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EASY-2004 Summary Report

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EASY-2004 Summary report

Introduction

The European Activation System (EASY) has been developed for fusion applications. A great deal of work has been carried out to validate it, and the current version (EASY-2003 [1]) is used extensively throughout the world. Its primary use – activation calculations for fusion – means that its upper energy range of 20 MeV is sufficient. However, it has been recognised that the materials testing that is foreseen as necessary in parallel with ITER, using proposed devices such as IFMIF, means that this energy limit needs to be raised. The IFMIF facility will be a d-Li device with deuterons accelerated to 40 MeV impinging on a flowing Li target and generating an intense neutron field by a stripping reaction. It is expected that the neutron spectrum will contain a significant number of neutrons above 20 MeV, probably as high as 55 MeV. To enable activation calculations to be carried out for IFMIF, EASY needs to be extended to handle neutrons with energies > 20 MeV.

The first decision to be made was the value of the new upper energy. By limiting this to 60 MeV it was judged possible to retain the same methodology as currently used. Such an energy was adequate for IFMIF but would not be large enough for applications such as incineration of nuclear waste using accelerators. Since IFMIF was the primary application this limit was judged suitable and this value is also used within the EFDA specification of the work. At energies above 20 MeV many new reaction types involving the emission of multiple particles are possible. Enumerating all these explicitly becomes impractical as the energy becomes too large. It was believed that use of a limited number of new reaction classes for EASY was feasible, and as described below this is what was found.

The development of a 60 MeV version of EASY is a major task and 2 years development time was required. This report summarises the results of the work after one year. The stage reached is the production of EASY-2004, which although not designed for distribution, is a version that can be used for activation calculations. Documentation of this test version has not been produced since it is not to be distributed to users. The sub-tasks that have been carried out are:

1. Extension of the SAFEPAQ-II application used in the production of the EAF libraries. Many of the modifications had a 'built-in' value of 20 MeV and options were required so that either 20 or 60 MeV could be used. Also the visualisation and collection of experimental data needed extending to 60 MeV.
2. Extension of the decay data library was necessary since the new reaction classes allowed many new nuclides to be produced.
3. Use of a source of calculated data for cross sections above 20 MeV. There are two tasks: the extension of all existing reactions (12,617) with cross section data between 20 and 60 MeV, and the data for new reactions with thresholds so high that they were not present in EAF-2003.
4. Extension of the uncertainty representation to include another energy group from 20 – 60 MeV.
5. Extension of the biological hazard, clearance and transport libraries so they are consistent with the decay data library.

6. Extensions of the FISPACT inventory code so that the EAF-2004 library with its much-increased size could be used for calculations.

No work has been done on the Windows User Interface for this version. This will be carried out over the next year when final testing and improvement of EAF and FISPACT have been completed. In parallel with the development work on EASY-2004 that treats energies > 20 MeV, improvements to the data below 20 MeV have been accumulated. These include new data sources, experimental data and changes in response to the integral data validation [2]. All these new results will be implemented next year during the production of EASY-2005.

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 from several sources 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.

The design of SAFEPAQ-II is very different from that of previous tools. All data are stored in relational databases and the application built using Visual Basic runs on a Windows platform. The status of the SAFEPAQ-II (**S**ystem for **A**ctivation **F**ile **E**valuation, **P**rocessing **A**nd **Q**uality assurance) application used to construct EAF-2003 is described in reference 3.

Over the last year many modifications have been made, both to add new features and to extend the energy range of the cross sections to 60 MeV. The main changes are:

- Validation histograms, which show the distribution of library to experimental ratios (C/E) for the various reaction classes, can be produced for any source library not just FINAL.
- The database of effective cross sections from the integral measurements can be used with any source library not just FINAL. Thus the Integral data C/E plots can be made for any library.
- Various time saving features, such as copying all reactions for a target into the CACHE with a single command, have been added.
- Bugs in the coding have been fixed, *e.g.* in systematics formulae.
- An option in the Decay data viewer has been added to show the decay chains for a nuclide.
- A_2 data for a nuclide can be viewed and changed.
- The Reaction search window has been extended so the data source can be specified.
- A new Modification type has been defined. This enables a merge of the existing reaction data above an energy with data from a different type of reaction. For example an (n,α) reaction can have its low energy region replaced with data from an (n,γ) reaction.
- New decay modes with RTPY=1.55 (β^-nn) and 5 (n) are defined.
- New group structures with 211 and 351 energy groups defined.

- New uncertainty group between 20 and 60 MeV defined.
- All non-threshold reactions - not just (n,γ) and (n,f) - can have 4 uncertainty values.
- The ability to read an IEAF-2001 type library with lumped cross sections added.
- New MT numbers for 49 new reaction classes have been defined.
- The ability to read a TALYS type library with an extended range of MT numbers added.
- Options to add new reactions (from TALYS) have been added. A minimum cross section is specified and any reaction not in the current EAF library with data above this value is added to the reaction list.
- Change existing Modifications so that upper energy limit is 60 MeV.
- Automatically merge existing reactions with TALYS data above 20 MeV, record the factor (*f*) used when making the join.
- If *f* is very large then automatically change the data source to TALYS.
- Define set of MT numbers that refer to summed reactions, enable all of these to be calculated in CACHE. This allows IEAF-2001 data to be graphically compared with TALYS data.
- If a reaction has been changed with two data merge modifications, an option to switch the order of the modifications has been added.
- The databases such as MASTER and FINAL can get very large during processing. Coding to automatically compact them and continue with the processing step has been added.
- A new set of Tests on FINAL relevant to high-energy data has been added.
- The facility to use data from a different reaction type for a reaction added. For example data for (n,n′p+d) can be used as the source for both (n,n′p) and (n,d) reactions.

Descriptions of the new features will be added to the SAFEPAQ-II User manual, but this has not been done so far. These and any additional features added during the development of EAF-2005 will be documented in a new issue that will be released with the remaining standard documentation for EASY-2005. Figure 1 shows the About box window for the current build of SAFEPAQ-II.

Figure 1. The About SAFEPAQ-II window.

Decay data

In a series of iterations the additional nuclides required as a result of the new reactions were identified. 278 new nuclides were added, the nuclides that have been added (+) or changed (>) since EAF-2003 are shown in Table 1. Column 1 shows the ID of the nuclide as used in FISPACT, column 2 is the nuclide name, column 3 is the nuclide spin, column 4 shows the decay modes, column 5 is the nuclide half-life, column 6 the uncertainty in the half-life, column 7 is the heavy particle energy (mean α), column 8 is the light particle energy (mean β), column 9 is the photon energy (mean γ) and column 10 is the data source. To aid readability zero values in columns 4 - 9 are replaced by blanks. The key to symbols is given at the end of the listing.

Data were mostly taken from JEF-2.2, but some data from the test version of JEFF-3.0 were included. Where data were taken by hand from other sources or the data were modified in any way the source culham_03 is shown. A total of 2195 nuclides are defined in EAF-2004. Most of the new nuclides have short half-lives ($T_{½}$):

- 58 have $T_{½} < 1$ s
- 131 have 1 s $< T_{½} <$ 1 min
- 75 have 1 min $< T_{½} <$ 10 min
- 14 have $T_{½} >$ 10 min

The longest-lived new nuclide is ^{199}Bi (27 min).

Table 1. New and amended nuclides in EAF-2004.

ID	Nuclide	J	Decay modes	T½	ΔT½(%)	<α>(eV)	<β>(eV)	<γ>(eV)	Source
> 7	Li-5	1.5	p	3.00E-22 s	0.00	1.9650E+06			jeff-3t2
+ 18	Be-12	0.0	β^-	0.024 s	12.50	5.8400E+03	5.5900E+06	3.9023E+06	jef22_dec
+ 19	Be-13	0.5	n	2.70E-21 s	0.00				jeff-3t2
> 21	B-9	1.5	p	8.00E-19 s	0.00	1.8504E+05			jeff-3t2
+ 26	B-14	2.0	β^-	0.016 s	7.45	1.2600E+04	7.1000E+06	5.6000E+06	jef22_dec
+ 27	B-15	1.5	β^-:6.0;β^-,n:93.6;β^-,2n:0.4	0.010 s	0.00		3.8188E+05	3.8188E+05	jeff-3t2
+ 35	C-16	0.0	β^-:2.0;β^-,n:98.0	0.747 s	1.07	1.1200E+03	2.0470E+06	7.1000E+03	jef22_dec
+ 36	C-17	?	β^-:71.6;β^-,n:28.4	0.193 s	0.00		3.1422E+06	3.1422E+06	jeff-3t2
+ 37	N-11	0.5	p	5.00E-22 s	0.00	1.9730E+06			jeff-3t2
+ 45	N-19	0.5	β^-:45.4;β^-,n:54.6	0.271 s	0.00		1.8957E+06	1.8957E+06	jeff-3t2
+ 46	N-20	?	β^-:43.0;β^-,n:57.0	0.130 s	0.00		2.5756E+06	2.5756E+06	jeff-3t2
+ 54	O-21	?	β^-	3.420 s	0.00		2.7031E+06	2.7031E+06	jeff-3t2
+ 55	O-22	0.0	β^-:78.0;β^-,n:22.0	2.250 s	0.00		1.6876E+06	1.6876E+06	jeff-3t2
+ 56	F-15	0.5	p	4.60E-22 s	0.00	1.4816E+06			jeff-3t2
+ 57	F-16	0.0	p	1.10E-20 s	0.00	5.3587E+05			jeff-3t2
+ 65	F-24	?	β^-:94.1;β^-,n:5.9	0.400 s	0.00		4.2320E+06	4.2320E+06	jeff-3t2
+ 66	Ne-17	0.5	β^+:1.3;β^+,p:96.0;β^+,α:2.7	0.109 s	0.00		6.2978E+04	6.2978E+04	jeff-3t2
+ 75	Ne-26	0.0	β^-:99.87;β^-,n:0.13	0.197 s	0.00		2.4409E+06	2.4409E+06	jeff-3t2
+ 76	Ne-27	1.5	β^-:98.0;β^-,n:2.0	0.032 s	0.00		4.1403E+06	4.1403E+06	jeff-3t2
+ 87	Na-29	?	β^-	0.043 s	3.50	2.5000E+03	5.1000E+06	4.4700E+06	jef22_dec
+ 88	Na-30	2.0	β^-:68.83;β^-,n:30.0;β^-,2n:1.17	0.048 s	0.00		4.0097E+06	4.0097E+06	culham_03
+ 89	Mg-21	?	β^+:70.7;β^+,p:29.3	0.122 s	2.46	3.2000E+03	4.7000E+06	1.5100E+06	jef22_dec
+ 98	Mg-30	0.0	β^-:99.94;β^-,n:0.06	0.335 s	0.00		2.3287E+06	2.3287E+06	jeff-3t2
+ 99	Mg-31	1.5	β^-:98.3;β^-,n:1.7	0.230 s	0.00		3.8465E+06	3.8465E+06	jeff-3t2
+ 100	Al-23	?	β^+	0.470 s	0.00		4.0793E+06	4.0793E+06	jef22_dec
+ 112	Al-33	2.5	β^-:91.5;β^-,n:8.5	0.041 s	0.00		3.6562E+06	3.6562E+06	jeff-3t2
+ 113	Al-34	4.0	β^-:87.5;β^-,n:12.5	0.042 s	0.00		4.9858E+06	4.9858E+06	jeff-3t2
+ 114	Si-25	2.5	β^+	0.220 s	1.36	1.2700E+03	2.3300E+06	1.0200E+06	jef22_dec
+ 124	Si-35	3.5	β^-:94.74;β^-,n:5.26	0.780 s	0.00		3.3152E+06	3.3152E+06	jeff-3t2
+ 125	Si-36	0.0	β^-:88.0;β^-,n:12.0	0.450 s	0.00		2.3027E+06	2.3027E+06	jeff-3t2
+ 135	P-37	0.5	β^-	2.310 s	0.00		2.6338E+06	2.6338E+06	jeff-3t2
+ 136	P-38	?	β^-:88.0;β^-,n:12.0	0.640 s	0.00		3.6359E+06	3.6359E+06	jeff-3t2
+ 137	P-39	0.5	β^-:74.0;β^-,n:26.0	0.190 s	0.00		2.5929E+06	2.5929E+06	jeff-3t2
+ 138	P-40	?	β^-:70.0;β^-,n:30.0	0.290 s	0.00		3.3863E+06	3.3863E+06	jeff-3t2
+ 139	S-29	2.5	β^+	0.187 s	2.14	3.6000E+03	4.0700E+06	4.6116E+06	jef22_dec
+ 151	S-41	3.5	β^-	2.600 s	0.00		2.9124E+06	2.9124E+06	jeff-3t2
+ 165	Cl-43	?	β^-	3.300 s	6.06		2.5700E+06	2.5700E+06	jef22_dec
+ 166	Cl-44	?	β^-:92.0;β^-,n:8.0	0.560 s	0.00		3.7631E+06	3.7631E+06	jeff-3t2
+ 167	Cl-45	1.5	β^-:76.0;β^-,n:24.0	0.400 s	0.00		2.7385E+06	2.7385E+06	jeff-3t2
+ 168	Ar-33	0.5	β^+:66.0;β^+,p:34.0	0.173 s	1.16	1.4400E+03	3.8000E+06	1.3830E+06	jef22_dec
+ 182	Ar-47	1.5	β^-:99.0;β^-,n:1.0	0.580 s	0.00		3.2302E+06	3.2302E+06	jeff-3t2
+ 197	Ca-37	1.5	β^+:24.0;β^+,p:76.0	0.175 s	1.71	1.1100E+03	3.2700E+06	1.1400E+06	jef22_dec
+ 226	Sc-51	3.5	β^-	12.400 s	0.81		1.8440E+06	2.3500E+06	jef22_dec
+ 227	Sc-52	3.0	β^-	8.200 s	0.00		3.0279E+06	3.0279E+06	jeff-3t2
+ 228	Ti-41	1.5	β^+:99.9;β^+,p:0.1	0.080 s	2.50	1.1670E+03	3.4300E+06	1.0960E+06	jef22_dec
+ 241	Ti-54	0.0	β^-	1.500 s	0.00		1.3742E+06	1.3742E+06	jeff-3t2
+ 242	Ti-55	1.5	β^-	0.460 s	0.00		2.4473E+06	2.4473E+06	jeff-3t2
+ 254	V-55	3.5	β^-	6.540 s	2.29		2.3800E+06	6.8900E+05	jef22_dec
+ 255	V-56	3.0	β^-	0.233 s	0.00		3.0164E+06	3.0164E+06	jeff-3t2
+ 256	V-57	3.5	β^-:99.6;β^-,n:0.4	0.320 s	0.00		2.6615E+06	2.6615E+06	jeff-3t2
+ 257	V-58	3.0	β^-:20.0;β^-,n:80.0	0.203 s	0.00		7.7004E+05	7.7004E+05	jeff-3t2
+ 271	Cr-59	2.5	β^-	0.460 s	0.00		2.5408E+06	2.5408E+06	jeff-3t2
+ 288	Mn-60m	3.0	β^-	1.790 s	5.59		2.7200E+06	2.6900E+06	culham_03
+ 289	Mn-61	2.5	β^-	0.670 s	0.00		2.3941E+06	2.3941E+06	jeff-3t2
+ 290	Mn-62	3.0	β^-	0.880 s	0.00		3.4774E+06	3.4774E+06	jeff-3t2
+ 291	Mn-63	2.5	β^-	0.275 s	0.00		3.0092E+06	3.0092E+06	jeff-3t2
+ 292	Mn-64	1.0	β^-	0.087 s	0.00		3.9930E+06	3.9930E+06	jeff-3t2
+ 312	Co-52	6.0	β_g^+:50.0;β_m^+:50.0	0.115 s	0.00		3.6677E+06	3.6677E+06	jeff-3t2
+ 313	Co-53	3.5	β^+	0.240 s	8.33		3.4000E+06	1.1000E+06	jef22_dec
+ 331	Co-67	3.5	β^-	0.425 s	0.00		2.8070E+06	2.8070E+06	jeff-3t2
+ 332	Co-68	7.0	β^-	0.200 s	0.00		3.8859E+06	3.8859E+06	jeff-3t2
+ 333	Co-68m	3.0	β^-:50.0;IT:50.0	1.600 s	0.00		1.9680E+06	2.0430E+06	jeff-3t2
+ 334	Co-69	3.5	β^-:99.0;β^-,n:1.0	0.220 s	0.00		3.0795E+06	3.0795E+06	culham_03
+ 335	Ni-53	3.5	β^+	0.045 s	33.33		1.6600E+06	4.5990E+05	jef22_dec
+ 336	Ni-54	0.0	β^+	0.143 s	0.00		2.9331E+06	2.9331E+06	culham_03
+ 373	Cu-73	?	β^-:99.99;β^-,n:0.01	3.900 s	7.69		1.9850E+06	7.2932E+05	jef22_dec
+ 374	Cu-74	?	β^-:99.71;β^-,n:0.29	1.600 s	9.38		1.9230E+06	4.9000E+06	jef22_dec

ID	Nuclide	J	Decay modes	T½	ΔT½(%)	<α>(eV)	<β>(eV)	<γ>(eV)	Source
+375	Cu-75	?	β^-:96.5;β^-,n:3.5	1.300 s	7.69		2.2270E+06	2.0890E+06	jef22_dec
+398	Ga-63	1.5	β^+	32.400 s	1.54		1.8880E+06	1.3700E+06	jef22_dec
+414	Ga-78	3.0	β^-	5.490 s	0.00		2.4385E+06	2.4899E+06	jef22_dec
+415	Ga-79	1.5	β_g^-:94.71;β_m^-:5.2;β^-,n:0.09	3.000 s	3.00	2.8000E+05	2.2300E+06	1.8400E+06	jef22_dec
+416	Ge-64	0.0	β^+	1.062 m	3.92		1.0800E+06	1.2130E+06	jef22_dec
+417	Ge-65	?	β^+	30.900 s	1.62		2.1000E+06	1.7000E+06	jef22_dec
+439	As-67	?	β^+	42.500 s	2.82		2.0033E+06	1.4700E+06	jef22_dec
+456	As-83	1.5	β_g^-:30.0;β_m^-:70.0	13.400 s	2.24		1.3700E+06	2.0200E+06	jef22_dec
+457	As-84	?	β^-:99.72;β^-,n:0.28	5.500 s	5.45		2.0000E+06	5.3400E+06	jef22_dec
+458	Se-68	?	β^+	2.000 s	0.00		1.6000E+06	1.6000E+06	jef22_dec
+459	Se-69	?	β^+:99.96;β^+,p:0.05	27.400 s	0.73		2.3000E+06	1.8700E+06	jef22_dec
+505	Br-87	1.5	β^-:97.48;β^-,n:2.52	55.690 s	0.23	2.2000E+05	1.8800E+06	3.3400E+06	jef22_dec
+506	Br-88	?	β^-:93.42;β^-,n:6.58	16.500 s	0.61	2.2000E+05	1.6800E+06	4.2900E+06	jef22_dec
+507	Kr-72	0.0	β^+	17.200 s	1.74		1.5300E+06	1.2900E+06	jef22_dec
+508	Kr-73	?	β^+:99.3;β^+,p:0.7	27.000 s	4.44	3.4400E+04	2.4800E+06	1.5700E+06	jef22_dec
+529	Kr-90	0.0	β_g^-:87.8;β_m^-:12.2	32.320 s	0.28		1.2950E+06	1.2370E+06	jef22_dec
+530	Rβ^-77	1.5	β^+	3.750 m	2.22		1.7000E+06	1.5300E+06	jef22_dec
+550	Rβ^-91	1.5	β^-:99.99;β^-,n:0.01	58.400 s	0.68		1.5600E+06	2.3350E+06	jef22_dec
+551	Rβ^-92	0.0	β^-:99.99;β^-,n:0.01	4.510 s	0.44	1.9000E+05	3.4990E+06	3.9300E+05	jef22_dec
+552	Rβ^-93	2.5	β^-:98.65;β^-,n:1.35	5.700 s	1.75	4.0000E+05	2.6300E+06	1.9200E+06	jef22_dec
+553	Rβ^-94	3.0	β^-:90.0;β^-,n:10.0	2.702 s	0.19	4.1000E+05	2.8300E+06	4.1200E+06	jef22_dec
+554	Sr-78	0.0	β^+	2.650 m	0.00		1.2538E+06	1.2538E+06	culham_03
+555	Sr-79	1.5	β^+	2.250 m	4.44		1.8000E+06	1.2836E+06	jef22_dec
+576	Y-81	0.5	β^+	1.207 m	1.80		2.0300E+06	1.0050E+06	jef22_dec
+604	Y-98	1.0	β^-:99.67;β^-,n:0.33	0.650 s	7.69	6.5000E+05	2.5400E+06	3.5894E+06	jef22_dec
+605	Y-98m	4.0	β^-:96.6;β^-,n:3.4	2.000 s	10.00		2.1743E+06	3.4268E+06	jef22_dec
+606	Zr-82	0.0	β^+	32.000 s	15.63		1.3333E+06	1.3333E+06	jef22_dec
+607	Zr-83	0.5	β^+	44.000 s	2.27		2.1000E+06	1.1400E+06	jef22_dec
+656	Nβ^-101	?	β^-	7.100 s	4.23		1.6950E+06	6.4900E+05	jef22_dec
+657	Nβ^-102	?	β^-	1.300 s	15.38		1.7860E+06	3.1050E+06	jef22_dec
+658	Nβ^-102m	4.0	β^-	4.300 s	9.30		2.2756E+06	2.0935E+06	culham_03
+659	Nβ^-103	2.5	β^-:99.99;β^-,n:0.01	1.500 s	13.33		2.0970E+06	7.6600E+05	jef22_dec
+660	Nβ^-104	4.5	β^-:99.99;β^-,n:0.01	0.800 s	25.00		2.0045E+06	3.1930E+06	jef22_dec
+681	Tc-90	1.0	β^+	7.900 s	2.53		3.6200E+06	1.1572E+06	jef22_dec
+682	Tc-90m	8.0	β^+	49.200 s	0.00		3.0902E+06	3.0902E+06	jeff-3t2
+683	Tc-91	4.5	β^+	3.140 m	0.64		1.6300E+06	2.4600E+06	jef22_dec
+684	Tc-91m	0.5	β^+	3.300 m	3.03		1.9800E+06	1.4800E+06	jef22_dec
+707	Tc-107	0.0	β^-	21.000 s	4.76		1.5838E+06	5.9752E+05	jef22_dec
+708	Tc-108	3.0	β^-	5.170 s	1.35		2.2600E+06	1.4900E+06	jef22_dec
+709	Tc-109	?	β^-:99.99;β^-,n:0.01	1.400 s	28.57		2.2530E+06	7.0800E+05	jef22_dec
+710	Ru-92	0.0	β^+	3.650 m	1.37		6.1200E+05	2.1237E+06	jef22_dec
+711	Ru-93	4.5	β^+	59.700 s	1.01		2.3500E+06	1.1670E+06	jef22_dec
+712	Ru-93m	0.5	β^+:77.8;IT:22.2	10.800 s	2.78		1.5500E+06	1.9900E+06	jef22_dec
+732	Rh-95	4.5	β^+	5.017 m	1.99		8.9000E+05	2.4700E+06	jef22_dec
+733	Rh-95m	0.5	β^+:12.0;IT:88.0	1.960 m	2.04		1.9000E+05	8.9000E+05	jef22_dec
+764	Rh-112m	5.0	β^-	6.800 s	2.94		1.9086E+06	2.2610E+06	culham_03
+765	Rh-113	?	β^-	2.720 s	0.00		1.8129E+06	5.2700E+05	jef22_dec
+766	Rh-114	1.0	β^-	1.850 s	2.70		2.7000E+06	4.7308E+05	jef22_dec
+767	Rh-114m	4.0	β^-	1.850 s	2.70		2.0300E+06	2.5157E+06	jef22_dec
+768	Pd-96	0.0	β_g^+:50.0;β_m^+:50.0	2.033 m	0.00		1.1413E+06	1.1413E+06	jeff-3t2
+769	Pd-97	2.5	β^+	3.100 m	3.23		7.6000E+05	2.4500E+06	jef22_dec
>791	Pd-115	2.5	β_g^-:73.0;$\beta\mu^-$:27.0	25.000 s	12.00		1.3600E+06	1.4400E+06	culham_03
+792	Pd-115m	5.5	β_m^-:92.0;IT_g:8.0	50.000 s	0.00		1.4205E+06	1.4276E+06	culham_03
+793	Pd-116	0.0	β^-	12.400 s	4.03		9.9000E+05	1.7480E+05	jef22_dec
+794	Pd-117	?	β_g^-:50.0;β_m^-:50.0	5.000 s	24.00		1.1190E+06	2.9130E+06	jef22_dec
+795	Pd-118	?	β_g^-:50.0;β_m^-:50.0	3.100 s	9.68		1.4830E+06	6.8700E+05	jef22_dec
+829	Ag-117	0.5	β_g^-:86.0;β_m^-:14.0	1.213 m	2.84		1.3067E+06	1.0924E+06	jef22_dec
+830	Ag-117m	3.5	β_g^-:21.5;β_m^-:78.5	5.340 s	0.94		1.5034E+06	6.4452E+05	jef22_dec
+831	Ag-118	0.0	β^-	3.700 s	0.00		2.5080E+06	8.9272E+05	jef22_dec
+832	Ag-118m	4.0	β^-:59.0;IT:41.0	2.000 s	10.00		1.2500E+06	1.5000E+06	culham_03
+833	Ag-119	3.5	β_g^-:78.99;β_m^-:21.0;β^-,n:0.01	2.100 s	4.76		1.7706E+06	1.3367E+06	jef22_dec
+834	Ag-119m	0.5	β_g^-:50.0;β_m^-:50.0	6.000 s	0.00		1.7589E+06	1.7589E+06	culham_03
+835	Ag-120	3.0	β^-:100.0;β^-,n:~	1.170 s	4.27		2.2838E+06	1.0766E+06	jef22_dec
+836	Ag-121	?	β^-:99.92;β^-,n:0.08	0.800 s	12.50		2.4600E+06	8.4400E+05	jef22_dec
+837	Ag-122	3.0	β^-:99.81;β^-,n:0.19	0.480 s	16.67		3.6000E+06	1.1200E+06	jef22_dec
+866	Cd-123m	5.5	β_g^-:98.78;β_m^-:1.22	1.820 s	1.65		1.6090E+06	2.3306E+06	culham_03
+916	In-127	4.5	β_g^-:15.4;β_m^-:84.57;β^-,n:0.03	1.150 s	4.35		2.2075E+06	1.7664E+06	jef22_dec
+917	In-127m	0.5	β_m^-:49.81;β_g^-:49.5;β^-,n:0.69	3.700 s	2.70	1.1000E+05	2.7420E+06	5.0120E+05	jef22_dec
+918	In-128	3.0	β^-:99.96;β^-,n:0.04	0.900 s	11.11		2.7786E+06	3.0721E+06	jef22_dec

ID	Nuclide	J	Decay modes	T½	ΔT½(%)	$\langle\alpha\rangle$(eV)	$\langle\beta\rangle$(eV)	$\langle\gamma\rangle$(eV)	Source
+ 919	Sn-107	?	β^+	2.900 m	1.72		1.7000E+06	1.7000E+06	jef22_dec
+ 989	Sβ-133	3.5	β_g^-:71.0;β_m^-:29.0	2.470 m	4.05		4.4000E+05	2.4030E+06	jef22_dec
+ 990	Te-113	3.5	β^+	1.700 m	11.76		1.4600E+06	2.3234E+06	jef22_dec
+1023	I-116	1.0	β^+	2.910 s	5.15		3.0200E+06	1.0552E+06	jef22_dec
+1024	I-117	2.5	β^+	2.300 m	4.35		6.0000E+05	1.0000E+06	jef22_dec
+1051	I-137	3.5	β^-:92.86;β^-,n:7.14	24.500 s	0.41	6.7000E+05	2.0300E+06	1.2300E+06	jef22_dec
+1052	Xe-117	2.5	β^+	1.017 m	0.00		1.2900E+04	2.9500E+05	jef22_dec
+1053	Xe-118	0.0	β^+	6.000 m	16.67		1.0667E+06	5.7000E+05	jef22_dec
+1054	Xe-119	3.5	β^+	5.800 m	5.17		1.6633E+06	1.3100E+06	jef22_dec
+1095	Cs-130m	5.0	IT:99.84;β^+:0.16	3.460 m	0.00		1.6760E+03	1.6467E+05	jeff-3t2
+1110	Cs-141	3.5	β^-:99.97;β^-,n:0.04	24.940 s	0.24	2.7000E+05	1.5800E+06	1.1400E+06	jef22_dec
+1111	Ba-123	?	β^+	2.700 m	14.81		1.8333E+06	3.8100E+05	jef22_dec
+1116	Ba-127m	3.5	IT	1.900 s	0.00			8.0330E+04	jeff-3t2
+1159	La-145	0.0	β^-	24.200 s	0.00		8.5000E+05	1.4800E+06	jef22_dec
+1160	La-146	2.0	β^-	6.270 s	1.59		1.9200E+06	2.2800E+06	jef22_dec
+1161	La-146m	6.0	β^-	10.000 s	1.00		2.1740E+06	1.3238E+06	jef22_dec
+1162	La-147	2.5	β^-:99.96;β^-,n:0.04	4.000 s	0.00		1.6000E+06	1.2600E+06	jef22_dec
+1163	Ce-129	2.5	β_g^+:50.0;β_m^+:50.0	3.500 m	0.00		1.6546E+06	1.6546E+06	jeff-3t2
+1211	Pr-151	0.5	β^-	18.900 s	0.37		1.4730E+06	6.5500E+05	jef22_dec
+1212	Nd-135	4.5	β^+	12.333 m	5.41		9.8000E+05	1.2700E+06	jef22_dec
+1213	Nd-135m	0.5	β^+:99.97;IT:0.03	5.500 m	0.00		1.6050E+06	1.6050E+06	jeff-3t2
+1235	Nd-154	0.0	β^-	25.900 s	0.77		7.9050E+05	3.9600E+05	jef22_dec
+1236	Pm-135	5.5	β^+	49.000 s	14.29		2.0000E+06	2.6585E+06	jef22_dec
+1237	Pm-135m	5.5	β_g^+:100.0;β_m^+:~	40.000 s	0.00		2.0300E+06	2.0300E+06	jeff-3t2
+1238	Pm-136	2.0	β^+	1.783 m	5.61		1.1200E+05	2.6300E+06	culham_03
+1239	Pm-136m	2.0	β^+	47.000 s	0.00		2.7100E+06	2.7100E+06	jeff-3t2
+1240	Pm-137	5.5	β^+	2.400 m	4.17		8.3800E+05	1.7259E+06	jef22_dec
+1241	Pm-138	1.0	β^+	10.000 s	20.00		2.6300E+06	9.5754E+05	jef22_dec
+1242	Pm-138m	3.0	β^+	3.233 m	1.55		9.1000E+03	2.4200E+06	culham_03
+1243	Pm-139	2.5	β^+	4.150 m	1.20		1.9100E+06	9.5000E+05	jef22_dec
+1244	Pm-139m	5.5	IT	0.180 s	11.11		1.0180E+05	8.5300E+04	jef22_dec
+1267	Pm-157	2.5	β^-	10.900 s	1.83		1.6890E+06	4.7700E+05	culham_03
+1268	Sm-136	0.0	β^+	42.700 s	5.15		5.3000E+04	3.0827E+05	jef22_dec
+1269	Sm-137	4.5	β^+	45.000 s	0.00		1.9068E+06	1.9068E+06	culham_03
+1270	Sm-137m	0.5	β^+	20.000 s	0.00		2.0268E+06	2.0268E+06	culham_03
+1271	Sm-138	0.0	β^+	3.000 m	10.00		1.2000E+06	1.2000E+06	jef22_dec
+1272	Sm-139	0.5	β^+	2.567 m	3.90		1.7100E+06	1.5100E+06	jef22_dec
+1273	Sm-139m	5.5	β^+:6.3;IT:93.7	10.700 s	5.61		1.5400E+05	2.6300E+05	jef22_dec
+1274	Sm-140	0.0	β^+	14.817 m	0.67		2.3000E+05	6.0000E+05	jef22_dec
+1275	Sm-141	0.5	β^+	10.200 m	1.96		7.0000E+05	1.4040E+06	jef22_dec
+1276	Sm-141m	5.5	β^+:99.69;IT:0.31	22.600 m	0.88		3.4900E+05	1.9100E+06	jef22_dec
+1296	Eu-138	7.0	β^+	12.100 s	4.96		3.0666E+06	3.0666E+06	jef22_dec
+1297	Eu-139	5.5	β^+	17.900 s	3.35		2.2000E+06	1.6200E+06	jef22_dec
+1298	Eu-140	1.0	β^+	1.540 s	8.44		2.7333E+06	7.8000E+05	culham_03
+1299	Eu-141	2.5	β^+	40.000 s	1.75		1.8090E+06	1.1710E+06	jef22_dec
+1300	Eu-141m	5.5	β^+:67.0;IT:33.0	2.700 s	11.11		1.3020E+06	6.2000E+05	jef22_dec
+1301	Eu-142	1.0	β^+	2.400 s	8.33		2.9500E+06	1.1364E+06	jef22_dec
+1302	Eu-142m	8.0	β^+	1.220 m	1.64		1.7400E+06	3.1509E+06	jef22_dec
+1325	Eu-161	?	β^-	25.000 s	0.00		1.4865E+06	3.8900E+05	jef22_dec
+1326	Eu-162	?	β^-	9.300 s	0.00		1.1450E+06	2.3110E+06	jef22_dec
+1327	Eu-163	2.5	β^-	6.000 s	0.00		1.6207E+06	1.6207E+06	jeff-3t2
+1328	Gd-139	?	β^+,p	4.900 s	20.41				jef22_dec
+1329	Gd-140	0.0	β^+	15.800 s	0.00		1.8201E+06	1.8201E+06	culham_03
+1330	Gd-141	0.5	β^+:99.97;β^+,p:0.03	14.000 s	0.00		2.2734E+06	2.2734E+06	culham_03
+1331	Gd-141m	5.5	β_m^+:89.0;IT_g:11.0	24.500 s	0.00		2.1074E+06	2.1490E+06	culham_03
+1332	Gd-142	0.0	β^+	1.500 m	20.00		9.0000E+05	6.5400E+05	jef22_dec
+1333	Gd-143	0.5	β^+	39.000 s	5.13		1.7200E+06	1.2040E+06	jef22_dec
+1334	Gd-143m	5.5	β^+	1.867 m	1.79		1.1200E+06	2.1050E+06	jef22_dec
+1335	Gd-144	0.0	β^+	4.500 m	2.22		1.2333E+06	1.2333E+06	jef22_dec
+1358	Tβ^-144	1.0	β^+	1.000 s	0.00		3.0000E+06	2.8770E+05	jef22_dec
+1359	Tβ^-144m	6.0	β^+:34.0;IT:66.0	4.250 s	3.53		2.4900E+03	6.5670E+05	jef22_dec
+1360	Tβ^-145	1.5	β_g^+:100.0;β_m^+:~	20.000 m	0.00		2.2332E+06	2.2332E+06	jeff-3t2
+1361	Tβ^-145m	5.5	β^+	29.500 s	5.08		1.0300E+06	2.2500E+06	culham_03
+1395	Tβ^-167	1.5	β^-	19.000 s	0.00		1.3665E+06	1.3665E+06	jeff-3t2
+1396	Tβ^-168	4.0	β^-	8.200 s	0.00		1.9903E+06	1.9903E+06	jeff-3t2
+1397	Dy-147	0.5	β^+:99.95;β^+,p:0.05	40.000 s	0.00		2.1232E+06	2.1232E+06	culham_03
+1398	Dy-147m	5.5	β^+:60.0;IT:40.0	59.000 s	5.08		2.5560E+06	1.1660E+06	jef22_dec
+1424	Ho-152	2.0	β^+:88.0;α:12.0	2.697 m	0.19	5.2830E+05	3.4100E+05	1.6500E+06	jef22_dec
+1425	Ho-152m	9.0	β^+:89.2;α:10.8	49.500 s	0.61	4.8200E+05	5.0710E+05	3.3700E+06	jef22_dec

ID	Nuclide	J	Decay modes	T½	ΔT½(%)	<α>(eV)	<β>(eV)	<γ>(eV)	Source
+1459	Ho-173	3.5	β^-	10.000 s	0.00		1.5183E+06	1.5183E+06	jeff-3t2
+1460	Er-153	?	β^+:47.0;α:53.0	37.100 s	0.54	2.5410E+06			jef22_dec
+1461	Er-154	0.0	β^+:99.53;α:0.47	3.683 m	4.07	6.8828E+05	1.4200E+04	9.3400E+03	jef22_dec
+1462	Er-155	3.5	β^+:99.98;α:0.02	5.300 m	5.66	8.8260E+02	2.8200E+05	1.7200E+06	jef22_dec
+1484	Tm-158	2.0	β^+	4.017 m	2.49		1.5500E+06	1.7100E+06	jef22_dec
+1485	Tm-159	2.5	β^+	9.150 m	2.00		1.3300E+06	1.3333E+06	jef22_dec
+1506	Tm-177	0.5	β_m^-	1.367 m	0.00		1.0641E+06	1.0641E+06	culham_03
+1507	Tm-178	?	β^-	30.000 s	0.00		1.8618E+06	1.8618E+06	jeff-3t2
+1508	Tm-179	0.5	β^-	20.000 s	0.00		1.6050E+06	1.6050E+06	jeff-3t2
+1509	$Y\beta^-159$	?	β^+	1.400 m	14.29		1.5333E+06	4.7100E+05	jef22_dec
+1510	$Y\beta^-160$	0.0	β^+	4.800 m	0.00		7.8000E+04	2.7929E+05	jef22_dec
+1511	$Y\beta^-161$	1.5	β^+	4.200 m	4.76		1.4267E+06	9.4000E+05	jef22_dec
+1534	$Y\beta^-181$	1.5	β^-	1.000 m	0.00		1.2980E+06	1.2980E+06	jeff-3t2
+1535	Lu-162	1.0	β^+	1.370 m	1.46		2.3633E+06	1.3800E+06	jef22_dec
+1536	Lu-163	0.5	β^+	3.967 m	3.36		1.3000E+06	4.1600E+06	jef22_dec
+1537	Lu-164	?	β^+	3.140 m	0.96		5.1000E+04	9.3000E+05	jef22_dec
+1538	Lu-165	3.5	β^+	10.733 m	0.93		3.5200E+05	1.3053E+06	jef22_dec
+1567	Lu-183	3.5	β^-	58.000 s	6.90		1.1200E+06	7.0000E+05	jef22_dec
+1568	Lu-184	3.0	β_g^-:50.0;β_m^-:50.0	20.000 s	0.00		1.5646E+06	1.5646E+06	jeff-3t2
+1569	Hf-163	?	β^+	40.000 s	1.50		3.1000E+05	7.3000E+05	jef22_dec
+1570	Hf-164	0.0	β^+	2.800 m	7.14		9.6666E+05	9.6666E+05	jef22_dec
+1571	Hf-165	5.5	β^+	1.700 m	5.88		1.5767E+06	3.9120E+05	jef22_dec
+1572	Hf-166	0.0	β^+	6.767 m	4.43		6.3200E+04	2.8200E+05	jef22_dec
+1573	Hf-167	2.5	β^+	2.050 m	2.44		5.8770E+05	6.8279E+05	jef22_dec
+1599	Hf-184m	8.0	β^-	48.000 s	0.00		8.7080E+05	8.7080E+05	jeff-3t2
+1626	Ta-189	?	β^-	34.700 s	10.09		1.2133E+06	1.2133E+06	culham_03
+1627	Ta-190	?	β^-	1.510 s	33.11		1.8600E+06	1.8600E+06	culham_03
+1628	W-171	2.5	β^+	2.380 m	0.00		1.5523E+06	1.5523E+06	jeff-3t2
+1654	W-194	?	β^-	24.430 s	204.67		1.0200E+06	1.0200E+06	culham_03
+1655	Re-174	?	β^+	2.300 m	4.35		2.1667E+06	5.0000E+05	jef22_dec
+1656	Re-175	2.5	β^+	5.890 m	0.00		1.4353E+06	1.4353E+06	jeff-3t2
+1657	Re-176	3.0	β^+	5.667 m	14.71		1.8667E+06	2.9900E+05	jef22_dec
+1658	Re-177	2.5	β^+	14.000 m	7.14		3.1200E+05	5.7233E+05	jef22_dec
+1682	Re-196	?	β^-	3.970 s	10.08		1.8767E+06	1.8767E+06	culham_03
+1683	Re-197	?	β^-	4.870 s	10.27		1.4767E+06	1.4767E+06	culham_03
+1684	Re-198	?	β^-	2.280 s	13.16		2.1267E+06	2.1267E+06	culham_03
+1685	Os-175	2.5	β^+	1.400 m	0.00		1.7657E+06	1.7657E+06	jeff-3t2
+1686	Os-176	0.0	β^+	3.000 m	27.78		9.6666E+05	9.6666E+05	jef22_dec
+1687	Os-177	0.5	β^+	2.800 m	0.00		1.4827E+06	1.4827E+06	jeff-3t2
+1688	Os-178	0.0	β^+	5.000 m	0.00		7.7536E+05	7.7536E+05	jeff-3t2
+1689	Os-179	0.5	β^+	6.500 m	4.62		1.2033E+06	1.2033E+06	jef22_dec
+1716	Os-200	?	β^-	16.000 s	12.50		8.6667E+05	8.6667E+05	culham_03
+1717	Os-201	?	β^-	9.440 s	21.19		1.4133E+06	1.4133E+06	culham_03
+1718	Ir-178	?	β^+	12.000 s	16.67		2.4333E+06	1.3800E+06	jef22_dec
+1719	Ir-179	2.5	β^+	1.317 m	0.00		1.6140E+06	1.6140E+06	jeff-3t2
+1720	Ir-180	?	β^+	1.500 m	6.67		2.1333E+06	1.6400E+06	jef22_dec
+1721	Ir-181	3.5	β^+	4.900 m	3.06		4.1000E+05	1.3333E+06	jef22_dec
+1753	Ir-201	?	β^-	18.500 s	10.81		1.2567E+06	1.2567E+06	culham_03
+1754	Ir-202	?	β^-	8.500 s	17.65		1.8133E+06	1.8133E+06	culham_03
+1755	Pt-181	0.5	β^+:99.94;α:0.06	51.000 s	9.80	1.6854E+06			jef22_dec
+1756	Pt-182	0.0	β^+:99.98;α:0.02	2.600 m	3.85	9.6700E+02		1.8255E+05	jef22_dec
+1757	Pt-183	0.5	β^+:100.0;α:~	6.500 m	15.38	6.1500E+01			culham_03
+1758	Pt-183m	3.5	β^+	43.000 s	11.63		6.8000E+04	1.1700E+06	jef22_dec
+1783	Pt-203	?	β^-	41.100 s	10.00		9.3000E+05	9.3000E+05	culham_03
+1784	Au-185	?	β^+	4.333 m	19.23		1.5833E+06	1.5833E+06	jef22_dec
+1785	Au-186	3.0	β^+	10.667 m	4.69		1.1700E+06	2.0300E+06	jef22_dec
+1817	Au-205	1.5	β^-	31.000 s	0.00		1.1035E+06	1.1035E+06	culham_03
+1818	Au-206	?	β^-	1.590 s	31.45		2.1933E+06	2.1933E+06	culham_03
+1819	Hg-186	0.0	β^+:99.98;α:0.02	1.383 m	6.02	8.1500E+02	1.3000E+05	4.1000E+05	jef22_dec
+1820	Hg-187	6.5	β^+:99.99;α:0.01	2.400 m	12.50	1.6071E+06		4.0458E+06	jef22_dec
+1821	Hg-187m	1.5	β^+:100.0;α:~	1.900 m	15.79	1.2590E+01			jef22_dec
+1822	Hg-188	0.0	β^+:99.99;α:0.01	3.250 m	4.62	4.6100E+06		6.4577E+05	jef22_dec
+1823	Hg-189	1.5	β^+:99.9;α:0.1	7.600 m	0.00	1.3198E+06	6.8000E+05	3.1130E+06	jef22_dec
+1824	Hg-189m	6.5	β^+	8.700 m	0.00		9.2000E+05	1.3170E+06	jef22_dec
+1850	Tl-192	7.0	β^+	10.800 m	1.85		4.3500E+04	2.0000E+06	jef22_dec
+1877	$P\beta^-193$	6.5	β^+	5.800 m	3.45		1.6500E+06	5.9600E+05	jef22_dec
+1878	$P\beta^-194$	0.0	β^+:100.0;α:~	12.000 m	4.17	3.3870E-01	7.4100E+04	1.0680E+06	jef22_dec
+1908	Bi-196	10.0	β^+	4.667 m	10.71		2.4600E+06	1.7100E+06	jef22_dec
+1909	Bi-197	4.5	β_m^+:100.0;α_m:~	9.300 m	0.00	5.0175E+00	1.6180E+06	1.6180E+06	culham_03

ID	Nuclide	J	Decay modes	T½	ΔT½(%)	<α>(eV)	<β>(eV)	<γ>(eV)	Source
+1910	Bi-197m	0.5	α:54.84;β+:44.87;IT:0.3	5.040 m	0.00	3.2334E+06	8.4996E+05	8.5149E+05	culham_03
+1911	Bi-198	2.0	β+	10.300 m	0.00		2.1871E+06	2.1871E+06	culham_03
+1912	Bi-198m	7.0	β+	11.850 m	1.55		2.1603E+06	1.8980E+06	culham_03
+1913	Bi-198n	10.0	IT	7.700 s	6.49		1.3800E+05	1.0700E+05	culham_03
+1914	Bi-199	4.5	β+	27.000 m	3.70		1.4400E+06	1.2220E+06	jef22_dec
+1915	Bi-199m	0.5	β+:99.99;α:0.01	24.700 m	0.61	5.4840E+02			jef22_dec

Key to listing: Nuclide names may contain 'm' or 'n' following the mass number, these refer to 1st and 2nd isomeric states respectively. A nuclide spin (J) shown by '?' means that it is unknown, the file actually contains -77.777. If no decay mode is given then the nuclide is stable, a single mode is labelled as beta - decay (β^-), beta + or electron capture decay (β^+), an isomeric transition (IT), alpha decay (α), proton decay (p) or neutron decay (n). Combinations of these are shown separated by a comma *e.g.* 'β^-,n' is a beta - followed by neutron emission. If the daughter nuclide is not in the ground state then the decay symbol has the subscript 'm' or 'n'; if it is required then the subscript 'g' distinguishes the daughter in the ground state. Multiple decay modes are separated by a semicolon; for each mode the branching ratio is given in percent. If the percentage branching is less than 0.01% then the symbol '~' is used. The nuclide half-life (T½) is given in units of seconds (s), minutes (m), hours (h), days (d) or years (y); fixed format is used wherever possible, for very short- or long-lived nuclides scientific notation is applied.

Cross section data > 20 MeV

Although there are some measurements and evaluated libraries with data > 20 MeV, these are rather sparse and for a source of cross section data at high energies it is necessary to rely on calculation. There is a major code development project underway led by A Koning (NRG Petten) involving the TALYS code system [4]. This is a very versatile system enabling the production of a wide range of data using a unified set of models. As part of this development a series of libraries was produced containing activation cross sections for energies up to 60 MeV. Feedback on early libraries enabled many bugs and problems with the code to be removed. The data library termed TALYS-4 was read into SAFEPAQ-II and was used as the basis for the production of EAF-2004.

There were two main tasks that had to be carried out with the TALYS data. Firstly all reactions in EAF-2003 required extending using TALYS data (note that for some reactions data were missing from TALYS-4 and another data source such as IEAF-2001 was used). It was decided that the TALYS-4 data above 20 MeV should be renormalised so as to fit smoothly onto the EAF-2003 data at 20 MeV. The scaling factor for each reaction (*f*) was stored in SAFEPAQ-II. Secondly, reactions not present in EAF-2003 but with threshold below 60 MeV and values above a minimum value (1 μb was chosen) needed to be added into the reaction list of EAF-2004. This was done automatically within SAFEPAQ-II. In collaboration with Koning new reaction classes and non-ENDF MT numbers (151 < MT < 201) were defined. The reaction MT number is the method used in ENDF formatted nuclear data files to refer to types of reactions.These and reactions with existing MT numbers but no examples in EAF-2003 are shown in Table 2. Note that reactions with up to 8 emitted particles are defined.

Table 2. New reaction types in EAF-2004.

Reaction type	MT number	Reaction type	MT number
(n,2nd)	11	(n,5nd)	170
(n,n′3α)	23	(n,6nd)	171
(n,2n2α)	30	(n,3nt)	172
(n,n'd2α)	35	(n,4nt)	173
(n,n′t2α)	36	(n,5nt)	174
(n,3np)	42	(n,6nt)	175
(n,n′2p)	44	(n,2nh)	176
(n,n′pα)	45	(n,3nh)	177
(n,3α)	109	(n,4nh)	178
(n,t2α)	113	(n,3n2p)	179
(n,d2α)	114	(n,3n2α)	180
(n,pd)	115	(n,3npα)	181
(n,pt)	116	(n,dt)	182
(n,dα)	117	(n,n′pd)	183
(n,5n)	152	(n,n′pt)	184
(n,6n)	153	(n,n′dt)	185
(n,2nt)	154	(n,n′ph)	186
(n,tα)	155	(n,n′dh)	187
(n,4np)	156	(n,n′th)	188
(n,3nd)	157	(n,n′tα)	189
(n,n′dα)	158	(n,2n2p)	190
(n,2npα)	159	(n,ph)	191
(n,7n)	160	(n,dh)	192
(n,8n)	161	(n,hα)	193
(n,5np)	162	(n,4n2p)	194
(n,6np)	163	(n,4n2α)	195
(n,7np)	164	(n,4npα)	196
(n,4nα)	165	(n,3p)	197
(n,5nα)	166	(n,n′3p)	198
(n,6nα)	167	(n,3n2pα)	199
(n,7nα)	168	(n,5n2p)	200
(n,4nd)	169		

Examples of reactions where the data are smoothly extended above 20 MeV and a reaction new to EAF-2004 are shown in Figures 2 and 3 respectively.

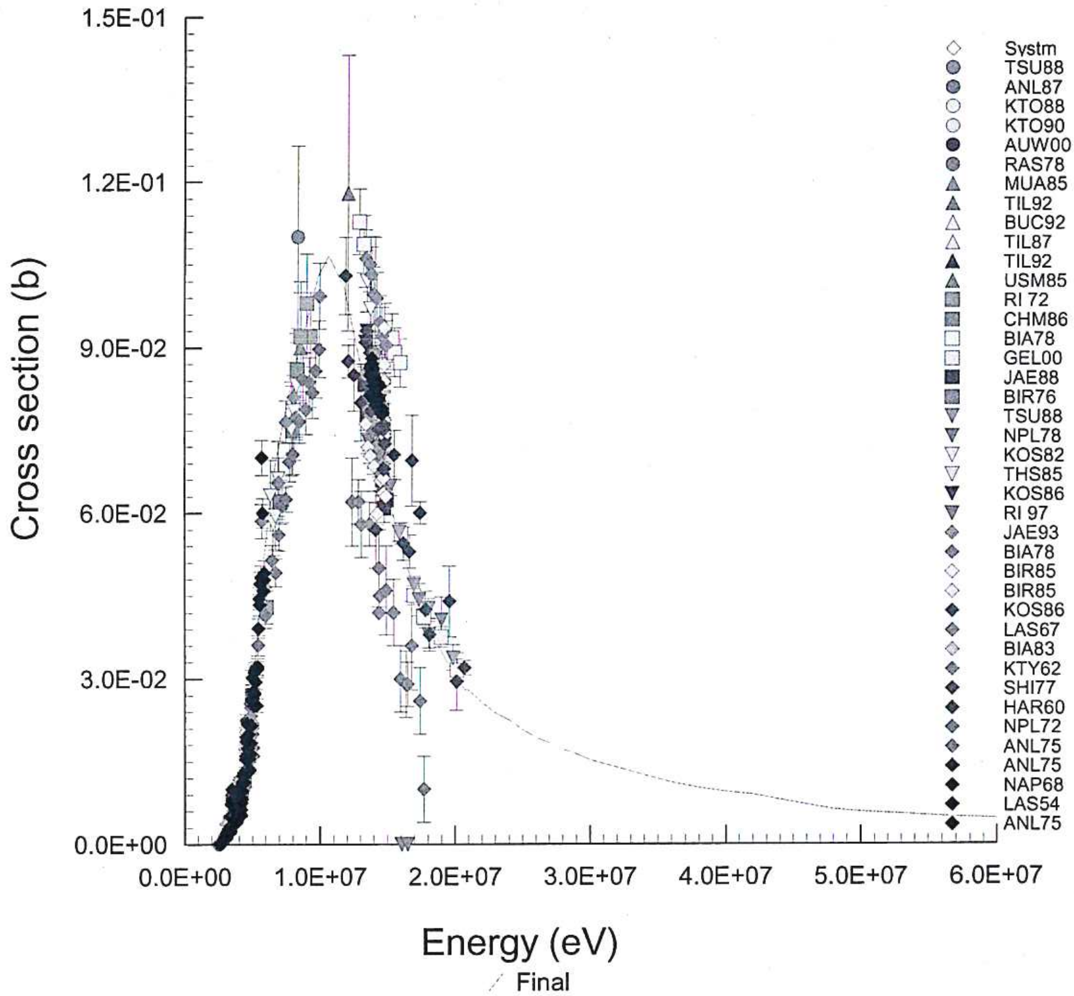

Figure 2. Data for $^{27}Al(n,p)^{27}Mg$, above 20 MeV this is taken from TALYS-4. The symbols are experimental data points taken from EXFOR.

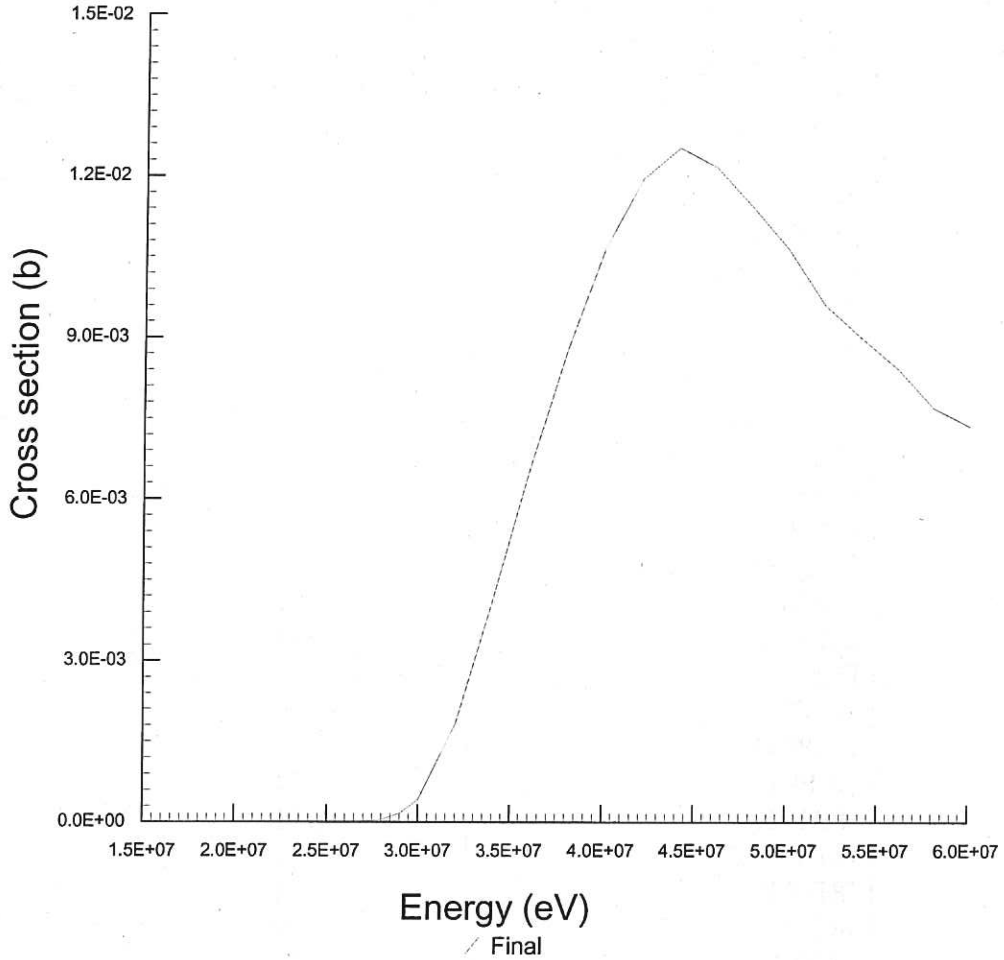

Figure 3. Data for $^{56}Fe(n,n'p\alpha)^{51}V$ taken from TALYS-4.

EAF-2004 contains 62,860 reactions, taken from 45 data sources. In total 86 different reaction types are included. The origin of data in EAF-2004 is shown in Table 3 and the number of reactions in the various reaction types is shown in Table 4.

Table 3. Origin of data in EAF-2004.

Data Source	Number of reactions
ACTL	2
ADL-3	8113
ADL-3/I	11
BRC	3
BROND-2.2	2
CENDL-2.1	1
CRP	8
EFF-2.4	383
EFF-2.4(MDF)	3
ENDF/B-VI	58
ENDF/B-VI(MDF)	7
ENDF/B-VI.7	18
ENDF/B-VI.8	3
ENEA(MENGONI)	4
ESTIMATE	17
EXIFON	217
FEI	9
FENDL/A-1	30
FISPRO	9
HEPRL	24
IEAF-2001	111
IRDF-90.2	16
IRDF-P	4
IRK	49
JAERI	36
JAERI(MDF)	15
JEF-2.2	1382
JEF-2.2(MDF)	8
JENDL-3.1	149
JENDL-3.2	162
JENDL-3.2/A	121
JENDL-3.2/A/I	1
JENDL-3.3	6
JENDL-99D	1
KOPECKY-2000	4
LANL	5
LANL(HERMAN)	11
LANL-2000	10
MASGAM	404
NGAMMA	23
NIPNE	1
SIG-ECN	1
SIGECN-MASGAM	64
TALYS-4	51153
THRES	201
Total	**62860**

Table 4. Number of examples of the reaction types in EAF-2004.

Reaction Type	Number of reactions
(n,n′)	262
(n,2nd)	1032
(n,2n)	1012
(n,3n)	1022
(n,f)	90
(n,n′α)	1006
(n,n′3α)	330
(n,2nα)	998
(n,3nα)	1002
(n,n′p)	1027
(n,n′2α)	844
(n,2n2α)	948
(n,n′d)	1052
(n,n′t)	1041
(n,n′h)	981
(n,n′d2α)	343
(n,nt2α)	252
(n,4n)	973
(n,2np)	1042
(n,3np)	1031
(n,n′2p)	961
(n,n′pα)	946
(n,γ)	1009
(n,p)	1019
(n,d)	1028
(n,t)	1052
(n,h)	968
(n,α)	994
(n,2α)	616
(n,3α)	163
(n,2p)	934
(n,pα)	732
(n,t2α)	194
(n,d2α)	199
(n,pd)	929
(n,pt)	540
(n,dα)	701
(n,5n)	902
(n,6n)	794
(n,2nt)	1036
(n,tα)	693
(n,4np)	1021
(n,3nd)	1026
(n,n′dα)	932

Reaction Type	Number of reactions
(n,2npα)	1005
(n,7n)	520
(n,8n)	207
(n,5np)	940
(n,6np)	709
(n,7np)	211
(n,4nα)	949
(n,5nα)	853
(n,6nα)	631
(n,7nα)	249
(n,4nd)	948
(n,5nd)	785
(n,6nd)	322
(n,3nt)	974
(n,4nt)	891
(n,5nt)	607
(n,6nt)	187
(n,2nh)	994
(n,3nh)	990
(n,4nh)	939
(n,3n2p)	992
(n,3n2α)	958
(n,3npα)	1010
(n,dt)	340
(n,n´pd)	968
(n,n´pt)	831
(n,n´dt)	712
(n,n´ph)	466
(n,n´dh)	315
(n,n'th)	201
(n,n´tα)	928
(n,2n2p)	980
(n,ph)	237
(n,dh)	129
(n,hα)	275
(n,4n2p)	960
(n,4n2α)	787
(n,4npα)	930
(n,3p)	184
(n,n´3p)	306
(n,3n2pα)	324
(n,5n2p)	439
Total	**62860**

Uncertainty data

Uncertainty data for EAF-2003 [5] are available for each reaction. They comprise values in three energy groups for the (n,γ) and (n,f) reactions, in all other cases a single value is used. Two changes have been made in EAF-2004. Firstly a new energy group has been defined from 20 – 60 MeV. This means that all reactions with a threshold ≤ 20 MeV will have two uncertainty values, reactions with a threshold > 20 MeV have a single value. The second change is that all non-threshold reactions, not just the two mentioned above, now have four rather than the current three uncertainty values. At present all values for the new energy group are standard values (usually set equal to the value below 20 MeV). This means that the 'infra-structure' is in place so that more precise data can be input and then used correctly.

Subsidiary EAF libraries

The biological hazard, clearance and transport (A_2) libraries are also part of EAF-2003 [6] as they are required for inventory calculations. Similar libraries are needed for EAF-2004 and they require to be extended because of the additional nuclides defined in the decay data library. In addition new A_2 values are available in the most recent IAEA documentation [7]. These new data are input into SAFEPAQ-II (this required the change detailed in the 6th bullet point in the SAFEPAQ-II section above). Values of any of these quantities that have changed (>) and data for the new nuclides (+) are shown in Table 5. Column 1 shows the ID of the nuclide as used in FISPACT, column 2 is the nuclide name, column 3 is the specific activity of the nuclide (not part of any library, but a quantity of relevance to hazards), columns 4 and 5 are the committed effective doses per unit uptake for ingestion and inhalation respectively, column 6 is the source of the biological data, column 7 is the A_2 value, column 8 is the source of the A_2 value, column 9 is the clearance value and column 10 is the source of the clearance value.

Table 5. Subsidiary data changed or added in EAF-2004.

ID	Nuclide	Act(Bq/kg)	E^{ing}(Sv/Bq)	E^{inh}(Sv/Bq)	Haz source	A_2(TBq)	A_2 source	C(Bq/kg)	Clear source
> 7	Li-5	2.7828E+47	2.0868E-35	1.2642E-35	Calculated	0.02000	BETA	1.00000E+30	Calculated
> 12	Be-6	1.3869E+46	6.3343E-34	5.4716E-34	Calculated	0.02000	BETA	1.00000E+30	Calculated
+ 18	Be-12	1.4461E+27	1.2510E-15	1.0806E-15	Calculated	0.02000	BETA	2.24150E+02	Calculated
+ 19	Be-13	1.1892E+46	1.4074E-34	1.2157E-34	Calculated	0.02000	BETA	1.00000E+30	Calculated
> 21	B-9	5.7975E+43	1.2613E-31	6.2279E-32	Calculated	0.02000	BETA	1.58561E+29	Calculated
+ 26	B-14	1.8486E+27	5.9360E-15	2.9309E-15	Calculated	0.02000	BETA	1.58479E+02	Calculated
+ 27	B-15	2.8195E+27	8.5834E-19	4.2381E-19	Calculated	0.02000	BETA	2.38059E+03	Calculated
> 28	C-9	3.6538E+26	2.9234E-14	2.1925E-14	Calculated	0.02000	BETA	1.65317E+02	Calculated
+ 35	C-16	3.4893E+25	2.1243E-14	1.5932E-14	Calculated	0.02000	BETA	4.72144E+03	Calculated
+ 36	C-17	1.2722E+26	6.0712E-14	4.5534E-14	Calculated	0.02000	BETA	2.89314E+02	Calculated
+ 37	N-11	7.5895E+46	2.8926E-34	2.1695E-34	Calculated	0.02000	BETA	1.00000E+30	Calculated
+ 45	N-19	8.1069E+25	7.8399E-15	5.8799E-15	Calculated	0.02000	BETA	4.79544E+02	Calculated
+ 46	N-20	1.6055E+26	1.7126E-14	1.2845E-14	Calculated	0.02000	BETA	3.52957E+02	Calculated
+ 54	O-21	5.8121E+24	3.9172E-13	2.9379E-13	Calculated	0.02000	BETA	3.36313E+02	Calculated
+ 55	O-22	8.4328E+24	3.2432E-13	2.4324E-13	Calculated	0.02000	BETA	5.38705E+02	Calculated
+ 56	F-15	6.0496E+46	9.3996E-35	1.1318E-34	Calculated	0.02000	BETA	1.00000E+30	Calculated
+ 57	F-16	2.3717E+45	8.3124E-34	1.0009E-33	Calculated	0.02000	BETA	1.00000E+30	Calculated
+ 65	F-24	4.3482E+25	3.4155E-14	4.1578E-14	Calculated	0.02000	BETA	2.14814E+02	Calculated
+ 66	Ne-17	2.2486E+26	5.4345E-16	7.5404E-16	Calculated	0.02000	BETA	1.44350E+04	Calculated
+ 75	Ne-26	8.1496E+25	5.3706E-14	7.4517E-14	Calculated	0.02000	BETA	3.72435E+02	Calculated
+ 76	Ne-27	4.8313E+26	1.2294E-14	1.7058E-14	Calculated	0.02000	BETA	2.19572E+02	Calculated
+ 87	Na-29	3.3549E+26	1.2478E-15	7.5593E-16	Calculated	0.02000	BETA	2.00805E+02	Calculated
+ 88	Na-30	2.8988E+26	1.4680E-15	8.8936E-16	Calculated	0.02000	BETA	2.26722E+02	Calculated
+ 89	Mg-21	1.6284E+26	4.5764E-15	2.2756E-15	Calculated	0.02000	BETA	5.05051E+02	Calculated
+ 98	Mg-30	4.1535E+25	7.1488E-14	3.5548E-14	Calculated	0.02000	BETA	3.90394E+02	Calculated
+ 99	Mg-31	5.8545E+25	6.6429E-14	3.3033E-14	Calculated	0.02000	BETA	2.36342E+02	Calculated
+ 100	Al-23	3.8602E+25	1.1245E-13	8.0321E-14	Calculated	0.02000	BETA	2.22855E+02	Calculated
+ 112	Al-33	3.0852E+26	1.0457E-14	7.4744E-15	Calculated	0.02000	BETA	2.48645E+02	Calculated
+ 113	Al-34	2.9231E+26	1.4106E-14	1.0077E-14	Calculated	0.02000	BETA	1.82335E+02	Calculated

ID	Nuclide	Act(Bq/kg)	E^{ing}(Sv/Bq)	E^{inh}(Sv/Bq)	Haz source	A_2(TBq)	A_2 source	C(Bq/kg)	Clear source
+ 114	Si-25	7.5883E+25	3.6725E-14	1.8133E-14	Calculated	0.02000	BETA	7.98085E+02	Calculated
+ 124	Si-35	1.5290E+25	2.0583E-13	1.0164E-13	Calculated	0.02000	BETA	2.74217E+02	Calculated
+ 125	Si-36	2.5767E+25	1.5495E-13	7.6507E-14	Calculated	0.02000	BETA	3.94788E+02	Calculated
+ 135	P-37	4.8839E+24	2.7840E-13	6.7860E-13	Calculated	0.02000	BETA	3.45158E+02	Calculated
+ 136	P-38	1.7164E+25	1.0477E-13	2.5137E-13	Calculated	0.02000	BETA	2.50035E+02	Calculated
+ 137	P-39	5.6332E+25	3.6959E-14	9.5636E-14	Calculated	0.02000	BETA	3.50612E+02	Calculated
+ 138	P-40	3.5985E+25	8.7988E-14	2.2139E-13	Calculated	0.02000	BETA	2.68462E+02	Calculated
+ 139	S-29	7.6982E+25	2.1465E-13	2.3059E-13	Calculated	0.02000	BETA	1.99258E+02	Calculated
+ 151	S-41	3.9158E+24	2.5361E-12	2.7245E-12	Calculated	0.02000	BETA	3.12144E+02	Calculated
+ 165	Cl-43	2.9434E+24	4.8574E-13	1.8780E-13	Calculated	0.02000	BETA	3.53736E+02	Calculated
+ 166	Cl-44	1.6941E+25	1.3735E-13	5.1584E-14	Calculated	0.02000	BETA	2.41580E+02	Calculated
+ 167	Cl-45	2.3190E+25	9.4178E-14	3.6380E-14	Calculated	0.02000	BETA	3.31962E+02	Calculated
+ 168	Ar-33	7.3139E+25	8.0459E-15	1.1164E-14	Calculated	0.02000	BETA	5.67215E+02	Calculated
+ 182	Ar-47	1.5313E+25	1.6760E-13	2.3186E-13	Calculated	0.02000	BETA	2.81433E+02	Calculated
+ 197	Ca-37	6.4492E+25	3.0362E-14	6.8389E-14	Calculated	0.02000	BETA	6.81663E+02	Calculated
+ 226	Sc-51	6.6066E+23	1.9533E-12	9.5283E-13	Calculated	0.02000	BETA	3.94571E+02	Calculated
+ 227	Sc-52	9.7895E+23	2.2485E-12	1.0687E-12	Calculated	0.02000	BETA	3.00236E+02	Calculated
+ 228	Ti-41	1.2732E+26	1.2718E-17	9.3265E-18	Calculated	0.02000	BETA	6.94927E+02	Calculated
+ 241	Ti-54	5.1534E+24	4.2999E-13	3.1533E-13	Calculated	0.02000	BETA	6.61566E+02	Calculated
+ 242	Ti-55	1.6499E+25	1.4570E-13	1.0685E-13	Calculated	0.02000	BETA	3.71470E+02	Calculated
+ 254	V-55	1.1616E+24	6.7620E-13	4.9182E-13	Calculated	0.02000	BETA	1.07875E+03	Calculated
+ 255	V-56	3.1991E+25	5.3483E-14	3.8900E-14	Calculated	0.02000	BETA	3.01382E+02	Calculated
+ 256	V-57	2.2885E+25	7.0177E-14	5.1042E-14	Calculated	0.02000	BETA	3.41568E+02	Calculated
+ 257	V-58	3.5453E+25	2.8595E-14	2.0798E-14	Calculated	0.02000	BETA	1.18058E+03	Calculated
+ 271	Cr-59	1.5380E+25	1.8829E-14	8.3427E-15	Calculated	0.02000	BETA	3.57804E+02	Calculated
+ 288	Mn-60m	3.8903E+24	1.0329E-13	4.9580E-14	Calculated	0.02000	BETA	3.37610E+02	Calculated
+ 289	Mn-61	1.0213E+25	5.5653E-14	2.6577E-14	Calculated	0.02000	BETA	3.79720E+02	Calculated
+ 290	Mn-62	7.6507E+24	1.0813E-13	5.1905E-14	Calculated	0.02000	BETA	2.61427E+02	Calculated
+ 291	Mn-63	2.4094E+25	3.1228E-14	1.4989E-14	Calculated	0.02000	BETA	3.02103E+02	Calculated
+ 292	Mn-64	7.4968E+25	1.3414E-14	6.4389E-15	Calculated	0.02000	BETA	2.27671E+02	Calculated
+ 312	Co-52	6.9803E+25	3.5938E-14	2.3112E-14	Calculated	0.02000	BETA	2.47863E+02	Calculated
+ 313	Co-53	3.2845E+25	3.6685E-14	2.7243E-14	Calculated	0.02000	BETA	6.94444E+02	Calculated
+ 331	Co-67	1.4659E+25	6.9076E-14	5.1751E-14	Calculated	0.02000	BETA	3.23865E+02	Calculated
+ 332	Co-68	3.0693E+25	5.2364E-14	3.8887E-14	Calculated	0.02000	BETA	2.33946E+02	Calculated
+ 333	Co-68m	3.8366E+24	4.2341E-13	3.1444E-13	Calculated	0.02000	BETA	4.46479E+02	Calculated
+ 334	Co-69	2.7498E+25	5.7303E-14	4.2831E-14	Calculated	0.02000	BETA	2.95206E+02	Calculated
+ 335	Ni-53	1.7512E+26	6.7448E-15	3.3724E-15	Calculated	0.02000	BETA	1.59770E+03	Calculated
+ 336	Ni-54	5.4056E+25	2.4741E-14	1.2371E-14	Calculated	0.02000	BETA	3.09944E+02	Calculated
+ 373	Cu-73	1.4675E+24	8.9749E-13	5.5719E-13	Calculated	0.02000	BETA	1.07780E+03	Calculated
+ 374	Cu-74	3.5255E+24	8.6635E-13	5.3606E-13	Calculated	0.02000	BETA	1.96375E+02	Calculated
+ 375	Cu-75	4.2813E+24	5.8951E-13	3.6476E-13	Calculated	0.02000	BETA	4.32582E+02	Calculated
+ 398	Ga-63	2.0470E+23	5.0885E-12	2.4396E-12	Calculated	0.02000	BETA	6.41519E+02	Calculated
+ 414	Ga-78	9.7564E+23	1.2486E-12	6.4581E-13	Calculated	0.02000	BETA	3.65798E+02	Calculated
+ 415	Ga-79	1.7628E+24	1.4099E-12	7.2767E-13	Calculated	0.02000	BETA	4.84731E+02	Calculated
+ 416	Ge-64	1.0248E+23	9.6920E-12	7.5850E-12	Calculated	0.02000	BETA	7.57002E+02	Calculated
+ 417	Ge-65	2.0802E+23	3.0627E-12	2.3386E-12	Calculated	0.02000	BETA	5.23560E+02	Calculated
+ 439	As-67	1.4673E+23	5.3618E-12	6.9269E-12	Calculated	0.02000	BETA	5.98684E+02	Calculated
+ 456	As-83	3.7565E+23	1.4309E-12	2.5502E-12	Calculated	0.02000	BETA	4.63607E+02	Calculated
+ 457	As-84	9.0428E+23	1.0467E-12	1.8445E-12	Calculated	0.02000	BETA	1.80505E+02	Calculated
+ 458	Se-68	3.0719E+24	7.0398E-13	3.9263E-13	Calculated	0.02000	BETA	5.68189E+02	Calculated
+ 459	Se-69	2.2098E+23	7.8623E-12	2.9071E-12	Calculated	0.02000	BETA	4.76190E+02	Calculated
+ 481	Br-71	2.7496E+23	3.5591E-12	1.0680E-12	Calculated	0.02000	BETA	1.09890E+03	Calculated
+ 505	Br-87	8.6233E+22	4.9476E-13	1.5002E-13	Calculated	0.02000	BETA	2.83447E+02	Calculated
+ 506	Br-88	2.8773E+23	9.1879E-12	2.7860E-12	Calculated	0.02000	BETA	2.24316E+02	Calculated
+ 507	Kr-72	3.3734E+23	3.9388E-12	5.5253E-12	Calculated	0.02000	BETA	6.93001E+02	Calculated
+ 508	Kr-73	2.1196E+23	5.5172E-12	7.8181E-12	Calculated	0.02000	BETA	5.50055E+02	Calculated
+ 529	Kr-90	1.4363E+23	5.6908E-12	7.9443E-12	Calculated	0.02000	BETA	7.31797E+02	Calculated
+ 530	Rb-77	2.4115E+22	3.4248E-11	6.1186E-12	Calculated	0.02000	BETA	5.88235E+02	Calculated
+ 550	Rb-91	7.8618E+22	1.2867E-11	2.2835E-12	Calculated	0.02000	BETA	4.01445E+02	Calculated
+ 551	Rb-92	1.0069E+24	2.1177E-12	3.4793E-13	Calculated	0.02000	BETA	1.34608E+03	Calculated
+ 552	Rb-93	7.8810E+23	2.9960E-12	5.0277E-13	Calculated	0.02000	BETA	4.58085E+02	Calculated
+ 553	Rb-94	1.6448E+24	1.6957E-12	2.7275E-13	Calculated	0.02000	BETA	2.27118E+02	Calculated
+ 554	Sr-78	3.3658E+22	7.5562E-12	4.7844E-12	Calculated	0.02000	BETA	7.25097E+02	Calculated
+ 555	Sr-79	3.9174E+22	3.4456E-12	2.6613E-12	Calculated	0.02000	BETA	6.83256E+02	Calculated
+ 576	Y-81	7.1241E+22	2.3986E-11	2.7186E-11	Calculated	0.02000	BETA	8.27815E+02	Calculated
+ 604	Y-98	6.5582E+24	3.7648E-13	5.2236E-13	Calculated	0.02000	BETA	2.60184E+02	Calculated
+ 605	Y-98m	2.1314E+24	4.4471E-13	6.1690E-13	Calculated	0.02000	BETA	2.74409E+02	Calculated
+ 606	Zr-82	1.5921E+23	1.1207E-11	5.9423E-12	Calculated	0.02000	BETA	6.81825E+02	Calculated
+ 607	Zr-83	1.1440E+23	1.3872E-11	6.6706E-12	Calculated	0.02000	BETA	7.40741E+02	Calculated
+ 656	Nb-101	5.8259E+23	4.2756E-13	2.5525E-13	Calculated	0.02000	BETA	1.22175E+03	Calculated
+ 657	Nb-102	3.1505E+24	1.3153E-13	8.7039E-14	Calculated	0.02000	BETA	3.04544E+02	Calculated
+ 658	Nb-102m	9.5248E+23	4.0393E-13	2.6731E-13	Calculated	0.02000	BETA	4.30836E+02	Calculated

ID	Nuclide	Act(Bq/kg)	E^{ing}(Sv/Bq)	E^{inh}(Sv/Bq)	Haz source	A_2(TBq)	A_2 source	C(Bq/kg)	Clear source
+ 659	Nb-103	2.7039E+24	1.2334E-13	8.2025E-14	Calculated	0.02000	BETA	1.02491E+03	Calculated
+ 660	Nb-104	5.0208E+24	9.8683E-14	5.7041E-14	Calculated	0.02000	BETA	2.94686E+02	Calculated
+ 681	Tc-90	5.8759E+23	1.1346E-12	7.8156E-13	Calculated	0.02000	BETA	6.58250E+02	Calculated
+ 682	Tc-90m	9.4269E+22	8.9592E-12	6.0631E-12	Calculated	0.02000	BETA	2.94183E+02	Calculated
+ 683	Tc-91	2.4369E+22	3.3685E-11	2.1275E-11	Calculated	0.02000	BETA	3.81243E+02	Calculated
+ 684	Tc-91m	2.3188E+22	3.1981E-11	2.0199E-11	Calculated	0.02000	BETA	5.95948E+02	Calculated
+ 707	Tc-107	1.8592E+23	2.4520E-12	1.5479E-12	Calculated	0.02000	BETA	1.32293E+03	Calculated
+ 708	Tc-108	7.4815E+23	1.0551E-12	6.6637E-13	Calculated	0.02000	BETA	5.82751E+02	Calculated
+ 709	Tc-109	2.7374E+24	2.8831E-13	1.8014E-13	Calculated	0.02000	BETA	1.07147E+03	Calculated
+ 710	Ru-92	2.0736E+22	1.0623E-10	4.9726E-11	Calculated	0.02000	BETA	4.57697E+02	Calculated
+ 711	Ru-93	7.5250E+22	1.2784E-11	5.9866E-12	Calculated	0.02000	BETA	7.13267E+02	Calculated
+ 712	Ru-93m	4.1597E+23	2.8125E-12	1.3169E-12	Calculated	0.02000	BETA	4.66200E+02	Calculated
+ 732	Rh-95	1.4611E+22	3.0029E-11	2.3441E-11	Calculated	0.02000	BETA	3.90778E+02	Calculated
+ 733	Rh-95m	3.7396E+22	1.3983E-11	1.0758E-11	Calculated	0.02000	BETA	1.10011E+03	Calculated
+ 764	Rh-112m	5.4851E+23	1.1248E-12	7.2358E-13	Calculated	0.02000	BETA	4.07852E+02	Calculated
+ 765	Rh-113	1.3591E+24	3.6434E-13	2.5709E-13	Calculated	0.02000	BETA	1.41185E+03	Calculated
+ 766	Rh-114	1.9807E+24	3.1914E-13	2.2676E-13	Calculated	0.02000	BETA	1.34576E+03	Calculated
+ 767	Rh-114m	1.9807E+24	3.9095E-13	2.7778E-13	Calculated	0.02000	BETA	3.67820E+02	Calculated
+ 768	Pd-96	3.5641E+22	4.7100E-11	5.1732E-11	Calculated	0.02000	BETA	7.96512E+02	Calculated
+ 769	Pd-97	2.3156E+22	5.2453E-11	5.7676E-11	Calculated	0.02000	BETA	3.95883E+02	Calculated
> 791	Pd-115	1.4530E+23	6.7262E-12	6.6565E-12	Calculated	0.02000	BETA	6.34518E+02	Calculated
+ 792	Pd-115m	7.2595E+22	1.3449E-11	1.4235E-11	Calculated	0.02000	BETA	6.37077E+02	Calculated
+ 793	Pd-116	2.9042E+23	3.2952E-12	3.6192E-12	Calculated	0.02000	BETA	3.65230E+03	Calculated
+ 794	Pd-117	7.1405E+23	1.8011E-12	1.9349E-12	Calculated	0.02000	BETA	3.30589E+02	Calculated
+ 795	Pd-118	1.1419E+24	1.3965E-12	1.5338E-12	Calculated	0.02000	BETA	1.19717E+03	Calculated
+ 829	Ag-117	4.9044E+22	4.3134E-12	2.6929E-12	Calculated	0.02000	BETA	8.17638E+02	Calculated
+ 830	Ag-117m	6.6862E+23	2.8077E-13	1.7741E-13	Calculated	0.02000	BETA	1.25809E+03	Calculated
+ 831	Ag-118	9.5677E+23	4.6082E-13	3.0664E-13	Calculated	0.02000	BETA	8.74493E+02	Calculated
+ 832	Ag-118m	1.7700E+24	2.8158E-13	1.8737E-13	Calculated	0.02000	BETA	6.15385E+02	Calculated
+ 833	Ag-119	1.6715E+24	3.4207E-13	2.0392E-13	Calculated	0.02000	BETA	6.60595E+02	Calculated
+ 834	Ag-119m	5.8462E+23	1.0296E-12	6.4181E-13	Calculated	0.02000	BETA	5.16849E+02	Calculated
+ 835	Ag-120	2.9751E+24	1.7178E-13	1.1431E-13	Calculated	0.02000	BETA	7.66295E+02	Calculated
+ 836	Ag-121	4.3151E+24	1.4276E-13	9.4412E-14	Calculated	0.02000	BETA	9.17431E+02	Calculated
+ 837	Ag-122	7.1326E+24	1.0119E-13	6.7335E-14	Calculated	0.02000	BETA	6.75676E+02	Calculated
+ 866	Cd-123m	1.8659E+24	1.2216E-12	1.5384E-12	Calculated	0.02000	BETA	4.01362E+02	Calculated
+ 916	In-127	2.8599E+24	1.3848E-13	1.0508E-13	Calculated	0.02000	BETA	5.03233E+02	Calculated
+ 917	In-127m	8.8890E+23	5.3824E-13	3.8585E-13	Calculated	0.02000	BETA	1.28966E+03	Calculated
+ 918	In-128	3.6257E+24	1.4298E-13	8.8712E-14	Calculated	0.02000	BETA	2.98511E+02	Calculated
+ 919	Sn-107	2.2438E+22	2.3519E-11	5.4217E-11	Calculated	0.02000	BETA	5.34766E+02	Calculated
+ 989	Sb-133	2.1191E+22	1.5776E-11	4.7484E-12	Calculated	0.02000	BETA	4.08664E+02	Calculated
+ 990	Te-113	3.6243E+22	2.0166E-11	4.2734E-11	Calculated	0.02000	BETA	4.04953E+02	Calculated
+1023	I-116	1.2375E+24	1.8574E-11	2.5384E-12	Calculated	0.02000	BETA	7.36811E+02	Calculated
+1024	I-117	2.5872E+22	3.7329E-10	5.3187E-11	Calculated	0.02000	BETA	9.43396E+02	Calculated
+1051	I-137	1.2444E+23	4.0156E-11	5.9881E-12	Calculated	0.02000	BETA	6.97837E+02	Calculated
+1052	Xe-117	5.8527E+22	3.6360E-12	4.8508E-12	Calculated	0.02000	BETA	3.37507E+03	Calculated
+1053	Xe-118	9.8333E+21	5.1586E-11	7.0341E-11	Calculated	0.02000	BETA	1.47783E+03	Calculated
+1054	Xe-119	1.0087E+22	4.0368E-11	5.5433E-11	Calculated	0.02000	BETA	6.77354E+02	Calculated
+1095	Cs-130m	1.5467E+22	9.5392E-16	4.7696E-16	Calculated	0.02000	BETA	6.06676E+03	Calculated
+1110	Cs-141	1.1877E+23	4.5741E-12	2.2500E-12	Calculated	0.02000	BETA	7.70416E+02	Calculated
+1111	Ba-123	2.0962E+22	2.0269E-11	1.0581E-11	Calculated	0.02000	BETA	1.77201E+03	Calculated
+1116	Ba-127m	1.7299E+24	7.0466E-14	4.0136E-14	Calculated	0.02000	BETA	1.24486E+04	Calculated
+1159	La-145	1.1902E+23	1.2068E-12	4.8106E-13	Calculated	0.02000	BETA	6.38978E+02	Calculated
+1160	La-146	4.5622E+23	4.9588E-13	2.1406E-13	Calculated	0.02000	BETA	4.04531E+02	Calculated
+1161	La-146m	2.8605E+23	7.1120E-13	3.0700E-13	Calculated	0.02000	BETA	6.48845E+02	Calculated
+1162	La-147	7.1025E+23	2.6695E-13	1.0453E-13	Calculated	0.02000	BETA	7.04225E+02	Calculated
+1163	Ce-129	1.5409E+22	2.0057E-11	4.8364E-11	Calculated	0.02000	BETA	5.49432E+02	Calculated
+1211	Pr-151	1.4633E+23	2.9317E-12	2.3626E-12	Calculated	0.02000	BETA	1.24642E+03	Calculated
+1212	Nd-135	4.1809E+21	3.4560E-11	1.8261E-11	Calculated	0.02000	BETA	7.30994E+02	Calculated
+1213	Nd-135m	9.3698E+21	1.8700E-11	1.0125E-11	Calculated	0.02000	BETA	5.66416E+02	Calculated
+1235	Nd-154	1.0470E+23	1.0380E-12	6.2529E-13	Calculated	0.02000	BETA	2.10504E+03	Calculated
+1236	Pm-135	6.3138E+22	5.4042E-12	4.7014E-12	Calculated	0.02000	BETA	3.49839E+02	Calculated
+1237	Pm-135m	7.7301E+22	4.1234E-12	3.5711E-12	Calculated	0.02000	BETA	4.47828E+02	Calculated
+1238	Pm-136	2.8701E+22	7.5779E-12	6.6619E-12	Calculated	0.02000	BETA	3.78620E+02	Calculated
+1239	Pm-136m	6.5304E+22	4.8440E-12	4.3293E-12	Calculated	0.02000	BETA	3.35458E+02	Calculated
+1240	Pm-137	2.1171E+22	7.4898E-12	6.7331E-12	Calculated	0.02000	BETA	5.52593E+02	Calculated
+1241	Pm-138	3.0266E+23	8.4231E-13	6.4629E-13	Calculated	0.02000	BETA	8.19309E+02	Calculated
+1242	Pm-138m	1.5601E+22	1.3635E-11	1.0033E-11	Calculated	0.02000	BETA	4.13068E+02	Calculated
+1243	Pm-139	1.2068E+22	1.1821E-11	1.0434E-11	Calculated	0.02000	BETA	8.76424E+02	Calculated
+1244	Pm-139m	1.6694E+25	8.9508E-15	7.9177E-15	Calculated	0.02000	BETA	1.04734E+04	Calculated
+1267	Pm-157	2.4403E+23	3.9477E-13	3.6690E-13	Calculated	0.02000	BETA	1.54823E+03	Calculated
+1268	Sm-136	7.1918E+22	5.4187E-12	3.1536E-12	Calculated	0.02000	BETA	3.18908E+03	Calculated
+1269	Sm-137	6.7709E+22	7.4393E-12	4.4756E-12	Calculated	0.02000	BETA	4.76758E+02	Calculated

ID	Nuclide	Act(Bq/kg)	E^{ing}(Sv/Bq)	E^{inh}(Sv/Bq)	Haz source	A_2(TBq)	A_2 source	C(Bq/kg)	Clear source
+1270	Sm-137m	1.5234E+23	3.4039E-12	2.0487E-12	Calculated	0.02000	BETA	4.48531E+02	Calculated
+1271	Sm-138	1.6814E+22	3.4376E-11	1.8326E-11	Calculated	0.02000	BETA	7.57582E+02	Calculated
+1272	Sm-139	1.9511E+22	2.2421E-11	1.3348E-11	Calculated	0.02000	BETA	5.94884E+02	Calculated
+1273	Sm-139m	2.8081E+23	1.6044E-12	9.5587E-13	Calculated	0.02000	BETA	3.59195E+03	Calculated
+1274	Sm-140	3.3558E+21	8.7472E-11	5.5349E-11	Calculated	0.02000	BETA	1.60514E+03	Calculated
+1275	Sm-141	4.8401E+21	5.5832E-11	2.4148E-11	Calculated	0.02000	BETA	6.78426E+02	Calculated
+1276	Sm-141m	2.1845E+21	1.2816E-10	5.6224E-11	Calculated	0.02000	BETA	5.14165E+02	Calculated
+1296	Eu-138	2.5010E+23	6.9175E-12	2.8692E-12	Calculated	0.02000	BETA	2.96445E+02	Calculated
+1297	Eu-139	1.6785E+23	7.2375E-12	3.1984E-12	Calculated	0.02000	BETA	5.43478E+02	Calculated
+1298	Eu-140	1.9371E+24	4.7363E-13	2.1726E-13	Calculated	0.02000	BETA	9.49369E+02	Calculated
+1299	Eu-141	7.4051E+22	1.0998E-11	4.0750E-12	Calculated	0.02000	BETA	7.39700E+02	Calculated
+1300	Eu-141m	1.0970E+24	7.3493E-13	2.7173E-13	Calculated	0.02000	BETA	1.33298E+03	Calculated
+1301	Eu-142	1.2255E+24	5.5096E-13	2.1447E-13	Calculated	0.02000	BETA	6.98636E+02	Calculated
+1302	Eu-142m	4.0180E+22	1.8972E-11	7.5158E-12	Calculated	0.02000	BETA	3.00759E+02	Calculated
+1325	Eu-161	1.0375E+23	2.6780E-12	1.2274E-12	Calculated	0.02000	BETA	1.85994E+03	Calculated
+1326	Eu-162	2.7717E+23	2.0137E-12	9.0505E-13	Calculated	0.02000	BETA	4.12286E+02	Calculated
+1327	Eu-163	4.2681E+23	1.4890E-12	6.6925E-13	Calculated	0.02000	BETA	5.60935E+02	Calculated
+1328	Gd-139	6.1314E+23	9.9628E-13	1.3517E-12	Calculated	0.02000	BETA	2.00746E+10	Calculated
+1329	Gd-140	1.8871E+23	4.1009E-12	6.4686E-12	Calculated	0.02000	BETA	4.99465E+02	Calculated
+1330	Gd-141	2.1146E+23	3.6397E-12	5.0424E-12	Calculated	0.02000	BETA	3.99876E+02	Calculated
+1331	Gd-141m	1.2083E+23	6.4459E-12	8.9425E-12	Calculated	0.02000	BETA	4.23777E+02	Calculated
+1332	Gd-142	3.2679E+22	1.5171E-11	2.1062E-11	Calculated	0.02000	BETA	1.34409E+03	Calculated
+1333	Gd-143	7.4885E+22	5.3323E-12	8.2985E-12	Calculated	0.02000	BETA	7.26744E+02	Calculated
+1334	Gd-143m	2.6076E+22	1.6043E-11	2.4966E-11	Calculated	0.02000	BETA	4.51060E+02	Calculated
+1335	Gd-144	1.0742E+22	3.2833E-11	5.1056E-11	Calculated	0.02000	BETA	7.37109E+02	Calculated
+1358	Tb-144	2.9001E+24	1.7635E-13	1.6409E-13	Calculated	0.02000	BETA	1.70156E+03	Calculated
+1359	Tb-144m	6.8238E+23	7.1088E-13	6.6149E-13	Calculated	0.02000	BETA	1.52219E+03	Calculated
+1360	Tb-145	2.3990E+21	1.4112E-10	1.0826E-10	Calculated	0.02000	BETA	4.07078E+02	Calculated
+1361	Tb-145m	9.7633E+22	2.7762E-12	2.0166E-12	Calculated	0.02000	BETA	4.24989E+02	Calculated
+1395	Tb-167	1.3155E+23	1.6033E-12	1.4887E-12	Calculated	0.02000	BETA	6.65265E+02	Calculated
+1396	Tb-168	3.0301E+23	1.0446E-12	9.7204E-13	Calculated	0.02000	BETA	4.56754E+02	Calculated
+1397	Dy-147	7.0990E+22	6.2217E-12	3.0435E-12	Calculated	0.02000	BETA	4.28180E+02	Calculated
+1398	Dy-147m	4.8152E+22	1.1097E-11	5.5554E-12	Calculated	0.02000	BETA	7.03433E+02	Calculated
+1424	Ho-152	1.6981E+22	5.7069E-11	2.2960E-10	Calculated	0.00009	ALPHA	5.93789E+02	Calculated
+1425	Ho-152m	5.5504E+22	1.8708E-11	7.2089E-11	Calculated	0.00009	ALPHA	2.92337E+02	Calculated
+1459	Ho-173	2.4128E+23	1.3044E-12	1.0706E-12	Calculated	0.02000	BETA	5.98744E+02	Calculated
+1460	Er-153	7.3569E+22	4.4708E-11	6.9623E-11	Calculated	0.00009	ALPHA	4.47349E+08	Calculated
+1461	Er-154	1.2270E+22	7.4554E-11	9.9306E-11	Calculated	0.00009	ALPHA	9.29368E+04	Calculated
+1462	Er-155	8.4724E+21	1.7859E-11	2.1978E-11	Calculated	0.00009	ALPHA	5.72017E+02	Calculated
+1484	Tm-158	1.0967E+22	1.7232E-11	4.0156E-11	Calculated	0.02000	BETA	5.36193E+02	Calculated
+1485	Tm-159	4.7839E+21	4.5129E-11	1.0473E-10	Calculated	0.02000	BETA	6.81979E+02	Calculated
+1506	Tm-177	2.8760E+22	5.8939E-12	1.2624E-11	Calculated	0.02000	BETA	8.54369E+02	Calculated
+1507	Tm-178	7.8169E+22	3.5841E-12	7.1326E-12	Calculated	0.02000	BETA	4.88291E+02	Calculated
+1508	Tm-179	1.1660E+23	2.6039E-12	6.0072E-12	Calculated	0.02000	BETA	5.66412E+02	Calculated
+1509	Yb-159	3.1265E+22	7.4755E-12	8.6036E-12	Calculated	0.02000	BETA	1.60171E+03	Calculated
+1510	Yb-160	9.0622E+21	1.6232E-11	1.8132E-11	Calculated	0.02000	BETA	3.48328E+03	Calculated
+1511	Yb-161	1.0292E+22	1.7910E-11	1.9918E-11	Calculated	0.02000	BETA	9.23647E+02	Calculated
+1534	Yb-181	3.8437E+22	3.0342E-12	3.5512E-12	Calculated	0.02000	BETA	7.00378E+02	Calculated
+1535	Lu-162	3.1358E+22	1.3281E-11	7.9637E-12	Calculated	0.02000	BETA	6.18685E+02	Calculated
+1536	Lu-163	1.0764E+22	5.3131E-11	3.5319E-11	Calculated	0.02000	BETA	2.33100E+02	Calculated
+1537	Lu-164	1.3515E+22	1.3439E-11	9.1896E-12	Calculated	0.02000	BETA	1.06940E+03	Calculated
+1538	Lu-165	3.9297E+21	4.6810E-11	3.0819E-11	Calculated	0.02000	BETA	7.45979E+02	Calculated
+1567	Lu-183	3.9337E+22	7.4931E-12	3.3986E-12	Calculated	0.02000	BETA	1.23153E+03	Calculated
+1568	Lu-184	1.1343E+23	4.1629E-12	2.2137E-12	Calculated	0.02000	BETA	5.81034E+02	Calculated
+1569	Hf-163	6.4043E+22	2.7430E-12	5.3849E-12	Calculated	0.02000	BETA	1.31406E+03	Calculated
+1570	Hf-164	1.5155E+22	5.9774E-12	1.2026E-11	Calculated	0.02000	BETA	9.40448E+02	Calculated
+1571	Hf-165	2.4811E+22	3.6962E-12	7.2880E-12	Calculated	0.02000	BETA	1.82194E+03	Calculated
+1572	Hf-166	6.1957E+21	1.0849E-11	2.1200E-11	Calculated	0.02000	BETA	3.46837E+03	Calculated
+1573	Hf-167	2.0328E+22	3.8134E-12	7.5778E-12	Calculated	0.02000	BETA	1.34851E+03	Calculated
+1599	Hf-184m	4.7263E+22	1.0958E-12	2.1326E-12	Calculated	0.02000	BETA	1.04397E+03	Calculated
+1626	Ta-189	6.3660E+22	3.8767E-12	2.6892E-12	Calculated	0.02000	BETA	7.49251E+02	Calculated
+1627	Ta-190	1.4552E+24	2.2498E-13	1.5699E-13	Calculated	0.02000	BETA	4.88759E+02	Calculated
+1628	W-171	1.7094E+22	2.0318E-11	2.4394E-12	Calculated	0.02000	BETA	5.85630E+02	Calculated
+1654	W-194	8.8087E+22	2.8885E-12	3.4445E-13	Calculated	0.02000	BETA	8.91266E+02	Calculated
+1655	Re-174	1.7389E+22	1.7433E-11	1.0692E-11	Calculated	0.02000	BETA	1.39535E+03	Calculated
+1656	Re-175	6.7495E+21	5.2122E-11	3.1463E-11	Calculated	0.02000	BETA	6.33367E+02	Calculated
+1657	Re-176	6.9776E+21	2.7296E-11	2.5524E-11	Calculated	0.02000	BETA	2.05903E+03	Calculated
+1658	Re-177	2.8083E+21	3.0313E-11	3.1723E-11	Calculated	0.02000	BETA	1.65691E+03	Calculated
+1682	Re-196	5.3652E+23	6.3001E-13	3.8232E-13	Calculated	0.02000	BETA	4.84418E+02	Calculated
+1683	Re-197	4.3514E+23	7.8734E-13	4.7966E-13	Calculated	0.02000	BETA	6.15637E+02	Calculated
+1684	Re-198	9.2474E+23	4.6905E-13	2.8464E-13	Calculated	0.02000	BETA	4.27472E+02	Calculated
+1685	Os-175	2.8396E+22	2.8748E-11	3.0583E-11	Calculated	0.02000	BETA	5.14870E+02	Calculated

ID	Nuclide	Act(Bq/kg)	E^{ing}(Sv/Bq)	E^{inh}(Sv/Bq)	Haz source	A_2(TBq)	A_2 source	C(Bq/kg)	Clear source
+1686	Os-176	1.3180E+22	3.3611E-11	4.7314E-11	Calculated	0.02000	BETA	9.40448E+02	Calculated
+1687	Os-177	1.4038E+22	2.8050E-11	3.6365E-11	Calculated	0.02000	BETA	6.13144E+02	Calculated
+1688	Os-178	7.8169E+21	3.1419E-11	3.2459E-11	Calculated	0.02000	BETA	1.17248E+03	Calculated
+1689	Os-179	5.9809E+21	5.5786E-11	6.1190E-11	Calculated	0.02000	BETA	7.55486E+02	Calculated
+1716	Os-200	1.3046E+23	3.4931E-12	3.6752E-12	Calculated	0.02000	BETA	1.04895E+03	Calculated
+1717	Os-201	2.2001E+23	2.7450E-12	2.8828E-12	Calculated	0.02000	BETA	6.43225E+02	Calculated
+1718	Ir-178	1.9547E+23	1.9658E-12	3.9037E-12	Calculated	0.02000	BETA	6.16017E+02	Calculated
+1719	Ir-179	2.9519E+22	1.3707E-11	2.7986E-11	Calculated	0.02000	BETA	5.63253E+02	Calculated
+1720	Ir-180	2.5773E+22	9.3745E-12	1.8598E-11	Calculated	0.02000	BETA	5.39569E+02	Calculated
+1721	Ir-181	7.8461E+21	1.7835E-11	3.5830E-11	Calculated	0.02000	BETA	7.27633E+02	Calculated
+1753	Ir-201	1.1227E+23	2.1189E-12	4.1535E-12	Calculated	0.02000	BETA	7.23414E+02	Calculated
+1754	Ir-202	2.4313E+23	1.0333E-12	2.2661E-12	Calculated	0.02000	BETA	5.01337E+02	Calculated
+1755	Pt-181	4.5229E+22	4.0153E-11	7.8602E-12	Calculated	0.00009	ALPHA	4.98096E+08	Calculated
+1756	Pt-182	1.4705E+22	7.8400E-12	4.8271E-13	Calculated	0.00009	ALPHA	5.47786E+03	Calculated
+1757	Pt-183	5.8499E+21	2.9415E-11	5.7726E-12	Calculated	0.00009	ALPHA	6.79934E+08	Calculated
+1758	Pt-183m	5.3058E+22	4.4030E-12	8.6352E-13	Calculated	0.02000	BETA	8.49762E+02	Calculated
+1783	Pt-203	5.0036E+22	2.3816E-12	4.6807E-13	Calculated	0.02000	BETA	9.77517E+02	Calculated
+1784	Au-185	8.6798E+21	6.2692E-11	5.8493E-11	Calculated	0.02000	BETA	5.74168E+02	Calculated
+1785	Au-186	3.5072E+21	8.1527E-11	8.7306E-11	Calculated	0.02000	BETA	4.65766E+02	Calculated
+1817	Au-205	6.5684E+22	2.8638E-12	2.7215E-12	Calculated	0.02000	BETA	8.23803E+02	Calculated
+1818	Au-206	1.2745E+24	2.9134E-13	2.7686E-13	Calculated	0.02000	BETA	4.14479E+02	Calculated
+1819	Hg-186	2.7043E+22	1.1586E-11	9.5399E-12	Calculated	0.00009	ALPHA	2.36407E+03	Calculated
+1820	Hg-187	1.5504E+22	3.1902E-10	2.3624E-10	Calculated	0.00009	ALPHA	2.47170E+02	Calculated
+1821	Hg-187m	1.9584E+22	1.2014E-10	8.8848E-11	Calculated	0.00009	ALPHA	1.66472E+08	Calculated
+1822	Hg-188	1.1388E+22	5.9453E-10	4.4114E-10	Calculated	0.00009	ALPHA	1.54854E+03	Calculated
+1823	Hg-189	4.8442E+21	4.5746E-10	3.4011E-10	Calculated	0.00009	ALPHA	3.14369E+02	Calculated
+1824	Hg-189m	4.2317E+21	5.5253E-11	4.2043E-11	Calculated	0.02000	BETA	7.09728E+02	Calculated
+1850	Tl-192	3.3555E+21	8.7874E-12	7.9876E-12	Calculated	0.02000	BETA	4.98915E+02	Calculated
+1877	Pb-193	6.2158E+21	2.6459E-11	2.8716E-11	Calculated	0.02000	BETA	1.31406E+03	Calculated
+1878	Pb-194	2.9888E+21	3.3327E-11	3.0516E-11	Calculated	0.00009	ALPHA	9.29878E+02	Calculated
+1908	Bi-196	7.6069E+21	7.1683E-12	3.7232E-12	Calculated	0.02000	BETA	5.11248E+02	Calculated
+1909	Bi-197	3.7973E+21	1.0964E-11	5.0304E-12	Calculated	0.00009	ALPHA	5.61850E+02	Calculated
+1910	Bi-197m	7.0069E+21	7.4932E-11	3.5137E-11	Calculated	0.00009	ALPHA	1.06782E+03	Calculated
+1911	Bi-198	3.4113E+21	1.0944E-11	4.9611E-12	Calculated	0.02000	BETA	4.15657E+02	Calculated
+1912	Bi-198m	2.9654E+21	1.1770E-11	5.3226E-12	Calculated	0.02000	BETA	4.73030E+02	Calculated
+1913	Bi-198n	2.7382E+23	1.4325E-13	6.5047E-14	Calculated	0.02000	BETA	8.27815E+03	Calculated
+1914	Bi-199	1.2950E+21	1.8160E-11	8.1140E-12	Calculated	0.02000	BETA	7.32065E+02	Calculated
+1915	Bi-199m	1.4155E+21	2.2556E-12	6.8752E-13	Calculated	0.00009	ALPHA	8.86672E+09	Calculated

FISPACT

The design choice of retaining the MT number description of reactions in EAF-2004 means that the changes required in the new version of FISPACT are relatively minor. Most of the information in the FISPACT-2003 User manual [8] remains valid. The issues that have been addressed in producing FISPACT-2004 are:

- The new reaction types are defined.
- Libraries after EAF-2003 become the default (EAFV=6).
- Add code to enable cross section libraries with 211 and 351 energy groups to be read and collapsed.
- Increase size of arrays and loops to allow the increased number of nuclides and reactions to be treated.
- Change coding so that the new uncertainty group can be read and used in calculations.
- Add coding to deal with two new decay modes present in the EAF-2004 decay data library.
- Coding added so that conversions between arbitrary group structures and the new ones correctly handled.
- Outputs (pathways and PRINTLIB) show all reaction types and neutron spectra correctly.

Testing with the complete suite of testcases and changes to add requested features remains for the future. A major feature that will be added is the ability to use cross section data in the IEAF format [9]. Sufficient testing was carried out using several of the testcases to be confident that the main calculational routines were behaving correctly.

Example calculation

As a demonstration of the ability of EASY-2004 to perform calculations on neutrons with energy > 20 MeV the following case was run. This used data supplied by FZK [10] for irradiation in an IFMIF spectrum and the result showed excellent agreement with the similar calculation carried out by FZK using IEAF-2001 nuclear data and reported in reference 9.

The calculation was of Eurofer steel irradiated for five years in the high flux test region (HFTM) of IFMIF. Two cases were considered. In the first all neutrons were considered and the flux was 7.5 x 10^{14} $ncm^{-2}s^{-1}$, while in the second neutrons with energy > 20 MeV were removed and the flux was 7.0132 x 10^{14} $ncm^{-2}s^{-1}$. The removed neutrons contribute 6.5% of the total flux. For the first case the spectrum in 211 groups was used while for the second the standard 175-group structure was used. The result of the calculation for activity is shown in Figure 4. It can be seen that at times up to 10 years there is a difference of about 40% between the two cases, dropping to about 18% at 10,000 years. The symbols show the contributions of the dominant nuclides, and it can be seen that the same dominant nuclides are present, but that more of each nuclide has been formed in the 211-group case. This is due both to high-energy neutrons increasing the contribution of existing reactions and to new reactions becoming important at the higher energies.

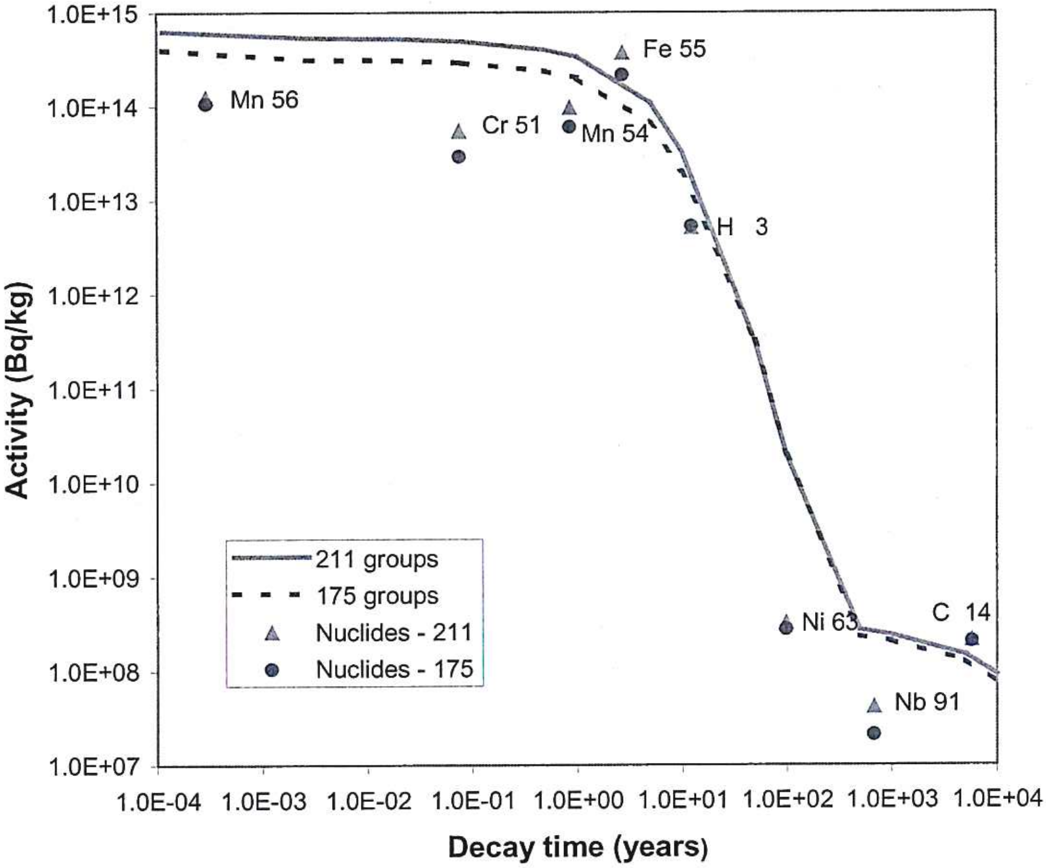

Figure 4. Activity of Eurofer steel as a function of time after irradiation.

The contributions of the various pathways to some of the dominant nuclides are shown in Table 6. Column 2 shows the reaction threshold, where a range is given this indicates that several reactions actually produce the daughter and that only the simplest is shown in column 1. The other reactions have higher thresholds indicated by the range. In columns 3 and 4 both the activity value and the percentage contribution are given. As an example in the 175-group case 97.5% of the activity of ^{54}Mn is due to the ^{54}Fe(n,p)^{54}Mn reaction, while in the 211-group case this reaction contributes only 62.7%, but the activity at 6.11 10^{13} Bq is larger than the 5.92 10^{13} Bq formed by the low energy neutrons. At high energy the remaining contribution is due to ^{56}Fe(n,t)^{54}Mn (35.1%), while this reaction contributes nothing in the low energy case. It can be seen that several new reaction types are present in the table e.g. ^{50}Co(n,3α)^{39}Ar contributes 13.4% of the ^{39}Ar activity.

Table 6. Examples of reactions in EAF-2004 and their contributions to the activity due to various nuclides in the 175 and 211 group cases.

Reaction	**Threshold (MeV)**	**Activity (Bq) at shutdown - 175 groups**	**Activity (Bq) at shutdown - 211 groups**
^{54}Fe(n,p)^{54}Mn	-	5.92 10^{13} (97.5%)	6.11 10^{13} (62.7%)
^{56}Fe(n,p)^{56}Mn	2.97	1.07 10^{14} (99.0%)	1.23 10^{14} (96.0%)
^{56}Fe(n,pα)^{52}V	11.00 - 31.95	0	5.82 10^{11} (5.0%)
^{56}Fe(n,2n)^{55}Fe	11.40	2.15 10^{14} (99.4%)	3.64 10^{14} (98.0%)
^{56}Fe(n,t)^{54}Mn	12.66 - 20.78	0	3.42 10^{13} (35.1%)
^{54}Fe(n,dα)^{49}V	16.08 - 37.04	0	1.69 10^{11} (7.4%)
^{57}Fe(n,3n)^{55}Fe	19.18	0	5.87 10^{12} (1.6%)
^{56}Fe(n,2nα)^{51}Cr	20.00 - 48.81	0	3.17 10^{12} (5.8%)
^{50}Co(n,3α)^{39}Ar	25.89	0	2.21 10^{4} (13.4%)
^{183}W(n,5n)^{179}W(β^+)^{179}Ta	29.51	0	1.03 10^{10} (3.1%)

Conclusions

A new version of the European Activation System (EASY-2004) has been produced. This differs from previous versions in having an upper energy of 60 MeV rather than 20 MeV. Production of this version, which will not be distributed to users, is designed to demonstrate that the methods that have been applied for the higher energies are successful. It will be used for testing prior to the production of a release version (EASY-2005) at the end of 2004. All the components of EASY have been extended: both the codes (SAFEPAQ-II and FISPACT) and the nuclear data libraries (EAF). The libraries are much larger than in EAF-2003, 2195 nuclides are present in the decay data library (1917 previously) and 62,860 reactions are present in the neutron-induced cross section library (12,617 previously). Work during the next year will concentrate on improving the physics of this 'proof of principle' library by including new data below 20 MeV that has been accumulated during 2003 and in responding to the validation work done in measuring integral data. A presentation covering EASY-2004 [11] was presented at the 11th ICFRM conference in Kyoto, Japan in December 2003. The submitted paper is appended to this report as Appendix 1.

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