)Ir192 &Os192(n,n')Os192m(β <sup>-</sup> )Ir192 &Os192(n,n')Os192m(β <sup>-</sup> )Ir192n(n,n')Ir192 &Os192(n,d)Re191(β <sup>-</sup> )Os191(β <sup>-</sup> )Ir191_ (n,γ)Ir192	60.4 35.7 3.2	96.8 3.2	94.5 5.4				
						65.4 27.6 0.4 0.3	87.7 4.1 2.3 0.9 1.6	81.6 4.1 4.0 1.0 4.6	73.8 4.1 7.7 1.5 7.1
W185	75.10 d	&Os188(n,α)W185 &Os187(n,γ)Os188(n,α)W185 &Os189(n,2n)Os188(n,α)W185 &Os189(n,α)W186(n,2n)W185 &Os186(n,2n)Os185(β <sup>+</sup> )Re185(n,p)W185 &Os190(n,2n)Os189(n,2n)Os188(n,α)W185 &Os189(n,nα)W185 &Os190(n,2n)Os189(n,nα)W185 &Os190(n,3n)Os188(n,α)W185 &Os190(n,nα)W186(n,2n)W185 &Os192(n,4n)Os189(n,nα)W185 &Os190(n,2nα)W185 &Os192(n,3n)Os190(n,2nα)W185 &Os188(n,4n)Os185(β <sup>+</sup> )Re185(n,p)W185 &Os189(n,t)Re187(n,t)W185 &Os192(n,5n)Os188(n,α)W185 &Os190(n,nt)Re187(n,t)W185 &Os192(n,4nα)W185	98.6 1.4	98.8 1.1	98.5 1.4	49.3 17.7 12.3 6.1 4.3 2.2 1.0 0.5 0.1	25.2 1.5 0.2 0.4 0.4 38.6 2.9 10.9 1.5 5.6 2.5 0.7 0.5	7.6 0.3 0.1 24.8 0.9 0.8 0.7 9.9 33.8 2.5 3.9 1.3 1.3 0.5	6.2 0.1 13.9 0.3 0.3 0.2 1.1 24.5 1.1 0.5 2.0 1.5 3.0 30.8
Os185	93.80 d	Os184(n,γ)Os185 Os186(n,2n)Os185 Os188(n,2n)Os187(n,2n)Os186(n,2n)Os185 Os187(n,2n)Os186(n,2n)Os185 Os188(n,3n)Os186(n,2n)Os185 Os189(n,3n)Os187(n,3n)Os185 Os187(n,3n)Os185 Os190(n,4n)Os187(n,3n)Os185 Os188(n,4n)Os185 Os188(n,2n)Os187(n,3n)Os185 Os189(n,4n)Os186(n,2n)Os185 Os190(n,3n)Os188(n,4n)Os185 Os190(n,3n)Os188(n,3n)Os186(n,2n)Os185 Os190(n,3n)Os188(n,2n)Os187(n,3n)Os185 Os192(n,3n)Os190(n,4n)Os187(n,3n)Os185 Os189(n,2n)Os188(n,4n)Os185 Os189(n,5n)Os185 Os192(n,5n)Os188(n,4n)Os185 &Os192(n,4n)Os189(n,5n)Os185 Os190(n,5n)Os186(n,2n)Os185 Os190(n,6n)Os185 Os192(n,6n)Os187(n,3n)Os185 Os192(n,3n)Os190(n,6n)Os185	100.0	100.0	100.0	58.4 20.7 17.2 0.2	5.7 0.3 10.9 26.3 14.1 9.4 8.0 6.3 3.6 3.4 2.4 1.4 1.3 0.5	1.9 1.0 1.1 0.7 11.4 0.2 0.5 26.7 2.7 2.3 1.7 41.3 2.6 1.8	1.2 0.3 0.3 1.1 0.7 11.4 0.2 0.5 0.7 0.3 0.2 0.3 0.3 0.3
Os194	5.989 y	Os192(n,γ)Os193(n,γ)Os194 &Os190(n,γ)Os191(n,γ)Os192(n,γ)_ Os193(n,γ)Os194 Os189(n,γ)Os190(n,γ)Os191(n,γ)Os192_ (n,γ)Os193(n,γ)Os194	95.5 3.6 0.3	93.6 2.9 0.5	100.0	99.9	99.4	99.5	99.7
H3	12.33 y ▶	&Os190(n,γ)Os191(β <sup>-</sup> )Ir191(n,γ)Ir192_ (n,X)H1(n,γ)H2(n,γ)H3	69.4						

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	Os186(n,γ)Os187(n,X)H1(n,γ)H2(n,γ)H3 &Os189(n,γ)Os190(n,γ)Os191(β <sup>-</sup> )Ir191_ (n,γ)Ir192(n,X)H1(n,γ)H2(n,γ)H3 Os189(n,X)H3 &Os192(n,2n)Os191(β <sup>-</sup> )Ir191(n,X)H3 &Os190(n,2n)Os189(n,X)H3 Os188(n,2n)Os187(n,X)H3 Os187(n,X)H3 Os188(n,X)H3 Os190(n,X)H3 Os189(n,2n)Os188(n,2n)Os187(n,X)H3 Os186(n,2n)Os185(β <sup>+</sup> )Re185(n,X)H3 Os186(n,X)H3 Os192(n,X)H3 Os189(n,3n)Os187(n,X)H3 Os192(n,3n)Os190(n,X)H3 Os190(n,3n)Os188(n,X)H3 Os188(n,3n)Os186(n,X)H3 &Os192(n,4n)Os189(n,X)H3 Os190(n,4n)Os187(n,X)H3 Os189(n,4n)Os186(n,X)H3 Os188(n,4n)Os185(β <sup>+</sup> )Re185(n,X)H3 Os192(n,5n)Os188(n,X)H3 Os192(n,6n)Os187(n,X)H3 Os190(n,5n)Os186(n,X)H3 Os190(n,6n)Os185(β <sup>+</sup> )Re185(n,X)H3	29.4 1.0				43.9 16.8 11.1 9.3 7.3 2.7 1.8 1.2 1.1 0.8 0.2 0.2 3.0 2.7 1.7	21.5	17.6	16.2 0.3 0.2 1.8 12.0 21.3 1.6 29.5 0.3 0.5 0.4 0.2 3.6 2.9 1.5 1.2 1.1 1.5 2.3 1.2 1.0
Hf178n	31.0 y	Very long pathways of (n,α), (n,2n), β <sup>-</sup>	100.0	100.0	100.0	100.0	100.0	100.0	100.0	
Pt193	50.0 y	&Os190(n,γ)Os191(β <sup>-</sup> )Ir191(n,γ)Ir192_ (β <sup>-</sup> )Pt192(n,γ)Pt193 &Os189(n,γ)Os190(n,γ)Os191(β <sup>-</sup> )Ir191_ (n,γ)Ir192(β <sup>-</sup> )Pt192(n,γ)Pt193 &Os188(n,γ)Os189(n,γ)Os190(n,γ)Os191_ (β <sup>-</sup> )Ir191(n,γ)Ir192(β <sup>-</sup> )Pt192(n,γ)Pt193 &Os187(n,γ)Os188(n,γ)Os189(n,γ)_ Os190(n,γ)Os191(β <sup>-</sup> )Ir191(n,γ)Ir192_ (β <sup>-</sup> )Pt192(n,γ)Pt193 &Os192(n,γ)Os193(β <sup>-</sup> )Ir193(n,γ)Ir194_ (β <sup>-</sup> )Pt194(n,2n)Pt193 &Os192(n,γ)Os193(β <sup>-</sup> )Ir193(n,2n)_ Ir192(β <sup>-</sup> )Pt192(n,γ)Pt193 &Os192(n,2n)Os191(β <sup>-</sup> )Ir191(n,γ)_ Ir192(β <sup>-</sup> )Pt192(n,γ)Pt193 &Os192(n,n')Os192m(β <sup>-</sup> )Ir192(β <sup>-</sup> )_ Pt192(n,γ)Pt193	79.2 19.5 0.5 0.8	47.6 40.2 6.8 0.8	97.1 2.8					
Ir192n	241.0 y	&Os190(n,γ)Os191(β <sup>-</sup> )Ir191(n,γ)Ir192n &Os189(n,γ)Os190(n,γ)Os191(β <sup>-</sup> )Ir191_ (n,γ)Ir192n &Os190(n,γ)Os191(n,γ)Os192m(β <sup>-</sup> )Ir192n &Os189(n,γ)Os190(n,γ)Os191(n,γ)_ Os192m(β <sup>-</sup> )Ir192n &Os188(n,γ)Os189(n,γ)Os190(n,γ)_ Os191(β <sup>-</sup> )Ir191(n,γ)Ir192n Os192(n,n')Os192m(β <sup>-</sup> )Ir192n Os192(n,γ)Os193(β <sup>-</sup> )Ir193(n,2n)Ir192n	42.7 25.3 17.6 10.5 2.3	97.4 0.7 1.9 0.2	92.4 3.8 3.6 0.2					
Re186m	2.0 10 <sup>5</sup> y	&Os188(n,α)W185(β <sup>-</sup> )Re185(n,γ)Re186m &Os187(n,γ)Os188(n,α)W185(β <sup>-</sup> )_ Re185(n,γ)Re186m Os186(n,p)Re186m Os190(n,α)W187(β <sup>-</sup> )Re187(n,2n)Re186m Os187(n,p)Re187(n,2n)Re186m Os188(n,2n)Os187(n,d)Re186m Os188(n,2n)Os187(n,p)Re187(n,2n)Re186m	81.9 9.5	99.6 0.4	99.5 0.4					
	▶					28.9 22.0 7.7 7.5 6.6	4.2 4.3	1.0 1.2	0.2 0.3	



# Osmium activation characteristics

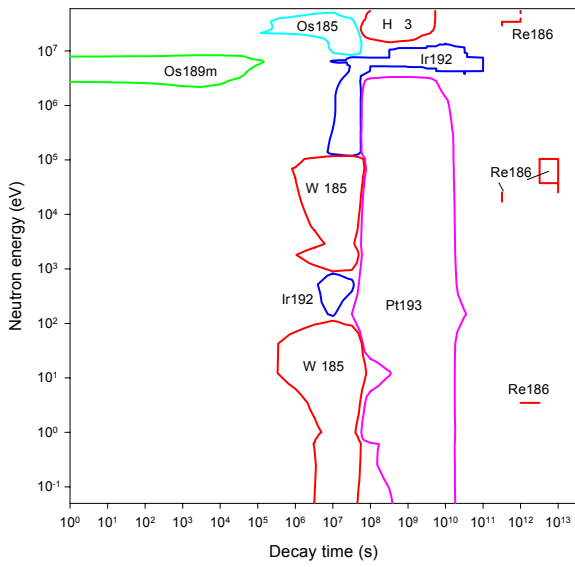


Decay time (years)

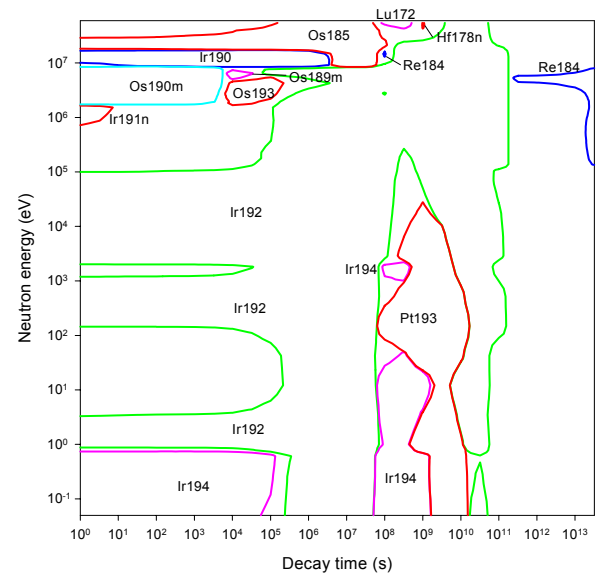
Decay time (years)

# Osmium importance diagrams & transmutation

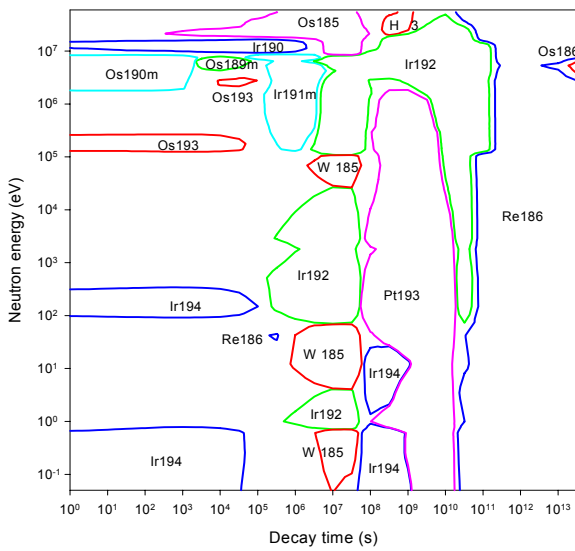
**Activity**



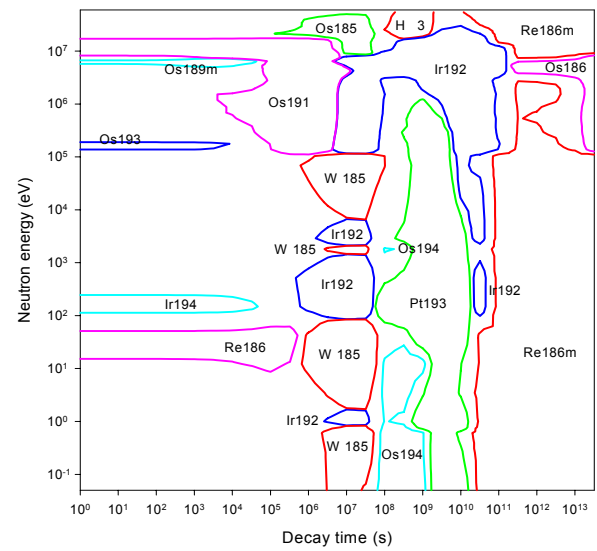
**Dose rate**



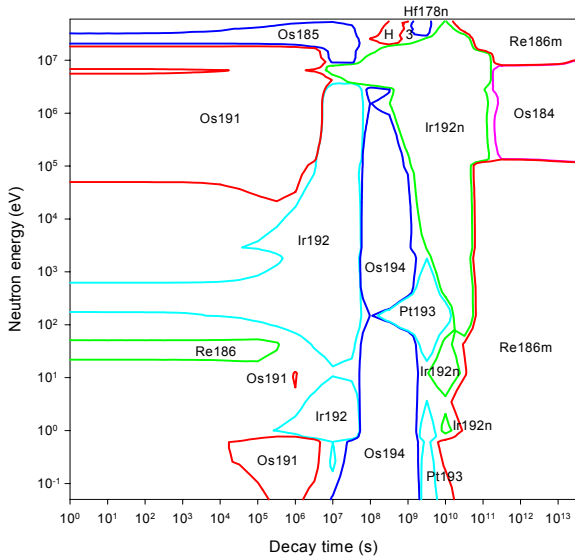
**Heat output**



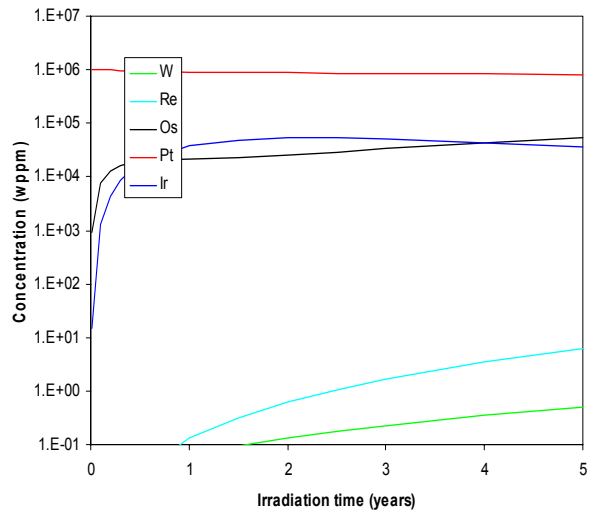
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**





# Iridium

## General properties

Atomic number	77	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	$1.0 \cdot 10^{-3}$	Ir191	37.3
Melting point / K	2719	Ir193	62.7
Boiling point / K	4701		
Density / $\text{kgm}^{-3}$	22420		
Thermal conductivity / $\text{Wm}^{-1}\text{K}^{-1}$	147		
Electrical resistivity / $\Omega\text{m}$	$5.3 \cdot 10^{-8}$		
Coefficient of thermal expansion / $\text{K}^{-1}$	$6.4 \cdot 10^{-6}$		
Crystal structure	FCC		
Number of stable isotopes	2		
Mean atomic weight	192.217		

## Activation properties

Act	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Heat	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Bq $\text{kg}^{-1}$	1.08E16	8.07E15	2.22E15	1.38E14	2.62E13	9.36E2	kW $\text{kg}^{-1}$	1.05E0	9.92E-1	2.31E-1	6.48E-3	1.85E-4	3.65E-14
Ir194	49.14	65.76	10.31				Ir194	73.21	77.24	14.31			
Ir194m	17.25						Ir192	16.97	17.96	74.67	89.36	5.02	
Ir192	9.93	13.33	46.89	25.33	0.21		Ir194m	4.19					
Pt193m	9.04	12.12	24.64				Pt193m	2.25	2.37	5.70			
Ir192m	8.47	0.90					Ir192m	0.80	0.07				
Ir193m	1.51	2.02	5.80				Pt191	0.72	0.77	1.34			
Pt191	1.22	1.63	2.41				Ir190	0.45	0.47	1.65			
Pt193	0.96	1.29	4.70	74.61	99.57		Pt195m	0.33	0.35	0.79			
Pt195m	0.81	1.08	2.10				Pt193	0.07	0.07	0.30	10.60	94.16	
Os191	0.26	0.35	1.09				Re186						73.52
Re186						49.98	Re186m						26.36
Re186m						49.98	Pt190						0.10
Dose	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Ing	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{h}^{-1}$	1.59E5	1.53E5	8.22E4	2.56E3	1.24E1	3.81E-10	Sv $\text{kg}^{-1}$	1.30E7	9.06E6	2.12E6	5.21E4	9.05E2	1.73E-6
Ir192	50.30	52.50	91.75	98.71	32.64		Ir194	53.21	76.14	14.01			
Ir194	41.22*	42.88	3.34				Ir194m	30.16					
Ir194m	2.61						Ir192	11.58	16.62	68.64	93.83	8.68	
Ir190	2.13	2.23	3.26				Pt193m	3.39	4.86	11.59			
Pt191	1.70	1.77	1.30				Pt195m	0.42	0.61	1.38			
Ir191n	1.38						Ir193m	0.34	0.49	1.64			
Pt193	0.02	0.02	0.04	1.29	67.32		Pt193	0.03	0.04	0.15	6.12	89.41	
Ir192n					0.04		Ir192n				0.04	1.92	
Re186m						60.79	Re186m						59.43
Re186						36.50*	Re186						40.52
Inh	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Clear	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{kg}^{-1}$	3.49E7	1.06E7	7.33E6	2.36E5	3.10E3	6.15E-6		1.49E12	1.18E12	1.07E12	3.85E10	9.57E8	3.22E-2
Ir194m	69.69						Ir192	72.45	90.94	96.73	90.78	5.86	
Ir192	20.37	67.27	93.64	97.83	11.93		Ir194m	18.50					
Ir194	8.55	28.15	1.75				Ir194	3.59	4.49	0.21			
Ir193m	0.61	2.01	2.28				Ir190	1.27	1.60	1.43			
Pt193m	0.34	1.11	0.90				Ir191n	1.25					
Os191	0.15	0.50	0.63				Pt191	0.89	1.11	0.50			
Ir192n	0.01	0.03	0.04	1.23	70.42		Pt195m	0.54	0.67	0.39			
Pt193	0.01	0.02	0.03	0.92	17.66		Pt193	0.24	0.30	0.33	9.22	94.03	
Re186m						91.24	Pt193m	0.07	0.08	0.05			
Re186						8.36	Re186m						96.73
Pt190						0.26	Re186						1.45

# Iridium

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Ir191n	5.50 s	Ir191(n,n')Ir191n				86.9	76.1	90.1	92.7
		Ir193(n,2n)Ir192(β <sup>-</sup> )Pt192(n,2n)Pt191 <sub>-</sub> (β <sup>+</sup> )Ir191(n,n')Ir191n &Ir193(n,3n)Ir191(n,n')Ir191n Ir193(n,3n)Ir191n				4.3	0.1	17.0	4.9
Ir194	19.30 h	&Ir193(n,γ)Ir194	59.0	65.5	99.8	99.0	100.0	99.8	100.0
		&Ir191(n,γ)Ir192(n,γ)Ir193(n,γ)Ir194	37.5	34.5	0.2				
Ir188	1.729 d	&Ir191(n,2n)Ir190(n,2n)Ir189(n,2n)Ir188 Ir191(n,3n)Ir189(n,2n)Ir188 Ir193(n,2n)Ir192(β <sup>-</sup> )Pt192(n,2n)Pt191(β <sup>+</sup> ) Ir191(n,2n)Ir190(n,2n)Ir189(n,2n)Ir188 &Ir191(n,2n)Ir190(n,3n)Ir188 Ir191(n,4n)Ir188 &Ir193(n,3n)Ir191(n,4n)Ir188 Ir193(n,2n)Ir192(β <sup>-</sup> )Pt192(n,3n)Pt190 <sub>-</sub> (n,3n)Pt188(β <sup>+</sup> )Ir188 Ir193(n,6n)Ir188				65.9	1.7		
					15.9		2.8	0.8	91.3
Au198	2.694 d	&Ir193(n,γ)Ir194(n,γ)Ir195(β <sup>-</sup> )Pt195(n,γ) <sub>-</sub> Pt196(n,γ)Pt197(β <sup>-</sup> )Au197(n,γ)Au198 &Ir193(n,γ)Ir194(β <sup>-</sup> )Pt194(n,γ)Pt195(n,γ) <sub>-</sub> Pt196(n,γ)Pt197(β <sup>-</sup> )Au197(n,γ)Au198 &Ir191(n,γ)Ir192(n,γ)Ir193(n,γ)Ir194 <sub>-</sub> (n,γ)Ir195(β <sup>-</sup> )Pt195(n,γ)Pt196(n,γ)Pt197 <sub>-</sub> (β <sup>-</sup> )Au197(n,γ)Au198 &Ir191(n,γ)Ir192(n,γ)Ir193(n,γ)Ir194 <sub>-</sub> (β <sup>-</sup> )Pt194(n,γ)Pt195(n,γ)Pt196(n,γ) <sub>-</sub> Pt197(β <sup>-</sup> )Au197(n,γ)Au198 &Ir193(n,γ)Ir194(n,γ)Ir195m(β <sup>-</sup> )Pt195 <sub>-</sub> (n,γ)Pt196(n,γ)Pt197(β <sup>-</sup> )Au197(n,γ)Au198 &Ir191(n,γ)Ir192(n,γ)Ir193(n,γ)Ir194 <sub>-</sub> (n,γ)Ir195m(β <sup>-</sup> )Pt195(n,γ)Pt196(n,γ) <sub>-</sub> Pt197(β <sup>-</sup> )Au197(n,γ)Au198 &Ir191(n,γ)Ir192(β <sup>-</sup> )Pt192(n,γ)Pt193 <sub>-</sub> (n,γ)Pt194(n,γ)Pt195(n,γ)Pt196(n,γ) <sub>-</sub> Pt197(β <sup>-</sup> )Au197(n,γ)Au198	35.4	0.8	0.2				
			23.1	68.4	99.2	100.0			
Au199	3.139 d	&Ir193(n,γ)Ir194(n,γ)Ir195(β <sup>-</sup> )Pt195 <sub>-</sub> (n,γ)Pt196(n,γ)Pt197(β <sup>-</sup> )Au197(n,γ) <sub>-</sub> Au198(n,γ)Au199 &Ir193(n,γ)Ir194(β <sup>-</sup> )Pt194(n,γ)Pt195 <sub>-</sub> (n,γ)Pt196(n,γ)Pt197(β <sup>-</sup> )Au197(n,γ) <sub>-</sub> Au198(n,γ)Au199 &Ir191(n,γ)Ir192(n,γ)Ir193(n,γ)Ir194 <sub>-</sub> (n,γ)Ir195(β <sup>-</sup> )Pt195(n,γ)Pt196(n,γ) <sub>-</sub> Pt197(β <sup>-</sup> )Au197(n,γ)Au198(n,γ)Au199 &Ir191(n,γ)Ir192(n,γ)Ir193(n,γ)Ir194 <sub>-</sub> (β <sup>-</sup> )Pt194(n,γ)Pt195(n,γ)Pt196(n,γ) <sub>-</sub> Pt197(β <sup>-</sup> )Au197(n,γ)Au198(n,γ)Au199 &Ir193(n,γ)Ir194(n,γ)Ir195m(β <sup>-</sup> )Pt195 <sub>-</sub> (n,γ)Pt196(n,γ)Pt197(β <sup>-</sup> )Au197(n,γ) <sub>-</sub> Au198(n,γ)Au199 &Ir191(n,γ)Ir192(n,γ)Ir193(n,γ)Ir194(n,γ) <sub>-</sub> Ir195m(β <sup>-</sup> )Pt195(n,γ)Pt196(n,γ)Pt197(β <sup>-</sup> ) <sub>-</sub> Au197(n,γ)Au198(n,γ)Au199 &Ir191(n,γ)Ir192(β <sup>-</sup> )Pt192(n,γ)Pt193 <sub>-</sub> (n,γ)Pt194(n,γ)Pt195(n,γ)Pt196(n,γ)Pt197 <sub>-</sub> (β <sup>-</sup> )Au197(n,γ)Au198(n,γ)Au199	35.7	0.8					
			22.6	66.2	100.0				
			19.9						
			12.1	15.9					
			4.8						
			2.2						
				11.2					

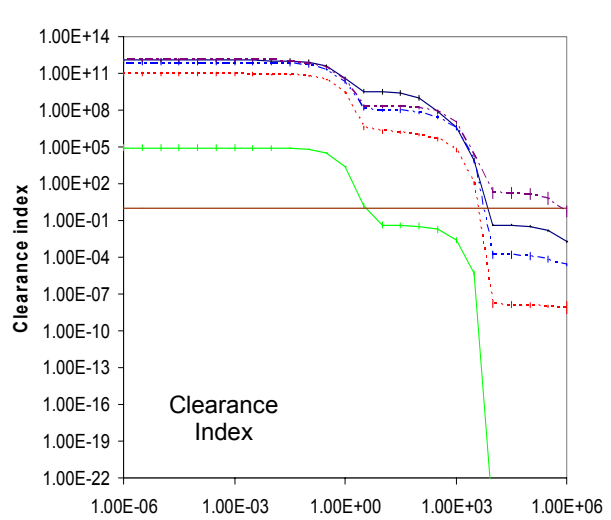
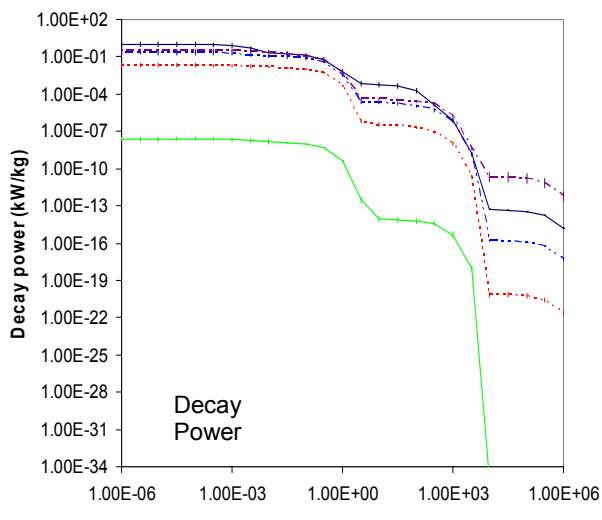
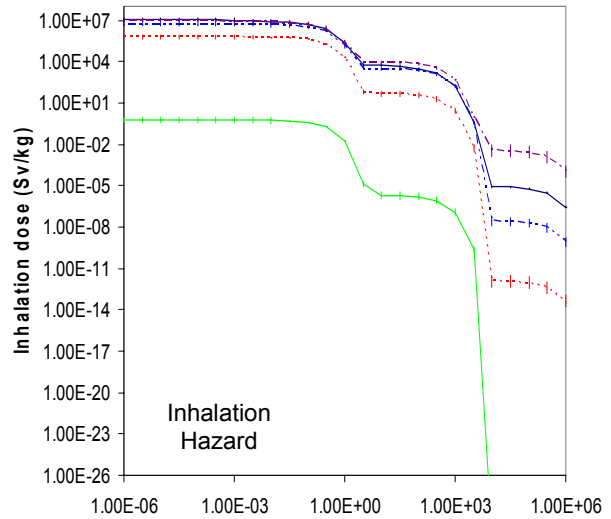
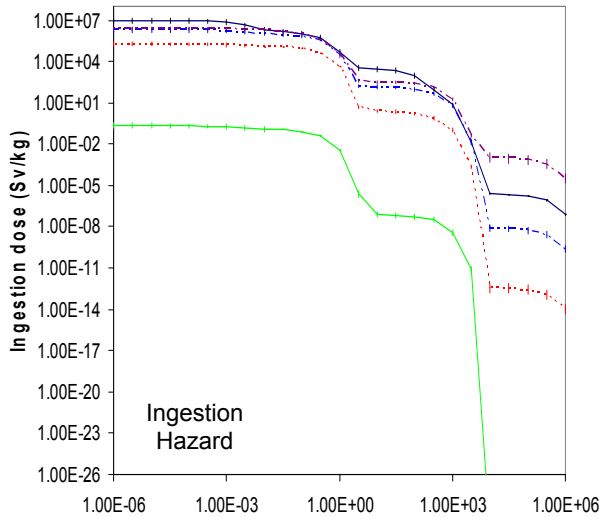
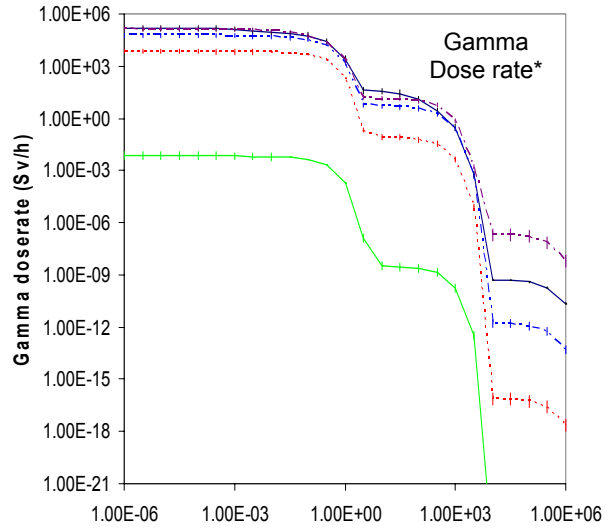
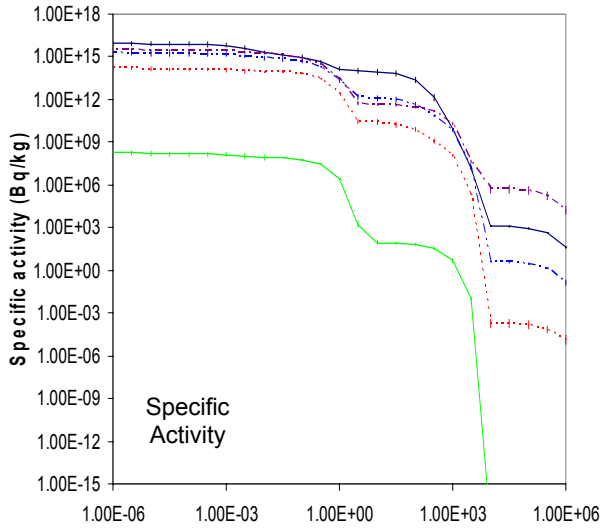


Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
Re186	3.775 d	&Ir191(n,α)Re188(β <sup>-</sup> )Os188(n,α) W185(β <sup>-</sup> )Re185(n,γ)Re186 &Ir191(n,2n)Ir190(β <sup>+</sup> )Os190(n,α) W187(β <sup>-</sup> )Re187(n,2n)Re186 Ir191(n,nα)Re187(n,2n)Re186 Ir191(n,2n)Ir190n(β <sup>+</sup> )Os190m(IT) Os190(n,α)W187(β <sup>-</sup> )Re187(n,2n)Re186 &Ir191(n,2n)Ir190(n,α)Re187(n,2n)Re186 &Ir191(n,3n)Ir189(β <sup>+</sup> )Os189(n,3n) Os187(n,d)Re186 Ir191(n,2nα)Re186 &Ir191(n,3n)Ir189(β <sup>+</sup> )Os189(n,nt)Re186 &Ir191(n,3n)Ir189(β <sup>+</sup> )Os189(n,4n) Os186(n,p)Re186 &Ir193(n,3n)Ir191(n,2nα)Re186 &Ir191(n,3n)Ir189(β <sup>+</sup> )Os189(n,t)Re187 (n,2n)Re186 Ir191(n,3n)Ir189(β <sup>+</sup> )Os189(n,2n)Os188 (n,t)Re186 Ir191(n,4n)Ir188(β <sup>+</sup> )Os188(n,t)Re186 Ir193(n,4n)Ir190(β <sup>+</sup> )Os190(n,4n)Os187 (n,d)Re186 Ir191(n,5n)Ir187(β <sup>+</sup> )Os187(n,d)Re186 &Ir193(n,5n)Ir189(β <sup>+</sup> )Os189(n,nt)Re186 Ir193(n,4n)Ir190(β <sup>+</sup> )Os190(n,2nt)Re186 Ir193(n,3nα)Re187(n,2n)Re186 Ir193(n,4nα)Re186 Ir193(n,6n)Ir188(β <sup>+</sup> )Os188(n,t)Re186 &Ir193(n,nt)Os190(n,2nt)Re186	100.0	100.0	100.0					
						61.8	0.2			
						22.5	17.2	2.2	0.4	
						4.0				
						1.9				
							26.2	0.6		
							14.6	30.4	13.4	
							12.4	6.2	5.0	
							3.5	0.4		
							3.3	1.7	0.4	
							3.0	0.6	0.1	
							1.0	0.3		
							0.9	28.1	3.5	
							0.6	3.9		
								3.8	11.2	
								3.1	19.5	
								0.9	1.9	
								0.4	1.1	
									17.6	
									10.5	
									1.1	
Pt195m	4.020 d	&Ir193(n,γ)Ir194(β <sup>-</sup> )Pt194(n,γ)Pt195m &Ir191(n,γ)Ir192(n,γ)Ir193(n,γ)Ir194 (β <sup>-</sup> )Pt194(n,γ)Pt195m &Ir191(n,γ)Ir192(β <sup>-</sup> )Pt192(n,γ)Pt193 (n,γ)Pt194(n,γ)Pt195m &Ir193(n,γ)Ir194(β <sup>-</sup> )Pt194(n,γ)Pt195 (n,n')Pt195m	63.1 36.1 0.1	63.4 20.7 15.7	99.6	94.5	96.4	97.5	98.4	
						2.4	1.4	0.9	0.6	
Pt193m	4.340 d	&Ir191(n,γ)Ir192(β <sup>-</sup> )Pt192(n,γ)Pt193m &Ir193(n,γ)Ir194(β <sup>-</sup> )Pt194(n,2n)Pt193m &Ir193(n,2n)Ir192(β <sup>-</sup> )Pt192(n,γ)Pt193m	99.5	99.9	100.0	71.2 24.3	71.1 25.8	73.3 24.2	75.8 22.6	
Ir193m	10.602 d	&Ir191(n,γ)Ir192(β <sup>+</sup> )Os192(n,γ)Os193 (β <sup>-</sup> )Ir193m &Ir191(n,γ)Ir192(n,γ)Ir193m Ir193(n,n')Ir193m	91.9	1.1 97.8	0.1 99.5					
						99.9	99.9	99.9	99.9	
Ir190	12.00 d	&Ir191(n,2n)Ir190 &Ir193(n,2n)Ir192(β <sup>-</sup> )Pt192(n,2n) Pt191(β <sup>+</sup> )Ir191(n,2n)Ir190 &Ir193(n,4n)Ir190 &Ir193(n,3n)Ir191(n,2n)Ir190 &Ir193(n,2n)Ir192n(n,3n)Ir190				87.8 3.8	43.4	10.8	28.3	
							40.9 9.4 3.2	86.8	69.0	
Ir189	13.20 d	&Ir191(n,2n)Ir190(n,2n)Ir189 Ir191(n,3n)Ir189 &Ir193(n,2n)Ir192(β <sup>-</sup> )Pt192(n,2n) Pt191(β <sup>+</sup> )Ir191(n,2n)Ir190(n,2n)Ir189 &Ir193(n,2n)Ir192(β <sup>-</sup> )Pt192(n,2n) Pt191(β <sup>+</sup> )Ir191(n,3n)Ir189 &Ir193(n,3n)Ir191(n,3n)Ir189 Ir193(n,2n)Ir192n(n,4n)Ir189 Ir193(n,5n)Ir189 Ir193(n,2n)Ir192(β <sup>-</sup> )Pt192(n,4n)Pt189(β <sup>+</sup> )Ir189				67.2 16.1 4.5	78.5	57.1	19.6	
						1.1				
							17.6 0.4	3.1 2.9	77.0	
								29.9		
								2.7		
Hg203	46.603 d	Very long pathways of (n,α), (n,2n), β <sup>-</sup>	100.0	100.0	100.0					
Ir192	73.822d	&Ir191(n,γ)Ir192	100.0	99.0	100.0					

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
		Ir193(n,2n)Ir192				95.9	96.9	97.7	97.5	
Os185	93.80 d	Ir191(n,n $\alpha$ )Re187(n,2n)Re186( $\beta^-$ )_Os186(n,2n)Os185 Ir191(n,2n $\alpha$ )Re186( $\beta^-$ )Os186(n,2n)Os185 &Ir191(n,3n)Ir189( $\beta^+$ )Os189(n,3n)_Os187(n,3n)Os185 &Ir191(n,3n)Ir189( $\beta^+$ )Os189(n,4n)_Os186(n,2n)Os185 Ir191(n,4n)Ir188( $\beta^+$ )Os188(n,4n)Os185 &Ir191(n,3n)Ir189( $\beta^+$ )Os189(n,5n)Os185 &Ir193(n,5n)Ir189( $\beta^+$ )Os189(n,5n)Os185 Ir191(n,5n)Ir187( $\beta^+$ )Os187(n,3n)Os185 Ir193(n,6n)Ir188( $\beta^+$ )Os188(n,4n)Os185 Ir193(n,4n)Ir190( $\beta^+$ )Os190(n,6n)Os185 &Ir193(n,nt)Os190(n,6n)Os185 Other similar long pathways				65.7 25.1 9.2	66.7 9.3 1.0 23.0	0.3 1.0 67.8 6.3 3.1 2.1 19.4	3.7 8.6 33.6 8.6 11.3 6.3 3.7 24.2	
Os194	5.989 y	&Ir191(n, $\gamma$ )Ir192( $\beta^+$ )Os192(n, $\gamma$ )Os193_(n, $\gamma$ )Os194 Ir193(n,p)Os193(n, $\gamma$ )Os194 &Ir193(n, $\gamma$ )Ir194(n,p)Os194	100.0	100.0	100.0		68.2 29.2	69.8 28.4	71.0 27.7	71.4 27.8
H3	12.33 y	&Ir191(n, $\gamma$ )Ir192(n,X)H1(n, $\gamma$ )H2(n, $\gamma$ )H3 Ir193(n,2n)Ir192n(n,X)H3 Ir191(n,X)H3 Ir193(n,X)H3 &Ir193(n,2n)Ir192(n,X)H3 Ir191(n,3n)Ir189( $\beta^+$ )Os189(n,X)H3 &Ir193(n,3n)Ir191(n,X)H3 Ir191(n,4n)Ir188( $\beta^+$ )Os188(n,X)H3 Ir191(n,5n)Ir187( $\beta^+$ )Os187(n,X)H3 Ir193(n,6n)Ir188( $\beta^+$ )Os188(n,X)H3	91.7			42.3 25.8 22.2 4.7	1.3 33.8 51.8 0.1 4.5 3.6	0.7 33.7 52.9 1.4 2.4	33.3 51.5 2.1 1.7	
Pt193	50.0 y	&Ir191(n, $\gamma$ )Ir192( $\beta^-$ )Pt192(n, $\gamma$ )Pt193 Ir191(n, $\gamma$ )Ir192m( $\beta^-$ )Pt192(n, $\gamma$ )Pt193 &Ir193(n, $\gamma$ )Ir194( $\beta^-$ )Pt194(n,2n)Pt193 &Ir193(n,2n)Ir192( $\beta^-$ )Pt192(n, $\gamma$ )Pt193	99.5 0.3	100.0	100.0		56.8 41.5	53.6 45.0	54.9 44.0	55.6 43.7
Ir192n	241.0 y	Ir191(n, $\gamma$ )Ir192n Ir193(n,2n)Ir192n	100.0	99.1	100.0		97.8	98.2	98.1	98.1
Re186m	2.0 10 <sup>5</sup> y	&Ir191(n, $\alpha$ )Re188( $\beta^-$ )Os188(n, $\alpha$ )_W185( $\beta^-$ )Re185(n, $\gamma$ )Re186m &Ir191(n,2n)Ir190( $\beta^+$ )Os190(n, $\alpha$ )_W187( $\beta^-$ )Re187(n,2n)Re186m Ir191(n,n $\alpha$ )Re187(n,2n)Re186m Ir191(n,2n)Ir190n( $\beta^+$ )Os190m(IT)Os190_(n, $\alpha$ )W187( $\beta^-$ )Re187(n,2n)Re186m &Ir191(n,2n)Ir190(n, $\alpha$ )Re186m &Ir191(n,2n)Ir190(n, $\alpha$ )Re187(n,2n)Re186m Ir191(n,2n $\alpha$ )Re186m &Ir191(n,3n)Ir189( $\beta^+$ )Os189(n,3n)_Os187(n,d)Re186m &Ir191(n,3n)Ir189( $\beta^+$ )Os189(n,nt)Re186m &Ir193(n,3n)Ir191(n,2n $\alpha$ )Re186m &Ir191(n,3n)Ir189( $\beta^+$ )Os189(n,4n)_Os186(n,p)Re186m Ir191(n,4n)Ir188( $\beta^+$ )Os188(n,t)Re186m Ir191(n,3n)Ir189( $\beta^+$ )Os189(n,2n)Os188_(n,t)Re186m Ir191(n,3n)Ir189( $\beta^+$ )Os189(n,t)Re187_(n,2n)Re186m Ir191(n,3n)Ir189(n,3n)Ir187( $\beta^+$ )Os187_(n,d)Re186m Ir193(n,4n)Ir190( $\beta^+$ )Os190(n,4n)Os187_(n,d)Re186m	94.6	100.0	100.0	54.1 30.2 3.5 2.6 2.5	9.2 0.5 0.2 31.4 25.8	0.1 0.1 16.1 3.7 1.3 4.2 2.1	4.3 0.2 4.2 4.3 0.2 4.2 2.1	



# Iridium activation characteristics

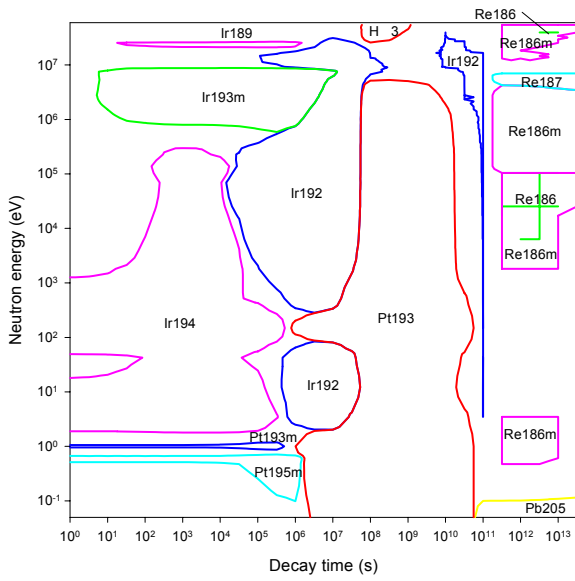


Decay time (years)

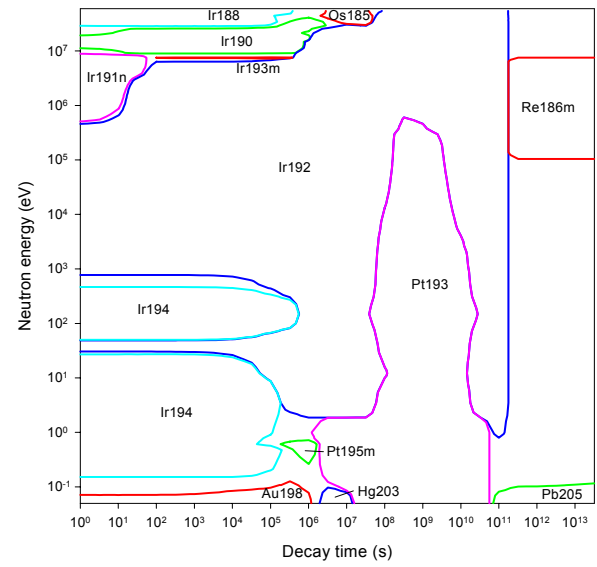
Decay time (years)

# Iridium importance diagrams & transmutation

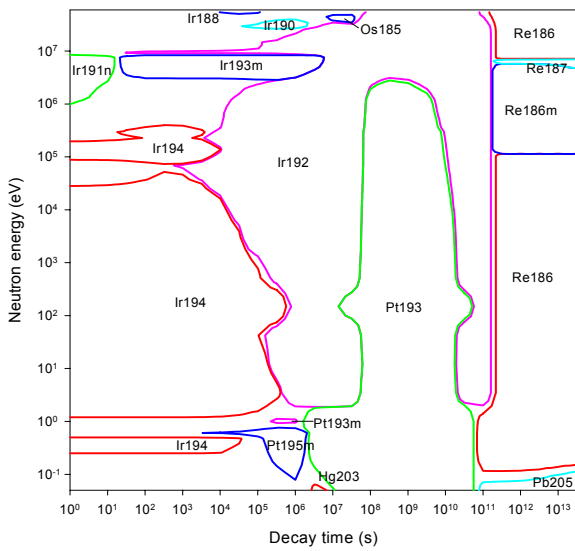
**Activity**



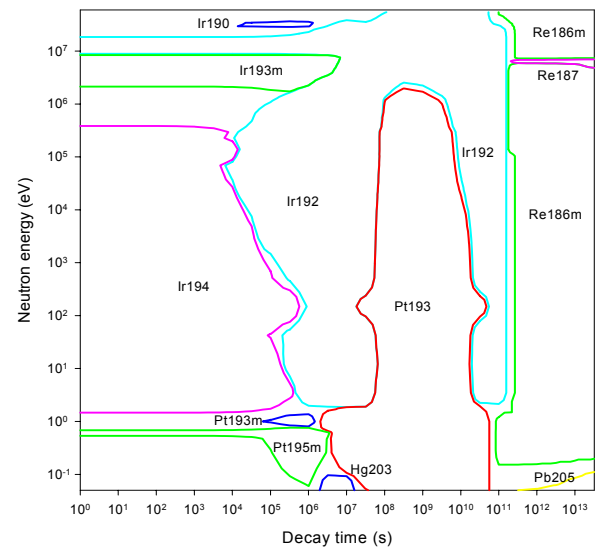
**Dose rate**



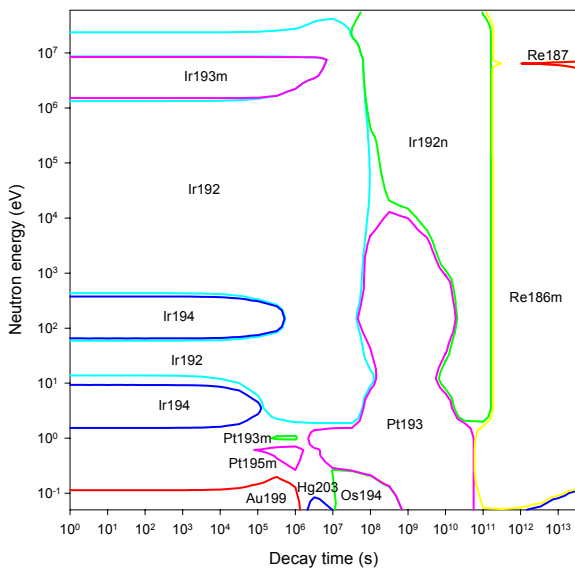
**Heat output**



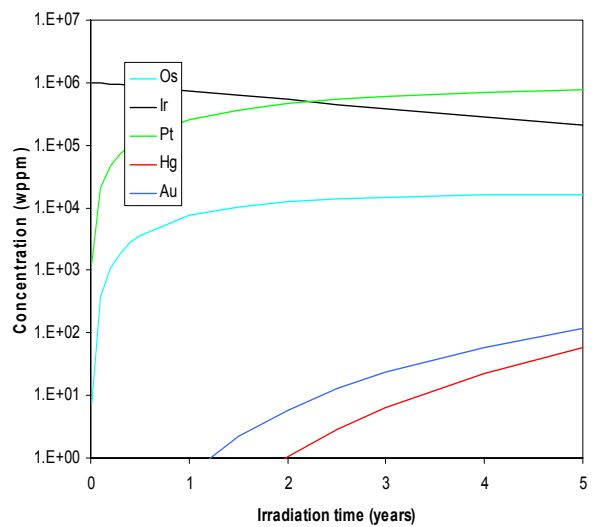
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**





# Platinum

## General properties

Atomic number	78	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	$5.0 \cdot 10^{-3}$	Pt190	0.014 ( $T_{1/2}=6.50 \cdot 10^{11}$ y)
Melting point / K	2041.6	Pt192	0.782
Boiling point / K	4098	Pt194	32.967
Density / $\text{kgm}^{-3}$	21450	Pt195	33.832
Thermal conductivity / $\text{Wm}^{-1}\text{K}^{-1}$	71.6	Pt196	25.242
Electrical resistivity / $\Omega\text{m}$	$1.06 \cdot 10^{-7}$	Pt198	7.163
Coefficient of thermal expansion / $\text{K}^{-1}$	$8.8 \cdot 10^{-6}$		
Crystal structure	FCC		
Number of stable isotopes	5 (6)		
Mean atomic weight	195.08		

## Activation properties

Act	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Heat	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Bq $\text{kg}^{-1}$	2.36E15	2.31E15	6.82E14	1.56E13	3.92E12	1.52E11	kW $\text{kg}^{-1}$	1.56E-1	1.51E-1	3.98E-2	1.24E-4	2.62E-5	4.04E-15
Pt197	26.05	26.58	4.28				Au198	35.84	36.98	55.07			
Au198	20.29	20.74	27.51				Pt199	22.22	20.38				
Pt195m	13.53	13.84	25.00				Pt197	17.59	18.12	3.28			
Au199	12.50	12.79	19.48				Pt195m	8.03	8.29	16.81			
Pt199	12.24	11.13					Au199	7.30	7.54	12.90			
Pt193m	9.47	9.68	18.33				Pt193m	3.45	3.56	7.56			
Pt197m	1.99	1.96					Pt197m	1.89	1.88				
Pt193	0.66	0.67	2.29	99.16	99.99		Ir194	0.96	0.99	0.16			
Au196	0.52	0.53	1.21				Au196	0.63	0.65	1.66			
Ir192	0.16	0.16	0.54	0.80			Ir192	0.40	0.42	1.55	16.74	0.04	
Pt190						47.35	Pt193	0.06	0.06	0.26	83.17	99.94	
Re186						26.31	Ir194m	0.05					
Re186m						26.31	Pt190						92.31
Dose	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Ing	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{h}^{-1}$	3.07E4	2.99E4	9.57E3	1.37E1	1.22E0	3.16E-12	Sv $\text{kg}^{-1}$	1.21E6	1.20E6	4.34E5	6.56E2	1.22E2	7.36E-8
Au198	72.50	74.54	90.98				Au198	39.51	39.80	43.24			
Pt199	21.04	19.23					Pt197	20.28	20.40	2.69			
Au196	1.14	1.17	2.44				Pt195m	16.60	16.73	24.76			
Au199	1.09	1.12	1.58				Au199	10.71	10.80	13.47			
Ir192	0.89	0.91	2.76	64.98	0.43		Pt193m	8.30	8.36	12.96			
Pt195m	0.76	0.78	1.30				Ir194	1.11	1.25	0.13			
Pt197	0.50	0.51	0.07				Pt199	0.93	0.83				
Ir194m	0.02						Ir194m	0.60					
Pt193		0.01	0.05	34.98	99.56		Ir192	0.44	0.44	1.20	26.74	0.08	
Re186m						60.37	Pt193	0.04	0.04	0.11	73.04	99.89	
Re186						36.58*	Pt190						79.95
							Re186m						11.92
							Re186						8.13
Inh	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Clear	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{kg}^{-1}$	8.79E5	8.32E5	3.46E5	1.17E3	8.57E1	1.70E-6		1.72E11	1.61E11	4.43E10	6.59E8	1.35E8	7.45E-3
Au198	46.94	49.53	46.64				Pt199	43.10	41.06				
Au199	26.57	28.06	30.34				Au198	27.85	29.84	42.31			
Pt195m	6.55	6.91	8.87				Pt195m	16.89	18.09	34.96			
Pt197	5.95	6.91	8.87				Au196	3.42	3.66	8.87			
Ir194m	5.20						Ir192	2.24	2.40	8.42	19.02	0.05	
Pt193m	3.05	3.22	4.33				Au199	1.71	1.84	2.99			
Ir192	2.90	3.06	7.12	70.95	0.57		Pt197	0.35	0.38	0.06			
Ir194	0.66	0.70	0.07				Pt193	0.31	0.33	1.21	80.90	99.94	
Au196	0.52	0.55	0.88				Ir194m	0.30					
Hg197	0.39	0.42	0.47				Pt197m	0.27	0.28				
Pt193	0.03	0.03	0.09	27.85	96.00		Pt193m	0.13	0.13	0.28			
Ir192n				0.33	3.41		Pt190						96.32
Os194				0.07			Re186m						3.56
Pt190						96.92	Re186						0.05

# Platinum

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
Pt199	30.80 m	&Pt198(n,γ)Pt199	100.0	100.0	100.0	100.0	100.0	100.0	100.0	
Pt197	19.892 h	&Pt195(n,γ)Pt196(n,γ)Pt197 &Pt196(n,γ)Pt197 &Pt194(n,γ)Pt195(n,γ)Pt196(n,γ)Pt197 &Pt198(n,2n)Pt197 &Pt198(n,d)Ir197(β <sup>-</sup> )Pt197	49.9 48.1 2.0	57.5 42.7	15.8 83.9 0.3	0.5 99.5	0.5 95.9 2.3	0.4 84.0 15.6	77.2 22.8	
Au194	1.584 d	&Pt198(n,2n)Pt197(β <sup>-</sup> )Au197(n,2n)Au196 (β <sup>-</sup> )Hg196(n,2n)Hg195(β <sup>+</sup> )Au195(n,2n)Au194 &Pt198(n,2n)Pt197(β <sup>-</sup> )Au197(n,2n) Au196(β <sup>-</sup> )Hg196(n,2n)Hg195m(β <sup>+</sup> ) Au195(n,2n)Au194 &Pt198(n,2n)Pt197(β <sup>-</sup> )Au197(n,2n) Au196(n,2n)Au195(n,2n)Au194 &Pt198(n,2n)Pt197(β <sup>-</sup> )Au197(n,4n)Au194 &Pt198(n,2n)Pt197(β <sup>-</sup> )Au197(n,3n) Au195(n,2n)Au194 &Pt198(n,d)Ir197m(β <sup>-</sup> )Pt197(β <sup>-</sup> ) Au197(n,4n)Au194 &Pt198(n,d)Ir197(β <sup>-</sup> )Pt197(β <sup>-</sup> )Au197 (n,4n)Au194 &Pt198(n,2n)Pt197m(β <sup>-</sup> )Au197(n,4n)Au194				49.5 27.5 12.2		62.7 26.5 2.4 1.5 1.5	81.1 81.1 1.2 5.9 2.0	74.5 74.5 13.0 8.8 1.9
Ir188	1.729 d	Pt190(n,2n)Pt189(β <sup>+</sup> )Ir189(n,2n)Ir188 Pt192(n,2n)Pt191(β <sup>+</sup> )Ir191(n,2n)Ir190 (n,2n)Ir189(n,2n)Ir188 Pt194(n,3n)Pt192(n,3n)Pt190(n,3n) Pt188(β <sup>+</sup> )Ir188 Pt192(n,3n)Pt190(n,3n)Pt188(β <sup>+</sup> )Ir188 Pt195(n,4n)Pt192(n,3n)Pt190(n,3n) Pt188(β <sup>+</sup> )Ir188 Pt196(n,3n)Pt194(n,3n)Pt192(n,3n) Pt190(n,3n)Pt188(β <sup>+</sup> )Ir188 Pt194(n,4n)Pt191(β <sup>+</sup> )Ir191(n,4n)Ir188 Pt195(n,5n)Pt191(β <sup>+</sup> )Ir191(n,4n)Ir188 Pt194(n,5n)Pt190(n,3n)Pt188(β <sup>+</sup> )Ir188 Pt195(n,4n)Pt192(n,5n)Pt188(β <sup>+</sup> )Ir188 Pt194(n,3n)Pt192(n,5n)Pt188(β <sup>+</sup> )Ir188 Pt196(n,5n)Pt192(n,5n)Pt188(β <sup>+</sup> )Ir188 Pt192(n,5n)Pt188(β <sup>+</sup> )Ir188 Pt195(n,6n)Pt190(n,3n)Pt188(β <sup>+</sup> )Ir188 Other long pathways				82.9 4.2	60.4 10.5 9.1 4.0 0.3	1.0 0.6 2.6	2.9 65.0 4.8 2.0 0.8 0.3 19.4 5.2 5.2 32.7	
Au198	2.694 d	&Pt196(n,γ)Pt197(β <sup>-</sup> )Au197(n,γ)Au198 &Pt195(n,γ)Pt196(n,γ)Pt197(β <sup>-</sup> )Au197 (n,γ)Au198 &Pt194(n,γ)Pt195(n,γ)Pt196(n,γ)Pt197 (β <sup>-</sup> )Au197(n,γ)Au198 &Pt198(n,2n)Pt197(β <sup>-</sup> )Au197(n,γ)Au198 Pt198(n,2n)Pt197m(β <sup>-</sup> )Au197m(IT) Au197(n,γ)Au198 &Pt198(n,γ)Pt199(β <sup>-</sup> )Au199(β <sup>-</sup> )Hg199 (n,d)Au198 Pt198(n,γ)Pt199m(IT)Pt199(β <sup>-</sup> )Au199 (β <sup>-</sup> )Hg199(n,d)Au198 Pt198(n,d)Ir197m(β <sup>-</sup> )Pt197m(IT)Pt197 (β <sup>-</sup> )Au197(n,γ)Au198 Pt198(n,d)Ir197(β <sup>-</sup> )Pt197(β <sup>-</sup> )Au197 (n,γ)Au198	50.9 47.3 1.5	42.9 56.8	91.0 8.8	0.4 95.0 1.6	0.3 63.2 1.5 19.9 8.3 2.4 1.5	0.2 49.0 1.2 27.0 11.2 5.4 3.5	0.3 48.2 1.2 24.3 10.1 8.4 5.7	



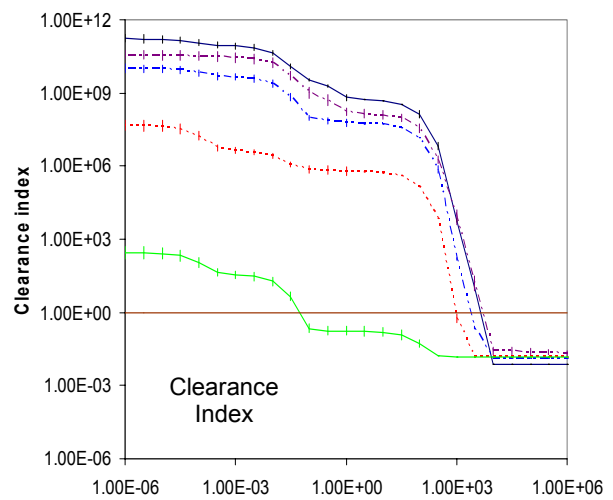
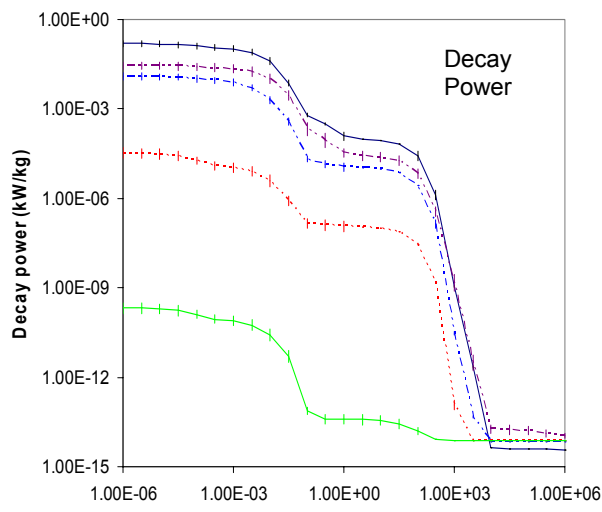
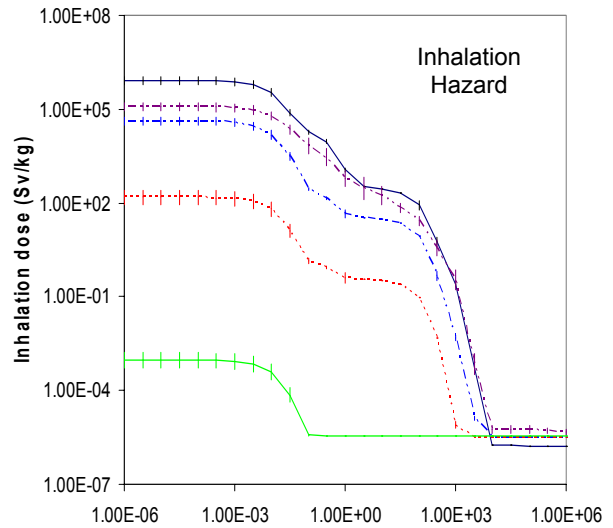
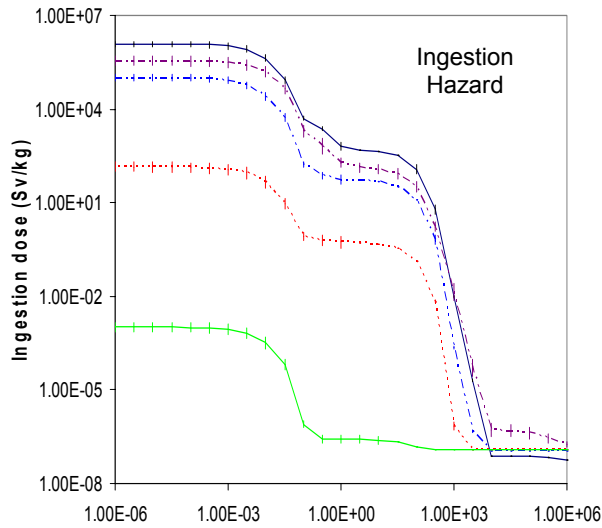
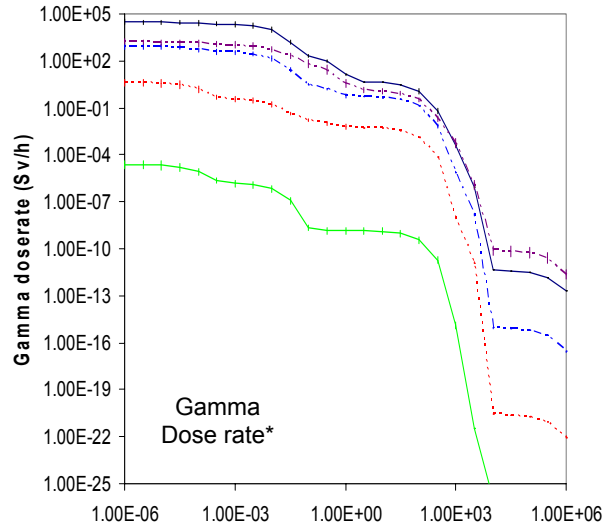
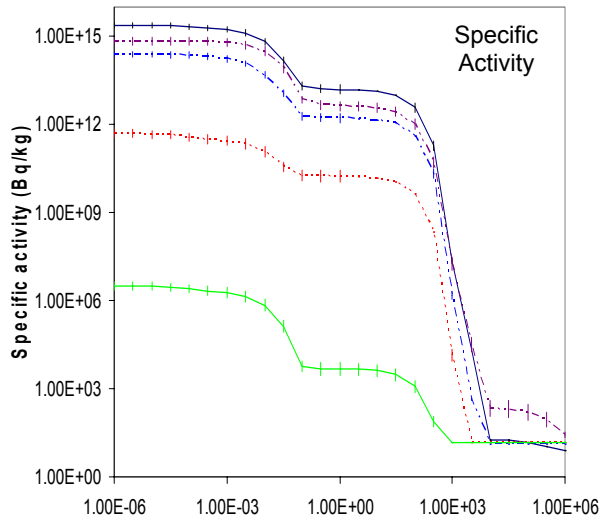
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Au199	3.139 d	&Pt198(n,γ)Pt199(β <sup>-</sup> )Au199 &Pt196(n,γ)Pt197(β <sup>-</sup> )Au197(n,γ) Au198(n,γ)Au199 &Pt195(n,γ)Pt196(n,γ)Pt197(β <sup>-</sup> )Au197 (n,γ)Au198(n,γ)Au199	40.4 30.8 28.4	98.8 0.4 0.6	100.0	99.9	99.3	99.3	99.6
Re186	3.775 d	&Pt190(n,α)Os187(n,γ)Os188(n,α) W185(β <sup>-</sup> )Re185(n,γ)Re186 &Pt190(n,γ)Pt191(β <sup>+</sup> )Ir191(n,α)Re188 (β <sup>-</sup> )Os188(n,α)W185(β <sup>-</sup> )Re185(n,γ)Re186 &Pt190(n,γ)Pt191(n,α)Os188(n,α) W185(β <sup>-</sup> )Re185(n,γ)Re186 &Pt192(n,2n)Pt191(β <sup>+</sup> )Ir191(n,2n)Ir190 (β <sup>+</sup> )Os190(n,α)W187(β <sup>-</sup> )Re187(n,2n)Re186 Pt192(n,2n)Pt191(β <sup>+</sup> )Ir191(n,nα) Re187(n,2n)Re186 &Pt194(n,2n)Pt193(n,2n)Pt192(n,2n) Pt191(β <sup>+</sup> )Ir191(n,nα)Re187(n,2n)Re186 Pt195(n,3n)Pt193m(IT)Pt193(n,3n) Pt191(β <sup>+</sup> )Ir191(n,2nα)Re186 Pt194(n,3n)Pt192(n,2n)Pt191(β <sup>+</sup> )Ir191 (n,2nα)Re186 Pt194(n,4n)Pt191(β <sup>+</sup> )Ir191(n,2nα)Re186 Pt194(n,4n)Pt191(β <sup>+</sup> )Ir191(n,4n)Ir188 (β <sup>+</sup> )Os188(n,t)Re186 Pt195(n,4n)Pt192(n,4n)Pt189(β <sup>+</sup> )Ir189 (β <sup>+</sup> )Os189(n,nt)Re186 Pt195(n,5n)Pt191(β <sup>+</sup> )Ir191(n,2nα)Re186 Pt194(n,6n)Pt189(β <sup>+</sup> )Ir189(β <sup>+</sup> )Os189 (n,nt)Re186 Pt196(n,6n)Pt191(β <sup>+</sup> )Ir191(n,2nα)Re186 Plus other long pathways	90.6 9.4	91.7 4.6 3.5 33.7 21.6 8.2 7.6 4.3 2.5 15.3 5.5 2.5 3.3 0.2 0.3 36.5	84.0 6.4 9.3	33.7 21.6 8.2	85.2	42.3	0.4 0.2 0.3 33.9 15.3 5.5 2.5 0.6 6.9 24.4 3.3 61.4
Pt195m	4.020 d	Pt194(n,γ)Pt195m &Pt192(n,γ)Pt193(n,γ)Pt194(n,γ)Pt195m Pt196(n,2n)Pt195m Pt195(n,n')Pt195m Pt198(n,4n)Pt195m Pt196(n,d)Ir195m(β <sup>-</sup> )Pt195m Pt198(n,nt)Ir195m(β <sup>-</sup> )Pt195m	99.4 0.5	97.7 2.3	100.0	83.0 12.3	54.0 25.4 12.3	32.7 15.0 46.0	46.2 21.0 22.2 6.4 2.4
Pt193m	4.340 d	Pt192(n,γ)Pt193m Pt194(n,2n)Pt193m Pt195(n,2n)Pt194(n,2n)Pt193m Pt195(n,3n)Pt193m Pt196(n,4n)Pt193m Pt196(n,3n)Pt194(n,2n)Pt193m &Pt196(n,2n)Pt195(n,3n)Pt193m Pt198(n,6n)Pt193m	99.9	100.0	100.0	70.0 23.7	16.0 1.0 67.5 4.2 3.2 2.8	15.0 21.4 56.8	22.5 28.2 26.5 17.7
Ir190	12.0 d	&Pt192(n,2n)Pt191(β <sup>+</sup> )Ir191(n,2n)Ir190 &Pt194(n,2n)Pt193(n,2n)Pt192(n,2n) Pt191(β <sup>+</sup> )Ir191(n,2n)Ir190 &Pt195(n,3n)Pt193(n,3n)Pt191(β <sup>+</sup> ) Ir191(n,2n)Ir190 &Pt194(n,3n)Pt192(n,2n)Pt191(β <sup>+</sup> ) Ir191(n,2n)Ir190 &Pt194(n,2n)Pt193(n,3n)Pt191(β <sup>+</sup> ) Ir191(n,2n)Ir190 &Pt194(n,4n)Pt191(β <sup>+</sup> )Ir191(n,2n)Ir190 &Pt194(n,3n)Pt192(n,t)Ir190 &Pt194(n,3n)Pt192(n,3n)Pt190(n,p)Ir190 &Pt194(n,d)Ir193(n,4n)Ir190 &Pt195(n,4n)Pt192(n,t)Ir190 &Pt195(n,t)Ir193(n,4n)Ir190 &Pt196(n,4n)Pt193(β <sup>+</sup> )Ir193(n,4n)Ir190				50.3 37.5	1.9 27.6 11.1 6.6 6.3 5.4 4.5 3.6 0.8 0.8 0.2	0.2 0.3 0.3 0.1 39.3 3.0 10.5 8.2 7.9 3.5	6.1 2.6 2.0 3.3 2.5 0.1

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	&Pt195(n,5n)Pt191(β <sup>+</sup> )Ir191(n,2n)Ir190 &Pt196(n,5n)Pt192(n,t)Ir190 &Pt194(n,2nt)Ir190 &Pt196(n,6n)Pt191(β <sup>+</sup> )Ir191(n,2n)Ir190 &Pt195(n,3nt)Ir190 Other long pathways						2.9 0.5 0.4 6.7 4.6 22.9	13.9 6.0 27.2 6.7 4.6 25.0	
Hg203	46.595 d	&Pt198(n,γ)Pt199(β <sup>-</sup> )Au199(β <sup>-</sup> ) Hg199(n,γ)Hg200(n,γ)Hg201(n,γ) Hg202(n,γ)Hg203 &Pt196(n,γ)Pt197(β <sup>-</sup> )Au197(n,γ) Au198(n,γ)Au199(β <sup>-</sup> )Hg199(n,γ) Hg200(n,γ)Hg201(n,γ)Hg202(n,γ)Hg203 &Pt195(n,γ)Pt196(n,γ)Pt197(β <sup>-</sup> )Au197 (n,γ)Au198(n,γ)Au199(β <sup>-</sup> )Hg199(n,γ) Hg200(n,γ)Hg201(n,γ)Hg202(n,γ)Hg203 &Pt198(n,γ)Pt199(β <sup>-</sup> )Au199(n,γ)Au200 (β <sup>-</sup> )Hg200(n,γ)Hg201(n,γ)Hg202(n,γ)Hg203	62.8  27.3  9.2	99.6  0.2  0.2	99.1      0.8	97.8      1.0				
Ir192	73.822 d	&Pt190(n,γ)Pt191(β <sup>+</sup> )Ir191(n,γ)Ir192 &Pt194(n,α)Os191(β <sup>-</sup> )Ir191(n,γ)Ir192 &Pt194(n,2n)Pt193(β <sup>+</sup> )Ir193(n,2n)Ir192 &Pt195(n,2n)Pt194(n,2n)Pt193(β <sup>+</sup> ) Ir193(n,2n)Ir192 &Pt192(n,p)Ir192 &Pt194(n,2n)Pt193(n,d)Ir192 &Pt195(n,3n)Pt193(n,d)Ir192 &Pt194(n,3n)Pt192(n,p)Ir192 &Pt194(n,t)Ir192 &Pt195(n,3n)Pt193(β <sup>+</sup> )Ir193(n,2n)Ir192 &Pt194(n,d)Ir193(n,2n)Ir192 &Pt195(n,4n)Pt192(n,p)Ir192 &Pt195(n,nt)Ir192 &Pt196(n,3n)Pt194(n,t)Ir192 &Pt196(n,3n)Pt194(n,3n)Pt192(n,p)Ir192 &Pt196(n,4n)Pt193(n,d)Ir192 Pt195(n,2n)Pt194(n,t)Ir192 &Pt196(n,2nt)Ir192	88.3 7.0	99.8	100.0	84.2 7.3	1.5	0.2		
Os185	93.80 d	Pt190(n,2n)Pt189(β <sup>+</sup> )Ir189(β <sup>+</sup> )Os189(n,2n) Os188(n,2n)Os187(n,2n)Os186(n,2n)Os185 Pt190(n,α)Os186(n,2n)Os185 Pt190(n,α)Os187(n,2n)Os186(n,2n)Os185 Pt190(n,2n)Pt189(β <sup>+</sup> )Ir189(β <sup>+</sup> )Os189 (n,3n)Os187(n,2n)Os186(n,2n)Os185 Pt192(n,3n)Pt190(n,3n)Pt188(β <sup>+</sup> )Ir188 (β <sup>+</sup> )Os188(n,4n)Os185 Pt194(n,3n)Pt192(n,3n)Pt190(n,2n)Os185 Pt194(n,4n)Pt191(β <sup>+</sup> )Ir191(n,4n)Ir188 (β <sup>+</sup> )Os188(n,4n)Os185 Pt195(n,4n)Pt192(n,4n)Pt189(β <sup>+</sup> )Ir189 (β <sup>+</sup> )Os189(n,5n)Os185 Pt194(n,4n)Pt191(β <sup>+</sup> )Ir191(n,3n)Ir189 (β <sup>+</sup> )Os189(n,5n)Os185 Pt195(n,5n)Pt191(β <sup>+</sup> )Ir191(n,4n)Ir188 (β <sup>+</sup> )Os188(n,4n)Os185 Pt194(n,3n)Pt192(n,4n)Pt189(β <sup>+</sup> )Ir189 (β <sup>+</sup> )Os189(n,5n)Os185 &Pt194(n,6n)Pt189(β <sup>+</sup> )Ir189(β <sup>+</sup> )Os189 (n,5n)Os185 Pt194(n,5n)Pt190(n,6n)Pt185(β <sup>+</sup> )Ir185(β <sup>+</sup> )Os185 Pt195(n,6n)Pt190(n,6n)Pt185(β <sup>+</sup> )Ir185(β <sup>+</sup> )Os185 Other long pathways				39.4 8.4 8.1 7.7	3.5 3.1 0.1	0.4 0.1 44.4		
Au195	186.09 d ▶	&Pt198(n,2n)Pt197(β <sup>-</sup> )Au197(n,2n) Au196(β <sup>-</sup> )Hg196(n,2n)Hg195(β <sup>+</sup> )Au195				48.5				

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&Pt198(n,2n)Pt197(β <sup>-</sup> )Au197(n,2n) Au196(β <sup>-</sup> )Hg196(n,2n)Hg195m(β <sup>+</sup> )Au195 &Pt198(n,2n)Pt197(β <sup>-</sup> )Au197(n,2n) Au196(n,2n)Au195 &Pt198(n,2n)Pt197(β <sup>-</sup> )Au197(n,3n)Au195 &Pt198(n,2n)Pt197m(β <sup>-</sup> )Au197m(IT) Au197(n,3n)Au195 &Pt198(n,d)Ir197(β <sup>-</sup> )Pt197(β <sup>-</sup> )Au197 (n,3n)Au195 &Pt198(n,d)Ir197m(β <sup>-</sup> )Pt197m(IT) Pt197(β <sup>-</sup> )Au197(n,3n)Au195				27.9			
						13.2			
							91.2	81.3	74.7
							2.1	2.0	1.9
								5.9	8.8
								1.7	13.0
Tl204	3.788 y	&Pt198(n,γ)Pt199(β <sup>-</sup> )Au199(β <sup>-</sup> ) Hg199(n,γ)Hg200(n,γ)Hg201(n,γ) Hg202(n,γ)Hg203(β <sup>-</sup> )Tl203(n,γ)Tl204 &Pt196(n,γ)Pt197(β <sup>-</sup> )Au197(n,γ) Au198(n,γ)Au199(β <sup>-</sup> )Hg199(n,γ) Hg200(n,γ)Hg201(n,γ)Hg202(n,γ) Hg203(β <sup>-</sup> )Tl203(n,γ)Tl204 Pt195(n,γ)Pt196(n,γ)Pt197(β <sup>-</sup> )Au197 (n,γ)Au198(n,γ)Au199(β <sup>-</sup> )Hg199(n,γ) Hg200(n,γ)Hg201(n,γ)Hg202(n,γ) Hg203(β <sup>-</sup> )Tl203(n,γ)Tl204 Pt198(n,γ)Pt199(β <sup>-</sup> )Au199(n,γ)Au200 (β <sup>-</sup> )Hg200(n,γ)Hg201(n,γ)Hg202(n,γ) Hg203(β <sup>-</sup> )Tl203(n,γ)Tl204	68.8	99.7	98.7				
			24.5	0.2					
			5.8	0.1					
					1.2				
Os194	5.989 y	&Pt196(n,γ)Pt197(n,α)Os194 &Pt195(n,α)Os192(n,γ)Os193(n,γ)Os194 Pt196(n,α)Os193(n,γ)Os194 Pt198(n,nα)Os194 &Pt198(n,2n)Pt197(n,α)Os194 Pt196(n,h)Os194 Pt195(n,2p)Os194	85.6	21.4	98.1				
			8.2	70.9	0.9				
			1.9		0.5				
						84.0	99.4	83.8	57.6
						15.4			
							0.2	15.5	38.4
									3.5
Pt193	50.0 y	&Pt192(n,γ)Pt193 &Pt190(n,γ)Pt191(β <sup>+</sup> )Ir191(n,γ)Ir192 (β <sup>-</sup> )Pt192(n,γ)Pt193 &Pt194(n,2n)Pt193 &Pt195(n,2n)Pt194(n,2n)Pt193 &Pt195(n,3n)Pt193 &Pt196(n,4n)Pt193 &Pt198(n,6n)Pt193	100.0	93.2	100.0				
				1.4					
						83.9	17.6	16.0	22.8
						14.4	0.2		
							72.2	23.3	29.4
							4.6	57.8	27.8
									17.3
Ir192n	240.84 y	&Pt190(n,γ)Pt191(β <sup>+</sup> )Ir191(n,γ)Ir192n Pt195(n,α)Os192m(β <sup>-</sup> )Ir192n &Pt194(n,α)Os191(β <sup>-</sup> )Ir191(n,γ)Ir192n &Pt194(n,γ)Pt195(n,α)Os192m(β <sup>-</sup> )Ir192n &Pt194(n,2n)Pt193(β <sup>+</sup> )Ir193(n,2n)Ir192n Pt196(n,α)Os193(β <sup>-</sup> )Ir193(n,2n)Ir192n &Pt194(n,d)Ir193(n,2n)Ir192n &Pt195(n,3n)Pt193(β <sup>+</sup> )Ir193(n,2n)Ir192n &Pt195(n,3n)Pt193(n,d)Ir192n Pt194(n,t)Ir192n &Pt195(n,t)Ir193(n,2n)Ir192n Pt196(n,nα)Os192m(β <sup>-</sup> )Ir192n Pt195(n,nt)Ir192n &Pt196(n,4n)Pt193(β <sup>+</sup> )Ir193(n,2n)Ir192n &Pt196(n,4n)Pt193(n,d)Ir192n Pt196(n,2nt)Ir192n	54.0	99.8	99.1				
			31.3		0.8	0.2	1.1	0.2	
			5.9						
			4.6						
						87.9	4.7	1.0	
						0.9	4.6	0.4	
						0.4	24.1	12.1	3.8
							19.1	1.5	
							11.6	1.7	
							7.5	42.6	35.3
							5.8	9.1	4.5
							4.2	1.6	
							3.2	13.0	34.9
							1.3	3.6	
							0.7	4.3	
								0.5	11.2
Hg194	519.68 y	&Pt198(n,2n)Pt197(β <sup>-</sup> )Au197(n,2n)Au196 (β <sup>-</sup> )Hg196(n,2n)Hg195m(n,2n)Hg194 &Pt198(n,2n)Pt197(β <sup>-</sup> )Au197(n,2n) Au196(β <sup>-</sup> )Hg196(n,2n)Hg195(n,2n)Hg194				77.9			
						13.7			

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&Pt198(n,2n)Pt197m(β <sup>-</sup> )Au197(n,2n) Au196(β <sup>-</sup> )Hg196(n,2n)Hg195m(n,2n)Hg194 &Pt198(n,2n)Pt197(β <sup>-</sup> )Au197(n,2n) Au196(β <sup>-</sup> )Hg196(n,3n)Hg194 Pt198(n,d)Ir197m(β <sup>-</sup> )Pt197m(IT)Pt197(β <sup>-</sup> ) Au197(n,2n)Au196(β <sup>-</sup> )Hg196(n,3n)Hg194 &Pt198(n,d)Ir197(β <sup>-</sup> )Pt197(β <sup>-</sup> )Au197 (n,2n)Au196(β <sup>-</sup> )Hg196(n,3n)Hg194 &Pt198(n,γ)Pt199(β <sup>-</sup> )Au199(β <sup>-</sup> ) Hg199(n,4n)Hg196(n,3n)Hg194 &Pt198(n,γ)Pt199(β <sup>-</sup> )Au199(β <sup>-</sup> ) Hg199(n,6n)Hg194				1.3	89.6	78.7	55.9
Re186m	2.0 10 <sup>5</sup> y	&Pt190(n,α)Os187(n,γ)Os188(n,α) W185(β <sup>-</sup> )Re185(n,γ)Re186m &Pt190(n,γ)Pt191(n,α)Os188(n,α) W185(β <sup>-</sup> )Re185(n,γ)Re186m &Pt190(n,γ)Pt191(β <sup>+</sup> )Ir191(n,α)Re188(β <sup>-</sup> ) Os188(n,α)W185(β <sup>-</sup> )Re185(n,γ)Re186m &Pt192(n,2n)Pt191(β <sup>+</sup> )Ir191(n,2n)Ir190(β <sup>+</sup> ) Os190(n,α)W187(β <sup>-</sup> )Re187(n,2n)Re186m Pt192(n,2n)Pt191(β <sup>+</sup> )Ir191(n,α) Re187(n,2n)Re186m &Pt194(n,2n)Pt193(n,2n)Pt192(n,2n) Pt191(β <sup>+</sup> )Ir191(n,α)Re187(n,2n)Re186m Pt192(n,2n)Pt191(β <sup>+</sup> )Ir191(n,2n)Ir190 (n,α)Re186m &Pt195(n,3n)Pt193(n,3n)Pt191(β <sup>+</sup> ) Ir191(n,2n)Re186m Pt194(n,3n)Pt192(n,2n)Pt191(β <sup>+</sup> )Ir191 (n,2n)Re186m Pt194(n,4n)Pt191(β <sup>+</sup> )Ir191(n,2n)Re186m Pt192(n,3n)Pt190(n,3n)Pt188(β <sup>+</sup> )Ir188 (β <sup>+</sup> )Os188(n,t)Re186m Pt194(n,4n)Pt191(β <sup>+</sup> )Ir191(n,4n)Ir188 (β <sup>+</sup> )Os188(n,t)Re186m Pt195(n,4n)Pt192(n,4n)Pt189(β <sup>+</sup> )Ir189 (β <sup>+</sup> )Os189(n,nt)Re186m Pt195(n,5n)Pt191(β <sup>+</sup> )Ir191(n,2n)Re186m Pt194(n,6n)Pt189(β <sup>+</sup> )Ir189(β <sup>+</sup> )Os189 (n,nt)Re186m Other long pathways	96.5	90.7	81.6				
				4.6	12.0				
				4.6	6.3				
						31.6			
						27.2	0.2		
						4.2			
						3.0			
							12.3	0.3	
							4.9	0.3	
							4.2	45.2	2.6
							3.9	0.1	
							0.1	15.6	0.4
								3.8	0.5
								3.4	5.8
									30.0
			3.5	0.1	0.1	34.0	74.4	31.3	60.7
Pb205	1.5 10 <sup>7</sup> y	&Pt198(n,γ)Pt199(β <sup>-</sup> )Au199(β <sup>-</sup> ) Hg199(n,γ)Hg200(n,γ)Hg201(n,γ) Hg202(n,γ)Hg203(β <sup>-</sup> )Tl203(n,γ)Tl204 (β <sup>-</sup> )Pb204(n,γ)Pb205 Pt198(n,γ)Pt199(β <sup>-</sup> )Au199(n,γ)Au200(β <sup>-</sup> ) Hg200(n,γ)Hg201(n,γ)Hg202(n,γ)Hg203 (β <sup>-</sup> )Tl203(n,γ)Tl204(β <sup>-</sup> )Pb204(n,γ)Pb205	97.5	99.7	98.3				
					1.6				
Pt190	6.6 10 <sup>11</sup> y	Pt192(n,2n)Pt191(n,2n)Pt190 Pt194(n,3n)Pt192(n,3n)Pt190 Pt192(n,3n)Pt190 Pt195(n,4n)Pt192(n,3n)Pt190 &Pt195(n,3n)Pt193(n,4n)Pt190 Pt196(n,3n)Pt194(n,3n)Pt192(n,3n)Pt190 Pt195(n,2n)Pt194(n,3n)Pt192(n,3n)Pt190 &Pt194(n,2n)Pt193(n,4n)Pt190 &Pt196(n,4n)Pt193(n,4n)Pt190 Pt194(n,5n)Pt190 Pt196(n,5n)Pt192(n,3n)Pt190 Pt195(n,6n)Pt190 Nuclide present in starting material				1.2	63.9	7.3	0.4
							11.0	4.6	0.5
							9.6	20.1	0.5
							4.8	11.2	0.4
							4.3	0.1	
							1.3	0.1	
							1.2	7.7	0.3
							0.2	27.6	0.3
								15.4	58.4
								1.3	0.9
									34.0
			100.0	100.0	100.0	98.8	3.7	4.6	4.3

# Platinum activation characteristics

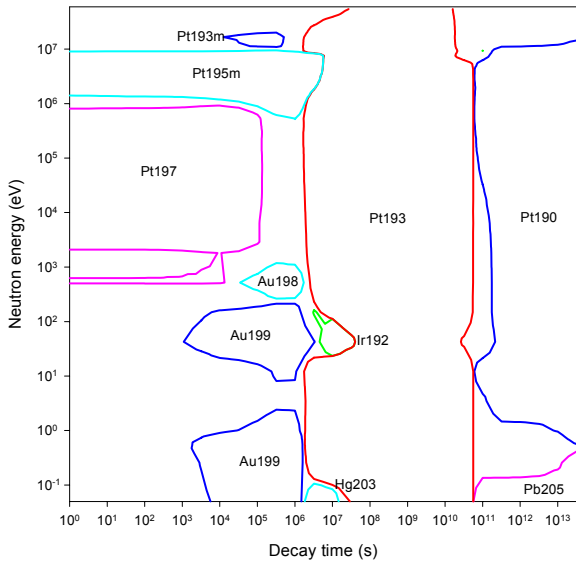


Decay time (years)

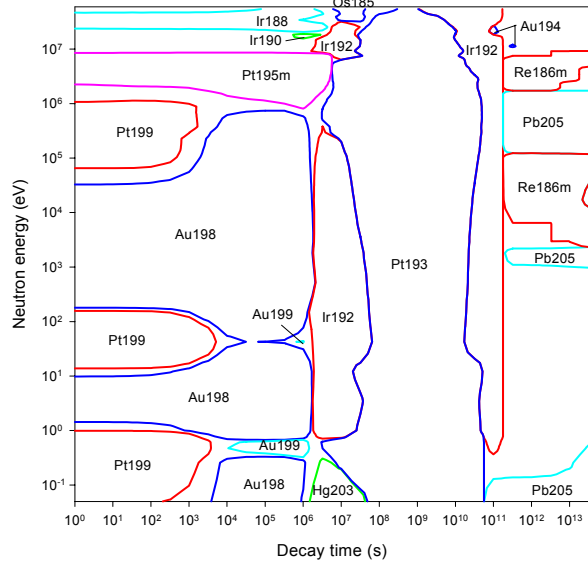
Decay time (years)

# Platinum importance diagrams & transmutation

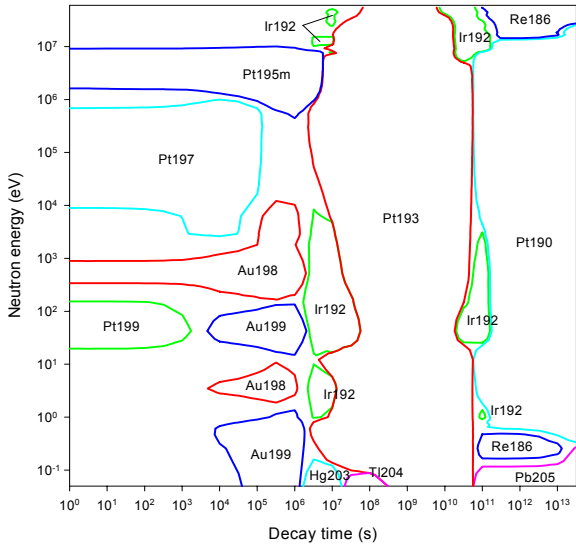
**Activity**



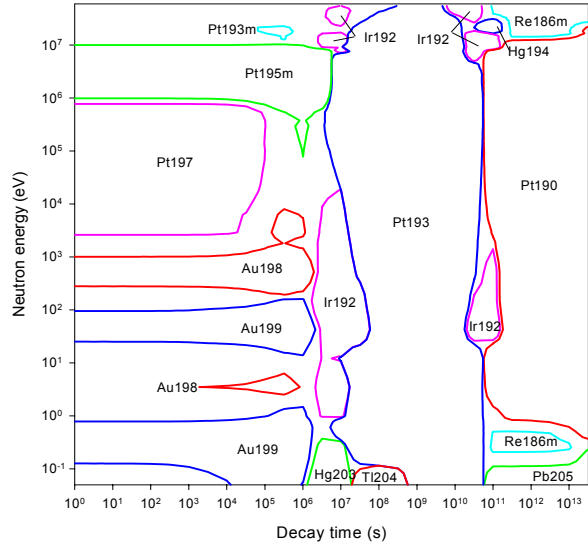
**Dose rate**



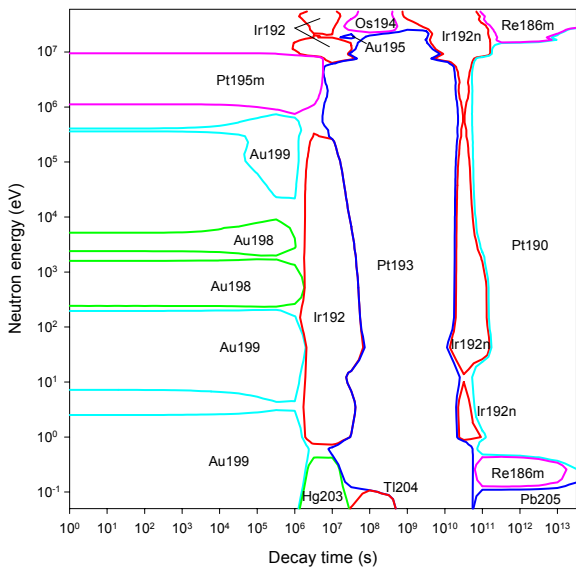
**Heat output**



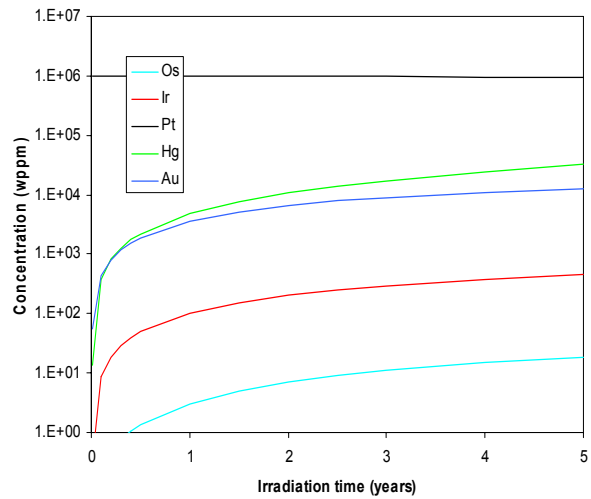
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**



# Gold

## General properties

Atomic number	79	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	$4.0 \cdot 10^{-3}$	Au197	100.0
Melting point / K	1337.3		
Boiling point / K	3129		
Density / $\text{kgm}^{-3}$	19300		
Thermal conductivity / $\text{Wm}^{-1}\text{K}^{-1}$	317		
Electrical resistivity / $\Omega\text{m}$	$2.35 \cdot 10^{-8}$		
Coefficient of thermal expansion / $\text{K}^{-1}$	$1.42 \cdot 10^{-5}$		
Crystal structure	FCC		
Number of stable isotopes	1		
Mean atomic weight	196.96655		

## Activation properties

Act	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Heat	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Bq $\text{kg}^{-1}$	6.62E15	6.52E15	2.50E15	2.43E11	8.21E7	1.06E-3	kW $\text{kg}^{-1}$	6.72E-1	6.66E-1	2.58E-1	5.00E-6	5.85E-10	1.85E-20
Au198	79.72	80.78	82.36				Au198	91.61	92.35	93.53			
Hg197	9.05	9.17	11.28				Hg197	2.03	2.05	2.50			
Hg197m	4.39	4.44	0.91				Hg197m	1.92	1.93	0.39			
Au196	2.06	2.09	3.63			2.69	Au196	1.62	1.63	2.82			12.38
Au197m	1.46	0.38	0.08				Hg199m	0.98	0.90				
Au199	1.18	1.20	1.39				Au195			0.01	99.91		
Hg199m	1.17	1.09					Pt193				0.04	90.06	
Au195	0.01	0.01	0.04	99.59			H3				0.01	0.39	
H3				0.26	3.00		Au194					8.63	
Pt193				0.13	96.22		Pb205						56.87
Pb205						90.62	Hg196						20.32
Hg196						2.69	Tl202						8.95
Tl202						1.99	Pb202						1.45
Pb202						1.99							
Dose	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Ing	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{h}^{-1}$	2.44E5	2.43E5	9.60E4	1.77E-1	8.70E-5	2.15E-15	Sv $\text{kg}^{-1}$	5.67E6	5.66E6	2.20E6	6.07E1	1.78E-2	6.13E-13
Au198	97.78	97.96	97.12				Au198	93.03	93.04	93.80			
Au196	1.54	1.54	2.61			36.82	Hg197	2.43	2.43	2.95			
Hg197	0.16	0.16	0.19				Hg197m	2.41	2.40	0.49			
Au195				99.76			Au196	1.06	1.06	1.82			2.06
Ir192				0.11	2.02		Au195			0.01	99.83		
Pt193				0.05	26.90		H3				0.04	0.58	
Au194				0.04	70.73		Hg194				0.03	84.70	
Tl202						45.09	Pt193				0.02	13.78	
Pb205						17.63	Pb205						43.99
Pb202						0.46	Pb202						30.36
							Hg196						21.95
							Tl202						1.55
Inh	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Clear	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{kg}^{-1}$	5.00E6	5.00E6	1.94E6	4.12E2	7.66E-3	1.33E-12		6.48E11	6.28E11	2.54E11	2.21E7	3.08E3	7.64E-8
Au198	90.70	90.71	91.61				Au198	81.43	83.90	81.03			
Hg197	3.59	3.59	4.37				Au196	10.01	10.32	16.99			17.85
Hg197m	3.08	3.07	0.62				Au197m	3.64	0.96	0.18			
Au199	1.24	1.24	1.42				Hg197	0.92	0.95	1.10			
Au196	1.01	1.01	1.74			0.80	Hg197m	0.44	0.46	0.09			
Au195	0.03	0.03	0.08	99.94			Au195	0.01	0.01	0.03	99.83		
H3				0.04	8.36		Pt193				0.04	88.41	
Hg194					53.92		Au194					9.87	
Pt193					21.64		Pb205						74.24
Ir192n					12.96		Hg196						3.13
Pb205						61.80	Tl202						2.77
Pb202						19.15	Pb202						1.97
Hg196						17.71							

# Gold

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
Ir191m	4.90 s	&Au197(n,α)Ir194(β <sup>-</sup> )Pt194(n,α) <sub>-</sub>	98.6			0.5	0.2			
		Os191(β <sup>-</sup> )Ir191m								
		&Au197(n,2n)Au196(β <sup>+</sup> )Pt196(n,2n) <sub>-</sub>								23.8
		Pt195(n,2n)Pt194(n,α)Os191(β <sup>-</sup> )Ir191m								20.4
		&Au197(n,2n)Au196(β <sup>+</sup> )Pt196(n,2n) <sub>-</sub>								
		Pt195(n,α)Os192(n,2n)Os191(β <sup>-</sup> )Ir191m								
		&Au197(n,3n)Au195(β <sup>+</sup> )Pt195(n,nα) <sub>-</sub>								
		Os191(β <sup>-</sup> )Ir191m								
		&Au197(n,nα)Ir193(n,3n)Ir191m								
		&Au197(n,4n)Au194(β <sup>+</sup> )Pt194(n,α) <sub>-</sub>								
		Os191(β <sup>-</sup> )Ir191m								
		&Au197(n,4n)Au194(β <sup>+</sup> )Pt194(n,4n) <sub>-</sub>								
		Pt191(β <sup>+</sup> )Ir191m								
		&Au197(n,4n)Au194(β <sup>+</sup> )Pt194(n,nt)Ir191m								
		&Au197(n,3nα)Ir191m								
&Au197(n,5n)Au193(β <sup>+</sup> )Pt193(n,t)Ir191m										
&Au197(n,6n)Au192(β <sup>+</sup> )Pt192(n,d)Ir191m										
Other very long pathways	1.4				55.3	54.4	60.4	41.1		
Au197m	7.74 s	Au197(n,γ)Au198(n,γ)Au199(β <sup>-</sup> )Hg199 <sub>-</sub>	99.5	90.9	4.7					
		(n,α)Pt196(n,γ)Pt197m(β <sup>-</sup> )Au197m								
		&Au197(n,γ)Au198(β <sup>-</sup> )Hg198(n,γ) <sub>-</sub>	0.7	6.1	57.2					
		Hg199(n,α)Pt196(n,γ)Pt197m(β <sup>-</sup> )Au197m								
		Au197(n,γ)Au198(n,α)Ir195(β <sup>-</sup> )Pt195 <sub>-</sub>	0.3	1.1	0.3					
		(n,γ)Pt196(n,γ)Pt197m(β <sup>-</sup> )Au197m								
		&Au197(n,γ)Au198(β <sup>-</sup> )Hg198(n,α) <sub>-</sub>		0.7	36.5					
		Pt195(n,γ)Pt196(n,γ)Pt197m(β <sup>-</sup> )Au197m								
		&Au197(n,α)Ir194m(β <sup>-</sup> )Pt194(n,γ) <sub>-</sub>			1.3					
		Pt195(n,γ)Pt196(n,γ)Pt197m(β <sup>-</sup> )Au197m								
Au197(n,n')Au197m					99.9	99.6	99.6	99.7		
Hg199m	42.10 m	Au197(n,γ)Au198(β <sup>-</sup> )Hg198(n,γ)Hg199m	100.0	100.0	99.9	95.6	97.6	98.2	98.7	
		&Au197(n,γ)Au198(β <sup>-</sup> )Hg198(n,γ) <sub>-</sub>				1.7	1.0	0.9	0.7	
Au192	4.94 h	Hg199(n,n')Hg199m								
		&Au197(n,2n)Au196(β <sup>-</sup> )Hg196(n,2n) <sub>-</sub>				29.2				
		Hg195m(n,2n)Hg194(n,2n)Hg193(β <sup>+</sup> ) <sub>-</sub>								
		Au193(n,2n)Au192								
		&Au197(n,2n)Au196(β <sup>-</sup> )Hg196(n,2n) <sub>-</sub>				10.2				
		Hg195m(n,2n)Hg194(n,2n)Hg193m <sub>-</sub>								
		(β <sup>+</sup> )Au193(n,2n)Au192								
		&Au197(n,2n)Au196(β <sup>-</sup> )Hg196(n,2n) <sub>-</sub>				8.6				
		Hg195m(n,2n)Hg194(n,2n)Hg193m <sub>-</sub>								
		(n,2n)Hg192(β <sup>+</sup> )Au192								
		&Au197(n,2n)Au196(β <sup>-</sup> )Hg196(n,2n) <sub>-</sub>				7.2				
		Hg195m(n,2n)Hg194(n,2n)Hg193 <sub>-</sub>								
		(n,2n)Hg192(β <sup>+</sup> )Au192								
		&Au197(n,2n)Au196(β <sup>-</sup> )Hg196(n,2n) <sub>-</sub>				2.8				
		Hg195(n,2n)Hg194(n,2n)Hg193(β <sup>+</sup> ) <sub>-</sub>								
Au193(n,2n)Au192										
&Au197(n,2n)Au196(β <sup>-</sup> )Hg196(n,3n) <sub>-</sub>						76.3				
Hg194(n,3n)Hg192(β <sup>+</sup> )Au192										
&Au197(n,3n)Au195(n,4n)Au192						11.0	97.0			
&Au197(n,6n)Au192										
Other very long pathways					42.0	12.7	3.0	100.0		
Ir194	19.30 h	&Au197(n,α)Ir194	100.0	100.0	100.0	93.3	33.6	10.6	25.8	
		&Au197(n,2n)Au196(β <sup>+</sup> )Pt196(n,2n) <sub>-</sub>				1.8				
		Pt195(n,2n)Pt194(n,p)Ir194								
▶ &Au197(n,3n)Au195(β <sup>+</sup> )Pt195(n,d)Ir194						54.8	27.7	21.5		

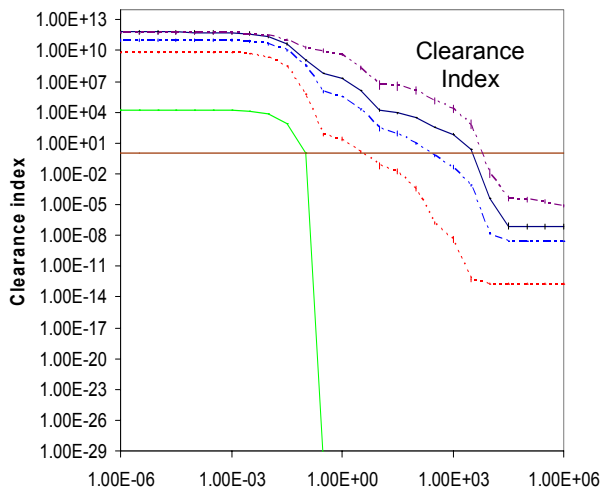
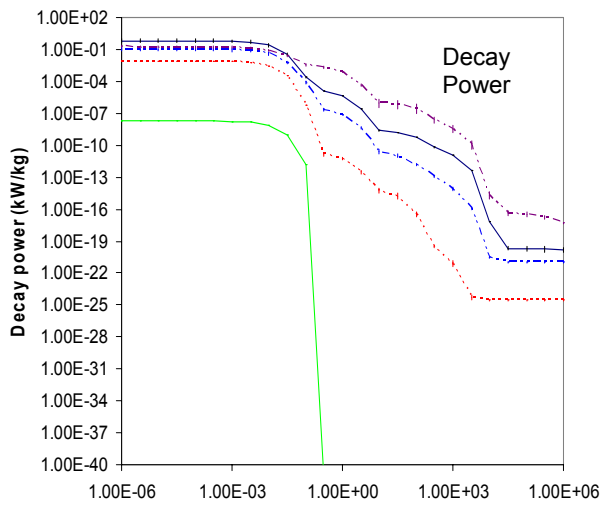
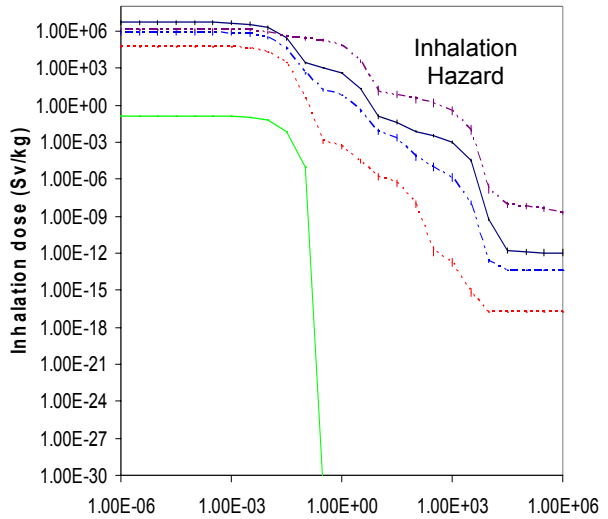
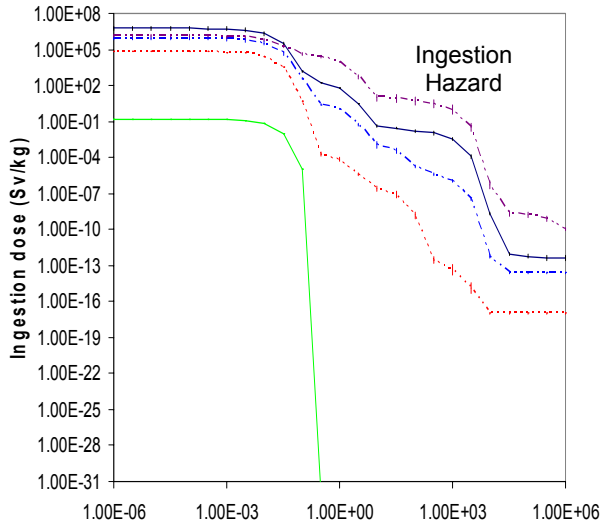
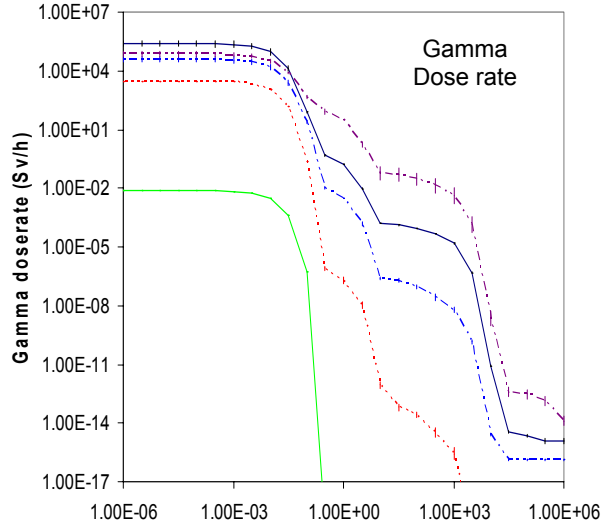
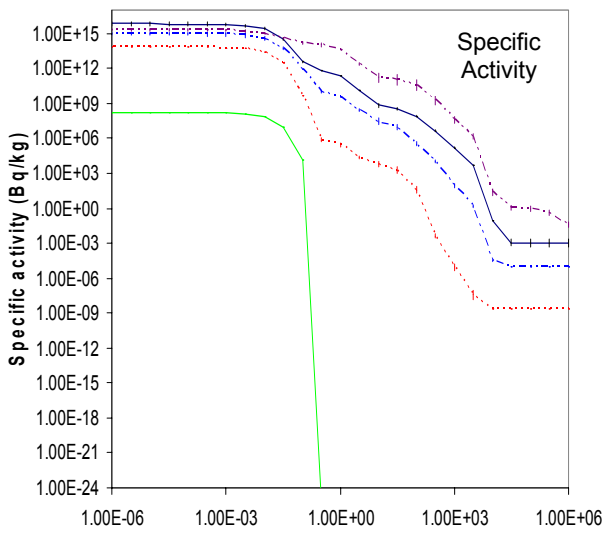


Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&Au197(n,2n)Au196(β <sup>+</sup> )Pt196(n,t)Ir194 Au197(n,2n)Au196(β <sup>+</sup> )Pt196(n,3n) Pt194(n,p)Ir194 &Au197(n,4n)Au194(β <sup>+</sup> )Pt194(n,p)Ir194 &Au197(n,t)Pt195(n,d)Ir194 &Au197(n,d)Pt196(n,t)Ir194 Au197(n,nt)Pt194(n,p)Ir194					1.7 1.3	12.5 0.2	21.4
Au194	1.584 d	&Au197(n,2n)Au196(β <sup>-</sup> )Hg196(n,2n) Hg195(β <sup>+</sup> )Au195(n,2n)Au194 &Au197(n,2n)Au196(β <sup>-</sup> )Hg196(n,2n) Hg195m(β <sup>+</sup> )Au195(n,2n)Au194 &Au197(n,2n)Au196(n,2n)Au195(n,2n)Au194 &Au197(n,4n)Au194 &Au197(n,3n)Au195(n,2n)Au194 &Au197(n,2n)Au196(n,3n)Au194				55.8 31.8 7.3	66.5 31.8 1.7	100.0	100.0
Ir188	1.729 d	Long pathways involving (n,α), (n,nα), β <sup>-</sup>				100.0	100.0	100.0	100.0
Au198	2.694 d	&Au197(n,γ)Au198	100.0	100.0	99.9	99.8	97.3	98.0	98.8
Au199	3.139 d	&Au197(n,γ)Au198(n,γ)Au199 &Au197(n,γ)Au198(β <sup>-</sup> )Hg198(n,γ) Hg199(n,p)Au199	100.0	100.0	100.0	83.2 12.3	59.7 37.5	63.4 34.6	73.9 24.6
Re186	3.775 d	Long pathways involving (n,α), (n,nα), β <sup>-</sup>				100.0	100.0	100.0	100.0
Au196	6.183 d	&Au197(n,2n)Au196				100.0	100.0	100.0	100.0
Ir193m	10.602 d	&Au197(n,α)Ir194(β <sup>-</sup> )Pt194(n,α) Os191(β <sup>-</sup> )Ir191(n,γ)Ir192(n,γ)Ir193m Au197(n,nα)Ir193m &Au197(n,2n)Au196(β <sup>+</sup> )Pt196(n,α) Os193(β <sup>-</sup> )Ir193(n,n')Ir193m &Au197(n,2n)Au196(n,α)Ir193m Au197(n,2n)Au196(β <sup>+</sup> )Pt196(n,α) Os193(β <sup>-</sup> )Ir193m &Au197(n,3n)Au195(β <sup>+</sup> )Pt195(n,t)Ir193m &Au197(n,4n)Au194(β <sup>+</sup> )Pt194(n,d)Ir193m &Au197(n,2n)Au196(β <sup>+</sup> )Pt196(n,nt)Ir193m &Au197(n,t)Pt195(n,t)Ir193m Au197(n,nt)Pt194(n,d)Ir193m &Au197(n,5n)Au193(β <sup>+</sup> )Pt193(n,p)Ir193m Other very long pathways	69.3 30.7	68.8 31.2		39.2 21.1 4.6 3.2 17.5 1.9 0.3	65.7 11.0 48.5 1.7 1.6 0.6 4.9	31.7 12.6 16.0 13.4 4.8 4.8 3.6 11.7	
Os191	15.30 d	&Au197(n,α)Ir194(β <sup>-</sup> )Pt194(n,α)Os191 Long pathways involving (n,α), (n,nα), β <sup>-</sup>	99.9	99.9	100.0				
Hg203	46.603 d	Au197(n,γ)Au198(n,γ)Au199(β <sup>-</sup> )Hg199 (n,γ)Hg200(n,γ)Hg201(n,γ)Hg202(n,γ) Hg203 &Au197(n,γ)Au198(β <sup>-</sup> )Hg198(n,γ) Hg199(n,γ)Hg200(n,γ)Hg201(n,γ) Hg202(n,γ)Hg203	99.3 0.3	96.5 3.3	9.0 90.8				
Ir192	73.822 d	&Au197(n,α)Ir194(β <sup>-</sup> )Pt194(n,α) Os191(β <sup>-</sup> )Ir191(n,γ)Ir192 &Au197(n,2n)Au196(β <sup>+</sup> )Pt196(n,α) Os193(β <sup>-</sup> )Ir193(n,2n)Ir192 &Au197(n,nα)Ir193(n,2n)Ir192 &Au197(n,3n)Au195(n,α)Ir192 &Au197(n,3n)Au195(β <sup>+</sup> )Pt195(n,3n) Pt193(n,d)Ir192 &Au197(n,3n)Au195(β <sup>+</sup> )Pt195(n,nt)Ir192 &Au197(n,2nα)Ir192 &Au197(n,4n)Au194(β <sup>+</sup> )Pt194(n,t)Ir192 &Au197(n,5n)Au193(β <sup>+</sup> )Pt193(n,d)Ir192 &Au197(n,nt)Pt194(n,t)Ir192 &Au197(n,t)Pt195(n,nt)Ir192 Other long pathways	99.1 0.9	99.1 0.9	98.1 1.9	51.2 6.7 42.1	0.3 10.1 26.7 9.4 4.5 4.4 0.7 2.4 0.5 0.5 12.8	1.4 0.5 0.1 3.3 31.9 46.6 2.4 0.5 0.5 15.9	0.3 7.0 25.9 13.8 30.2 3.6 3.3 15.9
Os185	93.80 d	Long pathways involving (n,α), (n,nα), β <sup>-</sup>				100.0	100.0	100.0	100.0

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Au195	186.09 d	&Au197(n,2n)Au196(β <sup>-</sup> )Hg196(n,2n) _ Hg195(β <sup>+</sup> )Au195 &Au197(n,2n)Au196(β <sup>-</sup> )Hg196(n,2n) _ Hg195m(β <sup>+</sup> )Au195 &Au197(n,2n)Au196(n,2n)Au195 &Au197(n,3n)Au195				52.5 30.5 7.5	99.6	99.5	99.7
Tl204	3.788 y	Au197(n,γ)Au198(n,γ)Au199(β <sup>-</sup> )Hg199 _ (n,γ)Hg200(n,γ)Hg201(n,γ)Hg202(n,γ) _ Hg203(β <sup>-</sup> )Tl203(n,γ)Tl204 &Au197(n,γ)Au198(β <sup>-</sup> )Hg198(n,γ) _ Hg199(n,γ)Hg200(n,γ)Hg201(n,γ) _ Hg202(n,γ)Hg203(β <sup>-</sup> )Tl203(n,γ)Tl204	99.4 0.2	97.6 2.3	12.0 87.7				
Os194	5.989 y	Long pathways involving (n,α), (n,nα), β <sup>-</sup>	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Pt193	50.0 y	&Au197(n,α)Ir194(β <sup>-</sup> )Pt194(n,α)Os191 _ (β <sup>-</sup> )Ir191(n,γ)Ir192(β <sup>-</sup> )Pt192(n,γ)Pt193 &Au197(n,2n)Au196(β <sup>+</sup> )Pt196(n,2n) _ Pt195(n,2n)Pt194(n,2n)Pt193 &Au197(n,α)Ir194(β <sup>-</sup> )Pt194(n,2n)Pt193 &Au197(n,2n)Au196(β <sup>+</sup> )Pt196(n,3n) _ Pt194(n,2n)Pt193 &Au197(n,2n)Au196(β <sup>-</sup> )Hg196(n,2n) _ Hg195(β <sup>+</sup> )Au195(β <sup>+</sup> )Pt195(n,2n)Pt194 _ (n,2n)Pt193 &Au197(n,3n)Au195(β <sup>+</sup> )Pt195(n,3n)Pt193 &Au197(n,3n)Au195(n,3n)Au193(β <sup>+</sup> )Pt193 &Au197(n,2n)Au196(β <sup>+</sup> )Pt196(n,4n)Pt193 &Au197(n,d)Pt196(n,4n)Pt193 &Au197(n,5n)Au193(β <sup>+</sup> )Pt193 &Au197(n,4n)Au194(β <sup>+</sup> )Pt194(n,2n)Pt193 &Au197(n,t)Pt195(n,3n)Pt193 &Au197(n,2nt)Pt193 Other long pathways	12.5 87.5	12.5 87.5	15.2 84.8	79.7 2.2 1.7 1.2 69.2 24.4 1.7 0.2 15.2	7.7 4.4 18.3 5.2 34.8 19.9 1.2 8.5	93.1 4.5 3.4	
Ir192n	241.0 y	&Au197(n,γ)Au198(n,α)Ir195(β <sup>-</sup> ) _ Pt195(n,α)Os192m(β <sup>-</sup> )Ir192n &Au197(n,α)Ir194(β <sup>-</sup> )Pt194(n,α) _ Os191(β <sup>-</sup> )Ir191(n,γ)Ir192n &Au197(n,γ)Au198(β <sup>-</sup> )Hg198(n,α) _ Pt195(n,α)Os192m(β <sup>-</sup> )Ir192n &Au197(n,α)Ir194(β <sup>-</sup> )Pt194(n,γ) _ Pt195(n,α)Os192m(β <sup>-</sup> )Ir192n &Au197(n,γ)Au198(n,α)Ir195m(β <sup>-</sup> ) _ Pt195(n,α)Os192m(β <sup>-</sup> )Ir192n &Au197(n,α)Ir194(β <sup>-</sup> )Pt194(n,α) _ Os191(n,γ)Os192m(β <sup>-</sup> )Ir192n &Au197(n,α)Ir194(n,γ)Ir195(β <sup>-</sup> ) _ Pt195(n,α)Os192m(β <sup>-</sup> )Ir192n &Au197(n,2n)Au196(β <sup>+</sup> )Pt196(n,α) _ Os193(β <sup>-</sup> )Ir193(n,2n)Ir192n &Au197(n,nα)Ir193(n,2n)Ir192n Au197(n,2nα)Ir192n &Au197(n,3n)Au195(β <sup>+</sup> )Pt195(n,nt)Ir192n &Au197(n,4n)Au194(β <sup>+</sup> )Pt194(n,t)Ir192n &Au197(n,5n)Au193(β <sup>+</sup> )Pt193(n,d)Ir192n &Au197(n,5n)Au193(β <sup>+</sup> )Pt193(β <sup>+</sup> ) _ Ir193(n,2n)Ir192n Au197(n,nt)Pt194(n,t)Ir192n Other long pathways	64.6 9.6 6.8 6.5 4.9 4.0 3.0 0.6	13.6 75.8 2.8 0.6	0.6 94.7 4.3	64.5 10.5 5.6 3.4 0.2 1.5 1.2 25.0	46.6 8.8 41.7 2.4 30.3 1.5 1.2 44.2	3.0 35.4 5.6 9.2 20.0 12.0 0.4 13.7	
Hg194	440.01 y ▶	&Au197(n,2n)Au196(β <sup>-</sup> )Hg196(n,2n) _ Hg195m(n,2n)Hg194				84.5			



# Gold activation characteristics

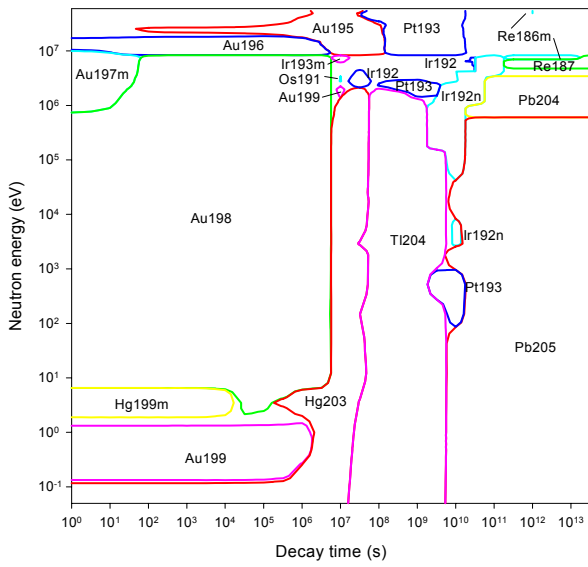


Decay time (years)

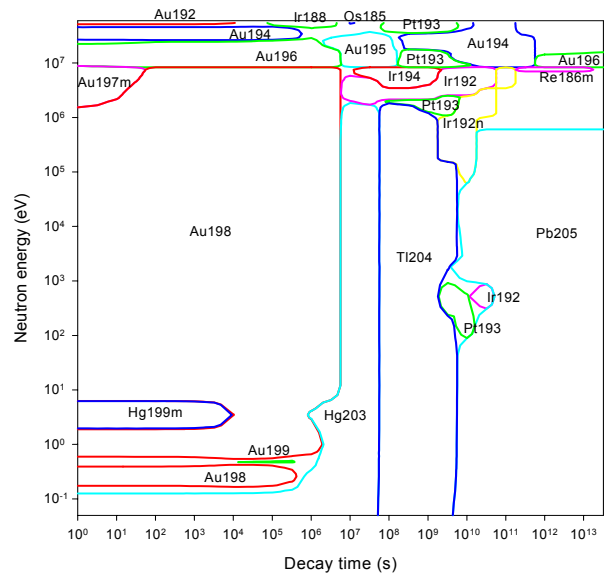
Decay time (years)

# Gold importance diagrams & transmutation

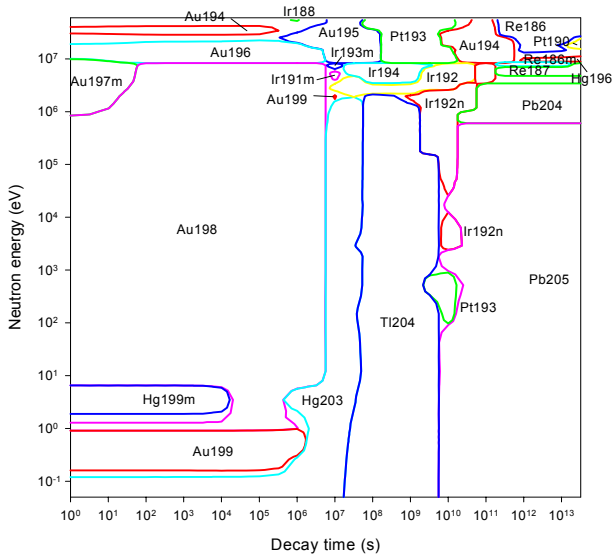
**Activity**



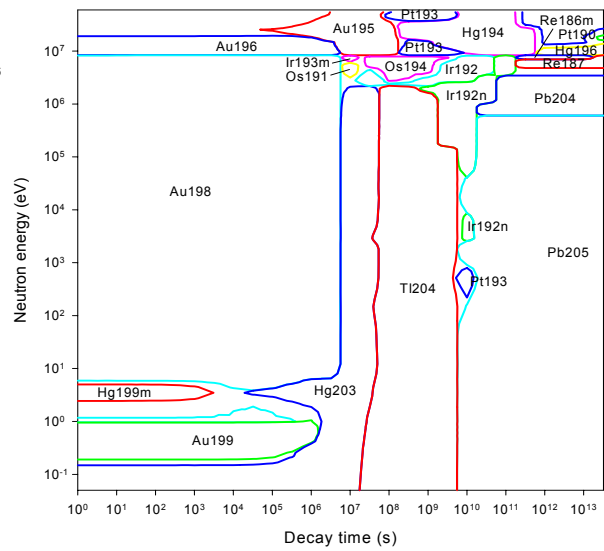
**Dose rate**



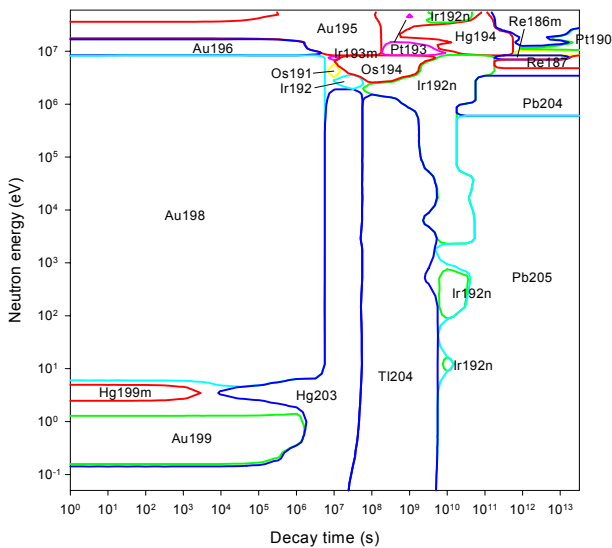
**Heat output**



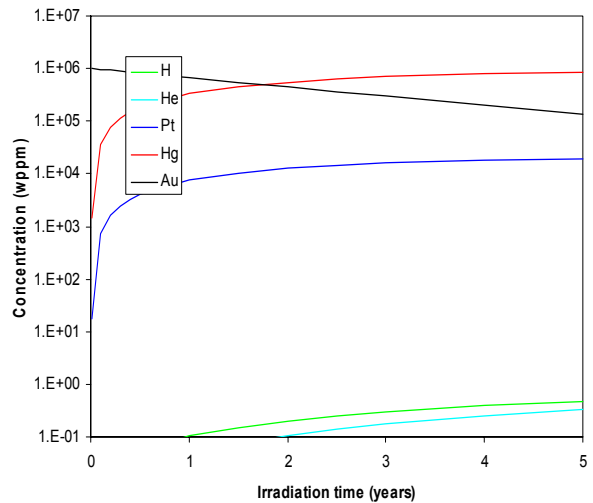
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**





# Mercury

## General properties

Atomic number	80	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	8.5 10 <sup>-2</sup>	Hg196	0.15 (T <sub>1/2</sub> =2.50 10 <sup>18</sup> y)
Melting point / K	234.3	Hg198	9.97
Boiling point / K	629.9	Hg199	16.87
Density / kgm <sup>-3</sup>	13546	Hg200	23.10
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	8.34	Hg201	13.18
Electrical resistivity /Ωm	9.41 10 <sup>-7</sup>	Hg202	29.86
Coefficient of thermal expansion / K <sup>-1</sup>	1.81 10 <sup>-4</sup>	Hg204	6.87
Crystal structure	Rhombohedral		
Number of stable isotopes	6 (7)		
Mean atomic weight	200.59		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	4.87E14	4.70E14	2.13E14	9.91E12	1.35E7	3.63E3	kW kg <sup>-1</sup>	3.29E-2	3.14E-2	1.21E-2	3.84E-4	1.49E-10	4.49E-14
Hg199m	28.16	26.76					Hg199m	35.60	34.17				
Hg203	28.06	29.07	60.80	6.03			Au198	25.76	26.94	27.36			
Hg197	15.20	15.74	16.12				Hg203	22.39	23.43	57.60	8.36		
Au198	14.88	15.40	13.30				Hg197	5.15	5.38	6.48			
Hg197m	6.66	6.89	1.20				Hg197m	4.41	4.60	0.94			
Tl204	2.25	2.33	5.14	92.21	0.91		Hg205	2.02	1.05				
Hg205	1.56	0.80					Tl204	1.27	1.33	3.45	90.70	3.16	
Tl202	1.06	1.10	1.98			2.05	Tl202	1.23	1.29	2.73		0.01	13.00
Au195	0.13	0.14	0.31	1.74			Au197m	0.75	0.58	0.12			
Pt193					86.64		Au196	0.48	0.50	0.86			
H3					6.83		Pt193					52.46	
Au194					2.78		Au194					43.30	
Hg194					2.78		H3					0.56	
Pb205					0.02	95.89	Pb205					0.03	84.88
Pb202						2.05	Pb202					0.02	2.11
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	5.10E3	5.01E3	2.34E3	4.69E0	8.23E-5	4.70E-9	Sv kg <sup>-1</sup>	3.86E5	3.86E5	3.00E5	1.21E4	2.00E-2	1.66E-6
Au198	63.09	64.19	53.70				Hg203	67.20	67.28	82.11	9.35		
Hg203	17.18	17.49	35.43	94.59			Au198	18.75	18.76	9.46			
Hg199m	10.77	10.05					Hg197	4.40	4.41	2.63			
Tl202	4.56	4.65	8.08		0.02	71.04	Hg197m	3.95	3.94	0.40			
Au196	1.04	1.06	1.50				Tl204	3.40	3.41	4.38	90.29	0.74	
Hg197	0.90	0.91	0.90				Hg199m	1.10	1.01				
Au197m	0.35	0.35	0.06				Tl202	0.60	0.60	0.63			2.01
Au195	0.01	0.01	0.02	3.02			Hg194					96.42	
Au194	0.02	0.02	0.01	0.00	95.39		Pt193					1.82	
Tl204			0.01*	2.38*			H3					0.19	
Pt193					4.10		Pb202					0.01	39.37
Pb205						28.23	Pb205						58.61
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	4.43E5	4.42E5	3.54E5	5.29E3	5.94E-3	3.87E-6		6.64E10	6.32E10	2.83E10	9.21E9	9.31E2	2.18E-1
Hg203	74.07	74.15	87.77	27.09			Hg199m	44.93	43.29				
Au198	14.07	14.08	6.88				Hg203	20.59	21.63	45.70	0.64		
Hg197	5.01	5.01	2.91				Tl204	16.53	17.36	38.66	99.18	13.31	
Hg197m	3.88	3.88	0.38				Au198	10.92	11.46	10.00			
Hg199m	0.99	0.91					Au196	1.40	1.47	2.19			
Tl204	0.96	0.96	1.20	67.33	0.81		Hg197	1.11	1.17	1.21			
Au195	0.25	0.25	0.31	5.56			Tl202	0.78	0.82	1.49			3.42
Tl202	0.22	0.22	0.22			0.36	Hg197m	0.48	0.51	0.09			
Hg194					89.11		Au195	0.09	0.09	0.21	0.17		
Pt193					4.15		Pt193					43.48	
H3					4.05		Au194					41.85	
Pb205					0.05	76.53	Pb205					0.02	94.13
Pb202					0.05	23.09	Pb202						2.44

# Mercury

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Hg205	5.20 m	Hg204(n,γ)Hg205 Hg202(n,γ)Hg203(n,γ)Hg204(n,γ)Hg205	98.9 0.9	100.0	100.0	99.9	99.4	99.4	99.6
Hg199m	42.10 m	Hg198(n,γ)Hg199m Hg200(n,2n)Hg199m Hg201(n,2n)Hg200(n,2n)Hg199m Hg202(n,2n)Hg201(n,2n)Hg200(n,2n)Hg199m   Hg199(n,n')Hg199m Hg201(n,3n)Hg199m Hg202(n,4n)Hg199m Hg202(n,2n)Hg201(n,3n)Hg199m Hg202(n,3n)Hg200(n,2n)Hg199m Hg204(n,6n)Hg199m	99.9	100.0	100.0	74.1 14.0 5.4 4.5	20.6 0.7 1.9 51.6 7.3 7.2 7.2	10.0 1.0 10.0 73.1	16.9 1.7 14.0 43.0 19.7
Au194	1.584 d	&Hg196(n,2n)Hg195(β <sup>+</sup> )Au195(n,2n)Au194   &Hg196(n,2n)Hg195m(β <sup>+</sup> )Au195(n,2n)Au194   &Hg198(n,2n)Hg197(β <sup>+</sup> )Au197(n,2n)_ Au196(β <sup>-</sup> )Hg196(n,2n)Hg195(β <sup>+</sup> )_ Au195(n,2n)Au194 &Hg198(n,2n)Hg197(β <sup>+</sup> )Au197(n,2n)_ Au196(β <sup>-</sup> )Hg196(n,2n)Hg195m(β <sup>+</sup> )_ Au195(n,2n)Au194 &Hg198(n,2n)Hg197(β <sup>+</sup> )Au197(n,2n)_ Au196(n,2n)Au195(n,2n)Au194 &Hg199(n,3n)Hg197(β <sup>+</sup> )Au197(n,4n)Au194   &Hg199(n,3n)Hg197(β <sup>+</sup> )Au197(n,3n)_ Au195(n,2n)Au194 &Hg201(n,3n)Hg199(n,3n)Hg197(β <sup>+</sup> )_ Au197(n,4n)Au194 &Hg198(n,3n)Hg196(n,2n)Hg195(β <sup>+</sup> ) Au195(n,2n)Au194 &Hg198(n,3n)Hg196(n,3n)Hg194(n,p)Au194   &Hg198(n,3n)Hg196(n,t)Au194   &Hg199(n,3n)Hg197m(β <sup>+</sup> )Au197(n,4n)Au194   &Hg200(n,4n)Hg197(β <sup>+</sup> )Au197(n,4n)Au194   &Hg200(n,4n)Hg197m(β <sup>+</sup> )Au197(n,4n)Au194   &Hg202(n,3n)Hg200(n,4n)Hg197(β <sup>+</sup> )_ Au197(n,4n)Au194 &Hg202(n,4n)Hg199(n,3n)Hg197(β <sup>+</sup> )_ Au197(n,4n)Au194 &Hg201(n,5n)Hg197(β <sup>+</sup> )Au197(n,4n)Au194   &Hg199(n,t)Au197(n,4n)Au194   &Hg202(n,6n)Hg197(β <sup>+</sup> )Au197(n,4n)Au194   &Hg201(n,5n)Hg197(β <sup>+</sup> )Au197(n,4n)Au194   &Hg198(n,2nt)Au194 &Hg200(n,5n)Hg196(n,t)Au194 &Hg202(n,5n)Hg198(n,2nt)Au194 &Hg200(n,nt)Au197(n,4n)Au194 Other very long pathways				50.1 27.6 5.6 4.0 2.0 39.3 16.6 4.0 2.5 2.5 2.3 2.2 56.1 3.1 2.4 2.3 2.1 1.8 17.2 14.1 9.4 5.4 3.4 2.5 10.7	30.6	16.6 15.6	5.9 11.1 2.1 17.2 14.1 9.4 5.4 3.4 2.5 28.9
Ir188	1.729 d	Long pathways involving (n,α), (n,α), β <sup>-</sup>				100.0	100.0	100.0	100.0
Hg197	2.692 d	&Hg196(n,γ)Hg197 &Hg198(n,2n)Hg197 &Hg199(n,2n)Hg198(n,2n)Hg197 &Hg200(n,2n)Hg199(n,2n)Hg198(n,2n)Hg197   &Hg199(n,3n)Hg197 &Hg201(n,3n)Hg199(n,3n)Hg197 &Hg200(n,2n)Hg199(n,3n)Hg197 &Hg202(n,4n)Hg199(n,3n)Hg197 ▶ &Hg200(n,4n)Hg197		100.0	100.0	60.3 33.0 5.7	2.6 0.3 67.3 13.8 6.1 2.2 1.3	1.4 11.2 0.9 1.0 6.8 59.6	



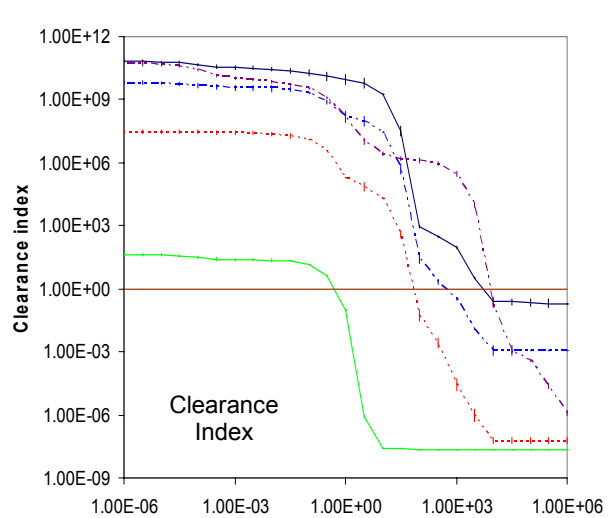
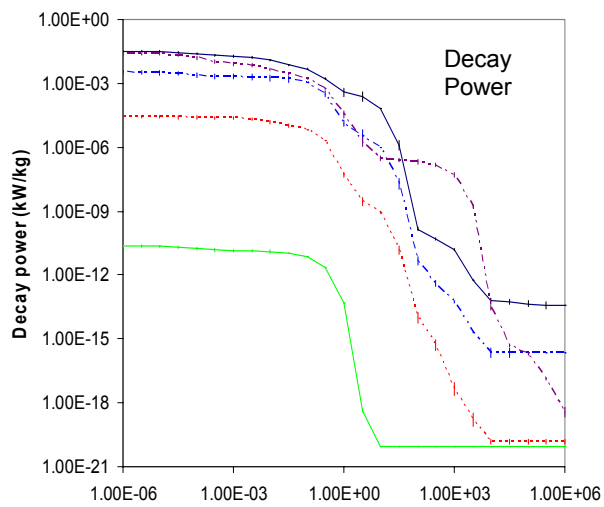
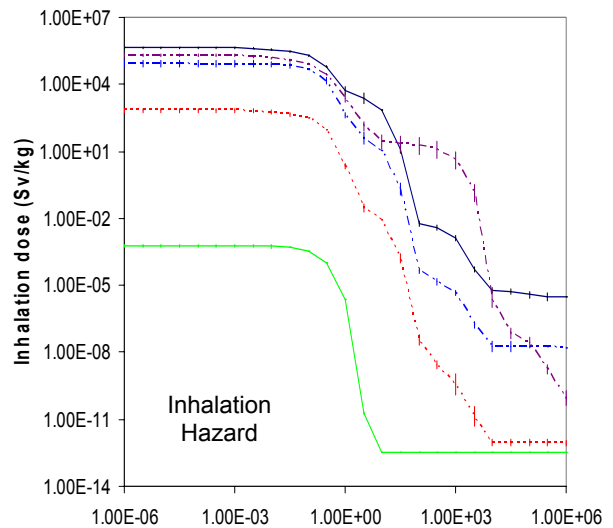
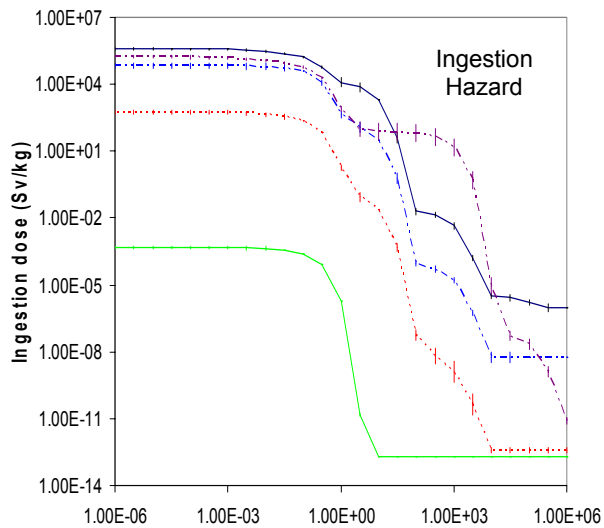
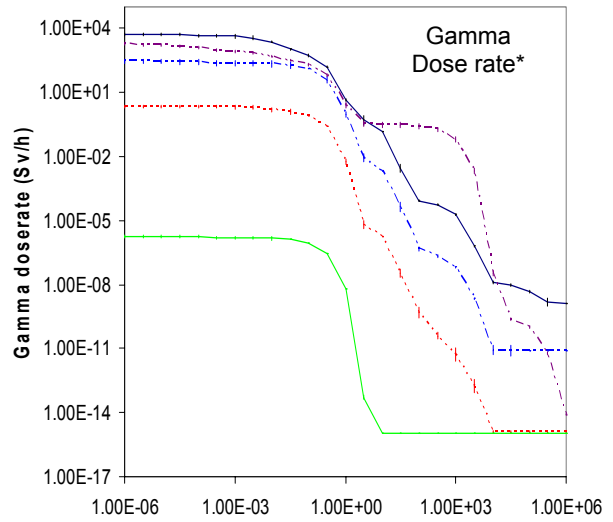
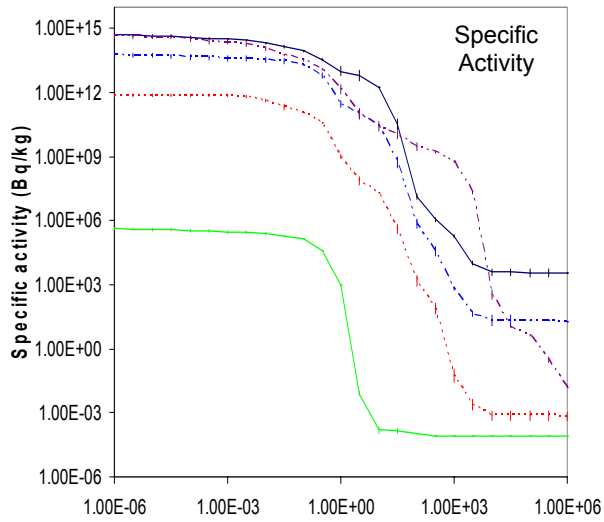
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&Hg202(n,3n)Hg200(n,4n)Hg197 &Hg201(n,5n)Hg197 &Hg202(n,6n)Hg197					0.5	5.1	
								2.3	26.7
									32.5
Au198	2.694 d	&Hg196(n,γ)Hg197(β <sup>+</sup> )Au197(n,γ)Au198 &Hg198(n,p)Au198 &Hg199(n,2n)Hg198(n,p)Au198 &Hg200(n,2n)Hg199(n,2n)Hg198(n,p)Au198 &Hg199(n,d)Au198 &Hg198(n,2n)Hg197(β <sup>+</sup> )Au197(n,γ)Au198 &Hg200(n,2n)Hg199(n,d)Au198 Hg200(n,3n)Hg198(n,p)Au198 &Hg201(n,3n)Hg199(n,d)Au198 &Hg200(n,t)Au198 Hg202(n,3n)Hg200(n,t)Au198 Hg202(n,3n)Hg200(n,3n)Hg198(n,p)Au198 &Hg202(n,4n)Hg199(n,d)Au198 &Hg201(n,nt)Au198 Hg201(n,4n)Hg198(n,p)Au198 &Hg202(n,2nt)Au198	99.7	99.7	99.7	53.9 30.2 5.5 3.7 3.3 1.4	16.3 1.7 42.6 3.7 1.9	6.4 0.5 34.1 1.9 1.2 1.8 27.7 2.3	2.3 0.1 20.5 0.8 0.2 0.6 33.5 1.5
Re186	3.775 d	Long pathways involving (n,α), (n,nα), β <sup>-</sup>				100.0	100.0	100.0	100.0
Au196	6.183 d	Hg196(β <sup>+</sup> )Au196 &Hg198(n,2n)Hg197(β <sup>+</sup> )Au197(n,2n)Au196 &Hg199(n,2n)Hg198(n,2n)Hg197(β <sup>+</sup> ) Au197(n,2n)Au196 &Hg198(n,2n)Hg197m(β <sup>+</sup> )Au197(n,2n)Au196 &Hg199(n,3n)Hg197(β <sup>+</sup> )Au197(n,2n)Au196 &Hg201(n,3n)Hg199(n,3n)Hg197(β <sup>+</sup> ) Au197(n,2n)Au196 &Hg199(n,3n)Hg197m(β <sup>+</sup> )Au197(n,2n)Au196 &Hg198(n,3n)Hg196(n,p)Au196 &Hg200(n,2n)Hg199(n,3n)Hg197(β <sup>+</sup> ) Au197(n,2n)Au196 &Hg200(n,4n)Hg197(β <sup>+</sup> )Au197(n,2n)Au196 &Hg198(n,t)Au196 &Hg202(n,4n)Hg199(n,3n)Hg197(β <sup>+</sup> ) Au197(n,2n)Au196 &Hg199(n,nt)Au196 &Hg200(n,4n)Hg197m(β <sup>+</sup> )Au197(n,2n)Au196 &Hg199(n,4n)Hg196(n,p)Au196 &Hg201(n,4n)Hg198(n,t)Au196 &Hg200(n,5n)Hg196(n,t)Au194 &Hg198(n,2nt)Au194 &Hg202(n,6n)Hg197(β <sup>+</sup> )Au197(n,4n)Au194 &Hg201(n,5n)Hg197(β <sup>+</sup> )Au197(n,4n)Au194 &Hg200(n,4n)Hg197(β <sup>+</sup> )Au197(n,4n)Au194 &Hg199(n,3n)Hg197(β <sup>+</sup> )Au197(n,4n)Au194 &Hg202(n,5n)Hg198(n,2nt)Au194 &Hg200(n,nt)Au197(n,4n)Au194 &Hg199(n,t)Au197(n,4n)Au194		100.0	100.0	69.9 18.8 2.9	2.4 66.3 5.8 3.7 2.5 2.5 1.3 1.0 0.9 0.2 0.1	0.8 13.1 0.3 0.8 0.3 44.2 8.5 2.2 3.4 2.5 2.5 2.2 0.2 0.1	0.3 1.5 5.4 9.4 17.2 14.1 11.1 5.9 3.4 2.5 2.1
Tl202	12.240 d	Hg204(n,2n)Hg203(β <sup>-</sup> )Tl203(n,2n)Tl202 Hg204(n,d)Au203(β <sup>-</sup> )Hg203(β <sup>-</sup> )Tl203 (n,2n)Tl202				99.8	92.1	80.6	72.9
							6.4	17.4	25.5
Hg203	46.603 d	Hg202(n,γ)Hg203 Hg201(n,γ)Hg202(n,γ)Hg203 Hg200(n,γ)Hg201(n,γ)Hg202(n,γ)Hg203 Hg204(n,2n)Hg203 Hg204(n,d)Au203(β <sup>-</sup> )Hg203	84.7 13.6 0.9	99.4 0.6	98.4 1.6	0.2		0.5	
						99.7	92.3	81.3	73.4
								17.6	25.7
Au195	186.09 d	&Hg196(n,2n)Hg195(β <sup>+</sup> )Au195 Hg196(n,2n)Hg195m(β <sup>+</sup> )Au195 &Hg198(n,2n)Hg197(β <sup>+</sup> )Au197(n,2n) Au196(β <sup>-</sup> )Hg196(n,2n)Hg195(β <sup>+</sup> )Au195				50.1 32.0 5.4	0.5 0.4	0.1	
	▶								

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
	◀	&Hg198(n,2n)Hg197(β <sup>+</sup> )Au197(n,2n) Au196(β <sup>-</sup> )Hg196(n,2n)Hg195m(β <sup>+</sup> )Au195 &Hg198(n,2n)Hg197(β <sup>+</sup> )Au197(n,2n) Au196(n,2n)Au195 &Hg199(n,2n)Hg198(n,2n)Hg197(β <sup>+</sup> ) Au197(n,2n)Au196(β <sup>-</sup> )Hg196(n,2n) Hg195(β <sup>+</sup> )Au195 &Hg199(n,3n)Hg197(β <sup>+</sup> )Au197(n,3n)Au195 &Hg198(n,3n)Hg196(n,2n)Hg195(β <sup>+</sup> )Au195 Hg198(n,3n)Hg196(n,2n)Hg195m(β <sup>+</sup> )Au195 &Hg199(n,3n)Hg197m(β <sup>+</sup> )Au197(n,3n)Au195 &Hg200(n,3n)Hg198(n,3n)Hg196 (n,2n)Hg195(β <sup>+</sup> )Au195 &Hg200(n,4n)Hg197(β <sup>+</sup> )Au197(n,3n)Au195 &Hg198(n,4n)Hg195(β <sup>+</sup> )Au195 &Hg199(n,4n)Hg196(n,2n)Hg195(β <sup>+</sup> )Au195 Hg199(n,4n)Hg196(n,2n)Hg195m(β <sup>+</sup> )Au195 Hg198(n,4n)Hg195m(β <sup>+</sup> )Au195 &Hg201(n,4n)Hg198(n,4n)Hg195(β <sup>+</sup> )Au195 &Hg200(n,3n)Hg198(n,4n)Hg195(β <sup>+</sup> )Au195 Hg201(n,4n)Hg198(n,4n)Hg195m(β <sup>+</sup> )Au195 Hg200(n,3n)Hg198(n,4n)Hg195m(β <sup>+</sup> )Au195 &Hg199(n,5n)Hg195(β <sup>+</sup> )Au195 Hg199(n,5n)Hg195m(β <sup>+</sup> )Au195 &Hg198(n,nt)Au195 &Hg200(n,6n)Hg195(β <sup>+</sup> )Au195 Hg200(n,6n)Hg195m(β <sup>+</sup> )Au195				4.3				
						2.0				
						0.4				
							54.8	2.1	0.4	
							8.4	0.7		
							5.8	0.5		
							3.1			
							2.2			
							0.6	2.8	0.3	
							0.3	30.6	6.7	
							0.3	2.3	0.2	
							0.3	1.7	0.2	
								18.3	4.4	
								6.9	0.3	
								4.8	0.4	
								4.1	0.2	
								2.9	0.3	
								0.9	25.5	
								0.5	17.7	
								0.4	2.7	
									8.3	
									4.8	
Tl204	3.788 y	Hg202(n,γ)Hg203(β <sup>-</sup> )Tl203(n,γ)Tl204 Hg201(n,γ)Hg202(n,γ)Hg203(β <sup>-</sup> )Tl203 (n,γ)Tl204 Hg204(n,γ)Hg205(β <sup>-</sup> )Tl205(n,2n)Tl204 Hg204(n,2n)Hg203(β <sup>-</sup> )Tl203(n,γ)Tl204 Hg204(n,d)Au203(β <sup>-</sup> )Hg203(β <sup>-</sup> )Tl203 (n,γ)Tl204	93.6 6.1	99.8 0.2	99.4 0.6	0.1	0.3	0.3	0.4	
						50.3	35.1	31.9	28.7	
						49.5	60.2	55.6	52.4	
							4.2	12.0	18.3	
H3	12.33 y	Hg199(n,X)H3 Hg201(n,X)H3 Hg202(n,2n)Hg201(n,X)H3 &Hg200(n,2n)Hg199(n,X)H3 Hg204(n,2n)Hg203(β <sup>-</sup> )Tl203(n,X)H3 &Hg198(n,2n)Hg197(β <sup>+</sup> )Au197(n,X)H3 Hg198(n,X)H3 Hg200(n,X)H3 Hg202(n,X)H3 Hg198(n,X)H3 Hg204(n,X)H3 Hg202(n,3n)Hg200(n,X)H3 &Hg202(n,4n)Hg199(n,X)H3 Hg202(n,5n)Hg198(n,X)H3				44.0 23.2 8.9 8.1 3.8 2.6 2.5 1.9 1.6 0.5 0.2	20.4 15.2 1.1 0.4 0.1	13.9 13.6 0.7 0.4 0.2	15.1 11.9 0.4 0.2	
							17.9	19.4	16.8	
							20.6	23.3	24.5	
							4.8	7.5	9.0	
							4.2	4.9	5.3	
							3.1	0.8	0.4	
								2.7	0.7	
								0.1	1.6	
Pt193	50.0 y	&Hg196(n,α)Pt193 &Hg196(n,2n)Hg195(β <sup>+</sup> )Au195(β <sup>+</sup> ) Pt195(n,2n)Pt194(n,2n)Pt193 &Hg196(n,2n)Hg195m(β <sup>+</sup> )Au195(β <sup>+</sup> ) Pt195(n,2n)Pt194(n,2n)Pt193 &Hg196(n,2n)Hg195(β <sup>+</sup> )Au195(n,2n) Au194(β <sup>+</sup> )Pt194(n,2n)Pt193 &Hg196(n,2n)Hg195m(β <sup>+</sup> )Au195 (n,2n)Au194(β <sup>+</sup> )Pt194(n,2n)Pt193 Hg198(n,3n)Hg196(n,3n)Hg194(n,2n) Hg193(β <sup>+</sup> )Au193(β <sup>+</sup> )Pt193 Hg198(n,3n)Hg196(n,3n)Hg194(n,2n) Hg193m(β <sup>+</sup> )Au193(β <sup>+</sup> )Pt193	100.0	100.0	100.0	3.3 27.3	0.4			
						15.1				
						8.2				
						6.8				
							6.9	0.2		
							3.5			

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	&Hg198(n,3n)Hg196(n,α)Pt193 &Hg199(n,4n)Hg196(n,4n)Hg193(β <sup>+</sup> ) Au193(β <sup>+</sup> )Pt193 Hg199(n,4n)Hg196(n,4n)Hg193m(β <sup>+</sup> ) Au193(β <sup>+</sup> )Pt193 &Hg198(n,3n)Hg196(n,4n)Hg193(β <sup>+</sup> ) Au193(β <sup>+</sup> )Pt193 Hg198(n,3n)Hg196(n,4n)Hg193m(β <sup>+</sup> ) Au193(β <sup>+</sup> )Pt193 &Hg200(n,5n)Hg196(n,4n)Hg193(β <sup>+</sup> ) Au193(β <sup>+</sup> )Pt193 &Hg198(n,6n)Hg193(β <sup>+</sup> )Au193(β <sup>+</sup> )Pt193 Hg198(n,6n)Hg193m(β <sup>+</sup> )Au193(β <sup>+</sup> )Pt193 Other long pathways					3.0	0.1	
								24.7	1.6
								11.1	0.8
								7.6	0.7
								3.4	0.3
								0.4	6.5
									7.9
									3.7
						39.3	86.2	52.5	78.5
Hg194	440.01 y	Hg196(n,2n)Hg195m(n,2n)Hg194 &Hg196(n,2n)Hg195(n,2n)Hg194 Hg198(n,3n)Hg196(n,3n)Hg194 Hg200(n,3n)Hg198(n,3n)Hg196(n,3n)Hg194 Hg196(n,3n)Hg194 Hg199(n,4n)Hg196(n,3n)Hg194 Hg199(n,2n)Hg198(n,3n)Hg196(n,3n)Hg194 Hg202(n,3n)Hg200(n,3n)Hg198(n,3n) Hg196(n,3n)Hg194 Hg201(n,4n)Hg198(n,3n)Hg196(n,3n)Hg194 &Hg202(n,4n)Hg199(n,4n)Hg196(n,3n)Hg194 Hg198(n,5n)Hg194 Hg200(n,5n)Hg196(n,3n)Hg194 Hg201(n,4n)Hg198(n,5n)Hg194 Hg200(n,3n)Hg198(n,5n)Hg194 Hg199(n,6n)Hg194 Hg202(n,5n)Hg198(n,5n)Hg194 Hg199(n,2n)Hg198(n,5n)Hg194				76.7 14.1	68.7 14.1 7.7 3.5 2.4 1.2	17.8 1.1 5.3 58.1 0.4	
								0.7	1.6
									7.5
								2.0	53.8
								1.1	2.7
								0.3	1.6
								0.2	2.3
									21.1
									9.8
									1.3
Pb202	5.3 10 <sup>4</sup> y	&Hg204(n,γ)Hg205(β <sup>-</sup> )Tl205(n,2n) Tl204(β <sup>-</sup> )Pb204(n,2n)Pb203(n,2n)Pb202 &Hg204(n,2n)Hg203(β <sup>-</sup> )Tl203(n,γ) Tl204(β <sup>-</sup> )Pb204(n,2n)Pb203(n,2n)Pb202 &Hg204(n,2n)Hg203(β <sup>-</sup> )Tl203(n,γ) Tl204(β <sup>-</sup> )Pb204(n,3n)Pb202 &Hg204(n,γ)Hg205(β <sup>-</sup> )Tl205(n,2n) Tl204(β <sup>-</sup> )Pb204(n,3n)Pb202 Hg204(n,d)Au203(β <sup>-</sup> )Hg203(β <sup>-</sup> )Tl203 (n,γ)Tl204(β <sup>-</sup> )Pb204(n,3n)Pb202 &Hg204(n,γ)Hg205(β <sup>-</sup> )Tl205(n,γ) Tl206(β <sup>-</sup> )Pb206(n,5n)Pb202				52.3 47.7	58.7 36.6 3.3	54.2 33.4 9.6	50.4 29.6 14.5
									1.7
Re186m	2.0 10 <sup>5</sup> y	Long pathways involving (n,α), (n,nα), β <sup>-</sup>				100.0	100.0	100.0	100.0
Pb205	1.5 10 <sup>7</sup> y	Hg202(n,γ)Hg203(β <sup>-</sup> )Tl203(n,γ)Tl204 (β <sup>-</sup> )Pb204(n,γ)Pb205 Hg201(n,γ)Hg202(n,γ)Hg203(β <sup>-</sup> )Tl203 (n,γ)Tl204(β <sup>-</sup> )Pb204(n,γ)Pb205 &Hg204(n,γ)Hg205(β <sup>-</sup> )Tl205(n,γ) Tl206(β <sup>-</sup> )Pb206(n,2n)Pb205 Hg204(n,γ)Hg205(β <sup>-</sup> )Tl205(n,2n)Tl204 (β <sup>-</sup> )Pb204(n,γ)Pb205 Hg204(n,2n)Hg203(β <sup>-</sup> )Tl203(n,γ)Tl204 (β <sup>-</sup> )Pb204(n,γ)Pb205	96.4 3.4	99.9 0.1	99.7 0.3	76.3 12.4 11.3	83.5 5.9 9.4	82.7 5.6 9.1	82.3 5.2 8.9
Pt190	6.5 10 <sup>11</sup> y	&Hg196(n,α)Pt193(n,2n)Pt192(n,2n) Pt191(n,2n)Pt190 Hg196(n,2n)Hg195m(n,2n)Hg194(n,nα)Pt190 Hg196(n,3n)Hg194(n,3n)Hg192(β <sup>+</sup> ) Au192(β <sup>+</sup> )Pt192(n,3n)Pt190 Hg198(n,3n)Hg196(n,3n)Hg194(n,nα)Pt190				10.3 4.3	6.6	0.2	
	▶						4.7	0.2	

Nuclide	T <sub>½</sub>	Pathway	210	186	151	42	30	21	6
	◀	Hg198(n,3n)Hg196(n,nα)Pt192(n,3n)Pt190					4.0		
		Hg198(n,nα)Pt194(n,3n)Pt192(n,3n)Pt190					3.1		
		Hg199(n,4n)Hg196(n,4n)Hg193(β <sup>+</sup> ) <sub>-</sub>						16.6	
		Au193(β <sup>+</sup> )Pt193(n,4n)Pt190							
		Hg199(n,4n)Hg196(n,4n)Hg193m(β <sup>+</sup> ) <sub>-</sub>						8.0	
		Au193(β <sup>+</sup> )Pt193(n,4n)Pt190							
		Hg198(n,3n)Hg196(n,4n)Hg193(β <sup>+</sup> ) <sub>-</sub>						5.1	
		Au193(β <sup>+</sup> )Pt193(n,4n)Pt190							
		Hg198(n,4n)Hg195m(β <sup>+</sup> )Au195(β <sup>+</sup> ) <sub>-</sub>						3.5	
		Pt195(n,4n)Pt192(n,3n)Pt190							
		Hg198(n,5n)Hg194(n,5n)Hg190(β <sup>+</sup> ) <sub>-</sub>							23.2
		Au190(β <sup>+</sup> )Pt190							
		Hg199(n,6n)Hg194(n,5n)Hg190(β <sup>+</sup> ) <sub>-</sub>							9.2
		Au190(β <sup>+</sup> )Pt190							
		&Hg199(n,5n)Hg195(β <sup>+</sup> )Au195(β <sup>+</sup> ) <sub>-</sub>							8.8
		Pt195(n,6n)Pt190							
		Hg199(n,5n)Hg195m(β <sup>+</sup> )Au195(β <sup>+</sup> ) <sub>-</sub>							7.6
		Pt195(n,6n)Pt190							
		Other very long pathways				85.4	81.6	66.4	51.2

# Mercury activation characteristics

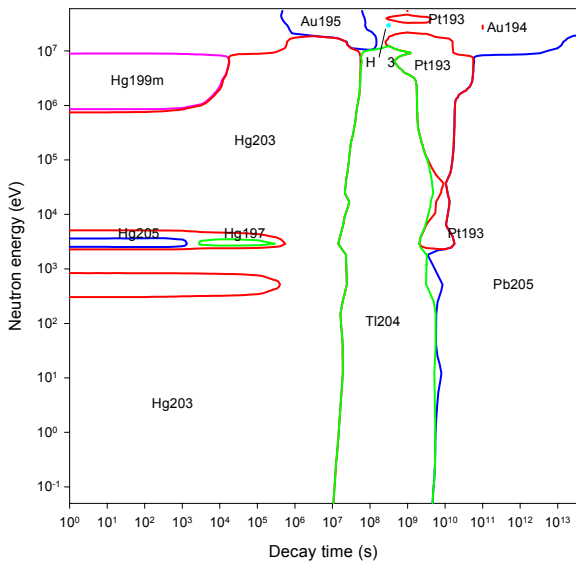


Decay time (years)

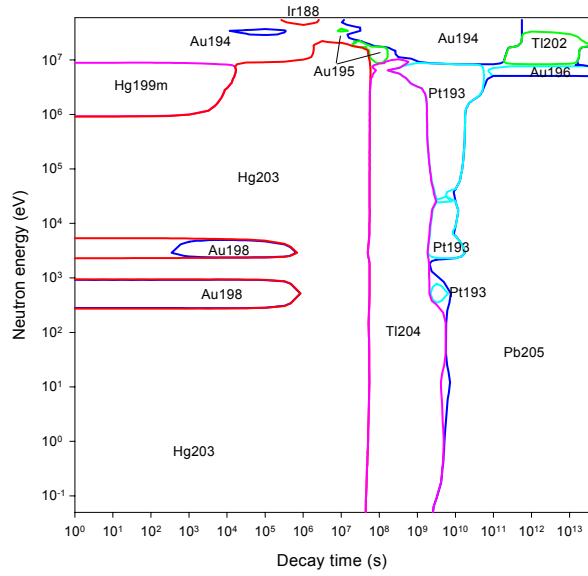
Decay time (years)

# Mercury importance diagrams & transmutation

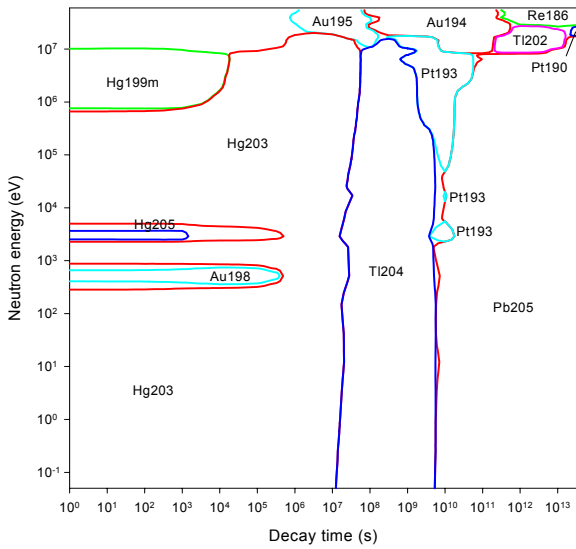
**Activity**



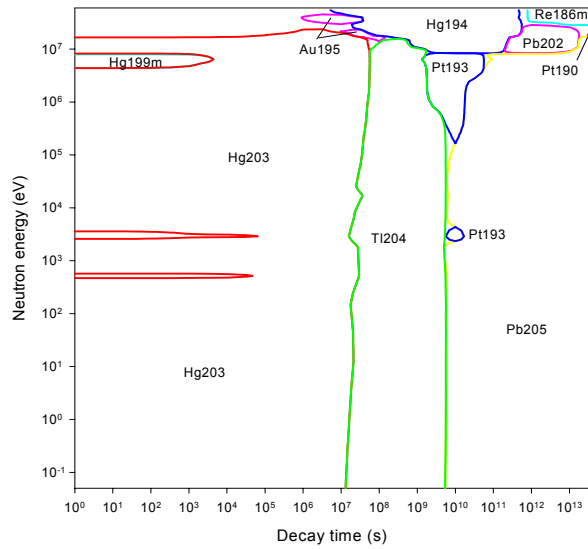
**Dose rate**



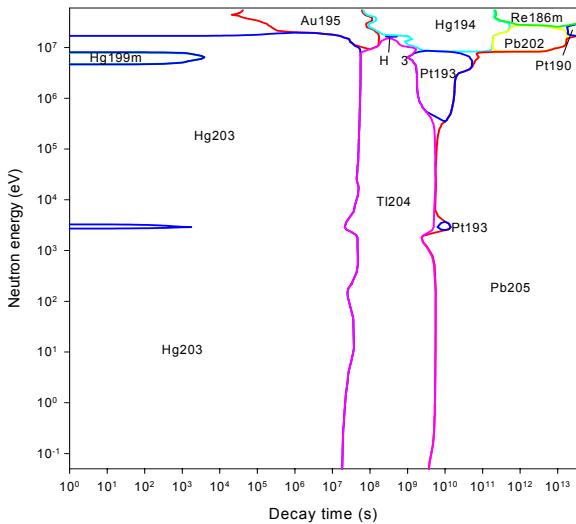
**Heat output**



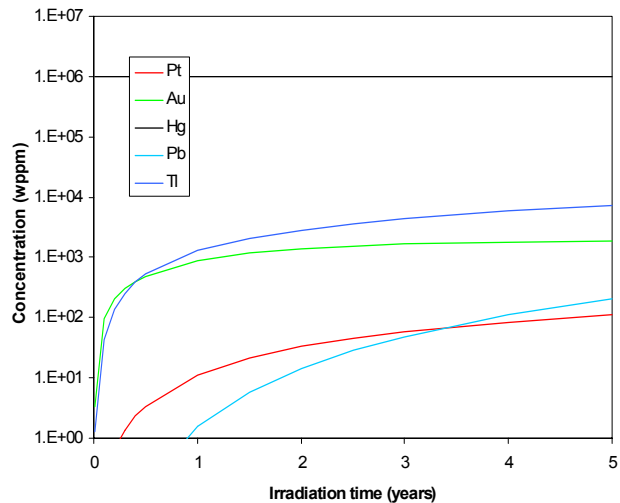
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**



# Thallium

## General properties

Atomic number	81	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	0.85	Tl203	29.524
Melting point / K	577	Tl205	70.476
Boiling point / K	1746		
Density / kgm <sup>-3</sup>	11850		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	46.1		
Electrical resistivity /Ωm	1.8 10 <sup>-7</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	2.99 10 <sup>-5</sup>		
Crystal structure	Hexagonal		
Number of stable isotopes	2		
Mean atomic weight	204.3833		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	1.37E15	1.31E15	1.21E15	8.75E14	2.16E7	1.31E6	kW kg <sup>-1</sup>	6.66E-2	6.01E-2	5.24E-2	3.34E-2	4.80E-10	1.56E-11
Tl204	76.52	80.36	86.60	99.99	54.90		Tl204	60.15	66.64	76.33	99.99	94.25	
Tl202	13.28	13.95	12.25		0.30	1.34	Tl202	21.44	23.75	22.16		1.06	8.90
Tl206	6.16	2.72					Tl206	10.96	5.10				
Pb203	2.38	2.50	0.83				Pb203m	3.16					
Pb203m	1.16						Pb203	2.84	3.15	1.12			
Hg203	0.28	0.29	0.30				Pb204m	0.89	0.94				
H3					38.54		Pb205					2.92	89.66
Pb205					5.94	97.30	H3					1.58	
Pb202					0.30	1.34	Pb202					0.17	1.44
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	1.14E4	9.12E3	6.76E3	6.93E1	4.34E-6	1.26E-6	Sv kg <sup>-1</sup>	1.36E6	1.36E6	1.33E6	1.05E6	1.55E-2	5.22E-4
Tl202	71.33	89.30	89.15		82.22	61.94	Tl204	92.82	92.83	94.29	99.99	91.54	
Pb203m	19.11						Tl202	6.04	6.04	5.00		0.18	1.52
Pb204m	5.80	6.88					Pb203	0.57	0.57	0.18			
Pb203	2.56	3.21	1.34				Hg203	0.54	0.54	0.52			
Hg203	0.21	0.26	0.34	1.16			Pb202					3.70	29.86
Tl204	0.09*	0.11*	0.16*	98.83*	3.44*		Pb205					2.31	68.60
Pb205					13.51	37.44	H3					2.24	
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	4.61E5	4.61E5	4.48E5	3.41E5	8.68E-3	1.30E-3	Tl204	1.17E12	1.11E12	1.06E12	8.75E11	1.20E4	7.82E1
Tl204	88.87	88.89	91.25	99.98	53.29		Tl206	89.65	94.51	98.47	100.0	98.58	
Tl202	7.51	7.51	6.28		0.14	0.25	Tl202	7.22	3.20				
Hg203	2.01	2.01	1.95	0.01			Tl202	1.55	1.64	1.39		0.05	2.26
Pb203	1.56	1.56	0.49				Pb203m	0.90					
Pb204m	0.01	0.01					Pb204m	0.30	0.30				
Tl206	0.01	0.01					Pb203	0.27	0.29	0.09			
H3					24.94		H3					0.69	
Pb205					12.57	83.43	Pb205					0.62	96.11
Pb202					9.04	16.31	Pb202					0.03	1.62

# Thallium

## Pathway analysis

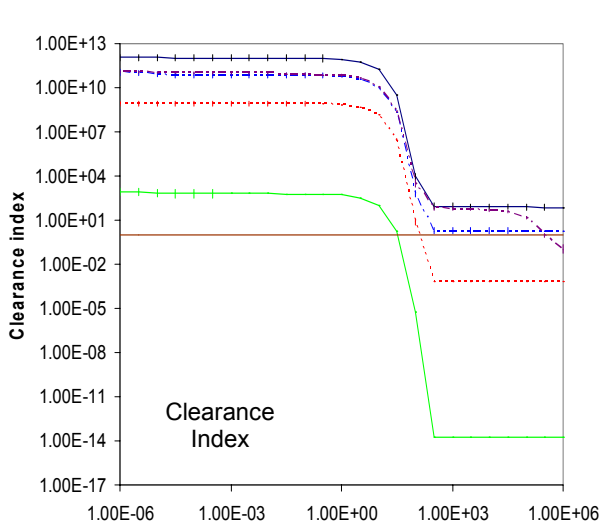
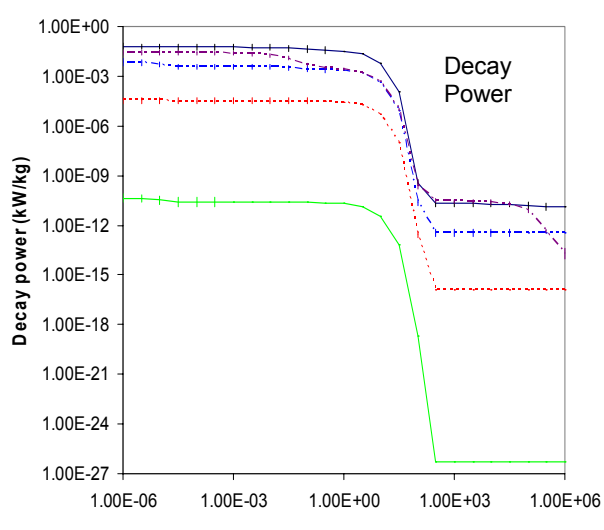
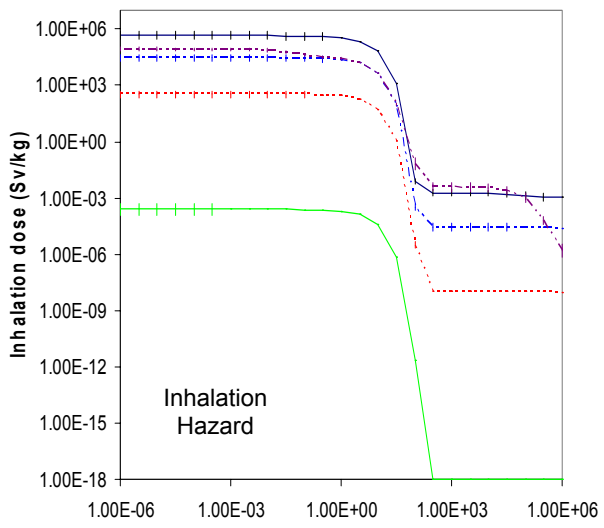
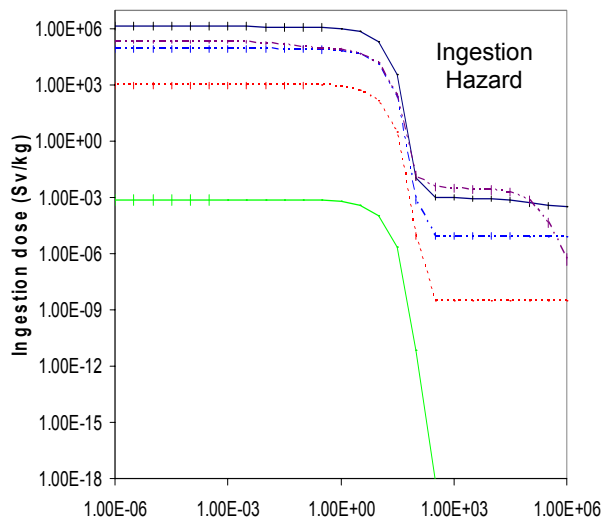
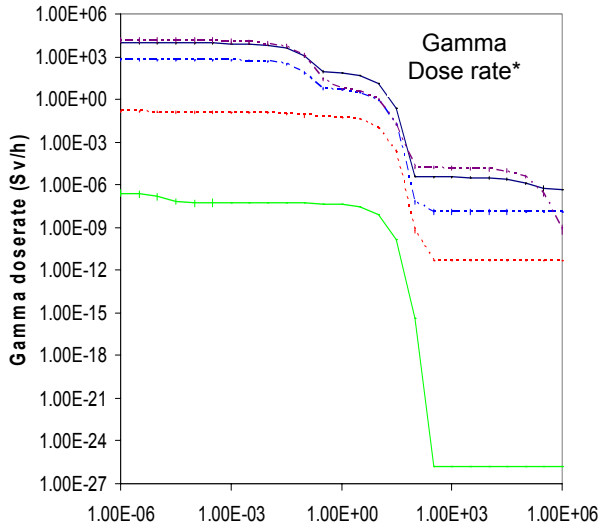
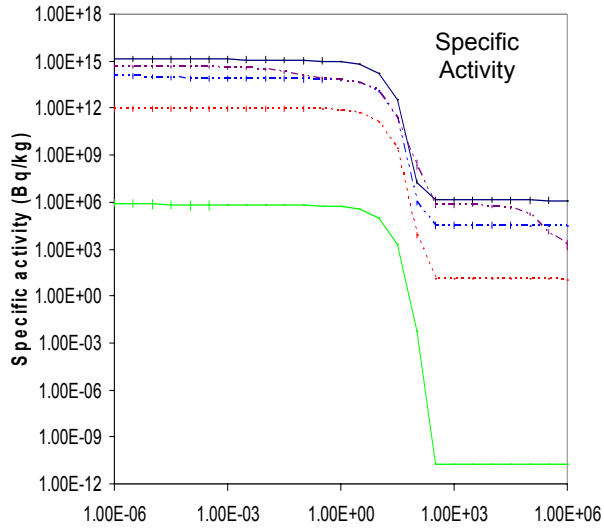
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Tl206	4.20 m	&Tl205(n, $\gamma$ )Tl206 Tl203(n, $\gamma$ )Tl204(n, $\gamma$ )Tl205(n, $\gamma$ )Tl206	93.8 6.2	100.0	100.0	99.9	99.6	99.6	99.8
Pb204m	1.125 h	Tl205(n,2n)Tl204( $\beta^-$ )Pb204(n,n')Pb204m Tl205(n, $\gamma$ )Tl206( $\beta^-$ )Pb206(n,3n)Pb204m				99.7	91.6 8.1	97.3 2.5	98.3 1.5
Tl200	1.088 d	Tl203(n,2n)Tl202(n,2n)Tl201(n,2n)Tl200 Tl205(n,2n)Tl204(n,2n)Tl203(n,2n) Tl202(n,2n)Tl201(n,2n)Tl200 Tl203(n,4n)Tl200 Tl205(n,3n)Tl203(n,4n)Tl200 Tl205(n,2n)Tl204( $\beta^-$ )Pb204(n,3n) Pb202(n,3n)Pb200( $\beta^+$ )Tl200 Tl203(n,2n)Tl202(n,3n)Tl200 Tl205(n,3n)Tl203(n,2n)Tl202(n,3n)Tl200 Tl205(n,4n)Tl202(n,3n)Tl200 Tl205(n,6n)Tl200				93.5 6.5	48.9 32.2 8.2	84.7 12.8	22.5
Au194	1.584 d	Tl203(n,4n)Tl200( $\beta^+$ )Hg200(n,4n) Hg197( $\beta^+$ )Au197(n,4n)Au194 &Tl205(n,6n)Tl200( $\beta^+$ )Hg200(n,5n) Hg196(n,t)Au194 &Tl205(n,5n)Tl201( $\beta^+$ )Hg201(n,6n) Hg196(n,t)Au194 &Tl203(n,6n)Tl198( $\beta^+$ )Hg198(n,2nt)Au194 &Tl203(n,5n)Tl199( $\beta^+$ )Hg199(n,3nt)Au194 Tl205(n,5n)Tl201( $\beta^+$ )Hg201(n,5n) Hg197( $\beta^+$ )Au197(n,4n)Au194 Other very long pathways						3.6	0.1 3.1 2.5 2.3 1.8 1.3
Tl201	3.041 d	Tl203(n,2n)Tl202(n,2n)Tl201 Tl205(n,2n)Tl204(n,2n)Tl203(n,2n) Tl202(n,2n)Tl201 Tl203(n,3n)Tl201 Tl205(n,3n)Tl203(n,3n)Tl201 Tl205(n,5n)Tl201 Tl205(n,2n)Tl204(n,4n)Tl201				91.6 7.4		59.6 39.2	61.3 9.3 14.7 84.5
Re186	3.777 d	Long pathways involving (n, $\alpha$ ), (n, $n\alpha$ ), $\beta^-$				100.0	100.0	100.0	100.0
Tl202	12.240 d	Tl203(n,2n)Tl202 Tl205(n,2n)Tl204(n,2n)Tl203(n,2n)Tl202 &Tl205(n,2n)Tl204( $\beta^-$ )Pb204(n,2n) Pb203( $\beta^+$ )Tl203(n,2n)Tl202 Tl205(n,3n)Tl203(n,2n)Tl202 Tl205(n,4n)Tl202 Tl205(n,2n)Tl204(n,3n)Tl202				88.7 8.5 1.3	37.0 24.4 21.2 16.6	6.8	16.8 79.9
Hg203	46.603 d	Tl203(n, $\alpha$ )Au200( $\beta^-$ )Hg200(n, $\gamma$ )Hg201 (n, $\gamma$ )Hg202(n, $\gamma$ )Hg203 Tl203(n, $\gamma$ )Tl204(n, $\alpha$ )Au201( $\beta^-$ )Hg201 (n, $\gamma$ )Hg202(n, $\gamma$ )Hg203 Tl203(n, $\gamma$ )Tl204( $\beta^-$ )Pb204(n, $\gamma$ )Pb205 (n, $\alpha$ )Hg202(n, $\gamma$ )Hg203 Tl205(n, $\gamma$ )Tl206( $\beta^-$ )Pb206(n, $\alpha$ )Hg203 Tl205(n,2n)Tl204( $\beta^+$ )Hg204(n,2n)Hg203 Tl203(n,p)Hg203 Tl205(n,2n)Tl204(n,2n)Tl203(n,p)Hg203 Tl203(n,2n)Tl202( $\beta^+$ )Hg202(n, $\gamma$ )Hg203 Tl205(n,d)Hg204(n,2n)Hg203 Tl205(n,2n)Tl204(n,d)Hg203 Tl205(n,2n)Tl204(n,p)Hg204(n,2n)Hg203 Tl205(n,t)Hg203 Tl205(n,3n)Tl203(n,p)Hg203	99.5	96.9 1.3 1.2 0.2	0.2 99.8		69.1 22.7 2.0 1.5 1.3 1.2 1.0 0.5	26.4 10.0	4.4 91.2



Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6		
Au195	186.09 d	Tl203(n,3n)Tl201(β <sup>+</sup> )Hg201(n,4n)_ Hg198(n,4n)Hg195m(β <sup>+</sup> )Au195						7.2			
		Tl203(n,4n)Tl200(β <sup>+</sup> )Hg200(n,3n)_ Hg198(n,4n)Hg195m(β <sup>+</sup> )Au195						7.1			
		Tl203(n,3n)Tl201(β <sup>+</sup> )Hg201(n,4n)_ Hg198(n,4n)Hg195(β <sup>+</sup> )Au195							3.4		
		Tl203(n,4n)Tl200(β <sup>+</sup> )Hg200(n,3n)_ Hg198(n,4n)Hg195(β <sup>+</sup> )Au195							3.4		
		Tl205(n,4n)Tl202(β <sup>+</sup> )Hg202(n,5n)_ Hg198(n,4n)Hg195m(β <sup>+</sup> )Au195							2.1	0.3	
		Tl205(n,5n)Tl201(β <sup>+</sup> )Hg201(n,4n)_ Hg198(n,4n)Hg195m(β <sup>+</sup> )Au195							1.7	0.3	
		Tl203(n,4n)Tl200(β <sup>+</sup> )Hg200(n,4n)_ Hg197(β <sup>+</sup> )Au197(n,3n)Au195							1.3		
		Tl205(n,4n)Tl202(β <sup>+</sup> )Hg202(n,5n)_ Hg198(n,4n)Hg195(β <sup>+</sup> )Au195							1.0		
		&Tl203(n,5n)Tl199(β <sup>+</sup> )Hg199(n,5n)_ <i>Hg195(β<sup>+</sup>)Au195</i>								27.5	
		Tl203(n,5n)Tl199(β <sup>+</sup> )Hg199(n,5n)_ Hg195m(β <sup>+</sup> )Au195								19.3	
		&Tl205(n,6n)Tl200(β <sup>+</sup> )Hg200(n,6n)_ Hg195(β <sup>+</sup> ) <i>Au195</i>								7.6	
		Tl205(n,6n)Tl200(β <sup>+</sup> )Hg200(n,6n)_ Hg195m(β <sup>+</sup> )Au195								4.5	
		&Tl203(n,4n)Tl200(β <sup>+</sup> )Hg200(n,6n) <i>Hg195(β<sup>+</sup>)Au195</i>								2.4	
		&Tl203(n,5n)Tl199(β <sup>+</sup> )Hg199(n,2nt) <i>Au195</i>								2.0	
		Tl203(n,4n)Tl200(β <sup>+</sup> )Hg200(n,6n)_ Hg195m(β <sup>+</sup> )Au195								1.4	
		Other very long pathways						100.0	100.0	72.8	34.7
		Tl204	3.788 y	Tl203(n,γ)Tl204 Tl205(n,2n)Tl204	100.0	100.0	100.0	100.0	99.7	99.8	99.8
H3	12.33 y	Tl205(n,X)H3				57.7	69.6	64.9	61.0		
		Tl205(n,2n)Tl204(n,X)H3				24.3	1.3				
		Tl203(n,X)H3				16.3	18.4	22.7	25.3		
		Tl205(n,2n)Tl204(n,2n)Tl203(n,X)H3				2.3					
		Tl205(n,3n)Tl203(n,X)H3					5.9	1.7	1.0		
		Tl203(n,3n)Tl201(β <sup>+</sup> )Hg201(n,X)H3					2.5				
		Tl205(n,4n)Tl202(β <sup>+</sup> )Hg202(n,X)H3						4.1	1.1		
		Tl203(n,4n)Tl200(β <sup>+</sup> )Hg200(n,X)H3						1.7			
		Tl205(n,5n)Tl201(β <sup>+</sup> )Hg201(n,X)H3							3.1		
		Tl203(n,5n)Tl199(β <sup>+</sup> )Hg199(n,X)H3							1.5		
Tl205(n,6n)Tl200(β <sup>+</sup> )Hg200(n,X)H3							1.4				
Pt193	50.0 y	Long pathways involving (n,α), (n,nα), β <sup>-</sup>				100.0	100.0	100.0	100.0		
Hg194	440.01 y	Tl203(n,3n)Tl201(β <sup>+</sup> )Hg201(n,4n)_ Hg198(n,3n)Hg196(n,3n)Hg194					42.0	3.9			
		&Tl203(n,3n)Tl201(β <sup>+</sup> )Hg201(n,3n)_ <i>Hg199(n,4n)Hg196(n,3n)Hg194</i>					14.0	2.7			
		Tl203(n,4n)Tl200(β <sup>+</sup> )Hg200(n,3n)_ Hg198(n,3n)Hg196(n,3n)Hg194					5.8	3.8			
		Tl205(n,3n)Tl203(n,3n)Tl201(β <sup>+</sup> )Hg201_ (n,4n)Hg198(n,3n)Hg196(n,3n)Hg194					5.4	0.1			
		Tl203(n,3n)Tl201(β <sup>+</sup> )Hg201(n,2n)Hg200_ (n,3n)Hg198(n,3n)Hg196(n,3n)Hg194					5.2				
		Tl203(n,2n)Tl202(β <sup>+</sup> )Hg202(n,3n)Hg200_ (n,3n)Hg198(n,3n)Hg196(n,3n)Hg194					4.3				
		&Tl205(n,4n)Tl202(β <sup>+</sup> )Hg202(n,4n)_ <i>Hg199(n,4n)Hg196(n,3n)Hg194</i>						47.6			
		Tl203(n,4n)Tl200(β <sup>+</sup> )Hg200(n,5n)_ Hg196(n,3n)Hg194						4.8	0.7		
		▶									

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
	◀	Tl203(n,5n)Tl199(β <sup>+</sup> )Hg199(n,4n) Hg196(n,3n)Hg194 &Tl203(n,2n)Tl202(β <sup>+</sup> )Hg202(n,4n) Hg199(n,4n)Hg196(n,3n)Hg194 Tl205(n,4n)Tl202(β <sup>+</sup> )Hg202(n,5n) Hg198(n,5n)Hg194 Tl205(n,5n)Tl201(β <sup>+</sup> )Hg201(n,4n) Hg198(n,5n)Hg194 Tl203(n,5n)Tl199(β <sup>+</sup> )Hg199(n,6n)Hg194 &Tl203(n,6n)Tl198(β <sup>+</sup> )Hg198(n,5n)Hg194 Tl203(n,6n)Tl198m(β <sup>+</sup> )Hg198(n,5n)Hg194 Other very long pathways						4.5 3.6 0.3 0.2	0.7  4.3 4.2 31.2 22.0 9.8 27.1
Pb202	5.3 10 <sup>4</sup> y	&Tl205(n,2n)Tl204(β <sup>-</sup> )Pb204(n,2n) Pb203(n,2n)Pb202 &Tl205(n,2n)Tl204(β <sup>-</sup> )Pb204(n,3n)Pb202 Tl205(n,γ)Tl206(β <sup>-</sup> )Pb206(n,5n)Pb202				100.0			
							99.8	99.8	95.5 3.5
Re186m	2.0 10 <sup>5</sup> y	Long pathways involving (n,α), (n,nα), β <sup>-</sup>				100.0	100.0	100.0	100.0
Pb205	1.5 10 <sup>7</sup> y	Tl203(n,γ)Tl204(β <sup>-</sup> )Pb204(n,γ)Pb205 &Tl205(n,γ)Tl206(β <sup>-</sup> )Pb206(n,2n)Pb205 Tl205(n,2n)Tl204(β <sup>-</sup> )Pb204(n,γ)Pb205	100.0	100.0	100.0	82.8 17.2	91.4 8.2	91.7 7.9	92.1 7.5

# Thallium activation characteristics

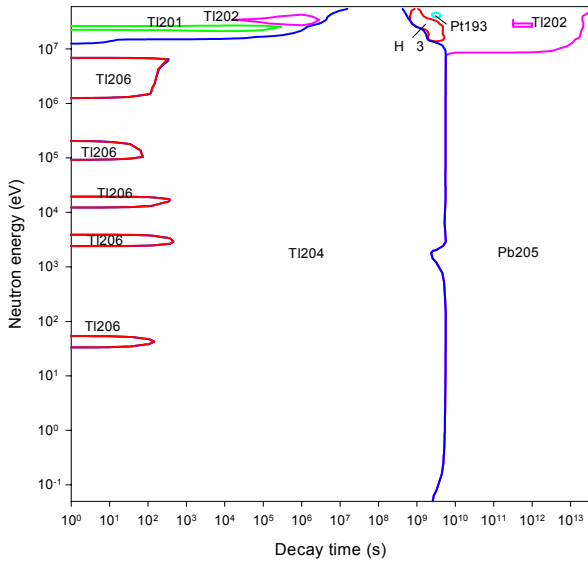


Decay time (years)

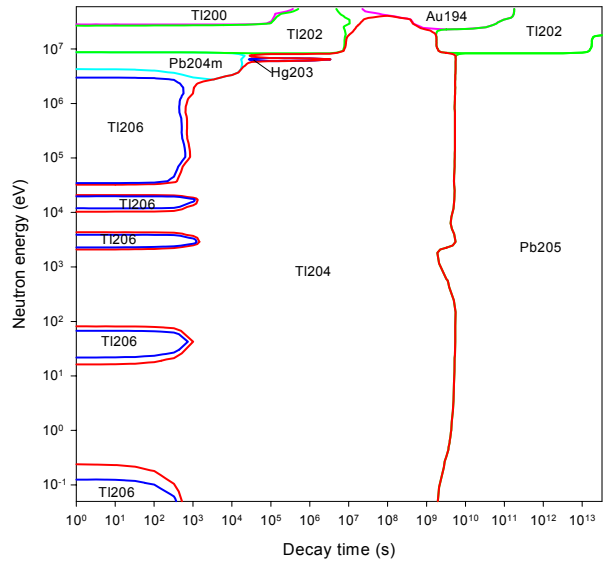
Decay time (years)

# Thallium importance diagrams & transmutation

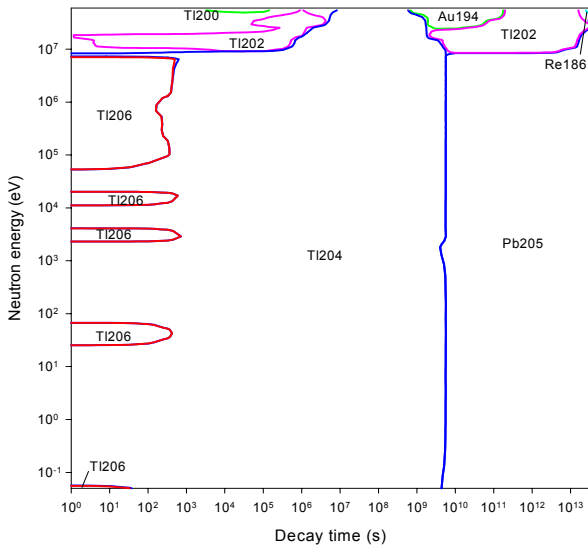
Activity



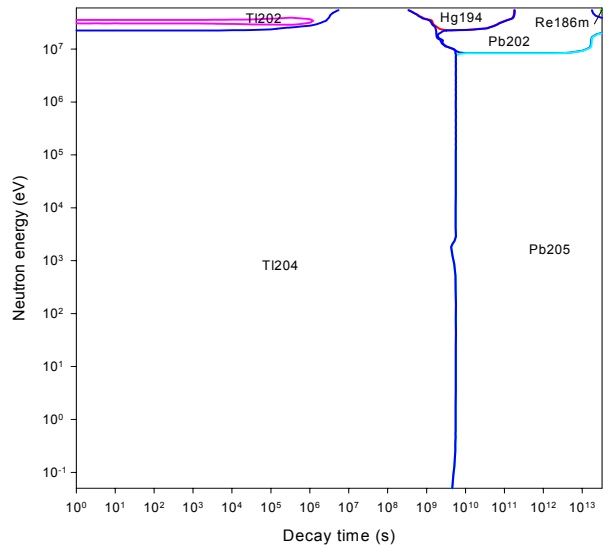
Dose rate



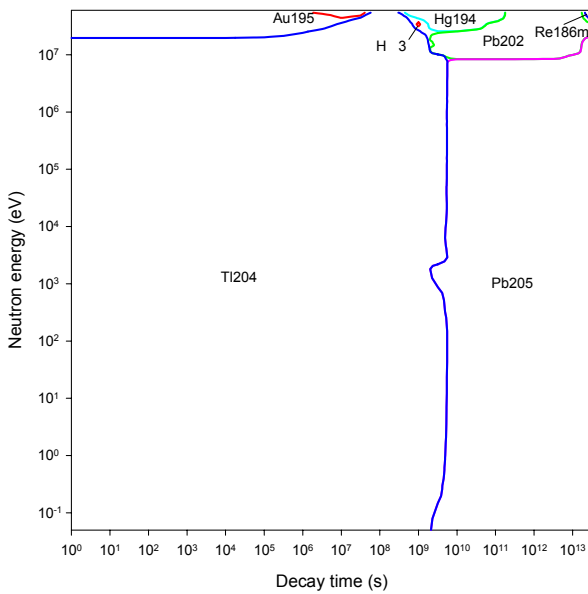
Heat output



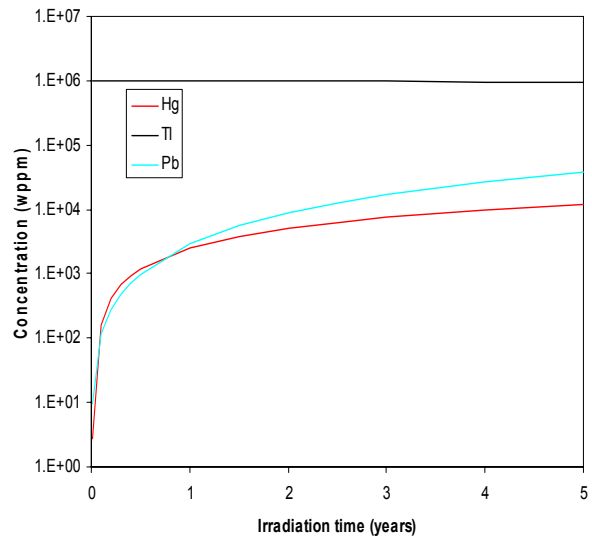
Ingestion dose



Inhalation dose



First wall transmutation



# Lead

## General properties

Atomic number	82	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	14.0	Pb204	1.4 ( $T_{1/2}=1.40 \cdot 10^{17}$ y)
Melting point / K	600.6	Pb206	24.1
Boiling point / K	2022	Pb207	22.1
Density / $\text{kgm}^{-3}$	11350	Pb208	52.4
Thermal conductivity / $\text{Wm}^{-1}\text{K}^{-1}$	35.3		
Electrical resistivity / $\Omega\text{m}$	$2.07 \cdot 10^{-7}$		
Coefficient of thermal expansion / $\text{K}^{-1}$	$2.89 \cdot 10^{-5}$		
Crystal structure	FCC		
Number of stable isotopes	3 (4)		
Mean atomic weight	207.2		

## Activation properties

Act	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Heat	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Bq $\text{kg}^{-1}$	3.09E14	1.83E13	5.58E12	9.30E11	5.62E7	4.97E7	kW $\text{kg}^{-1}$	7.69E-2	1.85E-3	3.11E-4	3.56E-5	2.13E-9	6.21E-10
Pb207m	91.81						Pb207m	96.29					
Pb203	4.18	70.28	71.75				Pb204m	1.30	51.23				
Pb203m	2.04						Pb203m	1.08					
Pb204m	0.93	14.76					Pb203	0.97	40.45	74.77			
Tl204	0.36	6.08	19.96	99.94	0.02		Tl204	0.06	2.30	13.69	99.57	0.02	
Pb209	0.27	4.46					Tl202	0.05	2.17	10.52		0.26	0.24
Tl202	0.17	2.79	7.47		0.12	0.04	Pb209	0.03	1.40				
Tl206	0.07	0.52					Bi207				0.04	68.19	
Hg203	0.02	0.25	0.78	0.02			Pb205					25.57	87.19
H3				0.02	1.01		Pb208					4.40	12.50
Pb205				0.01	88.53	99.56	Po209					1.48	
Bi207				0.01	9.72		H3					0.02	
Dose	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Ing	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{h}^{-1}$	8.41E4	1.19E3	5.31E1	8.71E-2	1.77E-3	1.54E-4	Sv $\text{kg}^{-1}$	6.01E3	6.00E3	3.62E3	1.29E3	5.28E-2	1.43E-2
Pb207m	97.38						Pb203	51.52	51.60	26.50			
Pb204m	1.29	86.11					Tl204	22.27	22.33	36.87	86.27	0.03	
Pb203m	1.01						Po210	17.60	17.65	29.14	13.69	0.48	
Pb203	0.13	9.34	65.29				Tl202	3.84	3.85	5.18		0.06	0.06
Tl208	0.12	2.64					Pb204m	2.42	2.30				
Tl202	0.03	1.87	34.15	0.01	0.17	0.53	Hg203	1.46	1.46	2.29	0.03		
Hg203		0.02	0.50	5.03			Po209				0.01	57.58	
Tl206m		0.01					Po207				0.01	13.44	
Bi207			0.03	56.47	89.54		Pb205					26.36	96.98
Tl204			0.02*	37.74*			Pb202					1.15	1.16
Bi208				0.67	9.26	87.81	Bi208					0.58	1.78
Pb205				0.07	1.02	11.66	H3					0.05	
Inh	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y	Clear	0	$10^{-5}$ y	$10^{-2}$ y	1 y	100 y	$10^5$ y
Sv $\text{kg}^{-1}$	7.52E3	7.50E3	5.34E3	9.97E2	1.72E-1	4.39E-2		4.44E11	9.06E9	1.56E9	9.30E8	5.81E4	3.39E3
Po210	50.42	50.54	70.88	63.55	0.52		Pb207m	96.84					
Pb203	37.76	37.80	16.49				Pb204m	1.34	62.23				
Tl204	5.79	5.80	8.14	36.34			Pb203m	0.95					
Hg203	1.47	1.47	1.96	0.05			Pb203	0.29	14.23	25.62			
Tl202	1.30	1.30	1.48		0.01	0.01	Tl204	0.25	12.31	71.30	99.93	0.02	
Bi210	1.22	1.23	1.04		0.01		Tl208	0.03	0.42				
Pb204m	1.22	1.16					Tl202	0.01	0.57	2.67		0.01	0.06
Bi207			0.01	0.03	17.73		Hg203		0.05	0.28			
Po209				0.02	54.95		Po210		0.01	0.06	0.02		
Pb205					24.50	95.83	Bi207		0.01	0.03	0.05	93.92	
Bi210m					0.52	2.00	Pb205					5.03	85.81
Bi208					0.51	1.66	Bi208					0.99	14.09
H3					0.09		H3					0.01	

# Lead

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
Pb207m	0.806 s	Pb206(n,γ)Pb207m	100.0	100.0	100.0					
		Pb208(n,2n)Pb207m				94.3	92.6	92.4	92.7	
		Pb207(n,n')Pb207m				3.2	6.2	6.6	6.7	
		Pb208(n,2n)Pb207(n,n')Pb207m				1.1				
Hg205	5.20 m	Pb208(n,α)Hg205	98.5	99.9	99.9	99.9	99.2	93.4	86.0	
		Pb207(n,γ)Pb208(n,α)Hg205	1.5		0.1					
		Pb206(n,d)Tl205(n,p)Hg205					0.3	1.5	0.9	
		Pb207(n,h)Hg205						3.0	8.4	
		Pb207(n,t)Tl205(n,p)Hg205						0.8	1.0	
		Pb208(n,nt)Tl205(n,p)Hg205						0.3	1.9	
Pb204m	1.125 h	Pb206(n,2n)Pb205(n,2n)Pb204m				80.7	0.9	0.7		
		Pb207(n,2n)Pb206(n,2n)Pb205(n,2n)Pb204m				12.1				
		&Pb208(n,2n)Pb207(n,2n)Pb206(n,2n)Pb205(n,2n)Pb204m				3.0				
		Pb205(n,2n)Pb204m								
		Pb204(n,n')Pb204m				1.8	0.3			
		Pb206(n,2n)Pb205(n,2n)Pb204(n,n')Pb204m				1.5				
		Pb206(n,3n)Pb204m					53.8	23.0	10.6	
		Pb208(n,3n)Pb206(n,3n)Pb204m					32.1	3.8		
		Pb207(n,2n)Pb206(n,3n)Pb204m					3.3	0.9		
		Pb207(n,3n)Pb205(n,2n)Pb204m					3.2	0.8		
		Pb207(n,4n)Pb204m					2.3	51.6	11.8	
		Pb206(n,3n)Pb204(n,n')Pb204m					1.0			
		Pb208(n,4n)Pb205(n,2n)Pb204m					0.3	5.5		
		&Pb208(n,2n)Pb207(n,4n)Pb204m					0.3	5.4		
		Pb208(n,5n)Pb204m						3.9	70.7	
		Pb207(n,4n)Pb204(n,n')Pb204m						1.0		
Pb209	3.253 h	Pb208(n,γ)Pb209	98.5	99.9	99.9	99.9	99.7	99.8	99.9	
		Pb207(n,γ)Pb208(n,γ)Pb209	1.5		0.1					
Tl200	1.088 d	&Pb204(n,2n)Pb203(β <sup>+</sup> )Tl203(n,2n)Tl202(n,2n)Tl201(n,2n)Tl200				61.6				
		&Pb206(n,2n)Pb205(n,2n)Pb204(n,2n)Pb203(β <sup>+</sup> )Tl203(n,2n)Tl202(n,2n)Tl201(n,2n)Tl200				18.1				
		&Pb204(n,2n)Pb203(n,2n)Pb202(n,2n)Pb201(β <sup>+</sup> )Tl201(n,2n)Tl200				6.7				
		&Pb206(n,3n)Pb204(n,3n)Pb202(n,3n)Pb200(β <sup>+</sup> )Tl200					48.3	1.2		
		&Pb204(n,3n)Pb202(n,3n)Pb200(β <sup>+</sup> )Tl200					21.9	2.1		
		&Pb207(n,4n)Pb204(n,3n)Pb202(n,3n)Pb200(β <sup>+</sup> )Tl200					1.8	2.5		
		&Pb206(n,4n)Pb203(β <sup>+</sup> )Tl203(n,4n)Tl200						48.1	1.3	
		&Pb208(n,4n)Pb205(n,4n)Pb202(n,3n)Pb200(β <sup>+</sup> )Tl200						12.7		
		&Pb208(n,4n)Pb205(n,3n)Pb203(β <sup>+</sup> )Tl203(n,4n)Tl200						4.2		
		&Pb208(n,3n)Pb206(n,4n)Pb203(β <sup>+</sup> )Tl203(n,4n)Tl200						4.1		
		&Pb206(n,5n)Pb202(n,3n)Pb200(β <sup>+</sup> )Tl200						1.0	5.8	
		&Pb207(n,4n)Pb204(n,5n)Pb200(β <sup>+</sup> )Tl200						0.1	5.8	
		&Pb208(n,5n)Pb204(n,5n)Pb200(β <sup>+</sup> )Tl200							36.4	
		Pb204(n,5n)Pb200(β <sup>+</sup> )Tl200							8.5	
		&Pb206(n,3n)Pb204(n,5n)Pb200(β <sup>+</sup> )Tl200							5.0	
		Pb208(n,4n)Pb205(n,6n)Pb200(β <sup>+</sup> )Tl200							3.8	
		&Pb208(n,6n)Pb203(β <sup>+</sup> )Tl203(n,4n)Tl200							3.6	
		&Pb206(n,5n)Pb202(n,t)Tl200							2.4	
		Pb207(n,6n)Pb202(n,3n)Pb200(β <sup>+</sup> )Tl200							2.2	
		Other very long pathways					13.6	28.0	24.0	25.2

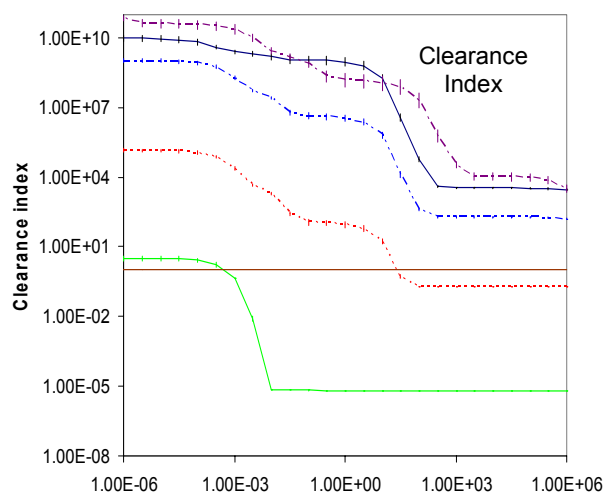
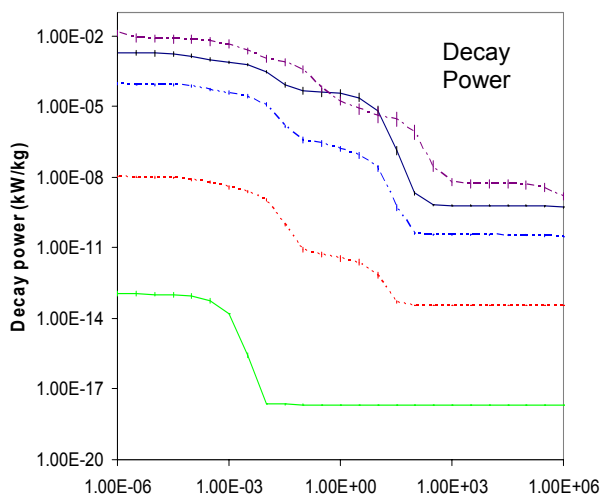
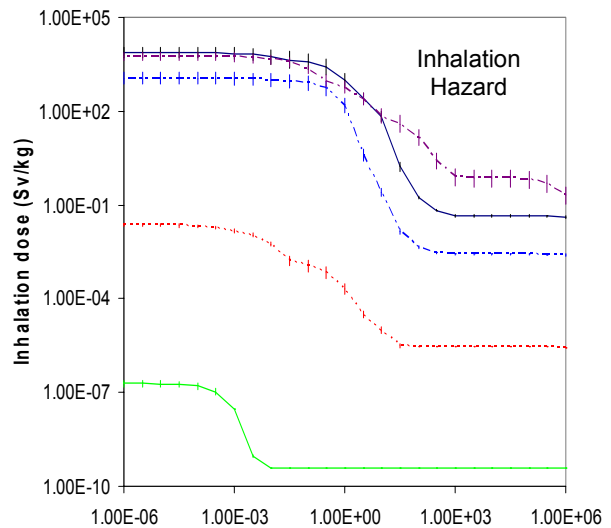
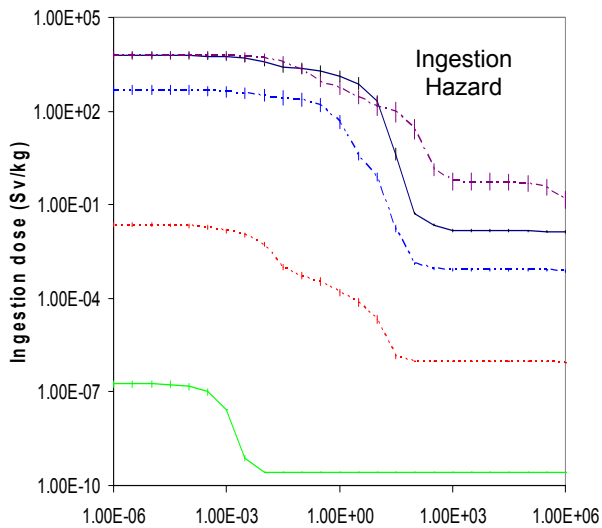
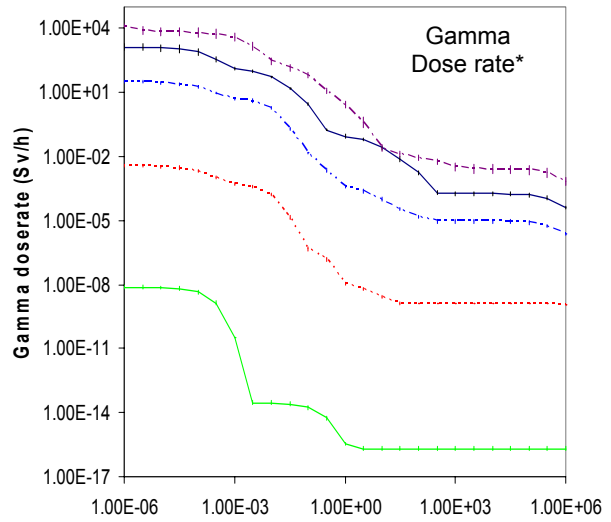
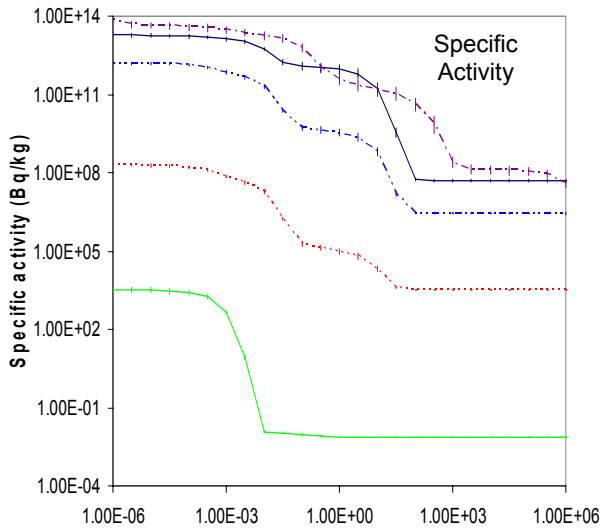
Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Au194	1.584 d	Long pathways involving (n,α), (n,nα), β <sup>-</sup>				100.0	100.0	100.0	100.0
Pb203	2.162 d	&Pb204(n,2n)Pb203 &Pb206(n,2n)Pb205(n,2n)Pb204(n,2n)Pb203   &Pb207(n,2n)Pb206(n,2n)Pb205(n,2n)_ Pb204(n,2n)Pb203 &Pb207(n,3n)Pb205(n,3n)Pb203 &Pb206(n,3n)Pb204(n,2n)Pb203 &Pb206(n,2n)Pb205(n,3n)Pb203 &Pb208(n,3n)Pb206(n,3n)Pb204(n,2n)Pb203   &Pb208(n,4n)Pb205(n,3n)Pb203   &Pb208(n,3n)Pb206(n,2n)Pb205(n,3n)Pb203   &Pb208(n,2n)Pb207(n,3n)Pb205(n,3n)Pb203   &Pb206(n,4n)Pb203 &Pb208(n,3n)Pb206(n,4n)Pb203 &Pb207(n,4n)Pb204(n,2n)Pb203 &Pb207(n,2n)Pb206(n,4n)Pb203 &Pb207(n,5n)Pb203 &Pb208(n,6n)Pb203 &Pb208(n,5n)Pb204(n,2n)Pb203				47.3 45.2 4.0	5.3 37.2 22.5 10.7 6.3 3.0 3.0 2.8 1.8 1.1 0.9	1.4 1.4 1.2 10.0 3.0 62.0 9.8 3.5 2.4 2.1	14.1 32.9 40.6 3.2
Tl202	12.240 d	&Pb204(n,2n)Pb203(β <sup>+</sup> )Tl203(n,2n)Tl202   &Pb206(n,2n)Pb205(n,2n)Pb204(n,2n)_ Pb203(β <sup>+</sup> )Tl203(n,2n)Tl202 &Pb207(n,2n)Pb206(n,2n)Pb205(n,2n)_ Pb204(n,2n)Pb203(β <sup>+</sup> )Tl203(n,2n)Tl202 &Pb206(n,3n)Pb204(n,3n)Pb202m(β <sup>+</sup> )Tl202   &Pb207(n,3n)Pb205(n,3n)Pb203(β <sup>+</sup> )_ Tl203(n,2n)Tl202 &Pb206(n,3n)Pb204(n,2n)Pb203(β <sup>+</sup> )_ Tl203(n,2n)Tl202 &Pb208(n,3n)Pb206(n,3n)Pb204(n,3n)_ Pb202m(β <sup>+</sup> )Tl202 &Pb206(n,3n)Pb204(n,t)Tl202 Pb204(n,3n)Pb202m(β <sup>+</sup> )Tl202 &Pb206(n,4n)Pb203(β <sup>+</sup> )Tl203(n,2n)Tl202   Pb206(n,d)Tl205(n,4n)Tl202 &Pb207(n,4n)Pb204(n,t)Tl202 Pb207(n,t)Tl205(n,4n)Tl202 Pb208(n,4n)Pb205(n,4n)Pb202m(β <sup>+</sup> )Tl202   Pb208(n,4n)Pb205(n,nt)Tl202 Pb208(n,nt)Tl205(n,4n)Tl202 &Pb207(n,5n)Pb203(β <sup>+</sup> )Tl203(n,2n)Tl202   &Pb208(n,5n)Pb204(n,t)Tl202 Pb206(n,5n)Pb202m(β <sup>+</sup> )Tl202 Pb206(n,2nt)Tl202 &Pb208(n,6n)Pb203(β <sup>+</sup> )Tl203(n,2n)Tl202   Pb207(n,6n)Pb202m(β <sup>+</sup> )Tl202				72.2 23.5 1.6	3.6 17.7 14.6 8.0 4.8 4.4 4.2 1.4 1.1 0.2 0.2	0.5 0.8 0.3 0.3 3.3 0.6 21.8 12.6 8.3 6.9 7.9 4.2 2.8 0.7 0.6 0.5 0.3	2.0 0.1 2.1 1.8 2.4 2.0 0.4 5.8 3.8 4.9 14.5 8.9 16.1 6.1 4.1
Hg203	46.603 d	Pb206(n,α)Hg203 Pb204(n,α)Hg201(n,γ)Hg202(n,γ)Hg203 Pb204(n,γ)Pb205(n,α)Hg202(n,γ)Hg203 Pb207(n,α)Hg204(n,2n)Hg203 &Pb208(n,2n)Pb207(n,α)Hg204(n,2n)Hg203   Pb207(n,2n)Pb206(n,α)Hg203 &Pb204(n,2n)Pb203(β <sup>+</sup> )Tl203(n,p)Hg203   &Pb208(n,2n)Pb207(n,2n)Pb206(n,α)Hg203   &Pb206(n,2n)Pb205(n,2n)Pb204(n,2n)_ Pb203(β <sup>+</sup> )Tl203(n,p)Hg203 Pb207(n,α)Hg203 &Pb208(n,2n)Pb207(n,α)Hg203 Pb208(n,3n)Pb206(n,α)Hg203 &Pb207(n,3n)Pb205(n,3n)Pb203(β <sup>+</sup> )_ Tl203(n,p)Hg203 ▶ Pb208(n,α)Hg204(n,2n)Hg203	58.1 25.5 16.3	97.8 2.2	99.9	30.9 34.2 13.3 9.0 6.1 3.5 1.0 0.3 0.1	31.1 3.7 0.3 1.9 0.6 28.4 4.4 17.9 2.3	8.2 0.6 0.2 29.4 3.0 1.3	9.3 0.2 0.2 15.1 0.8 0.8 0.6

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6	
		Pb208(n,2n $\alpha$ )Hg203 Pb206(n,d)Tl205(n,t)Hg203 &Pb206(n,4n)Pb203( $\beta^+$ )Tl203(n,p)Hg203 Pb206(n,t)Tl204(n,d)Hg203 Pb207(n,t)Tl205(n,t)Hg203 Pb208(n,nt)Tl205(n,t)Hg203 &Pb208(n,6n)Pb203( $\beta^+$ )Tl203(n,p)Hg203 &Pb207(n,5n)Pb203( $\beta^+$ )Tl203(n,p)Hg203 Pb207(n,nt)Tl204(n,d)Hg203 Pb208(n,2nt)Tl204(n,d)Hg203					0.6 0.5 0.2 0.2	31.4 2.9 8.3 1.6	44.4 3.1 0.8 2.2 3.4 6.6 2.4 2.0 1.8 1.4	
Po210	138.39 d	Pb208(n, $\gamma$ )Pb209( $\beta^-$ )Bi209(n, $\gamma$ )Bi210_ ( $\beta^-$ )Po210 Pb207(n, $\gamma$ )Pb208(n, $\gamma$ )Pb209( $\beta^-$ )Bi209_ (n, $\gamma$ )Bi210( $\beta^-$ )Po210	99.3 0.7	100.0	99.9	100.0	99.8	99.8	99.9	
Tl204	3.788 y	Pb206(n, $\alpha$ )Hg203( $\beta^-$ )Tl203(n, $\gamma$ )Tl204_ Pb204(n, $\alpha$ )Hg201(n, $\gamma$ )Hg202(n, $\gamma$ )_ Hg203( $\beta^-$ )Tl203(n, $\gamma$ )Tl204 Pb204(n, $\gamma$ )Pb205(n, $\alpha$ )Hg202(n, $\gamma$ )_ Hg203( $\beta^-$ )Tl203(n, $\gamma$ )Tl204 Pb204(n,p)Tl204 Pb208(n, $\alpha$ )Hg205( $\beta^-$ )Tl205(n,2n)Tl204 &Pb206(n,2n)Pb205(n,2n)Pb204(n,p)Tl204 Pb206(n,2n)Pb205(n,p)Tl205(n,2n)Tl204 Pb206(n,2n)Pb205(n,d)Tl204 Pb206(n,d)Tl205(n,2n)Tl204 Pb206(n,t)Tl204 Pb207(n,3n)Pb205(n,d)Tl204 &Pb206(n,3n)Pb204(n,p)Tl204 Pb208(n,3n)Pb206(n,t)Tl204 &Pb208(n,3n)Pb206(n,3n)Pb204(n,p)Tl204 Pb207(n,nt)Tl204 Pb208(n,4n)Pb205(n,d)Tl204 Pb208(n,2nt)Tl204	85.0 9.2 5.8	99.6 0.4	100.0			35.0 20.7 14.6 10.8 9.1 3.2 0.2	4.6 1.8	1.0 2.5 1.7 36.6 2.0 29.8 2.2 22.2
H3	12.33 y	Pb207(n,X)H3 Pb206(n,2n)Pb205(n,X)H3 &Pb208(n,2n)Pb207(n,X)H3 Pb208(n,X)H3 Pb206(n,X)H3 Pb207(n,2n)Pb206(n,2n)Pb205(n,X)H3 Pb207(n,2n)Pb206(n,X)H3 Pb204(n,X)H3 Pb208(n,3n)Pb206(n,X)H3 Pb207(n,3n)Pb205(n,X)H3 &Pb206(n,3n)Pb204(n,X)H3 Pb208(n,4n)Pb205(n,X)H3 Pb207(n,4n)Pb204(n,X)H3 &Pb208(n,5n)Pb204(n,X)H3 &Pb206(n,5n)Pb202(n,X)H3					37.6 21.5 14.9 11.2 7.2 2.1 1.1 0.9	21.8 1.2 1.7 38.6 18.7 0.6 1.3 5.5 4.0 3.1 0.3 1.7 0.4 0.4 2.8 1.7	19.9 0.7 0.6 42.0 20.4 0.3 1.3 0.9 0.4 0.3 1.5 0.4 2.8 1.7	
Pb210	22.16 y	Pb208(n, $\gamma$ )Pb209(n, $\gamma$ )Pb210 Pb207(n, $\gamma$ )Pb208(n, $\gamma$ )Pb209(n, $\gamma$ )Pb210 Pb208(n, $\gamma$ )Pb209( $\beta^-$ )Bi209(n, $\gamma$ )Bi210m_ (n,p)Pb210	99.2 0.8	100.0	99.9	97.4	96.8	97.5	98.6	
Bi207	31.76 y	&Pb208(n, $\gamma$ )Pb209( $\beta^-$ )Bi209(n,2n)_ Bi208(n,2n)Bi207 Pb208(n, $\gamma$ )Pb209( $\beta^-$ )Bi209(n,3n)Bi207				99.1 0.9			0.7 99.3	
Hg194	440.01 y	&Pb204(n,3n)Pb202(n, $\alpha$ )Hg198(n,3n)_ Hg196(n,3n)Hg194 Pb204(n, $\alpha$ )Hg200(n,3n)Hg198(n,3n)_ Hg196(n,3n)Hg194 Pb206(n,3n)Pb204(n,3n)Pb202(n, $\alpha$ )_ Hg198(n,3n)Hg196(n,3n)Hg194 Pb206(n,3n)Pb204(n, $\alpha$ )Hg200(n,3n)_ Hg198(n,3n)Hg196(n,3n)Hg194					3.3	2.6 2.2 2.1		



Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
		Pb207(n,6n)Pb202(n,5n)Pb198(β <sup>+</sup> )_							9.8
		Tl198(β <sup>+</sup> )Hg198(n,5n)Hg194							2.0
		Pb208(n,6n)Pb203(β <sup>+</sup> )Tl203(n,5n)_							
		Tl199(β <sup>+</sup> )Hg199(n,6n)Hg194							
		Other very long pathways				100.0	96.7	93.1	88.2
Pb202	5.3 10 <sup>4</sup> y	&Pb204(n,2n)Pb203(n,2n)Pb202 &Pb206(n,2n)Pb205(n,2n)Pb204(n,2n)_ Pb203(n,2n)Pb202 &Pb206(n,3n)Pb204(n,3n)Pb202 &Pb204(n,3n)Pb202 &Pb208(n,3n)Pb206(n,3n)Pb204(n,3n)Pb202   &Pb207(n,4n)Pb204(n,3n)Pb202 &Pb207(n,3n)Pb205(n,4n)Pb202 &Pb206(n,2n)Pb205(n,4n)Pb202 &Pb208(n,4n)Pb205(n,4n)Pb202 &Pb206(n,5n)Pb202 Pb208(n,5n)Pb204(n,3n)Pb202 &Pb207(n,6n)Pb202 Pb208(n,3n)Pb206(n,5n)Pb202				73.6 17.8		57.8 4.8 23.4 7.8 11.0 2.6 12.6 0.9 7.6 0.2 6.2 52.7 1.1 3.7 60.4 0.6 1.5 27.4 2.3	
Bi208	3.7 10 <sup>5</sup> y	&Pb208(n,γ)Pb209(β <sup>-</sup> )Bi209(n,2n)Bi208				100.0	99.9	99.9	99.9
Bi210m	3.0 10 <sup>6</sup> y	Pb208(n,γ)Pb209(β <sup>-</sup> )Bi209(n,γ)Bi210m Pb207(n,γ)Pb208(n,γ)Pb209(β <sup>-</sup> )Bi209_ (n,γ)Bi210m	99.5 0.5	100.0	100.0	99.9	99.9	99.9	99.9
Pb205	1.5 10 <sup>7</sup> y	Pb204(n,γ)Pb205 Pb206(n,2n)Pb205 Pb207(n,2n)Pb206(n,2n)Pb205 &Pb208(n,2n)Pb207(n,2n)Pb206(n,2n)Pb205   Pb207(n,3n)Pb205 Pb208(n,3n)Pb206(n,2n)Pb205 Pb208(n,4n)Pb205 &Pb208(n,2n)Pb207(n,3n)Pb205	100.0	100.0	100.0	83.9 12.6 3.4	18.8 0.6 64.3 11.2 5.5 5.2 77.7 5.1	9.2 18.6	17.0 62.2

# Lead activation characteristics

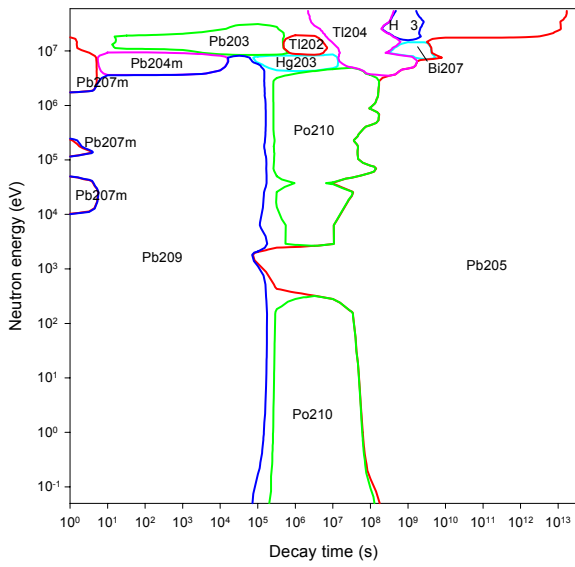


Decay time (years)

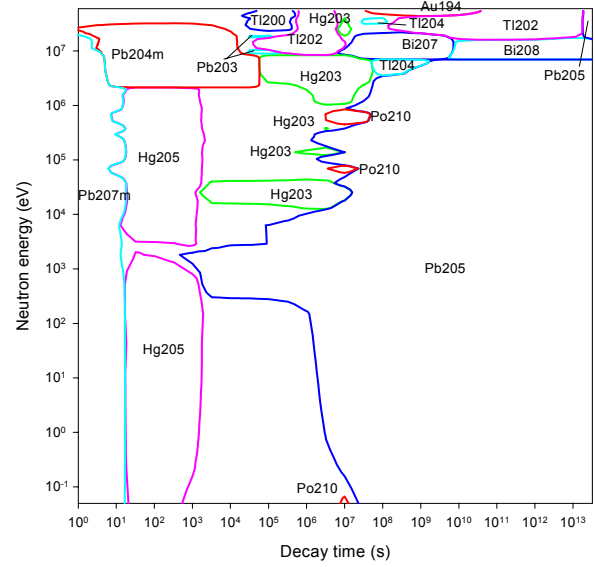
Decay time (years)

# Lead importance diagrams & transmutation

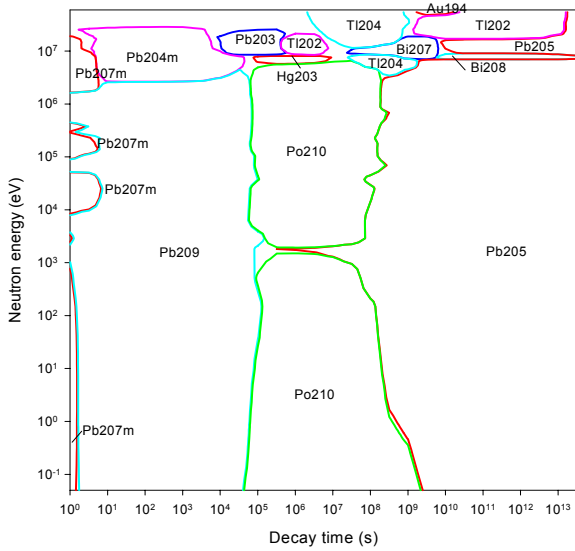
**Activity**



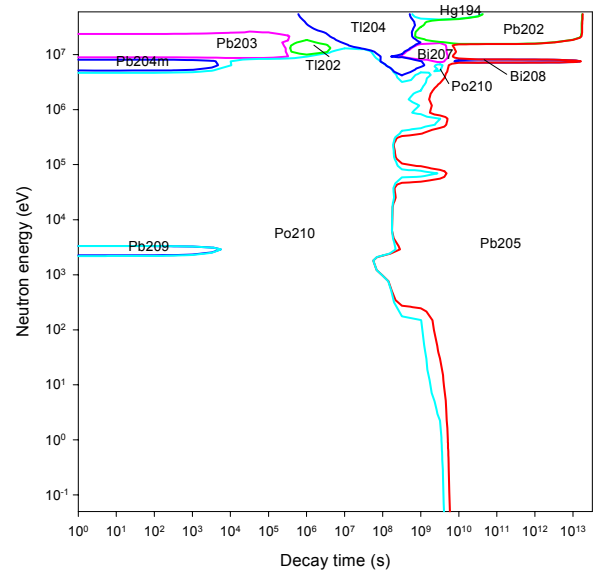
**Dose rate**



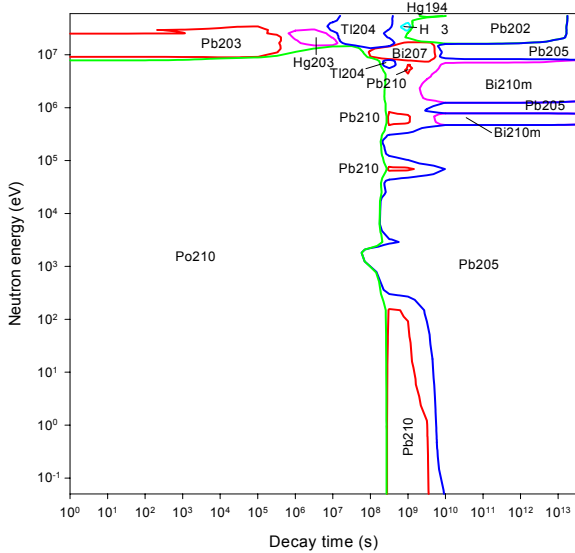
**Heat output**



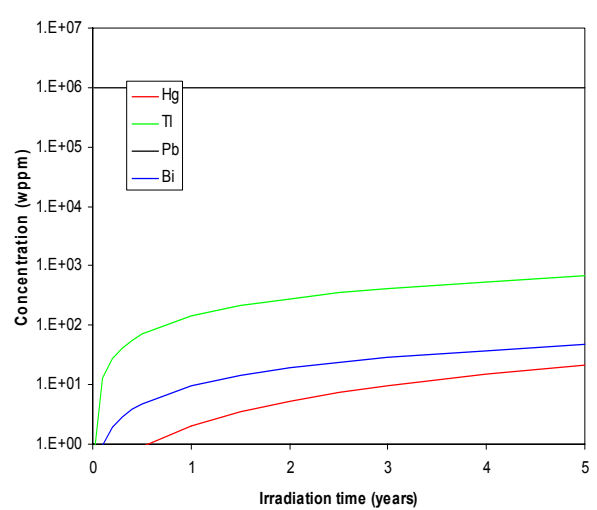
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**





# Bismuth

## General properties

Atomic number	83	Isotopes	Isotopic abundances / %
Crustal abundance / wppm	8.5 10 <sup>-3</sup>	Bi209	100.0 (T <sub>1/2</sub> =1.90 10 <sup>19</sup> y)
Melting point / K	544.6		
Boiling point / K	1837		
Density / kgm <sup>-3</sup>	9747		
Thermal conductivity / Wm <sup>-1</sup> K <sup>-1</sup>	7.87		
Electrical resistivity / Ωm	1.068 10 <sup>-6</sup>		
Coefficient of thermal expansion / K <sup>-1</sup>	1.34 10 <sup>-5</sup>		
Crystal structure	Rhombohedral		
Number of stable isotopes	0 (1)		
Mean atomic weight	208.98038		

## Activation properties

Act	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Heat	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Bq kg <sup>-1</sup>	1.87E14	4.66E13	3.69E13	6.33E12	3.41E11	7.53E9	kW kg <sup>-1</sup>	5.61E-2	2.07E-2	1.99E-2	3.74E-3	9.30E-5	3.22E-6
Bi208m	74.85						Bi208m	62.89					
Po210	11.01	44.14	55.58	54.08			Po210	31.80	85.92	89.43	79.41		
Bi210	11.01	44.12	33.67				Bi210	2.28	6.17	3.89			
Bi207	1.57	6.28	7.94	45.23	96.78		Bi206	1.44	3.90	2.72			
Bi206	0.80	3.19	2.69				Bi207	1.39	3.75	3.92	20.37	94.28	
Pb209	0.45	1.77					Bi208	0.01	0.02	0.02	0.10	4.16	99.69
Bi208	0.01	0.02	0.03	0.14	2.66	99.71	Po209	0.01	0.01	0.01	0.08	1.55	
Dose	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Ing	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv h <sup>-1</sup>	3.68E4	1.81E3	1.48E3	8.22E2	1.01E2	5.54E0	Sv kg <sup>-1</sup>	2.47E7	2.47E7	2.46E7	4.12E6	1.83E3	1.07E1
Bi208m	95.02						Po210	99.83	99.85	99.89	99.81	0.08	
Bi206	2.62	53.32	43.31				Bi210	0.11	0.11	0.07			
Bi207	2.27	46.18	56.23	99.19	93.36		Bi207	0.02	0.02	0.02	0.09	23.39	
Bi208	0.02	0.37	0.45	0.81	6.64	100.0	Po209	0.01	0.01	0.01	0.07	75.78	
Pb204m		0.09					Bi208					0.69	98.50
							Bi210m					0.01	1.51
Inh	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y	Clear	0	10 <sup>-5</sup> y	10 <sup>-2</sup> y	1 y	100 y	10 <sup>5</sup> y
Sv kg <sup>-1</sup>	9.08E7	9.05E7	8.93E7	1.48E7	6.27E3	6.64E1		2.85E11	7.29E10	6.32E10	3.21E10	3.32E9	1.98E7
Po210	97.48	97.78	98.67	99.80	0.09		Bi208m	74.29					
Bi210	2.11	2.11	1.29				Bi207	10.26	40.13	46.31	89.25	99.28	
Bi207	0.02	0.02	0.02	0.11	29.49		Po210	7.21	28.21	32.43	10.67		
Po209	0.01	0.01	0.01	0.06	69.14		Bi210	7.21	28.20	19.65			
Bi210m					0.59	54.80	Bi206	0.52	2.04	1.57			
Bi208					0.58	45.20	Bi208	0.01	0.03	0.04	0.07	0.72	99.93
Pb210					0.11								

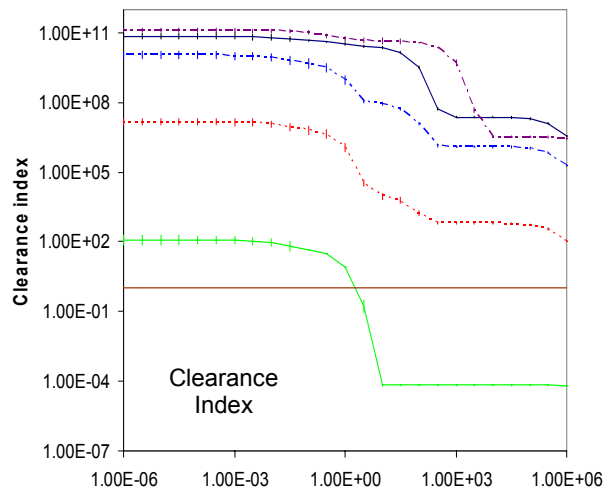
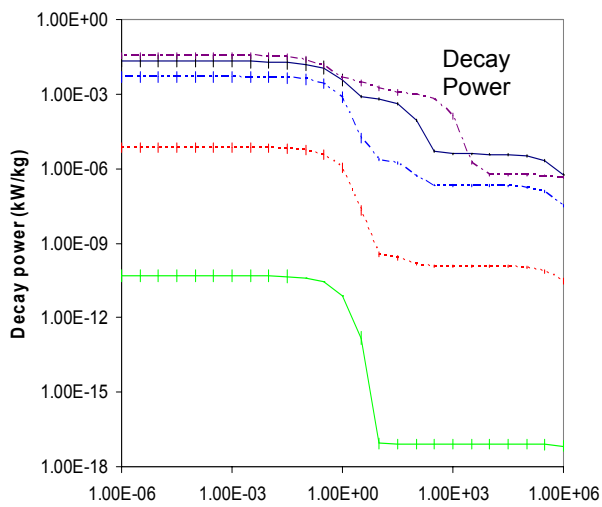
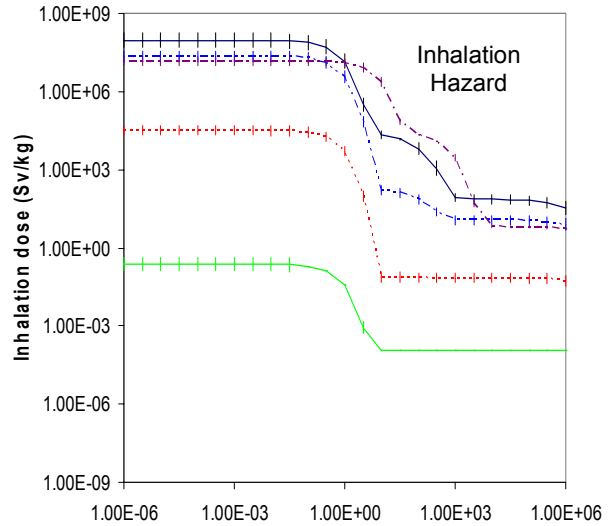
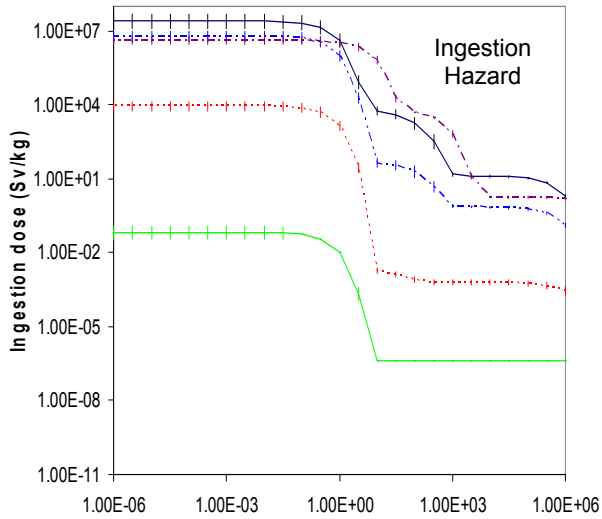
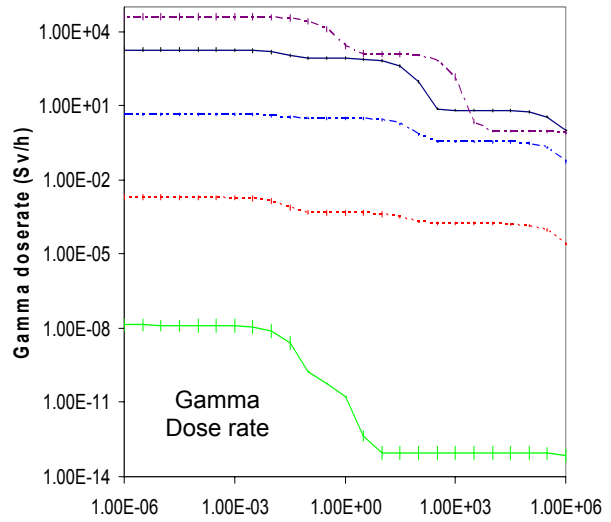
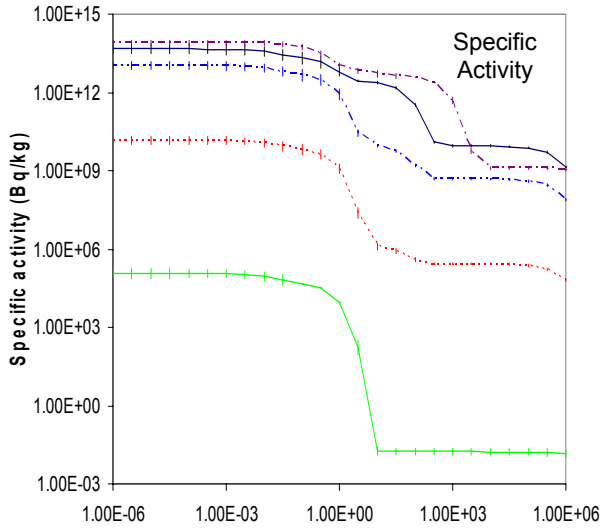
# Bismuth

## Pathway analysis

Nuclide	T <sub>1/2</sub>	Pathway	210	186	151	42	30	21	6
Tl206m	3.76 m	Bi209(n,α)Tl206m Bi209(n,3n)Bi207(β <sup>+</sup> )Pb207(n,d)Tl206m &Bi209(n,t)Pb207(n,d)Tl206m Bi209(n,4n)Bi206(β <sup>+</sup> )Pb206(n,p)Tl206m Bi209(n,3n)Bi207(n,2n)Bi206(β <sup>+</sup> ) Pb206(n,p)Tl206m Bi209(n,d)Pb208(n,t)Tl206m	100.0	100.0	100.0	99.0	50.8 32.6 6.3 3.0 1.4 1.1	17.9 10.9 30.3 18.7 0.1 19.0	57.7 2.8 19.7 1.3
Tl206	4.20 m	&Bi209(n,α)Tl206 Bi209(n,2n)Bi208(n,2n)Bi207(n,2n) Bi206(β <sup>+</sup> )Pb206(n,p)Tl206 &Bi209(n,3n)Bi207(β <sup>+</sup> )Pb207(n,d)Tl206 &Bi209(n,4n)Bi206(β <sup>+</sup> )Pb206(n,p)Tl206 &Bi209(n,2n)Bi208(n,3n)Bi206(β <sup>+</sup> ) Pb206(n,p)Tl206 Bi209(n,3n)Bi207(n,2n)Bi206(β <sup>+</sup> ) Pb206(n,p)Tl206 &Bi209(n,t)Pb207(n,d)Tl206 &Bi209(n,d)Pb208(n,t)Tl206 Bi209(n,nt)Pb206(n,p)Tl206	100.0	100.0	100.0	97.4 2.1	56.3 15.9 9.6 5.6 4.5 3.0 1.3 0.3	13.5 4.6 57.6 0.4 0.4 12.8 7.5 1.0	50.5 2.6 9.1
Bi201m	59.10 m	&Bi209(n,3n)Bi207(n,3n)Bi205(n,3n) Bi203(n,3n)Bi201m Bi209(n,2n)Bi208(n,4n)Bi205(n,3n) Bi203(n,3n)Bi201m Bi209(n,4n)Bi206(n,4n)Bi203(n,3n)Bi201m Bi209(n,3n)Bi207(n,4n)Bi204(n,4n)Bi201m Bi209(n,3n)Bi207(n,5n)Bi203(n,3n)Bi201m &Bi209(n,2n)Bi208(n,5n)Bi204(n,4n)Bi201m Bi209(n,5n)Bi205(n,5n)Bi201m Bi209(n,4n)Bi206(n,6n)Bi201m Bi209(n,6n)Bi204(n,4n)Bi201m					90.9 1.3 0.2 83.2 2.5 1.8 0.7		2.7 93.2 2.1 1.4
Bi210	5.012 d	Bi209(n,γ)Bi210	100.0	100.0	100.0	99.9	99.8	99.9	99.9
Bi206	6.243 d	&Bi209(n,2n)Bi208(n,2n)Bi207(n,2n)Bi206 Bi209(n,3n)Bi207(n,2n)Bi206 &Bi209(n,2n)Bi208(n,3n)Bi206 Bi209(n,4n)Bi206				99.4 0.6	0.2 29.7 37.6 32.4	1.5 1.4	95.6
Bi205	15.31 d	&Bi209(n,2n)Bi208(n,2n)Bi207(n,2n) Bi206(n,2n)Bi205 Bi209(n,3n)Bi207(n,3n)Bi205 &Bi209(n,2n)Bi208(n,4n)Bi205 Bi209(n,5n)Bi205				99.4	98.0 1.4 42.9	19.3 37.6	96.8
Po210	138.39 d	Bi209(n,γ)Bi210(β <sup>-</sup> )Po210	100.0	100.0	100.0	99.9	99.9	99.9	100.0
Bi207	31.76 y	&Bi209(n,2n)Bi208(n,2n)Bi207 Bi209(n,3n)Bi207				99.4 0.6	99.1	98.5	98.9
Po209	102.0 y	Bi209(n,γ)Bi210(β <sup>-</sup> )Po210(n,2n)Po209				99.9	99.8	99.9	99.9
Hg194	440.01 y	Long pathways involving (n,α), (n,α), β <sup>-</sup>				100.0	100.0	100.0	100.0
Pb202	5.3 10 <sup>4</sup> y	Bi209(n,2n)Bi208(n,2n)Bi207(n,2n) Bi206(β <sup>+</sup> )Pb206(n,2n)Pb205(n,2n) Pb204(n,2n)Pb203(n,2n)Pb202 &Bi209(n,α)Tl206(β <sup>-</sup> )Pb206(n,2n)Pb205 (n,2n)Pb204(n,2n)Pb203(n,2n)Pb202 &Bi209(n,γ)Bi210(β <sup>-</sup> )Po210(α)Pb206(n,2n) Pb205(n,2n)Pb204(n,2n)Pb203(n,2n)Pb202 &Bi209(n,4n)Bi206(β <sup>+</sup> )Pb206(n,3n) Pb204(n,3n)Pb202 &Bi209(n,2n)Bi208(n,3n)Bi206(β <sup>+</sup> ) Pb206(n,3n)Pb204(n,3n)Pb202				20.5 6.8 3.8	39.5 8.2 10.4		

Nuclide	T <sub>½</sub>	Pathway	210	186	151	42	30	21	6	
	◀	&Bi209(n,3n)Bi207(n,2n)Bi206(β <sup>+</sup> ) Pb206(n,3n)Pb204(n,3n)Pb202 &Bi209(n,3n)Bi207(n,3n)Bi205(β <sup>+</sup> ) Pb205(n,4n)Pb202 &Bi209(n,3n)Bi207(n,3n)Bi205(β <sup>+</sup> ) Pb205(n,2n)Pb204(n,3n)Pb202 &Bi209(n,3n)Bi207(n,4n)Bi204(β <sup>+</sup> ) Pb204(n,3n)Pb202 &Bi209(n,4n)Bi206(β <sup>+</sup> )Pb206(n,2n) Pb205(n,4n)Pb202 &Bi209(n,5n)Bi205(β <sup>+</sup> )Pb205(n,4n)Pb202 &Bi209(n,2n)Bi208(n,4n)Bi205(β <sup>+</sup> ) Pb205(n,4n)Pb202 &Bi209(n,4n)Bi206(β <sup>+</sup> )Pb206(n,5n)Pb202 &Bi209(n,d)Pb208(n,4n)Pb205(n,4n)Pb202 &Bi209(n,nt)Pb206(n,5n)Pb202 &Bi209(n,6n)Bi204(β <sup>+</sup> )Pb204(n,3n)Pb202 Bi209(n,3n)Bi207(n,6n)Bi202(β <sup>+</sup> )Pb202 &Bi209(n,t)Pb207(n,6n)Pb202 Other very long pathways					9.0			
							8.6	4.7		
							8.6			
							5.5	8.7		
							0.1	10.4	0.4	
								35.7	25.6	
								9.6		
								9.4	34.5	
								2.4		
								0.1	10.3	
									12.0	
									5.1	
									5.0	
							68.9	18.3	11.1	
Bi208	3.7 10 <sup>5</sup> y	&Bi209(n,2n)Bi208				100.0	99.9	99.9	99.9	
Bi210m	3.0 10 <sup>6</sup> y	Bi209(n,γ)Bi210m	100.0	100.0	100.0	99.9	99.9	99.9	99.9	

# Bismuth activation characteristics



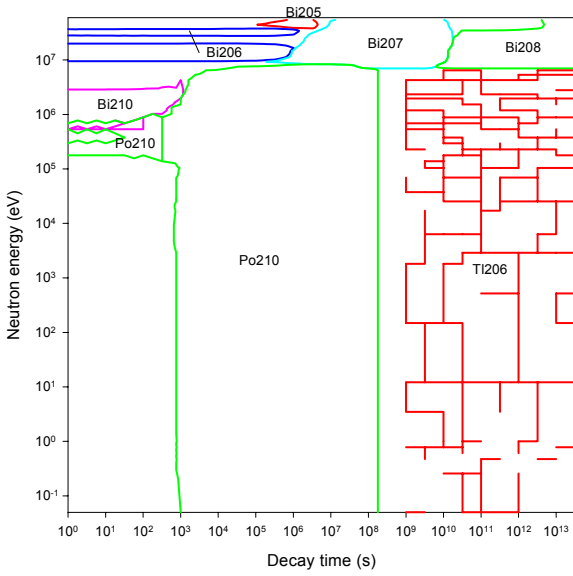
Decay time (years)

Decay time (years)

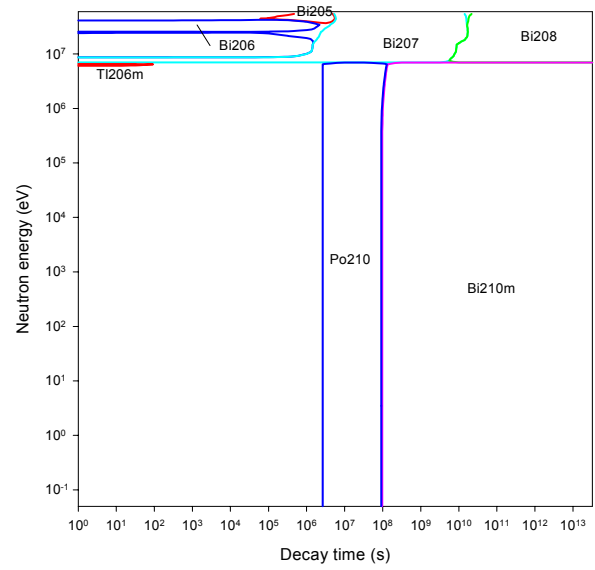


# Bismuth importance diagrams & transmutation

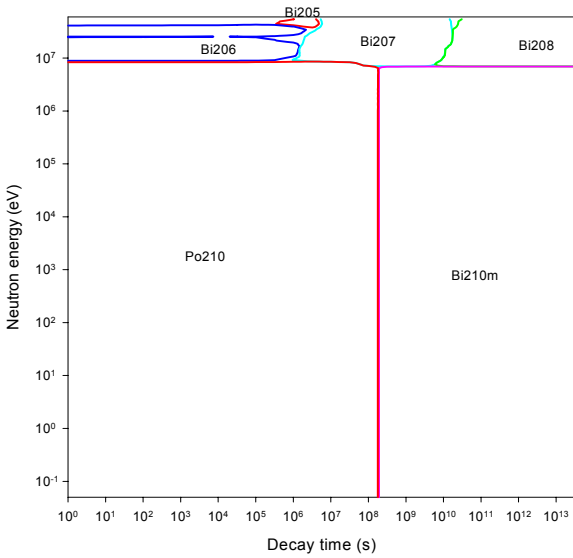
**Activity**



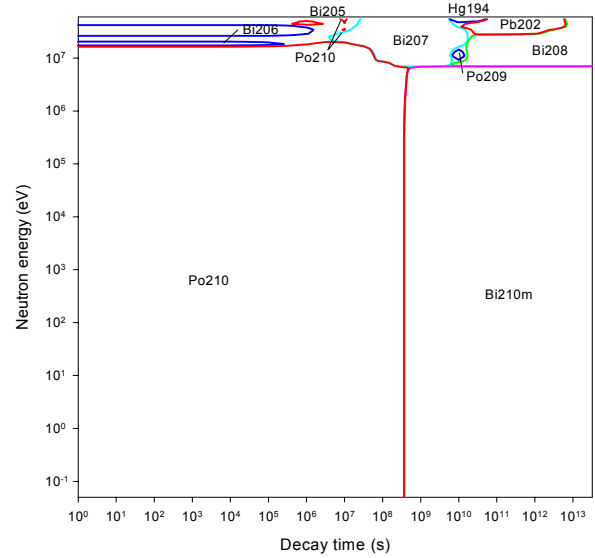
**Dose rate**



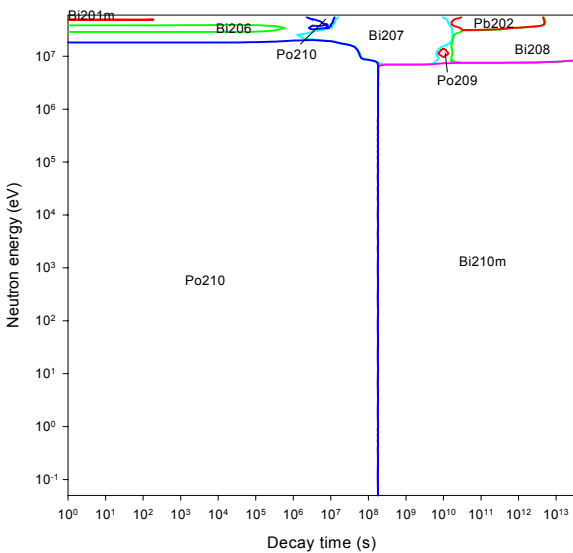
**Heat output**



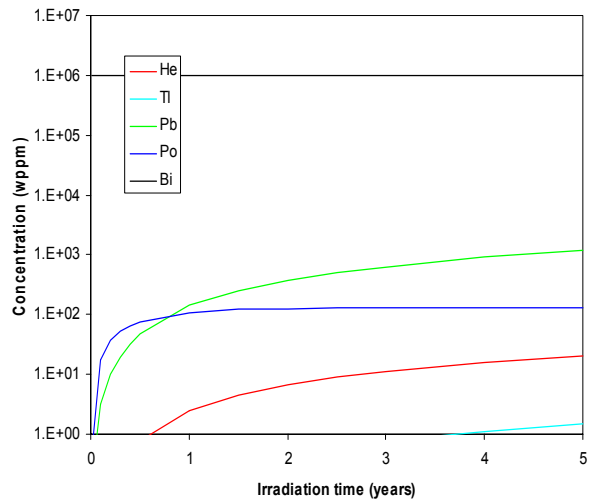
**Ingestion dose**



**Inhalation dose**



**First wall transmutation**





**PART 2:**  
**The Summary Tables**

# Summary of Primary and Secondary nuclides

Nuclide	T <sub>1/2</sub>	Contributing elements	
		Primary	Secondary
H-3	12.330 y	H, He, Li, Be, B, C, N, O, F, Ne, Na, Mg, Al, Si, P, S, Cl, Ar, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Zn, Ga, Ge, As, Se, Br, Kr, Rb, Sr, Y, Zr, Nb, Mo, Ru, Rh, Pd, Ag, Sn, Sb, Te, I, Xe, Cs, La, Ce, Pr, Nd, Tb, Ho, Er, Tm, Yb, Lu, Hf, Ta, W, Re, Os, Ir, Hg, Tl, Pb	Cu, Cd, In, Ba, Sm, Eu, Gd, Dy, Pt, Au, Bi
He-6	0.808 s	Li, Be, B, C	N, O
Li-8	0.838 s	Li, Be, B, C, N	O
Li-9	0.178 s		Be
* Be-7	53.220 d	C, N, O, F, Ne	B
Be-10	1.60E+06 y	Be, B, C, N, O, F, Ne, Na, Mg, Al, Si, P	
Be-11	13.810 s	Be, B, C	N
+ C-10	19.255 s		C, N
* C-11	20.370 m	B, C, N, O	F, Ne
C-14	5699.985 y	C, N, O, F, Ne, Na, Mg, Al, Si, P, S	
C-15	2.449 s	C, N, O	F
N-13	9.967 m	N, O	C, F, Ne
N-16	7.130 s	N, O, F	Ne, Na, Mg
N-17	4.170 s		O, F
+ O-14	1.177 m		O
O-15	2.041 m	O	F, Ne, Na, Mg
O-19	26.910 s	O, F, Ne	Na
+ F-17	1.075 m		F, Ne, Na
F-18	1.829 h	O, F, Ne	Na, Mg, Al, Si
F-20	11.030 s	F, Ne, Na	Mg, Al
F-21	4.158 s	Ne	Na, Mg
F-22	4.230 s		Ne, Na
* Ne-19	17.220 s	Ne	Mg
Ne-23	37.200 s	F, Ne, Na	Mg, Al, Si, P
+ Ne-24	3.380 m		Mg, Al, Si, P
+ Na-21	22.490 s		Na, Mg, Al
Na-22	2.603 y	Ne, Na, Mg, Al, Si, P, S, Cl, Ar, K	Ca
Na-24	14.957 h	O, F, Ne, Na, Mg, Al, Si, P, S, Cl	Ar, K
Na-25	59.600 s	Mg	Al, Si
Na-26	1.080 s		Mg, Al
Mg-23	11.317 s		Mg, Al, Si
Mg-27	9.458 m	Mg, Al	Si, P, S
+ Mg-28	20.900 h		Si, P, S, Cl, Ar, K
+ Al-25	7.183 s		Al, Si
Al-26	7.17E+05 y	Mg, Al, Si, P, S, Cl, Ar, K, Ca	Sc, Ti, V, Cr
Al-26m	6.345 s		Al, Si, P, S
Al-28	2.241 m	Al, Si, P, S	Mg, Cl, Ar, K
Al-29	6.560 m	Si, S	P, Cl
Al-30	3.650 s		Si, P, S, Cl
+ Si-27	4.170 s		Si, S
Si-31	2.620 h	Mg, Al, Si, P, S	Cl, Ar, K
Si-32	132.003 y	Na, Mg, Al, Si, P, S, Cl	
+ P-29	4.140 s		P, S, Cl
P-30	2.498 m	P, S	Cl, K
P-32	14.270 d	Na, Mg, Al, Si, P, S, Cl, Ar, K, Ca	Sc
P-33	25.383 d	S, Cl, Ar, K	Ca
P-34	12.400 s		S, Cl, Ar, K, Ca
P-35	47.300 s		Cl
P-36	5.600 s		Cl, Ar
S-31	2.572 s		S
S-35	87.320 d	S, Cl, Ar, K	Si, P, Ca, Sc
S-37	4.990 m	S, Cl, Ar, Ca	S, K
+ S-38	2.838 h		Ar, K
+ Cl-33	2.511 s		Cl
Cl-34	1.526 s		Cl, K, Ca
Cl-34m	32.100 m	Cl	K, Ca

Nuclide	T <sub>1/2</sub>	Contributing elements	
		Primary	Secondary
Cl-36	3.01E+05 y	Mg, Al, Si, P, S, Cl, Ar, K, Ca, Sc, Ti, V, Cr, Mn	
Cl-38	37.200 m	S, Cl, Ar, K, Ca	
Cl-38m	0.715 s		S, Cl, Ar, K, Ca
Cl-39	55.600 m	Ar, K	Ca
> Cl-40	1.350 m	Ar	
Ar-37	35.040 d	Ar, K, Ca	Cl, Sc, Ti
Ar-39	269.006 y	S, Cl, Ar, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Ni	Cu, Zn
Ar-41	1.827 h	Cl, Ar, K	S, Ca, Sc, Ti, V, Cr
Ar-42	33.001 y	Ar, K, Sc, Ti, V, Cr, Mn, Fe	Ca, Fe, Ni
+ K-37	1.226 s		K
K-38	7.610 m	K, Ca	
K-38m	0.924 s		K, Ca
K-40	1.26E+09 y	K, Ca, Sc, Ti, V, Cr	Ar
K-42	12.359 h	Cl, Ar, K, Ca, Sc, Ti, V, Cr, Mn	S, Fe
K-43	22.200 h	Ca	K, Sc, Ti
K-44	22.130 m		Ca, Sc
> Ca-39	0.860 s	Ca	
Ca-41	1.03E+05 y	Ca, Sc, Ti, V, Cr	Mn
Ca-45	163.000 d	K, Ca, Sc, Ti, V, Cr, Mn	Ar
Ca-47	4.538 d	Ca, Mn	Ti, V, Cr
* Ca-48	5.30E+19 y	Sc, Ti, Mn	
Ca-49	8.720 m	Ca	
+ Sc-42m	1.033 m		Sc
+ Sc-43	3.891 h		Sc, Ti
Sc-44	3.970 h	Sc, Ti, V, Cr, Mn, Fe	Ca, Ni
Sc-44m	2.442 d	Sc	Ti, V, Cr
Sc-45m	0.316 s	Sc	Ti
Sc-46	83.788 d	Ar, K, Ca, Sc, Ti, V, Cr, Mn	Cl
Sc-46m	18.700 s		Ca, Sc, Ti, V
Sc-47	3.351 d	Ti, V, Cr	Ca, Sc, Mn
Sc-48	1.820 d	Ti, V, Mn	Cr
Sc-49	57.200 m		Ca, Ti, V, Cr
Sc-50	1.708 m		Ti, V
+ Ti-44	60.000 y		Ti, V, Cr, Mn, Fe, Ni
Ti-45	3.080 h		Ti, Cr
Ti-51	5.800 m	Ti, V	Cr
+ V-47	32.600 m		V, Cr
> V-48	15.974 d	V, Cr	Mn, Fe
V-49	330.000 d	V, Cr	Mn, Fe
V-50	1.40E+17 y	V, Cr	
V-52	3.745 m	Ti, V, Cr, Mn	Fe
V-53	1.620 m		Cr, Mn, Fe
V-54	49.800 s		Cr, Mn
Cr-49	41.900 m		Cr
* Cr-50	1.80E+17 y	Cr	
Cr-51	27.703 d	Cr	V, Mn, Fe, Ni
Cr-55	3.540 m	Cr, Mn	Fe
+ Cr-56	5.940 m		Fe
+ Mn-51	46.200 m		Mn, Fe
Mn-52	5.595 d		Mn, Fe, Co, Ni
Mn-52m	21.200 m		Mn, Fe, Ni
Mn-53	3.68E+06 y	Cr, Mn, Fe, Co, Ni, As	Cu, Zn, Ga, Ge
Mn-54	312.130 d	Mn, Fe, Co	Cr, Ni, Cu, Zn
Mn-56	2.582 h	Ti, V, Cr, Mn, Fe	Co, Ni, Cu
Mn-57	1.423 m		Co, Ni
Fe-53	8.510 m		Fe, Ni
Fe-53m	2.580 m		Fe, Ni
Fe-55	2.735 y	Fe, Co, Ni	Mn, Cu, Zn
Fe-59	44.495 d	V, Mn, Fe, Co, Ga	Cr, Ni, Cu, Ge, As
Fe-60	1.50E+06 y	Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Ge, As	
+ Co-55	17.530 h		Ni

Nuclide	T <sub>1/2</sub>	Contributing elements	
		Primary	Secondary
> Co-56	77.310 d	Ni	Co, Cu, Zn
Co-57	271.800 d	Co, Ni	Cu, Zn
Co-58	70.860 d	Co, Ni, Cu	Zn, Ga
Co-58m	8.900 h		Co, Ni, Cu, Zn
Co-60	5.271 y	Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Ge, As, Se, Br	
Co-60m	10.470 m	Co	Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, Ga, Ge, As
Co-61	1.650 h		Fe, Ni, Cu, Zn
Co-62	1.500 m		Ni, Cu
Co-62m	13.910 m		Cu
+ Co-63	27.400 s		Cu
Ni-57	1.496 d		Ni
Ni-59	7.60E+04 y	Co, Ni, Cu, Zn, Ga, Ge, As	Se, Br
Ni-63	100.600 y	V, Cr, Mn, Fe, Ni, Cu, Zn, Ga, Ge, As	Ti, Se, Br
Ni-65	2.520 h	Ni	Cu, Zn
+ Cu-60	23.700 m		Cu, Zn
+ Cu-61	3.333 h		Cu, Zn
Cu-62	9.750 m	Cu, Zn	Ga
Cu-64	12.701 h	Ni, Cu, Zn	Ga, Ge
Cu-66	5.100 m	Cu	Ni, Zn, Ga
< Cu-67	2.579 d		Zn, Ga, Ge
Cu-68	31.100 s		Zn, Ga
Cu-68m	3.750 m		Zn, Ga
+ Zn-61	1.485 m		Zn
+ Zn-62	9.260 h		Zn
< Zn-63	38.400 m		Cu, Zn
* Zn-64	2.30E+18 y	Cu, Zn, Ga	
Zn-65	244.150 d	Cu, Zn, Ga, Ge, As	Ni, Se, Br
Zn-69	56.400 m	Zn, Ga	Ge
Zn-69m	13.780 h	Zn, Ga	Ge
> Zn-71	2.450 m	Ga	Zn, Ga, Ge
Zn-71m	3.960 h		Ga, Ge
+ Zn-73	23.500 s		Ge
+ Ga-65	15.200 m		Ga
* Ga-66	9.490 h	Ga	Ge
> Ga-67	3.261 d	Ga	Ge
Ga-68	1.128 h	Ga, Ge, As, Se, Br	Kr
Ga-70	21.140 m	Zn, Ga, Ge	As
Ga-72	14.100 h	Ga, Ge, As	Zn, Se
Ga-73	4.860 h		Ge, As
Ga-74	8.120 m		Ge, As
Ga-75	2.170 m		Ge
+ Ga-76	32.600 s		Ge
+ Ge-67	18.900 m		Ge
> Ge-68	270.950 d	Ga, Ge	As, Se, Br
Ge-69	1.627 d	Ga, Ge	As, Se
Ge-71	11.430 d	Ga, Ge, As	Zn, Se, Br, Kr
Ge-73m	0.499 s		Ga, Ge, As
Ge-75	1.380 h	Ge, As	Se
Ge-75m	47.700 s		Ge, As
Ge-77	11.300 h	Ge	As, Se
Ge-77m	52.900 s		Ge
+ Ge-79m	39.000 s		Se
+ As-71	2.720 d		As, Se
* As-72	1.083 d	As	Se, Br, Kr
As-73	80.301 d	As	Ge, Se, Br, Kr
As-74	17.780 d	Ge, As, Se, Br	Kr
As-76	1.093 d	Ge, As, Se, Br	
As-77	1.618 d	Ge, As	Se, Br
As-78	1.512 h		Se, Br
As-79	9.010 m		Se
As-80	15.200 s		Se
+ As-81	33.300 s		Se

Nuclide	T <sub>½</sub>	Contributing elements	
		Primary	Secondary
+ As-82	19.100 s		Se
+ As-82m	13.600 s		Se
+ Se-71	4.740 m		As, Se
+ Se-72	8.400 d		As, Se
Se-73	7.150 h		As, Se, Br
Se-73m	39.800 m		As, Se
Se-75	119.640 d	As, Se, Br, Kr	Rb, Sr
Se-77m	17.360 s	As, Se	Ge, Br, Kr
Se-79	1.10E+06 y	Zn, Ga, Ge, As, Se, Br, Kr, Y	Rb, Sr
Se-79m	3.900 m	As	Se, Br
Se-81	18.450 m	Se	As, Br, Kr
Se-81m	57.280 m		As, Se, Br, Kr
Se-83	22.333 m		Se, Kr
> Se-83m	1.168 m	Se	
+ Br-75	1.612 h		Br
* Br-76	16.200 h	Br	Kr
+ Br-76m	1.310 s		Br
> Br-77	2.377 d	Br	Kr
+ Br-77m	4.280 m		Br, Kr
Br-78	6.460 m	Br, Kr	Se, Rb
Br-79m	4.864 s	Br	Kr, Rb
Br-80	17.600 m	Br	As, Se, Kr, Rb
Br-80m	4.410 h	Br	As, Se, Kr, Rb
Br-82	1.472 d	As, Se, Br, Kr, Rb	Sr
Br-82m	6.090 m		Se, Br, Kr, Rb
Br-83	2.400 h		Se, Kr
Br-84	31.800 m		Kr, Rb
Br-84m	6.000 m		Kr, Rb
Br-85	2.900 m		Kr
Br-86	55.000 s		Kr
+ Kr-76	14.806 h		Br
Kr-77	1.240 h		Br, Kr
Kr-79	1.460 d	Se, Br, Kr	Rb, Sr, Y, Zr, Nb, Mo
Kr-79m	50.000 s		Br, Kr, Rb
Kr-81	2.10E+05 y	Ga, Ge, As, Se, Br, Kr, Rb, Sr, Y, Zr, Nb	Mo
Kr-81m	13.200 s		Br, Kr
Kr-83m	1.830 h	Se, Br, Kr	As, Rb, Sr, Y, Zr, Nb, Mo
Kr-85	10.752 y	Ga, Ge, As, Se, Br, Kr, Rb, Sr, Y, Zr, Nb, Mo, Ru	Rh
Kr-85m	4.480 h	Kr	Se, Br, Rb, Sr, Y
Kr-87	1.272 h	Kr	Rb
+ Rb-81	4.576 h		Rb, Sr
+ Rb-81m	30.250 m		Rb, Sr
+ Rb-82	1.273 m		Rb, Sr, Y
* Rb-82m	6.472 h	Rb	Sr, Y
Rb-83	86.200 d	Kr, Rb	Sr, Y, Zr, Nb, Mo
Rb-84	33.500 d	Kr, Rb, Sr	Y, Zr, Nb, Mo
Rb-84m	20.400 m		Kr, Rb, Sr, Y
Rb-86	18.640 d	Br, Kr, Rb, Sr, Y	As, Se, Zr, Nb, Kr, Rb, Sr, Y
Rb-86m	1.017 m		Kr, Rb, Sr, Y
Rb-87	4.75E+10 y	Rb, Sr, Y	
Rb-88	17.800 m		Rb, Sr, Y
+ Sr-82	25.550 d		Sr, Y
Sr-83	1.350 d		Sr, Y
Sr-85	64.849 d	Rb, Sr	Y, Zr, Nb, Mo
Sr-85m	1.127 h		Sr, Y
Sr-87m	2.803 h	Sr	Kr, Rb, Y
Sr-89	50.570 d	Rb, Sr, Y	Zr, Nb, Mo
Sr-90	28.790 y	Rb, Sr, Y, Zr	Nb, Mo
Sr-91	9.630 h		Zr
+ Y-84m	40.000 m		Zr
+ Y-85	2.681 h		Y
+ Y-85m	4.861 h		Y

Nuclide	T <sub>1/2</sub>	Contributing elements	
		Primary	Secondary
* Y-86	14.740 h	Y	Zr, Nb, Mo
+ Y-86m	48.000 m		Y
Y-87	3.346 d		Y, Zr, Nb, Mo
Y-87m	13.370 h		Y, Zr, Nb, Mo
Y-88	106.629 d	Y, Zr, Nb, Mo, Ru	Sr
Y-89m	15.663 s	Y, Zr	Sr, Nb, Mo, Ru
Y-90	2.671 d	Rb, Sr, Y, Zr, Nb	Mo, Rh
Y-90m	3.190 h	Y, Nb	Zr
Y-91	58.510 d	Y, Zr	Nb, Mo
Y-91m	49.710 m		Y, Zr
Y-92	3.540 h		Zr
+ Y-93	10.180 h		Zr
Y-94	18.700 m		Zr
+ Zr-87	1.680 h		Zr, Nb, Mo
+ Zr-88	83.000 d		Zr, Nb, Mo, Ru
Zr-89	3.267 d	Zr	Nb, Mo, Ru
Zr-89m	4.180 m		Zr, Nb
Zr-90m	0.809 s	Zr, Nb	Mo
Zr-93	1.53E+06 y	Sr, Y, Zr, Nb	Mo
Zr-95	64.032 d	Zr	
Zr-97	16.744 h	Zr	
+ Nb-88m	7.780 m		Mo
+ Nb-89	2.030 h		Nb, Mo
Nb-90	14.600 h	Nb, Mo	Ru
Nb-90m	18.820 s		Nb, Mo
Nb-91	680.016 y	Nb, Mo, Ru	Zr, Rh, Pd
Nb-91m	60.900 d	Nb, Mo	Ru
Nb-92	3.50E+07 y	Nb, Mo	Zr
Nb-92m	10.150 d	Nb, Mo	Ru
Nb-93m	16.126 y	Rb, Sr, Y, Zr, Nb, Mo, Ru	Rh, Pd, Ag, Cd, In, Sn, Sb
Nb-94	2.00E+04 y	Zr, Nb, Mo, Ru, Rh, Pd, Ag, Cd, In, Sn, Sb	Y
Nb-94m	6.260 m	Nb	Mo
Nb-95	34.991 d	Zr, Nb, Mo	Ru
Nb-95m	3.608 d		Nb, Mo
Nb-96	23.350 h	Nb	Zr, Mo
Nb-97	1.202 h		Zr, Mo
Nb-97m	52.700 s		Zr
Nb-98m	51.300 m		Mo
+ Mo-90	5.560 h		Mo
Mo-91	15.490 m		Mo, Ru
Mo-91m	1.077 m		Mo
Mo-93	4000.009 y	Zr, Mo, Ru, Rh, Pd, Ag, Cd, In, Sn, Sb	I
Mo-93m	6.850 h		Mo, Ru
Mo-99	2.748 d	Mo	Zr, Ru
Mo-101	14.610 m	Mo	
+ Tc-92	4.400 m		Ru, Rh, Pd
+ Tc-93	2.750 h		Ru
+ Tc-94	4.883 h		Ru, Rh
+ Tc-94m	52.000 m		Ru
Tc-95	20.000 h		Ru, Rh
Tc-95m	61.000 d		Ru
Tc-96	4.280 d	Ru	Mo, Rh, Pd
Tc-96m	51.500 m		Ru
Tc-97	2.60E+06 y	Ru, Rh	Mo, Pd, Ag, Cd, In, Sn, Sb
Tc-97m	90.200 d	Ru	Mo, Rh
Tc-98	4.20E+06 y	Mo, Ru, Rh, Pd, Ag, Cd, In, Sn, Sb	I
Tc-99	2.14E+05 y	Zr, Nb, Mo, Ru, Rh, Pd, Ag, Cd	In, Sn, Sb
Tc-99m	6.010 h		Zr, Mo, Ru
> Tc-100	15.800 s	Mo, Ru	Zr, Rh, Pd
Tc-101	14.200 m		Mo, Ru
Tc-102	5.280 s		Ru
> Tc-102m	4.350 m	Ru	Rh, Pd
+ Tc-103	54.200 s		Ru



Nuclide	T <sub>½</sub>	Contributing elements	
		Primary	Secondary
Tc-104	18.300 m		Ru
+ Ru-94	51.800 m		Ru
Ru-95	1.643 h		Ru
Ru-97	2.900 d	Ru	Rh, Pd
Ru-103	39.260 d	Mo, Ru, Rh	Pd, Ag
Ru-105	4.440 h	Rh	Ru, Pd
Ru-106	1.020 y	Ru, Rh	Pd
+ Rh-98	8.720 m		Rh, Pd
+ Rh-98m	3.500 m		Rh, Pd
+ Rh-99	16.100 d		Rh, Pd
+ Rh-99m	4.694 h		Rh, Pd
> Rh-100	20.800 h	Rh, Pd	Ru, Ag, Cd
+ Rh-100m	4.600 m		Rh, Pd, Ag
> Rh-101	3.300 y	Rh	Ru, Pd, Ag
> Rh-101m	4.340 d	Rh	Ru, Pd, Ag
Rh-102	2.902 y	Ru, Rh, Pd, Ag	Cd, In, Sn, Sb
Rh-102m	208.000 d		Ru, Rh, Pd, Ag
Rh-103m	56.114 m	Rh	Mo, Ru, Pd, Ag, Cd
Rh-104	42.300 s	Ru, Rh	Pd, Ag
Rh-104m	4.340 m	Rh	Ru, Pd, Ag
Rh-105	1.473 d	Rh	Ru, Pd, Ag
Rh-105m	40.000 s		Ru, Rh, Pd
Rh-106	30.000 s	Ru, Rh	Pd
Rh-106m	2.200 h	Rh	Ru, Pd, Ag
Rh-107	21.700 m		Pd
Rh-108	16.800 s		Pd
Rh-108m	6.000 m		Pd
+ Rh-109	1.333 m		Pd
+ Rh-110	28.500 s		Pd
+ Pd-99	21.400 m		Pd
+ Pd-100	3.630 d		Pd, Ag
Pd-101	8.470 h		Rh, Pd, Ag
Pd-103	16.980 d	Pd	Ag, Cd
Pd-107	6.50E+06 y	Rh, Pd, Ag, Cd, In, Sn, Sb, I	Ru
Pd-107m	21.300 s		Rh, Pd, Ag
Pd-109	13.701 h	Pd, Ag	Rh
Pd-109m	4.690 m		Pd, Ag
+ Pd-110	6.00E+17 y		Ag
Pd-111	23.400 m		Pd
Pd-111m	5.500 h	Pd	
+ Ag-102	12.900 m		Cd
+ Ag-103	1.095 h		Ag, Cd
+ Ag-104	1.153 h		Ag, Cd, In
+ Ag-104m	33.500 m		Ag, Cd
> Ag-105	41.300 d	Ag	Cd, In, Sn
+ Ag-105m	7.230 m		Ag, Cd
Ag-106	24.000 m		Ag, Cd
Ag-106m	8.460 d	Ag, Cd	Pd, In, Sn
Ag-107m	44.300 s	Ag	Cd, In
Ag-108	2.400 m	Ag	Pd, Cd, In, Sn, Sb, I
Ag-108m	418.010 y	Rh, Pd, Ag, Cd, In, Sn, Sb, I, Xe, Cs	Te, Ba
Ag-109m	39.600 s	Ag, Cd	Rh, Pd, In, Sn, Sb
Ag-110	24.560 s	Pd, Ag	Rh, Cd, In
Ag-110m	249.780 d	Ru, Rh, Pd, Ag, Cd, In, Sn, Sb	
Ag-111	7.450 d	Pd, Ag	Rh, Cd, In
Ag-111m	1.080 m		Pd, Ag, Cd, In
Ag-112	3.130 h		Pd, Cd, In
Ag-113	5.370 h		Cd
+ Ag-113m	1.145 m		Cd
Ag-114	4.600 s		Cd
+ Ag-115	20.000 m		Cd
Ag-116	2.680 m		Cd
Cd-105	55.500 m		Cd

Nuclide	T <sub>1/2</sub>	Contributing elements	
		Primary	Secondary
Cd-107	6.520 h		Ag, Cd, In
* Cd-108	4.10E+17 y	Ag	Cd
Cd-109	1.267 y	Ag, Cd	In, Sn, Sb
Cd-111m	48.540 m	Cd	Pd, Ag, In, Sn
Cd-113	7.70E+15 y	Cd	Ag
Cd-113m	14.100 y	Pd, Ag, Cd, In, Sn, Sb	Rh, Te, I, Xe
* Cd-114	6.00E+17 y	Cd	In
Cd-115	2.228 d	Cd	Pd, Ag, In, Sn
> Cd-115m	44.600 d	Cd	Pd, Ag, In, Sn, Sb
+ Cd-116	3.40E+19 y		Cd
Cd-117	2.490 h		Cd, Sn
Cd-117m	3.360 h		Cd, Sn
+ In-108	58.000 m		In, Sn
+ In-108m	39.667 m		In, Sn
+ In-109	4.200 h		In, Sn
+ In-110	4.900 h		In, Sn
+ In-110m	1.152 h		In, Sn
In-111	2.805 d		In, Sn
+ In-111m	7.900 m		In
In-112	14.700 m		Cd, In, Sn
In-112m	20.700 m		In, Sn
In-113m	1.658 h	In, Sn, Sb	Cd
In-114	1.198 m	In	Cd, Sn, Sb
In-114m	50.000 d	In	Cd, Sn, Sb
In-115	4.41E+14 y	Cd, In, Sb	Rh, Pd, Ag
In-115m	4.486 h	In	Ag, Cd, Sn
In-116	14.200 s		Ag, Cd, In, Sn
In-116m	54.600 m	Ag, Cd, In, Sn	Pd, Sb
In-116n	2.170 s		Ag, Cd, In, Sn
In-117	43.200 m		Cd, Sn, Sb
In-117m	1.937 h		Cd, Sn
In-118	5.000 s		Sn
In-118m	4.450 m		Sn, Sb
+ In-118n	8.500 s		Sn
In-119	2.400 m		Sn, Sb
+ In-119m	18.000 m		Sn
In-120	3.080 s		Sn
In-120m	46.200 s		Sn, Sb
In-120n	46.200 s		Sn
+ In-121	23.100 s		Sn
+ In-123	5.980 s		Sn
+ Sn-108	10.300 m		In, Sn, Sb
* Sn-109	18.000 m	In	Cd, Sn, Sb
+ Sn-110	4.100 h		In, Sn
Sn-111	35.300 m		In, Sn
Sn-113	115.090 d	Sn	In, Sb
> Sn-113m	20.900 m	In, Sn, Sb	Cd, Te, I
Sn-117m	13.600 d	In, Sn	Cd, Sb
Sn-119m	293.000 d	In, Sn, Sb	Te, I, Xe
Sn-121	1.128 d	In, Sn, Sb, Te, I, Xe, Cs	
Sn-121m	55.001 y	In, Sn, Sb, Te, I, Xe, Cs	
Sn-123	129.200 d	Sn, Sb	Te, I
Sn-123m	40.060 m		Sn
* Sn-124	1.00E+17 y	Sn, Sb	
Sn-125	9.640 d		Sn
> Sn-125m	9.520 m	Sn	Te
Sn-126	2.30E+05 y	Sn, Sb, Te, I	
+ Sn-127	2.100 h		Te
+ Sn-127m	4.130 m		Te
+ Sb-116	15.800 m		Sb, Te
+ Sb-116m	1.005 h		Sb
+ Sb-117	2.800 h		Sb
+ Sb-118	3.600 m		Sb, Te, I, Xe

Nuclide	T <sub>½</sub>	Contributing elements	
		Primary	Secondary
+ Sb-118m	5.000 h		Sn, Sb, Te, I
> Sb-119	1.596 d	Sb	Te, I
Sb-120	15.900 m		Sn, Sb, Te, I
> Sb-120m	5.760 d	Sb	Sn, Te, I, Xe
Sb-122	2.700 d	Sn, Sb	Te, I, Xe
Sb-122m	4.190 m		Sn, Sb, I
Sb-124	60.200 d	Sn, Sb, I	Te, Xe, Cs
Sb-124m	1.550 m		Sb, Te, I
+ Sb-124n	20.200 m		Te
Sb-125	2.759 y	Sn, Sb, Te, I, Xe, Cs	In
Sb-126	12.400 d		Sn, Te, I, Xe, Cs, Ba
Sb-126m	19.100 m	Sn, Te, I, Xe	Cs, Ba
Sb-126n	11.000 s		Sn, Te, I
Sb-127	3.850 d		Te
Sb-128	9.010 h		Te
Sb-128m	10.400 m		Te
Sb-129	4.360 h		Te
+ Sb-129m	17.700 m		Te
Sb-130	39.500 m		Te
Sb-130m	6.300 m		Te
+ Te-117	1.033 h		Te
+ Te-118	6.000 d		Sb, Te, I
+ Te-119	16.050 h		Te, I
Te-119m	4.700 d		Sb, Te, I, Xe
Te-121	19.160 d	Sb, Te, I, Xe	Sn, Cs
Te-121m	154.000 d	Sb	Sn, Te, I, Xe, Cs
Te-123	9.20E+16 y	Sb	
Te-123m	119.500 d	Sb, Te	Sn, I, Xe, Cs
Te-125m	57.400 d	Te	Sn, Sb, I, Xe, Cs
Te-127	9.350 h	Te, I	Xe, Cs
Te-127m	109.000 d	Te, I	Xe, Cs
Te-129	1.160 h	Te, I	Cs
Te-129m	33.600 d	Te, I	Cs
Te-131	25.000 m		Te
+ Te-131m	1.250 d		Te, Xe
+ Te-133m	55.400 m		Xe
+ I-120m	53.000 m		Xe
+ I-122	3.630 m		I, Xe, Cs
+ I-123	13.223 h		I, Xe
* I-124	4.176 d	I, Xe	Te, Cs
I-125	59.407 d	I, Xe	Te, Cs, Ba
I-126	12.980 d	I	Te, Xe, Cs
I-128	24.990 m	Te, I	Xe, Cs
I-129	1.61E+07 y	Sb, Te, I, Xe, Cs, Ba	Sn, La, Ce, Pr, Nd
I-130	12.360 h	Te, I	Xe, Cs, Ba, La
I-130m	9.000 m		Te
I-131	8.023 d	Te	Xe, Cs
I-132	2.295 h		Xe
I-133	20.800 h		Xe
+ I-133m	9.000 s		Xe
I-134	52.500 m		Xe
I-135	6.570 h		Xe
I-136	1.390 m		Xe
+ I-136m	45.000 s		Xe
+ Xe-122	20.100 h		Te, I, Xe, Cs
Xe-123	2.080 h		I, Xe
* Xe-124	2.00E+14 y	I	Xe
Xe-125	16.900 h		Te, I, Xe, Cs, Pr
Xe-125m	56.000 s		I, Xe, Cs
Xe-127	36.400 d	Te, Xe, Cs, Ba, La, Ce, Pr, Nd	I
Xe-127m	1.160 m		Xe, Cs
Xe-129m	8.880 d	I, Xe, Cs	Te, Ba, La, Pr
Xe-131m	11.930 d	Te, I, Xe, Cs, Ba	La, Pr

Nuclide	T <sub>1/2</sub>	Contributing elements	
		Primary	Secondary
Xe-133	5.244 d	Xe, Cs, Ba	Te, I, La, Pr
Xe-133m	2.188 d		Te, Xe, Cs, Ba, La
+ Xe-134	1.10E+16 y		Xe
Xe-134m	0.290 s	Xe	
Xe-135	9.140 h	Xe	Ba, La
> Xe-135m	15.290 m	Xe	Xe, Ba
Xe-137	3.818 m		Xe
+ Cs-126	1.640 m		Ba
+ Cs-128	3.620 m		Cs, Ba, La, Ce, Pr
Cs-129	1.342 d		Cs, Ba, La
* Cs-130	29.210 m	Cs	Xe, Ba, La
+ Cs-130m	3.460 m		Cs
Cs-131	9.690 d	Cs, Ba	Xe, La, Ce, Pr
Cs-132	6.530 d	Cs	Xe, Ba, La, Ce, Pr, Nd
Cs-134	2.065 y	Te, I, Xe, Cs, Ba, La, Ce, Pr	Nd
Cs-134m	2.908 h		Xe, Cs, Ba, La
Cs-135	2.30E+06 y	I, Xe, Cs, Ba, La, Ce, Pr, Nd	Te
Cs-135m	53.000 m		Xe, Cs, Ba, La
Cs-136	13.030 d	I, Xe, Cs, Ba, La	Te, Ce, Pr, Nd
Cs-136m	19.000 s		Cs, Ba, La
Cs-137	30.041 y	Te, I, Xe, Cs, Ba, La, Pr	Ce, Nd
Cs-138	33.410 m		Ba
+ Ba-128	2.430 d		Ba
Ba-129	2.380 h		Ba, La, Ce, Pr, Nd
> Ba-129m	2.140 h	Ce, Pr	Ba, La, Nd, Sm
Ba-131	11.550 d	Ba	Cs, La, Ce, Pr, Nd
Ba-131m	14.600 m		Ba, La
Ba-133	10.540 y	Xe, Cs, Ba, La, Ce, Pr, Nd	
Ba-133m	1.592 d		Ba, La
Ba-135m	1.196 d	Ba	Cs, La, Ce
Ba-136m	0.308 s		Ba, La, Ce
Ba-137m	2.552 m	Te, I, Xe, Cs, Ba, La, Ce, Pr, Nd	Sb
Ba-139	1.384 h	Ba	La
+ La-132	4.800 h		La, Ce, Pr, Nd
+ La-133	3.912 h		La, Ce, Pr
+ La-134	6.450 m		La, Ce, Pr, Nd
> La-135	19.500 h	La	Ce, Pr, Nd
La-136	9.870 m	La, Ce	Pr, Nd
La-137	6.00E+04 y	Ba, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho	Er, Tm
La-138	1.02E+11 y	Cs, Ba, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy	Ho
La-140	1.679 d	Ba, La, Ce, Pr	Nd
+ La-141	3.920 h		Ce
La-142	1.518 h		Ce
+ Ce-132	3.510 h		Ce
+ Ce-133m	4.900 h		Ce, Pr
+ Ce-134	3.160 d		Ce, Pr, Nd
> Ce-135	17.700 h	Pr	Ce, Nd
+ Ce-135m	20.000 s		Ce
* Ce-136	7.00E+13 y	Ce	
Ce-137	9.000 h	Ce	Pr, Nd
Ce-137m	1.433 d		Ce, Pr, Nd
Ce-139	137.641 d	La, Ce, Pr, Nd	Sm
Ce-139m	56.100 s	Ce	Pr, Nd
Ce-141	32.500 d	Ba, La, Ce, Pr	Nd
< Ce-142	5.00E+16 y		Ce, Pr
Ce-143	1.379 d	Ce	Nd
Ce-144	285.000 d	Ce, Pr	La, Nd
+ Pr-136	13.100 m		Pr
+ Pr-137	1.280 h		Pr
+ Pr-138	1.450 m		Pr, Sm
* Pr-138m	2.120 h	Pr	Ce, Sm
> Pr-139	4.410 h	Pr	Ce, Sm
Pr-140	3.390 m	Pr, Nd	Ce, Sm

Nuclide	T <sub>½</sub>	Contributing elements	
		Primary	Secondary
Pr-142	19.120 h	Ce, Pr	Ba, La
Pr-142m	14.600 m		La, Ce, Pr
Pr-143	13.560 d	Ce, Pr	La
Pr-144	17.280 m	Ce, Pr	La
+ Nd-138	5.040 h		Nd
+ Nd-139	29.700 m		Nd
* Nd-139m	5.500 h	Nd	Sm, Eu
> Nd-140	3.370 d	Nd	Sm, Eu
Nd-141	2.490 h	Nd	Sm, Eu
Nd-141m	1.033 m	Nd	Sm
Nd-144	2.29E+15 y	Pr, Nd	La, Ce
Nd-147	10.980 d	Pr, Nd	Ce, Sm
Nd-149	1.728 h	Nd	
Nd-151	12.440 m	Nd	
+ Pm-140	9.200 s		Sm
+ Pm-140m	5.950 m		Sm
+ Pm-141	20.900 m		Sm
Pm-142	40.500 s		Sm, Eu, Gd
Pm-143	266.000 d		Nd, Sm, Eu, Gd
Pm-144	363.000 d	Nd, Sm	Eu, Gd, Tb
Pm-145	17.700 y	Nd, Sm	Eu, Gd
Pm-146	5.531 y	Nd, Sm	Eu
Pm-147	2.623 y	La, Ce, Pr, Nd	Sm, Eu
Pm-148	5.368 d		Ce, Pr, Nd, Sm, Eu
Pm-148m	41.050 d	Pr, Nd	Ce, Sm, Eu
Pm-149	2.212 d		Pr, Nd, Sm, Eu
Pm-150	2.680 h		Ce, Pr, Nd, Sm, Eu
Pm-151	1.183 d		Nd, Sm
Pm-152m	7.520 m		Sm
Pm-153	5.250 m		Sm
Pm-154	1.700 m		Sm
+ Sm-140	14.817 m		Sm
+ Sm-141	10.200 m		Sm
+ Sm-141m	22.600 m		Sm
+ Sm-142	1.208 h		Eu
Sm-143	8.750 m		Eu
Sm-143m	1.100 m		Eu
Sm-145	340.000 d	Sm	Eu, Gd, Tb
Sm-146	1.00E+08 y	Nd, Sm, Eu	Gd, Tb
Sm-147	1.06E+11 y	La, Ce, Pr, Nd, Sm, Eu	
Sm-148	8.00E+15 y		Eu
< Sm-149	2.00E+15 y		Eu
Sm-151	90.002 y	La, Pr, Nd, Sm, Eu, Gd, Tb	
Sm-153	1.928 d	Sm	Pr, Eu, Gd
Sm-155	22.300 m	Sm	Gd
+ Eu-145	5.930 d		Eu, Gd
+ Eu-146	4.590 d		Eu, Gd, Tb, Dy, Er
+ Eu-147	24.000 d		Eu, Gd, Tb
> Eu-148	54.500 d	Eu	Sm, Gd, Tb, Dy, Ho, Er
Eu-149	93.100 d	Eu	Sm, Gd, Tb, Dy
Eu-150	36.359 y	Nd, Sm, Eu, Gd	Tb, Dy, Ho, Er, Tm
Eu-150m	12.800 h		Eu, Gd
Eu-152	13.525 y	Nd, Sm, Eu, Gd	Pr, Tb, Dy, Ho, Er, Tm, Yb
Eu-152m	9.275 h	Eu	Sm, Gd
Eu-152n	1.600 h		Eu
Eu-154	8.593 y	La, Ce, Pr, Nd, Sm, Eu, Gd, Tb	Dy, Ho, Er, Tm, Yb
Eu-154m	46.400 m		Eu, Gd
Eu-155	4.753 y	Nd, Sm, Eu, Gd, Tb	La, Ce, Pr, Dy, Ho
Eu-156	15.190 d	Pr, Nd, Sm, Eu, Gd	La, Ce, Tb, Dy
Eu-157	15.180 h		Pr, Nd, Sm, Eu, Gd
Eu-158	45.900 m		Sm, Eu, Gd
Eu-159	18.100 m		Gd
Eu-160	38.000 s		Gd

Nuclide	T <sub>1/2</sub>	Contributing elements	
		Primary	Secondary
+ Gd-145	23.000 m		Gd
+ Gd-146	48.270 d		Gd, Tb
+ Gd-147	1.588 d		Eu, Gd
Gd-148	74.602 y	Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm	Yb, Lu, Ta
Gd-149	9.280 d		Eu, Gd, Tb, Dy
Gd-150	1.82E+06 y	Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta	
Gd-151	124.000 d		Sm, Eu, Gd, Tb, Dy, Ho, Er
Gd-152	1.08E+14 y	Eu, Gd, Dy	
Gd-153	240.400 d	Eu, Gd, Tb	Sm, Dy, Ho, Er, Tm
Gd-159	18.479 h	Gd	Nd, Sm, Eu, Tb, Dy
* Gd-160	1.30E+17 y	Eu, Gd, Tb, Ho, Tm	Dy
Gd-161	3.660 m	Gd	Dy
+ Tb-151	17.609 h		Dy
+ Tb-152	17.500 h		Tb, Dy, Ho, Er
+ Tb-152m	4.300 m		Dy
+ Tb-153	2.340 d		Tb, Dy, Ho, Er
+ Tb-154	21.500 h		Gd, Tb, Dy, Ho, Er
* Tb-154m	9.000 h	Gd, Tb, Dy, Ho, Er, Tm	Yb, Lu
+ Tb-154n	22.694 h		Tb, Dy, Ho
> Tb-155	5.320 d	Tb	Dy, Ho, Er
Tb-156	5.170 d	Tb, Dy	Gd, Ho, Er
Tb-156m	1.017 d		Tb
Tb-156n	5.100 h		Tb
Tb-157	99.002 y	Gd, Tb, Dy, Ho	Tm, Yb, Lu, Hf
Tb-158	180.000 y	Gd, Tb, Dy, Ho, Tm	Yb, Lu, Hf
Tb-158m	10.800 s	Tb	Gd, Dy
Tb-160	72.300 d	Sm, Eu, Gd, Tb, Dy, Ho, Er	Pr, Tm
Tb-161	6.890 d	Sm, Eu, Gd, Tb, Dy	Ho
> Tb-162	7.600 m	Gd, Tb, Ho	Dy, Tm
> Tb-163	19.500 m	Dy	Tm
Tb-164	3.000 m		Dy
+ Dy-151	17.900 m		Dy
+ Dy-153	6.400 h		Dy
Dy-154	3.00E+06 y	Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta	Tb
Dy-155	9.900 h		Dy, Ho, Er
* Dy-156	1.00E+18 y	Dy	
Dy-157	8.140 h	Dy	Ho, Er
Dy-159	144.400 d	Dy, Ho, Er	Tm, Yb
Dy-165	2.334 h	Dy	Nd, Sm, Eu, Gd, Tb, Ho, Er
Dy-165m	1.258 m		Sm, Eu, Gd, Tb, Dy
Dy-166	3.400 d		Sm, Eu, Gd, Tb, Dy, Er
* Ho-158	11.000 m	Er	Ho, Tm, Yb
+ Ho-158n	21.333 m		Ho, Er
+ Ho-159	33.050 m		Ho, Er, Tm
> Ho-160	25.300 m	Er	Ho, Tm, Yb
+ Ho-160m	5.000 h		Ho, Er, Tm
+ Ho-160n	2.900 s		Ho
> Ho-161	2.480 h	Ho	Er, Tm, Yb
Ho-161m	6.770 s		Ho
> Ho-162	15.000 m	Ho, Er, Tm	
Ho-162m	1.117 h	Ho	Er, Tm
Ho-163	4570.090 y	Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, W	
Ho-163m	1.100 s		Ho, Er
Ho-164	28.600 m	Ho	Er, Tm
Ho-164m	37.600 m		Ho, Er
Ho-166	1.117 d	Tb, Dy, Ho	Nd, Sm, Eu, Gd, Er, Tm
Ho-166m	1200.000 y	Cs, Ba, La, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, W	Ce, Re
Ho-167	3.100 h	Ho	Eu, Gd, Tb, Dy, Er
Ho-168	2.990 m		Er
Ho-169	4.400 m		Er
Ho-170	2.780 m		Er

Nuclide	T <sub>½</sub>	Contributing elements	
		Primary	Secondary
+ Ho-170m	43.000 s		Er
+ Er-158	2.250 h		Er
+ Er-159	36.000 m		Er, Tm
Er-160	1.191 d		Ho, Er, Tm
Er-161	3.211 h		Ho, Er, Tm, Yb
* Er-162	1.40E+14 y	Ho, Er	Tm
Er-163	1.250 h		Ho, Er, Tm, Yb
Er-165	10.360 h	Er	Ho, Tm, Yb, Lu
Er-167m	2.269 s	Dy, Ho, Er	Sm, Eu, Gd, Tb, Tm, Yb, Lu, Hf
Er-169	9.400 d	Dy, Ho, Er	Eu, Gd, Tb, Tm
Er-171	7.516 h	Er	Dy, Ho
+ Tm-163	1.810 h		Tm, Yb
+ Tm-164	2.000 m		Tm, Yb
+ Tm-164m	5.100 m		Tm
+ Tm-165	1.253 d		Tm, Yb, Lu
> Tm-166	7.700 h	Tm, Yb	Lu, Hf
> Tm-167	9.250 d	Tm	Yb, Lu, Hf
Tm-168	93.100 d	Er, Tm, Yb, Lu	
Tm-170	128.600 d	Gd, Tb, Dy, Ho, Er, Tm, Yb	Lu
Tm-171	1.917 y	Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu	
Tm-172	2.650 d	Tb, Dy, Ho, Er, Tm, Lu	Gd, Yb
Tm-173	8.240 h		Yb
Tm-174	5.400 m		Yb
+ Tm-175	15.167 m		Yb
Tm-176	1.900 m		Yb
+ Yb-163	11.050 m		Yb
+ Yb-164	1.263 h		Yb
+ Yb-165	9.900 m		Lu
+ Yb-166	2.363 d		Lu
Yb-167	17.500 m		Lu
* Yb-168	1.30E+14 y	Tm, Yb	
Yb-169	32.018 d	Yb	Lu
Yb-169m	46.000 s		Lu
Yb-175	4.185 d	Tm, Yb	
Yb-176m	11.400 s	Yb	
Yb-177	1.911 h	Yb	
+ Lu-167	51.500 m		Lu, Hf, Ta
+ Lu-168	5.500 m		Lu, Hf
+ Lu-168m	6.700 m		Hf, Ta
+ Lu-169	1.419 d		Lu, Hf, Ta, W
+ Lu-169m	2.667 m		Lu
* Lu-170	2.002 d	Lu	Yb, Hf, Ta, W
+ Lu-170m	0.670 s		Lu
Lu-171	8.250 d		Yb, Lu, Hf, Ta, W
+ Lu-171m	1.300 m		Lu, Hf
Lu-172	6.700 d	Lu, Hf, Ta, W, Re, Os	Yb, Ir, Pt, Au
Lu-172m	3.700 m		Lu, Hf, Ta, W, Re, Os
> Lu-173	1.336 y	Yb, Lu, Hf	Ta, W, Re, Os, Ir
Lu-174	3.559 y	Yb, Lu, Hf	Ta, W, Re, Os
Lu-174m	142.000 d		Yb, Lu, Hf, Ta
Lu-176	4.00E+10 y	Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta	
Lu-176m	3.635 h	Yb, Lu	Er, Tm, Hf, Ta
Lu-177	6.647 d	Yb, Lu	Tm, Hf, Ta
Lu-177m	160.300 d	Yb, Lu	Tm, Hf, Ta
Lu-178	28.400 m	Lu	Tm, Yb, Hf, Ta
Lu-178m	23.100 m		Lu, Hf, Ta
+ Lu-179	4.590 h		Hf, Ta
Lu-180	5.700 m		Hf, Ta
+ Hf-169	3.240 m		Hf
+ Hf-170	16.000 h		Hf
* Hf-171	12.111 h	Hf, Ta	W, Re, Os
* Hf-172	1.870 y	Hf, Ta, W, Re	Os, Ir

Nuclide	T <sub>1/2</sub>	Contributing elements	
		Primary	Secondary
Hf-173	23.900 h		Hf, Ta, W
Hf-174	2.00E+15 y		Hf
Hf-175	70.000 d	Hf, Ta	W, Re
Hf-177m	1.080 s	Yb, Lu, Hf	Er, Tm, Ta
Hf-177n	51.400 m		Yb, Lu, Hf
Hf-178m	4.000 s	Hf	Tm, Yb, Lu, Ta, W, Re, Os
Hf-178n	31.001 y	Yb, Lu, Hf, Ta, W, Re, Os	Tm
Hf-179m	18.670 s	Lu, Hf	Tm, Yb, Ta
Hf-179n	25.100 d	Hf	Tm, Yb, Lu, Ta, W
Hf-180m	5.500 h		Tm, Yb, Lu, Hf, Ta, W
Hf-181	42.380 d	Er, Tm, Yb, Lu, Hf	Dy, Ho, Ta, W
Hf-182	9.00E+06 y	Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, W	Nd, Sm, Eu, Gd, Re, Os, Ir
Hf-183	1.067 h		Tm, Yb, Lu, Hf, W
+ Ta-174	1.140 h		W
+ Ta-175	10.500 h		Ta, W, Re
* Ta-176	8.090 h	Ta	W, Re
Ta-177	2.350 d		Ta, W, Re
Ta-178	9.290 m		Ta, W, Re
Ta-178m	2.361 h	Ta	W
Ta-179	1.610 y	Ta, W, Re	Ir, Pt
Ta-180	8.080 h	Ta	W
Ta-180m	1.80E+15 y	Ta	
Ta-182	114.700 d	Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, W, Re	Ir, Pt, Au
Ta-182m	0.283 s		Ta
Ta-183	5.090 d	Hf, Ta	Tm, Yb, Lu
Ta-184	8.700 h		Tm, Yb, Lu, Hf
+ W-175	35.200 m		Re
+ W-177	2.200 h		Re
W-178	21.600 d		Re
W-179	37.050 m		Re
W-181	120.980 d	W	Re, Ir, Pt
* W-183	1.10E+17 y	Ta, W	
W-183m	5.250 s	W	Yb, Lu, Re
W-185	75.100 d	Hf, Ta, W, Re, Os	Yb, Lu
W-185m	1.667 m		Re
W-187	23.850 h	W, Re	
< W-188	69.780 d		Re
+ Re-179	19.500 m		Os
+ Re-180	2.440 m		Re, Os
+ Re-181	19.900 h		W, Re, Os, Ir
Re-182	2.667 d		W, Re, Os, Ir, Pt
+ Re-182m	12.700 h		W, Re, Os
> Re-183	70.000 d	Re	W, Os, Ir, Pt, Au
Re-184	37.900 d	W, Re, Os	Ir, Pt, Au, Hg
Re-184m	168.000 d	W, Re	Os, Ir, Pt, Au
Re-186	3.775 d	Ta, W, Re, Os, Ir, Pt, Au, Hg, Tl	Lu, Hf
Re-186m	2.00E+05 y	Ta, W, Re, Os, Ir, Pt, Au, Hg, Tl	Lu, Hf
Re-187	4.35E+10 y	W, Re, Ir, Au	Ta, Os
Re-188	16.980 h	W, Re	Ta, Ir
Re-188m	18.600 m		Re
Re-189	1.013 d		Ir
+ Os-179	6.500 m		Os
+ Os-180	21.500 m		Os
+ Os-181m	1.750 h		Os
+ Os-182	22.100 h		Os, Ir
Os-183	13.000 h		Os, Ir, Pt
Os-183m	9.889 h		Os
* Os-184	5.60E+13 y	Os	
Os-185	93.800 d	Os, Ir, Pt, Au	Re, Hg, Tl, Pb
Os-186	2.00E+15 y	Os	Re
Os-189m	4.806 h	Os	W, Re, Ir, Pt, Au
Os-190m	9.900 m	Os	Ir, Pt



Nuclide	T <sub>½</sub>	Contributing elements	
		Primary	Secondary
Os-191	15.300 d	Os, Au	Ta, W, Re, Ir, Pt
Os-191m	13.100 h		W, Re, Os
Os-192m	5.900 s		Os
Os-193	1.255 d	Os	Re, Ir
Os-194	5.989 y	Ta, W, Re, Os, Ir, Pt, Au	Hf
+ Ir-185	13.889 h		Ir, Pt, Au, Hg
+ Ir-186	16.639 h		Ir, Pt, Au, Hg
+ Ir-186m	2.000 h		Ir, Pt
+ Ir-187	10.500 h		Ir, Pt, Au
> Ir-188	1.729 d	Ir, Pt, Au, Hg	Os, Tl, Pb
> Ir-189	13.200 d	Ir	Os, Pt, Au, Hg
Ir-190	12.000 d	Os, Ir, Pt	Au, Hg
Ir-190m	1.120 h		Os, Ir
Ir-190n	3.087 h		Ir
Ir-191m	4.900 s	Os, Au	W, Re, Ir, Pt
> Ir-191n	5.500 s	Os, Ir	Pt
Ir-192	73.822 d	Ta, W, Re, Os, Ir, Pt, Au	Hg, Tl, Pb
Ir-192m	1.440 m		W, Re, Os, Ir
Ir-192n	241.000 y	Ta, W, Re, Os, Ir, Pt, Au	Hg
> Ir-193m	10.602 d	Ir, Au	W, Re, Os, Pt
Ir-194	19.300 h	Ta, W, Re, Os, Ir, Au	Hf, Pt
Ir-195	2.500 h		Os, Ir
Ir-195m	3.800 h		Os, Ir, Pt
+ Ir-196	52.000 s		Pt
+ Ir-198	8.000 s		Pt
+ Pt-185	1.183 h		Pt
+ Pt-186	2.080 h		Pt
+ Pt-187	2.350 h		Pt, Au
Pt-188	10.200 d		Pt, Au, Hg
Pt-189	10.870 h		Pt, Au, Hg
Pt-190	6.50E+11 y	Pt, Au, Hg	Ir, Tl
Pt-191	2.802 d		Ir, Pt, Au, Hg
Pt-193	50.001 y	Hf, Ta, W, Re, Os, Ir, Pt, Au, Hg, Tl	Lu, Pb
Pt-193m	4.340 d	Ir, Pt	Re, Os, Au, Hg
Pt-195m	4.020 d	Ir, Pt	Os, Au, Hg
Pt-197	19.892 h	Pt	Ir, Au, Hg
Pt-197m	1.588 h		Ir, Pt
Pt-199	30.800 m	Pt	
Pt-199m	13.600 s		Pt
+ Au-190	42.800 m		Hg
+ Au-191	3.180 h		Au, Hg
* Au-192	4.940 h	Au	Hg, Tl, Pb
+ Au-193	17.650 h		Au, Hg, Tl
+ Au-193m	3.900 s		Au, Hg
Au-194	1.584 d	Pt, Au, Hg, Tl, Pb	Bi
+ Au-194m	0.600 s		Au
+ Au-194n	0.420 s		Au
Au-195	186.090 d	Pt, Au, Hg, Tl	Pb, Bi
Au-195m	30.500 s		Au, Hg
Au-196	6.183 d	Au, Hg	Pt, Tl, Pb
Au-196m	8.100 s		Au, Hg
Au-196n	9.600 h		Au, Hg
Au-197m	7.740 s	Au	Pt, Hg
Au-198	2.694 d	Ir, Pt, Au, Hg	Os, Tl, Pb
Au-199	3.139 d	Ir, Pt, Au	Hg, Tl, Pb
Au-200	48.400 m		Ir, Pt, Au, Hg, Tl
+ Au-201	26.000 m		Hg
Au-202	28.800 s		Hg, Tl
Au-204	39.800 s		Hg
+ Hg-189m	8.700 m		Hg
+ Hg-191	48.333 m		Hg
+ Hg-191m	50.833 m		Hg
+ Hg-192	4.850 h		Hg

Nuclide	T <sub>1/2</sub>	Contributing elements	
		Primary	Secondary
+ Hg-193	3.800 h		Hg, Tl
+ Hg-193m	11.806 h		Hg
Hg-194	440.008 y	Pt, Au, Hg, Tl, Pb, Bi	
Hg-195	9.900 h		Au, Hg, Tl
Hg-195m	1.736 d		Au, Hg, Tl, Pb
* Hg-196	2.50E+18 y	Au	Hg
Hg-197	2.692 d	Hg	Tl, Pb
Hg-197m	23.900 h		Hg, Tl, Pb
Hg-199m	42.100 m	Au, Hg	Tl
Hg-203	46.603 d	Ir, Pt, Au, Hg, Tl, Pb	
Hg-205	5.200 m	Hg, Pb	
+ Tl-198	5.300 h		Tl, Pb
+ Tl-198m	1.870 h		Tl, Pb
+ Tl-199	7.420 h		Tl, Pb, Bi
> Tl-200	1.088 d	Tl, Pb	Bi
> Tl-201	3.041 d	Tl	Pb, Bi
Tl-202	12.240 d	Hg, Tl, Pb	Bi
Tl-204	3.788 y	Pt, Au, Hg, Tl, Pb	Ir, Bi
Tl-206	4.202 m	Tl, Bi	Pb
Tl-206m	3.760 m	Bi	Tl, Pb
Tl-207	4.770 m		Pb
Tl-207m	1.330 s		Pb
< Tl-208	3.053 m		Pb
+ Pb-198	2.400 h		Pb
+ Pb-199	1.500 h		Pb, Bi
+ Pb-199m	12.200 m		Pb
+ Pb-200	21.500 h		Pb, Bi
Pb-201	9.400 h		Tl, Pb, Bi
+ Pb-201m	1.017 m		Pb, Bi
Pb-202	5.30E+04 y	Hg, Tl, Pb, Bi	
+ Pb-202m	3.570 h		Tl, Pb, Bi
Pb-203	2.162 d	Pb	Tl, Bi
Pb-203m	6.290 s		Tl, Pb, Bi
Pb-204	1.40E+17 y	Au	
Pb-204m	1.125 h	Tl, Pb	Bi
Pb-205	1.53E+07 y	Ir, Pt, Au, Hg, Tl, Pb	Bi
+ Pb-205m	0.006 s		Bi
Pb-207m	0.806 s	Pb	Tl, Bi
Pb-209	3.253 h	Pb	Bi
Pb-210	22.160 y	Pb	Pb, Bi
+ Bi-199	27.000 m		Bi
+ Bi-200m	31.000 m		Bi
* Bi-201m	59.100 m	Bi	
+ Bi-202	1.720 h		Bi
+ Bi-203	11.761 h		Bi
+ Bi-204	11.220 h		Bi
> Bi-205	15.310 d	Bi	
Bi-206	6.243 d	Bi	
Bi-207	31.760 y	Pb, Bi	
Bi-208	3.68E+05 y	Pb, Bi	
Bi-210	5.012 d	Bi	Pb
Bi210m	3.00E+06 y	Pb, Bi	
Bi211	2.170 m		Pb, Bi
Po208	2.930 y		Pb, Bi
Po209	102.002 y	Bi	Pb
Po210	138.388 d	Pb, Bi	

## Summary of Major reactions

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>H1(n,<math>\gamma</math>)H2</b>	H3	5	4*	•	
<b>H2(n,<math>\gamma</math>)H3</b>	H3	5	4*	•	
<b>He3(n,p)H3</b>	H3	5	4	•	
<b>He4(n,2n)He3</b>	H3	5	0		
<b>Li6(n,<math>\alpha</math>)H3</b>	H3	5	4	•	
<b>Li7(n,<math>n\alpha</math>)H3</b>	H3	5	5 <sub>3</sub>	•	•
<b>Li7(n,<math>\gamma</math>)Li8</b>	Li8	5	4	•	
<b>Li7(n,d)He6</b>	He6	5	2	•	
<b>Be9(n,<math>\gamma</math>)Be10</b>	H3, Li8, Be10, Be11	5	2	•	
<b>Be9(n,d)Li8</b>	Li8	5	4	•	
<b>Be9(n,t)Li7</b>	H3, He6, Li8	5	5 <sub>2</sub>	•	
<b>Be9(n,<math>\alpha</math>)He6</b>	He6	5	4	•	
<b>Be10(n,<math>\gamma</math>)Be11</b>	Li8, Be11	5	2*	•	
<b>B10(n,p)Be10</b>	He6, Li8, Be10, Be11	5	2	•	
<b>B10(n,h)Li8</b>	Li8	5	0		
<b>B10(n,<math>\alpha</math>)Li7</b>	H3, He6, Li8	5	4	•	
<b>B10(n,2<math>\alpha</math>)H3</b>	H3	5	6	•	•
<b>B11(n,<math>n\alpha</math>)Li7</b>	H3, He6	4	0		
<b>B11(n,n2<math>\alpha</math>)H3</b>	H3	5	0		
<b>B11(n,<math>\gamma</math>)B12</b>	C11	5	2	•	
<b>B11(n,p)Be11</b>	Be11	5	2	•	
<b>B11(n,d)Be10</b>	H3, He6, Li8, Be10	5	2	•	
<b>B11(n,t)Be9</b>	H3, He6, Li8	4	5 <sub>2</sub>	•	•
<b>B11(n,<math>\alpha</math>)Li8</b>	Li8	5	4	•	
<b>B11(n,d<math>\alpha</math>)He6</b>	He6	5	0		
<b>C12(n,2n)C11</b>	H3, He6, Li8, Be10, Be11, C11	5	3	•	
<b>C12(n,2n<math>\alpha</math>)Be7</b>	H3, He6, Be7	5	0		
<b>C12(n,d)B11</b>	H3, He6, Li8, Be10, Be11	5	3	•	
<b>C12(n,h)Be10</b>	H3, He6, Li8, Be10	5	0		
<b>C12(n,<math>\alpha</math>)Be9</b>	H3, He6, Li8	5	4	•	
<b>C12(n,2p)Be11</b>	Be11	5	0		
<b>C12(n,p<math>\alpha</math>)Li8</b>	Li8	5	0		
<b>C12(n,d2<math>\alpha</math>)H3</b>	H3	5	0		
<b>C12(n,d<math>\alpha</math>)Li7</b>	H3, He6	4	0		
<b>C12(n,h<math>\alpha</math>)He6</b>	He6	4	0		
<b>C13(n,3n<math>\alpha</math>)Be7</b>	Be7	4	0		
<b>C13(n,<math>\gamma</math>)C14</b>	H3, Be11, C14, C15	5	4	•	
<b>C13(n,t)B11</b>	He6, Li8, Be10, Be11	5	2	•	
<b>C13(n,<math>\alpha</math>)Be10</b>	He6, Li8, Be10, Be11	5	1	•	
<b>C13(n,t2<math>\alpha</math>)H3</b>	H3	5	0		
<b>C14(n,<math>n\alpha</math>)Be10</b>	Li8, Be10	5	0		
<b>C14(n,<math>\gamma</math>)C15</b>	C15, N16	5	2	•	
<b>C14(n,<math>\alpha</math>)Be11</b>	Be11	5	0		
<b>N14(n,2n)N13</b>	Li8, Be7, Be10, Be11, C11, N13	5	6	•	•
<b>N14(n,<math>n\alpha</math>)B10</b>	H3, Li8, Be10	5	0		
<b>N14(n,nt)C11</b>	Li8, Be10, Be11, C11	5	0		
<b>N14(n,<math>\gamma</math>)N15</b>	N16	5	5 <sub>2</sub>	•	•
<b>N14(n,p)C14</b>	H3, Li8, Be10, Be11, C14, C15	5	2	•	
<b>N14(n,d)C13</b>	H3, Li8, Be7, Be10, Be11, C11	5	0		
<b>N14(n,t)C12</b>	H3, Li8, Be7, Be10, Be11, C11	5	5 <sub>2</sub>	•	•
<b>N14(n,<math>\alpha</math>)B11</b>	H3, Li8, Be10, Be11	5	4	•	
<b>N14(n,3<math>\alpha</math>)H3</b>	H3	5	0		
<b>N14(n,p<math>\alpha</math>)Be10</b>	H3, Li8, Be10	5	0		
<b>N14(n,d<math>\alpha</math>)Be9</b>	H3, Li8	5	0		
<b>N14(n,n<math>\alpha</math>)Be7</b>	Be7	5	0		
<b>N14(n,ph)Be11</b>	Be11	5	0		
<b>N15(n,2n)N14</b>	H3, Be7, Be10, C14, N13	5	0		

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>N15(n,n<math>\alpha</math>)B11</b>	Li8, Be10, Be11	4	0		
<b>N15(n,<math>\gamma</math>)N16</b>	N16	5	4	•	
<b>N15(n,p)C15</b>	C15	5	2	•	
<b>N15(n,d)C14</b>	Be10, Be11, C14	5	0		
<b>N15(n,t)C13</b>	Be7, Be10	4	0		
<b>N15(n,d<math>\alpha</math>)Be10</b>	Be10	5	0		
<b>O16(n,2n)O15</b>	H3, Be7, Be10, C14, C15, N13, O15	5	3	•	
<b>O16(n,n<math>\alpha</math>)C12</b>	H3, Be7, Be10, C11	5	1	•	
<b>O16(n,2n<math>\alpha</math>)C11</b>	Be10, C11	5	0		
<b>O16(n,2n2<math>\alpha</math>)Be7</b>	Be7	5	0		
<b>O16(n,nt)N13</b>	Be7, Be10, C11, N13	5	0		
<b>O16(n,p)N16</b>	N16	5	6	•	•
<b>O16(n,d)N15</b>	H3, Be10, C14, C15, N13	5	2	•	
<b>O16(n,t)N14</b>	H3, Be7, Be10, C11, C14, N13	5	5 <sub>2</sub>	•	•
<b>O16(n,h)C14</b>	H3, Be7, Be10, C11, C14	5	0		
<b>O16(n,<math>\alpha</math>)C13</b>	H3, Be7, Be10, C11	5	4	•	
<b>O16(n,2p)C15</b>	Be10, C15	5	0		
<b>O16(n,d<math>\alpha</math>)B11</b>	Be10	4	0		
<b>O16(n,h<math>\alpha</math>)Be10</b>	Be10	5	0		
<b>O17(n,<math>\alpha</math>)C14</b>	H3, Be10, C14, C15, N16	5	4	•	
<b>O17(n,2<math>\alpha</math>)Be10</b>	Be10	5	0		
<b>O18(n,n<math>\alpha</math>)C14</b>	Be10, C14	5	0		
<b>O18(n,<math>\gamma</math>)O19</b>	O19, F18, F20, Na24	5	4	•	
<b>O18(n,t)N16</b>	N16	4	0		
<b>O18(n,<math>\alpha</math>)C15</b>	C15	4	2	•	
<b>F19(n,2n)F18</b>	H3, Be7, Be10, C14, N16, F18	5	6	•	•
<b>F19(n,n<math>\alpha</math>)N15</b>	H3, Be7, Be10, C14	5	0		
<b>F19(n,<math>\gamma</math>)F20</b>	O19, F20, Na24	5	4	•	
<b>F19(n,p)O19</b>	O19	5	6	•	•
<b>F19(n,<math>\alpha</math>)N16</b>	Be7, Be10, N16	5	4	•	
<b>F19(n,2<math>\alpha</math>)B12</b>	Be7, Be10	4	0		
<b>F19(n,d2<math>\alpha</math>)Be10</b>	Be10	5	0		
<b>F19(n,d<math>\alpha</math>)C14</b>	H3, Be7, Be10, C14	5	0		
<b>F19(n,t<math>\alpha</math>)C13</b>	H3, Be7, Be10	4	0		
<b>F19(n,nt<math>\alpha</math>)C12</b>	Be7, Be10	4	0		
<b>Ne20(n,2n)Ne19</b>	H3, Be10, C14, O19, F18, Ne19	5	0		
<b>Ne20(n,n2<math>\alpha</math>)C12</b>	H3, Be7, Be10	5	0		
<b>Ne20(n,<math>\gamma</math>)Ne21</b>	O19, F20, F21, Na24	5	3	•	
<b>Ne20(n,p)F20</b>	F20	5	0		
<b>Ne20(n,d)F19</b>	H3, Be7, Be10, C14, O19, F18	5	0		
<b>Ne20(n,t)F18</b>	H3, Be7, Be10, C14, F18	5	5 <sub>0</sub>		•
<b>Ne20(n,<math>\alpha</math>)O17</b>	H3, Be7, Be10, C14	5	4	•	
<b>Ne20(n,2<math>\alpha</math>)C13</b>	H3, Be7, Be10	5	0		
<b>Ne20(n,2p)O19</b>	C14, O19, F18	5	0		
<b>Ne20(n,d<math>\alpha</math>)N15</b>	H3, Be7, Be10, C14	5	0		
<b>Ne20(n,h<math>\alpha</math>)C14</b>	Be10, C14	4	0		
<b>Ne21(n,<math>\gamma</math>)Ne22</b>	Na24	5	3	•	
<b>Ne21(n,p)F21</b>	F21	5	0		
<b>Ne21(n,d)F20</b>	F20	4	0		
<b>Ne21(n,<math>\alpha</math>)O18</b>	Be10, C14, O19, F20	5	2	•	
<b>Ne21(n,2<math>\alpha</math>)C14</b>	Be10, C14	5	0		
<b>Ne22(n,2n)Ne21</b>	H3, Be10, C14, O19, F20, F21	5	0		
<b>Ne22(n,n2<math>\alpha</math>)C14</b>	Be10, C14	4	0		
<b>Ne22(n,<math>\gamma</math>)Ne23</b>	Ne23, Na22, Na24	5	3	•	
<b>Ne22(n,d)F21</b>	C14, O19, F20, F21	5	0		
<b>Ne22(n,t)F20</b>	F18, F20, Ne19	4	0		
<b>Ne22(n,<math>\alpha</math>)O19</b>	H3, O19, F18	5	0		
<b>Na23(n,2n)Na22</b>	H3, Be10, C14, F20, Na22	5	6	•	•
<b>Na23(n,n<math>\alpha</math>)F19</b>	H3, Be10, C14	4	4	•	
<b>Na23(n,n2<math>\alpha</math>)N15</b>	H3, Be10, C14	5	0		

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Na23</b> (n, $\gamma$ ) <b>Na24m</b>	Ne23, Na24	5	2	•	
<b>Na23</b> (n, $\gamma$ ) <b>Na24</b>	Ne23, Na24	5	2	•	
<b>Na23</b> (n,p) <b>Ne23</b>	Ne23	5	6*	•	•
<b>Na23</b> (n,d) <b>Ne22</b>	H3, Be10, C14, F20, Ne23	4	0		
<b>Na23</b> (n,t) <b>Ne21</b>	H3, Be10, C14, F20	4	5 <sub>2</sub> *	•	•
<b>Na23</b> (n, $\alpha$ ) <b>F20</b>	Be10, C14, F20	5	4	•	
<b>Na23</b> (n,d2 $\alpha$ ) <b>C14</b>	Be10, C14	5	0		
<b>Mg24</b> (n, $\alpha$ ) <b>Ne20</b>	H3, Be10, C14	5	0		
<b>Mg24</b> (n,n2 $\alpha$ ) <b>O16</b>	H3, Be10, C14	4	0		
<b>Mg24</b> (n,2n2 $\alpha$ ) <b>O15</b>	Be10, C14	4	0		
<b>Mg24</b> (n, $\gamma$ ) <b>Mg25</b>	Ne23, Na24	4	0		
<b>Mg24</b> (n,p) <b>Na24</b>	Na24	5	0		
<b>Mg24</b> (n,p) <b>Na24m</b>	Na24	4	0		
<b>Mg24</b> (n,d) <b>Na23</b>	H3, Be10, C14, Na22	5	0		
<b>Mg24</b> (n,t) <b>Na22</b>	H3, Be10, C14, Na22	5	5 <sub>0</sub>		•
<b>Mg24</b> (n, $\alpha$ ) <b>Ne21</b>	H3, Be10, C14	5	0		
<b>Mg24</b> (n,2 $\alpha$ ) <b>O17</b>	H3, Be10, C14	5	0		
<b>Mg24</b> (n,d $\alpha$ ) <b>F19</b>	H3, Be10, C14	4	0		
<b>Mg25</b> (n, $\alpha$ ) <b>Ne21</b>	H3, Be10, C14	4	0		
<b>Mg25</b> (n,p) <b>Na25</b>	Na25	5	6	•	•
<b>Mg25</b> (n,d) <b>Na24</b>	Be10, C14, Na22, Na24	4	0		
<b>Mg25</b> (n, $\alpha$ ) <b>Ne22</b>	Be10, C14, Ne23, Na24	5	2	•	
<b>Mg26</b> (n,n3 $\alpha$ ) <b>C14</b>	Be10, C14	4	0		
<b>Mg26</b> (n, $\gamma$ ) <b>Mg27</b>	Mg27, Al26, Si31, Si32, P32	5	4	•	
<b>Mg26</b> (n,d) <b>Na25</b>	H3, Be10, C14, Na24, Na25	5	0		
<b>Mg26</b> (n,t) <b>Na24</b>	Na22, Na24	4	0		
<b>Mg26</b> (n, $\alpha$ ) <b>Ne23</b>	H3, Be10, Na22	4	6*	•	•
<b>Al26</b> (n, $\alpha$ ) <b>Na22</b>	Be10, C14, Na22	4	0		
<b>Al27</b> (n,2n) <b>Al26</b>	H3, Be10, C14, Na22, Na24, Al26	5	4/3	•	
<b>Al27</b> (n, $\alpha$ ) <b>Na23</b>	H3, Be10, C14, Na22	5	2	•	
<b>Al27</b> (n,n3 $\alpha$ ) <b>N15</b>	Be10, C14	5	0		
<b>Al27</b> (n,2n $\alpha$ ) <b>Na22</b>	Be10, C14, Na22	5	5 <sub>3</sub>		•
<b>Al27</b> (n,n2 $\alpha$ ) <b>F19</b>	Be10, C14	4	0		
<b>Al27</b> (n, $\gamma$ ) <b>Al28</b>	Al28, Si31, Si32, P32	5	4	•	
<b>Al27</b> (n,p) <b>Mg27</b>	Mg27	5	6	•	•
<b>Al27</b> (n,t) <b>Mg25</b>	H3, Be10, C14, Na22, Na24	4	6	•	•
<b>Al27</b> (n, $\alpha$ ) <b>Na24</b>	Be10, C14, Na22, Na24	5	2	•	
<b>Al27</b> (n, $\alpha$ ) <b>Na24m</b>	Be10, C14, Na22, Na24	4	2	•	
<b>Al27</b> (n,d $\alpha$ ) <b>Ne22</b>	H3, Be10, C14	4	0		
<b>Si28</b> (n, $\alpha$ ) <b>Mg24</b>	H3, Be10, C14, Na22, Na24	5	0		
<b>Si28</b> (n,n3 $\alpha$ ) <b>O16</b>	Be10, C14	4	0		
<b>Si28</b> (n, $\gamma$ ) <b>Si29</b>	Al29, Si31, Si32, P32	5	4	•	
<b>Si28</b> (n,p) <b>Al28</b>	Al28	5	6	•	•
<b>Si28</b> (n,d) <b>Al27</b>	H3, Be10, C14, Na22, Na24, Al26	5	1	•	
<b>Si28</b> (n,t) <b>Al26</b>	H3, Be10, C14, Na22, Na24, Al26	5	0		
<b>Si28</b> (n, $\alpha$ ) <b>Mg25</b>	H3, Be10, C14, Na22, Na24	4	2	•	
<b>Si28</b> (n,2 $\alpha$ ) <b>Ne21</b>	Be10, C14	5	0		
<b>Si28</b> (n,p $\alpha$ ) <b>Na24</b>	Be10, C14, Na22, Na24	5	0		
<b>Si28</b> (n,p $\alpha$ ) <b>Na24m</b>	Be10, C14, Na22, Na24	4	0		
<b>Si28</b> (n,t $\alpha$ ) <b>Na22</b>	Be10, C14, Na22	5	0		
<b>Si29</b> (n, $\gamma$ ) <b>Si30</b>	Si31, Si32, P32, Cl36	5	2	•	
<b>Si29</b> (n,p) <b>Al29</b>	Al29	5	6	•	•
<b>Si29</b> (n,d) <b>Al28</b>	C14, Na22, Na24, Al26, Al28	4	0		
<b>Si29</b> (n, $\alpha$ ) <b>Mg26</b>	C14, Na22, Na24	4	3	•	
<b>Si29</b> (n,d $\alpha$ ) <b>Na24</b>	Na22, Na24	4	0		
<b>Si30</b> (n, $\gamma$ ) <b>Si31</b>	Si31, Si32, P32, Cl36	5	4	•	
<b>Si30</b> (n,d) <b>Al29</b>	C14, Na22, Na24, Al28, Al29	5	0		
<b>Si30</b> (n,t) <b>Al28</b>	Na22, Na24, Al26, Al28	4	0		
<b>Si30</b> (n, $\alpha$ ) <b>Mg27</b>	H3, Be10, C14, Na22, Na24, Al26	4	6	•	•
<b>Si31</b> (n, $\gamma$ ) <b>Si32</b>	Si32	5	2	•	

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>P31(n,2n)P30</b>	H3, C14, Na24, Al26, Al28, Al29, P30	5	4	•	
<b>P31(n,n<math>\alpha</math>)Al27</b>	H3, Be10, C14, Na22, Na24, Al26	5	0		
<b>P31(n,2n<math>\alpha</math>)Al26</b>	Be10, C14, Na22, Na24, Al26	5	0		
<b>P31(n,n2<math>\alpha</math>)Na23</b>	Be10, C14, Na22	4	0		
<b>P31(n,2n2<math>\alpha</math>)Na22</b>	Be10, C14, Na22	4	0		
<b>P31(n,<math>\gamma</math>)P32</b>	Si31, Si32, P32, S35, Cl36	5	4	•	
<b>P31(n,p)Si31</b>	Si31, Si32	5	6	•	•
<b>P31(n,d)Si30</b>	H3, Be10, C14, Na22, Na24, Al26, Al28, Al29	4	0		
<b>P31(n,t)Si29</b>	H3, Be10, C14, Na22, Na24, Al26, Al28, Al29	4	5 <sub>3</sub>		•
<b>P31(n,<math>\alpha</math>)Al28</b>	H3, Be10, C14, Na22, Na24, Al26, Al28	5	6	•	•
<b>P31(n,2<math>\alpha</math>)Na24</b>	Be10, C14, Na22, Na24	5	0		
<b>P31(n,2<math>\alpha</math>)Na24m</b>	Be10, C14, Na22, Na24	4	0		
<b>P31(n,d<math>\alpha</math>)Mg26</b>	H3, Be10, C14, Na22, Na24	4	0		
<b>P32(n,p)Si32</b>	Si32	5	0		
<b>P33(n,<math>\gamma</math>)P34</b>	S35, Cl36	4	0		
<b>S32(n,n<math>\alpha</math>)Si28</b>	H3, C14, Na22, Na24, Al26, Al28	5	0		
<b>S32(n,n2<math>\alpha</math>)Mg24</b>	C14, Na22, Na24	4	0		
<b>S32(n,<math>\gamma</math>)S33</b>	H3, Si31, Si32, P32, P33, S35, Cl36	5	4	•	
<b>S32(n,p)P32</b>	H3, Al29, Si31, Si32, P32	5	6	•	•
<b>S32(n,d)P31</b>	H3, C14, Na22, Na24, Al26, Al28, Al29, Si31, P30	5	0		
<b>S32(n,t)P30</b>	H3, C14, Na22, Na24, Al26, Al28, Al29, P30	5	5 <sub>2</sub>	•	•
<b>S32(n,h)Si30</b>	H3, C14, Na22, Na24, Al26, Al28, Al29	5	0		
<b>S32(n,<math>\alpha</math>)Si29</b>	H3, C14, Na22, Na24, Al26, Al28, Al29, Si31, Si32, P32	5	4	•	
<b>S32(n,2<math>\alpha</math>)Mg25</b>	C14, Na22, Na24	4	0		
<b>S32(n,2p)Si31</b>	H3, Na22, Na24, Al26, Al28, Al29, Si31, P30	5	0		
<b>S32(n,p<math>\alpha</math>)Al28</b>	C14, Na22, Na24, Al26, Al28	5	0		
<b>S32(n,d<math>\alpha</math>)Al27</b>	H3, C14, Na22, Na24, Al26	4	0		
<b>S32(n,t<math>\alpha</math>)Al26</b>	C14, Na22, Na24, Al26	5	0		
<b>S32(n,ph)Al29</b>	Na24, Al28, Al29	4	0		
<b>S33(n,<math>\gamma</math>)S34</b>	S35, Cl36	5	2	•	
<b>S33(n,p)P33</b>	Si32, P33	5	2	•	
<b>S33(n,d)P32</b>	Na22, Al26, Si32, P32	4	0		
<b>S33(n,<math>\alpha</math>)Si30</b>	Na22, Na24, Al26, Al28, Al29, Si31, Si32, P32	5	4	•	
<b>S33(n,2p)Si32</b>	Si32	4	0		
<b>S34(n,n<math>\alpha</math>)Si30</b>	Na22, Na24, Al26, Al28, Al29	4	0		
<b>S34(n,<math>\gamma</math>)S35</b>	H3, Si32, P32, P33, S35, S37, Cl36, Cl38, Ar39	5	4	•	
<b>S34(n,d)P33</b>	H3, Na22, Al26, Al29, Si31, Si32, P32, P33	5	0		
<b>S34(n,t)P32</b>	Na22, Al26, Si31, P30, P32	4	0		
<b>S34(n,h)Si32</b>	Si31, Si32	5	0		
<b>S34(n,<math>\alpha</math>)Si31</b>	H3, Na22, Na24, Al26, Al28, Si31, P30	4	6	•	•
<b>S35(n,<math>\gamma</math>)S36</b>	S37	5	0		
<b>S35(n,<math>\alpha</math>)Si32</b>	Si32	5	0		
<b>S36(n,2n)S35</b>	Na22, Al26, Si32, P32, P33, S35, Cl36	5	0		
<b>S36(n,n<math>\alpha</math>)Si32</b>	Si32, P32	4	0		
<b>S36(n,<math>\gamma</math>)S37</b>	S37, Cl36, Cl38, Ar39	5	2	•	
<b>S36(n,d)P35</b>	P32, S35	4	0		
<b>S36(n,<math>\alpha</math>)Si33</b>	P32, P33	4	0		
<b>Cl35(n,2n)Cl34m</b>	Si32, P32, P33, Cl34m	5	5 <sub>2</sub> *	•	•
<b>Cl35(n,n<math>\alpha</math>)P31</b>	H3, Na22, Na24, Al26	5	0		
<b>Cl35(n,n2<math>\alpha</math>)Al27</b>	Na22, Na24, Al26	5	0		
<b>Cl35(n,2n2<math>\alpha</math>)Al26</b>	Na22, Na24, Al26	5	0		
<b>Cl35(n,<math>\gamma</math>)Cl36</b>	H3, P33, S37, Cl36, Cl38, Ar39, Ar41, K42	5	4	•	
<b>Cl35(n,p)S35</b>	Si32, S35, S37	5	4	•	
<b>Cl35(n,d)S34</b>	H3, Na22, Na24, Al26, Si32, P32, P33	4	0		
<b>Cl35(n,t)S33</b>	H3, Na22, Na24, Al26, Si32, P32, P33	4	5 <sub>3</sub>		•
<b>Cl35(n,h)P33</b>	H3, Na22, Na24, Al26, Si32, P32, P33	5	0		
<b>Cl35(n,<math>\alpha</math>)P32</b>	H3, Na22, Na24, Al26, Si32, P32	5	4	•	
<b>Cl35(n,t<math>\alpha</math>)Si29</b>	H3, Na22, Na24, Al26	4	0		
<b>Cl35(n,ph)Si32</b>	Si32	4	0		

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
Cl36(n,n $\alpha$ )P32	Na22, Al26, Si32, P32	4	0		
Cl36(n, $\gamma$ )Cl37	Cl38, Ar39, Ar41, K42	5	2	•	
Cl36(n,p)S36	Si32, P33, S35, S37	5	2	•	
Cl36(n, $\alpha$ )P33	Na22, Al26, Si32, P32, P33, S35	5	0		
Cl37(n,2n)Cl36	H3, Al26, Si32, P32, P33, S35, Cl34m, Cl36	5	0		
Cl37(n,n $\alpha$ )P33	H3, Na24, Al26, Si32, P32, P33	5	0		
Cl37(n,2n $\alpha$ )P32	Na22, Na24, Al26, P32	4	0		
Cl37(n, $\gamma$ )Cl38	S37, Cl38, Ar39, Ar41, K40, K42	5	4	•	
Cl37(n, $\gamma$ )Cl38m	S37, Cl38, Ar39, Ar41, K40, K42	5	2	•	
Cl37(n,p)S37	S37	5	6*	•	•
Cl37(n,d)S36	H3, Si32, P33, S35	4	0		
Cl37(n,t)S35	H3, Na22, Al26, Si32, P32, P33, S35, Cl34m	5	0		
Cl37(n,d $\alpha$ )Si32	Si32	5	0		
Ar36(n,n $\alpha$ )S32	Na22, Al26, P32	4	0		
Ar36(n,n2 $\alpha$ )Si28	Na22, Al26	4	0		
Ar36(n, $\gamma$ )Ar37	H3, P32, P33, S35, S37, Cl36, Cl38, Ar37, Ar39	5	2	•	
Ar36(n,p)Cl36	H3, Al26, P32, P33, S35, S37, Cl36	5	2	•	
Ar36(n,d)Cl35	H3, Na22, Al26, P32, P33, S35	4	0		
Ar36(n,2 $\alpha$ )Si29	Na22, Al26	4	0		
Ar36(n,p $\alpha$ )P32	Na22, Al26, P32	5	0		
Ar36(n,d $\alpha$ )P31	Na22, Al26	4	0		
Ar37(n, $\alpha$ )S34	Al26, P32, P33, S35, S37, Cl36	5	2	•	
Ar37(n,2 $\alpha$ )Si30	Al26	4	0		
Ar38(n,2n)Ar37	Al26, P32, P33, S35, S37, Cl36, Ar37	5	0		
Ar38(n,n $\alpha$ )S34	Na22, Al26, P32, P33	4	0		
Ar38(n, $\gamma$ )Ar39	S37, Ar39, Ar41, K40, K42	5	2	•	
Ar38(n,p)Cl38m	Cl38	4	0		
Ar38(n,p)Cl38	Cl38	4	0		
Ar38(n,t)Cl36	Al26, P32, P33, S35, Cl36	5	0		
Ar38(n, $\alpha$ )S35	Na22, Al26, P32, S35	4	0		
Ar38(n,2p)S37	S37	4	0		
Ar38(n,d $\alpha$ )P33	Al26, P32, P33	4	0		
Ar38(n,t $\alpha$ )P32	Na22, Al26, P32	4	0		
Ar39(n,2n)Ar38	Na22, Al26, P32, P33, S35, S37, Cl36, Cl38, Ar37	5	0		
Ar39(n,3n)Ar37	P32, P33, S37, Cl36, Ar37	4	0		
Ar39(n,n $\alpha$ )S35	Na22, Al26, P32, P33, S35	5	0		
Ar39(n, $\gamma$ )Ar40	Ar41, K42	5	2	•	
Ar39(n,p)Cl39	Cl39	5	0		
Ar39(n,d)Cl38	P33, Cl36, Cl38, Ar37	4	0		
Ar39(n,d)Cl38m	Cl36, Cl38, Ar37	4	0		
Ar39(n, $\alpha$ )S36	P32, P33, S35, S37	5	0		
Ar40(n,2n)Ar39	H3, Na22, Al26, P32, P33, S35, S37, Cl36, Cl38, Cl39, Ar37, Ar39	5	0		
Ar40(n,3n)Ar38	H3, Na22, Al26, P32, P33, S35, S37, Cl36, Cl38, Ar37	5	0		
Ar40(n,n $\alpha$ )S36	H3, Na22, Al26, P32, P33, S35	4	0		
Ar40(n,2n $\alpha$ )S35	H3, Na22, Al26, P32, P33, S35	5	0		
Ar40(n,3n $\alpha$ )S34	H3, Na22, Al26, P32, P33	4	0		
Ar40(n,4n)Ar37	H3, Na22, Al26, P32, P33, S35, S37, Cl36, Ar37	5	0		
Ar40(n, $\gamma$ )Ar41	Ar41, Ar42, K42, Sc46	5	4	•	
Ar40(n,p)Cl40	Cl40	5	2	•	
Ar40(n,d)Cl39	H3, Al26, P32, P33, S35, S37, Cl36, Cl38, Cl39, Ar37, Ar39	5	0		
Ar40(n,t)Cl38	H3, Al26, P32, P33, S35, S37, Cl36, Cl38, Ar37	5	0		
Ar40(n,t)Cl38m	Al26, P32, P33, S35, S37, Cl36, Cl38, Ar37	4	0		
Ar40(n, $\alpha$ )S37	H3, P32, P33, S35, S37, Cl36	5	4	•	
Ar40(n,2nt)Cl36	H3, Na22, Al26, P32, P33, S35, Cl36	5	0		
Ar40(n,nt $\alpha$ )P33	Na22, Al26, P32, P33	4	0		
Ar41(n, $\gamma$ )Ar42	Ar42	5	2	•	
K39(n,2n)K38	H3, Na22, Al26, P32, P33, S35, S37, Cl36, Cl38,	5	5/4	•	•

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>K39</b> (n,n $\alpha$ ) <b>Cl35</b>	Ar37, K38				
	H3, Na22, Al26, P32, P33, S35	4	4	•	
<b>K39</b> (n,n2 $\alpha$ ) <b>P31</b>	Na22, Al26	5	0		
<b>K39</b> (n, $\gamma$ ) <b>K40</b>	H3, Cl38, Ar39, Ar41, Ar42, K40, K42, Ca45, Sc46	5	4	•	
<b>K39</b> (n,p)Ar39	H3, Na22, Al26, P32, P33, S35, S37, Cl36, Cl38, Cl39, Ar37, Ar39	5	2	•	
<b>K39</b> (n,d)Ar38	H3, Na22, Al26, P32, P33, S35, S37, Cl36, Cl38, Ar37	5	0		
<b>K39</b> (n,t)Ar37	H3, Na22, Al26, P32, P33, S35, S37, Cl36, Ar37	5	2	•	
<b>K39</b> (n, $\alpha$ )Cl36	H3, Na22, Al26, P32, P33, S35, Cl36, Cl38, Ar37, Ar39	5	4	•	
<b>K39</b> (n,2 $\alpha$ )P32	Na22, Al26, P32	5	5 <sub>1</sub>	•	•
<b>K39</b> (n,2p)Cl38m	Cl36, Cl38, Ar37	4	0		
<b>K39</b> (n,2p)Cl38	P33, Cl36, Cl38, Ar37	5	0		
<b>K39</b> (n,p $\alpha$ )S35	H3, Na22, Al26, P32, P33, S35	5	0		
<b>K39</b> (n,d $\alpha$ ) <b>S34</b>	H3, Na22, Al26, P32, P33	4	0		
<b>K40</b> (n,n $\alpha$ )Cl36	H3, P32, P33, Cl36	4	0		
<b>K40</b> (n, $\gamma$ ) <b>K41</b>	K42, Ca45, Sc46	4	2	•	
<b>K40</b> (n,p)Ar40	S37, Cl39, Ar41, Ar42	5	2	•	
<b>K40</b> (n, $\alpha$ )Cl37	P32, S37, Cl36, Cl38, Ar39	5	2	•	
<b>K41</b> (n,2n)K40	H3, P33, S35, Cl36, Cl38, Cl39, Ar39, K38, K40	5	0		
<b>K41</b> (n,n $\alpha$ )Cl37	P32, P33, S35, Cl36	4	0		
<b>K41</b> (n,2n $\alpha$ )Cl36	Al26, P32, P33, S35, Cl36	5	0		
<b>K41</b> (n, $\gamma$ )K42	Ar42, K42, K43, Ca45, Sc46	5	6*	•	•
<b>K41</b> (n,p)Ar41	Ar41, Ar42	5	6*	•	•
<b>K41</b> (n,d)Ar40	S35, Cl38, Cl39, Ar39	4	0		
<b>K41</b> (n,t)Ar39	H3, P33, S35, Cl38, Cl39, Ar37, Ar39	4	0		
<b>K41</b> (n,h)Cl39	Cl39, Ar39	5	5 <sub>1</sub>	•	•
K42(n, $\gamma$ )K43	K43, Ca45, Sc46	5	0		
K42(n,p)Ar42	Ar42	5	0		
<b>Ca40</b> (n,2n)Ca39	H3, Al26, P32, S37, Cl36, Cl38, Ar37, Ar39, K38, Ca39	5	4	•	
<b>Ca40</b> (n,n3 $\alpha$ ) <b>Si28</b>	Al26	4	0		
<b>Ca40</b> (n,n2 $\alpha$ ) <b>S32</b>	Al26, P32	4	0		
<b>Ca40</b> (n, $\gamma$ )Ca41	H3, S37, Ar39, K40, K42, K43, Ca41	5	4	•	
<b>Ca40</b> (n,p)K40	H3, P32, S37, Cl36, Cl38, Ar37, Ar39, K38, K40	5	2	•	
<b>Ca40</b> (n,d) <b>K39</b>	H3, Al26, P32, S37, Cl36, Cl38, Ar37, Ar39, K38	5	0		
<b>Ca40</b> (n,t)K38	H3, Al26, P32, S37, Cl36, Cl38, Ar37, K38	5	5 <sub>1</sub>	•	•
<b>Ca40</b> (n,h)Ar38	H3, Al26, P32, S37, Cl36, Cl38, Ar37	4	5 <sub>3</sub>		•
<b>Ca40</b> (n, $\alpha$ )Ar37	H3, Al26, P32, S37, Cl36, Cl38, Ar37, Ar39, K40	5	4	•	
<b>Ca40</b> (n,2 $\alpha$ ) <b>S33</b>	H3, Al26, P32	4	0		
<b>Ca40</b> (n,2p)Ar39	H3, Al26, P32, S37, Cl36, Cl38, Ar37, Ar39	5	0		
<b>Ca40</b> (n,p $\alpha$ )Cl36	H3, Al26, P32, Cl36	5	0		
<b>Ca40</b> (n,3p)Cl38	Cl38	4	0		
<b>Ca40</b> (n,3p)Cl38m	Cl38	4	0		
Ca41(n,p) <b>K41</b>	K40, K42, K43	5	2	•	
Ca41(n, $\alpha$ )Ar38	S37, Cl36, Ar39, K40	5	2	•	
Ca41(n,d $\alpha$ )Cl36	Cl36	4	0		
<b>Ca42</b> (n,2n)Ca41	H3, Cl36, Ar39, K40, Ca41	5	0		
<b>Ca42</b> (n, $\gamma$ ) <b>Ca43</b>	Ca45, Sc46	5	4	•	
<b>Ca42</b> (n,p)K42	K42	5	5 <sub>3</sub> *		•
<b>Ca42</b> (n,t)K40	Cl36, Ar39, K40	4	0		
<b>Ca42</b> (n, $\alpha$ )Ar39	Cl36, Cl38, Ar39	5	0		
<b>Ca43</b> (n,2n)Ca42	Cl36, Ar39, K40, K42, Ca41	4	0		
<b>Ca43</b> (n,3n)Ca41	Cl36, Ar39, K40, Ca41	5	0		
<b>Ca43</b> (n,n $\alpha$ )Ar39	Cl36, Ar39	5	0		
<b>Ca43</b> (n, $\gamma$ ) <b>Ca44</b>	Ca45, Ca47, Sc46	5	2	•	
<b>Ca43</b> (n,p)K43	K43	5	2	•	



Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Ca43</b> (n,d)K42	Cl36, Ar39, K40, K42, Ca41	4	0		
<b>Ca44</b> (n,2n) <b>Ca43</b>	H3, Cl36, Ar39, Ar42, K40, K42, K43, Ca41	5	0		
<b>Ca44</b> (n,4n)Ca41	Cl36, Ca41	5	0		
<b>Ca44</b> (n, $\gamma$ )Ca45	H3, Ca45, Ca47, Ca48, Sc46, Sc47, Sc48	5	2	•	
<b>Ca44</b> (n,d)K43	Cl36, Ar39, Ar42, K40, K42, K43, Ca41	5	0		
<b>Ca44</b> (n,t)K42	Cl36, K40, K42, Ca41	5	5 <sub>0</sub>		•
<b>Ca44</b> (n,h)Ar42	Ar42, K42	4	0		
<b>Ca44</b> (n, $\alpha$ )Ar41	Cl36, Cl38, Ar39, K40	5	4	•	
Ca45(n, $\gamma$ ) <b>Ca46</b>	Ca47, Ca48, Sc47, Sc48	5	2	•	
Ca45(n, $\alpha$ )Ar42	Ar39, Ar42, K40, K42, Ca41	5	0		
<b>Ca46</b> (n,2n)Ca45	Ar39, Ar42, K42, Ca41, Ca45, Sc44	5	0		
<b>Ca46</b> (n, $n\alpha$ )Ar42	Ar42	4	0		
<b>Ca46</b> (n, $\gamma$ )Ca47	Ca47, Ca48, Sc47, Sc48	5	2	•	
Ca47(n, $\gamma$ )Ca48	Ca48	5	0		
<b>Ca48</b> (n,2n)Ca47	Ca45, Ca47, Sc46	5	6	•	•
<b>Ca48</b> (n,3n) <b>Ca46</b>	K43, Ca45	5	0		
<b>Ca48</b> (n,4n)Ca45	Ca45	5	0		
<b>Ca48</b> (n, $\gamma$ )Ca49	Ca49	5	4	•	
<b>Ca48</b> (n,d)K47	Ca47, Sc46	4	0		
<b>Sc45</b> (n,n')Sc45m	Sc45m	5	0		
<b>Sc45</b> (n,2n)Sc44	H3, Cl36, Ar39, Ar42, K40, K42, Ca41, Sc44	5	5 <sub>2</sub>	•	•
<b>Sc45</b> (n,2n)Sc44m	Cl36, Ar39, Ar42, K40, K42, Ca41, Sc44, Sc44m	5	6*	•	•
<b>Sc45</b> (n, $n\alpha$ ) <b>K41</b>	H3, Cl36, Ar39, K40	5	0		
<b>Sc45</b> (n,2n $\alpha$ )K40	H3, Cl36, Ar39, K40	5	0		
<b>Sc45</b> (n,2n2 $\alpha$ )Cl36	Cl36	5	0		
<b>Sc45</b> (n, $\gamma$ )Sc46	H3, Ca48, Sc46, Sc47, Sc48	5	3	•	
<b>Sc45</b> (n, $\gamma$ )Sc46m	H3, Ca48, Sc46, Sc47, Sc48	4	3	•	
<b>Sc45</b> (n,p)Ca45	Ar42, Ca45, Ca48, Sc45m	5	4	•	
<b>Sc45</b> (n,d) <b>Ca44</b>	H3, Cl36, Ar39, Ar42, K40, K42, Ca41	4	0		
<b>Sc45</b> (n,t) <b>Ca43</b>	H3, Cl36, Ar39, Ar42, K40, K42, Ca41	5	0		
<b>Sc45</b> (n, $\alpha$ )K42	H3, Cl36, Ar39, Ar42, K40, K42, Ca41	5	6*	•	•
<b>Sc45</b> (n,2nt)Ca41	Cl36, Ar39, K40, Ca41	5	0		
<b>Sc45</b> (n,t $\alpha$ )Ar39	H3, Cl36, Ar39	5	0		
<b>Sc45</b> (n,ph)Ar42	Ar42	5	0		
Sc46(n, $\gamma$ )Sc47	Ca48, Sc47, Sc48	5	2	•	
Sc46(n,p) <b>Ca46</b>	Ar42, Ca48	5	0		
Sc47(n, $\gamma$ )Sc48	Sc48	4	0		
Sc48(n,p)Ca48	Ca48	5	0		
<b>Ti46</b> (n, $n\alpha$ ) <b>Ca42</b>	Cl36, Ar39, K40, K42, Ca41	5	0		
<b>Ti46</b> (n,2n $\alpha$ )Ca41	Cl36, Ar39, K40, Ca41	5	0		
<b>Ti46</b> (n,p)Sc46	H3, Ar42, K42, Sc44, Sc46	5	6	•	•
<b>Ti46</b> (n,d) <b>Sc45</b>	H3, Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45, Sc44	4	0		
<b>Ti46</b> (n,t)Sc44	Cl36, Ar39, Ar42, K40, K42, Ca41, Sc44	4	5/5	•	•
<b>Ti46</b> (n, $\alpha$ ) <b>Ca43</b>	H3, Cl36, Ar39, Ar42, K40, K42, Ca41	5	0		
<b>Ti46</b> (n,2 $\alpha$ )Ar39	Cl36, Ar39	5	0		
<b>Ti46</b> (n,p $\alpha$ )K42	Cl36, Ar39, K40, K42, Ca41	4	0		
<b>Ti46</b> (n,t $\alpha$ )K40	Cl36, Ar39, K40	5	0		
<b>Ti47</b> (n,2n) <b>Ti46</b>	H3, Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45, Sc44, Sc46	4	0		
<b>Ti47</b> (n, $n\alpha$ ) <b>Ca43</b>	Cl36, Ar39, Ar42, K40, K42, Ca41	5	0		
<b>Ti47</b> (n,3n $\alpha$ )Ca41	Cl36, Ar39, K40, Ca41	4	0		
<b>Ti47</b> (n,p)Sc47	Sc47	4	6	•	•
<b>Ti47</b> (n,d)Sc46	H3, Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45, Sc44, Sc46	5	0		
<b>Ti47</b> (n, $\alpha$ ) <b>Ca44</b>	H3, Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45, Ca48, Sc46, Sc47, Sc48	5	0		
<b>Ti48</b> (n,2n) <b>Ti47</b>	H3, Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45, Sc44, Sc46, Sc47	4	4	•	
<b>Ti48</b> (n,2n2 $\alpha$ )Ar39	Cl36, Ar39	4	0		

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Ti48(n,<math>\gamma</math>)Ti49</b>	Ti51, V52, Mn56	4	4	•	
<b>Ti48(n,p)Sc48</b>	H3, Ca48, Sc48	5	6	•	•
<b>Ti48(n,d)Sc47</b>	H3, Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45, Sc44, Sc46, Sc47	5	5 <sub>0</sub> *	•	•
<b>Ti48(n,t)Sc46</b>	H3, Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45, Sc44, Sc46	5	5/5	•	•
<b>Ti48(n,<math>\alpha</math>)Ca45</b>	H3, Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45, Sc44	5	4	•	
<b>Ti48(n,<math>\alpha</math>)K42</b>	Cl36, Ar39, K40, K42, Ca41	4	0		
<b>Ti49(n,2n)Ti48</b>	H3, Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45, Ca48, Sc44, Sc46, Sc47, Sc48	4	0		
<b>Ti49(n,<math>\alpha</math>)Ca45</b>	Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45, Sc44	5	0		
<b>Ti49(n,<math>\gamma</math>)Ti50</b>	Ti51, V52, Mn56	4	4	•	
<b>Ti49(n,d)Sc48</b>	Ar39, Ar42, K42, Ca45, Ca48, Sc44, Sc46, Sc47, Sc48	4	0		
<b>Ti49(n,h)Ca47</b>	Ca47, Sc47	4	0		
<b>Ti49(n,2<math>\alpha</math>)Ar42</b>	Ar42	4	0		
<b>Ti49(n,2p)Ca48</b>	Ca48	4	0		
<b>Ti50(n,<math>\alpha</math>)Ca46</b>	Cl36, Ar39, Ar42, K42, Ca45, Sc44	4	0		
<b>Ti50(n,n2<math>\alpha</math>)Ar42</b>	Ar42	4	0		
<b>Ti50(n,<math>\gamma</math>)Ti51</b>	Ti51, V52, Mn56	5	4	•	
<b>Ti50(n,t)Sc48</b>	Sc48	4	0		
<b>Ti50(n,h)Ca48</b>	Ar42, Ca48	5	0		
<b>Ti50(n,<math>\alpha</math>)Ca47</b>	Ar39, Ca41, Ca47, Sc46, Sc47	5	5 <sub>2</sub>	•	•
<b>V49(n,2n)V48</b>	Ar39, Ar42, K42, Ca45, Sc44, Sc46, Sc47, V48	5	0		
<b>V49(n,<math>\alpha</math>)Sc46</b>	Ar39, Ar42, K40, K42, Ca41, Sc44, Sc46	5	0		
<b>V49(n,<math>\alpha</math>)Sc46m</b>	Ar39, K42, Ca41, Sc44, Sc46	4	0		
<b>V50(n,2n)V49</b>	H3, Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45, Ca47, Ca48, Sc44, Sc46, Sc47, Sc48, V48, V49	5	1	•	
<b>V50(n,3n)V48</b>	Cl36, Ar39, Ar42, K42, Ca41, Ca45, Ca47, Sc44, Sc46, Sc47, Sc48, V48	5	0		
<b>V50(n,<math>\alpha</math>)Sc46</b>	Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45, Ar42, Ca45, Ca47, Ca48, Sc47, Ti51	5	0		
<b>V50(n,p)Ti50</b>	Ar42, Ca45, Ca47, Ca48, Sc47, Ti51	5	2	•	
<b>V50(n,<math>\alpha</math>)Sc47</b>	Cl36, Ar39, K40, K42, Ca41, Sc44, Sc46, Sc47	5	2	•	
<b>V50(n,d<math>\alpha</math>)Ca45</b>	Cl36, Ar39, Ar42, K40, K42, Ca45, Sc44	4	0		
<b>V51(n,2n)V50</b>	H3, Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45, Ca47, Ca48, Sc44, Sc46, Sc47, Sc48, V48, V49, V50	5	4	•	
<b>V51(n,3n)V49</b>	H3, Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45, Ca47, Ca48, Sc44, Sc46, Sc47, Sc48, V48, V49	5	0		
<b>V51(n,<math>\alpha</math>)Sc47</b>	H3, Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45, Sc44, Sc46, Sc47	5	6	•	•
<b>V51(n,2n<math>\alpha</math>)Sc46</b>	Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45, Sc44, Sc46	5	5 <sub>3</sub>		•
<b>V51(n,3n<math>\alpha</math>)Sc45</b>	Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45, Sc44	4	0		
<b>V51(n,4n)V48</b>	H3, Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45, Sc44, Sc46, Sc47, Sc48, V48	5	5 <sub>3</sub>		•
<b>V51(n,<math>\gamma</math>)V52</b>	V52, Mn56, Fe59, Fe60	5	6	•	•
<b>V51(n,p)Ti51</b>	Ti51	5	6	•	•
<b>V51(n,d)Ti50</b>	H3, Ar39, Ar42, K40, K42, Ca41, Ca45, Ca47, Ca48, Sc44, Sc46, Sc47, Sc48	4	2	•	
<b>V51(n,t)Ti49</b>	H3, Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45, Ca47, Ca48, Sc44, Sc46, Sc47, Sc48	4	6	•	•
<b>V51(n,<math>\alpha</math>)Sc48</b>	Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45, Ca48, Sc44, Sc46, Sc47, Sc48	5	6	•	•
<b>V51(n,d<math>\alpha</math>)Ca46</b>	Cl36, Ar39, Ar42, K42, Ca45	4	0		
<b>V51(n,t<math>\alpha</math>)Ca45</b>	Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45, Sc44	5	0		
<b>Cr50(n,<math>\alpha</math>)Ti46</b>	Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45, Sc44, Sc46	5	0		
<b>Cr50(n,<math>\gamma</math>)Cr51</b>	H3, V52, Cr51	5	4	•	
<b>Cr50(n,p)V50</b>	H3, Ar42, Ca45, Sc46, Sc47, V48, V49, V50	4	4	•	
<b>Cr50(n,d)V49</b>	H3, Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45,	5	2	•	

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Cr50(n,t)V48</b>	Sc44, Sc46, Sc47, V48, V49 Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45, Sc44, Sc46, Sc47, V48	4	5 <sub>2</sub>	•	•
<b>Cr50(n,α)Ti47</b>	Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45, Sc44, Sc46, Sc47	5	2	•	
<b>Cr50(n,pα)Sc46</b>	Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45, Sc44, Sc46	4	5 <sub>3</sub>		•
<b>Cr52(n,2n)Cr51</b>	H3, Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45, Ca47, Ca48, Sc44, Sc46, Sc47, Sc48, V48, V49, V50, Cr50, Cr51	5	6	•	•
<b>Cr52(n,3n)Cr50</b>	H3, Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45, Sc44, Sc46, Sc47, V48, V49, V50, Cr50	4	0		
<b>Cr52(n,nα)Ti48</b>	H3, Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45, Ca47, Sc44, Sc46, Sc47	4	1	•	
<b>Cr52(n,3nα)Ti46</b>	Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45, Sc44, Sc46	4	0		
<b>Cr52(n,nt)V49</b>	H3, Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45, Ca47, Ca48, Sc44, Sc46, Sc47, Sc48, V48, V49	5	0		
<b>Cr52(n,γ)Cr53</b>	Cr55, Mn56, Fe59, Fe60, Co60	5	4	•	
<b>Cr52(n,p)V52</b>	V52	5	6	•	•
<b>Cr52(n,d)V51</b>	H3, Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45, Ca47, Ca48, Sc44, Sc46, Sc47, Sc48, V48, V49, V50	4	2	•	
<b>Cr52(n,t)V50</b>	H3, Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45, Sc44, Sc46, Sc47, Sc48, V48, V49, V50	5	5 <sub>3</sub>		•
<b>Cr52(n,α)Ti49</b>	H3, Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45, Ca47, Ca48, Sc44, Sc46, Sc47, Sc48	4	2	•	
<b>Cr52(n,2α)Ca45</b>	Cl36, Ar39, Ar42, K40, K42, Ca45, Sc44	4	0		
<b>Cr52(n,dα)Sc47</b>	Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45, Sc44, Sc46, Sc47	4	5 <sub>3</sub>		•
<b>Cr52(n,tα)Sc46</b>	Cl36, Ar39, Ar42, K40, K42, Ca41, Ca45, Sc44, Sc46	4	0		
<b>Cr53(n,γ)Cr54</b>	Cr55, Mn56, Fe59, Fe60, Co60	5	4	•	
<b>Cr53(n,d)V52</b>	V52, Cr51	4	0		
<b>Cr53(n,α)Ti50</b>	Ar39, Ar42, Ca45, Ca47, Ca48, Sc44, Sc46, Sc47, Sc48	5	2	•	
<b>Cr54(n,2n)Cr53</b>	H3, Ar42, Ca45, Ca47, Ca48, Sc46, Sc48, V52, Cr51	5	0		
<b>Cr54(n,nα)Ti50</b>	Ar39, Ar42, K42, Ca45, Ca47, Ca48, Sc44, Sc46, Sc48	4	0		
<b>Cr54(n,γ)Cr55</b>	Cr55, Mn53, Mn56, Fe59, Fe60, Co60	5	4	•	
<b>Cr54(n,t)V52</b>	Ar39, V52	4	0		
<b>Mn53(n,nα)V49</b>	Cl36, Ar39, Ar42, K42, Ca45, Ca47, Ca48, Sc44, Sc46, Sc48	4	0		
<b>Mn54(n,2n)Mn53</b>	Cl36, Ar39, Ar42, K42, Ca45, Ca47, Ca48, Sc44, Sc46, Sc48, Mn53	5	0		
<b>Mn54(n,α)V51</b>	Ar39, Ar42, K42, Ca45, Ca47, Ca48, Sc44, Sc46, Sc48	4	0		
<b>Mn55(n,2n)Mn54</b>	H3, Cl36, Ar39, Ar42, K42, Ca45, Ca47, Ca48, Sc44, Sc46, Sc48, V52, Mn53, Mn54	5	6	•	•
<b>Mn55(n,3n)Mn53</b>	H3, Cl36, Ar39, Ar42, K42, Ca45, Ca47, Ca48, Sc44, Sc46, Sc48, V52, Mn53	5	0		
<b>Mn55(n,nα)V51</b>	Cl36, Ar39, Ar42, K42, Ca45, Ca47, Ca48, Sc44, Sc46, Sc48	4	0		
<b>Mn55(n,2nα)V50</b>	H3, Cl36, Ar39, Ar42, K42, Ca45, Ca47, Ca48, Sc44, Sc46, Sc48	4	0		
<b>Mn55(n,3nα)V49</b>	Cl36, Ar39, Ar42, K42, Ca45, Ca47, Ca48, Sc44, Sc46, Sc48	4	0		
<b>Mn55(n,γ)Mn56</b>	Cr55, Mn56, Fe59, Fe60, Co60, Ni63	5	6	•	•
<b>Mn55(n,p)Cr55</b>	Cr55	5	6	•	•
<b>Mn55(n,t)Cr53</b>	H3, Cl36, Ar39, Ar42, K42, Ca45, Ca47, Ca48, Sc44, Sc46, Sc48, V52	4	6	•	•
<b>Mn55(n,α)V52</b>	Cl36, Ar39, Ar42, K42, Ca45, Ca47, Ca48, Sc44,	5	6	•	•

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Mn55</b> (n,2 $\alpha$ )Sc48	Sc46, Sc48, V52 Cl36, Ar39, Ar42, K42, Ca45, Ca47, Sc44, Sc46, Sc48	4	5 <sub>3</sub>		•
<b>Mn55</b> (n,d $\alpha$ )Ti50	Cl36, Ar39, Ar42, K42, Ca45, Ca47, Ca48, Sc44, Sc46, Sc48	5	0		
<b>Fe54</b> (n,n $\alpha$ )Cr50	Ar39, Ar42, Sc44	5	1	•	
<b>Fe54</b> (n, $\gamma$ )Fe55	H3, Mn56, Fe55	5	4	•	
<b>Fe54</b> (n,p)Mn54	H3, Ar42, Sc44, Mn53, Mn54	4	6	•	•
<b>Fe54</b> (n,d)Mn53	H3, Ar39, Ar42, Sc44, Mn53	5	2	•	
<b>Fe54</b> (n,d $\alpha$ )V49	Ar39, Ar42, Sc44	4	0		
<b>Fe56</b> (n,2n)Fe55	H3, Ar39, Ar42, Sc44, Mn53, Mn54, Fe55	5	4	•	
<b>Fe56</b> (n,nt)Mn53	H3, Ar39, Ar42, Sc44, Mn53	5	0		
<b>Fe56</b> (n, $\gamma$ )Fe57	Cr55, Mn56, Fe59, Fe60, Co60, Ni63	5	4	•	
<b>Fe56</b> (n,p)Mn56	Mn56	5	6	•	•
<b>Fe56</b> (n,t)Mn54	H3, Ar39, Ar42, Sc44, Mn53, Mn54	5	6	•	•
<b>Fe57</b> (n,3n)Fe55	Mn53, Mn54, Fe55	4	0		
<b>Fe57</b> (n, $\gamma$ )Fe58	Mn56, Fe59, Fe60, Co60, Ni63	5	4	•	
<b>Fe57</b> (n, $\alpha$ )Cr54	Cr55	5	2	•	
<b>Fe58</b> (n, $\gamma$ )Fe59	Mn56, Fe59, Fe60, Co60, Ni63	5	6	•	•
<b>Fe59</b> (n, $\gamma$ )Fe60	Fe60, Ni63	5	2	•	
Co57(n,2n)Co56	Mn53, Fe55, Co56	5	0		
Co57(n,n $\alpha$ )Mn53	Ar39, Sc44, Mn53	4	0		
Co58(n,2n)Co57	Mn53, Mn54, Fe55, Co56, Co57	5	0		
<b>Co59</b> (n,2n)Co58	H3, Ar39, Sc44, Mn53, Mn54, Fe55, Co57, Co58	4	5 <sub>2</sub>	•	•
<b>Co59</b> (n,2n)Co58m	H3, Ar39, Sc44, Mn53, Mn54, Fe55, Fe59, Co57, Co58	5	6*	•	•
<b>Co59</b> (n,3n)Co57	H3, Ar39, Sc44, Mn53, Mn54, Fe55, Co57	5	6	•	•
<b>Co59</b> (n,n $\alpha$ )Mn55	H3, Ar39, Sc44, Mn53, Mn54	5	0		
<b>Co59</b> (n,2n $\alpha$ )Mn54	H3, Ar39, Sc44, Mn53, Mn54	5	0		
<b>Co59</b> (n,3n $\alpha$ )Mn53	Ar39, Sc44, Mn53	5	0		
<b>Co59</b> (n, $\gamma$ )Co60	Fe59, Fe60, Co60, Co60m, Ni59, Ni63	5	6	•	•
<b>Co59</b> (n, $\gamma$ )Co60m	H3, Fe59, Fe60, Co60, Co60m, Ni59, Ni63	5	3*	•	
<b>Co59</b> (n,p)Fe59	Fe59, Fe60	5	6	•	•
<b>Co59</b> (n,t)Fe57	H3, Ar39, Sc44, Mn53, Mn54, Fe55	4	6	•	•
<b>Co59</b> (n, $\alpha$ )Mn56	Ar39, Sc44, Mn53, Mn54, Fe55	5	6	•	•
<b>Co59</b> (n,2nt)Fe55	Ar39, Sc44, Mn53, Mn54, Fe55	5	0		
Co60(n, $\gamma$ )Co61	Fe59, Fe60, Ni63	5	2	•	
Co60(n,p)Fe60	Fe60	5	0		
<b>Ni58</b> (n,n $\alpha$ )Fe54	H3, Ar39, Mn53	5	2	•	
<b>Ni58</b> (n, $\gamma$ )Ni59	H3, Fe60, Co60, Ni59, Ni63	5	2	•	
<b>Ni58</b> (n,p)Co58	H3, Fe60, Co56, Co57, Co58	5	6	•	•
<b>Ni58</b> (n,p)Co58m	H3, Fe60, Co56, Co57, Co58	5	4	•	
<b>Ni58</b> (n,d)Co57	H3, Ar39, Mn53, Fe55, Co56, Co57	5	6	•	•
<b>Ni58</b> (n,t)Co56	H3, Ar39, Mn53, Fe55, Co56	5	6	•	•
<b>Ni58</b> (n, $\alpha$ )Fe55	H3, Ar39, Mn53, Fe55	5	4	•	
<b>Ni58</b> (n,d $\alpha$ )Mn53	H3, Ar39, Mn53	5	0		
Ni59(n,p)Co59	Co60	5	4	•	
Ni59(n, $\alpha$ )Fe56	Fe60	5	4	•	
<b>Ni60</b> (n,2n)Ni59	H3, Mn53, Fe55, Co57, Co58, Ni59	5	2	•	
<b>Ni60</b> (n,2n $\alpha$ )Fe55	Mn53, Fe55	4	0		
<b>Ni60</b> (n,nt)Co57	Mn53, Fe55, Co57	4	0		
<b>Ni60</b> (n,p)Co60	H3, Fe60, Co58, Co60	4	6	•	•
<b>Ni60</b> (n,p)Co60m	H3, Fe60, Co58, Co60, Co60m	5	6	•	•
<b>Ni60</b> (n,t)Co58	H3, Mn53, Fe55, Co58	4	6	•	•
<b>Ni60</b> (n,t)Co58m	Fe55, Co58	4	0		
<b>Ni61</b> (n,2n)Ni60	Co58, Co60, Ni59	4	0		
<b>Ni61</b> (n,3n)Ni59	Mn53, Co58, Ni59	5	0		
<b>Ni61</b> (n, $\gamma$ )Ni62	Ni63, Ni65, Cu64	5	2	•	
<b>Ni61</b> (n, $\alpha$ )Fe58	Fe59, Fe60, Co60	5	2	•	
<b>Ni62</b> (n,2n)Ni61	H3, Fe60, Co60, Ni59	4	0		

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Ni62</b> (n, $\gamma$ )Ni63	Ni63, Ni65, Cu64	5	4	•	
<b>Ni62</b> (n,t)Co60	Mn53, Fe59, Fe60, Co60	4	0		
<b>Ni62</b> (n,h)Fe60	Fe60	4	0		
<b>Ni62</b> (n, $\alpha$ )Fe59	Fe59, Co58	5	6*	•	•
Ni63(n, $n\alpha$ )Fe59	Mn53, Fe59	4	0		
Ni63(n, $\gamma$ ) <b>Ni64</b>	Ni65	4	2	•	
Ni63(n, $\alpha$ )Fe60	Fe59, Fe60	5	0		
<b>Ni64</b> (n,2n)Ni63	H3, Fe59, Fe60, Co60, Ni59, Ni63, Cu64	5	2	•	
<b>Ni64</b> (n, $n\alpha$ )Fe60	Fe59, Fe60	5	1	•	
<b>Ni64</b> (n,2n $\alpha$ )Fe59	Fe59	5	0		
<b>Ni64</b> (n, $\gamma$ )Ni65	Ni63, Ni65, Cu64, Cu66	5	4	•	
<b>Ni64</b> (n,d)Co63	Fe59, Ni63, Cu64	4	0		
<b>Cu63</b> (n,2n)Cu62	Fe59, Fe60, Co58, Co60, Ni59, Cu62	5	6	•	•
<b>Cu63</b> (n, $n\alpha$ ) <b>Co59</b>	Mn53, Fe59, Co58	5	2	•	
<b>Cu63</b> (n,2n $\alpha$ )Co58	Mn53, Co58	5	0		
<b>Cu63</b> (n,2n $\alpha$ )Co58m	Mn53, Co58	4	0		
<b>Cu63</b> (n, $\gamma$ )Cu64	Fe60, Co60, Ni63, Cu64, Cu66, Zn64, Zn65	5	5 <sub>2</sub>	•	•
<b>Cu63</b> (n,p)Ni63	Fe60, Ni59, Ni63	5	4	•	
<b>Cu63</b> (n,t) <b>Ni61</b>	Fe59, Fe60, Co58, Co60, Ni59	5	5 <sub>3</sub>		•
<b>Cu63</b> (n, $\alpha$ )Co60	Fe59, Fe60, Co58, Co60, Ni59	5	6	•	•
<b>Cu63</b> (n, $\alpha$ )Co60m	Fe59, Fe60, Co58, Co60, Ni59	4	4	•	
<b>Cu63</b> (n,2nt)Ni59	Mn53, Co58, Ni59	5	0		
<b>Cu65</b> (n,2n)Cu64	Fe59, Fe60, Co58, Co60, Ni59, Ni63, Cu62, Cu64, Zn64, Zn65	5	6	•	•
<b>Cu65</b> (n, $n\alpha$ )Co61	Fe59, Co58, Co60, Ni59	4	6	•	•
<b>Cu65</b> (n,2n $\alpha$ )Co60	Mn53, Fe59, Fe60, Co58, Co60, Ni59	4	0		
<b>Cu65</b> (n, $\gamma$ )Cu66	Ni63, Cu66, Zn65	5	6	•	•
<b>Cu65</b> (n,d) <b>Ni64</b>	Fe59, Fe60, Ni63	4	4	•	
<b>Cu65</b> (n,t)Ni63	Fe59, Fe60, Co60, Ni59, Ni63	5	0		
<b>Cu65</b> (n, $\alpha$ )Fe60	Fe60	4	0		
<b>Zn64</b> (n,2n)Zn63	H3, Fe60, Co60, Ni59, Ni63, Cu62	4	6	•	•
<b>Zn64</b> (n, $n\alpha$ ) <b>Ni60</b>	H3, Mn53, Fe59, Fe60, Co60, Ni59	5	2	•	
<b>Zn64</b> (n,2n $\alpha$ )Ni59	H3, Mn53, Ni59	5	0		
<b>Zn64</b> (n, $\gamma$ )Zn65	H3, Ni63, Cu64, Cu66, Zn65	5	4	•	
<b>Zn64</b> (n,p)Cu64	Fe60, Ni63, Cu64	5	6	•	•
<b>Zn64</b> (n,d) <b>Cu63</b>	H3, Fe59, Fe60, Co60, Ni59, Ni63, Cu62, Cu64	5	0		
<b>Zn64</b> (n,t)Cu62	H3, Fe59, Fe60, Co60, Ni59, Cu62	5	6	•	•
<b>Zn64</b> (n, $\alpha$ ) <b>Ni61</b>	H3, Fe60, Co60, Ni59	5	4	•	
<b>Zn64</b> (n,2p)Ni63	Fe60, Ni63	4	0		
<b>Zn64</b> (n,p $\alpha$ )Co60	Fe60, Co60, Ni59	4	0		
<b>Zn64</b> (n,p $\alpha$ )Co60m	Fe60, Co60, Ni59	4	0		
Zn65(n,2n)Zn64	Co60, Ni59, Zn64	4	0		
Zn65(n, $\alpha$ ) <b>Ni62</b>	Fe59, Co60, Ni59, Ni63, Cu64	5	0		
<b>Zn66</b> (n,2n)Zn65	H3, Fe59, Fe60, Co60, Ni59, Ni63, Cu62, Cu64, Zn64, Zn65	5	4	•	
<b>Zn66</b> (n, $n\alpha$ ) <b>Ni62</b>	Fe59, Fe60, Co60, Ni59	5	0		
<b>Zn66</b> (n,t)Cu64	H3, Fe59, Fe60, Co60, Ni59, Ni63, Cu62, Cu64, Zn64	5	0		
<b>Zn66</b> (n, $\alpha$ )Ni63	Fe59, Fe60, Co60, Ni59, Ni63, Cu64, Zn64, Zn65	5	2	•	
<b>Zn66</b> (n,t $\alpha$ )Co60	Fe59, Fe60, Co60	4	0		
<b>Zn67</b> (n,3n)Zn65	Fe59, Fe60, Co60, Ni59, Ni63, Cu64, Zn64, Zn65	5	0		
<b>Zn67</b> (n, $n\alpha$ )Ni63	Fe59, Fe60, Co60, Ni59, Ni63	4	0		
<b>Zn68</b> (n,2n) <b>Zn67</b>	H3, Fe59, Fe60, Co60, Ni63, Cu64, Zn64, Zn65	4	1	•	
<b>Zn68</b> (n,2n $\alpha$ )Ni63	Fe59, Fe60, Co60, Ni59, Ni63	4	0		
<b>Zn68</b> (n,4n)Zn65	Mn53, Fe59, Fe60, Co60, Ni59, Ni63, Cu64, Zn65	4	0		
<b>Zn68</b> (n, $\gamma$ )Zn69	Ni63, Zn69, Ga70	5	4	•	
<b>Zn68</b> (n, $\gamma$ )Zn69m	Ni63, Zn69, Zn69m, Ga70	5	5 <sub>2</sub>	•	•
<b>Zn70</b> (n,2n)Zn69	H3, Zn69, Zn69m, Ga68, Ga70	4	2	•	

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Zn70</b> (n,2n) <b>Zn69m</b>	Zn69, Zn69m, Ga68, Ga70	5	4	•	
<b>Zn70</b> (n,γ) <b>Zn71</b>	Zn71, Ga70	5	2	•	
<b>Zn70</b> (n,γ) <b>Zn71m</b>	Ga70	4	2	•	
<b>Zn70</b> (n,d) <b>Cu69</b>	Zn69, Ga70	4	0		
<b>Ga67</b> (n,2n) <b>Ga66</b>	Ga66	5	0		
<b>Ga69</b> (n,2n) <b>Ga68</b>	H3, Fe59, Fe60, Co60, Ni59, Ni63, Zn64, Zn65, Zn69m, Ga68	5	6	•	•
<b>Ga69</b> (n,3n) <b>Ga67</b>	H3, Fe59, Fe60, Co60, Ni59, Ni63, Zn64, Zn65, Ga66, Ga67	5	0		
<b>Ga69</b> (n,nα) <b>Cu65</b>	H3, Mn53, Fe59, Fe60, Co60, Ni59, Ni63, Zn64	5	0		
<b>Ga69</b> (n,2nα) <b>Cu64</b>	Mn53, Fe59, Fe60, Co60, Ni59, Ni63, Zn64	5	0		
<b>Ga69</b> (n,3nα) <b>Cu63</b>	Mn53, Fe59, Fe60, Co60, Ni59, Ni63	4	0		
<b>Ga69</b> (n,2n2α) <b>Co60</b>	Mn53, Fe59, Fe60, Co60, Ni59	4	0		
<b>Ga69</b> (n,4n) <b>Ga66</b>	Fe59, Fe60, Co60, Ni59, Ni63, Zn64, Zn65, Ga66	5	0		
<b>Ga69</b> (n,γ) <b>Ga70</b>	H3, Zn69, Zn69m, Zn71, Ga70, Ga72, Ge71	5	4	•	
<b>Ga69</b> (n,p) <b>Zn69</b>	Zn69	4	2	•	
<b>Ga69</b> (n,p) <b>Zn69m</b>	Zn69, Zn69m	5	2	•	
<b>Ga69</b> (n,t) <b>Zn67</b>	H3, Fe59, Fe60, Co60, Ni59, Ni63, Zn64, Zn65	4	5 <sub>3</sub>		•
<b>Ga69</b> (n,α) <b>Cu66</b>	Fe59, Fe60, Co60, Ni59, Ni63, Zn64, Zn65	5	4	•	
<b>Ga69</b> (n,2nt) <b>Zn65</b>	Mn53, Fe59, Fe60, Co60, Ni59, Ni63, Zn64, Zn65	5	0		
<b>Ga69</b> (n,tα) <b>Ni63</b>	Mn53, Fe59, Fe60, Co60, Ni59, Ni63	5	0		
<b>Ga71</b> (n,2n) <b>Ga70</b>	H3, Fe59, Fe60, Co60, Ni59, Ni63, Zn64, Zn65, Zn69, Zn69m, Ga66, Ga67, Ga68, Ga70, Ge68, Ge69, Ge71	5	6	•	•
<b>Ga71</b> (n,3n) <b>Ga69</b>	H3, Mn53, Fe59, Fe60, Co60, Ni59, Ni63, Zn64, Zn65, Zn69, Zn69m, Ga66, Ga67, Ga68	4	0		
<b>Ga71</b> (n,nα) <b>Cu67</b>	H3, Mn53, Fe59, Fe60, Co60, Ni59, Ni63, Zn64, Zn65	4	4	•	
<b>Ga71</b> (n,4n) <b>Ga68</b>	H3, Fe59, Fe60, Co60, Ni59, Ni63, Zn64, Zn65, Ga68	4	0		
<b>Ga71</b> (n,γ) <b>Ga72</b>	Zn69, Ga72, Ge71, Se79	5	4	•	
<b>Ga71</b> (n,p) <b>Zn71</b>	Zn71	5	2/2	•	
<b>Ga71</b> (n,t) <b>Zn69</b>	Fe60, Co60, Ni63, Zn64, Zn69, Ga66, Ga67, Ga68	4	0		
<b>Ga71</b> (n,t) <b>Zn69m</b>	Fe60, Co60, Ni59, Ni63, Zn64, Zn65, Zn69, Zn69m, Ga66, Ga67, Ga68	5	0		
<b>Ga71</b> (n,5n) <b>Ga67</b>	Fe59, Fe60, Ni59, Ni63, Zn64, Zn65, Ga67	4	0		
<b>Ge68</b> (n,d) <b>Ga67</b>	Ni63, Zn65, Ga66, Ga67	5	0		
<b>Ge68</b> (n,t) <b>Ga66</b>	Fe60, Ni59, Ga66	4	0		
<b>Ge69</b> (n,2n) <b>Ge68</b>	Ni59, Ga66, Ga67, Ge68	5	0		
<b>Ge70</b> (n,2n) <b>Ge69</b>	H3, Fe60, Co60, Ni59, Ni63, Zn65, Zn69m, Ga66, Ga67, Ga68, Ge68, Ge69	5	4	•	
<b>Ge70</b> (n,3n) <b>Ge68</b>	Mn53, Fe60, Co60, Ni59, Ni63, Zn64, Zn65, Ga66, Ga68, Ge68	5	0		
<b>Ge70</b> (n,nα) <b>Zn66</b>	H3, Mn53, Fe59, Fe60, Co60, Ni59, Ni63, Zn64, Zn65	5	0		
<b>Ge70</b> (n,2nα) <b>Zn65</b>	Mn53, Fe60, Co60, Ni59, Ni63, Zn65	5	0		
<b>Ge70</b> (n,3nα) <b>Zn64</b>	Mn53, Fe60, Co60, Ni59, Ni63, Zn64	4	0		
<b>Ge70</b> (n,γ) <b>Ge71</b>	H3, Ni63, Zn69, Zn69m, Ga70, Ga72, Ge71	5	4	•	
<b>Ge70</b> (n,p) <b>Ga70</b>	Ga70	4	4	•	
<b>Ge70</b> (n,d) <b>Ga69</b>	H3, Fe60, Co60, Ni59, Ni63, Zn65, Zn69m, Ga67, Ga68	4	0		
<b>Ge70</b> (n,t) <b>Ga68</b>	H3, Fe60, Co60, Ni59, Ni63, Zn65, Ga68	5	2	•	
<b>Ge70</b> (n,α) <b>Zn67</b>	H3, Fe60, Co60, Ni59, Ni63, Zn65, Zn69, Zn69m, Ga70	4	0		
<b>Ge70</b> (n,2α) <b>Ni63</b>	Mn53, Fe59, Fe60, Co60, Ni59, Ni63	4	0		
<b>Ge70</b> (n,tα) <b>Cu64</b>	Fe60, Co60, Ni59, Ni63	4	0		
<b>Ge71</b> (n,α) <b>Zn68</b>	Ni63, Zn69, Zn69m, Ga70	5	0		
<b>Ge72</b> (n,2n) <b>Ge71</b>	H3, Fe60, Co60, Ni63, Zn65, Ga68, Ga70, Ga72, Ge68, Ge69, Ge71	5	0		

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Ge72(n,4n)Ge69</b>	Fe60, Co60, Ni59, Ni63, Zn65, Ga68, Ge69	4	0		
<b>Ge72(n,γ)Ge73</b>	Ge75, As76, Se79	4	0		
<b>Ge72(n,p)Ga72</b>	Ga72	5	4	•	
<b>Ge72(n,t)Ga70</b>	H3, Fe60, Co60, Ni59, Ni63, Zn65, Ga68, Ga70, Ge68, Ge69	5	0		
<b>Ge72(n,5n)Ge68</b>	Mn53, Fe60, Ni59, Ni63, Zn65, Ga68, Ge68	4	0		
<b>Ge73(n,3n)Ge71</b>	H3, Fe60, Co60, Ni59, Ni63, Zn65, Ga68, Ga70, Ge69, Ge71	5	0		
<b>Ge73(n,γ)Ge74</b>	Ge75, As76, Se79	4	2	•	
<b>Ge73(n,d)Ga72</b>	Fe60, Ni63, Zn65, Ga68, Ga70, Ga72, Ge71	5	0		
<b>Ge74(n,4n)Ge71</b>	H3, Fe60, Co60, Ni63, Zn65, Ga68, Ga70, Ge71	5	0		
<b>Ge74(n,γ)Ge75</b>	H3, Ge75, As76, As77, Se79, Kr81	5	2	•	
<b>Ge74(n,γ)Ge75m</b>	H3, Ge75, As74, As76, Se79, Kr81	4	2	•	
<b>Ge74(n,t)Ga72</b>	H3, Ni63, Zn65, Ga68, Ga70, Ga72, Ge69, Ge71	5	5 <sub>0</sub>		•
<b>Ge76(n,2n)Ge75</b>	H3, Ga72, Ge75, As74, As76	4	6	•	•
<b>Ge76(n,2n)Ge75m</b>	Ga70, Ga72, Ge75, As74, As76	5	6	•	•
<b>Ge76(n,γ)Ge77</b>	Ge77, As76, As77, Se79, Kr81	5	2	•	
<b>Ge76(n,γ)Ge77m</b>	Ge77, As76, As77, Se79, Kr81	4	2	•	
<b>Ge76(n,d)Ga75</b>	Ge75, As74, As76	4	0		
<b>As73(n,2n)As72</b>	Fe60, Ni63, Zn65, Ga68, Ge71, As72	4	0		
<b>As75(n,2n)As74</b>	H3, Mn53, Fe60, Co60, Ni59, Ni63, Zn65, Ga68, Ga72, Ge71, As72, As73, As74, Se75	5	0		
<b>As75(n,3n)As73</b>	H3, Mn53, Fe60, Co60, Ni59, Ni63, Zn65, Ga68, Ga72, Ge71, As72, As73	5	0		
<b>As75(n,nα)Ga71</b>	H3, Mn53, Fe60, Co60, Ni59, Ni63, Zn65, Ga68	4	0		
<b>As75(n,2nα)Ga70</b>	H3, Mn53, Fe60, Co60, Ni59, Ni63, Zn65, Ga68, Ga70	5	0		
<b>As75(n,3nα)Ga69</b>	H3, Mn53, Fe60, Co60, Ni59, Ni63, Zn65, Ga68	4	0		
<b>As75(n,4n)As72</b>	H3, Mn53, Fe60, Co60, Ni59, Ni63, Zn65, Ga68, Ga72, Ge71, As72	5	0		
<b>As75(n,γ)As76</b>	H3, Ge75, As76, As77, Se75, Se77m, Se79, Se79m, Br82, Kr81	5	4	•	
<b>As75(n,p)Ge75</b>	Ge75	5	6	•	•
<b>As75(n,p)Ge75m</b>	Ge75	5	6	•	•
<b>As75(n,α)Ga72</b>	Fe60, Co60, Ni63, Zn65, Ga68, Ga72, Ge71	5	6	•	•
<b>As75(n,5n)As71</b>	Fe60, Co60, Ni63, Zn65, Ga68, Ge71	4	0		
<b>As75(n,2nt)Ge71</b>	H3, Mn53, Fe60, Co60, Ni59, Ni63, Zn65, Ga68, Ge71	5	0		
<b>As75(n,4nα)Ga68</b>	Mn53, Fe60, Co60, Ni59, Ni63, Zn65, Ga68	4	0		
<b>As76(n,γ)As77</b>	Ge75, As77, Se79, Se79m, Br82, Kr81	5	0		
<b>Se74(n,2n)Se73</b>	Co60, Zn65, Ga68, Ge71, As72, As73	4	4/4	•	
<b>Se74(n,3n)Se72</b>	Co60, Zn65, Ga68, As72	4	0		
<b>Se74(n,nα)Ge70</b>	Fe60, Co60, Ni59, Ni63, Zn65, Ga68	5	0		
<b>Se74(n,γ)Se75</b>	H3, As76, Se75, Se77m	5	2	•	
<b>Se74(n,d)As73</b>	H3, Fe60, Co60, Ni63, Zn65, Ga68, Ga72, Ge71, As72, As73	4	0		
<b>Se74(n,t)As72</b>	Co60, Ga68, Ge71, As72	4	0		
<b>Se74(n,α)Ge71</b>	Fe60, Co60, Ni63, Zn65, Ga68, Ge71	4	0		
<b>Se75(n,γ)Se76</b>	Se77m	4	2	•	
<b>Se76(n,2n)Se75</b>	H3, Co60, Ga68, As74, As76, Se75	5	4	•	
<b>Se76(n,γ)Se77</b>	Ge75, As77, Se77m, Se79, Se79m, Br82, Kr81	5	2	•	
<b>Se76(n,γ)Se77m</b>	Ge75, As77, Se77m, Se79, Se79m, Br82, Kr81	5	2	•	
<b>Se76(n,p)As76</b>	As76	5	4	•	
<b>Se76(n,t)As74</b>	Ga68, As74	5	0		
<b>Se77(n,3n)Se75</b>	H3, Co60, Ga68, As74, Se75	4	0		
<b>Se77(n,nt)As74</b>	Ga68, As74	4	0		
<b>Se77(n,γ)Se78</b>	Se79, Se79m, Br82, Kr81	5	4	•	
<b>Se77(n,p)As77</b>	As77	5	2	•	
<b>Se77(n,d)As76</b>	As74, As76, Se75	5	2	•	
<b>Se77(n,α)Ge74</b>	Ga68, Ge75	4	2	•	
<b>Se78(n,2n)Se77m</b>	H3, Ga68, As74, As76, Se75, Se77m	5	6	•	•

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Se78(n,4n)Se75</b>	H3, Co60, Ga68, As74, Se75	5	0		
<b>Se78(n,γ)Se79</b>	Se79, Se79m, Br82	5	2	•	
<b>Se78(n,γ)Se79m</b>	Se79, Se79m, Se81, Br82, Kr81	5	2	•	
<b>Se78(n,t)As76</b>	H3, Ga68, As74, As76, Se75	5	0		
<b>Se79(n,γ)Se80</b>	Se81, Br82	4	1	•	
<b>Se80(n,2n)Se79</b>	H3, As74, As76, Se75, Se77m, Se79	5	0*/4*	•	
<b>Se80(n,4n)Se77m</b>	H3, Ga68, As74, As76, Se75, Se77m	5	0		
<b>Se80(n,γ)Se81</b>	Se81, Br82, Kr83m, Kr85	5	4/3	•	
<b>Se80(n,d)As79</b>	As76, Se77m, Se79	4	0		
<b>Se82(n,2n)Se81</b>	H3, Se81, Br82, Kr79, Kr81	4	5 <sub>2</sub>	•	•
<b>Se82(n,2n)Se81m</b>	As76, Se81, Br82, Kr79, Kr81	5	2	•	
<b>Se82(n,γ)Se83</b>	Br82, Kr79, Kr81, Kr83m, Kr85	5	2	•	
<b>Se82(n,γ)Se83m</b>	Se83m, Br82, Kr79, Kr81, Kr83m, Kr85	5	2	•	
<b>Se82(n,d)As81</b>	Se81, Br82, Kr79	4	0		
<b>Br79(n,n')Br79m</b>	Br79m	5	4	•	
<b>Br79(n,2n)Br78</b>	H3, Ga68, As74, As76, Se75, Se79, Br78	5	6	•	•
<b>Br79(n,3n)Br77</b>	H3, Co60, Ga68, As74, As76, Se75, Br76, Br77	4	0		
<b>Br79(n,3n)Br77m</b>	Ga68, As74, As76, Se75, Br76, Br77	5	0		
<b>Br79(n,nα)As75</b>	H3, Co60, Ga68, As74	4	0		
<b>Br79(n,2nα)As74</b>	Co60, Ga68, As74	5	0		
<b>Br79(n,4n)Br76</b>	Ga68, As74, As76, Se75, Br76	4	0		
<b>Br79(n,4n)Br76m</b>	Ga68, As74, As76, Se75, Br76	5	0		
<b>Br79(n,γ)Br80</b>	H3, Se79, Br80, Br82, Kr81, Kr83m, Kr85, Rb86	5	4	•	
<b>Br79(n,γ)Br80m</b>	H3, Se79, Br80, Br80m, Br82, Kr81, Kr83m, Kr85, Rb86	5	4	•	
<b>Br79(n,p)Se79</b>	As76, Se75, Se79	5	0		
<b>Br79(n,p)Se79m</b>	Se79	4	2	•	
<b>Br79(n,α)As76</b>	Co60, Ga68, As74, As76, Se75	5	4	•	
<b>Br79(n,2nt)Se75</b>	Co60, Ga68, As74, Se75	4	0		
<b>Br81(n,2n)Br80</b>	H3, As74, As76, Se75, Se79, Br76, Br77, Br78, Br79m, Br80, Br80m, Kr79, Kr81	4	6/2	•	•
<b>Br81(n,2n)Br80m</b>	As74, Se75, Se79, Br76, Br77, Br78, Br79m, Br80, Br80m, Kr79, Kr81	5	2	•	
<b>Br81(n,3n)Br79m</b>	H3, Ga68, As74, As76, Se75, Se79, Br76, Br77, Br78, Br79m	5	0		
<b>Br81(n,2nα)As76</b>	Co60, Ga68, As74, As76, Se75	4	0		
<b>Br81(n,4n)Br78</b>	H3, Ga68, As74, As76, Se75, Br78	5	0		
<b>Br81(n,γ)Br82</b>	Br82, Kr81, Kr83m, Kr85, Rb86	5	2	•	
<b>Br81(n,γ)Br82m</b>	Br82, Kr81, Kr83m, Kr85, Rb86	5	2	•	
<b>Br81(n,t)Se79</b>	H3, As76, Se75, Se79	5	0		
<b>Br81(n,5n)Br77m</b>	As74, As76, Se75, Br77	4	0		
<b>Br82(n,γ)Br83</b>	Kr83m, Kr85, Rb86	4	0		
<b>Kr78(n,γ)Kr79</b>	H3, Se79, Br82, Kr79, Kr81	5	2/2	•	
<b>Kr78(n,α)Se75</b>	Se75	5	0		
<b>Kr80(n,2n)Kr79</b>	H3, As76, Se75, Se79, Br76, Br77, Br78, Br79m, Kr79	4	2	•	
<b>Kr80(n,2n)Kr79m</b>	Se75, Se79, Br76, Br77, Br78, Kr79	4	2	•	
<b>Kr80(n,2nα)Se75</b>	Se75	4	0		
<b>Kr80(n,γ)Kr81</b>	H3, Se79, Br82, Kr81, Kr83m, Kr85, Rb86	5	2	•	
<b>Kr80(n,γ)Kr81m</b>	H3, Se79, Br82, Kr81, Kr83m, Kr85, Rb86	5	2	•	
<b>Kr80(n,t)Br78</b>	Se75, Br78	4	0		
<b>Kr81(n,α)Se78</b>	Se79	5	0		
<b>Kr82(n,2n)Kr81</b>	H3, Se75, Br78, Kr79, Kr81	5	2/2	•	
<b>Kr82(n,3n)Kr80</b>	H3, Se75, Br78, Kr79	4	0		
<b>Kr82(n,4n)Kr79m</b>	Se75, Se79, Br78, Kr79	4	0		
<b>Kr82(n,γ)Kr83</b>	Kr83m, Kr85, Kr85m, Rb86	4	2	•	
<b>Kr82(n,γ)Kr83m</b>	Kr83m, Kr85, Kr85m, Rb86	5	2	•	
<b>Kr82(n,p)Br82</b>	Br82	4	0		
<b>Kr82(n,p)Br82m</b>	Br82	4	0		
<b>Kr82(n,α)Se79</b>	Se75, Se79	5	0		
<b>Kr83(n,3n)Kr81</b>	H3, Se75, Br78, Kr79, Kr81	5	0		



Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Kr83</b> (n,n $\alpha$ )Se79	Se75, Se79	4	0		
<b>Kr83</b> (n, $\gamma$ ) <b>Kr84</b>	Kr85, Kr85m, Rb86	5	0		
<b>Kr83</b> (n,d)Br82	Se79, Br78, Br82, Kr79, Kr81	4	0		
<b>Kr84</b> (n,2n) <b>Kr83</b>	H3, Se75, Se79, Br78, Br82, Kr79, Kr81, Kr83m	4	0		
<b>Kr84</b> (n,2n)Kr83m	H3, Se79, Br82, Kr79, Kr81, Kr83m	5	0		
<b>Kr84</b> (n,2n $\alpha$ )Se79	Se75, Se79	5	0		
<b>Kr84</b> (n,4n)Kr81	H3, Se75, Se79, Br78, Kr79, Kr81	5	0		
<b>Kr84</b> (n, $\gamma$ )Kr85	Kr85, Rb86	5	2	•	
<b>Kr84</b> (n, $\gamma$ )Kr85m	Kr85, Kr85m, Rb83, Rb86	5	2	•	
<b>Kr84</b> (n,d)Br83	Se75, Se79, Br78, Br82, Kr79, Kr81, Kr83m	5	0		
<b>Kr84</b> (n,t)Br82	Se75, Se79, Br78, Br82, Kr79	5	0		
<b>Kr84</b> (n,t)Br82m	Br78, Br82, Kr79	4	0		
<b>Kr86</b> (n,2n)Kr85	H3, Se79, Br82, Kr83m, Kr85, Kr85m, Rb83, Rb84, Rb86	5	0		
<b>Kr86</b> (n,2n)Kr85m	H3, Br82, Kr83m, Kr85, Kr85m, Rb83, Rb84, Rb86	5	2	•	
<b>Kr86</b> (n, $\gamma$ )Kr87	Kr87, Rb86	5	4	•	
<b>Kr86</b> (n,d)Br85	Kr83m, Kr85, Kr85m, Rb83, Rb84, Rb86	5	0		
Rb83(n,2n)Rb82m	Kr81, Rb82m	5	0		
Rb84(n,2n)Rb83	Kr81, Rb82m, Rb83	4	0		
<b>Rb85</b> (n,2n)Rb84	H3, Se79, Br82, Kr81, Kr85, Rb82m, Rb83, Rb84	5	6	•	•
<b>Rb85</b> (n,2n)Rb84m	H3, Se79, Br82, Kr81, Kr85, Rb82m, Rb83, Rb84	5	4*	•	
<b>Rb85</b> (n,3n)Rb83	H3, Se79, Br82, Kr81, Kr83m, Rb82m, Rb83	5	0		
<b>Rb85</b> (n,4n)Rb82m	Se79, Br82, Kr81, Rb82m	5	0		
<b>Rb85</b> (n, $\gamma$ )Rb86	H3, Kr85, Rb86, Rb87, Sr89, Sr90, Y90	5	4/4	•	
<b>Rb85</b> (n,p)Kr85	H3, Br82, Kr85	5	0/4	•	
<b>Rb85</b> (n, $\alpha$ )Br82	Se79, Br82, Kr81	5	0		
<b>Rb85</b> (n, $\alpha$ )Br82m	Se79, Br82, Kr81	4	0		
<b>Rb85</b> (n,5n)Rb81m	Kr81	4	0		
<b>Rb85</b> (n,2nt)Kr81	Kr81	4	0		
<b>Rb87</b> (n,2n)Rb86	H3, Kr81, Rb82m, Rb84, Rb86, Sr85	5	4	•	
<b>Rb87</b> (n,2n)Rb86m	H3, Kr81, Rb82m, Rb86, Sr85	5	6	•	•
<b>Rb87</b> (n, $\gamma$ )Rb88	Sr89, Sr90, Y90, Nb93m	5	4	•	
<b>Rb87</b> (n,t)Kr85	Br82, Kr81, Kr85	5	0		
<b>Sr84</b> (n, $\gamma$ )Sr85	H3, Kr85, Rb86, Sr85	4	2	•	
<b>Sr84</b> (n, $\gamma$ )Sr85m	H3, Kr85, Rb86, Rb87, Sr85	5	6	•	•
<b>Sr84</b> (n, $\alpha$ )Kr81	Kr81	5	0		
<b>Sr86</b> (n,2n)Sr85	H3, Se79, Kr81, Kr85, Rb82m, Rb84, Sr85	5	6	•	•
<b>Sr86</b> (n,2n $\alpha$ )Kr81	Kr81	4	0		
<b>Sr86</b> (n, $\gamma$ )Sr87m	Kr85, Rb87, Sr87m, Sr89, Sr90, Y90	5	5 <sub>2</sub>	•	•
<b>Sr86</b> (n,p)Rb86	H3, Rb86	4	2/4	•	
<b>Sr87</b> (n,3n)Sr85	H3, Se79, Kr81, Kr85, Rb84, Sr85	4	0		
<b>Sr87</b> (n,p)Rb87	Kr85, Rb86, Rb87	4	2	•	
<b>Sr87</b> (n, $\alpha$ ) <b>Kr84</b>	Se79, Kr81, Kr85	5	0		
<b>Sr88</b> (n,2n) <b>Sr87</b>	H3, Se79, Kr81, Rb84, Rb86, Rb87, Sr85, Sr87m	4	2	•	
<b>Sr88</b> (n,2n)Sr87m	H3, Se79, Kr81, Rb84, Rb86, Rb87, Sr85, Sr87m	5	6	•	•
<b>Sr88</b> (n,4n)Sr85	H3, Se79, Kr81, Kr85, Rb84, Sr85	5	0		
<b>Sr88</b> (n, $\gamma$ )Sr89	H3, Sr89, Sr90, Y89m, Y90, Y91, Zr93, Nb93m, Nb94	5	4	•	
<b>Sr88</b> (n,d)Rb87	H3, Kr85, Rb84, Rb86, Rb87	5	0		
<b>Sr88</b> (n,t)Rb86	Kr81, Rb84, Rb86, Sr85	4	2	•	
<b>Sr88</b> (n,t)Rb86m	Kr81, Rb84, Rb86, Sr85	5	0		
<b>Sr88</b> (n, $\alpha$ )Kr85	H3, Se79, Kr81, Kr85, Rb84	5	0/4	•	
Sr89(n, $\gamma$ )Sr90	Sr90, Y90, Y91, Zr93, Nb93m	5	2	•	
Sr90(n, $\gamma$ )Sr91	Y91, Zr93, Nb93m	5	2	•	
Y87(n,2n)Y86	Y86	5	0		
Y88(n,2n)Y87m	Se79, Kr81, Rb86, Rb87, Y86	5	2	•	
Y88(n,3n)Y86	Se79, Kr81, Y86	5	0		
Y88(n,3n)Y86m	Kr81, Y86	4	0		

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Y89</b> (n,n')Y89m	Y89m	5	6	•	•
<b>Y89</b> (n,2n)Y88	H3, Se79, Kr81, Kr85, Rb86, Rb87, Sr89, Sr90, Y86, Y88	5	6	•	•
<b>Y89</b> (n,n $\alpha$ ) <b>Rb85</b>	Se79, Kr81, Kr85	4	0		
<b>Y89</b> (n,2n $\alpha$ )Rb84	Se79, Kr81	4	0		
<b>Y89</b> (n,2n $\alpha$ )Rb84m	Se79, Kr81	4	0		
<b>Y89</b> (n,4n)Y86	Se79, Kr81, Kr85, Rb86, Y86	5	0		
<b>Y89</b> (n,4n)Y86m	Kr81, Kr85, Rb86, Y86	4	0		
<b>Y89</b> (n, $\gamma$ )Y90	Rb87, Sr89, Sr90, Y89m, Y90, Y90m, Y91, Zr93, Nb93m, Nb94	5	4	•	
<b>Y89</b> (n, $\gamma$ )Y90m	Rb87, Sr90, Y90, Y90m, Y91, Zr93, Nb93m	5	6	•	•
<b>Y89</b> (n,p)Sr89	Rb87, Sr89, Sr90, Y91	5	4	•	
<b>Y89</b> (n,d) <b>Sr88</b>	H3, Se79, Kr81, Kr85, Rb86, Rb87	4	2	•	
<b>Y89</b> (n,h)Rb87	Kr85, Rb86, Rb87	5	0		
<b>Y89</b> (n, $\alpha$ )Rb86	Se79, Kr81, Kr85, Rb86	5	5 <sub>2</sub>	•	•
<b>Y89</b> (n, $\alpha$ )Rb86m	Se79, Kr81, Kr85, Rb86	4	6	•	•
Y90(n, $\gamma$ )Y91	Sr89, Sr90, Y89m, Y91, Zr93, Nb93m, Nb94	5	0		
Y90(n, $\gamma$ )Y91m	Sr89, Sr90, Y89m, Y91, Zr93, Nb93m, Nb94	4	0		
Y90(n, $\alpha$ )Rb87	Rb87	5	0		
<b>Zr90</b> (n,n')Zr90m	Zr90m	5	4	•	
<b>Zr90</b> (n,2n)Zr89	Kr81, Kr85, Y88, Y89m, Y90, Zr89	5	6	•	•
<b>Zr90</b> (n,3n)Zr88	Kr81, Kr85, Y88	5	0		
<b>Zr90</b> (n, $\gamma$ ) <b>Zr91</b>	Sr89, Sr90, Y89m, Y90, Y91, Zr93, Nb93m	5	4	•	
<b>Zr90</b> (n,p)Y90	Y90	5	4	•	
<b>Zr90</b> (n,p)Y90m	Y90, Y90m	4	6	•	•
<b>Zr90</b> (n,t)Y88	Kr81, Kr85, Y88	4	6	•	•
<b>Zr91</b> (n,2n)Zr90m	H3, Kr85, Y88, Y89m, Y90, Zr89, Zr90m	5	0		
<b>Zr91</b> (n, $\gamma$ ) <b>Zr92</b>	Sr90, Y90, Y91, Zr93, Nb93m, Nb94	5	4	•	
<b>Zr91</b> (n,p)Y91m	Y91	4	4	•	
<b>Zr91</b> (n,p)Y91	Y91	4	2	•	
<b>Zr91</b> (n,d)Y90m	Y90, Y90m	4	0		
<b>Zr91</b> (n, $\alpha$ ) <b>Sr88</b>	Kr85, Sr89, Sr90, Y89m, Y90, Y91, Nb94	5	0		
<b>Zr92</b> (n,2n) <b>Zr91</b>	H3, Kr85, Y88, Y89m, Y90, Y90m, Y91, Zr89, Zr90m	5	0		
<b>Zr92</b> (n,3n)Zr90m	H3, Kr81, Kr85, Y88, Y89m, Y90, Y90m, Zr89, Zr90m	4	0		
<b>Zr92</b> (n,4n)Zr89	Kr85, Y89m, Zr89	4	0		
<b>Zr92</b> (n, $\gamma$ )Zr93	Sr90, Y90, Y91, Zr93, Nb93m, Nb94	5	4	•	
<b>Zr92</b> (n,d)Y91	Y91, Zr90m	4	0		
<b>Zr92</b> (n,d)Y91m	Y90m, Y91, Zr90m	4	0		
<b>Zr92</b> (n,t)Y90m	Y90, Y90m	4	0		
Zr93(n, $\alpha$ )Sr90	Sr90, Y90, Y91, Nb94	5	0		
<b>Zr94</b> (n,2n)Zr93	H3, Sr90, Y91, Zr90m, Zr93, Nb93m	5	0		
<b>Zr94</b> (n, $\alpha$ )Sr90	Kr85, Sr90, Y90	5	0		
<b>Zr94</b> (n,nt)Y91m	Y91	4	0		
<b>Zr94</b> (n, $\gamma$ )Zr95	Zr95, Nb93m, Nb94, Nb95, Nb96, Mo93, Tc99	5	6	•	•
<b>Zr94</b> (n,5n)Zr90m	Zr90m	4	0		
<b>Zr96</b> (n,2n)Zr95	H3, Zr93, Zr95, Nb93m, Nb94, Nb95, Mo93	5	6	•	•
<b>Zr96</b> (n,4n)Zr93	Y91, Zr93	4	0		
<b>Zr96</b> (n, $\gamma$ )Zr97	Zr97, Nb94, Mo93, Tc99	5	5 <sub>2</sub>	•	•
<b>Zr96</b> (n,d)Y95	Zr95, Nb93m, Nb94, Nb95, Mo93	4	0		
Nb91(n,2n)Nb90	Kr81, Kr85, Y88, Y90, Y90m, Zr90m, Nb90	5	0		
Nb91(n,d)Zr90m	Y88, Y90, Y90m, Zr90m	4	0		
Nb91(n, $\alpha$ )Y88	Kr81, Kr85, Y88	4	0		
Nb92(n,2n)Nb91	Kr81, Kr85, Y88, Zr90m, Nb90, Nb91, Nb91m	5	0		
Nb92(n,2n)Nb91m	Kr85, Y88, Zr90m, Nb90, Nb91, Nb91m	5	0		
<b>Nb93</b> (n,n')Nb93m	H3, Y88, Y90, Y90m, Zr90m, Zr93, Nb90, Nb91, Nb91m, Nb92, Nb92m, Nb93m, Nb94, Nb94m, Nb95, Nb96	5	4	•	
<b>Nb93</b> (n,2n)Nb92	H3, Kr81, Kr85, Y88, Y90, Y90m, Zr90m, Nb90, Nb91, Nb91m, Nb92, Nb92m	5	4	•	

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Nb93</b> (n,2n) <b>Nb92m</b>	H3, Kr85, Y88, Y90, Y90m, Zr90m, Nb90, Nb91, Nb91m, Nb92m	5	6	•	•
<b>Nb93</b> (n,3n) <b>Nb91</b>	H3, Kr81, Kr85, Y88, Y90, Y90m, Zr90m, Nb90, Nb91, Nb91m	5	0		
<b>Nb93</b> (n,3n) <b>Nb91m</b>	H3, Kr81, Kr85, Y88, Y90, Y90m, Zr90m, Nb90, Nb91, Nb91m	5	5 <sub>4</sub>	•	•
<b>Nb93</b> (n,n $\alpha$ ) <b>Y89</b>	H3, Kr81, Kr85, Y88	4	0		
<b>Nb93</b> (n,n $\alpha$ ) <b>Y89m</b>	H3, Kr81, Kr85, Y88	4	6	•	•
<b>Nb93</b> (n,2n $\alpha$ ) <b>Y88</b>	Kr81, Kr85, Y88	5	0		
<b>Nb93</b> (n,3n $\alpha$ ) <b>Y87m</b>	Kr81, Kr85	4	0		
<b>Nb93</b> (n,nt) <b>Zr90m</b>	H3, Kr81, Kr85, Y88, Y90, Y90m, Zr90m	5	0		
<b>Nb93</b> (n,4n) <b>Nb90</b>	H3, Kr81, Kr85, Y88, Y90, Y90m, Zr90m, Nb90	5	5 <sub>3</sub>		•
<b>Nb93</b> (n, $\gamma$ ) <b>Nb94</b>	H3, Zr93, Nb93m, Nb94, Nb94m, Nb95, Nb96, Tc99	4	4	•	
<b>Nb93</b> (n, $\gamma$ ) <b>Nb94m</b>	H3, Zr93, Nb93m, Nb94, Nb94m, Nb95, Nb96, Tc99	5	6	•	•
<b>Nb93</b> (n,p) <b>Zr93</b>	H3, Kr85, Y90, Y90m, Zr90m, Zr93, Nb93m, Nb95, Nb96	5	2	•	
<b>Nb93</b> (n,t) <b>Zr91</b>	H3, Kr81, Kr85, Y88, Y90, Y90m, Zr90m	4	6*	•	•
<b>Nb93</b> (n, $\alpha$ ) <b>Y90</b>	Kr81, Kr85, Y88, Y90, Y90m, Zr90m	5	6	•	•
<b>Nb93</b> (n, $\alpha$ ) <b>Y90m</b>	Kr81, Y88, Y90, Y90m, Zr90m	5	6	•	•
<b>Nb93m</b> (n, $\gamma$ ) <b>Nb94</b>	Y91, Nb94, Nb95	4	0		
<b>Nb93m</b> (n, $\gamma$ ) <b>Nb94m</b>	Y91, Nb94, Nb94m, Nb95, Nb96	5	0		
<b>Nb94</b> (n,2n) <b>Nb93m</b>	Nb93m	4	0		
<b>Nb94</b> (n, $\gamma$ ) <b>Nb95</b>	Zr93, Nb93m, Nb95, Nb96, Tc99	5	2/2	•	
<b>Nb95</b> (n,2n) <b>Nb94</b>	Nb93m, Nb94	4	0		
<b>Nb95</b> (n,2n) <b>Nb94m</b>	Nb93m, Nb94	4	0		
<b>Nb95</b> (n,3n) <b>Nb93m</b>	Nb93m	4	0		
<b>Nb95</b> (n, $\gamma$ ) <b>Nb96</b>	Zr93, Nb93m, Nb96, Tc99	5	4	•	
<b>Mo92</b> (n,2n) <b>Mo91</b>	H3, Kr85, Y88, Nb90, Nb91, Nb91m	4	5 <sub>2</sub>	•	•
<b>Mo92</b> (n,2n) <b>Mo91m</b>	Kr85, Y88, Nb90, Nb91, Nb91m	4	5 <sub>2</sub> *	•	•
<b>Mo92</b> (n,n $\alpha$ ) <b>Zr88</b>	Kr85, Y88	5	6*	•	•
<b>Mo92</b> (n, $\gamma$ ) <b>Mo93</b>	H3, Nb93m, Nb94, Nb95, Mo93	5	1/3	•	
<b>Mo92</b> (n,p) <b>Nb92</b>	H3, Y88, Nb90, Nb91, Nb91m, Nb92, Nb92m	5	5 <sub>1</sub>	•	•
<b>Mo92</b> (n,p) <b>Nb92m</b>	Kr85, Nb92m	5	6	•	•
<b>Mo92</b> (n,d) <b>Nb91</b>	H3, Kr85, Y88, Nb90, Nb91, Nb91m	5	1	•	
<b>Mo92</b> (n,d) <b>Nb91m</b>	Kr85, Y88, Nb90, Nb91, Nb91m	5	6	•	•
<b>Mo92</b> (n,t) <b>Nb90</b>	H3, Kr85, Y88, Nb90	5	5 <sub>4</sub>	•	•
<b>Mo92</b> (n, $\alpha$ ) <b>Zr89</b>	H3, Kr85, Y88	4	6	•	•
<b>Mo93</b> (n,p) <b>Nb93m</b>	Nb93m	4	0		
<b>Mo94</b> (n,2n) <b>Mo93</b>	H3, Kr85, Y88, Nb90, Nb91, Nb91m, Nb92, Nb92m, Nb93m, Mo93	5	2/4	•	
<b>Mo94</b> (n,nt) <b>Nb91m</b>	Y88, Nb90, Nb91, Nb91m	4	0		
<b>Mo94</b> (n,p) <b>Nb94</b>	H3, Nb92, Nb92m, Nb93m, Nb94	4	1	•	
<b>Mo94</b> (n,p) <b>Nb94m</b>	H3, Nb92, Nb92m, Nb93m, Nb94	4	3	•	
<b>Mo94</b> (n,d) <b>Nb93m</b>	Nb91m, Nb92, Nb92m, Nb93m	5	0		
<b>Mo94</b> (n,t) <b>Nb92</b>	Kr85, Y88, Nb90, Nb91m, Nb92, Nb92m	5	0		
<b>Mo94</b> (n,t) <b>Nb92m</b>	Y88, Nb92m	4	0		
<b>Mo95</b> (n,2n) <b>Mo94</b>	H3, Kr85, Y88, Nb90, Nb91, Nb91m, Nb92, Nb92m, Nb93m, Nb94, Mo93	5	0		
<b>Mo95</b> (n,3n) <b>Mo93</b>	H3, Kr85, Y88, Nb90, Nb91, Nb91m, Nb92, Nb92m, Nb93m, Mo93	5	0/5		•
<b>Mo95</b> (n,nt) <b>Nb92</b>	H3, Kr85, Y88, Nb90, Nb91, Nb92, Nb92m	4	0		
<b>Mo95</b> (n,nt) <b>Nb92m</b>	Y88, Nb92m	4	0		
<b>Mo95</b> (n, $\gamma$ ) <b>Mo96</b>	Zr93, Nb93m, Nb95, Nb96, Mo99, Tc99, Tc100	5	4	•	
<b>Mo95</b> (n,p) <b>Nb95</b>	Nb94, Nb95	5	5 <sub>2</sub>	•	•
<b>Mo95</b> (n,d) <b>Nb94</b>	H3, Y88, Nb90, Nb92, Nb92m, Nb93m, Nb94	4	0		
<b>Mo95</b> (n,d) <b>Nb94m</b>	H3, Nb90, Nb92, Nb92m, Nb93m, Nb94	4	0		
<b>Mo95</b> (n,t) <b>Nb93m</b>	Nb90, Nb91m, Nb92, Nb92m, Nb93m	5	0		
<b>Mo95</b> (n, $\alpha$ ) <b>Zr92</b>	Kr85, Zr93, Nb93m	4	0		
<b>Mo96</b> (n,nt) <b>Nb93m</b>	Nb92m, Nb93m	4	0		
<b>Mo96</b> (n,4n) <b>Mo93</b>	H3, Kr85, Y88, Nb90, Nb91, Nb91m, Nb92,	4	0		

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Mo96(n,<math>\gamma</math>)Mo97</b>	Nb92m, Nb93m, Mo93	5	4	•	
<b>Mo96(n,d)Nb95</b>	Nb95, Mo99, Tc99, Tc100	4	6	•	•
<b>Mo96(n,t)Nb94</b>	H3, Nb92, Nb92m, Nb93m, Nb94, Nb95, Mo93	4	0		
<b>Mo96(n,<math>\alpha</math>)Zr93</b>	H3, Y88, Nb90, Nb91m, Nb92, Nb92m, Nb93m, Nb94	5	2	•	
<b>Mo96(n,2nt)Nb92</b>	Zr93, Nb93m	4	0		
<b>Mo97(n,<math>\gamma</math>)Mo98</b>	H3, Kr85, Y88, Nb90, Nb92, Nb92m	5	4	•	
<b>Mo98(n,nt)Nb95</b>	Mo99, Tc99, Tc100	4	0		
<b>Mo98(n,<math>\gamma</math>)Mo99</b>	H3, Nb91, Nb92, Nb92m, Nb93m, Nb95, Mo93	5	6	•	•
<b>Mo100(n,2n)Mo99</b>	Mo99, Tc98, Tc99, Tc100, Ru103	5	6	•	•
<b>Mo100(n,<math>\gamma</math>)Mo101</b>	H3, Nb95, Mo99, Tc98, Tc99, Tc100	5	6	•	•
<b>Mo100(n,d)Nb99</b>	Mo101, Tc98, Tc100, Ru103	4	0		
Tc97(n,2n)Tc96	Mo99, Tc98, Tc99, Tc100	4	0		
Tc97(n, $\gamma$ )Tc98	Nb94, Mo93, Tc96	5	0		
Tc97(n, $\alpha$ )Nb94	H3, Tc98, Tc99, Tc100	4	0		
Tc97(n, $\alpha$ )Nb94m	Nb93m, Nb94	5	0		
Tc98(n,2n)Tc97	Nb93m, Nb94	4	0		
Tc98(n, $\gamma$ )Tc99	Nb94, Mo93, Tc96, Tc97, Tc97m	5	0		
Tc98(n, $\gamma$ )Tc99m	Tc99, Tc100	4	0		
Tc99(n,2n)Tc98	Tc99, Tc100	5	2	•	
Tc99(n,3n)Tc97	Nb94, Nb95, Mo93, Tc96, Tc97, Tc97m, Tc98	4	0		
Tc99(n, $\gamma$ )Tc100	Nb94, Mo93, Tc96, Tc97	5	4	•	
<b>Ru96(n,2n)Ru95</b>	Tc100, Ru103	4	6	•	•
<b>Ru96(n,n<math>\alpha</math>)Mo92</b>	H3, Kr85, Y88, Nb91, Nb93m, Nb94, Mo93	5	0		
<b>Ru96(n,2n<math>\alpha</math>)Mo91</b>	Kr85, Y88, Nb91	4	0		
<b>Ru96(n,nt)Tc93</b>	Kr85, Y88, Nb91	4	0		
<b>Ru96(n,<math>\gamma</math>)Ru97</b>	H3, Kr85, Y88, Nb91, Nb93m, Mo93	5	4	•	
<b>Ru96(n,p)Tc96m</b>	H3, Nb94, Tc97, Tc97m, Tc98, Tc99, Tc100, Ru97	4	0		
<b>Ru96(n,d)Tc95</b>	Nb93m, Nb94, Mo93, Tc96	4	0		
<b>Ru96(n,<math>\alpha</math>)Mo93</b>	H3, Kr85, Y88, Nb91, Nb93m, Nb94, Mo93	5	0		
<b>Ru96(n,d<math>\alpha</math>)Nb91</b>	Kr85, Y88, Nb91	4	0		
<b>Ru98(n,2n)Ru97</b>	Kr85, Y88, Nb91	5	2	•	
<b>Ru98(n,n<math>\alpha</math>)Mo94</b>	H3, Nb91, Nb93m, Nb94, Mo93, Tc96, Tc97, Tc97m, Ru97	5	0		
<b>Ru98(n,p)Tc98</b>	Kr85, Y88, Nb91, Nb93m, Nb94, Mo93	4	0		
<b>Ru98(n,d)Tc97m</b>	H3, Nb94, Tc96, Tc97, Tc97m, Tc98	4	0		
<b>Ru99(n,2n)Ru98</b>	Nb94, Tc96, Tc97, Tc97m	5	0		
<b>Ru99(n,3n)Ru97</b>	H3, Y88, Nb91, Nb93m, Nb94, Mo93, Tc96, Tc97, Tc97m, Tc98, Ru97	5	0		
<b>Ru99(n,nt)Tc96</b>	H3, Kr85, Y88, Nb91, Nb93m, Nb94, Mo93, Tc96, Tc97, Tc97m, Ru97	4	0		
<b>Ru99(n,p)Tc99</b>	H3, Y88, Nb93m, Nb94, Mo93, Tc96	4	0/4	•	
<b>Ru99(n,d)Tc98</b>	H3, Nb94, Tc96, Tc97, Tc97m, Tc98, Tc99	5	0		
<b>Ru99(n,t)Tc97m</b>	H3, Nb91, Nb93m, Nb94, Tc96, Tc97, Tc97m, Tc98	4	0		
<b>Ru99(n,<math>\alpha</math>)Mo96</b>	Nb93m, Tc96, Tc97, Tc97m	5	0		
<b>Ru100(n,nt)Tc97m</b>	Nb93m, Nb94, Mo93, Tc99	4	0		
<b>Ru100(n,4n)Ru97</b>	Tc97, Tc97m	4	0		
<b>Ru100(n,p)Tc100</b>	H3, Kr85, Y88, Nb91, Nb93m, Nb94, Mo93, Tc96, Tc97, Tc97m, Ru97	5	6*	•	•
<b>Ru100(n,d)Tc99</b>	Tc100	4	0		
<b>Ru100(n,t)Tc98</b>	H3, Nb93m, Nb94, Tc96, Tc97, Tc97m, Tc98, Tc99	4	0		
<b>Ru101(n,3n)Ru99</b>	H3, Nb91, Nb93m, Nb94, Tc96, Tc97, Tc97m, Tc98	4	0		
<b>Ru101(n,nt)Tc98</b>	H3, Nb93m, Nb94, Mo93, Tc96, Tc97, Tc97m, Tc98, Tc99, Ru97	4	0		
<b>Ru101(n,<math>\gamma</math>)Ru102</b>	H3, Nb91, Nb93m, Nb94, Tc96, Tc97, Tc97m, Tc98	5	4	•	
<b>Ru101(n,d)Tc100</b>	Ru103, Rh103m, Rh104	4	0		
	Tc96, Tc97, Tc97m, Tc98, Tc99, Tc100, Ru97				

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Ru101</b> (n,t)Tc99	H3, Nb93m, Nb94, Tc96, Tc97, Tc97m, Tc98	4	0		
<b>Ru101</b> (n, $\alpha$ )Mo98	Nb94, Tc99	5	2	•	
<b>Ru101</b> (n,5n)Ru97	H3, Kr85, Y88, Nb91, Nb93m, Nb94, Mo93, Tc96, Tc97, Tc97m, Ru97	4	0		
<b>Ru102</b> (n,nt)Tc99	H3, Nb93m, Nb94, Tc96, Tc97, Tc97m, Tc98, Tc99	4	0		
<b>Ru102</b> (n, $\gamma$ )Ru103	Ru103, Ru106, Rh102, Rh103m, Rh104, Rh106, Ag110m	5	4	•	
<b>Ru102</b> (n,p)Tc102m	Tc102m	5	6	•	•
<b>Ru102</b> (n,t)Tc100	H3, Nb94, Tc96, Tc97, Tc97m, Tc98, Tc99, Tc100, Ru97	5	0		
<b>Ru102</b> (n,2nt)Tc98	H3, Nb91, Nb93m, Nb94, Tc96, Tc97, Tc97m, Tc98	4	0		
<b>Ru104</b> (n,2n)Ru103	H3, Tc96, Tc97m, Tc98, Tc99, Tc100, Ru103, Rh102, Rh104	5	4	•	
<b>Ru104</b> (n, $\gamma$ )Ru105	Ru103, Ru105, Ru106, Rh102, Rh103m, Rh104, Rh105, Rh106, Rh106m, Pd107, Ag110m	5	4	•	
<b>Ru104</b> (n,d)Tc103	Ru103, Rh102, Rh104	4	0		
<b>Ru104</b> (n,t)Tc102m	Tc100, Tc102m	5	0		
<b>Ru105</b> (n, $\gamma$ )Ru106	Ru106, Rh106	5	2	•	
<b>Rh101</b> (n,2n)Rh100	Mo93, Rh100	4	0		
<b>Rh101</b> (n,2n)Rh100m	Rh100	4	0		
<b>Rh102</b> (n,2n)Rh101	Nb94, Mo93, Tc97, Tc98, Rh100, Rh101, Rh101m	5	0		
<b>Rh102</b> (n,2n)Rh101m	Nb94, Mo93, Tc97, Tc98, Tc99, Rh100, Rh101, Rh101m	5	0		
<b>Rh102</b> (n,3n)Rh100m	Mo93, Tc98, Tc99, Rh100	4	0		
<b>Rh102</b> (n, $\alpha$ )Tc98	Nb94, Mo93, Tc97, Tc98	4	0		
<b>Rh102</b> (n, $\alpha$ )Tc99	Nb94, Mo93, Tc97, Tc98, Tc99	4	0		
<b>Rh103</b> (n,n')Rh103m	Rh103m	5	5 <sub>2</sub>	•	•
<b>Rh103</b> (n,2n)Rh102	H3, Nb94, Mo93, Tc97, Tc98, Tc99, Ru103, Rh100, Rh101, Rh101m, Rh102	5	5/4	•	•
<b>Rh103</b> (n,3n)Rh101	H3, Nb94, Mo93, Tc97, Tc98, Tc99, Rh100, Rh101, Rh101m	5	0		
<b>Rh103</b> (n,3n)Rh101m	H3, Nb94, Mo93, Tc97, Tc98, Tc99, Rh100, Rh101, Rh101m	5	5 <sub>2</sub>	•	•
<b>Rh103</b> (n, $\alpha$ )Tc99	H3, Nb94, Mo93, Tc97, Tc98, Tc99	5	0		
<b>Rh103</b> (n,2n $\alpha$ )Tc98	Nb94, Mo93, Tc97, Tc98	5	0		
<b>Rh103</b> (n,3n $\alpha$ )Tc97	Nb94, Mo93, Tc97	4	0		
<b>Rh103</b> (n,2n2 $\alpha$ )Nb94	Nb94	4	0		
<b>Rh103</b> (n,4n)Rh100	H3, Nb94, Mo93, Tc97, Tc98, Tc99, Rh100	4	5 <sub>3</sub>		•
<b>Rh103</b> (n,4n)Rh100m	Nb94, Mo93, Tc97, Tc98, Tc99, Rh100	5	0		
<b>Rh103</b> (n, $\gamma$ )Rh104	Tc99, Ru103, Ru105, Ru106, Rh103m, Rh104, Rh104m, Rh105, Rh106, Rh106m, Pd107, Ag108m, Ag110m	5	5 <sub>2</sub>	•	•
<b>Rh103</b> (n, $\gamma$ )Rh104m	Tc99, Ru103, Ru105, Ru106, Rh103m, Rh104, Rh104m, Rh105, Rh106, Rh106m, Pd107, Ag108m, Ag110m	5	4*	•	
<b>Rh103</b> (n,p)Ru103	Ru103, Ru105, Ru106, Rh103m, Rh105	5	5 <sub>2</sub>	•	•
<b>Rh105</b> (n, $\gamma$ )Rh106	Rh106, Ag110m	5	1	•	
<b>Rh105</b> (n, $\gamma$ )Rh106m	Rh106m, Ag110m	5	1	•	
<b>Pd102</b> (n,2n)Pd101	H3, Nb94, Tc97, Tc98, Tc99, Rh100, Rh101, Rh101m	4	4	•	
<b>Pd102</b> (n,3n)Pd100	Nb94, Mo93, Tc98, Tc99, Rh100	4	0		
<b>Pd102</b> (n, $\alpha$ ) <b>Ru98</b>	Nb94, Mo93, Tc97, Tc98	5	0		
<b>Pd102</b> (n, $\gamma$ )Pd103	H3, Tc99, Pd103	5	2	•	
<b>Pd102</b> (n, $\alpha$ ) <b>Ru99</b>	Nb94, Mo93, Tc97, Tc98, Tc99	5	0		
<b>Pd104</b> (n,2n)Pd103	H3, Nb94, Mo93, Tc98, Tc99, Rh100, Rh102, Pd103	5	0		
<b>Pd104</b> (n,3n) <b>Pd102</b>	H3, Nb94, Mo93, Tc98, Tc99, Rh100, Rh102	4	0		
<b>Pd104</b> (n, $\gamma$ ) <b>Pd105</b>	Ru103, Rh103m, Rh105, Rh106, Rh106m, Pd107, Ag108m, Ag110m	5	4	•	

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Pd104</b> (n,t)Rh102	Nb94, Mo93, Tc98, Tc99, Rh100, Rh102	4	0		
<b>Pd104</b> (n, $\alpha$ ) <b>Ru101</b>	Mo93, Tc98, Tc99, Ru103, Rh103m	5	0		
<b>Pd104</b> (n,5n)Pd100	Nb94, Mo93, Tc98, Tc99, Rh100	4	0		
<b>Pd105</b> (n,2n) <b>Pd104</b>	H3, Mo93, Tc98, Tc99, Rh100, Rh102, Rh104, Pd103	4	0		
<b>Pd105</b> (n,3n)Pd103	H3, Nb94, Mo93, Tc98, Tc99, Rh100, Rh102, Pd103	5	0		
<b>Pd105</b> (n,nt)Rh102	Nb94, Tc98, Tc99, Rh100, Rh102	4	0		
<b>Pd105</b> (n, $\gamma$ ) <b>Pd106</b>	Rh106, Rh106m, Pd107, Ag108m, Ag110m	5	4	•	
<b>Pd105</b> (n, $\alpha$ ) <b>Ru102</b>	Tc98, Tc99, Ru103, Rh103m	5	2	•	
<b>Pd106</b> (n,4n)Pd103	H3, Nb94, Mo93, Tc98, Tc99, Rh100, Rh102, Pd103	4	0		
<b>Pd106</b> (n, $\gamma$ )Pd107	Pd107, Pd109, Ag108m, Ag110m	5	2	•	
<b>Pd106</b> (n, $\gamma$ )Pd107m	Pd107, Ag108m, Ag110m	4	2	•	
<b>Pd106</b> (n,p)Rh106	Rh106	5	1	•	
<b>Pd106</b> (n,p)Rh106m	Rh106m	5	6	•	•
Pd107(n, $\gamma$ ) <b>Pd108</b>	Pd109, Ag110m	5	4	•	
<b>Pd108</b> (n,2n)Pd107	H3, Pd103, Pd107	5	0		
<b>Pd108</b> (n,2n)Pd107m	H3, Pd103, Pd107	4	5 <sub>2</sub> *	•	•
<b>Pd108</b> (n, $\gamma$ )Pd109	H3, Pd109, Ag109m, Ag110, Ag110m, Ag111, Cd113m	5	2/3	•	
<b>Pd108</b> (n,d)Rh107	H3, Pd103, Pd107	4	0		
<b>Pd110</b> (n,2n)Pd109	H3, Pd109, Ag108m, Ag110, Ag110m	5	6	•	•
<b>Pd110</b> (n,2n)Pd109m	H3, Pd109, Ag108m, Ag110, Ag110m	4	6	•	•
<b>Pd110</b> (n,4n)Pd107m	H3, Pd103, Pd107	4	0		
<b>Pd110</b> (n, $\gamma$ )Pd111	Ag110, Ag110m, Ag111, Cd113m	5	4	•	
<b>Pd110</b> (n, $\gamma$ )Pd111m	Pd111m, Ag110, Ag110m, Ag111, Cd113m	5	4	•	
<b>Pd110</b> (n,d)Rh109	Pd109, Ag108m, Ag110, Ag110m	4	0		
Ag106m(n,2n)Ag105m	Ag105	5	0		
<b>Ag107</b> (n,n')Ag107m	Ag107m	5	4	•	
<b>Ag107</b> (n,2n)Ag106	H3, Nb94, Mo93, Tc98, Tc99, Rh102, Pd107, Ag105	4	6/4	•	•
<b>Ag107</b> (n,2n)Ag106m	H3, Nb94, Mo93, Tc98, Tc99, Rh102, Ag105, Ag106m	5	4	•	
<b>Ag107</b> (n,3n)Ag105m	H3, Nb94, Mo93, Tc98, Tc99, Rh102, Ag105	5	0		
<b>Ag107</b> (n, $\alpha$ )Rh103m	H3, Nb94, Mo93, Tc98, Tc99, Rh102	4	0		
<b>Ag107</b> (n,2n $\alpha$ )Rh102	Nb94, Mo93, Tc98, Tc99, Rh102	5	0		
<b>Ag107</b> (n, $\gamma$ )Ag108	Pd107, Pd109, Ag108, Ag109m, Ag110, Ag110m, Ag111, Cd108, Cd109, Cd113m, In116m	5	4	•	
<b>Ag107</b> (n, $\gamma$ )Ag108m	H3, Pd107, Pd109, Ag108m, Ag109m, Ag110, Ag110m, Ag111	5	2	•	
<b>Ag107</b> (n,p)Pd107	Pd107	5	0		
<b>Ag107</b> (n,p)Pd107m	Pd107	4	4	•	
Ag108m(n,2n)Ag107m	Pd107, Ag106m, Ag107m	4	0		
Ag108m(n, $\gamma$ )Ag109m	Ag109m, Ag110, Ag110m, Ag111	4	0		
<b>Ag109</b> (n,n')Ag109m	Ag109m	5	4	•	
<b>Ag109</b> (n,2n)Ag108	H3, Tc98, Rh102, Pd107, Ag106m, Ag107m, Ag108, Ag108m, Cd108, Cd109	5	6/4	•	•
<b>Ag109</b> (n,2n)Ag108m	H3, Tc98, Rh102, Pd107, Ag105, Ag106m, Ag107m, Ag108, Ag108m, Cd108, Cd109	5	4	•	
<b>Ag109</b> (n,3n)Ag107m	H3, Nb94, Tc98, Tc99, Rh102, Pd107, Ag105, Ag106m, Ag107m	5	0		
<b>Ag109</b> (n,4n)Ag106m	H3, Nb94, Mo93, Tc98, Tc99, Rh102, Ag106m	5	0		
<b>Ag109</b> (n, $\gamma$ )Ag110	Ag110, Ag110m, Ag111, Cd109, Cd113m, In116m	5	4	•	
<b>Ag109</b> (n, $\gamma$ )Ag110m	H3, Pd107, Ag110, Ag110m, Ag111, Cd109, Cd113m, In116m	5	4	•	
<b>Ag109</b> (n,p)Pd109	Pd109, Ag109m	5	2	•	
<b>Ag109</b> (n,p)Pd109m	Pd109, Ag109m	5	4	•	
<b>Ag109</b> (n,t)Pd107	Pd107	4	0		
<b>Ag109</b> (n,t)Pd107m	Pd107	5	0		

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Ag109</b> (n,5n)Ag105m	Nb94, Mo93, Tc98, Tc99, Rh102, Ag105	4	0		
Ag110m(n, $\gamma$ )Ag111	Ag111, Cd113m	5	0		
Ag110m(n, $\gamma$ )Ag111m	Ag111, Cd113m, In116m	5	0		
Ag110m(n, $\alpha$ )Rh107	Pd107	5	0		
<b>Cd106</b> (n,2n)Cd105	Nb94, Tc98, Tc99, Ag105	4	4	•	
<b>Cd106</b> (n, $\alpha$ ) <b>Pd102</b>	Nb94, Mo93, Tc98, Tc99	5	0		
<b>Cd106</b> (n,2n $\alpha$ )Pd101	Nb94, Mo93, Tc98, Tc99	4	0		
<b>Cd106</b> (n, $\gamma$ )Cd107	Ag108m, Ag109m	5	4	•	
<b>Cd106</b> (n,p)Ag106m	Ag106m	4	2	•	
<b>Cd106</b> (n, $\alpha$ )Pd103	Nb94, Mo93, Tc98, Tc99, Rh102	4	2	•	
<b>Cd108</b> (n,2n)Cd107	Tc98, Pd107, Ag106m, Ag107m	5	2	•	
<b>Cd108</b> (n, $\gamma$ )Cd109	Pd107, Ag109m, Ag110, Ag110m, Ag111, Cd109, Cd111m, Cd113m, In116m	5	4	•	
Cd109(n, $\alpha$ ) <b>Pd106</b>	Pd107	5	2	•	
<b>Cd110</b> (n,2n)Cd109	Pd107, Ag106m, Ag108m, Ag109m, Ag110m, Cd109	5	2	•	
<b>Cd110</b> (n, $\gamma$ ) <b>Cd111</b>	Ag111, Cd113, Cd113m, Cd115, Cd115m, In115, In116m	5	5 <sub>2</sub>	•	•
<b>Cd110</b> (n, $\gamma$ )Cd111m	Ag111, Cd111m, Cd113m, In116m	5	3	•	
<b>Cd110</b> (n,p)Ag110m	Ag106m, Ag108m, Ag110m, Ag111	5	4	•	
<b>Cd110</b> (n,t)Ag108m	Tc98, Tc99, Pd107, Ag106m, Ag108m	5	0		
<b>Cd110</b> (n, $\alpha$ )Pd107	Pd107	4	0		
<b>Cd110</b> (n, $\alpha$ )Pd107m	Pd107	4	0		
<b>Cd110</b> (n,2nt)Ag106m	Mo93, Tc98, Tc99, Ag106m	4	0		
<b>Cd111</b> (n,2n) <b>Cd110</b>	Pd107, Ag106m, Ag108m, Ag109m, Ag110, Ag110m, Cd109	4	0		
<b>Cd111</b> (n,3n)Cd109	Pd107, Ag106m, Ag108m, Ag109m, Cd109	5	0		
<b>Cd111</b> (n, $\alpha$ )Pd107m	Pd107	4	0		
<b>Cd111</b> (n,nt)Ag108m	Tc99, Pd107, Ag106m, Ag108m	4	0		
<b>Cd111</b> (n, $\gamma$ ) <b>Cd112</b>	Cd113, Cd113m, Cd114, Cd115, Cd115m, In115, In116m	5	4	•	
<b>Cd111</b> (n,d)Ag110m	Pd107, Ag106m, Ag108m, Ag110, Ag110m	4	0		
<b>Cd111</b> (n, $\alpha$ ) <b>Pd108</b>	Pd107, Ag110m	4	0		
<b>Cd112</b> (n,2n)Cd111m	Pd107, Ag106m, Ag108m, Ag109m, Ag110m, Cd109, Cd111m	5	6	•	•
<b>Cd112</b> (n,2n $\alpha$ )Pd107m	Pd107	4	0		
<b>Cd112</b> (n,4n)Cd109	Tc98, Tc99, Pd107, Ag106m, Ag108m, Ag109m, Cd109	4	0		
<b>Cd112</b> (n, $\gamma$ )Cd113	Cd113, Cd113m, Cd114, Cd115, Cd115m, In115, In116m	5	2	•	
<b>Cd112</b> (n, $\gamma$ )Cd113m	Cd113m, Cd114, Cd115, Cd115m, In115, In116m	5	2	•	
<b>Cd112</b> (n,t)Ag110m	Pd107, Ag106m, Ag108m, Ag110m	4	0		
<b>Cd112</b> (n,2nt)Ag108m	Tc99, Pd107, Ag106m, Ag108m	4	0		
<b>Cd113</b> (n,3n)Cd111m	Pd107, Ag106m, Ag108m, Ag109m, Ag110m, Cd109, Cd111m	4	0		
<b>Cd113</b> (n, $\gamma$ )Cd114	Cd114, Cd115, Cd115m, In115, In116m	5	4	•	
<b>Cd113</b> (n,5n)Cd109	Tc98, Pd107, Ag106m, Ag108m, Ag109m, Cd109	4	0		
<b>Cd114</b> (n,2n)Cd113	Pd107, Ag110m, Cd109, Cd111m, Cd113, Cd113m	4	0		
<b>Cd114</b> (n,2n)Cd113m	Pd107, Ag110m, Cd109, Cd111m, Cd113m	5	2	•	
<b>Cd114</b> (n,4n)Cd111m	Pd107, Ag106m, Ag108m, Ag110m, Cd109, Cd111m	5	0		
<b>Cd114</b> (n, $\gamma$ )Cd115	Cd113m, Cd115, In115, In115m, In116m	5	4	•	
<b>Cd114</b> (n, $\gamma$ )Cd115m	Cd115m, In115, In116m	5	2	•	
<b>Cd116</b> (n,2n)Cd115	Cd115, In115, In116m	5	4	•	
<b>Cd116</b> (n,2n)Cd115m	Cd113m, Cd115m, In113m, In115, In116m	5	2	•	
<b>Cd116</b> (n,4n)Cd113m	Pd107, Ag110m, Cd109, Cd113m	4	0		
<b>Cd116</b> (n,d)Ag115	Cd115, In115, In116m	4	0		
<b>In113</b> (n,2n)In112m	Pd107, Ag108m, Ag110m, Sn109	4	5 <sub>2</sub>	•	•
<b>In113</b> (n,2n $\alpha$ )Ag108m	Tc98, Pd107, Ag108m	4	0		

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>In113</b> (n, $\gamma$ )In114	Cd113m, In114, In115m	5	1	•	
<b>In113</b> (n, $\gamma$ )In114m	H3, Ag110m, Cd113m, In114, In114m, In115, In115m, In116m	5	4	•	
<b>In113</b> (n, $\alpha$ )Ag110m	Pd107, Ag108m, Ag110m	5	0		
In114m(n, $\gamma$ )In115	In115, In116m	5	0		
In114m(n, $\gamma$ )In115m	Cd113m, In115, In115m, In116m	5	0		
In114m(n, $\alpha$ )Ag111	Ag110m, Cd113m	4	0		
<b>In115</b> (n,n')In115m	In113m, In115m, Sn113m	5	4	•	
<b>In115</b> (n,2n)In114m	Pd107, Ag108m, Ag110m, Cd113m, In113m, In114, In114m, Sn113m	5	4	•	
<b>In115</b> (n,3n) <b>In113</b>	Tc98, Pd107, Ag108m, Ag110m, Cd113m, In113m	4	0		
<b>In115</b> (n,3n)In113m	Pd107, Ag108m, Ag110m, In113m	5	0		
<b>In115</b> (n,2n $\alpha$ )Ag110m	Pd107, Ag108m, Ag110m	5	0		
<b>In115</b> (n,4n)In112m	Pd107, Ag108m, Ag110m, Sn109	5	0		
<b>In115</b> (n, $\gamma$ )In116	Sn117m, Sn119m, Sn121, Sn121m	4	5 <sub>2</sub>	•	•
<b>In115</b> (n, $\gamma$ )In116m	In116m, Sn117m, Sn119m, Sn121, Sn121m	5	5 <sub>1</sub>	•	•
<b>In115</b> (n, $\gamma$ )In116n	In116m, Sn117m, Sn119m, Sn121, Sn121m	5	2	•	
<b>In115</b> (n,t)Cd113m	Pd107, Ag108m, Ag110m, Cd113m	5	0		
<b>In115</b> (n,4n $\alpha$ )Ag108m	Pd107, Ag108m	4	0		
<b>Sn112</b> (n,2n)Sn111	H3, Pd107, Ag108m, Ag110m	4	6	•	•
<b>Sn112</b> (n,4n)Sn109	Ag108m, Sn109	5	0		
<b>Sn112</b> (n, $\gamma$ )Sn113	H3, Cd113m, In113m, In116m, Sn113	5	1	•	
<b>Sn112</b> (n, $\gamma$ )Sn113m	H3, Cd113m, In113m, In116m, Sn113, Sn113m	5	2	•	
<b>Sn112</b> (n, $\alpha$ )Cd109	Pd107, Ag108m, Ag110m, Cd113m	5	2	•	
Sn113(n, $\alpha$ ) <b>Cd110</b>	Pd107, Cd113m	4	0		
<b>Sn114</b> (n,2n)Sn113	H3, Pd107, Ag108m, Ag110m, Cd113m, In113m, Sn113, Sn113m	4	5 <sub>2</sub>	•	•
<b>Sn114</b> (n,2n)Sn113m	H3, Pd107, Ag108m, Ag110m, In113m, Sn113, Sn113m	5	2	•	
<b>Sn114</b> (n, $\gamma$ ) <b>Sn115</b>	Cd113m	4	4	•	
<b>Sn115</b> (n,2n) <b>Sn114</b>	Ag110m, In113m, Sn113, Sn113m	4	0		
<b>Sn115</b> (n,3n)Sn113m	Ag108m, Ag110m, In113m, Sn113, Sn113m	4	0		
<b>Sn115</b> (n, $\alpha$ ) <b>Cd112</b>	Cd113m	5	2	•	
<b>Sn116</b> (n,2n) <b>Sn115</b>	H3, Pd107, Ag108m, Ag110m, In113m, Sn113, Sn113m	4	0		
<b>Sn116</b> (n,3n) <b>Sn114</b>	H3, Pd107, Ag108m, Ag110m, In113m, Sn113, Sn113m	4	0		
<b>Sn116</b> (n,4n)Sn113m	Ag108m, Ag110m, In113m, Sn113, Sn113m	4	0		
<b>Sn116</b> (n, $\gamma$ ) <b>Sn117</b>	Sn117m, Sn119m, Sn121, Sn121m	5	4	•	
<b>Sn116</b> (n, $\gamma$ ) <b>Sn117m</b>	Sn117m, Sn119m, Sn121, Sn121m	5	4	•	
<b>Sn116</b> (n,p)In116m	In116m	5	6	•	•
<b>Sn116</b> (n,p)In116n	In116m	4	2	•	
<b>Sn116</b> (n, $\alpha$ )Cd113m	Pd107, Ag108m, Ag110m, Cd113m	5	0		
<b>Sn117</b> (n,3n) <b>Sn115</b>	H3, Pd107, Ag108m, Ag110m, In113m, In115, Sn113, Sn113m	4	0		
<b>Sn117</b> (n, $\alpha$ )Cd113m	Pd107, Ag108m, Ag110m, Cd113m	4	0		
<b>Sn117</b> (n, $\gamma$ ) <b>Sn118</b>	Sn119m, Sn121, Sn121m	5	4	•	
<b>Sn117</b> (n,5n)Sn113m	Ag108m, Ag110m, In113m, Sn113, Sn113m	5	0		
<b>Sn118</b> (n,2n)Sn117m	H3, Ag110m, Cd113m, In113m, In115, In116m, Sn113, Sn113m, Sn117m	5	5 <sub>2</sub> *	•	•
<b>Sn118</b> (n,2n $\alpha$ )Cd113m	Pd107, Ag108m, Ag110m, Cd113m	4	0		
<b>Sn118</b> (n, $\gamma$ ) <b>Sn119</b>	Sn119m, Sn121, Sn121m	5	4	•	
<b>Sn118</b> (n, $\gamma$ )Sn119m	Sn119m, Sn121, Sn121m	5	2	•	
<b>Sn118</b> (n,t)In116m	In113m, In116m, Sn113, Sn113m	4	0		
<b>Sn118</b> (n,t)In116n	In116m, Sn113m	4	0		
<b>Sn119</b> (n,n')Sn119m	In115, Sn117m, Sn119m	4	0		
<b>Sn119</b> (n,3n) <b>Sn117</b>	H3, Cd113m, In113m, In115, In116m, Sn113, Sn113m, Sn117m	4	0		
<b>Sn119</b> (n,3n)Sn117m	H3, Cd113m, In113m, In115, In116m, Sn113, Sn113m, Sn117m	4	0		



Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Sn119</b> (n,n $\alpha$ )Cd115	Ag110m, Cd113m, In113m, In115, Sn113m	4	0		
<b>Sn119</b> (n,n $\alpha$ )Cd115m	Ag110m, Cd113m, In113m, In115	4	0		
<b>Sn119</b> (n,3n $\alpha$ )Cd113m	Pd107, Ag110m, Cd113m	4	0		
<b>Sn119</b> (n, $\gamma$ ) <b>Sn120</b>	H3, Sn121, Sn121m, Sb122, Sb124	5	4	•	
<b>Sn120</b> (n,2n)Sn119m	H3, Cd113m, In115, In116m, Sn117m, Sn119m	5	6	•	•
<b>Sn120</b> (n,4n)Sn117m	H3, Ag108m, Ag110m, Cd113m, In113m, In115, In116m, Sn113, Sn113m, Sn117m	5	0		
<b>Sn120</b> (n, $\gamma$ )Sn121	H3, Sn121, Sb122, Sb124	5	4	•	
<b>Sn120</b> (n, $\gamma$ )Sn121m	Sn121, Sn121m	5	2	•	
<b>Sn122</b> (n,2n)Sn121	H3, Sn121	5	0		
<b>Sn122</b> (n,2n)Sn121m	H3, Sn121, Sn121m	5	2	•	
<b>Sn122</b> (n,4n)Sn119m	H3, Sn117m, Sn119m	4	0		
<b>Sn122</b> (n, $\gamma$ )Sn123	Sn123, Sn124, Sn126, Sb124	5	2	•	
<b>Sn122</b> (n, $\gamma$ )Sn123m	Sb124, Sb125, Sb126m	5	3	•	
<b>Sn122</b> (n,d)In121	Sn121, Sn121m	4	0		
Sn123(n, $\gamma$ )Sn124	Sn124, Sn126	5	0		
<b>Sn124</b> (n,2n)Sn123	H3, Sn121, Sn121m, Sn123, Sb122, Sb124	5	6/6	•	•
<b>Sn124</b> (n,2n)Sn123m	H3, Sb122, Sb124	4	6	•	•
<b>Sn124</b> (n,nt)In121	Sn121	4	0		
<b>Sn124</b> (n,4n)Sn121	Sn121, Sb122	4	0		
<b>Sn124</b> (n,4n)Sn121m	H3, Sn121, Sn121m	5	0		
<b>Sn124</b> (n, $\gamma$ )Sn125	Sn126, Sb124, Sb125, Sb126m	5	2	•	
<b>Sn124</b> (n, $\gamma$ )Sn125m	Sn125m, Sb124, Sb125, Sb126m	5	4	•	
Sn125(n, $\gamma$ )Sn126	Sn126	5	0		
Sb120m(n,2n)Sb119	In115, Sb119	5	0		
<b>Sb121</b> (n,2n)Sb120	H3, Cd113m, In113m, In115, Sn113m, Sn119m, Sn121, Sn121m	5	6/4	•	•
<b>Sb121</b> (n,2n)Sb120m	H3, Cd113m, In113m, In115, Sn113m, Sn119m, Sn121, Sn121m, Sb119, Sb120m	5	4	•	
<b>Sb121</b> (n,3n)Sb119	H3, Pd107, Cd113m, In113m, In115, Sn113m, Sn119m, Sb119	5	0		
<b>Sb121</b> (n,3n $\alpha$ )In115	Ag108m, Ag110m, Cd113m, In113m, In115	4	0		
<b>Sb121</b> (n,4n)Sb118	H3, Pd107, Ag110m, Cd113m, In113m, In115, Sn113m	4	0		
<b>Sb121</b> (n, $\gamma$ )Sb122	H3, Sn119m, Sn121, Sn121m, Sn123, Sn124, Sn126, Sb122, Sb124, Sb125, Sb126m, Te121, Te121m, Te123, Te123m, I129	5	3/3	•	
<b>Sb121</b> (n,p)Sn121	Sn121	4	2	•	
<b>Sb121</b> (n,p)Sn121m	Sn119m, Sn121, Sn121m	5	0		
<b>Sb121</b> (n,t)Sn119m	Cd113m, In113m, In115, Sn113m, Sn119m	5	0		
<b>Sb121</b> (n,5n)Sb117	H3, Cd113m, In113m, In115, Sn113m	5	0		
Sb122(n, $\gamma$ ) <b>Sb123</b>	Sb124, Sb125, Sb126m	5	0		
<b>Sb123</b> (n,2n)Sb122	H3, Sn113m, Sn119m, Sn121, Sn121m, Sn123, Sb119, Sb120m, Sb122, Te121, Te121m, Te123, Te123m	5	1	•	
<b>Sb123</b> (n,2n)Sb122m	Sn119m, Sn121, Sn121m, Sb119, Sb122, Te121, Te121m, Te123, Te123m	4	2	•	
<b>Sb123</b> (n,4n)Sb120m	Cd113m, In113m, In115, Sn113m, Sn119m, Sb120m	4	0		
<b>Sb123</b> (n, $\gamma$ )Sb124	Sn121, Sn121m, Sn124, Sn126, Sb124, Sb125, Sb126m, Te123, Te123m, I129	5	4/2/2	•	
<b>Sb123</b> (n, $\gamma$ )Sb124m	Sn121, Sn121m, Sn124, Sn126, Sb124, Sb125, Te123, Te123m, I129	4	2	•	
<b>Sb123</b> (n,p)Sn123	Sn121, Sn121m, Sn123, Sn124, Sn126	5	1/2	•	
<b>Sb123</b> (n,t)Sn121	Sn121	5	0		
<b>Sb123</b> (n,t)Sn121m	Cd113m, In113m, In115, Sn113m, Sn119m, Sn121, Sn121m	5	0		
<b>Sb123</b> (n,5n)Sb119	H3, Cd113m, In113m, In115, Sn113m, Sn119m, Sb119	5	0		
Sb124(n, $\gamma$ )Sb125	Sn126, Sb125, Sb126m, I129	5	2	•	
Sb125(n, $\gamma$ )Sb126m	Sn126, Sb126m, I129	4	0		
Sb125(n, $\gamma$ )Sb126n	Sb126m, I129	5	0		

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
Sb125(n,p)Sn125	Sn126	4	0		
Sb126(n,p)Sn126	Sn126	5	0		
<b>Te120(n,<math>\gamma</math>)Te121m</b>	H3, Sb125, Sb126m, Te121	5	2	•	
<b>Te120(n,<math>\gamma</math>)Te121</b>	H3, Sb125, Sb126m, Te121	5	2	•	
<b>Te122(n,2n)Te121m</b>	H3, Sn113m, Sn121, Sn121m, Sb119, Te121, Te121m	5	4	•	
<b>Te122(n,2n)Te121</b>	H3, Sn121, Sn121m, Sb119, Sb120m, Te121	4	4	•	
<b>Te122(n,<math>\gamma</math>)Te123m</b>	Sn121, Sn121m, Te123, Te123m, Te125m	5	1	•	
<b>Te122(n,<math>\gamma</math>)Te123</b>	Sn121, Sn121m, Te123, Te123m, Te125m, I129	5	2	•	
<b>Te122(n,<math>\alpha</math>)Sn119m</b>	Sn119m	5	0		
<b>Te123(n,2n)Te122</b>	Sn121, Sn121m, Te121	4	0		
<b>Te123(n,<math>\alpha</math>)Sn120</b>	Sn121, Sn121m	5	2	•	
Te123m(n, $\alpha$ )Sn120	Sn121, Sn121m	5	0		
<b>Te124(n,2n)Te123m</b>	H3, Te121, Te123, Te123m, Te125m	5	4	•	
<b>Te124(n,4n)Te121m</b>	H3, Sn121, Te121	4	0		
<b>Te124(n,4n)Te121</b>	Sn121, Te121	4	0		
<b>Te124(n,<math>\gamma</math>)Te125m</b>	Te125m	5	2	•	
<b>Te124(n,<math>\alpha</math>)Sn121</b>	Sn121	4	1	•	
<b>Te124(n,<math>\alpha</math>)Sn121m</b>	Sn121, Sn121m	5	0		
<b>Te125(n,2n)Te124</b>	H3, Sn121, Sn121m, Sb124, Te121, Te123m, Te125m	4	0		
<b>Te125(n,3n)Te123m</b>	H3, Sn121, Te121, Te123m, Te125m	5	0		
<b>Te125(n,<math>n\alpha</math>)Sn121</b>	Sn121	5	0		
<b>Te125(n,<math>n\alpha</math>)Sn121m</b>	Sn121, Sn121m	5	0		
<b>Te125(n,<math>\gamma</math>)Te126</b>	H3, Te127, Te127m, I128, I129	4	4	•	
<b>Te125(n,p)Sb125</b>	Sb125	4	0		
<b>Te125(n,d)Sb124m</b>	Sb124	4	0		
<b>Te125(n,<math>\alpha</math>)Sn122</b>	Sn121, Sn121m, Sb124, Sb125, Sb126m	5	0		
<b>Te125(n,5n)Te121m</b>	H3, Sn121, Te121	4	0		
<b>Te126(n,2n)Te125m</b>	H3, Sn121, Sn121m, Sb124, Sb125, Te121, Te123m, Te125m	5	2	•	
<b>Te126(n,2n<math>\alpha</math>)Sn121</b>	Sn121	4	0		
<b>Te126(n,2n<math>\alpha</math>)Sn121m</b>	Sn121, Sn121m	4	0		
<b>Te126(n,4n)Te123m</b>	H3, Sn121, Sn121m, Te121, Te123m, Te125m	5	0		
<b>Te126(n,<math>\gamma</math>)Te127</b>	H3, Te127, Te129, Te129m, I128, I129, Xe131m	5	4	•	
<b>Te126(n,<math>\gamma</math>)Te127m</b>	H3, Sn126, Te127, Te127m, Te129, Te129m, I128, I129, I130	5	2	•	
<b>Te126(n,p)Sb126n</b>	Sn126, Sb126m	4	2	•	
<b>Te126(n,p)Sb126</b>	Sn126, Sb125	5	2	•	
<b>Te126(n,p)Sb126m</b>	Sn126, Sb126m	5	2	•	
<b>Te126(n,d)Sb125</b>	Sn121, Sn121m, Sb125, Te121, Te123m, Te125m	5	0		
Te127m(n, $\gamma$ )Te128	Sn126, Te129, Te129m, I129, I130	4	2	•	
Te127m(n,2p)Sn126	Sn126	5	0		
<b>Te128(n,2n)Te127m</b>	H3, Sn121, Sn121m, Sb125, Sb126m, Te123m, Te125m, Te127, Te127m, I128, Xe127	5	2	•	
<b>Te128(n,2n)Te127</b>	H3, Sb126m, Te127	4	4	•	
<b>Te128(n,3n)Te126</b>	H3, Sn121, Sn121m, Sb125, Sb126m, Te121, Te123m, Te125m	4	0		
<b>Te128(n,nt)Sb125</b>	H3, Sn121, Sn121m, Sb125, Te121, Te123m, Te125m	5	0		
<b>Te128(n,4n)Te125m</b>	H3, Sn121, Sn121m, Sb125, Te121, Te123m, Te125m	4	0		
<b>Te128(n,<math>\gamma</math>)Te129</b>	Sn126, Te129, I129, I130, Xe131m, Cs134, Cs137	5	4	•	
<b>Te128(n,<math>\gamma</math>)Te129m</b>	Sn126, Te129, Te129m, I129, I130, Xe131m	5	2	•	
<b>Te128(n,t)Sb126m</b>	Sn121, Sn121m, Sb125, Sb126m, Te123m, Te125m	4	0		
<b>Te128(n,t)Sb126n</b>	Sb125, Sb126m, Te123m, Te125m	4	0		
<b>Te128(n,h)Sn126</b>	Sn121, Sn126	5	0		
<b>Te128(n,4n<math>\alpha</math>)Sn121m</b>	Sn121, Sn121m	4	0		

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
Te129m(n, $\alpha$ )Sn126	Sn126	5	0		
<b>Te130</b> (n,2n)Te129m	H3, Sn126, Sb125, Sb126m, Te127, Te127m, Te129, Te129m, I128, I129, I130, Xe127	5	4	•	
<b>Te130</b> (n,2n)Te129	H3, Sb125, Sb126m, Te129, I128, I129, I130, Xe127	4	6	•	•
<b>Te130</b> (n, $\alpha$ )Sn126	Sn121, Sn121m, Sn126, Sb125	5	0		
<b>Te130</b> (n,4n)Te127m	H3, Sn121, Sn121m, Sb125, Te121, Te123m, Te125m, Te127, Te127m, I128, Xe127	5	0		
<b>Te130</b> (n, $\gamma$ )Te131	I128, I130, I131, Xe127, Xe131m, Cs134, Cs137, Ba137m	5	2	•	
<b>Te130</b> (n, $\gamma$ )Te131m	I130, I131, Xe127, Xe131m, Cs134, Cs137, Ba137m	4	4	•	
<b>Te130</b> (n,d)Sb129	H3, Te129, Te129m, I128, I129, I130, Xe127	4	0		
<b>Te130</b> (n,6n)Te125m	H3, Sn121, Sn121m, Te121, Te123m, Te125m	4	0		
I125(n,2n)I124	Sn121, Sn121m, Te121, I124	5	0		
I125(n, $\gamma$ )I126	H3, Sn121m, Sb125, Sb126m, I129, Xe127	5	2	•	
I126(n, $\gamma$ ) <b>I127</b>	I129	5	2	•	
I126(n, $\alpha$ ) <b>Sb123</b>	Sn121m, Sb125, Sb126m, Te121	5	0		
<b>I127</b> (n,2n)I126	H3, Sn121, Sn121m, Sn126, Sb124, Sb125, Sb126m, Te121, Te127, Te127m, I124, I125, I126, Xe124, Xe127	5	6	•	•
<b>I127</b> (n,3n)I125	H3, Sn121, Sn121m, Sb124, Sb125, Te121, I124, I125	5	2	•	
<b>I127</b> (n,4n)I124	H3, Sn121, Sn121m, Sb124, Te121, I124	5	0		
<b>I127</b> (n, $\gamma$ )I128	H3, Sn126, Sb124, Sb125, Sb126m, Te127, Te127m, Te129, Te129m, I128, I129, I130, Xe127, Xe129m, Xe131m, Cs134, Cs135, Cs136, Cs137	5	5 <sub>2</sub>	•	•
<b>I127</b> (n,p)Te127	Te127	5	2	•	
<b>I127</b> (n,p)Te127m	Sn126, Sb126m, Te127, Te127m, Te129, Te129m	5	2	•	
<b>I127</b> (n,d) <b>Te126</b>	H3, Sn121, Sn121m, Sn126, Sb124, Sb125, Sb126m, Te121	4	0		
<b>I127</b> (n,h)Sb125	Sn121, Sb125	5	5 <sub>3</sub>		•
<b>I127</b> (n, $\alpha$ )Sb124	Sn121, Sn121m, Sb124, Sb125, Sb126m, Te121	5	5 <sub>0</sub>		•
<b>I127</b> (n, $\alpha$ )Sb124m	Sn121, Sn121m, Sb124, Sb125, Te121	4	2	•	
I128(n, $\alpha$ )Sb125	Sb124, Sb125, Sb126m	5	0		
I129(n,2n)I128	Sn121, Sn121m, Sb125, I128, Xe127	4	2	•	
I129(n, $\alpha$ )Sb125	Sn121, Sn121m, Sb125	5	0		
I129(n, $\gamma$ )I130	I130, Xe127, Xe131m, Cs134, Cs137	4	2	•	
I129(n, $\gamma$ )I130m	I130, Xe131m, Cs134	5	2	•	
<b>Xe124</b> (n,2n)Xe123	Te121	4	2	•	
<b>Xe124</b> (n, $\gamma$ )Xe125	H3, Sn121, Sn121m, Sb125, Sb126m, I125, I129, Xe127	5	2/2	•	
<b>Xe124</b> (n,p)I124	Sn121, Sn121m, I124	5	0		
<b>Xe124</b> (n, $\alpha$ )Te121	Sn121, Sn121m, Sb125, Sb126m, Te121	5	0		
<b>Xe124</b> (n, $\alpha$ )Te121m	Sn121, Sn121m, Sb125, Te121	4	0		
Xe125(n,2n)Xe124	Xe124	5	0		
Xe125(n, $\alpha$ ) <b>Te122</b>	Sn121, Sn121m	5	2	•	
<b>Xe126</b> (n,2n)Xe125	Sn121, Sn121m, Sb125, Te121, I124, I125, Xe124	5	2	•	
<b>Xe126</b> (n,2n)Xe125m	Sn121, Sn121m, Sb125, Te121, I124, I125, Xe124	4	2	•	
<b>Xe126</b> (n,3n)Xe124	Te121, I124, Xe124	5	0		
<b>Xe126</b> (n, $\gamma$ )Xe127	Sn121, Sn121m, Sb125, Sb126m, I129, Xe127	5	2/2	•	
<b>Xe126</b> (n, $\alpha$ )Te123	Sn121, Sn121m, Te121	5	0		
<b>Xe126</b> (n, $\alpha$ )Te123m	Sn121, Sn121m, Te121	4	0		
Xe127(n, $\alpha$ ) <b>Te124</b>	Sn121, Sn121m	4	2	•	
<b>Xe128</b> (n,2n)Xe127	H3, Sn121, Sn121m, Sb125, Sb126m, I124, I125, Xe127	5	2/2	•	
<b>Xe128</b> (n, $\gamma$ ) <b>Xe129</b>	Te127, Te127m, I129, I130, Xe129m, Xe131m, Cs134, Cs135, Cs136, Cs137	5	2	•	

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Xe128</b> (n, $\gamma$ )Xe129m	Te127, I129, I130, Xe129m, Xe131m, Cs134, Cs135, Cs136	5	2	•	
<b>Xe128</b> (n, $\alpha$ ) <b>Te125</b>	Sn121, Sn121m, Sb124, Sb125, Te127, Te127m	5	0		
<b>Xe129</b> (n,n')Xe129m	Xe129m	4	0		
<b>Xe129</b> (n,2n) <b>Xe128</b>	H3, Sn121, Sn121m, Sb125, Sb126m, Te121, I124, I125, Xe127	5	0		
<b>Xe129</b> (n,3n)Xe127	H3, Sn121, Sn121m, Sb125, Sb126m, Te121, I124, I125, Xe127	4	0		
<b>Xe129</b> (n,3n)Xe127m	H3, Sn121, Sn121m, Sb125, Sb126m, Te121, I124, I125, Xe127	5	0		
<b>Xe129</b> (n,nt)I126	Sn121, Sn121m, Sb125, Sb126m, Te121, I124, I125	4	0		
<b>Xe129</b> (n, $\gamma$ ) <b>Xe130</b>	I130, Xe131m, Xe133, Xe134m, Cs134, Cs135, Cs136, Cs137	5	2	•	
<b>Xe129</b> (n,p)I129	Sb125, Sb126m, I129, I130	5	0		
<b>Xe129</b> (n, $\alpha$ ) <b>Te126</b>	Sn121, Sn121m, Sb125, Sb126m, Te127, Te127m	5	0		
<b>Xe129</b> (n,5n)Xe125m	Sn121, Sn121m, Sb125, Te121, I124, I125	5	0		
<b>Xe130</b> (n,2n)Xe129m	H3, Sn121, Sn121m, I125, I129, Xe127, Xe129m	5	1	•	
<b>Xe130</b> (n,4n)Xe127m	Sn121, Sn121m, Sb125, Sb126m, I124, I125, Xe127	4	0		
<b>Xe130</b> (n, $\gamma$ ) <b>Xe131</b>	Xe131m, Xe133, Xe134m, Cs134, Cs135, Cs136, Cs137	5	2	•	
<b>Xe130</b> (n, $\gamma$ )Xe131m	Xe131m, Xe133, Xe134m, Cs134, Cs135, Cs136	5	2	•	
<b>Xe131</b> (n,n')Xe131m	Xe131m	4	0		
<b>Xe131</b> (n,2n) <b>Xe130</b>	H3, Sn121, Sn121m, Sb125, Sb126m, I124, I125, I129, Xe127, Xe129m	5	0		
<b>Xe131</b> (n,3n)Xe129m	H3, Sn121, Sn121m, Sb125, Sb126m, Te121, I124, I125, I129, Xe127, Xe129m	5	0		
<b>Xe131</b> (n, $\gamma$ ) <b>Xe132</b>	Xe133, Xe134m, Xe135, Xe135m, Cs134, Cs135, Cs136, Cs137, Ba137m	5	2	•	
<b>Xe131</b> (n,t)I129	H3, Sn121, Sn121m, Sb125, Sb126m, Te121, I124, I125, I129	5	0		
<b>Xe131</b> (n, $\alpha$ )Te128	Sn121, Sn121m, Sb125, Sb126m, I129	5	0		
<b>Xe131</b> (n,5n)Xe127m	Sn121, Sn121m, Sb125, Sb126m, I124, I125, Xe127	4	0		
<b>Xe132</b> (n,2n) <b>Xe131</b>	H3, Sn121, Sn121m, Sb125, I129, Xe127, Xe129m, Xe131m	4	0		
<b>Xe132</b> (n,2n)Xe131m	H3, Sb125, Sb126m, I125, I129, Xe127, Xe129m, Xe131m	5	2	•	
<b>Xe132</b> (n,nt)I129	H3, Sn121, Sn121m, Sb125, Sb126m, Te121, I124, I125, I129	4	0		
<b>Xe132</b> (n,4n)Xe129m	H3, Sn121, Sn121m, Sb125, Sb126m, Te121, I124, I125, I129, Xe127, Xe129m	5	0		
<b>Xe132</b> (n, $\gamma$ )Xe133	Xe133, Xe134m, Xe135, Xe135m, Cs134, Cs135, Cs136, Cs137, Ba137m	5	2	•	
<b>Xe132</b> (n, $\gamma$ )Xe133m	Xe133, Xe134m, Cs134, Cs135, Cs136, Cs137, Ba137m	5	2	•	
<b>Xe132</b> (n, $\alpha$ )Te129	Sb125, Sb126m, I129, Xe127	4	0		
Xe133(n, $\gamma$ )Xe134m	Xe134m, Cs137	5	0		
Xe133m(n, $\gamma$ )Xe134m	Xe134m	5	0		
<b>Xe134</b> (n,n')Xe134m	Xe134m	5	0		
<b>Xe134</b> (n,2n)Xe133	H3, Xe131m, Xe133	5	2	•	
<b>Xe134</b> (n,2n)Xe133m	Xe133	4	2	•	
<b>Xe134</b> (n,4n)Xe131m	H3, Sb125, Sb126m, I125, I129, Xe127, Xe129m, Xe131m	4	0		
<b>Xe134</b> (n, $\gamma$ )Xe135	Xe135, Cs134, Cs135, Cs136, Cs137, Ba137m	5	2	•	
<b>Xe134</b> (n, $\gamma$ )Xe135m	Xe135, Xe135m, Cs135, Cs136	5	2	•	
<b>Xe134</b> (n,d)I133	Xe133	4	0		
<b>Xe136</b> (n,2n)Xe135	H3, Xe134m, Xe135, Cs134, Cs135, Cs136, Ba133	5	2	•	
<b>Xe136</b> (n,2n)Xe135m	Xe134m, Xe135, Xe135m, Cs134, Cs135,	5	2	•	

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Xe136</b> (n,3n) <b>Xe134m</b>	Cs136, Ba133	5	0		
<b>Xe136</b> (n,4n) <b>Xe133m</b>	H3, Xe133, Xe134m	5	0		
<b>Xe136</b> (n,γ) <b>Xe137</b>	I129, Xe133, Cs134, Ba133	5	2	•	
<b>Xe136</b> (n,d) <b>I135</b>	Cs134, Cs136, Cs137, Ba133, Ba137m	5	0		
Cs131(n,2n) <b>Cs130</b>	Xe135, Xe135m, Cs134, Cs135, Cs136, Ba133	5	0		
Cs131(n,γ) <b>Cs132</b>	Cs130, Ba129m	5	0		
Cs132(n,2n) <b>Cs131</b>	I129, Xe131m, Xe133, Cs134, Cs136, Cs137	4	0		
Cs132(n,3n) <b>Cs130</b>	Xe127, Xe129m, Cs130, Cs131	4	0		
Cs132(n,α) <b>I129</b>	Cs130	4	0		
<b>Cs133</b> (n,2n) <b>Cs132</b>	Sb125, I129, Xe127, Xe131m	5	2	•	
<b>Cs133</b> (n,3n) <b>Cs131</b>	H3, Sn121, Sn121m, Sb125, I129, Xe127, Xe129m, Xe131m, Cs130, Cs131, Cs132, Ba133	5	6	•	•
<b>Cs133</b> (n,nα) <b>I129</b>	H3, Sn121, Sn121m, Sb125, I129, Xe127, Xe129m, Xe131m, Cs130, Cs131	5	1	•	
<b>Cs133</b> (n,4n) <b>Cs130</b>	H3, Sn121, Sn121m, Sb125, I129, Xe127, Xe129m, Cs130	5	0		
<b>Cs133</b> (n,4n) <b>Cs130m</b>	Sn121, Sn121m, Sb125, I129, Xe127, Xe129m, Cs130	5	0		
<b>Cs133</b> (n,γ) <b>Cs134</b>	H3, I129, Xe131m, Xe133, Cs134, Cs135, Cs136, Cs137, Ba133, Ba135m, Ba137m	5	4	•	
<b>Cs133</b> (n,γ) <b>Cs134m</b>	H3, I129, Xe131m, Xe133, Cs134, Cs135, Cs136, Cs137, Ba133, Ba137m	4	3	•	
<b>Cs133</b> (n,p) <b>Xe133</b>	Xe133	5	2	•	
<b>Cs133</b> (n,p) <b>Xe133m</b>	Xe133	5	2	•	
<b>Cs133</b> (n,t) <b>Xe131m</b>	Sn121, Sn121m, Sb125, I129, Xe127, Xe129m, Xe131m	5	0		
<b>Cs133</b> (n,5n) <b>Cs129</b>	H3, Sn121, Sn121m, I129, Xe127, Xe129m	4	0		
<b>Cs133</b> (n,2nt) <b>Xe129m</b>	Sn121, Sn121m, Xe127, Xe129m	5	0		
<b>Cs133</b> (n,4nα) <b>I126</b>	Sn121, Sn121m, Sb125	4	0		
Cs134(n,γ) <b>Cs135</b>	Xe133, Cs135, Cs136, Cs137, Ba137m	5	2/0	•	
Cs134(n,α) <b>I131</b>	I129, Xe131m, Xe133	5	0		
Cs135(n,2n) <b>Cs134</b>	Xe127, Cs134, Ba133	4	0		
Cs135(n,γ) <b>Cs136</b>	Xe133, Cs134, Cs136, Cs137, Ba133, Ba137m	5	2/0	•	
Cs136(n,γ) <b>Cs137</b>	Cs136, Cs137, Ba137m	5	0		
Cs136(n,α) <b>I133</b>	Xe133, Cs134	5	0		
Cs137(n,2n) <b>Cs136</b>	Cs136, Ba133	4	0		
<b>Ba130</b> (n,2n) <b>Ba129</b>	I129, Xe127	4	0		
<b>Ba130</b> (n,2n) <b>Ba129m</b>	I129, Xe127, Ba129m	4	2	•	
<b>Ba130</b> (n,γ) <b>Ba131</b>	I129, Xe131m, Xe133, Cs131, Cs134, Cs136, Cs137, Ba131, Ba133	5	2	•	
<b>Ba130</b> (n,γ) <b>Ba131m</b>	I129, Xe131m, Xe133, Cs131, Cs136, Ba131, Ba133	4	2	•	
<b>Ba130</b> (n,α) <b>Xe127</b>	Xe127, Xe131m	5	0		
<b>Ba131</b> (n,2n) <b>Ba130</b>	Cs130, Ba129m	4	0		
<b>Ba132</b> (n,2n) <b>Ba131</b>	I129, Xe129m, Xe131m, Cs130, Cs131, Ba129m, Ba131	4	6	•	•
<b>Ba132</b> (n,2n) <b>Ba131m</b>	I129, Xe127, Xe131m, Cs130, Cs131, Ba129 m, Ba131	4	4	•	
<b>Ba132</b> (n,γ) <b>Ba133</b>	Xe131m, Cs134, Cs135, Cs136, Cs137, Ba133, Ba135m	5	2/2	•	
<b>Ba133</b> (n,3n) <b>Ba131m</b>	I129, Xe131m, Cs131, Ba129m, Ba131	4	0		
<b>Ba133</b> (n,α) <b>Xe130</b>	Xe131m	5	0		
<b>Ba134</b> (n,2n) <b>Ba133</b>	I129, Xe127, Xe131m, Xe133, Cs131, Ba129m, Ba131, Ba133	4	3	•	
<b>Ba134</b> (n,2n) <b>Ba133m</b>	I129, Xe127, Xe131m, Xe133, Cs131, Ba129m, Ba131, Ba133	4	6	•	•
<b>Ba134</b> (n,4n) <b>Ba131m</b>	I129, Xe127, Xe131m, Cs131, Ba131	4	0		
<b>Ba134</b> (n,γ) <b>Ba135</b>	Xe133, Ba137m	5	5 <sub>2</sub>	•	•
<b>Ba134</b> (n,γ) <b>Ba135m</b>	Xe133, Ba135m, Ba137m	5	4	•	
<b>Ba134</b> (n,p) <b>Cs134</b>	Cs134	4	2/0	•	
<b>Ba134</b> (n,α) <b>Xe131m</b>	I129, Xe127, Xe131m	4	0		

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Ba135(n,2n)Ba134</b>	I129, Xe127, Xe131m, Xe133, Cs131, Cs134, Ba129m, Ba131, Ba133	4	0		
<b>Ba135(n,3n)Ba133</b>	I129, Xe127, Xe131m, Xe133, Cs131, Ba129m, Ba131, Ba133	4	0		
<b>Ba135(n,3n)Ba133m</b>	I129, Xe127, Xe131m, Xe133, Cs131, Ba129m, Ba131, Ba133	4	0		
<b>Ba135(n,<math>\alpha</math>)Xe131m</b>	I129, Xe127, Xe131m	4	0		
<b>Ba135(n,d)Cs134</b>	I129, Xe131m, Xe133, Cs131, Cs134, Ba131	4	0		
<b>Ba135(n,<math>\alpha</math>)Xe132</b>	I129, Xe131m, Xe133	5	0		
<b>Ba135(n,5n)Ba131m</b>	I129, Xe127, Xe131m, Cs131, Ba131	4	0		
<b>Ba136(n,2n)Ba135m</b>	I129, Xe131m, Cs131, Cs134, Cs135, Ba131, Ba133, Ba135m	5	6	•	•
<b>Ba136(n,4n)Ba133</b>	I129, Xe127, Xe131m, Cs131, Ba129m, Ba131, Ba133	4	0		
<b>Ba136(n,4n)Ba133m</b>	I129, Xe127, Xe131m, Cs131, Ba129m, Ba133	4	0		
<b>Ba136(n,<math>\gamma</math>)Ba137m</b>	Ba137m	5	2	•	
<b>Ba136(n,p)Cs136</b>	Cs136	4	1/0	•	
<b>Ba136(n,<math>\alpha</math>)Xe133</b>	I129, Xe131m, Xe133, Cs134	4	0/1	•	
<b>Ba137(n,3n)Ba135m</b>	I129, Xe127, Xe131m, Cs131, Cs134, Cs135, Ba131, Ba133, Ba135m	4	0		
<b>Ba137(n,<math>\alpha</math>)Xe133m</b>	I129, Xe131m, Xe133, Cs131	4	0		
<b>Ba137(n,p)Cs137</b>	Cs135, Cs136, Cs137	5	2	•	
<b>Ba137(n,d)Cs136</b>	Xe131m, Cs136, Ba135m	4	0		
<b>Ba138(n,2n)Ba137m</b>	I129, Xe131m, Xe133, Cs131, Cs134, Cs135, Cs136, Cs137, Ba131, Ba133, Ba135m, Ba137m	5	6	•	•
<b>Ba138(n,2n<math>\alpha</math>)Xe133m</b>	I129, Xe131m, Xe133, Cs131	5	0		
<b>Ba138(n,nt)Cs135</b>	I129, Xe127, Xe131m, Xe133, Cs131, Cs134, Cs135	5	0		
<b>Ba138(n,4n)Ba135m</b>	I129, Xe127, Xe131m, Xe133, Cs131, Cs134, Cs135, Ba131, Ba133, Ba135m	5	0		
<b>Ba138(n,<math>\gamma</math>)Ba139</b>	Cs137, Ba139, La137, La138, La140, Ce141	5	6*	•	•
<b>Ba138(n,d)Cs137</b>	I129, Xe131m, Xe133, Cs131, Cs134, Cs135, Cs136, Cs137, Ba137m	5	0		
<b>Ba138(n,t)Cs136</b>	Xe131m, Xe133, Cs131, Cs134, Cs136, Ba131, Ba133	5	0		
<b>Ba138(n,<math>\alpha</math>)Xe135</b>	I129, Cs131, Cs134, Cs135	4	2	•	
<b>Ba138(n,<math>\alpha</math>)Xe135m</b>	I129, Xe133, Cs131, Cs134, Cs135	4	4	•	
<b>Ba138(n,2nt)Cs134</b>	I129, Xe131m, Xe133, Cs131, Cs134, Ba131	4	0		
<b>Ba138(n,4n<math>\alpha</math>)Xe131m</b>	I129, Xe127, Xe131m	4	0		
<b>La137(n,2n)La136</b>	Cs134, Cs135, Cs136, Ba133, Ba137m, La136	5	0		
<b>La137(n,2n)La136m</b>	Cs134, Cs135, Cs136, Ba133, La136	4	0		
<b>La137(n,3n)La135</b>	Xe127, Cs134, Cs135, Ba129m, Ba133, La135	5	0		
<b>La137(n,<math>\gamma</math>)La138</b>	H3, Cs135, Ba137m, La138, La140	5	0		
<b>La137(n,<math>\alpha</math>)Cs134</b>	Cs134, Cs135, Ba133	4	0		
<b>La137(n,5n)La133</b>	Xe127, Ba129m, Ba133	5	0		
<b>La138(n,2n)La137</b>	H3, Xe127, Cs134, Cs135, Cs136, Cs137, Ba133, Ba137m, La136, La137	5	0		
<b>La138(n,3n)La136</b>	Cs134, Cs135, Cs136, Ba133, La136	4	0		
<b>La138(n,4n)La135</b>	Xe127, Cs134, Cs135, Ba129m, Ba133, La135	4	0		
<b>La138(n,<math>\gamma</math>)La139</b>	Cs137, Ba137m, La140, Ce141	5	2	•	
<b>La138(n,d)Ba137m</b>	Cs135, Cs136, Cs137, Ba137m	4	0		
<b>La138(n,<math>\alpha</math>)Cs135</b>	Cs134, Cs135, Cs136, Cs137, Ba129m, Ba133, Ba137m	5	0		
<b>La139(n,2n)La138</b>	H3, Xe127, Cs134, Cs135, Cs136, Cs137, Ba129m, Ba133, Ba137m, La135, La136, La137, La138	5	0		
<b>La139(n,3n)La137</b>	H3, Xe127, Cs134, Cs135, Cs136, Cs137, Ba133, Ba137m, La135, La136, La137	5	0		
<b>La139(n,<math>\alpha</math>)Cs135</b>	Xe127, Cs134, Cs135, Ba133	5	0		
<b>La139(n,2n<math>\alpha</math>)Cs134</b>	Xe127, Cs134	4	0		
<b>La139(n,2n<math>\alpha</math>)Cs134m</b>	Cs134	4	0		
<b>La139(n,4n)La136</b>	H3, Xe127, Cs134, Cs135, Cs136, Ba133, La136	5	0		

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>La139</b> (n,4n)La136m	Xe127, Cs134, Cs135, Cs136, Ba133, La136	4	0		
<b>La139</b> (n,γ)La140	Cs137, Ba137m, La135, La138, La140, Ce139, Ce141, Pm147	5	6*	•	•
<b>La139</b> (n,d) <b>Ba138</b>	H3, Cs134, Cs135, Cs136, Cs137, Ba133, Ba137m	5	0		
<b>La139</b> (n,t)Ba137m	Xe127, Cs134, Cs135, Cs136, Cs137, Ba133, Ba137m	5	2	•	
<b>La139</b> (n,h)Cs137	Cs134, Cs135, Cs136, Cs137	5	5 <sub>3</sub>		•
<b>La139</b> (n,α)Cs136	Cs134, Cs135, Cs136, Cs137, Ba133	5	6	•	•
<b>La139</b> (n,5n)La135	H3, Xe127, Cs134, Cs135, Ba133, La135	5	0		
La140(n,γ)La141	La138, Ce139, Ce141, Pm147	5	2	•	
La140(n,α)Cs137	Cs137, Ba137m	5	0		
La141(n,γ)La142	Pm147	4	0		
<b>Ce136</b> (n,2n)Ce135	Cs134, Cs135, Ba129m, Ba133, La135, Ce135	5	0		
<b>Ce136</b> (n,nα) <b>Ba132</b>	Ba129m	4	0		
<b>Ce136</b> (n,4n)Ce133m	Ba129m, Ba133	4	0		
<b>Ce136</b> (n,γ)Ce137	H3, Cs134, Cs135, Ba137m, La137, La138, La140, Ce137, Ce139, Ce139m	5	2/2	•	
<b>Ce136</b> (n,α)Ba133	Cs134, Cs135, Ba129m, Ba133, Ba137m	5	0		
Ce137m(n,2n)Ce136	La135, Ce135	4	0		
<b>Ce138</b> (n,2n)Ce137m	H3, Cs134, Cs135, Ba137m, La135, La136, La137, Ce135, Ce137	5	4	•	
<b>Ce138</b> (n,3n)Ce136	H3, Cs134, Ba129m, Ba133, La136, Ce135, Ce136	5	0		
<b>Ce138</b> (n,4n)Ce135	Cs134, Cs135, Ba129m, Ba133, Ce135	4	0		
<b>Ce138</b> (n,γ)Ce139	Ba137m, La140, Ce139	5	2	•	
<b>Ce138</b> (n,γ)Ce139m	La140, Ce139, Ce139m	5	2	•	
Ce139(n,2n) <b>Ce138</b>	Cs134, Ba133, La135, La136, La137, Ce135, Ce136, Ce137	4	0		
Ce139(n,α) <b>Ba136</b>	Ba133, Ba137m	5	0		
<b>Ce140</b> (n,2n)Ce139	H3, Cs134, Cs135, Cs137, Ba129m, Ba133, Ba137m, La135, La136, La137, La138, La140, Ce135, Ce136, Ce137, Ce139, Ce139m	5	2	•	
<b>Ce140</b> (n,2n)Ce139m	H3, Cs134, Cs135, Ba133, Ba137m, La135, La136, La137, La138, La140, Ce135, Ce136, Ce137, Ce139, Ce139m	5	6	•	•
<b>Ce140</b> (n,3n) <b>Ce138</b>	H3, Cs134, Cs135, Ba129m, Ba133, Ba137m, La136, La137, La138, Ce135, Ce136, Ce137	5	0		
<b>Ce140</b> (n,4n)Ce137	H3, Cs134, Cs135, Ba129m, Ba133, Ba137m, La136, La137, Ce137	4	0		
<b>Ce140</b> (n,4n)Ce137m	Cs134, Cs135, Ba129m, Ba133, Ba137m, La136, La137, Ce137	5	0		
<b>Ce140</b> (n,γ)Ce141	Cs135, La138, Ce139, Ce141, Ce143, Ce144, Pr142, Pr143, Pr144, Pm147, Sm147	5	4	•	
<b>Ce140</b> (n,p)La140	Cs137, La140	5	4	•	
<b>Ce140</b> (n,t)La138	H3, Cs134, Cs135, Ba129m, Ba133, Ba137m, La136, La137, La138	5	0		
<b>Ce140</b> (n,α) <b>Ba137</b>	Cs134, Cs135, Cs137, Ba133, Ba137m	4	0		
<b>Ce140</b> (n,α)Ba137m	Cs134, Cs135, Cs137, Ba129m, Ba133, Ba137m	5	6	•	•
<b>Ce140</b> (n,5n)Ce136	H3, Cs134, Cs135, Ba129m, Ba133, La136, Ce135, Ce136	5	0		
<b>Ce140</b> (n,2nt)La136	Cs134, Cs135, Ba129m, Ba133, La136	4	0		
<b>Ce142</b> (n,2n)Ce141	H3, Ba137m, La140, Ce139, Ce139m, Ce141, Pr142	5	4	•	
<b>Ce142</b> (n,4n)Ce139m	Cs134, Cs135, Ba137m, La136, La137, La138, Ce136, Ce139, Ce139m	4	0		
<b>Ce142</b> (n,γ)Ce143	Ce143, Ce144, Pr142, Pr143, Pr144, Pm147, Sm147	5	4	•	
<b>Ce142</b> (n,d)La141	Ce141, Pr142	4	0		
<b>Ce142</b> (n,t)La140	La140	4	0		
Ce143(n,γ)Ce144	Ce144, Pr144, Pm147, Sm147	5	2	•	
<b>Pr141</b> (n,2n)Pr140	H3, Cs134, Cs135, Cs137, Ba129m, Ba133,	5	5 <sub>2</sub>	•	•

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Pr141</b> (n,3n)Pr139	Ba137m, La137, La138, La140, Ce135, Ce139, Ce139m, Ce141, Pr140 H3, Cs134, Cs135, Cs137, Ba129m, Ba133, Ba137m, La137, La138, La140, Ce135, Ce139, Pr139	5	4	•	
<b>Pr141</b> (n,4n)Pr138	H3, Cs134, Cs135, Ba129m, Ba133, La137, La138, Ce135	4	0		
<b>Pr141</b> (n,4n)Pr138m	H3, Cs134, Cs135, Ba129m, Ba133, La137, La138, Ce135, Pr138m	5	0		
<b>Pr141</b> (n, $\gamma$ )Pr142	H3, Cs137, Ba137m, La140, Ce139, Ce141, Ce144, Pr138m, Pr139, Pr142, Pr143, Pr144, Nd144, Nd147, Pm147, Pm148m, Sm147	5	2	•	
<b>Pr141</b> (n, $\gamma$ )Pr142m	H3, Cs137, Ba137m, La140, Ce139, Ce141, Ce144, Pr138m, Pr139, Pr142, Pr143, Pr144, Nd144, Nd147, Pm147, Pm148m, Sm147	5	2	•	
<b>Pr141</b> (n,p)Ce141	La140, Ce141, Ce144, Pr143	5	4	•	
<b>Pr141</b> (n,d)Ce140	H3, Cs135, Cs137, Ba129m, Ba133, Ba137m, La137, La138, La140, Ce135, Ce139	4	0		
<b>Pr141</b> (n, $\alpha$ )La138	H3, Cs134, Cs135, Cs137, Ba129m, Ba133, Ba137m, La137, La138, La140, Ce141	5	2	•	
<b>Pr141</b> (n,5n)Pr137	Cs134, Cs135, Ba129m, Ba133, Ba137m, La137	5	0		
Pr142(n, $\gamma$ )Pr143	La140, Ce141, Pr143, Pr144, Nd144, Nd147, Pm147, Pm148m, Sm147	5	2	•	
Pr142(n, $\alpha$ ) <b>La139</b>	Cs137, Ba137m, La140, Ce141	5	0		
Pr143(n, $\gamma$ )Pr144	Pr144, Nd147, Pm147, Sm147	4	0		
Pr143(n, $\gamma$ )Pr144m	Pr144, Nd144, Nd147, Pm147, Pm148m, Sm147	5	0		
Nd140(n,2n)Nd139m	Pr139, Nd139m	5	0		
Nd140(n,t)Pr138m	Pr138m	5	0		
Nd141(n,2n)Nd140	Pr138m, Pr139, Nd139m, Nd140	5	0		
<b>Nd142</b> (n,2n)Nd141	H3, La137, La138, Ce139, Pr138m, Pr139, Pr140, Nd139m, Nd140, Nd141	5	2	•	
<b>Nd142</b> (n,2n)Nd141m	H3, La137, La138, Ce139, Pr138m, Pr139, Pr140, Nd139m, Nd140, Nd141, Nd141m	5	6	•	•
<b>Nd142</b> (n,3n)Nd140	H3, La137, La138, Ce139, Pr138m, Pr140, Nd139m, Nd140	5	0		
<b>Nd142</b> (n,4n)Nd139m	H3, La137, La138, Ce139, Nd139m	5	0		
<b>Nd142</b> (n, $\gamma$ ) <b>Nd143</b>	Cs135, Ba137m, La138, Ce141, Pr143, Pr144, Nd144, Nd147, Pm147, Pm148m, Sm147	5	4	•	
<b>Nd142</b> (n, $\alpha$ )Ce139	Cs135, Cs137, Ba137m, La137, La138, La140, Ce139, Ce141	5	2	•	
<b>Nd142</b> (n, $\alpha$ )Ce139m	Cs137, Ba137m, La137, La138, La140, Ce139	4	1	•	
<b>Nd143</b> (n,3n)Nd141m	H3, La137, La138, Ce139, Pr140, Nd139m, Nd141, Nd141m	4	0		
<b>Nd143</b> (n, $\gamma$ )Nd144	Cs135, La138, Ce141, Pr144, Nd144, Nd147, Pm147, Pm148m, Sm147, Sm151, Eu152	5	4	•	
<b>Nd143</b> (n,p)Pr143	Pr143, Pr144	4	2	•	
<b>Nd143</b> (n, $\alpha$ )Ce140	Cs135, Ba137m, La137, La138, Ce139, Ce141	4	4	•	
<b>Nd143</b> (n,5n)Nd139m	La137, La138, Ce139, Nd139m	4	0		
<b>Nd144</b> (n,4n)Nd141m	H3, La137, La138, Ce139, Pr140, Nd141, Nd141m	4	0		
<b>Nd144</b> (n, $\gamma$ ) <b>Nd145</b>	Nd147, Nd149, Pm147, Pm148m, Sm147, Sm151, Eu152	5	4	•	
<b>Nd144</b> (n,p)Pr144	Pr144	4	2/2	•	
<b>Nd144</b> (n, $\alpha$ )Ce141	Cs135, La137, La138, Ce139, Ce141, Pr140	5	2	•	
<b>Nd144</b> (n,5n)Nd140	H3, La137, La138, Ce139, Pr140, Nd140	4	0		
<b>Nd145</b> (n, $\gamma$ ) <b>Nd146</b>	H3, Nd147, Nd149, Pm147, Pm148m, Sm147, Sm151, Eu152, Eu154	5	4	•	
<b>Nd146</b> (n, $\gamma$ )Nd147	H3, Nd147, Nd149, Pm144, Pm145, Pm146, Pm147, Pm148m, Sm146, Sm147, Sm151, Eu152	5	4	•	
<b>Nd148</b> (n,2n)Nd147	H3, Nd147, Pm144, Pm145, Pm146, Pm147, Pm148m, Sm146, Sm147	5	4	•	
<b>Nd148</b> (n, $\gamma$ )Nd149	Nd149, Pm148m, Sm146, Sm151, Eu152,	5	4	•	



Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Nd150</b> (n,2n)Nd149	Eu154, Eu155, Eu156 H3, Nd149, Pm144, Pm145, Pm146, Pm147, Pm148m, Sm146, Sm147	5	5 <sub>2</sub>	•	•
<b>Nd150</b> (n,4n)Nd147	H3, Nd147, Pm144, Pm145, Pm146, Pm147, Pm148m, Sm146, Sm147	5	0		
<b>Nd150</b> (n,γ)Nd151	H3, Nd151, Pm148m, Sm146, Sm151, Eu150, Eu152, Eu154, Eu155, Eu156	5	4	•	
<b>Nd150</b> (n,d)Pr149	Nd149, Pm144, Pm145, Pm146, Pm148m, Sm146, Sm147	4	0		
Pm145(n,2n)Pm144	Pm144	5	0		
Pm145(n,γ)Pm146	Pm146, Sm146, Sm147	5	0		
Pm146(n,2n)Pm145	La137, La138, Pm144, Pm145	5	0		
Pm147(n,2n)Pm146	La137, La138, Pm144, Pm145, Pm146, Sm146	5	0		
Pm147(n,3n)Pm145	La137, La138, Pm144, Pm145	4	0		
Pm147(n,4n)Pm144	Pm144	5	0		
Pm147(n,γ)Pm148m	Pm148m, Sm151	5	2	•	
Pm149(n,2n)Pm148m	Pm148m	4	0		
<b>Sm144</b> (n,γ)Sm145	Pm145, Pm146, Sm145, Sm146, Sm147	5	4	•	
<b>Sm144</b> (n,α)Nd141	La137, La138	5	0		
Sm145(n,γ)Sm146	Sm146, Sm147	5	2	•	
Sm146(n,2n)Sm145	Pm144, Pm145, Sm145	5	0		
Sm146(n,p)Pm146	Pm144, Pm145, Pm146	4	0		
<b>Sm147</b> (n,2n)Sm146	La138, Pm144, Pm145, Pm146, Sm145, Sm146	5	0		
<b>Sm147</b> (n,3n)Sm145	La137, La138, Pm144, Pm145, Sm145	5	0		
<b>Sm147</b> (n,nt)Pm144	La137, La138, Pm144	4	0		
<b>Sm147</b> (n,γ)Sm148	Sm151, Sm153, Eu152, Eu154, Eu155, Eu156	4	4	•	
<b>Sm147</b> (n,d)Pm146	Pm144, Pm145, Pm146, Sm146	5	0		
<b>Sm148</b> (n,2n)Sm147	Pm144, Pm145, Pm146, Sm145, Sm146, Sm147	4	4	•	
<b>Sm148</b> (n,3n)Sm146	La138, Pm144, Pm145, Pm146, Sm145, Sm146	5	0		
<b>Sm148</b> (n,4n)Sm145	La138, Pm144, Pm145, Sm145	4	0		
<b>Sm148</b> (n,γ)Sm149	Sm151, Sm153, Eu152, Eu154, Eu155, Eu156	4	4	•	
<b>Sm148</b> (n,p)Pm148m	Pm148m	4	2	•	
<b>Sm148</b> (n,t)Pm146	Pm144, Pm146, Sm146	4	0		
<b>Sm148</b> (n,2nt)Pm144	Pm144	4	0		
<b>Sm149</b> (n,2n)Sm148	Pm144, Pm145, Pm146, Pm148m, Sm145, Sm146, Sm147	4	0		
<b>Sm149</b> (n,3n)Sm147	Pm144, Pm145, Pm146, Sm145, Sm146, Sm147	5	0		
<b>Sm149</b> (n,nt)Pm146	Pm144, Pm146, Sm146	4	0		
<b>Sm149</b> (n,4n)Sm146	La138, Pm144, Pm145, Pm146, Sm145, Sm146	5	0		
<b>Sm149</b> (n,γ) <b>Sm150</b>	Sm147, Sm151, Sm153, Eu152, Eu154, Eu155, Eu156	5	4	•	
<b>Sm149</b> (n,d)Pm148m	Pm148m, Sm145, Sm146	5	0		
<b>Sm149</b> (n,α) <b>Nd146</b>	Sm147	5	4	•	
<b>Sm149</b> (n,5n)Sm145	La138, Pm144, Pm145, Sm145	4	0		
<b>Sm150</b> (n,γ)Sm151	Sm151, Sm153, Sm155, Eu152, Eu154, Eu155, Eu156, Gd152	5	4	•	
<b>Sm150</b> (n,α)Nd147	Pm146, Sm146, Sm147	5	3	•	
<b>Sm150</b> (n,5n)Sm146	La138, Pm144, Pm145, Pm146, Sm145, Sm146	4	0		
Sm151(n,γ) <b>Sm152</b>	Sm153, Sm155, Eu154, Eu155, Eu156	5	2	•	
<b>Sm152</b> (n,2n)Sm151	Pm146, Sm145, Sm146, Sm147, Sm151, Eu150, Gd148, Gd150	5	4	•	
<b>Sm152</b> (n,γ)Sm153	Sm153, Sm155, Eu150, Eu152, Eu154, Eu155, Eu156, Gd148, Gd150, Tb160, Tb161	5	4*	•	
Sm153(n,γ) <b>Sm154</b>	Sm155, Eu155, Eu156, Tb160, Tb161	4	2	•	
<b>Sm154</b> (n,2n)Sm153	Pm146, Sm153, Eu150, Eu152, Eu154, Gd148, Gd150	5	6	•	•
<b>Sm154</b> (n,4n)Sm151	Pm145, Pm146, Sm145, Sm146, Sm147, Sm151, Eu150, Gd148, Gd150	5	0		
<b>Sm154</b> (n,γ)Sm155	Sm155, Eu150, Eu152, Eu154, Eu155, Eu156, Gd148, Gd150, Tb160, Tb161	5	4	•	
<b>Sm154</b> (n,d)Pm153	Sm153, Eu150, Eu152, Eu154, Gd148, Gd150	4	0		
Eu149(n,2n)Eu148	Sm146, Sm147, Eu148	5	0		

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
Eu150(n,2n)Eu149	La137, La138, Sm146, Sm147, Eu148, Eu149	5	0		
Eu150(n,3n)Eu148	Sm146, Sm147, Eu148	4	0		
<b>Eu151</b> (n,2n)Eu150	La137, La138, Sm146, Sm147, Eu148, Eu149, Eu150, Gd148, Gd150	5	4	•	
<b>Eu151</b> (n,2n)Eu150m	Sm146, Sm147, Eu148, Eu149, Gd148, Gd150	5	4	•	
<b>Eu151</b> (n,3n)Eu149	Sm146, Sm147, Eu148, Eu149	5	4	•	
<b>Eu151</b> (n,4n)Eu148	Sm146, Sm147, Eu148	5	0		
<b>Eu151</b> (n,γ)Eu152	H3, Sm147, Sm151, Eu152, Eu154, Eu155, Eu156, Gd152, Gd153, Gd160, Tb160, Tb161	5	2/5/2	•	
<b>Eu151</b> (n,γ)Eu152m	H3, Sm147, Sm151, Eu152m, Eu154, Eu155, Eu156, Gd152, Gd153, Gd160, Tb160, Tb161	5	5 <sub>2</sub>	•	•
<b>Eu151</b> (n,p)Sm151	Sm147, Sm151	4	0		
<b>Eu151</b> (n,5n)Eu147	Sm146, Sm147	5	0		
<b>Eu151</b> (n,6n)Eu146	Sm146	5	0		
Eu152(n,2n) <b>Eu151</b>	Sm146, Sm147, Sm151, Eu148, Eu149, Eu150, Gd148, Gd150	4	0		
Eu152(n,γ) <b>Eu153</b>	Sm151, Eu154, Eu155, Eu156, Gd160, Tb160, Tb161	4	4	•	
Eu152(n,α)Pm149	Sm147, Sm151	4	0		
<b>Eu153</b> (n,2n)Eu152	Sm146, Sm147, Sm151, Eu148, Eu149, Eu150, Eu152, Eu152m, Gd148, Gd150, Gd152, Gd153	5	4/4/4	•	
<b>Eu153</b> (n,2n)Eu152m	Sm151, Eu150, Eu152m, Gd148, Gd150, Gd152, Gd153	5	4	•	
<b>Eu153</b> (n,4n)Eu150	Sm146, Sm147, Eu148, Eu149, Eu150, Gd148, Gd150	5	0		
<b>Eu153</b> (n,4n)Eu150m	Sm146, Sm147, Gd148, Gd150	5	0		
<b>Eu153</b> (n,γ)Eu154	Sm151, Eu154, Eu155, Eu156, Gd152, Gd153, Gd160, Tb160, Tb161	5	4/0	•	
<b>Eu153</b> (n,t)Sm151	Sm146, Sm147, Sm151	5	0		
<b>Eu153</b> (n,5n)Eu149	Sm146, Sm147, Eu149	5	0		
<b>Eu153</b> (n,6n)Eu148	Sm146, Sm147, Eu148	5	0		
Eu154(n,γ)Eu155	Eu155, Eu156, Gd160, Tb160, Tb161	5	4	•	
Eu155(n,2n)Eu154	Sm151, Eu154, Gd148, Gd150, Gd153	4	0		
Eu155(n,γ)Eu156	Eu156, Gd160, Tb160, Tb161	5	4	•	
Eu156(n,γ)Eu157	Gd160, Tb160, Tb161	5	0		
Eu156(n,α)Pm153	Eu154, Eu155, Gd150	4	0		
Gd149(n,2n)Gd148	Sm147, Gd148	5	0		
Gd150(n,2n)Gd149	Sm146, Sm147, Eu148, Eu149, Gd148	5	0		
Gd150(n,3n)Gd148	Gd148	5	0		
Gd150(n,nα)Sm146	Sm146	4	0		
Gd151(n,2n)Gd150	Gd148, Gd150	5	0		
<b>Gd152</b> (n,2n)Gd151	La138, Sm151, Eu150, Gd148, Gd150	5	2	•	
<b>Gd152</b> (n,3n)Gd150	Eu150, Gd148, Gd150	4	0		
<b>Gd152</b> (n,γ)Gd153	Sm147, Sm151, Eu152, Eu154, Eu155, Eu156, Gd153, Gd160, Tb160, Tb161	5	4	•	
<b>Gd152</b> (n,α)Sm149	La137, La138, Sm147, Sm151, Eu152	5	2	•	
<b>Gd152</b> (n,5n)Gd148	Gd148	4	0		
Gd153(n,2n)Gd152	Eu150, Gd148, Gd150, Gd152	4	0		
Gd153(n,4n)Gd150	Eu150, Gd148, Gd150	4	0		
Gd153(n,γ) <b>Gd154</b>	Sm151, Eu152, Gd152, Gd160, Tb160, Tb161	5	2	•	
Gd153(n,α) <b>Sm150</b>	Sm147, Sm151, Eu152, Gd152	4	2	•	
<b>Gd154</b> (n,2n)Gd153	Sm151, Eu150, Eu152, Eu154, Gd148, Gd150, Gd152, Gd153	5	2	•	
<b>Gd154</b> (n,3n)Gd152	Eu150, Eu152, Gd148, Gd150, Gd152	4	0		
<b>Gd154</b> (n,p)Eu154	Eu152, Eu154	4	0		
<b>Gd154</b> (n,α)Sm151	Sm151, Eu152, Gd152	5	2	•	
<b>Gd155</b> (n,2n) <b>Gd154</b>	Sm151, Eu150, Eu152, Eu154, Gd148, Gd150, Gd152, Gd153	5	4	•	
<b>Gd155</b> (n,3n)Gd153	Sm151, Eu150, Eu152, Gd148, Gd150, Gd152, Gd153	5	0		
<b>Gd155</b> (n,nα)Sm151	Sm151	5	0		
<b>Gd155</b> (n,nt)Eu152	Sm151, Eu150, Eu152	4	0		

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Gd155</b> (n,4n)Gd152	Eu150, Eu152, Gd148, Gd150, Gd152	5	0		
<b>Gd155</b> (n, $\gamma$ ) <b>Gd156</b>	Gd159, Gd160, Tb160, Tb161, Tb162	4	4	•	
<b>Gd155</b> (n,p)Eu155	Eu150, Eu152, Eu154, Eu155	5	0		
<b>Gd155</b> (n,d)Eu154	Sm151, Eu150, Eu152, Eu154	4	0		
<b>Gd155</b> (n,6n)Gd150	Eu150, Gd148, Gd150	5	0		
<b>Gd156</b> (n,2n) <b>Gd155</b>	Sm151, Eu150, Eu152, Eu154, Eu155, Gd148, Gd150, Gd152, Gd153	4	4	•	
<b>Gd156</b> (n,3n) <b>Gd154</b>	Sm151, Eu150, Eu152, Eu154, Gd148, Gd150, Gd152, Gd153	4	0		
<b>Gd156</b> (n,2 $\alpha$ )Sm151	Sm151	4	0		
<b>Gd156</b> (n,4n)Gd153	Sm151, Eu150, Eu152, Gd148, Gd150, Gd152, Gd153	5	0		
<b>Gd156</b> (n, $\gamma$ ) <b>Gd157</b>	Eu155, Gd159, Gd160, Tb160, Tb161, Tb162	5	4	•	
<b>Gd156</b> (n,p)Eu156	Eu155, Eu156	5	2	•	
<b>Gd156</b> (n,d)Eu155	Sm151, Eu150, Eu152, Eu154, Eu155, Gd150, Gd152	5	0		
<b>Gd156</b> (n,t)Eu154	Sm151, Eu150, Eu152, Eu154, Gd150	4	0		
<b>Gd156</b> (n, $\alpha$ )Sm153	Sm151, Eu150, Eu152, Eu154, Eu155, Gd150	5	2	•	
<b>Gd156</b> (n,5n)Gd152	Eu150, Eu152, Gd148, Gd150, Gd152	4	0		
<b>Gd157</b> (n,3 $\alpha$ )Sm151	Sm151	4	0		
<b>Gd157</b> (n, $\gamma$ ) <b>Gd158</b>	Eu155, Gd159, Gd160, Tb160, Tb161, Tb162, Ho166m	5	4	•	
<b>Gd157</b> (n,d)Eu156	Sm151, Eu150, Eu156, Gd152, Gd153	4	0		
<b>Gd157</b> (n,t)Eu155	Sm151, Eu150, Eu152, Eu154, Eu155, Gd150	4	0		
<b>Gd157</b> (n, $\alpha$ ) <b>Sm154</b>	Sm151, Eu155	5	2	•	
<b>Gd157</b> (n,5n)Gd153	Sm151, Eu150, Eu152, Gd148, Gd150, Gd152, Gd153	4	0		
<b>Gd157</b> (n,6n)Gd152	Eu150, Eu152, Gd148, Gd150, Gd152	4	0		
<b>Gd158</b> (n,nt)Eu155	Sm151, Eu150, Eu152, Eu155, Gd150	4	0		
<b>Gd158</b> (n, $\gamma$ )Gd159	Gd159, Gd160, Tb154m, Tb157, Tb158, Tb160, Tb161, Tb162, Ho166m	5	4	•	
<b>Gd158</b> (n,t)Eu156	Sm151, Eu150, Eu152, Eu156, Gd152, Gd153	4	0		
<b>Gd158</b> (n, $\alpha$ )Sm155	Eu150, Eu152, Eu154, Eu155	4	5 <sub>2</sub>	•	•
<b>Gd158</b> (n,6n)Gd153	Sm151, Eu150, Eu152, Gd148, Gd150, Gd152, Gd153	4	0		
Gd159(n, $\gamma$ )Gd160	Gd160	5	0		
<b>Gd160</b> (n,2n)Gd159	Eu155, Eu156, Gd159, Tb154m, Tb157, Tb158, Tb160	5	5 <sub>2</sub>	•	•
<b>Gd160</b> (n, $\gamma$ )Gd161	Gd161, Tb157, Tb160, Tb161, Tb162, Ho166m	5	6	•	•
<b>Gd160</b> (n,d)Eu159	Gd159, Tb154m, Tb157, Tb158, Tb160	4	0		
<b>Gd160</b> (n,2nt)Eu156	Eu156, Gd152	4	0		
Tb155(n,2n)Tb154m	Gd152, Tb154m	5	0		
Tb156(n,2n)Tb155	Sm151, Gd153, Tb154m, Tb155	4	0		
Tb157(n,2n)Tb156	Sm151, Eu154, Eu155, Gd148, Gd150, Gd152, Gd153, Tb154m, Tb155, Tb156	4	0		
Tb157(n,2n)Tb156m	Sm151, Eu154, Gd150, Gd153, Tb154m, Tb155	4	0		
Tb157(n,3n)Tb155	Sm151, Eu154, Eu155, Gd148, Gd150, Gd152, Gd153, Tb154m, Tb155	5	0		
Tb157(n,4n)Tb154m	Sm151, Gd148, Gd150, Gd152, Gd153, Tb154m	5	0		
Tb157(n, $\gamma$ )Tb158	Tb158, Tb160, Tb161	5	0		
Tb157(n, $\gamma$ )Tb158m	Tb158, Tb160, Tb161	4	0		
Tb157(n, $\alpha$ )Eu154	Sm151, Eu154, Gd148, Gd150, Gd153	4	0		
Tb157(n,5n)Tb153	Sm151, Gd148, Gd150, Gd152, Gd153	4	0		
Tb158(n,2n)Tb157	H3, Sm151, Eu154, Gd148, Gd150, Gd153, Tb154m, Tb155, Tb156, Tb157	5	0		
Tb158(n,3n)Tb156	Sm151, Eu154, Eu155, Gd148, Gd150, Gd153, Tb154m, Tb156	4	0		
Tb158(n,4n)Tb155	Sm151, Eu154, Gd148, Gd150, Gd152, Gd153, Tb154m, Tb155	4	0		
Tb158(n, $\gamma$ ) <b>Tb159</b>	Tb160, Tb161	5	0		
Tb158(n, $\alpha$ )Eu155	Sm151, Eu154, Eu155, Gd150, Gd153	5	0		
<b>Tb159</b> (n,2n)Tb158	H3, Sm151, Eu154, Eu155, Gd148, Gd150,	5	4	•	

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Tb159(n,2n)Tb158m</b>	Gd153, Tb154m, Tb155, Tb156, Tb157, Tb158, Tb158m	5	5 <sub>4</sub>	•	•
<b>Tb159(n,3n)Tb157</b>	H3, Sm151, Eu154, Eu155, Gd148, Gd150, Gd153, Tb154m, Tb155, Tb156, Tb157, Tb158, Tb158m	5	0		
<b>Tb159(n,α)Eu155</b>	H3, Sm151, Eu154, Eu155, Gd148, Gd150, Gd152, Gd153	5	0		
<b>Tb159(n,2nα)Eu154</b>	Sm151, Eu154, Gd148, Gd150	4	0		
<b>Tb159(n,4n)Tb156</b>	H3, Sm151, Eu154, Eu155, Gd148, Gd150, Gd152, Gd153, Tb154m, Tb156	5	0		
<b>Tb159(n,γ)Tb160</b>	Eu155, Gd160, Tb160, Tb161, Tb162, Ho166, Ho166m	5	4	•	
<b>Tb159(n,α)Eu156</b>	Sm151, Eu154, Eu155, Eu156, Gd148, Gd150, Gd153	5	6*	•	•
<b>Tb159(n,5n)Tb155</b>	H3, Sm151, Eu154, Eu155, Gd148, Gd150, Gd152, Gd153, Tb155	5	0		
<b>Tb159(n,6n)Tb154m</b>	Sm151, Eu154, Gd148, Gd150, Gd153, Tb154	5	0		
<b>Tb160(n,γ)Tb161</b>	Eu155, Gd160, Tb161, Tb162, Ho166, Ho166m	5	2	•	
<b>Tb160(n,p)Gd160</b>	Gd160, Tb161	5	0		
<b>Tb160(n,α)Eu157</b>	Eu155	4	0		
<b>Tb161(n,γ)Tb162</b>	Gd160, Tb162, Ho166, Ho166m	5	0		
<b>Dy154(n,3n)Dy152</b>	Gd148, Gd150, Gd152	4	0		
<b>Dy155(n,2n)Dy154</b>	Gd148, Gd150, Dy154	5	0		
<b>Dy156(n,2n)Dy155</b>	Gd148, Gd150, Gd152, Tb154m, Dy154	5	6	•	•
<b>Dy156(n,3n)Dy154</b>	Gd148, Gd150, Gd152, Tb154m, Dy154	4	0		
<b>Dy156(n,α)Gd152</b>	Gd148, Gd150, Gd152	4	0		
<b>Dy156(n,γ)Dy157</b>	Tb157, Tb158, Tb160, Tb161, Dy157, Dy159	5	4	•	
<b>Dy156(n,α)Gd153</b>	Gd148, Gd150, Gd152	5	2	•	
<b>Dy156(n,5n)Dy152</b>	Gd148, Gd150, Gd152	4	0		
<b>Dy157(n,2n)Dy156</b>	Tb154m, Dy154	4	0		
<b>Dy158(n,2n)Dy157</b>	Gd152, Tb154m, Tb156, Tb157, Dy154, Dy157	5	6	•	•
<b>Dy158(n,3n)Dy156</b>	Gd148, Gd150, Gd152, Tb154m, Tb156, Dy154, Dy156	4	0		
<b>Dy158(n,4n)Dy155</b>	Gd148, Gd150, Gd152	4	0		
<b>Dy158(n,γ)Dy159</b>	Tb160, Tb161, Dy159, Dy165, Ho166, Ho166m	5	4	•	
<b>Dy158(n,5n)Dy154</b>	Gd148, Gd150, Gd152, Dy154	4	0		
<b>Dy159(n,2n)Dy158</b>	Gd148, Tb154m, Tb156, Tb157, Dy154, Dy156, Dy157	4	0		
<b>Dy159(n,3n)Dy157</b>	Tb154m, Tb156, Tb157, Dy157	4	0		
<b>Dy159(n,4n)Dy156</b>	Gd148, Gd150, Gd152, Tb154m, Dy154, Dy156	4	0		
<b>Dy160(n,2n)Dy159</b>	Gd150, Tb154m, Tb156, Tb157, Tb158, Tb160, Dy154, Dy156, Dy157, Dy159	5	2	•	
<b>Dy160(n,4n)Dy157</b>	Gd148, Gd150, Gd152, Tb154m, Tb156, Tb157, Dy154, Dy157	4	0		
<b>Dy160(n,γ)Dy161</b>	Eu155, Gd160, Tb161, Tb162, Tb163, Dy165, Ho166, Ho166m	5	4	•	
<b>Dy160(n,p)Tb160</b>	Tb160	4	2	•	
<b>Dy160(n,α)Gd157</b>	Eu155, Gd152	5	2	•	
<b>Dy161(n,2n)Dy160</b>	Gd148, Gd150, Gd152, Tb154m, Tb156, Tb157, Tb158, Tb160, Dy154, Dy156, Dy157, Dy159	5	0		
<b>Dy161(n,3n)Dy159</b>	Gd148, Gd150, Gd152, Tb154m, Tb156, Tb157, Tb158, Tb160, Dy154, Dy156, Dy157, Dy159	5	0		
<b>Dy161(n,nt)Tb158</b>	Gd148, Gd150, Gd152, Tb154m, Tb156, Tb158	4	0		
<b>Dy161(n,4n)Dy158</b>	Gd148, Gd150, Gd152, Tb154m, Tb156, Tb157, Tb158, Dy154, Dy156, Dy157	4	0		
<b>Dy161(n,γ)Dy162</b>	Gd160, Tb162, Tb163, Dy165, Ho166, Ho166m, Er167m, Tm170	5	4	•	
<b>Dy161(n,p)Tb161</b>	Tb160, Tb161, Tb162	5	2	•	
<b>Dy161(n,d)Tb160</b>	Tb154m, Tb156, Tb157, Tb158, Tb160, Dy156, Dy157, Dy159	5	0		

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Dy161</b> (n,5n) <b>Dy157</b>	Gd148, Gd150, Gd152, Tb154m, Tb156, Tb157, Dy157	5	0		
<b>Dy161</b> (n,6n) <b>Dy156</b>	Gd148, Gd150, Gd152, Tb154m, Tb156, Dy154, Dy156	5	0		
<b>Dy162</b> (n,2n) <b>Dy161</b>	Gd152, Tb154m, Tb156, Tb157, Tb158, Tb160, Tb161, Dy154, Dy156, Dy157, Dy159	4	0		
<b>Dy162</b> (n,4n) <b>Dy159</b>	Gd148, Gd150, Gd152, Tb154m, Tb156, Tb157, Tb158, Dy154, Dy156, Dy157, Dy159	5	0		
<b>Dy162</b> (n, $\gamma$ ) <b>Dy163</b>	Gd160, Tb163, Dy165, Ho166, Ho166m, Er167m, Tm170, Tm171	5	4	•	
<b>Dy162</b> (n,p) <b>Tb162</b>	Tb162	5	6	•	•
<b>Dy162</b> (n,d) <b>Tb161</b>	Tb157, Tb158, Tb160, Tb161, Dy156, Dy157, Dy159	5	0		
<b>Dy162</b> (n,t) <b>Tb160</b>	Tb154m, Tb156, Tb157, Tb158, Tb160, Dy156, Dy157	4	5 <sub>0</sub>		•
<b>Dy162</b> (n, $\alpha$ ) <b>Gd159</b>	Tb156, Tb157, Tb158, Tb160	5	2	•	
<b>Dy162</b> (n,5n) <b>Dy158</b>	Gd148, Gd150, Gd152, Tb154m, Tb156, Tb157, Tb158, Dy154, Dy156, Dy157	4	0		
<b>Dy162</b> (n,6n) <b>Dy157</b>	Gd148, Gd150, Gd152, Tb154m, Tb156, Tb157, Dy157	4	0		
<b>Dy162</b> (n,2nt) <b>Tb158</b>	Gd148, Gd150, Tb154m, Tb156, Tb158	4	0		
<b>Dy163</b> (n,nt) <b>Tb160</b>	Tb154m, Tb156, Tb157, Tb158, Tb160, Dy156	4	0		
<b>Dy163</b> (n,4n) <b>Dy160</b>	Gd148, Gd150, Gd152, Tb154m, Tb156, Tb157, Tb158, Tb160, Dy154, Dy156, Dy157, Dy159	4	0		
<b>Dy163</b> (n, $\gamma$ ) <b>Dy164</b>	Tb163, Dy165, Ho166, Ho166m, Er167m, Er169, Tm170, Tm171, Tm172	5	4	•	
<b>Dy163</b> (n,p) <b>Tb163</b>	Tb163	5	6	•	•
<b>Dy163</b> (n,t) <b>Tb161</b>	Tb157, Tb158, Tb160, Tb161, Dy156, Dy159	4	0		
<b>Dy163</b> (n, $\alpha$ ) <b>Gd160</b>	Gd160, Tb157, Tb158	5	2	•	
<b>Dy163</b> (n,5n) <b>Dy159</b>	Gd148, Gd150, Gd152, Tb154m, Tb156, Tb157, Tb158, Dy154, Dy156, Dy159	4	0		
<b>Dy163</b> (n,6n) <b>Dy158</b>	Gd148, Gd150, Gd152, Tb154m, Tb156, Tb157, Tb158, Dy154, Dy156, Dy157	4	0		
<b>Dy164</b> (n,2n) <b>Dy163</b>	Gd160, Tb154m, Tb156, Tb157, Tb158, Tb160, Tb161, Tb162, Tb163, Dy157, Dy159	5	0		
<b>Dy164</b> (n, $\alpha$ ) <b>Gd160</b>	Gd160, Tb157, Tb158	4	0		
<b>Dy164</b> (n,nt) <b>Tb161</b>	Tb157, Tb158, Tb161, Dy156	4	0		
<b>Dy164</b> (n, $\gamma$ ) <b>Dy165</b>	Tb163, Dy165, Ho163, Ho166, Ho166m, Er167m, Er169, Tm170, Tm171, Tm172	5	5 <sub>2</sub>	•	•
<b>Dy164</b> (n, $\gamma$ ) <b>Dy165m</b>	Tb163, Dy165, Ho163, Ho166, Ho166m, Er167m, Er169, Tm170, Tm171, Tm172	5	6	•	•
<b>Dy164</b> (n,d) <b>Tb163</b>	Tb163	5	0		
<b>Dy164</b> (n,6n) <b>Dy159</b>	Gd148, Gd150, Gd152, Tb154m, Tb156, Tb157, Tb158, Dy154, Dy156, Dy159	4	0		
<b>Ho163</b> (n,2n) <b>Ho162</b>	Tb157, Tb158, Tb160, Tb162, Dy154, Dy159, Ho162	5	0		
<b>Ho163</b> (n,2n) <b>Ho162m</b>	Tb157, Tb158, Tb160, Tb162, Dy154, Dy159, Ho162, Ho162m	5	0		
<b>Ho163</b> (n,3n) <b>Ho161</b>	Tb157, Tb158, Tb160, Dy154, Dy159, Ho161	5	0		
<b>Ho163</b> (n,2n $\alpha$ ) <b>Tb158</b>	Tb154m, Tb157, Tb158	4	0		
<b>Ho163</b> (n,4n) <b>Ho160</b>	Tb154m, Tb157, Tb158, Tb160, Dy154, Dy159, Ho160	5	0		
<b>Ho163</b> (n, $\gamma$ ) <b>Ho164</b>	Ho166m, Er165	5	2/0	•	
<b>Ho163</b> (n, $\alpha$ ) <b>Tb160</b>	Tb157, Tb158, Tb160, Dy154, Dy159	5	0		
<b>Ho163</b> (n,5n) <b>Ho159</b>	Tb154m, Tb157, Tb158, Dy154, Dy159	4	0		
<b>Ho165</b> (n,2n) <b>Ho164</b>	H3, Gd160, Tb154m, Tb157, Tb158, Tb160, Tb162, Dy154, Dy159, Ho161, Ho162, Ho162m, Ho163, Ho164, Er162	5	6	•	•
<b>Ho165</b> (n,2n) <b>Ho164m</b>	Gd160, Tb157, Tb158, Tb160, Tb162, Dy154, Dy159, Ho162, Ho162m, Ho163, Ho164, Er162	4	6*	•	•
<b>Ho165</b> (n,3n) <b>Ho163</b>	H3, Tb154m, Tb157, Tb158, Tb160, Tb162, Dy154, Dy159, Ho160, Ho161, Ho162, Ho162m, Ho163	5	0		

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Ho165</b> (n,2n $\alpha$ )Tb160	Gd160, Tb154m, Tb157, Tb158, Tb160, Dy154, Dy159	4	0		
<b>Ho165</b> (n,4n)Ho162	H3, Gd160, Tb154m, Tb157, Tb158, Tb160, Tb162, Dy154, Dy159, Ho162	4	0		
<b>Ho165</b> (n,4n)Ho162m	H3, Gd160, Tb154m, Tb157, Tb158, Tb160, Tb162, Dy154, Dy159, Ho162, Ho162m	5	0		
<b>Ho165</b> (n, $\gamma$ )Ho166	Gd160, Tb163, Ho166, Ho167, Er162, Er167m, Er169, Tm170, Tm171, Tm172	5	4	•	
<b>Ho165</b> (n, $\gamma$ )Ho166m	Tb163, Ho166, Ho166m, Ho167, Er167m, Er169, Tm170, Tm171	5	2	•	
<b>Ho165</b> (n,d) <b>Dy164</b>	H3, Gd160, Tb154m, Tb157, Tb158, Tb160, Tb162, Dy154, Dy159	4	0		
<b>Ho165</b> (n, $\alpha$ )Tb162	Gd160, Tb157, Tb158, Tb160, Tb162, Dy154, Dy159	5	6*	•	•
<b>Ho165</b> (n,5n)Ho161	H3, Gd160, Tb154m, Tb157, Tb158, Tb160, Dy154, Dy159, Ho161	5	0		
<b>Ho165</b> (n,4n $\alpha$ )Tb158	Tb154m, Tb157, Tb158	4	0		
Ho166m(n, $\gamma$ )Ho167	Ho167, Er167m, Er169, Tm170, Tm171	5	2	•	
Ho166m(n, $\alpha$ )Tb163	Gd160, Tb158, Tb163	5	0		
Er160(n,3n)Er158	Ho158	4	0		
Er160(n,t)Ho158	Ho158	5	0		
Er160(n,t)Ho158m	Ho158	4	0		
Er161(n,2n)Er160	Dy154, Ho158, Ho160	5	0		
<b>Er162</b> (n,2n)Er161	Tb160, Dy154, Dy159, Ho158, Ho160, Ho161	5	6*	•	•
<b>Er162</b> (n,3n)Er160	Tb160, Dy154, Dy159, Ho158, Ho160	4	0		
<b>Er162</b> (n, $\alpha$ ) <b>Dy158</b>	Gd150, Tb154m, Dy154	4	0		
<b>Er162</b> (n, $\gamma$ )Er163	Tb160, Ho163, Ho166m, Er165	5	2	•	
<b>Er162</b> (n, $\alpha$ )Dy159	Tb154m, Tb160, Dy154, Dy159	5	2	•	
<b>Er162</b> (n,5n)Er158	Tb154m, Dy154, Ho158	4	0		
<b>Er164</b> (n,2n)Er163	H3, Tb157, Tb158, Tb160, Dy159, Ho160, Ho161, Ho162, Ho162m, Ho163	5	5 <sub>2</sub> *	•	•
<b>Er164</b> (n,3n)Er162	H3, Gd150, Tb154m, Tb160, Dy154, Dy159, Ho158, Ho160, Ho161, Ho162, Er162	5	0		
<b>Er164</b> (n, $\gamma$ )Er165	Ho166m, Er165, Er167m, Tm170	5	3	•	
<b>Er166</b> (n,2n)Er165	H3, Gd160, Tb154m, Tb158, Tb160, Dy154, Dy159, Ho160, Ho162, Ho163, Ho166m, Er162, Er165	5	5 <sub>2</sub> *	•	•
<b>Er166</b> (n,3n) <b>Er164</b>	H3, Tb154m, Tb158, Tb160, Dy154, Dy159, Ho158, Ho160, Ho162, Ho163, Er162	5	0		
<b>Er166</b> (n,4n)Er163	H3, Gd160, Tb154m, Tb158, Tb160, Dy154, Dy159, Ho158, Ho160, Ho162, Ho163	5	0		
<b>Er166</b> (n, $\gamma$ ) <b>Er167</b>	Ho167, Er167m, Er169, Tm170, Tm171, Tm172	5	2	•	
<b>Er166</b> (n, $\gamma$ )Er167m	Ho167, Er167m, Er169, Tm170, Tm171, Tm172	5	2	•	
<b>Er166</b> (n,p)Ho166m	Ho166m, Ho167	5	0		
<b>Er166</b> (n, $\alpha$ ) <b>Dy163</b>	Gd160, Tb154m, Tb158, Tb160, Dy154, Dy159	5	2	•	
<b>Er166</b> (n,5n)Er162	H3, Tb154m, Tb160, Dy154, Dy159, Ho158, Ho160, Ho162, Er162	5	0		
<b>Er166</b> (n,6n)Er161	H3, Gd160, Tb154m, Tb158, Tb160, Dy154, Dy159	4	0		
<b>Er167</b> (n,3n)Er165	H3, Gd160, Tb158, Tb160, Dy154, Dy159, Ho160, Ho162, Ho163, Er162, Er165	5	0		
<b>Er167</b> (n, $\gamma$ ) <b>Er168</b>	Ho166m, Er169, Er171, Tm170, Tm171, Tm172, Lu176	5	4	•	
<b>Er167</b> (n,d)Ho166m	H3, Tb158, Tb160, Ho160, Ho162, Ho163, Ho166m	5	0		
<b>Er167</b> (n,5n)Er163	H3, Tb154m, Tb158, Tb160, Dy154, Dy159, Ho158, Ho160, Ho162, Ho163	4	0		
<b>Er167</b> (n,6n)Er162	H3, Tb154m, Tb160, Dy154, Dy159, Ho158, Ho160, Ho162, Er162	4	0		
<b>Er168</b> (n,2n)Er167m	H3, Gd160, Ho166m, Er162, Er165, Er167m	5	2	•	
<b>Er168</b> (n,4n)Er165	H3, Gd160, Tb154m, Tb158, Tb160, Dy154, Dy159, Ho160, Ho162, Ho163, Er165	5	0		

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Er168</b> (n, $\gamma$ )Er169	Ho166m, Er169, Er171, Tm168, Tm170, Tm171, Tm172, Lu176	5	4	•	
<b>Er168</b> (n,t)Ho166m	H3, Tb160, Ho160, Ho162, Ho163, Ho166m	4	0		
<b>Er168</b> (n, $\alpha$ )Dy165	Gd160, Ho163, Ho166m	4	1	•	
<b>Er168</b> (n, $\alpha$ )Dy165m	Gd160, Ho166m	4	2	•	
<b>Er168</b> (n,6n)Er163	H3, Tb154m, Tb158, Tb160, Dy154, Dy159, Ho158, Ho160, Ho162, Ho163	4	0		
<b>Er170</b> (n,2n)Er169	H3, Ho166m, Er167m, Er169, Tm168, Tm170	5	2	•	
<b>Er170</b> (n,4n)Er167m	Er167m	4	0		
<b>Er170</b> (n, $\gamma$ )Er171	Er171, Tm168, Tm170, Tm171, Tm172, Lu176	5	4	•	
<b>Er170</b> (n,d)Ho169	Er167m, Er169, Tm168, Tm170	4	6*	•	•
<b>Er170</b> (n,6n)Er165	H3, Tb154m, Tb160, Dy154, Dy159, Ho160, Ho162, Er165	4	0		
Tm167(n,2n)Tm166	Tm166	5	0		
Tm168(n,2n)Tm167	Gd160, Tb158, Ho163, Er167m, Tm166, Tm167	5	0		
Tm168(n,3n)Tm166	Tm166	5	0		
<b>Tm169</b> (n,2n)Tm168	H3, Gd160, Tb158, Dy154, Ho162, Ho163, Ho166m, Er167m, Tm166, Tm167, Tm168, Yb168	5	6	•	•
<b>Tm169</b> (n,3n)Tm167	H3, Gd160, Tb158, Ho162, Ho163, Ho166m, Er167m, Tm166, Tm167	5	4	•	
<b>Tm169</b> (n,2n $\alpha$ )Ho164	Gd160, Tb154m, Tb158, Dy154	4	0		
<b>Tm169</b> (n,2n $\alpha$ )Ho164m	Gd160, Tb158, Dy154, Ho163	4	0		
<b>Tm169</b> (n,3n $\alpha$ )Ho163	H3, Tb154m, Tb158, Dy154, Ho162, Ho163	4	0		
<b>Tm169</b> (n,4n)Tm166	H3, Gd160, Tb154m, Tb158, Dy154, Ho162, Ho163, Ho166m, Tm166	5	0		
<b>Tm169</b> (n, $\gamma$ )Tm170	Tm170, Tm171, Tm172, Yb168, Yb175, Lu176	5	4	•	
<b>Tm169</b> (n, $\alpha$ )Ho166	Gd160, Tb158, Ho163	5	2	•	
<b>Tm169</b> (n, $\alpha$ )Ho166m	Gd160, Tb158, Ho162, Ho163, Ho166m	5	2	•	
<b>Tm169</b> (n,5n)Tm165	H3, Gd160, Tb154m, Tb158, Ho162, Ho163, Ho166m	4	0		
Tm170(n, $\gamma$ )Tm171	Tm171, Tm172, Yb175, Lu176	5	4	•	
Tm171(n,2n)Tm170	Ho166m, Tm168, Tm170	4	0		
Tm171(n, $\gamma$ )Tm172	Tm172, Yb175, Lu176	5	4	•	
<b>Yb168</b> (n,2n)Yb167	Ho163, Ho166m, Tm166, Tm167	5	6	•	•
<b>Yb168</b> (n,3n)Yb166	Ho163, Ho166m, Tm166	4	0		
<b>Yb168</b> (n, $\alpha$ )Er164	Ho163	4	0		
<b>Yb168</b> (n, $\gamma$ )Yb169	H3, Ho166m, Tm170, Tm171, Yb169	5	1	•	
<b>Yb168</b> (n, $\gamma$ )Yb169m	H3, Ho166m, Tm170, Tm171, Yb169	5	0		
<b>Yb168</b> (n, $\alpha$ )Er165	Ho163, Ho166m	5	2	•	
<b>Yb170</b> (n,2n)Yb169	H3, Ho163, Ho166m, Tm166, Tm168, Tm170, Yb168, Yb169	4	0		
<b>Yb170</b> (n,3n)Yb168	H3, Ho163, Ho166m, Tm166, Tm168, Yb168	5	0		
<b>Yb170</b> (n,4n)Yb167	Ho163, Ho166m	4	0		
<b>Yb170</b> (n, $\gamma$ )Yb171	Tm171, Tm172, Yb175, Lu176	4	4	•	
<b>Yb170</b> (n,p)Tm170	Tm170	4	0		
<b>Yb171</b> (n,2n)Yb170	H3, Ho163, Ho166m, Tm166, Tm168, Tm170, Yb168, Yb169	4	0		
<b>Yb171</b> (n,3n)Yb169	H3, Ho163, Ho166m, Tm166, Tm168, Yb168, Yb169	4	0		
<b>Yb171</b> (n,nt)Tm168	Ho163, Ho166m, Tm168	4	0		
<b>Yb171</b> (n,4n)Yb168	H3, Ho163, Ho166m, Tm166, Tm168, Yb168	5	0		
<b>Yb171</b> (n, $\gamma$ )Yb172	Ho166m, Tm170, Tm171, Tm172, Yb175, Yb176m, Lu176, Lu176m, Lu177, Lu177m, Hf177m	4	4	•	
<b>Yb171</b> (n,p)Tm171	Tm168, Tm170, Tm171, Tm172	4	0		
<b>Yb171</b> (n,d)Tm170	Ho166m, Tm166, Tm168, Tm170, Yb168	4	0		
<b>Yb171</b> (n, $\alpha$ )Er168	Ho166m	4	2	•	
<b>Yb171</b> (n,5n)Yb167	Ho163, Ho166m	4	0		
<b>Yb171</b> (n,6n)Yb166	H3, Ho163, Ho166m, Tm166	4	0		
<b>Yb172</b> (n,3n)Yb170	H3, Ho163, Ho166m, Tm166, Tm168, Tm170, Yb168, Yb169	4	0		

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Yb172</b> (n,4n)Yb169	H3, Ho163, Ho166m, Tm166, Tm168, Yb169	4	0		
<b>Yb172</b> (n, $\gamma$ ) <b>Yb173</b>	Tm171, Yb175, Yb176m, Lu176, Lu176m, Lu177, Lu177m, Hf177m	5	4	•	
<b>Yb172</b> (n,d)Tm171	Ho166m, Tm166, Tm168, Tm170, Tm171, Yb168, Yb169	5	0		
<b>Yb172</b> (n,t)Tm170	H3, Ho166m, Tm166, Tm168, Tm170, Yb168	4	0		
<b>Yb172</b> (n, $\alpha$ )Er169	Ho166m, Tm168, Tm170, Tm171	5	2	•	
<b>Yb172</b> (n,5n)Yb168	H3, Ho163, Ho166m, Tm166, Tm168, Yb168	4	0		
<b>Yb172</b> (n,6n)Yb167	Ho163, Ho166m	4	0		
<b>Yb172</b> (n,2nt)Tm168	Ho163, Ho166m, Tm168	4	0		
<b>Yb173</b> (n,nt)Tm170	Ho166m, Tm166, Tm168, Tm170	4	0		
<b>Yb173</b> (n, $\gamma$ ) <b>Yb174</b>	Tm171, Yb175, Yb176m, Yb177, Lu176, Lu176m, Lu177, Lu177m, Hf177m, Hf181, Hf182, Ta182	5	4	•	
<b>Yb173</b> (n,d)Tm172	Tm166, Tm168, Tm170, Tm172, Yb168	5	0		
<b>Yb173</b> (n,t)Tm171	Ho166m, Tm166, Tm168, Tm170, Tm171, Yb168	4	0		
<b>Yb173</b> (n, $\alpha$ ) <b>Er170</b>	Ho166m, Tm168, Tm171	5	2	•	
<b>Yb173</b> (n,6n)Yb168	H3, Ho163, Ho166m, Tm166, Tm168, Yb168	4	0		
<b>Yb174</b> (n,nt)Tm171	H3, Ho166m, Tm166, Tm168, Tm170, Tm171	4	0		
<b>Yb174</b> (n, $\gamma$ )Yb175	Yb175, Yb176m, Yb177, Lu173, Lu174, Lu176, Lu176m, Lu177, Lu177m, Hf177m, Hf178n, Hf181, Hf182, Ta182	5	4	•	
<b>Yb174</b> (n, $\alpha$ )Er171	Ho166m, Tm168, Tm170, Tm171	4	6	•	•
<b>Yb174</b> (n,6n)Yb169	H3, Ho163, Ho166m, Tm166, Tm168, Yb169	4	0		
<b>Yb174</b> (n,2nt)Tm170	Ho166m, Tm166, Tm168, Tm170	4	0		
Yb175(n, $\gamma$ )Yb176m	Yb176m	5	2	•	
<b>Yb176</b> (n,n')Yb176m	Yb176m	5	0		
<b>Yb176</b> (n,2n)Yb175	H3, Tm171, Yb175, Lu172, Lu173, Lu174, Lu176, Lu176m, Lu177m	5	2	•	
<b>Yb176</b> (n, $\gamma$ )Yb177	Yb177, Lu173, Lu176, Lu176m, Lu177, Lu177m, Hf177m, Hf178n, Hf181, Hf182, Ta182	5	4	•	
<b>Yb176</b> (n, $\gamma$ )Yb177m	Yb177, Lu176, Lu176m, Lu177, Lu177m, Hf177m, Hf178n, Hf181, Hf182, Ta182	5	0		
<b>Yb176</b> (n,d)Tm175	Yb175, Lu173, Lu174, Lu176, Lu176m	4	0		
Lu173(n,2n)Lu172	Ho166m, Tm168, Tm171, Tm172, Lu170, Lu172	4	0		
Lu173(n,4n)Lu170	Tm168, Lu170	5	0		
Lu173(n,4n)Lu170m	Tm168, Lu170	4	0		
Lu174(n,2n)Lu173	H3, Ho166m, Tm168, Tm171, Tm172, Lu170, Lu172, Lu173	5	0		
Lu174(n, $\alpha$ )Tm171	Ho166m, Tm168, Tm171	4	0		
<b>Lu175</b> (n,2n)Lu174	H3, Ho166m, Tm168, Tm171, Tm172, Lu170, Lu172, Lu173, Lu174	5	5/4	•	•
<b>Lu175</b> (n,2n)Lu174m	H3, Ho166m, Tm168, Tm171, Tm172, Lu170, Lu172, Lu173, Lu174	4	4	•	
<b>Lu175</b> (n,3n)Lu173	H3, Ho166m, Tm168, Tm171, Tm172, Lu170, Lu172, Lu173	5	5 <sub>2</sub> *	•	•
<b>Lu175</b> (n, $\alpha$ )Tm171	Ho166m, Tm168, Tm171	5	0		
<b>Lu175</b> (n,4n)Lu172	H3, Ho166m, Tm168, Tm171, Tm172, Lu170, Lu172	5	5 <sub>3</sub>		•
<b>Lu175</b> (n,4n)Lu172m	Ho166m, Tm168, Tm171, Tm172, Lu170, Lu172	4	0		
<b>Lu175</b> (n, $\gamma$ )Lu176	Tm171, Lu176, Lu176m, Lu177, Lu177m, Lu178, Hf177m, Hf178m, Hf178n, Hf179m, Hf181, Hf182, Ta182	5	2	•	
<b>Lu175</b> (n, $\gamma$ )Lu176m	Tm171, Lu176m, Lu177, Hf177m, Hf178m, Hf178n, Hf179m, Hf181, Hf182, Ta182	5	6	•	•
<b>Lu175</b> (n, $\alpha$ )Tm172	Ho166m, Tm168, Tm171, Tm172	5	2	•	
<b>Lu175</b> (n,6n)Lu170	H3, Ho166m, Tm168, Lu170	5	0		
<b>Lu175</b> (n,6n)Lu170m	Tm168, Lu170	4	0		
<b>Lu175</b> (n,4n $\alpha$ )Tm168	Ho166m, Tm168	4	0		



Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Lu176</b> (n,n')Lu176m	Lu176m, Hf177m, Hf178n, Hf179m	5	0		
<b>Lu176</b> (n,γ)Lu177	Tm171, Lu177, Lu177m, Lu178, Hf177m, Hf178m, Hf178n, Hf179m, Hf181, Hf182, Ta182	5	4	•	
<b>Lu176</b> (n,γ)Lu177m	Lu177, Lu177m, Lu178, Hf177m, Hf178n, Hf179m, Hf181	5	2	•	
<b>Lu176</b> (n,α)Tm173	Tm171	4	2	•	
Lu177(n,n')Lu177m	Lu177m	5	0		
Lu177(n,γ)Lu178	Lu178, Hf178n, Hf179m, Hf181, Hf182, Ta182	5	0		
Hf172(n,2n)Hf171	Hf171	5	0		
Hf173(n,2n)Hf172	Hf171, Hf172	5	0		
<b>Hf174</b> (n,2n)Hf173	Ho166m, Lu172, Lu173, Hf171, Hf172	5	6	•	•
<b>Hf174</b> (n,3n)Hf172	Ho166m, Lu172, Hf171, Hf172	4	0		
<b>Hf174</b> (n,4n)Hf171	Hf171	5	0		
<b>Hf174</b> (n,γ)Hf175	H3, Ho166m, Lu176, Hf175, Hf177m, Hf178m, Hf178n, Hf179m, Hf179n	5	4	•	
<b>Hf174</b> (n,α)Yb171	Ho166m	4	0		
Hf175(n,4n)Hf172	Lu172, Hf171, Hf172	4	0		
<b>Hf176</b> (n,2n)Hf175	H3, Ho166m, Lu172, Lu173, Lu174, Lu176, Hf171, Hf172, Hf175	5	6	•	•
<b>Hf176</b> (n,3n)Hf174	H3, Ho166m, Lu172, Lu173, Lu174, Hf171, Hf172	4	0		
<b>Hf176</b> (n,4n)Hf173	Ho166m, Lu172, Lu173	4	0		
<b>Hf176</b> (n,γ)Hf177	Tm171, Hf177m, Hf178m, Hf178n, Hf179m, Hf179n, Hf181, Hf182, Ta182, Ta183, W185	5	4	•	
<b>Hf176</b> (n,γ)Hf177m	Hf177m	5	0		
<b>Hf176</b> (n,p)Lu176	Lu174, Lu176	4	0		
<b>Hf176</b> (n,α)Yb173	Ho166m, Tm171	5	0		
<b>Hf176</b> (n,5n)Hf172	H3, Lu172, Hf171, Hf172	5	0		
<b>Hf176</b> (n,6n)Hf171	Hf171	5	0		
<b>Hf177</b> (n,n')Hf177m	Hf177m	5	0		
<b>Hf177</b> (n,2n)Hf176	H3, Ho166m, Lu172, Lu173, Lu174, Lu176, Hf171, Hf172, Hf175	4	0		
<b>Hf177</b> (n,3n)Hf175	H3, Ho166m, Lu172, Lu173, Lu174, Hf171, Hf172, Hf175	4	0		
<b>Hf177</b> (n,nt)Lu174	Lu174	4	0		
<b>Hf177</b> (n,4n)Hf174	H3, Ho166m, Lu172, Lu173, Lu174, Hf171, Hf172	5	0		
<b>Hf177</b> (n,γ)Hf178	Lu178, Hf178n, Hf179m, Hf179n, Hf181, Hf182, Ta182, Ta183, W185	5	4/2/2	•	
<b>Hf177</b> (n,γ)Hf178m	Lu178, Hf178m, Hf178n, Hf179m, Hf181	5	2	•	
<b>Hf177</b> (n,γ)Hf178n	Hf178n	5	2	•	
<b>Hf177</b> (n,p)Lu177m	Lu177m	4	0		
<b>Hf177</b> (n,d)Lu176	Lu172, Lu173, Lu174, Lu176, Lu176m	5	0		
<b>Hf177</b> (n,α)Yb174	Tm171	4	2	•	
<b>Hf177</b> (n,5n)Hf173	H3, Lu172, Lu173	4	0		
<b>Hf177</b> (n,6n)Hf172	H3, Lu172, Hf171, Hf172	4	0		
<b>Hf178</b> (n,n')Hf178n	H3, Lu176, Hf177m, Hf178m, Hf178n, Hf179m	5	0		
<b>Hf178</b> (n,n')Hf178m	Hf178m	4	0		
<b>Hf178</b> (n,2n)Hf177m	H3, Lu176, Hf175, Hf177m	4	0		
<b>Hf178</b> (n,4n)Hf175	H3, Ho166m, Lu172, Lu173, Lu174, Hf171, Hf172, Hf175	5	0		
<b>Hf178</b> (n,γ)Hf179	Hf179m, Hf181, Hf182, Ta180m, Ta182, Ta183, W185	5	2/2/2	•	
<b>Hf178</b> (n,γ)Hf179m	Hf179m, Hf181, Hf182, Ta180m, Ta182, Ta183, W185	5	2	•	
<b>Hf178</b> (n,γ)Hf179n	Hf179n, Hf181	5	2	•	
<b>Hf178</b> (n,t)Lu176	H3, Lu172, Lu173, Lu174, Lu176	4	0		
<b>Hf178</b> (n,α)Yb175	Lu172, Lu173, Lu174, Lu176	5	4	•	
<b>Hf178</b> (n,5n)Hf174	H3, Lu172, Lu173, Lu174, Hf171, Hf172	4	0		
<b>Hf178</b> (n,6n)Hf173	H3, Lu172, Lu173	4	0		
<b>Hf179</b> (n,n')Hf179n	Hf179n	5	3	•	

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Hf179</b> (n,2n) <b>Hf178m</b>	H3, Lu172, Lu173, Lu176, Hf175, Hf177m, Hf178m, Hf178n	5	2	•	
<b>Hf179</b> (n,2n) <b>Hf178n</b>	H3, Hf178n	4	4	•	
<b>Hf179</b> (n,3n) <b>Hf177m</b>	Lu176, Hf175, Hf177m	4	0		
<b>Hf179</b> (n,4n) <b>Hf176</b>	H3, Lu172, Lu173, Lu174, Lu176, Hf171, Hf172, Hf175	4	0		
<b>Hf179</b> (n, $\gamma$ ) <b>Hf180</b>	Hf181, Hf182, Ta182, Ta183, W185	5	4	•	
<b>Hf179</b> (n, $\gamma$ ) <b>Hf180m</b>	Hf181, Hf182, Ta180m, Ta182, Ta183, W185	4	2	•	
<b>Hf180</b> (n,2n) <b>Hf179</b>	H3, Lu172, Lu176, Hf175, Hf177m, Hf178m, Hf178n, Hf179m, Hf179n	4	0/6/2	•	•
<b>Hf180</b> (n,2n) <b>Hf179m</b>	H3, Hf175, Hf177m, Hf178m, Hf178n, Hf179m, Hf179n	5	6	•	•
<b>Hf180</b> (n,2n) <b>Hf179n</b>	Hf178m, Hf178n, Hf179n	4	2	•	
<b>Hf180</b> (n,3n) <b>Hf178m</b>	H3, Lu176, Hf175, Hf177m, Hf178m, Hf178n	4	0		
<b>Hf180</b> (n,4n) <b>Hf177m</b>	Lu173, Lu176, Hf175, Hf177m	4	0		
<b>Hf180</b> (n, $\gamma$ ) <b>Hf181</b>	Hf181, Hf182, Ta182, Ta183, W185	5	5 <sub>2</sub>	•	•
<b>Hf180</b> (n,6n) <b>Hf175</b>	H3, Lu172, Lu173, Lu174, Hf171, Hf175	5	0		
<b>Hf180</b> (n,2nt) <b>Lu176</b>	Lu172, Lu174, Lu176	4	0		
<b>Hf181</b> (n, $\gamma$ ) <b>Hf182</b>	Hf182, Ta183, W185	5	2/0	•	
<b>Ta177</b> (n,2n) <b>Ta176</b>	Ta176	5	0		
<b>Ta179</b> (n,2n) <b>Ta178m</b>	Lu172, Lu176, Hf172, Hf175, Hf178n, Ta178m	5	0		
<b>Ta179</b> (n,3n) <b>Ta177</b>	Lu172, Lu176, Hf171, Hf172, Hf175, Ta176	5	0		
<b>Ta179</b> (n,4n) <b>Ta176</b>	Lu172, Lu176, Hf171, Hf172, Hf175, Ta176	5	0		
<b>Ta179</b> (n, $\alpha$ ) <b>Lu176</b>	Lu172, Lu176	4	0		
<b>Ta180m</b> (n,n') <b>Ta180</b>	Ta180	5	0		
<b>Ta180m</b> (n,2n) <b>Ta179</b>	H3, Lu172, Lu176, Hf172, Hf175, Hf178n, Ta176, Ta178m, Ta179	5	0		
<b>Ta180m</b> (n,3n) <b>Ta178m</b>	Lu172, Lu176, Hf172, Hf175, Hf178n, Ta178m	4	0		
<b>Ta180m</b> (n,n $\alpha$ ) <b>Lu176</b>	Lu172, Lu176	4	0		
<b>Ta180m</b> (n, $\alpha$ ) <b>Lu177</b>	Lu176, Hf172, Hf175, Hf178n	5	0		
<b>Ta181</b> (n,2n) <b>Ta180</b>	H3, Lu172, Lu176, Hf171, Hf172, Hf175, Hf178n, Hf182, Ta176, Ta178m, Ta179, Ta180	5	6/4	•	•
<b>Ta181</b> (n,2n) <b>Ta180m</b>	H3, Lu172, Lu176, Hf171, Hf172, Hf175, Hf178n, Ta176, Ta178m, Ta179, Ta180, Ta180m	5	4	•	
<b>Ta181</b> (n,3n) <b>Ta179</b>	H3, Lu172, Lu176, Hf171, Hf172, Hf175, Hf178n, Ta176, Ta178m, Ta179	5	4	•	
<b>Ta181</b> (n,2n $\alpha$ ) <b>Lu176</b>	Lu172, Lu176	5	0		
<b>Ta181</b> (n,4n) <b>Ta178</b>	H3, Lu172, Lu176, Hf171, Hf172, Hf175, Hf178n	5	0		
<b>Ta181</b> (n,4n) <b>Ta178m</b>	H3, Lu172, Lu176, Hf171, Hf172, Hf175, Hf178n, Ta178m	5	5 <sub>0</sub>		•
<b>Ta181</b> (n, $\gamma$ ) <b>Ta182</b>	Hf182, Ta180m, Ta182, Ta183, W183, W185, Re186, Re186m	5	6	•	•
<b>Ta181</b> (n, $\gamma$ ) <b>Ta182m</b>	Hf182, Ta182, Ta183, W183, W185, Re186, Re186m	5	2	•	
<b>Ta181</b> (n, $\alpha$ ) <b>Lu178</b>	Lu172, Lu176, Hf171, Hf172, Hf175, Hf178n, Hf182, Ta180m	5	5/6	•	•
<b>Ta181</b> (n, $\alpha$ ) <b>Lu178m</b>	Lu172, Lu176, Hf171, Hf172, Hf175, Hf178n, Hf182, Ta180m	4	6	•	•
<b>Ta181</b> (n,5n) <b>Ta177</b>	H3, Lu172, Lu176, Hf171, Hf172, Hf175	4	0		
<b>Ta181</b> (n,6n) <b>Ta176</b>	H3, Lu172, Lu176, Hf171, Hf172, Hf175, Ta176	5	0		
<b>Ta182</b> (n, $\gamma$ ) <b>Ta183</b>	Hf182, Ta180m, Ta183, W183, W185, Re186, Re186m	5	4	•	
<b>Ta182</b> (n,p) <b>Hf182</b>	Hf182	4	0		
<b>Ta182</b> (n, $\alpha$ ) <b>Lu179</b>	Hf182, Ta180m	4	0		
<b>W180</b> (n, $\gamma$ ) <b>W181</b>	Hf178n, Ta182, W181, W183	5	4	•	
<b>W181</b> (n, $\alpha$ ) <b>Hf178n</b>	Hf178n	5	0		
<b>W182</b> (n,2n) <b>W181</b>	H3, Hf172, Hf178n, Ta179, Ta182, W181	5	6	•	•
<b>W182</b> (n,n $\alpha$ ) <b>Hf178n</b>	Hf172, Hf178n	5	2	•	
<b>W182</b> (n,4n) <b>W179</b>	Hf172, Hf178n, Ta179	5	0		
<b>W182</b> (n, $\gamma$ ) <b>W183</b>	Hf182, Ta183, W183, W185, Re186, Re186m,	5	4/0	•	

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>W182(n,<math>\gamma</math>)W183m</b>	Re187 Hf182, Ta183, W183, W183m, W185, Re186, Re186m	5	0		
<b>W182(n,p)Ta182</b>	Hf182, Ta182	5	6	•	•
<b>W182(n,6n)W177</b>	Hf172	4	0		
<b>W183(n,2n)W182</b>	Hf172, Hf178n, Ta179, Ta182, W181	4	4	•	
<b>W183(n,3n)W181</b>	H3, Hf172, Hf178n, Ta179, W181	4	0		
<b>W183(n,<math>\gamma</math>)W184</b>	Hf182, W185, W187, Re186, Re186m, Re187, Re188	5	4	•	
<b>W183(n,d)Ta182m</b>	Ta182	4	0		
<b>W183(n,<math>\alpha</math>)Hf180</b>	Hf178n, Hf182	5	0		
<b>W183(n,<math>\alpha</math>)Hf180m</b>	Ta180m	4	6*	•	•
<b>W184(n,2n)W183</b>	H3, Hf178n, Ta179, Ta182, W183, W183m	4	0		
<b>W184(n,2n)W183m</b>	H3, Hf178n, Ta182, W183, W183m	5	2	•	
<b>W184(n,4n)W181</b>	Ta179, W181	5	0		
<b>W184(n,<math>\gamma</math>)W185</b>	Hf182, W183, W183m, W185, W187, Re186, Re186m, Re187, Re188, Os194, Ir192	5	4/2	•	
<b>W184(n,t)Ta182m</b>	Ta182	4	0		
<b>W184(n,6n)W179</b>	Ta179	4	0		
<b>W185(n,<math>\alpha</math>)Hf182</b>	Hf182	5	0		
<b>W186(n,2n)W185</b>	H3, Hf182, Ta182, W183, W185, Re184, Re184m, Re186, Re186m	5	6	•	•
<b>W186(n,2n)W185m</b>	Ta182, W183, W185, Re184, Re184m, Re186, Re186m	4	6	•	•
<b>W186(n,<math>\alpha</math>)Hf182</b>	Hf182	5	0/5	•	•
<b>W186(n,4n)W183m</b>	Ta179, W183, W183m	5	0		
<b>W186(n,<math>\gamma</math>)W187</b>	W185, W187, Re184, Re184m, Re186, Re186m, Re187, Re188, Os194, Ir192, Ir192n, Ir194, Pt193	5	6	•	•
<b>W186(n,d)Ta185</b>	W185, Re184, Re184m, Re186, Re186m	4	5 <sub>2</sub>	•	•
<b>W186(n,6n)W181</b>	Hf172, Hf178n, W181	4	0		
<b>Re184(n,2n)Re183</b>	Hf178n, Ta179, Re183	4	0		
<b>Re184m(n,2n)Re183</b>	Hf178n, Ta179, Re183	4	0		
<b>Re185(n,2n)Re184</b>	H3, Hf178n, Ta179, Ta182, W183, W185, Re183, Re184	5	5/6	•	•
<b>Re185(n,2n)Re184m</b>	H3, Hf178n, Ta179, Ta182, Re183, Re184, Re184m	5	6	•	•
<b>Re185(n,3n)Re183</b>	H3, Hf178n, Ta179, Ta182, W183, Re183	5	5 <sub>3</sub> *		•
<b>Re185(n,4n)Re182</b>	H3, Hf178n, Ta179, Ta182	4	0		
<b>Re185(n,4n)Re182m</b>	H3, Hf178n, Ta179, Ta182	5	0		
<b>Re185(n,<math>\gamma</math>)Re186</b>	Hf178n, W183, W183m, W187, Re186, Re187, Re188, Os186, Os194, Ir192, Ir194, Pt193	5	4	•	
<b>Re185(n,<math>\gamma</math>)Re186m</b>	Re186m, Re187	5	2	•	
<b>Re185(n,<math>\alpha</math>)Ta182</b>	Hf178n, Ta179, Ta182	5	0		
<b>Re185(n,<math>\alpha</math>)Ta182m</b>	Hf178n, Ta179, Ta182	4	0		
<b>Re186(n,<math>\gamma</math>)Re187</b>	Re187, Re188, Os194, Ir192	5	2	•	
<b>Re187(n,2n)Re186</b>	H3, Hf178n, Ta182, W185, W187, Re183, Re184, Re184m, Re186, Os185	5	6/4	•	•
<b>Re187(n,2n)Re186m</b>	H3, Hf178n, Ta182, W185, Re183, Re184, Re184m, Re186, Re186m	5	4	•	
<b>Re187(n,3n)Re185</b>	H3, Hf178n, Ta179, Ta182, W185, Re183, Re184, Re184m	4	0		
<b>Re187(n,4n)Re184</b>	H3, Hf178n, Ta179, Ta182, Re184	5	0		
<b>Re187(n,4n)Re184m</b>	H3, Hf178n, Ta179, Ta182, Re183, Re184, Re184m	5	0		
<b>Re187(n,<math>\gamma</math>)Re188</b>	Ta182, W185, W187, Re186, Re186m, Re188, Os194, Ir192, Ir192n, Ir194, Pt193	5	6	•	•
<b>Re187(n,<math>\gamma</math>)Re188m</b>	W185, Re188, Os194, Ir192, Ir192n, Ir194, Pt193	4	6*	•	•
<b>Re187(n,p)W187</b>	W187	5	6*	•	•
<b>Re187(n,t)W185</b>	H3, W185	4	5 <sub>3</sub>		•
<b>Re187(n,t)W185m</b>	H3, W185	5	0		

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Re187</b> (n,5n)Re183	H3, Hf178n, Ta179, Ta182, Re183	5	0		
<b>Re187</b> (n,6n)Re182m	H3, Hf178n, Ta179, Ta182	4	0		
<b>Os184</b> (n,γ)Os185	H3, Re186, Re186m, Os185	5	2	•	
Os185(n,2n)Os184	Os184	4	0		
<b>Os186</b> (n,2n)Os185	H3, Ta182, W185, Re183, Re184, Re184m, Re186, Re186m, Os184, Os185	5	2	•	
<b>Os186</b> (n,3n)Os184	Re184, Os184	4	0		
<b>Os186</b> (n,p)Re186	W185, Re186	4	2	•	
<b>Os186</b> (n,p)Re186m	Re184, Re186m	4	0		
<b>Os187</b> (n,2n)Os186	H3, W185, Re184, Re186, Re186m, Os184, Os185, Os186	4	0		
<b>Os187</b> (n,3n)Os185	W185, Re184, Os184, Os185	5	0		
<b>Os187</b> (n,4n)Os184	Re184, Os184	4	0		
<b>Os187</b> (n,γ)Os188	W185, Re186, Re186m, Re187, Os186, Os189m, Os190m, Os191, Os194, Ir191m, Ir192, Ir192n, Ir194, Pt193	5	4	•	
<b>Os187</b> (n,d)Re186	Re186, Os186	4	0		
<b>Os187</b> (n,d)Re186m	Re184, Re186m	4	0		
<b>Os188</b> (n,2n)Os187	H3, W185, Re184, Re186, Re186m, Os184, Os185, Os186	4	0		
<b>Os188</b> (n,3n)Os186	H3, W185, Re184, Re186, Re186m, Os184, Os185, Os186	4	0		
<b>Os188</b> (n,4n)Os185	H3, W185, Re184, Os184, Os185	5	0		
<b>Os188</b> (n,γ)Os189	Os190m, Os191, Os194, Ir191m, Ir192, Ir192n, Ir194, Pt193	4	0		
<b>Os188</b> (n,γ)Os189m	Os189m, Os190m, Os191, Os194, Ir191m, Ir192, Ir192n, Ir194, Pt193	5	0		
<b>Os188</b> (n,d)Re187	W185, Re184, Re186, Re186m, Re187	4	0		
<b>Os188</b> (n,t)Re186	Re186, Os184, Os186	4	0		
<b>Os188</b> (n,t)Re186m	W185, Re184, Re186, Re186m	4	0		
<b>Os188</b> (n,α)W185	Ta182, W185, W187, Re184, Re186, Re186m, Re187, Os186	4	0		
<b>Os188</b> (n,α)W185m	W185, Re184, Re186, Re186m, Re187, Os186	5	0		
<b>Os188</b> (n,5n)Os184	H3, Re184, Os184	4	0		
<b>Os189</b> (n,2n)Os188	H3, W185, Re184, Re186, Re186m, Re187, Os184, Os185, Os186	4	0		
<b>Os189</b> (n,3n)Os187	H3, W185, Re184, Re186, Re186m, Re187, Os184, Os185, Os186	5	0		
<b>Os189</b> (n,α)W185	W185, Re184	4	0		
<b>Os189</b> (n,nt)Re186	Re184, Re186, Os186	4	0		
<b>Os189</b> (n,nt)Re186m	W185, Re184, Re186, Re186m	4	0		
<b>Os189</b> (n,4n)Os186	H3, Re184, Re186, Re186m, Os184, Os185, Os186	4	0		
<b>Os189</b> (n,γ)Os190	H3, Re187, Os191, Os193, Os194, Ir191m, Ir192, Ir192n, Ir194, Pt193	4	4	•	
<b>Os189</b> (n,γ)Os190m	Os190m, Ir192n	5	2	•	
<b>Os189</b> (n,5n)Os185	H3, W185, Re184, Os184, Os185	4	0		
<b>Os189</b> (n,6n)Os184	H3, Re184, Os184	4	0		
<b>Os190</b> (n,n')Os190m	Os190m	4	5 <sub>2</sub>	•	•
<b>Os190</b> (n,2n)Os189m	H3, W185, Re186, Re186m, Re187, Os184, Os185, Os186, Os189m	5	0		
<b>Os190</b> (n,2nα)W185	W185, Re184	4	0		
<b>Os190</b> (n,4n)Os187	H3, W185, Re184, Re186, Re186m, Re187, Os184, Os185, Os186	4	0		
<b>Os190</b> (n,γ)Os191	H3, Os191, Os193, Os194, Ir190, Ir191m, Ir191n, Ir192, Ir192n, Ir194, Pt193	4	2	•	
<b>Os190</b> (n,γ)Os191m	H3, Os191, Os193, Os194, Ir190, Ir191m, Ir191n, Ir192, Ir192n, Ir194, Pt193	5	2	•	
<b>Os190</b> (n,α)W187	Re184, Re186, Re186m, Re187, Os185	5	4	•	
<b>Os190</b> (n,5n)Os186	H3, Re184, Re186, Re186m, Os184, Os185, Os186	4	0		
<b>Os190</b> (n,6n)Os185	H3, W185, Re184, Os184, Os185	4	0		
<b>Os190</b> (n,2nt)Re186	Re186, Os186	4	0		

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Os190</b> (n,2nt)Re186m	W185, Re184, Re186, Re186m	4	0		
Os191(n, $\gamma$ ) <b>Os192</b>	Os193, Os194, Ir194	4	0		
<b>Os192</b> (n,n')Os192m	Ir190, Ir192, Ir192n, Pt193	5	2	•	
<b>Os192</b> (n,2n)Os191	H3, Os189m, Os190m, Os191, Ir190, Ir191m, Ir191n, Ir192, Ir192n, Pt193	5	2	•	
<b>Os192</b> (n,2n)Os191m	H3, Os190m, Os191, Ir190, Ir191m, Ir191n, Ir192, Ir192n, Pt193	4	2	•	
<b>Os192</b> (n,3n)Os190m	W185, Os189m, Os190m	5	4	•	
<b>Os192</b> (n,4n)Os189m	H3, W185, Re184, Re186, Re186m, Os184, Os185, Os186, Os189m	5	0		
<b>Os192</b> (n, $\gamma$ )Os193	Os193, Os194, Ir190, Ir191m, Ir192, Ir192n, Ir193m, Ir194, Pt193	5	4	•	
<b>Os192</b> (n,d)Re191	Re186, Re186m, Os190m, Os191, Ir190, Ir191m, Ir191n, Ir192	5	0		
<b>Os192</b> (n,4n $\alpha$ )W185	W185, Re184	4	0		
Os193(n, $\gamma$ )Os194	Os194	5	2	•	
Ir189(n,2n)Ir188	Os185, Ir188	5	0		
Ir190(n,2n)Ir189	Ir188, Ir189	5	0		
<b>Ir191</b> (n,n')Ir191n	Ir191m, Ir191n	5	0		
<b>Ir191</b> (n,2n)Ir190	H3, Re186, Re186m, Re187, Os185, Os190m, Ir188, Ir189, Ir190	5	2/4/4*	•	
<b>Ir191</b> (n,2n)Ir190n	Re186, Re186m, Re187, Os190m, Ir188, Ir189, Ir190	4	6	•	•
<b>Ir191</b> (n,3n)Ir189	H3, Re186, Re186m, Re187, Os185, Os189m, Ir188, Ir189	5	4	•	
<b>Ir191</b> (n, $\alpha$ )Re187	Re186, Re186m, Re187, Os185	5	0		
<b>Ir191</b> (n,2n $\alpha$ )Re186	Re186, Os185	4	0		
<b>Ir191</b> (n,2n $\alpha$ )Re186m	Re186, Re186m	5	0		
<b>Ir191</b> (n,4n)Ir188	H3, Re186, Re186m, Re187, Os185, Ir188	5	0		
<b>Ir191</b> (n, $\gamma$ )Ir192	H3, Re187, Os194, Ir192, Ir192n, Ir193m, Ir194, Pt193, Pt193m, Pt195m, Au198, Au199	4	2/2/2	•	
<b>Ir191</b> (n, $\gamma$ )Ir192m	H3, Re187, Os194, Ir192, Ir192n, Ir193m, Ir194, Pt193, Pt193m, Pt195m, Au198, Au199	5	2	•	
<b>Ir191</b> (n, $\gamma$ )Ir192n	Ir192n, Ir193m	5	2	•	
<b>Ir191</b> (n, $\alpha$ )Re188	Re186, Re186m, Re187, Os185	5	0		
Ir192(n, $\gamma$ )Ir193m	Ir193m, Ir194, Pt195m, Au198, Au199	5	4	•	
<b>Ir193</b> (n,n')Ir193m	Ir193m	5	4	•	
<b>Ir193</b> (n,2n)Ir192	H3, Re186, Re186m, Re187, Os194, Ir188, Ir189, Ir190, Ir191m, Ir191n, Ir192, Pt190, Pt193, Pt193m	5	0/5/2	•	•
<b>Ir193</b> (n,2n)Ir192m	H3, Re186, Re187, Os194, Ir188, Ir189, Ir190, Ir191m, Ir191n, Ir192, Pt190, Pt193, Pt193m	4	5 <sub>2</sub>	•	•
<b>Ir193</b> (n,2n)Ir192n	H3, Re186, Re186m, Re187, Os185, Ir188, Ir189, Ir190, Ir191m, Ir191n, Ir192, Ir192n, Pt193, Pt193m	5	2	•	
<b>Ir193</b> (n,3n $\alpha$ )Re187	Re186, Re186m, Re187	4	0		
<b>Ir193</b> (n,4n)Ir190	H3, Re186, Re186m, Re187, Os185, Ir188, Ir190	5	0		
<b>Ir193</b> (n, $\gamma$ )Ir194	Os194, Ir194, Pt193, Pt193m, Pt195m, Au198, Au199	5	4	•	
<b>Ir193</b> (n, $\gamma$ )Ir194m	Os194, Ir194, Pt193, Pt193m, Pt195m, Au198, Au199	5	0		
<b>Ir193</b> (n,p)Os193	Os194	5	4	•	
<b>Ir193</b> (n, $\alpha$ )Re190	Re187	4	2/4	•	
<b>Ir193</b> (n,5n)Ir189	H3, Re186, Re186m, Re187, Os185, Ir189	5	0		
<b>Ir193</b> (n,6n)Ir188	H3, Re186, Re186m, Re187, Os185, Ir188	5	0		
<b>Ir193</b> (n,4n $\alpha$ )Re186m	Re186m	4	0		
Ir194(n, $\gamma$ )Ir195	Ir192n, Au198, Au199	4	2	•	
<b>Pt190</b> (n,2n)Pt189	Re186, Re186m, Os185, Ir188, Ir189	5	0		
<b>Pt190</b> (n,3n)Pt188	Re186, Re186m, Os185, Ir188	5	0		
<b>Pt190</b> (n, $\gamma$ )Pt191	Re186, Re186m, Ir192, Ir192n, Pt193	5	2	•	
<b>Pt190</b> (n, $\alpha$ ) <b>Os187</b>	Re186, Re186m, Os185	5	2	•	
<b>Pt192</b> (n,2n)Pt191	H3, Re186, Re186m, Re187, Os185, Ir188,	4	2	•	

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Pt192</b> (n,3n) <b>Pt190</b>	Ir189, Ir190, Ir191m, Ir191n, Pt190 Re186, Re186m, Os185, Ir188, Ir189, Ir190, Pt190	5	0		
<b>Pt192</b> (n, $\gamma$ ) <b>Pt193</b>	Ir194, Pt193, Pt193m, Pt195m, Au198, Au199	5	2	•	
<b>Pt192</b> (n, $\gamma$ ) <b>Pt193m</b>	Pt193, Pt193m, Pt195m, Au198, Au199	5	2	•	
<b>Pt193</b> (n,2n) <b>Pt192</b>	Re186, Re186m, Os185, Ir188, Ir190, Ir191m, Ir192, Pt190	4	0		
<b>Pt193</b> (n,4n) <b>Pt190</b>	Os185, Ir188, Ir190, Pt190	4	0		
<b>Pt193</b> (n,d) <b>Ir192</b>	Ir190, Ir192	4	0		
<b>Pt194</b> (n,2n) <b>Pt193</b>	Re186, Re186m, Os185, Ir188, Ir190, Ir191m, Ir192, Ir192n, Ir193m, Pt190, Pt193, Pt193m	4	0		
<b>Pt194</b> (n,2n) <b>Pt193m</b>	Re186, Re186m, Os185, Ir188, Ir190, Ir191m, Ir192, Ir192n, Ir193m, Pt190, Pt193, Pt193m	5	0		
<b>Pt194</b> (n,3n) <b>Pt192</b>	Re186, Re186m, Os185, Ir188, Ir190, Ir191m, Ir192, Ir192n, Pt190	5	0		
<b>Pt194</b> (n,4n) <b>Pt191</b>	Re186, Re186m, Os185, Ir188, Ir190, Ir191m	5	0		
<b>Pt194</b> (n, $\gamma$ ) <b>Pt195</b>	Ir192n, Pt195m, Pt197, Au197m, Au198, Au199	5	4	•	
<b>Pt194</b> (n, $\gamma$ ) <b>Pt195m</b>	Ir192n, Pt195m, Pt197, Au197m, Au198, Au199	5	2	•	
<b>Pt194</b> (n,p) <b>Ir194</b>	Os194, Ir194	4	4/2	•	
<b>Pt194</b> (n,d) <b>Ir193m</b>	Re186, Re186m, Os185, Ir188, Ir190, Ir192, Ir192n, Ir193m	4	0		
<b>Pt194</b> (n,t) <b>Ir192</b>	Ir188, Ir190, Ir192, Ir192n, Pt190	4	0		
<b>Pt194</b> (n,t) <b>Ir192n</b>	Ir192n	4	0		
<b>Pt194</b> (n, $\alpha$ ) <b>Os191</b>	Re186, Re186m, Os191, Ir188, Ir190, Ir191m, Ir192, Ir192n, Ir193m, Pt193	5	0		
<b>Pt194</b> (n, $\alpha$ ) <b>Os191m</b>	Re186, Re186m, Os191, Ir190, Ir191m, Ir192, Ir192n, Ir193m	5	0		
<b>Pt194</b> (n,5n) <b>Pt190</b>	Re186, Re186m, Os185, Ir188, Ir190, Pt190	5	0		
<b>Pt194</b> (n,6n) <b>Pt189</b>	Re186, Re186m, Os185	4	0		
<b>Pt194</b> (n,2nt) <b>Ir190</b>	Re186, Re186m, Os185, Ir190	4	0		
<b>Pt195</b> (n,n') <b>Pt195m</b>	Pt195m	4	0		
<b>Pt195</b> (n,2n) <b>Pt194</b>	Re186, Re186m, Os185, Ir188, Ir190, Ir191m, Ir192, Ir192n, Ir193m, Ir194, Pt190, Pt193, Pt193m	4	0		
<b>Pt195</b> (n,3n) <b>Pt193m</b>	Re186, Re186m, Os185, Ir188, Ir190, Ir191m, Ir192, Ir192n, Ir193m, Pt190, Pt193, Pt193m	5	0		
<b>Pt195</b> (n,n $\alpha$ ) <b>Os191</b>	Re186, Re186m, Ir188, Ir190, Ir191m	4	0		
<b>Pt195</b> (n,nt) <b>Ir192</b>	Ir188, Ir190, Ir192, Pt190	4	0		
<b>Pt195</b> (n,nt) <b>Ir192n</b>	Ir192n	4	0		
<b>Pt195</b> (n,4n) <b>Pt192</b>	Re186, Re186m, Os185, Ir188, Ir190, Ir191m, Ir192, Ir192n, Pt190	4	0		
<b>Pt195</b> (n, $\gamma$ ) <b>Pt196</b>	Os194, Pt197, Au197m, Au198, Au199, Hg203, Tl204	5	4	•	
<b>Pt195</b> (n,d) <b>Ir194m</b>	Ir190, Ir192, Ir192n, Ir194, Pt190	4	0		
<b>Pt195</b> (n, $\alpha$ ) <b>Os192</b>	Os194, Ir190, Ir191m, Ir193m	5	0		
<b>Pt195</b> (n, $\alpha$ ) <b>Os192m</b>	Os194, Ir191m, Ir192n, Ir193m	5	0		
<b>Pt195</b> (n,6n) <b>Pt190</b>	Re186, Re186m, Os185, Ir188, Ir190, Pt190	4	0		
<b>Pt196</b> (n,2n) <b>Pt195</b>	Ir191m, Ir192, Ir192n, Ir193m, Ir194, Pt190, Pt193, Pt193m	4	0		
<b>Pt196</b> (n,2n) <b>Pt195m</b>	Ir191m, Ir192, Ir192n, Ir193m, Ir194, Pt190, Pt193, Pt193m, Pt195m	5	0		
<b>Pt196</b> (n,4n) <b>Pt193m</b>	Re186, Re186m, Os185, Ir188, Ir190, Ir191m, Ir192, Ir192n, Pt190, Pt193, Pt193m	5	0		
<b>Pt196</b> (n, $\gamma$ ) <b>Pt197</b>	Os194, Pt197, Au194, Au195, Au198, Au199	5	4	•	
<b>Pt196</b> (n, $\gamma$ ) <b>Pt197m</b>	Os194, Pt197, Au194, Au195, Au197m, Au198, Au199, Hg194, Hg203, Tl204	5	4	•	
<b>Pt196</b> (n,h) <b>Os194</b>	Os194	4	0		
<b>Pt196</b> (n, $\alpha$ ) <b>Os193</b>	Os194, Ir190, Ir191m, Ir192, Ir192n, Ir193m, Pt190	5	2	•	
<b>Pt197</b> (n, $\alpha$ ) <b>Os194</b>	Os194	5	0		
<b>Pt198</b> (n,2n) <b>Pt197</b>	Os194, Pt197, Au194, Au195, Au198, Hg194	5	2	•	
<b>Pt198</b> (n,2n) <b>Pt197m</b>	Os194, Pt197, Au194, Au195, Au198, Hg194	5	6	•	•

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Pt198</b> (n,n $\alpha$ )Os194	Os194	5	0		
<b>Pt198</b> (n,4n)Pt195m	Ir190, Ir192, Ir192n, Pt190, Pt193m, Pt195m	4	0		
<b>Pt198</b> (n, $\gamma$ )Pt199	Pt199, Au198, Au199, Hg194, Hg203, Tl204, Pb205	5	4	•	
<b>Pt198</b> (n, $\gamma$ )Pt199m	Pt199, Au198, Au199, Hg194, Hg203, Tl204, Pb205	4	2	•	
Au195(n,2n)Au194m	Ir193m, Pt190, Pt193, Au192, Au194	4	0		
Au195(n,4n)Au192	Pt190, Au192	4	0		
Au195(n,4n)Au192m	Pt190, Au192	4	0		
<b>Au197</b> (n,n')Au197m	Au197m	5	5 <sub>2</sub>	•	•
<b>Au197</b> (n,2n)Au196	Ir191m, Ir192, Ir192n, Ir193m, Ir194, Pt190, Pt193, Au192, Au194, Au195, Au196, Hg194, Hg196	5	6	•	•
<b>Au197</b> (n,3n)Au195	Ir191m, Ir192, Ir192n, Ir193m, Ir194, Pt190, Pt193, Au192, Au194, Au195	4	6	•	•
<b>Au197</b> (n,3n)Au195m	Ir191m, Ir192, Ir192n, Ir193m, Ir194, Pt190, Pt193, Au192, Au194, Au195	5	5 <sub>3</sub>		•
<b>Au197</b> (n,n $\alpha$ )Ir193m	Ir191m, Ir192, Ir192n, Ir193m, Pt190	5	0		
<b>Au197</b> (n,2n $\alpha$ )Ir192	Ir192, Ir192n, Pt190	4	0		
<b>Au197</b> (n,2n $\alpha$ )Ir192n	Ir192n	4	0		
<b>Au197</b> (n,4n)Au194m	Ir191m, Ir192, Ir192n, Ir193m, Ir194, Pt190, Pt193, Au192, Au194	5	0		
<b>Au197</b> (n,4n)Au194n	Ir191m, Ir192, Ir192n, Ir193m, Ir194, Pt190, Pt193, Au194	4	0		
<b>Au197</b> (n, $\gamma$ )Au198	Ir192n, Ir193m, Au197m, Au198, Au199, Hg194, Hg199m, Hg203, Tl204, Pb204, Pb205	5	6	•	•
<b>Au197</b> (n, $\alpha$ )Ir194	Os191, Ir191m, Ir192, Ir192n, Ir193m, Ir194, Pt190, Pt193, Au197m	5	6/6	•	•
<b>Au197</b> (n,5n)Au193m	Ir191m, Ir192, Ir192n, Ir193m, Pt190, Pt193	5	0		
<b>Au197</b> (n,6n)Au192	Ir191m, Ir192, Pt190, Au192	4	0		
<b>Au197</b> (n,6n)Au192m	Ir191m, Ir192, Ir192n, Pt190, Au192	5	0		
Au198(n, $\gamma$ )Au199	Au197m, Au199, Hg203, Tl204, Pb204, Pb205	5	2/2	•	
Au198(n, $\alpha$ )Ir195	Ir192n, Ir193m, Au197m	5	0		
Hg194(n,3n)Hg192	Pt190, Au192	5	0		
Hg194(n,5n)Hg190	Pt190	4	0		
Hg195m(n,2n)Hg194	Pt190, Au192, Hg194	5	0		
<b>Hg196</b> (n,2n)Hg195m	Ir192, Pt190, Pt193, Au192, Au194, Au195, Hg194	5	2	•	
<b>Hg196</b> (n,3n)Hg194	Pt190, Pt193, Au192, Au194, Hg194	5	0		
<b>Hg196</b> (n,4n)Hg193	Pt190, Pt193	4	0		
<b>Hg196</b> (n, $\gamma$ )Hg197	Au198, Hg197, Hg199m	5	4/2	•	
<b>Hg196</b> (n, $\alpha$ )Pt193	Ir192, Ir192n, Pt190, Pt193	5	0		
<b>Hg198</b> (n,2n)Hg197	H3, Pt193, Au194, Au195, Au196, Au198, Hg194, Hg197	4	4	•	
<b>Hg198</b> (n,2n)Hg197m	Pt193, Au194, Au195, Au196, Au198, Hg194, Hg197	4	4	•	
<b>Hg198</b> (n,3n)Hg196	H3, Pt190, Pt193, Au194, Au195, Au196, Hg194	5	0		
<b>Hg198</b> (n,4n)Hg195m	H3, Pt190, Pt193, Au194, Au195	4	0		
<b>Hg198</b> (n, $\gamma$ ) <b>Hg199</b>	Au197m, Au199, Hg199m, Hg203, Tl204, Pb204, Pb205	5	5 <sub>2</sub>	•	•
<b>Hg198</b> (n, $\gamma$ )Hg199m	Au197m, Au199, Hg199m, Hg203, Tl204, Pb204, Pb205	5	2	•	
<b>Hg198</b> (n,p)Au198	Au198	5	0		
<b>Hg198</b> (n, $\alpha$ ) <b>Pt195</b>	Ir192n, Ir193m, Pt190, Pt193, Au197m	5	0		
<b>Hg198</b> (n,5n)Hg194	H3, Pt190, Pt193, Au194, Hg194	5	0		
<b>Hg199</b> (n,2n) <b>Hg198</b>	H3, Pt190, Pt193, Au194, Au195, Au196, Au198, Hg194, Hg197	4	0		
<b>Hg199</b> (n,3n)Hg197	H3, Pt190, Pt193, Au194, Au195, Au196, Hg197	4	0		
<b>Hg199</b> (n,3n)Hg197m	H3, Pt193, Au194, Au195, Au196, Hg197	4	0		
<b>Hg199</b> (n,4n)Hg196	H3, Pt190, Pt193, Au194, Au195, Au196, Hg194	5	0		
<b>Hg199</b> (n, $\gamma$ ) <b>Hg200</b>	Hg203, Tl204, Pb204, Pb205	5	4	•	
<b>Hg199</b> (n,p)Au199	Au199	4	2	•	

Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Hg199</b> (n,d)Au198	Au195, Au196, Au198, Hg194	4	0		
<b>Hg199</b> (n, $\alpha$ ) <b>Pt196</b>	Pt190, Pt193, Au197m	5	0		
<b>Hg199</b> (n,5n)Hg195m	H3, Pt190, Pt193, Au194, Au195	4	0		
<b>Hg199</b> (n,6n)Hg194	H3, Pt190, Pt193, Au194, Hg194	4	0		
<b>Hg200</b> (n,2n)Hg199m	H3, Au194, Au195, Au196, Au198, Hg194, Hg197, Hg199m	5	6	•	•
<b>Hg200</b> (n,4n)Hg197	H3, Pt190, Pt193, Au194, Au195, Au196, Hg194, Hg197	4	0		
<b>Hg200</b> (n,4n)Hg197m	H3, Pt193, Au194, Au195, Au196, Hg194, Hg197	4	0		
<b>Hg200</b> (n, $\gamma$ ) <b>Hg201</b>	Hg203, Tl204, Pb204, Pb205	5	4	•	
<b>Hg200</b> (n,t)Au198	H3, Pt193, Au194, Au195, Au196, Au198, Hg194	4	0		
<b>Hg201</b> (n,3n)Hg199m	H3, Au194, Au195, Au196, Au198, Hg194, Hg197, Hg199m	5	0		
<b>Hg201</b> (n,4n) <b>Hg198</b>	H3, Pt190, Pt193, Au194, Au195, Au196, Au198, Hg194, Hg197	4	0		
<b>Hg201</b> (n, $\gamma$ ) <b>Hg202</b>	Hg203, Tl204, Pb204, Pb205	5	4	•	
<b>Hg202</b> (n,4n)Hg199m	H3, Au194, Au195, Au196, Au198, Hg194, Hg197, Hg199m	5	0		
<b>Hg202</b> (n, $\gamma$ )Hg203	Hg203, Hg205, Tl202, Tl204, Pb202, Pb204, Pb205	5	4	•	
<b>Hg204</b> (n,2n)Hg203	H3, Hg199m, Hg203, Tl200, Tl202, Tl204, Pb202, Pb205	5	4	•	
<b>Hg204</b> (n, $\gamma$ )Hg205	Hg205, Tl202, Tl204, Pb202, Pb205	5	4	•	
<b>Hg204</b> (n,d)Au203	Hg203, Tl202, Tl204, Pb202	4	0		
Tl201(n,2n)Tl200	Hg194, Tl200	5	0		
Tl202(n,2n)Tl201	Tl200, Tl201	5	0		
<b>Tl203</b> (n,2n)Tl202	H3, Au194, Au195, Hg194, Hg203, Tl200, Tl201, Tl202	5	6	•	•
<b>Tl203</b> (n,3n)Tl201	H3, Au194, Au195, Hg194, Hg199m, Tl200,	5	4	•	
<b>Tl203</b> (n,4n)Tl200	H3, Au194, Au195, Hg194, Tl200	5	0		
<b>Tl203</b> (n, $\gamma$ )Tl204	Hg203, Hg205, Tl204, Tl206, Pb202, Pb204, Pb204m, Pb205	5	4	•	
<b>Tl203</b> (n,p)Hg203	Hg203	4	2	•	
<b>Tl203</b> (n, $\alpha$ )Au200	Hg194, Hg203	5	2/2	•	
<b>Tl203</b> (n,5n)Tl199	H3, Au194, Au195, Hg194	4	0		
<b>Tl205</b> (n,2n)Tl204	H3, Au195, Hg194, Hg203, Tl200, Tl201, Tl202, Tl204, Pb202, Pb204m, Pb205	5	4	•	
<b>Tl205</b> (n,3n) <b>Tl203</b>	H3, Au195, Hg194, Hg203, Tl200, Tl201, Tl202	4	0		
<b>Tl205</b> (n,4n)Tl202	H3, Au194, Au195, Hg194, Tl200, Tl202	5	0		
<b>Tl205</b> (n, $\gamma$ )Tl206	Hg203, Tl206, Pb202, Pb204m, Pb205	5	6	•	•
<b>Tl205</b> (n,t)Hg203	Hg194, Hg203	5	6	•	•
<b>Tl205</b> (n,5n)Tl201	H3, Au194, Au195, Hg194, Tl201	5	0		
<b>Tl205</b> (n,6n)Tl200	H3, Au194, Au195, Hg194, Tl200	5	0		
Pb202(n,3n)Pb200	Tl200	4	0		
Pb202(n,5n)Pb198	Hg194	4	0		
Pb203(n,2n)Pb202	Tl200, Pb202	4	0		
<b>Pb204</b> (n,n')Pb204m	Pb204m	5	6	•	•
<b>Pb204</b> (n,2n)Pb203	H3, Hg203, Tl200, Tl202, Tl204, Pb202, Pb203	4	6	•	•
<b>Pb204</b> (n,2n)Pb203m	Hg203, Tl200, Tl202, Tl204, Pb202, Pb203	4	5 <sub>2</sub>	•	•
<b>Pb204</b> (n,3n)Pb202	H3, Hg194, Tl200, Tl202, Pb202	5	0/4	•	
<b>Pb204</b> (n, $\gamma$ )Pb205	Hg203, Tl204, Pb205	5	4	•	
<b>Pb204</b> (n,p)Tl204	Tl202, Tl204	4	0		
<b>Pb204</b> (n, $\alpha$ ) <b>Hg201</b>	Hg194, Hg203, Tl204	4	0		
<b>Pb204</b> (n,5n)Pb200	Hg194, Tl200	4	0		
Pb205(n,2n)Pb204	H3, Hg203, Tl200, Tl202, Tl204, Pb202, Pb203, Pb204m	4	0		
Pb205(n,2n)Pb204m	Tl200, Tl202, Tl204, Pb202, Pb203, Pb204m	5	0		
Pb205(n,4n)Pb202	Hg194, Tl200, Tl202, Pb202	4	0		
Pb205(n,d)Tl204	Hg203, Tl202, Tl204, Pb202	4	0		
<b>Pb206</b> (n,2n)Pb205	H3, Hg203, Tl200, Tl202, Tl204, Pb202, Pb203,	5	4	•	



Reaction	Daughter nuclide	Imp	Score	Exp data	
				Diff	Int
<b>Pb206</b> (n,3n)Pb204	Pb204m, Pb205 H3, Hg194, Hg203, Tl200, Tl202, Tl204, Pb202, Pb203, Pb204m	4	0		
<b>Pb206</b> (n,3n)Pb204m	H3, Hg203, Tl200, Tl202, Tl204, Pb202, Pb203, Pb204m	5	4	•	
<b>Pb206</b> (n,4n)Pb203	H3, Hg194, Hg203, Tl200, Tl202, Pb203	4	0		
<b>Pb206</b> (n,4n)Pb203m	H3, Hg203, Tl200, Tl202, Pb203	4	0		
<b>Pb206</b> (n,γ)Pb207m	Pb207m	5	2	•	
<b>Pb206</b> (n,p)Tl206	Tl206	5	5 <sub>2</sub>	•	•
<b>Pb206</b> (n,t)Tl204	H3, Hg194, Hg203, Tl200, Tl202, Tl204, Pb202	4	0		
<b>Pb206</b> (n,α)Hg203	Hg203, Tl200, Tl202, Tl204	5	6	•	•
<b>Pb206</b> (n,5n)Pb202	H3, Hg194, Tl200, Tl202, Pb202	4	0		
<b>Pb207</b> (n,3n)Pb205	H3, Hg194, Hg203, Tl200, Tl202, Tl204, Pb202, Pb203, Pb204m, Pb205	5	0		
<b>Pb207</b> (n,nα)Hg203	Hg203, Tl200, Tl202	4	0		
<b>Pb207</b> (n,nt)Tl204	H3, Hg194, Hg203, Tl200, Tl202, Tl204	4	0		
<b>Pb207</b> (n,4n)Pb204m	Hg194, Tl200, Tl202, Tl204, Pb202, Pb203, Pb204m	5	0		
<b>Pb207</b> (n,d)Tl206m	Tl206, Tl206m	4	0		
<b>Pb207</b> (n,α)Hg204	Hg203, Tl200, Tl202	4	2	•	
<b>Pb207</b> (n,6n)Pb202	H3, Hg194, Tl200, Tl202, Pb202	4	0		
<b>Pb208</b> (n,2n)Pb207m	H3, Hg203, Hg205, Tl202, Tl204, Tl206, T	5	4	•	
<b>Pb208</b> (n,3n)Pb206	H3, Hg203, Hg205, Tl200, Tl202, Tl204, Tl206, Tl206m, Pb202, Pb203, Pb204m, Pb205	4	0		
<b>Pb208</b> (n,2nα)Hg203	Hg203, Tl200, Tl202	4	0		
<b>Pb208</b> (n,4n)Pb205	H3, Hg194, Hg203, Tl200, Tl202, Tl204, Pb202, Pb203, Pb204m, Pb205	5	0		
<b>Pb208</b> (n,γ)Pb209	H3, Pb209, Pb210, Bi207, Bi208, Bi210m, Po210	5	4	•	
<b>Pb208</b> (n,α)Hg205	Hg203, Hg205, Tl202, Tl204	5	4	•	
<b>Pb208</b> (n,5n)Pb204	H3, Hg194, Tl200, Tl202, Pb202, Pb203	4	0		
<b>Pb208</b> (n,5n)Pb204m	H3, Hg194, Tl200, Tl202, Pb204m	5	0		
<b>Pb208</b> (n,6n)Pb203	H3, Hg194, Hg203, Tl200, Tl202, Pb203	4	0		
<b>Pb208</b> (n,2nt)Tl204	Hg194, Hg203, Tl200, Tl202, Tl204	4	0		
<b>Pb209</b> (n,γ)Pb210	Pb210	5	0		
Bi203(n,3n)Bi201m	Bi201m	5	0		
Bi204(n,4n)Bi201m	Bi201m	5	0		
Bi205(n,3n)Bi203	Bi201m	5	0		
Bi205(n,5n)Bi201m	Bi201m	5	0		
Bi206(n,2n)Bi205	Pb202, Bi205	5	0		
Bi207(n,2n)Bi206	Tl206, Tl206m, Pb202, Bi201m, Bi205, Bi206	5	0		
Bi207(n,3n)Bi205	Pb202, Bi201m, Bi205	5	0		
Bi207(n,4n)Bi204	Pb202, Bi201m	5	0		
Bi208(n,2n)Bi207	Tl206, Tl206m, Pb202, Bi201m, Bi205, Bi206, Bi207	5	0		
Bi208(n,3n)Bi206	Tl206, Tl206m, Pb202, Bi201m, Bi206	4	0		
Bi208(n,4n)Bi205	Pb202, Bi201m, Bi205	4	0		
<b>Bi209</b> (n,2n)Bi208	Tl206, Tl206m, Pb202, Bi201m, Bi205, Bi206, Bi207, Bi208	5	0/4	•	
<b>Bi209</b> (n,3n)Bi207	Tl206, Tl206m, Pb202, Bi201m, Bi205, Bi206, Bi207	5	6	•	•
<b>Bi209</b> (n,4n)Bi206	Tl206, Tl206m, Pb202, Bi201m, Bi206	5	6	•	•
<b>Bi209</b> (n,γ)Bi210	Pb202, Pb210, Bi210, Po209, Po210	5	4	•	
<b>Bi209</b> (n,γ)Bi210m	Pb210, Bi210m	5	2	•	
<b>Bi209</b> (n,α)Tl206	Tl206, Pb202	5	6	•	•
<b>Bi209</b> (n,α)Tl206m	Tl206, Tl206m	5	4*	•	
<b>Bi209</b> (n,5n)Bi205	Pb202, Bi201m, Bi205	5	4	•	
Po210(n,2n)Po209	Pb202, Po209	5	0		

## Summary of reaction types

Reaction↓	Importance→	5	4	3	2	1	Total
(n,n')		22	6	4	9	15	56
(n,2n)		245	120	65	55	75	560
(n,3n)		86	66	69	55	120	396
(n,4n)		82	74	38	44	88	326
(n,5n)		24	45	38	25	75	207
(n,6n)		12	29	16	15	50	122
(n,7n)		0	0	0	1	4	5
(n,γ)		379	53	23	19	49	523
(n,p)		102	50	21	11	37	221
(n,d)	(n,n'p)	50	80	52	41	94	317
(n,t)	(n,n'd)+(n,2np)	54	66	44	38	106	308
(n,h)	(n,pd)+(n,n'2p)	12	5	9	11	28	65
(n,α)	(n,n'h)+(n,n'pd)+(n,pt)+(n,2n2p)	170	66	38	43	66	383
(n,n't)	(n,2nd)+(n,3np)	7	34	41	55	105	242
(n,n'α)	(n,2nh)+(n,3n2p)	53	49	42	46	91	281
(n,2nt)	(n,3nd)+(n,4np)	7	18	36	35	79	175
(n,2nα)	(n,3nh)+(n,4n2p)	25	31	34	34	110	234
(n,3nt)	(n,4nd)+(n,5np)	0	0	0	2	28	30
(n,3nα)	(n,4nh)+(n,5n2p)	1	16	16	18	83	134
(n,4nα)		0	9	5	10	38	62
(n,5nα)		0	0	0	0	2	2
(n,2p)		7	5	4	1	9	26
(n,2α)		9	10	6	7	19	51
(n,n'2α)	(n,3n2pα)	5	8	9	9	28	59
(n,2n2α)		3	5	8	4	26	46
(n,3n2α)		0	0	0	0	1	1
(n,ph)		2	2	1	1	6	12
(n,pα)	(n,n'ph)+(n,dh)	7	5	4	10	18	44
(n,dα)	(n,n'pα)+(n,n'dh)	8	17	5	8	26	64
(n,tα)	(n,n'dα)+(n,2npα)+(n,n'th)	7	7	10	15	39	78
(n,hα)		1	2	3	0	5	11
(n,n'tα)	(n,3npα)	1	2	0	2	20	25
(n,d2α)		3	0	1	0	5	9
(n,t2α)	(n,n'd2α)	1	0	0	1	1	3
(n,3p)		0	2	0	0	1	3
(n,3α)		1	0	2	3	6	12
(n,n'3α)		1	3	1	2	5	12
<b>Standard</b>		<b>1316</b>	<b>744</b>	<b>519</b>	<b>506</b>	<b>1141</b>	<b>4226</b>
<b>Exotic</b>		<b>71</b>	<b>141</b>	<b>126</b>	<b>124</b>	<b>417</b>	<b>879</b>
<b>Total</b>		<b>1387</b>	<b>885</b>	<b>645</b>	<b>630</b>	<b>1558</b>	<b>5105</b>