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Report

THE LASER-PRODUCED SPECTRUM OF Fe XVII TO Fe XXI BELOW 18 Å

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ABSTRACT

Spectra of Fe XVII to Fe XXI emitted from plasmas produced by focusing the output from high power neodymium glass lasers onto solid plane targets were recorded with convex crystal spectrographs in the wavelength region between 8 and 18 Å. A comprehensive analysis of the spectra, which are due to over thirty transition arrays, was made with the aid of Hartree-X and Slater-Condon theoretical calculations. This analysis provides many new line identifications and a detailed survey of the iron spectrum in this wavelength region.

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Erratum

THE LASER-PRODUCED SPECTRUM OF Fe XVII TO Fe XXI BELOW 18 Å

by

G.E. Bromage, R.D. Cowan, B.C. Fawcett, H. Gordon,
M.G. Hobby, N.J. Peacock and A. Ridgeley.

1. Page 4. First sentence of Section 3c

For "The $2s2p^4$-$2s2p^3 3s,3d,4d,5d$ transitions of Fe XX....."
read "The $2s^2 2p^3$-$2s^2 2p^2 3s,4d,5d$ and $2s2p^4$-$2s2p^3 3d$ transitions of Fe XX....."

2. Table 1 entries

(a)	15.450:	For "^1S-^3D"	read	"^1S-^3P"	
(b)	15.262:	For "^1S-^3P"	read	"^1S-^3D"	
(c)	14.966:	For "2-2"	read	"2-1"	
(d)	12.322:	For "^1S-^3D"	read	"^1S-^3P"	
(e)	12.264:	For "^1S-^3P"	read	"^1S-^3D"	
(f)	11.778:	For "^2P-$(^3P)^2D$"	read	"^2P-$(^1D)^2D$"	
(g)	11.440:	For "11.440	4	49	XVIII......$\frac{3}{2}$-$\frac{3}{2}$
					XVIII......$\frac{3}{2}$ $\frac{5}{2}$ ..."
		read "11.440	4	49	XVIII......$\frac{1}{2}$-$\frac{3}{2}$
		11.420	4	49	XVIII......$\frac{3}{2}$-$\frac{5}{2}$ ..."
(h)	10.933:	For "2-2"	read	"1-2"	
(i)	10.685,10.658:	For "10.685	4	25	XIX...
					XIX...
		10.658	4	36	XIX..."
		read "10.685	4	25	XIX...
		10.658	4	36	XIX...
					XIX..."
(j)	10.580:	For "2-2"	read	'1-1"	

3. Table 3, entry 11 and entry 13

For "10.685 25" read "10.658 36" in both entries.

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1. INTRODUCTION

This analysis of the spectrum of Fe XVII to Fe XXI in the wavelength region between 8 and 18 Å reported in this paper is based on the study of new spectrograms of laser-produced plasmas acquired with convex crystal spectrographs. Multi-gigawatt lasers were focused onto plane iron targets, giving power densities of over 10^{14} W cm^{-2} to generate the plasmas. Laser-produced iron spectra have been reported previously by Boiko et al. (1976b), Chase et al. (1976) and Mallozzi et al. (1974) and additional observational data are available from vacuum spark spectra of iron (Cohen and Feldman, 1970: Swartz et al., 1971). Kelly and Palumbo (1973) have compiled published data for Fe XVII to Fe XXI spectra and it is apparent from the data provided in the present paper that the analysis of Fe XIX to Fe XXI requires extensive revision and that a critical survey of these spectra is needed. The present work provides such a survey, facilitated by the improved observational data reported here and further aided by the comparison of observed wavelengths with wavelengths predicted by means of the Hartree-X and Slater-Condon programmes of Cowan (1967, 1968). Recent wavelength classifications and predictions for the $2s^2 2p^n - 2s^2 2p^{n-1} 3d$ transition arrays by Fawcett and Hayes (1975) and Bromage and Fawcett (1977a,b,c) were also applied to the interpretation. Reliable data on Fe XVII spectra already exist and have been critically reviewed by Hutcheon et al. (1976); spectra of the $2s^2 2p^5 - 2s^2 2p^4 3s,3d$ transition arrays of Fe XVIII were definitely identified by Feldman et al. (1973). The origin of the errors in the compilation of Kelly and Palumbo (1973) for Fe XIX to Fe XXI lies in the papers from which their material was obtained.

2. EXPERIMENTAL APPARATUS

Two different multi-gigawatt neodymium lasers and convex crystal spectrographs were employed. The first assembly is located at the UKAEA, Culham Laboratory, and was utilised to obtain the wavelength measurements presented, and the spectrum illustrated in this paper. The second, capable of higher output powers, is located at the Science Research Council's Rutherford Laboratory, and provided spectra radiated from more highly-stripped ions. Comparison of the different spectra facilitated the discrimination between spectral lines belonging to different ions.

The Culham Laboratory neodymium laser is described by Peacock et al. (1977) and has a power output capability of 50 GW for a 1.8 ns pulse duration. It was operated at 25 GW for the present experiments. A 10 cm focal length aspheric lens focused the laser output onto the target surface giving a power density of over 10^{14} W cm^{-2}. The convex crystal instrument used in conjunction with this laser is described by Peacock et al. (1969). It is in the de Broglie configuration in which a mica crystal is curved convex to the source on a radius of 4.0 cm. A film cassette, forming a segment of an outer concentric cylinder, records the Bragg reflections from the crystal surface on Kodirex or SC5 film. The instrument has no entrance slit and was situated at a distance of 80 cm from the laser-produced plasma. This avoids the broadening of the lines due to imaging of the source which has effective dimensions of < 100 μm for the resonance wavelengths below 18 Å. An example of the iron spectrum taken with this apparatus is shown in Figure 1 where the resolving power, which is mainly limited by source dimensions, just exceeds 1000.

The spectrograms were measured with a travelling microscope and wavelengths computed through interpolation on a master dispersion curve drawn up from Cu $K\alpha_\beta$ lines in twelve orders. Normalisation on to this curve was effected through aluminium He-like and H-like reference lines, generated at the same focal spot position, superimposed in first and second orders on the iron spectrum. Wavelengths could be determined in this way with an accuracy of a few milli-Angstroms.

In the experiment using the 100 ps pulse duration laser at the Rutherford Laboratory only the driver stage of 100 GW maximum output was used and it was operated at between 30 GW and 90 GW to obtain varying degrees of ionisation. A 7.5 cm Soro lens focused the output with power densities between 10^{14} and 2 x 10^{15} W cm^{-2}. The crystal instrument has the same basic configuration as the one described above. In this case a 5 cm long RAP crystal was bent to a 4 cm convex radius and the film cassette moved as close to the crystal as possible to reduce the length of photographic exposures required to obtain records. In both spectrographs the recording X-ray film was protected from visible light by a filter on the cassette consisting of 1 μm of polypropylene with 1000 Å of aluminium evaporated on each side. A notable feature of laser-produced plasmas generated with 100 ps pulses is their smaller extent in a direction perpendicular to the plane of the target compared with those formed with pulses longer than 1 ns. X-ray pinhole photographs show that this dimension is about 50 μm. The crystal instrument was therefore placed so that the axis of the curved crystal was parallel to the plane of the target. Because of the smaller source dimensions it was possible to locate the crystal 20 cm from the source and still maintain an empirical resolving power of approximately 1000. Useful spectra could be recorded with ten laser shots in both experiments.

3. RESULTS AND ANALYSIS

The measured wavelengths are listed in Table 1. The wavelength accuracy attained for measurements corresponding to different spectral features varies because of their spectral widths. A figure is therefore given in column 2 which corresponds to the accuracy attained for each individual line. Table 1 also includes line classification data and references to Tables 2 to 8 or published work, whichever provides most detail. The less reliable identifications are excluded from Table 1 but wavelength coincidences with predicted wavelengths or tentative identifications can be found by consulting the other tables or the references included in the last column. The degree of confidence which can be placed on individual line classifications varies for different transition arrays. This is in part due to the blending of more than one spectral line into observed spectral features and in part due to approximations made in the theoretical prediction of wavelengths; the more important of these is probably the omission of configuration-interaction in the calculation of the energy levels of some of the configurations. It is therefore necessary to illuminate these problems further in the ensuing discussion of the data listed in Tables 2 to 8. In Tables 2 to 5 we make detailed comparisons between calculated and observed lines for various multiplets in ion stages Fe XVIII to Fe XXI. The latter tables, 6, 7 and 8, contain ab initio calculations of Fe XIX, Fe XX and Fe XXI.

a. Fluorine-like spectra of Fe XVIII

Firm classifications for the $2s^2 2p^5 - 2s^2 2p^4 3d,3s$ transition arrays are published by Feldman et al. (1973). In Table 2 line identifications for $2s^2 2p^5 - 2s^2 2p^4 4d,5d,4s$ transitions are listed. The wavelengths for the $2s^2 2p^5 - 2s^2 2p^4 4d$ transition arrays are related to the recent classifications by Bromage et al. (1977a). For each of the other three transition arrays the Hartree-X and Slater-Condon computer programmes were used to calculate wavelengths and oscillator strengths neglecting configuration-interaction. The measured wavelengths listed in Table 2 are those nearest to the predicted values. The pattern of observed line intensities for a particular transition array shows a close correlation with the calculated oscillator strengths which implies that the majority of the classifications are correct; nevertheless, individual lines can be displaced relative to others due to configuration-interaction; so erroneous identifications are likely in a minority of cases.

b. Oxygen-like spectra of Fe XIX

The same general aforementioned remarks apply to the $2s^2 2p^4 - 2s^2 2p^3 4d,5d$ Fe XIX line classifications listed in **Table 3.** The wavelengths for the $2s^2 2p^4 - 2s^2 2p^3 4d$ array are again related to the analysis by Bromage et al. (1977a). The $2s^2 2p^4 - 2s^2 2p^3 4s$ classifications are substantiated with wavelength predictions based on isoelectronic extrapolation from the established data (Feldman et al., 1973) on Cl X through to Mn XVIII, as well as with our theoretical predictions and those of Gruzdev (1969a,b).

A study of $2s^2 2p^4 - 2s^2 2p^3 3d$ transitions was recently made by Bromage and Fawcett (1977a). The single configuration approximation was adopted and the Slater parameters used in the calculations were adjusted to obtain consistency with isoelectronic observational data. To reduce still further the remaining minor errors in the predicted wavelengths in the forementioned paper we have performed further calculations which include configuration-interaction. The interaction $2s^2 2p^3 3d \times 2s2p^4 3p$ was found to be the most important. Allowance for the small wavelength shifts due to this interaction **facilitated the final line identifications** for this array which are inserted in **Table 1.**

Listed in Table 6 are the calculated wavelengths for the $2s2p^5 - 2s2p^4 3d$ **transitions** and they probably correspond to the observed values in Table 1 marked Fe XIX $3d^*$. Although further studies must be made before identifications in this latter array can be relied upon, the tentative suggestions account for most of the features in that wavelength region of the observed spectrum which remain after other possibilities have been taken into account.

c. Nitrogen-like spectra of Fe XX

The $2s2p^4 - 2s2p^3 3s,3d,4d,5d$ **transitions of Fe XX are dealt with in Tables 4 and 7 in the same way as described in the preceding section for the analogous transitions** in Fe XIX.

The line classifications for the $2s^2 2p^3 - 2s^2 2p^2 3d$ transitions of Fe XX included in Table 1 are based on the study by Bromage and Fawcett (1977b) which once again uses the method of adjusting Slater parameters described above for the similar transition array in Fe XIX. Inclusion of the interaction $2s^2 2p^2 3d \times 2s2p^3 3p$ affects the classification of the two ^2D levels based on the ^1S parent and involves a smaller but significant adjustment of the two $(^3P)^2D$ levels. One serious effect of this configuration is that the oscillator strength of the leading $^4S_{\frac{1}{2}} - ^4P_{2\frac{1}{2}}$ resonance line, which is observed in solar flares, is reduced by up to a factor of two because small energy level shifts induced by configuration-interaction in the $2s^2 2p^2 3d$ configuration lead to substantial mixing of the $^4P_{2\frac{1}{2}}$ level with neighbouring $J = 2\frac{1}{2}$ levels. The precise reduction is difficult to determine without an empirical knowledge of the position of all the energy levels involved.

The data in **Table 4** relating to the two Fe XX transition arrays mentioned, which have 4d and 5d electrons, account for two groups of observed lines but many are unresolved, thereby preventing detailed classification. The wavelengths published by Boiko et al. (1976b) for laser-produced iron spectra are at present the best available for the Fe XX and Fe XXI spectra between 8.5 and 9.7 Å and these are tabulated.

d. <u>Carbon-like spectra of Fe XXI</u>

Data for Fe XXI spectra are listed in Tables 5 and 8. The discussion of the essential ingredients of the analysis of the analogous transition arrays of Fe XX outlined in the preceding section is also relevant to Fe XXI and will not be repeated.

4. DISCUSSION

These results, taken together with the classification of Fe XXII and Fe XXIII by Bromage et al. (1977b) and Boiko et al. (1976a) and of Fe XXIV by Boiko et al. (1976a), add new information and provide a comprehensive survey of the status of the iron spectrum below 18 Å. This survey is relevant to the study of solar flares with satellite-borne crystal spectrographs. Further progress in the classification of this spectrum could be achieved with the aid of improved observations of the isoelectronic spectra of lighter elements and the detailed consideration of configuration-interaction effects.

5. CONCLUSION

The complexity of the iron spectrum below 17 Å is well illustrated in this paper. Many of the emission lines are prominent features of the spectrum from much lower density plasmas such as solar flares. They are also expected to be present in controlled fusion plasmas such as Tokamaks. In these devices, unresolved contributions from densely packed lines in the spectrum, especially below 13 Å, may be included in "continuum" measurements using energy-dispersive X-ray detectors. The detailed line identifications should also be of use in controlled fusion studies.

In the spectrum from the 'TFR' Tokamak for example, Schwob et al. (1977), reference to the present paper leads to identifications of lines at 13.520, 12.809 and 12.400 Å as strong transitions to the ground terms in the ions of Fe XIX, Fe XX and Fe XXI, respectively.

ACKNOWLEDGMENTS

The authors thank Mr A H Jones for the operation of the Culham laser system, and the staff of the Rutherford Laboratory Central Laser Facility for providing plasmas with their laser. The Appleton Laboratory contribution to this paper is with the permission of its Director.

TABLE 1

MEASURED WAVELENGTHS OF Fe XVII TO Fe XXI LINES WITH IDENTIFICATIONS

Wavelength Å	Accuracy x 10^{-3} Å	Intensity	Ion	Configuration†	Classification	J-J	Reference to Key or Table Number
17.054	5	75	XVII	3s	$^1S-^3P$	0-1	H
16.777	5	77	XVII	3s	$^1S-^1P$	0-1	H
16.306	5	16	XVIII	3s*	$^2S-^2P$	$\frac{1}{2}-\frac{1}{2}$	
16.272	5	7	XVIII	3s	$^2P-(^3P)^4P$	$\frac{1}{2}-\frac{3}{2}$	L
16.166	4	14					
16.072	4	22	XVIII	3s	$^2P-(^3P)^4P$	$\frac{3}{2}-\frac{5}{2}$	L
16.026	4	44	XVIII	3s	$^2P-(^3P)^2P$	$\frac{1}{2}-\frac{1}{2}$	L
16.005	5	70	XVIII	3s	$^2P-(^3P)^4P$	$\frac{3}{2}-\frac{3}{2}$	L
15.870	4	61	XVIII	3s	$^2P-(^1D)^2D$	$\frac{1}{2}-\frac{3}{2}$	L
15.828	4	50	XVIII	3s	$^2P-(^3P)^2P$	$\frac{3}{2}-\frac{3}{2}$	L
15.766	4	35	XVIII	3s	$^2P-(^3P)^2P$	$\frac{3}{2}-\frac{1}{2}$	L
15.625	5	69	XVIII	3s	$^2P-(^1D)^2D$	$\frac{3}{2}-\frac{5}{2}$	L
15.491	4	37	XVIII	3s	$^2P-(^1S)^2S$	$\frac{1}{2}-\frac{1}{2}$	L
15.450	4	29	XVII	3d	$^1S-^3D$	0-1	H
15.360	6	14					
15.339	6	14					
15.313	6	17					
15.289	6	28					
15.262	4	85	XVII	3d	$^1S-^3P$	0-1	H
15.237	6	34					
15.193	4	26					
15.172	6	26	XIX	3s	$^3P-^3S$	1-1	3
15.138	6	5	XIX	3s	$^3P-^3S$	0-1	3
15.111	5	11					
15.075	6	30					
15.015	5	98	XVII	3d	$^1S-^1P$	0-1	H
			XIX	3s	$^1S-^1P$	0-1	3
14.995	5	53	XIX	3s	$^1D-^1D$	2-2	3
14.966	4	33	XIX	3s	$^3P-^3S$	2-2	3
14.929	4	28	XIX	3s	$^3P-^3D$	1-2,1	3
14.868	4	25					
14.833	5	16	XIX	3s			3
14.806	4	21	XIX	3s			3
14.772	4	24	XVIII	3d	$^2P-(^3P)^4P$	$\frac{1}{2}-\frac{3}{2}$	L

†Outer electron of configuration is given: see Key and tables

*Refers to a separate configuration

TABLE 1 (cont.)

Wavelength Å	Accuracy x 10^{-3} Å	Intensity	Ion	Configuration†	Classification	J-J	Reference to Key or Table Number
14.750	4	36					
14.735	4	38	XIX	3s	$^3P-^3D$	2-2	3
14.706	4	49	XIX	3s			3
14.668	4	53	XIX	3s	$^3P-^3D$	2-3	3
14.610	4	37	XVIII	3d	$^2P-(^3P)^2P$	$\frac{1}{2}-\frac{3}{2}$	C
14.581	5	59	XVIII	3d	$^2P-(^3P)^4P$	$\frac{3}{2}-\frac{1}{2}$	L
14.551	4	59	XVIII	3d	$^2P-(^3P)^4P$	$\frac{3}{2}-\frac{3}{2}$	L
14.534	5	71	XVIII	3d	$^2P-(^3P)^4F$	$\frac{3}{2}-\frac{5}{2}$	L
14.486	6	40	XVIII	3d	$^2P-(^3P)^4P$	$\frac{3}{2}-\frac{5}{2}$	L
14.469	6	36	XVIII	3d	$^2P-(^1D)^2S$	$\frac{1}{2}-\frac{1}{2}$	L
14.453	6	34	XVIII	3d	$^2P-(^3P)^4D$	$\frac{3}{2}-\frac{3}{2}$	C
14.418	5	68	XVIII	3d	$^2P-(^1D)^2P$	$\frac{1}{2}-\frac{3}{2}$	L
14.374	5	68	XVIII	3d	$^2P-(^3P)^2D$	$\frac{3}{2}-\frac{5}{2}$	L
14.360	6	61	XVIII	3d	$^2P-(^1D)^2D$	$\frac{1}{2}-\frac{3}{2}$	L
14.344	6	52	XVIII	3d	$^2P-(^1D)^2P$	$\frac{1}{2}-\frac{1}{2}$	C
14.256	6	30	XVIII	3d	$^2P-(^1D)^2S$	$\frac{3}{2}-\frac{1}{2}$	L
14.203	5	60	XVIII	3d	$^2P-(^1D)^2D$	$\frac{3}{2}-\frac{5}{2}$	L
14.152	5	58	XVIII	3d	$^2P-(^1D)^2D$	$\frac{3}{2}-\frac{3}{2}$	L
14.121	5	74	XVIII	3d	$^2P-(^1S)^2D$	$\frac{1}{2}-\frac{3}{2}$	L
14.064	4	30	XX	3s			7
14.041	6	29					
14.021	6	43	XIX	3d*			6
			XX	3s			7
13.956	5	56	XVIII	3d	$^2P-(^1S)^2D$	$\frac{3}{2}-\frac{5}{2}$	L
13.936	4	48	XIX	3d*			6
13.891	4	39	XVII	3p	$^1S-^3P$	0-1	H
13.823	5	64	XVII	3p	$^1S-^1P$	0-1	H
13.795	4	55	XIX	3d	$^3P-(^4S)^3D$	2-3	B
13.770	6	36					
13.735	5	45	XIX	3d	$^1D-(^2D)^1F$	2-3	B
			XIX	3d	$^3P-(^2D)^3D$	1-2	B
			XIX	3d*			6
			XX	3s			7
13.719	5	42					
13.700	6	45	XIX	3d	$^1D-(^2P)^3P$	2-2	B
			XIX	3d*			6

†Outer electron of configuration is given: see Key and Tables.

*Refers to a separate configuration.

TABLE 1 (cont.)

Wavelength Å	Accuracy x 10^{-3} Å	Intensity	Ion	Configuration†	Classification	J-J	Reference to Key or Table Number
13.669	4	51	XIX	3d*			6
13.648	4	48					
13.607	6	25	XIX	3d*			6
13.578	4	48					
13.555	6	42	XIX	3d	$^3P-(^2P)^3P$	1-2	B
13.520	4	75	XIX	3d	$^3P-(^2D)^3D$	2-3	B
			XIX	3d	$^1D-(^2P)^1F$	2-3	B
			XIX	3d	$^1D-(^2P)^1D$	2-2	B
13.504	5	55	XIX	3d	$^3P-(^2D)^3P$	2-2	B
13.464	4	59	XIX	3d	$^3P-(^2P)^3P$	0-1	B
			XVIII	3p	$^2P-(^3P)^4D$	$\frac{3}{2}-\frac{5}{2}$	2
13.440	6	43	XIX	3d	$^3P-(^2P)^3D$	1-1	B
13.424	4	48	XIX	3d	$^3P-(^2D)^1F$	2-3	B
13.397	4	55	XIX	3d	$^3P-(^2P)^3D$	1-2	B
			XVIII	3p	$^2P-(^3P)^2D$	$\frac{1}{2}-\frac{3}{2}$	2
13.374	4	48	XVIII	3p	$^2P-(^3P)^2D$	$\frac{3}{2}-\frac{5}{2}$	2
			XX	3d*			7
13.355	4	48	XVIII	3p	$^2P-(^3P)^2P$	$\frac{3}{2}-\frac{3}{2}$	2
			XVIII	3p	$^2P-(^3P)^2S$	$\frac{1}{2}-\frac{1}{2}$	2
			XX	3d*			7
13.319	6	51	XVIII	3p	$^2P-(^3P)^2P$	$\frac{3}{2}-\frac{1}{2}$	2
			XVIII	3p	$^2P-(^3P)^4P$	$\frac{3}{2}-\frac{5}{2}$	2
13.264	5	11	XIX	3d	$^3P-(^2P)^3D$	2-3	B
			XIX	3d*			7
13.247	4	23					
13.194	6	23	XX	3d*			7
13.159	4	30	XVIII	3p			2
			XX	3d*			7
			XX	3d	$^2P-(^3P)^2D$	$\frac{1}{2}-\frac{3}{2}$	F
13.138	4	37	XX	3d*			7
13.082	4	53	XX	3d	$^2P-(^1D)^2F$	$\frac{3}{2}-\frac{5}{2}$	F
				3d	$^2D-(^3P)^2F$	$\frac{5}{2}-\frac{7}{2}$	F
				3d	$^2P-(^1D)^2P$	$\frac{3}{2}-\frac{3}{2}$	F
				3d*			7
13.049	4	47	XVIII	3p			2
			XX	3d	$^2D-(^3P)^2D$	$\frac{5}{2}-\frac{5}{2}$	FC

†Outer electron of configuration is given: see Key and Tables

*Refers to a separate configuration

TABLE 1 (cont.)

Wavelength Å	Accuracy x 10^{-3} Å	Intensity	Ion	Configuration†	Classification	J-J	Reference to Key or Table Number
13.015	5	38	XVIII	3p			2
			XX	3d			F
12.990	5	38	XVIII	3p			2
			XX	3d*			7
12.978	5	38	XX	3d	$^2D-(^3P)^2D$	$\frac{3}{2}-\frac{5}{2}$	FC
12.946	5	49	XX	3d	$^2P-(^1S)^2D$	$\frac{3}{2}-\frac{5}{2}$	C
			XX	3d*			7
			XIX	3p			3
			XXI	3s			C
12.924	5	55	XX	3d	$^2D-(^1D)^2D$	$\frac{5}{2}-\frac{5}{2}$	F
			XX	3d*			7
			XIX	3p			3
			XXI	3s			C
12.888	5	44	XX	3d	$^2D-(^1D)^2F$	$\frac{5}{2}-\frac{7}{2}$	F
			XX	3d*			7
12.857	5	30	XX	3d	$^2D-(^1D)^2D$	$\frac{3}{2}-\frac{3}{2}$	F
12.847	5	48	XVIII	3p			2
			XX	3d	$^2D-(^1D)^2D$	$\frac{3}{2}-\frac{5}{2}$	F
			XX	3d*			7
12.818	5	48	XX	3d	$^4S-(^3P)^4P$	$\frac{3}{2}-\frac{5}{2},\frac{3}{2}$	F
12.763	4	30	XX	3d	$^2D-(^1D)^2F$	$\frac{3}{2}-\frac{5}{2}$	F
			XXI	3d*			8
12.743	4	32	XXI	3d			D
12.714	4	22	XXI	3d			D
			XXI	3d*			8
12.681	4	18	XXI	3d*			8
			XVII	4s	$^1S-^3P$	0-1	H
12.581	5	40	XXI	3d			D
			XXI	3d*			8
12.548	4	36	XXI	3d*			8
12.526	4	31	XXI	3d			D
			XVII	4s	$^1S-^1P$	0-1	H
12.494	6	36					
12.463	4	37	XXI	3d			D
12.429	4	41	XXI	3d			D
12.411	4	38	XXI	3d*			8
12.387	4	54	XXI	3d	$^3P-^3D$	2-3	D
			XXI	3d*			8

†Outer electron of configuration is given: see Key and Tables.

*Refers to a separate configuration.

TABLE 1 (cont.)

Wavelength Å	Accuracy x 10^{-3} Å	Intensity	Ion	Configuration†	Classification	J-J	Reference to Key or Table Number
12.355	6	27	XXI	3d*			8
12.322	6	37	XXI	3d			D
			XVII	4d	$^1S-^3D$	0-1	H
12.291	6	37	XXI	3d*			8
12.264	4	64	XXI	3d			D
			XVII	4d	$^1S-^3P$	0-1	H
12.248	6	40	XXI	3d			D
12.231	6	40					
12.201	6	23	XXI	3d			D
			XXI	3d*			8
12.155	4	9					
12.123	4	41	XVII	4d	$^1S-^1P$	0-1	H
12.088	6	5					
12.050	5	18					
12.003	5	23	XVIII	4s	$^2P-(^3P)^4P$	$\frac{1}{2}-\frac{3}{2}$	2
11.980	6	19					
11.969	5	23					
11.953	5	24					
11.865	4	20	XVIII	4s	$^2P-(^3P)^4P$	$\frac{3}{2}-\frac{3}{2}$	2
			XVIII	4s	$^2P-(^3P)^2P$	$\frac{1}{2}-\frac{1}{2}$	2
11.793	5	8					
11.778	5	13	XVIII	4s	$^2P-(^3P)^2D$	$\frac{1}{2}-\frac{3}{2}$	2
11.762	5	10	XVIII	4s	$^2P-(^3P)^4P$	$\frac{3}{2}-\frac{1}{2}$	2
11.741	6	11	XVIII	4s	$^2P-(^3P)^2P$	$\frac{3}{2}-\frac{3}{2}$	2
11.707	6	14					
11.640	4	17	XVIII	4s	$^2P-(^1D)^2D$	$\frac{3}{2}-\frac{5}{2}$	2
11.575	5	21					
11.551	5	27	XVIII	4d	$^2P-(^3P)^2D$	$\frac{1}{2}-\frac{3}{2}$	2E
11.526	5	52	XVIII	4d	$^2P-(^3P)^2D$	$\frac{3}{2}-\frac{5}{2},\frac{3}{2}$	2E
11.458	4	28	XVIII	4d	$^2P-(^3P)^4F$	$\frac{3}{2}-\frac{5}{2},\frac{3}{2}$	2E
11.440	4	49	XVIII	4d	$^2P-(^1D)^2D$	$\frac{3}{2}-\frac{3}{2}$	2E
			XVIII	4d	$^2P-(^3P)^2F$	$\frac{3}{2}-\frac{5}{2}$	2E
11.326	4	57	XVIII	4d	$^2P-(^1D)^2F$	$\frac{3}{2}-\frac{5}{2}$	2E
			XVIII	4d	$^2P-(^1D)^2P$	$\frac{3}{2}-\frac{3}{2}$	2E
			XVIII	4d	$^2P-(^1D)^2S$	$\frac{3}{2}-\frac{1}{2}$	2E
11.309	6	27					

†Outer electron of configuration is given: see Key and Tables.

*Refers to a separate configuration.

TABLE 1 (cont.)

Wavelength Å	Accuracy x 10^{-3} Å	Intensity	Ion	Configuration†	Classification	J-J	Reference to Key or Table Number
11.287	4	26					
11.253	4	44	XVIII	4d	$^2P-(^1S)^2D$	$\frac{1}{2}-\frac{3}{2}$	2E
			XVII	5d	$^1S-^3P$	0-1	H
11.133	4	37	XVII	5d	$^1S-^1P$	0-1	H
11.090	5	21					
11.070	4	15					
11.043	4	21	XVII	4p	$^1S-^3P$	0-1	H
11.023	4						
10.985	4						
10.966	4						
10.933	5	25	XIX	4d	$^3P-(^4S)^3D$	2-2	3E
10.907	6	20					
10.877	5	15					
10.851	4	20					
10.824	6	12	XIX	4d	$^1D-(^2D)^1D$	2-2	3E
10.813	5	54	XIX	4d	$^1D-(^2D)^1F$	2-3	3E
			XIX	4d	$^3P-(^4S)^3D$	2-3	3E
			XIX	4d	$^1S-(^2P)^1P$	0-1	3E
10.770	5	37	XIX	4d	$^3P-(^2D)^3D$	1-2	3E
10.736	4	20	XIX	4d	$^1D-(^2D)^3F$	2-3	3E
10.685	4	25	XIX	4d	$^3P-(^2D)^3F$	2-3	3E
			XIX	4d	$^1D-(^2P)^1F$	2-3	3E
10.658	4	36	XIX	4d	$^3P-(^2D)^3D$	2-3	3E
10.644	5	34	XIX	4d	$^3P-(^2D)^3P$	2-2	3E
10.635	5	38	XIX	4d	$^3P-(^2D)^3S$	2-1	3E
10.617	4	25	XIX	4d	$^3P-(^2P)^3D$	0-1	3E
10.580	4	28	XIX	4d	$^3P-(^2P)^3P$	2-2	3E
10.564	4	33					
10.543	4	21	XVIII	5d	$^2P-(^3P)^2D$	$\frac{1}{2}-\frac{3}{2}$	2
10.529	4	32	XVIII	5d	$^2P-(^3P)^4F$	$\frac{3}{2}-\frac{5}{2},\frac{3}{2}$	2
10.502	4	18					
10.460	4	23	XVIII	5d	$^2P-(^1D)^2D$	$\frac{1}{2}-\frac{3}{2}$	2
			XVIII	5d	$^2P-(^1D)^2P$	$\frac{1}{2}-\frac{1}{2}$	2
10.437	5	26					
10.367	5	18					
10.352	4	31	XVIII	5d	$^2P-(^1D)^2F$	$\frac{3}{2}-\frac{5}{2}$	2
			XVIII	5d	$^2P-(^1D)^2P$	$\frac{3}{2}-\frac{3}{2}$	2
			XVIII	5d	$^2P-(^1D)^2S$	$\frac{3}{2}-\frac{1}{2}$	2
10.318	5	15					
10.298	6	10	XVIII	5d	$^2P-(^1S)^2D$	$\frac{1}{2}-\frac{3}{2}$	2

†Outer electron of configuration is given: see Key and Tables

*Refers to a separate configuration.

TABLE 1 (cont.)

Wavelength Å	Accuracy x 10^{-3} Å	Intensity	Ion	Configuration†	Classification	J-J	Reference to Key or Table Number
10.251	6	13					
10.222	4	22	XX	4d			4
10.192	6	15					
10.177	4	20	XX	4d			4
10.159	4	22	XX	4d			4
10.121	6	25	XX	4d			4
10.058	6	25	XX	4d			4
10.008	4	20	XX	4d			4
9.991	6	27	XX	4d			4
9.936	6	5					
9.917	6	2	XIX	5d			3
9.894	6	5					
9.871	6	5					
9.842	4	20	XIX	5d			3
9.799	6	10	XIX	5d			3
9.766	6	4					
9.724	4	13	XIX	5d			3
9.705	4	14	XIX	5d			3
9.688	4	13	XIX	5d			3
9.640	6	6					
9.597	4	7					
9.578	6	7					
9.514	6	5					
9.385	4	11					
9.222	6	5					

KEY:

H ≡ Fe XVII reviewed by Hutcheon et al. 1976 Astron.Astrophys 51, 421-460.

L ≡ See Feldman et al. 1973 J.Opt.Soc.Am., 63, 1445-53.

B ≡ Classification based on Bromage and Fawcett 1977 Mon.Not.Roy.astr.Soc. 178, 591-598 and further configuration interaction calculations.

C ≡ Classified on basis of new theoretical calculations.

D ≡ Nearest predicted wavelengths given by Bromage and Fawcett 1977, Mon.Not. Roy.astr.Soc. 178, 605-610.

E ≡ Classifications by Bromage et al. 1977 Mon.Not.Roy.astr.Soc. 178, 599-604.

F ≡ Nearest predicted wavelengths given by Bromage and Fawcett 1977, Mon.Not.Roy. astr.Soc. 179, 683-689.

† ≡ The outer electron of the configuration is given; the last column gives a reference to the full classification.

* ≡ Refers to a separate configuration.

TABLE 2

Fe XVIII FLUORINE-LIKE SPECTRA

(WAVELENGTHS Å)

Transition	J-J	Observed Wavelength	Obs Int	Ref	Calc. Wave-length	Obsvd. Wave-length	Calc gf	Obs Int	Ref
$2s^22p^5-2s^22p^44d$					$2s^22p^5-2s^22p^4\ 5d$				
$^2P-(^3P)^2D$	1½-2½	11.526	52	Ba	10.431	10.437	0.15	26	Aa
	1½-1½	11.526	52b	Ba	10.427		0.0093		
	½-1½	11.551	49	Ba	10.540	10.543	0.11	21	Aa
$^2P-(^3P)^2F$	1½-2½	11.420	28	Ba	10.434		0.0098		
$^2P-(^3P)^4F$	1½-2½	11.458	28b	Aa	10.522	10.529	0.23	32	Aa
	1½-1½	11.458	28b	Aa	10.523	10.529	0.13	32b	Aa
$^2P-(^1D)^2F$	1½-2½	11.326	57b	Ba	10.356	10.352	0.087	31	Aa
$^2P-(^1D)^2D$	½-1½	11.440	49b	Ba	10.463	10.460	0.11	23b	Aa
$^2P-(^1D)^2P$	1½-1½	11.326	57b	Ba	10.358	10.352	0.095	31b	Aa
	½-½	11.440	49b	Ba	10.462	10.460	0.11	23b	Aa
$^2P-(^1D)^2S$	1½-½	11.326	57b	Ba	10.358	10.352	0.07	31b	Aa
$^2P-(^1S)^2D$	½-1½	11.253	44b	Ba	10.292	10.298	0.082	10	Aa
$2s^22p^5-2s^22p^44s$									
$^2P-(^3P)^4P$	1½-2½				11.870		0.0027		
	1½-1½				11.858	11.865	0.036	20	Aa
	½-1½				12.004	12.003	0.0012	23b	Aa
	1½-½				11.764	11.762	0.0038	10	Aa
$^2P-(^3P)^2P$	1½-1½				11.744	11.741	0.0088	11b	Aa
	½-½				11.878	11.865	0.013	20b	Aa
	1½-½				11.735		0.0087		
$^2P-(^1D)^2D$	1½-2½				11.647	11.640	0.023	17	Aa
	½-1½				11.786	11.778	0.020	8	Aa
$^2P-(^1S)^2S$	½-½				11.564		0.007		

TABLE 2 (cont.)

TRANSITION	J-J	CALCULATED WAVELENGTH	OBSERVED WAVELENGTH	Calc gf	Obs Int	Ref.
$2s^2 2p^5 - 2s2p^5 3p$						
$^2P-(^3P)^4D$	$\frac{3}{2}-\frac{5}{2}$	13.451		0.20		
	$\frac{3}{2}-\frac{3}{2}$	13.405		0.19		
$^2P-(^3P)^4P$	$\frac{3}{2}-\frac{5}{2}$	13.299	13.319	0.31	51b	Aa
	$\frac{1}{2}-\frac{3}{2}$	13.480		0.12		
$^2P-(^3P)^2D$	$\frac{3}{2}-\frac{5}{2}$	13.384	13.374	0.42	48b	Aa
	$\frac{1}{2}-\frac{3}{2}$	13.396	13.397	0.28	55b	Aa
$^2P-(^3P)^2P$	$\frac{3}{2}-\frac{3}{2}$	13.335	13.355	0.33	48b	Aa
	$\frac{3}{2}-\frac{1}{2}$	13.299	13.319	0.24	51b	Aa
$^2P-(^3P)^2S$	$\frac{3}{2}-\frac{1}{2}$	13.155	13.159	0.10		
	$\frac{1}{2}-\frac{1}{2}$	13.339	13.355	0.20	48b	Aa
$^2P-(^1P)^2D$	$\frac{3}{2}-\frac{5}{2}$	12.847	12.847	0.20		
	$\frac{1}{2}-\frac{3}{2}$	13.065	13.049	0.18		
$^2P-(^1P)^2P$	$\frac{1}{2}-\frac{1}{2}$	13.016	13.015	0.14		
	$\frac{1}{2}-\frac{3}{2}$	12.998	13.001	0.14		

Key for Tables 2 to 5

B = Classifications by Bromage et al. 1977a.

A = Classified in this paper.

k = Wavelength measurements of Boiko et al. (1976)

a = Wavelength measurements from present work.

gf = weighted oscillator strength.

b = blend.

TABLE 3

Fe XIX OXYGEN-LIKE SPECTRA (WAVELENGTHS Å)

Transition	J-J	Observed Wavelength	Obs Int	Ref	Calc. Wave-length	Obsvd. Wave-length	Calc gf	Obs Int	Ref
$2s^2 2p^4 - 2s^2 2p^3 4d$					$2s^2 2p^4 - 2s^2 2p^3 5d$				
$^3P-(^2D)^3D$	2-3	10.658	36	Ba	9.691	9.688	0.11	13	Aa
	1-2	10.770	37	Ba	9.803	9.799	0.11	10	Aa
$^3P-(^2D)^3F$	2-3	10.685	25b	Ba	9.724	9.724	0.11	13	Aa
$^3P-(^2D)^3P$	2-2	10.644	34	Ba	9.688	9.688	0.14	13b	Aa
$^3P-(^2D)^3S$	2-1	10.635	38	Ba	9.683	9.688	0.083	13b	
$^1D-(^2D)^1F$	2-3	10.813	54	Ba	9.835	9.842	0.27	20	Aa
$^1D-(^2D)^1D$	2-2	10.824	12	Ba	9.837	9.842	0.17	20b	Aa
$^3P-(^2P)^3D$	1-2	10.564	33	Ba	9.623		0.049		
	0-1	10.617	25	Ba	9.667		0.082		
$^3P-(^2P)^3P$	1-1	10.580	28	Ba	9.627		0.056		
$^1D-(^2P)^1F$	2-3	10.685	25b	Ba	9.693	9.705	0.18	14b	Aa
$^1D-(^2P)^3F$	2-3	10.735	20	Ba	9.752		0.081		
$^1D-(^2P)^3D$	2-2	10.685	25	Ba	9.692		0.060		
$^1S-(^2P)^1P$	0-1	10.813	54b	Ba	9.845		0.16		
$^3P-(^4S)^3D$	2-3	10.813	54b	Ba	9.838	9.842	0.27	20b	Aa
	1-2	10.933	25b	Ba	9.929	9.917	0.067	2b	Aa
	0-1	10.933	25b	Ba	9.913	9.917	0.063	2b	Aa

TABLE 3 (cont.)

TRANSITION	J-J	CALCULATED WAVELENGTH	OBSERVED WAVELENGTH	Calc gf	Obs Int	Ref
$2s^2 2p^4 - 2s^2 2p^3 3s$						
$^3P-^3D$	2-3	14.664	14.668	0.19	53	Aa
	2-2	14.734	14.735	0.12	38	Aa
	1-2	14.928	14.929	0.035	28	Aa
	1-1	14.925	14.929	0.091	28	Aa
$^3P-^3P$	1-2	14.517		0.083		
	1-0	14.653		0.029		
	0-1	14.598		0.055		
$^3P-^3S$	2-1	14.950	14.966	0.18	33	Aa
	1-1	15.150	15.172	0.043	26	Aa
	0-1	15.109	15.138	0.038	5	Aa
$^1D-^1D$	2-2	14.983	14.995	0.27	53	Aa
$^1D-^1P$	2-1	14.644	(14.706?)	0.081	49b	?a
$^1D-^3P$	2-2	14.675		0.076		
	2-1	14.798		0.042		
$^3P-^1D$	1-2	14.817		0.033		

TABLE 4

Fe XX NITROGEN-LIKE SPECTRA (WAVELENGTHS Å)

TRANSITION	J-J	CALCULATED WAVELENGTH	OBSERVED LINE	Calc gf	Obs Int	Ref	CALCULATED WAVELENGTH	OBSERVED LINE	Calc gf	Obs Int	Ref
$2s^2 2p^3 - 2s^2 2p^2 4d$							$2s^2 2p^3 - 2s^2 2p^2 5d$				
$^4S-(^3P)^4F$	$1\frac{1}{2}-2\frac{1}{2}$	10.040	10.058	0.23	25b	Aa	9.105	9.110	0.098	41b	Ak
$^4S-(^3P)^4D$	$1\frac{1}{2}-2\frac{1}{2}$	9.996	10.008	0.25	20	Aa	9.069	9.065	0.078	38b	Ak
$^4S-(^3P)^4P$	$1\frac{1}{2}-2\frac{1}{2}$	10.109	10.121	0.21	25	Aa	9.163	9.163	0.091	28b	Ak
	$1\frac{1}{2}-1\frac{1}{2}$	9.992	9.991	0.32	27b	Aa	9.067	9.065	0.115	38b	Ak
	$1\frac{1}{2}-\frac{1}{2}$	9.989	9.991	0.19	27b	Aa	9.066	9.065	0.075	38b	Ak
$^2D-(^3P)^2F$	$2\frac{1}{2}-3\frac{1}{2}$	10.144	10.159	0.77	22b	Aa	9.202	9.199	0.32	28	Ak
	$1\frac{1}{2}-2\frac{1}{2}$	10.153	10.177	0.35	20b	Aa	9.208	9.208	0.18	26b	Ak
$^2D-(^3P)^2D$	$2\frac{1}{2}-2\frac{1}{2}$	10.148	10.159	0.18	22b	Aa	9.205	9.208	0.085	26b	Ak
	$1\frac{1}{2}-2\frac{1}{2}$	10.106	10.121	0.29	25	Aa	9.171	9.163	0.066	28b	Ak
$^2P-(^3P)^2D$	$\frac{1}{2}-1\frac{1}{2}$	10.219	10.222	0.21	22	Aa					
$^2D-(^1D)^2G$	$2\frac{1}{2}-3\frac{1}{2}$	10.034	10.034	0.57	62b	Aa	9.105	9.110	0.17	41b	Ak
$^2D-(^1D)^2D$	$2\frac{1}{2}-2\frac{1}{2}$	10.037	10.034	0.31	62b	Aa	9.106	9.110	0.12	41b	Ak
	$1\frac{1}{2}-1\frac{1}{2}$	9.996	10.008	0.20	20b	Aa	9.072	9.073	0.077	21	Ak
$^2P-(^1D)^2F$	$1\frac{1}{2}-2\frac{1}{2}$	10.161	10.177	0.60	20b	Aa	9.218	9.220	0.22	28b	Ak
$^2P-(^1D)^2P$	$1\frac{1}{2}-1\frac{1}{2}$	10.159	10.177	0.32	20b	Aa	9.217	9.220	0.12	28b	Ak
$^2P-(^1S)^2D$	$1\frac{1}{2}-2\frac{1}{2}$	10.036	10.034	0.25	62b	Aa					
	$\frac{1}{2}-1\frac{1}{2}$	9.966	9.991	0.24	27b	Aa					

TABLE 5

Fe XXI CARBON-LIKE SPECTRA (WAVELENGTHS IN Å)

TRANSITION	J-J	CALCULATED WAVELENGTH	OBSERVED LINE	Calc gf	Obs Int	Ref	CALCULATED WAVELENGTH	OBSERVED LINE	Calc gf	Obs Int	Ref
$2s^2 2p^2 - 2s^2 2p4d$							$2s^2 2p^2 - 2s^2 2p5d$				
$^3P-^3D$	2-3	9.469	9.460	0.47	50	Ak	8.555	8.558	0.16	21	Ak
	2-2	9.464	9.451	0.20	34b	Ak	8.553		0.072		Ak
	0-1	9.463	9.451	0.23	34b	Ak	8.553		0.086		Ak
$^3P-^3P$	1-2	9.533	9.518	0.32	46b	Ak	8.610		0.12		Ak
	1-1	9.425	9.421	0.14	19	Ak	8.521	8.521	0.054	21	Ak
$^3P-^1D$	1-2	9.435	9.433	0.11	26	Ak	8.525	8.521	0.039		Ak
$^1D-^1F$	2-3	9.561	9.581	0.89	55	Ak	8.638	8.643	0.33	18b	Ak
$^3P-^3F$	2-3	9.572	9.581	0.35	bb	Ak	8.642		0.147		Ak

TABLE 6

ADDITIONAL PREDICTED WAVELENGTHS AND WEIGHTED OSCILLATOR STRENGTHS FOR Fe XIX OXYGEN-LIKE SPECTRA (WAVELENGTHS IN Å)

TRANSITION	J-J	CALCULATED WAVELENGTH	Calc gf
$2s2p^5$-$2s2p^4 3d$			
^3P-$(^2D)^3D$	2-3	13.597	2.45
^3P-$(^2D)^3P$	2-2	13.598	2.52
^1P-$(^2P)^1D$	1-2	13.655	4.02
^1P-$(^2P)^1P$	1-1	13.683	1.35
^3P-$(^2D)^3D$	1-2	13.731	1.63
^3P-$(^2D)^3P$	0-1	13.790	1.11
^1P-$(^2P)^3F$	1-2	13.837	1.15
^3P-$(^4P)^3D$	2-3	13.932	2.48
^3P-$(^4P)^3P$	1-2	14.020	1.05

TABLE 7

ADDITIONAL PREDICTED WAVELENGTHS & WEIGHTED OSCILLATOR STRENGTHS FOR Fe XX SPECTRA (WAVELENGTHS IN Å)

TRANSITION	J-J	CALCULATED WAVELENGTH	Calc gf
$2s2p^4-2s2p^33d$			
$(^3P)^4P-(^3P)^4D$	$1\frac{1}{2}-2\frac{1}{2}$	12.851	1.2
$(^1D)^2D-(^1D)^2F$	$1\frac{1}{2}-2\frac{1}{2}$	12.881	1.9
$(^3P)^4P-(^3D)^4S$	$2\frac{1}{2}-1\frac{1}{2}$	12.906	1.5
$(^1D)^2D-(^1D)^2F$	$2\frac{1}{2}-3\frac{1}{2}$	12.916	3.6
$(^3P)^4P-(^3P)^4P$	$\frac{1}{2}-1\frac{1}{2}$	12.924	1.3
$(^3P)^4P-(^3D)^4P$	$2\frac{1}{2}-2\frac{1}{2}$	12.943	3.1
$(^3P)^4P-(^3D)^4D$	$2\frac{1}{2}-3\frac{1}{2}$	12.958	2.8
$(^3P)^2P-(^1P)^2F$	$1\frac{1}{2}-2\frac{1}{2}$	12.981	3.0
$(^3P)^2P-(^3D)^2D$	$\frac{1}{2}-1\frac{1}{2}$	13.079	2.7
$(^3P)^4P-(^3D)^4D$	$1\frac{1}{2}-2\frac{1}{2}$	13.111	2.0
$(^1D)^2D-(^3P)^2D$	$2\frac{1}{2}-2\frac{1}{2}$	13.142	1.1
$(^3P)^2P-(^3S)^2D$(21%)	$1\frac{1}{2}-2\frac{1}{2}$	13.143	2.5
$(^1D)^2D-(^3P)^2F$	$2\frac{1}{2}-3\frac{1}{2}$	13.166	2.5
$(^3P)^2P-(^3D)^4P$	$1\frac{1}{2}-1\frac{1}{2}$	13.184	1.4
$(^1S)^2S-(^5S)^4D$	$\frac{1}{2}-1\frac{1}{2}$	13.279	1.4
$(^3P)^2P-(^1D)^2S$	$\frac{1}{2}-\frac{1}{2}$	13.292	1.0
$(^1D)^2D-(^3D)^2F$	$2\frac{1}{2}-2\frac{1}{2}$	13.329	1.4
$(^1D)^2D-(^3D)^2F$	$2\frac{1}{2}-3\frac{1}{2}$	13.335	1.5
$(^3P)^4P-(^5S)^4D$	$2\frac{1}{2}-3\frac{1}{2}$	13.361	2.0
$(^1D)^2D-(^3D)^2D$	$1\frac{1}{2}-2\frac{1}{2}$	13.401	1.0
$2s^22p^3-2s^22p^23s$			
$^4S-^4P$	$\frac{3}{2}-\frac{5}{2}$	13.736	0.15
	$\frac{3}{2}-\frac{3}{2}$	13.818	0.096
	$\frac{3}{2}-\frac{1}{2}$	13.945	0.06
$^2D-^2D$	$\frac{5}{2}-\frac{5}{2}$	13.810	0.16
	$\frac{3}{2}-\frac{5}{2}$	13.734	0.068
$^2D-^2P$	$\frac{5}{2}-\frac{3}{2}$	14.009	0.18
	$\frac{3}{2}-\frac{1}{2}$	14.014	0.12
$^2P-^2D$	$\frac{3}{2}-\frac{3}{2}$	14.064	0.17

TABLE 8

ADDITIONAL PREDICTED WAVELENGTHS AND WEIGHTED OSCILLATOR STRENGTHS FOR Fe XXI SPECTRA (WAVELENGTHS IN Å)

TRANSITION	J-J	CALCULATED WAVELENGTH	Calc gf
$2s2p^3-2s2p^23d$			
$^3D-(^2P)^3F$	2-3	12.215	1.1
$^5S-(^4P)^5P$	2-1	12.280	1.8
	2-2	12.290	2.6
	2-3	12.312	2.5
$^3D-(^2D)^1G$	3-4	12.346	1.9
$^3D-(^2D)^3D$	2-2	12.359	1.2
$^3D-(^2D)^3F$	2-3	12.371	1.7
$^3D-(^2D)^3F$	1-2	12.383	1.4
$^3D-(^2D)^3D$	3-3	12.393	2.3
$^5S-(^4P)^5D$	2-3	12.400	1.5
$^3D-(^2D)^3F$	3-4	12.404	3.8
$^1D-(^2P)^1F$	2-3	12.451	5.2
$^3P-(^2D)^1F$	2-3	12.549	1.2
$^1P-(^2P)^1D$	1-2	12.572	3.1
$^3D-(^4P)^3D$	2-3	12.573	1.1
$^3P-(^2D)^3F$	2-3	12.617	1.0
$^3D-(^4P)^3D$	3-3	13.623	1.0
$^3D-(^4P)^3F$	3-4	12.669	2.3
	2-3	12.699	1.5
$^1D-(^2D)^1D$	2-2	12.777	1.4

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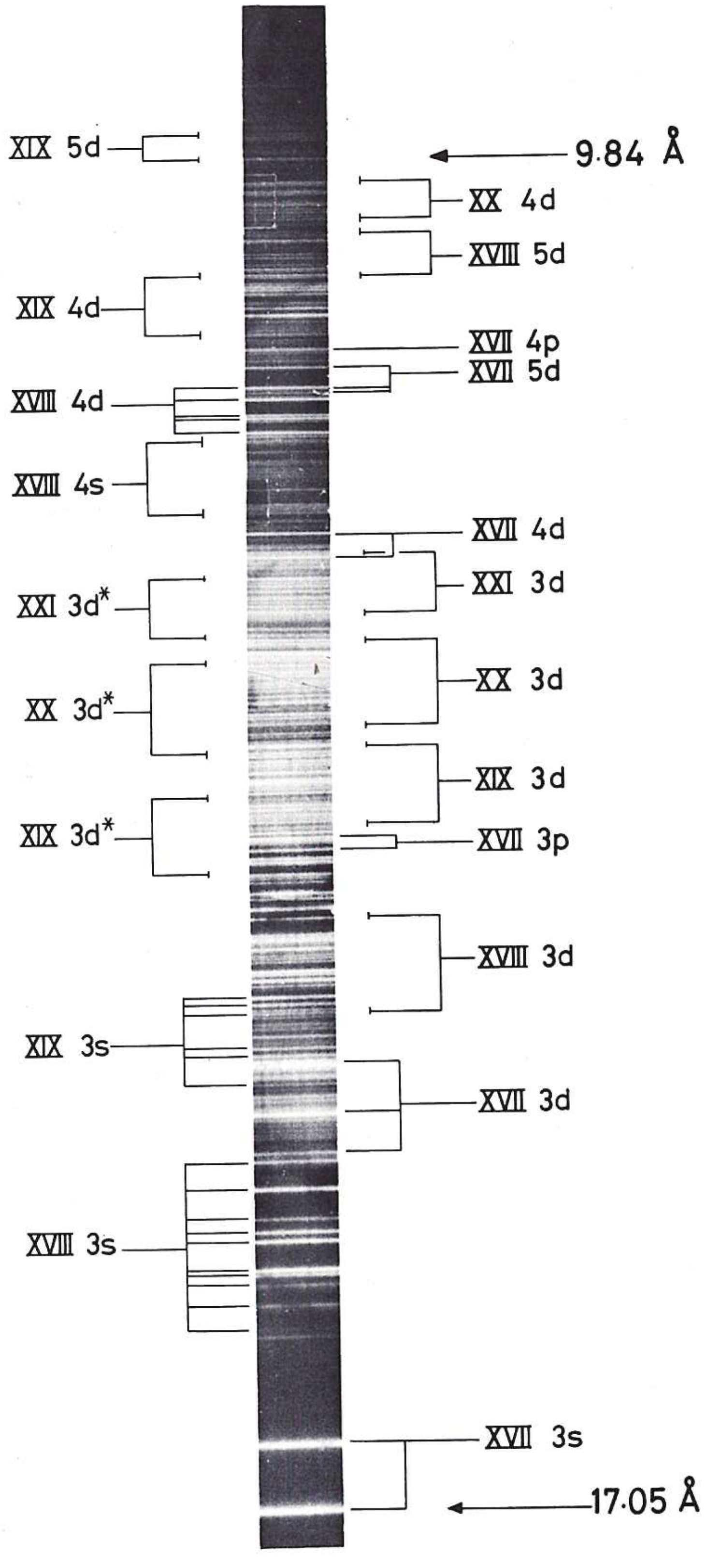
LASER PRODUCED SPECTRA OF Fe XVII to Fe XXI



Spectrum of iron in the range 9–17 Å produced by focusing a 25 GW, 1.8 ns Nd laser pulse on to a plane solid target with power densities of the order of 10^{14} W cm^{-2}.

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