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To cite this article: B C Fawcett *et al* 1971 *J. Phys. B: Atom. Mol. Phys.* **4** 986

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New observations of the spectra of argon x to xv and of isoelectronic emission lines in silicon VII to x, phosphorus x, sulphur ix to xii and chlorine x to xiv

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MS. received 30th November 1970

Abstract. This paper reports the classification of spectral lines of chlorine ix to xiv and of argon x to xv emitted from the plasma formed in a θ pinch. The spectra were recorded photographically using a fast shutter to isolate the period of interest. Additional wavelengths of isoelectronic lines in silicon, phosphorus and sulphur are also presented; these lines were emitted from laser produced plasmas. The transitions identified are $2p^n-2p^{n-1}$, $3s$, $4s$, $3d$, $4d$ and $2s^22p^n-2s2p^{n+1}$ and $2s2p^n-2p^{n+1}$. The wavelengths of the $2s^22p^n-2s2p^{n+1}$ emission lines enable the calculation of ground term intervals in the solar abundant elements silicon, sulphur and argon. The measured interval in argon xiv adds confirmation to the identification of the coronal forbidden line at 4412 Å.

1. Introduction

These new classifications of spectral lines of argon x to xv and of isoelectronic lines in silicon, phosphorus, sulphur and chlorine extend the data listing the energy levels of multiply ionized atoms belonging to the beryllium, boron, carbon, nitrogen oxygen and fluorine-like isoelectronic sequences. Some of the spectra are the result of transitions from shells of principal quantum number $n = 3$ or 4 to $n = 2$; these lie between 18 Å and 60 Å. Their analysis has presented difficulties on account of the large number of closely spaced emission lines occurring in this region and also because of the problem of discriminating between different stages of ionization.

The other argon x to xv like spectra observed are in the spectral region between 140 Å and 300 Å. These transitions do not involve a change of principal quantum number. The additional observations in silicon complete the analysis of the $2s^22p^n-2s2p^{n+1}$ and $2s2p^n-2p^{n+1}$ transitions and are of particular importance to the interpretation of solar spectra.

2. Earlier work on which new classifications are based

Transitions from the $n = 3$ or 4 to the $n = 2$ shell in argon x to xii are already reported (Fawcett *et al.* 1964b) but these are now extended with further identifications and all the wavelengths measured to higher accuracy. Previous identifications in chlorine (Edlen 1936, Fawcett 1970) and lighter elements (Moore 1949, Kelly 1968, Tondello 1969, Fawcett *et al.* 1970) permitted the prediction of the wavelengths of the argon lines and hence aided their classification. The extrapolated wavenumbers were obtained through plotting the wavenumbers of listed spectral lines minus the wavenumbers of corresponding hydrogen-like lines against atomic number (Edlen 1964). The strongest multiplets in the fluorine isoelectronic sequence have

already been observed as far as Fe XVIII (Edlen and Tyren 1936, Fawcett 1965, Fawcett *et al.* 1967a).

In the case of transitions with $\Delta n = 0$ previous observations are reported for argon x to XIII (Fawcett *et al.* 1964a, Deutschman and House 1967). The prediction of further lines in A XIII to xv is based on isoelectronic lines in the period between sodium and chlorine (Deutschman and House 1967, Fawcett 1970). The A x to XII sequences have also been studied in potassium and calcium and the A x sequence in scandium and titanium (Fawcett *et al.* 1967b, Basov *et al.* 1967).

3. Apparatus and measurement

The source used to obtain argon and chlorine spectra was the plasma generated in a 30 kJoule 37 kV θ pinch device. The magnetically compressed plasma reaches an electron temperature of 270 eV and electron density of $4 \times 10^{16} \text{ cm}^{-3}$ in a pulse of duration 6 μs for the first half cycle. The electron temperature and density were determined by measuring the profile and intensity of ruby laser radiation, Thomson scattered by the plasma electrons. The single-turn coil 30 cm long and 9.5 cm diameter produces a compressed plasma, approximately 15 cm long by 1 cm diameter, which in these experiments was viewed radially at its mid-plane. The gas filling was hydrogen at 40 mtorr, containing small percentages of argon. After establishing a slow reverse bias field of 240 gauss, the gas was preionized with a short pulse of 10 MHz current, followed 10 μs later by a preheater discharge of 1 μF at 40 kV through the θ coil. 20 μs later the main discharge was initiated through the same coil. These main bank, preionization and bias bank parameters were necessary to achieve the high electron temperatures required for the production of highly stripped ions. The conditions result in greater plasma stability and confinement and a lower injection of impurities. The percentage of argon impurity was adjusted to enhance different stages of ionization. 0.5%, 1%, 3% and 5% were used. With 0.5% the strongest spectral lines recorded during the first half cycle were of argon XII to XIV and with 5%: argon IX to XI. Additional plates were taken with 0.5% added nitrogen to provide reference lines.

The spectrograph, a two meter grazing incidence instrument (Gabriel *et al.* 1965) used a 600 line mm^{-1} grating at an angle of incidence of 88° and a slit width of 5 μm . Only the radiation emitted during a portion of the first half cycle close to peak current was allowed to enter the spectrograph and this was accomplished by the use of a 2 μs mechanical shutter (Fawcett and Gabriel 1966). Otherwise the spectrum is dominated by impurity lines and lines due to lower stages of ionization emitted at other times during the discharge. The same instrument was used in conjunction with a neodymium 750 MW giant pulse laser (Fawcett 1970) to record the spectra emitted from the laser-produced plasmas of silicon, phosphorus, sulphur and chlorine. The experimental arrangement was described in an earlier paper (Fawcett *et al.* 1970). These plasmas were generated by focussing the laser beam with a 10 cm lens onto 0.1 mm^2 of a solid target situated in a vacuum close to the entrance slit and consisting of the pure element or a compound. The spectra were recorded on Ilford Q2 plates and measured with a travelling microscope. A least squares fit computer program calculated the wavelengths. The wavelength accuracy obtained was 0.01 Å.

4. Line classification

Two conditions aided the classification; firstly impurity lines emitted from stages of ionization lower than argon IX and chlorine VIII were almost entirely absent from

the recorded spectra of argon and chlorine, and secondly it was possible to discriminate between different stages of ionization through comparing their relative intensity on different plates taken with altered percentages of argon or chlorine in the plasma.

Table 1. Wavelength in Å of emission lines of argon x to xv and chlorine xi below 45 Å

Argon x					
Configuration	Term	<i>J-J</i>	Wavelength	Intensity	Ref.
$2s^2 2p^5-2s^2 2p^4(^3P)3s$	$^2P-^4P$	$\frac{3}{2}-\frac{5}{2}$	44.45	9	F
		$\frac{3}{2}-\frac{3}{2}$	44.27	9 B	F
	$^2P-^2P$	$\frac{1}{2}-\frac{3}{2}$	44.63	8	F
		$\frac{3}{2}-\frac{3}{2}$	43.92	9	F
		$\frac{3}{2}-\frac{1}{2}$	43.69	7	F
		$\frac{1}{2}-\frac{1}{2}$	44.05	7	F
		$\frac{1}{2}-\frac{3}{2}$	44.27	9 B	
		$\frac{1}{2}-\frac{5}{2}$	42.94	5	F
$2s^2 2p^5-2s^2 2p^4(^1D)3s$	$^2P-^2D$	$\frac{1}{2}-\frac{3}{2}$	43.27	3	F
$2s^2 2p^5-2s^2 2p^4(^1S)3s$	$^2P-^2S$	$\frac{3}{2}-\frac{1}{2}$	41.57	4	F
		$\frac{1}{2}-\frac{1}{2}$	41.89	2	F
		$\frac{1}{2}-\frac{3}{2}$	45.03	7	F
$2s 2p^6-2s 2p^5(^3P)3s$	$^2S-^2P$	$\frac{1}{2}-\frac{1}{2}$	44.84	6	F
$2s^2 2p^5-2s^2 2p^4(^3P)3d$	$^2P-^2D$	$\frac{3}{2}-\frac{5}{2}$	38.23	3	H
$2s^2 2p^5-2s^2 2p^4(^1D)3d$	$^2P-^2D$	$\frac{3}{2}-\frac{3}{2}$	37.43	5	H
		$\frac{1}{2}-\frac{3}{2}$	37.60	4	
		$\frac{3}{2}-\frac{5}{2}$	36.69	4	
$2s^2 2p^5-2s^2 2p^4(^1S)3d$	$^2P-^2D$	$\frac{1}{2}-\frac{3}{2}$	36.78	3	
$2s^2 2p^5-2s^2 2p^4 3d$			36.96	2	
$2s^2 2p^5-2s^2 2p^4 4s$			32.55	1	
			32.74	1	
			30.96	3	
$2s^2 2p^5-2s^2 2p^4(^1D)4d$	$^2P-^2D$	$\frac{3}{2}-\frac{5}{2}$	31.08	2	
			29.1	2	
$2s^2 2p^5-2s^2 2p^4(^1D)5d$	$^2P-^2D$	$\frac{3}{2}-\frac{5}{2}$	29.2	1	
Argon xi					
Configuration	Term	<i>J-J</i>	Wavelength	Intensity	Ref.
$2s^2 2p^4-2s^2 2p^3(^4S)3s$	$^3P-^3S$	2-1	39.75	5	F
		1-1	39.98	3	F
		0-1	40.02	2	F
$2s^2 2p^4-2s^2 2p^3(^2D)3s$	$^1D-^1D$	2-2	39.49	6	F
$2s^2 2p^4-2s^2 2p^3(^2P)3s$	$^1S-^1P$	0-1	40.04	5	
$2s^2 2p^4-2s^2 2p^3(^2P)3s$	$^1D-^1P$	2-1	38.87	5	
$2s^2 2p^4-2s^2 2p^3(^2D)3s$	$^3P-^3D$	2-3	38.62	8	
		1-2	38.79	3	
		2-3	35.37	4	F
$2s^2 2p^4-2s^2 2p^3(^4S)3d$	$^3P-^3D$	1-2	35.58	3	F
		0-1	35.70	1	
		2-3	34.33 B	6	F
$2s^2 2p^4-2s^2 2p^3(^2D)3d$	$^3P-^3P$	2-2	34.52	2	F
		2-2	34.24	3	F
	$^3P-^3S$	2-1	34.10	1	
	$^1D-^1F$	2-3	34.80 B	5	
	$^1D-^1D$	2-2	35.07 B	1	
	$^1S-^1P$	0-1	35.96	1	

Table 1. (cont.)

Argon xi (cont.)					
Configuration	Term	$J-J$	Wavelength	Intensity	Ref.
$2s^2 2p^4-2s^2 2p^3(^2P)3d$	$^3P-^3D$	2-3	33.65	3	
		1-2	33.84	2	
		0-1	33.96	1	
	$^1D-^1F$	2-3	34.33	6	
Chlorine xi and argon xii					
Configuration	Term	$J-J$	Wavelength		Intensity
			Cl xi	A xii	
$2s^2 2p^3-2s^2 2p^2(^3P)3s$	$^4S-^4P$	$\frac{3}{2}-\frac{5}{2}$	40.392 E	34.67	6
		$\frac{3}{2}-\frac{3}{2}$		34.80 B	5
		$\frac{3}{2}-\frac{1}{2}$		34.88	4
$2s^2 2p^3-2s^2 2p^2(^3P)3d$	$^4S-^4P$	$\frac{3}{2}-\frac{5}{2}$	36.29	31.39	6
		$\frac{3}{2}-\frac{3}{2}$		31.35	5
		$\frac{3}{2}-\frac{1}{2}$		32.35 T	5
	$^2D-^2F$	$\frac{5}{2}-\frac{7}{2}$	37.05 diffuse	32.55 T	3
	$^2P-^2D$	$\frac{3}{2}-\frac{5}{2}$		31.99 diffuse	4
	$^2D-^2D$	$\frac{5}{2}-\frac{5}{2}$		31.65	7
$2s^2 2p^3-2s^2 2p^2(^1D)3d$	$^2D-^2F$	$\frac{3}{2}-\frac{7}{2}$	36.67	32.74	2
$2s^2 2p^3-2s^2 2p^2 3d$				32.20	1
				32.16	1
				31.55	2
				31.48	2
				25.24	2
				25.19	2
				25.04	2
			$2s^2 2p^3-2s^2 2p 4d$		
Argon xiii					
Configuration	Term	$J-J$	Wavelength	Intensity	
$2s^2 2p^2-2s^2 2p(^2P)3s$	$^3P-^3P$	2-2	31.84	2	
$2s^2 2p-2s^2 2p(^2P)3d$	$^2P-^3D$	2-3	29.37	5	
		1-2	29.32	3	
	$^1D-^1F$	2-3	29.56	5	
	$2s 2p^3-2s 2p^2(^4P)3d$	$^5S-^5P$	2-3	29.20	2
$2s^2 2p^2-2s^2 2p 3d$			30.34	1	
			30.24	1	
			30.21	1	
			29.90	1	
			29.67	1	
Argon xiv					
Configuration	Term	$J-J$	Wavelength	Intensity	
$2s^2 2p-3s^2(^1S)3d$	$^2P-^2D$	$\frac{3}{2}-\frac{5}{2}$	27.63	6	
		$\frac{1}{2}-\frac{3}{2}$	27.47	6	
$2s 2p^2-2s 2p(^1P)3d$	$^2D-^2F$	$\frac{5}{2}-\frac{7}{2}$	27.22	1	
$2s 2p^2-2s 2p(^1P)3d$	$P-D$		27.42	4	
$2s 2p^2-2s 2p(^3P)3d$	$^2D-^2F$	}	28.32 diffuse	3	
$2s 2p^2-2s 2p(^1P)3d$	$^2P-^2D$				
Argon xv					
Configuration	Term	$J-J$	Wavelength		
$2s(^2S)2p-2s(^2S)3d$	$^3P-^3D$	2-3	25.94		

4.1. Spectra below 50 Å

The new chlorine XI and argon x to xv spectra below 50 Å involve the transitions $2p^n-2p^{n-1}3s$ and $2p^n-2p^{n-1}3d$. Their wavelengths are listed in table 1 which also lists earlier identifications for convenience. In the observed spectra the former transitions are strongest in the case of argon x; they are of similar intensity in argon XI, but in the remaining ions the $2p^n-2p^{n-1}3d$ transitions dominate the spectrum and account for the majority of the strong lines in the argon spectrum below 33 Å. Well resolved spectra of these transitions were obtained in the second order. Additional lines are classified in the spectrum of argon x and XI, and lines identified earlier (Fawcett *et al.* 1964b) with a wavelength accuracy of 0.03 Å are now remeasured to 0.01 Å. The forementioned intense $2p^n-2p^{n-1}3d$ emission lines are now classified in argon XII, XIII and XIV. One faint line of argon xv was also observed.

4.2. $\Delta n = 0$ transitions

Only the new identifications of $2s^22p^n-2s2p^{n+1}$ and $2s2p^n-2p^{n+1}$ transitions of argon XI to xv like spectra are tabulated in table 2. These, when added to earlier data

Table 2. Additional wavelengths in Å of emission lines of silicon, phosphorus, sulphur, chlorine and argon due to $2s^n2p^m-2s^{n-1}2p^{m+1}$ transitions

Chlorine x and argon xi						
Configuration	Term	J - J	Si vii	S ix	Cl x	A xi
$2s^22p^4$ - $2s2p^5$	1S - 1P	0-1	246.06 B	202.65 BR	186.06 R	171.86
Silicon viii, sulphur x, chlorine xi and argon xii						
Configuration	Term	J - J	Si viii	S x	Cl xi	A xii
$2s^22p^3$ - $2s2p^4$	2P - 2P	$\frac{3}{2}$ - $\frac{1}{2}$				164.51
		$\frac{1}{2}$ - $\frac{3}{2}$			180.85	
	2P - 2S	$\frac{1}{2}$ - $\frac{1}{2}$	250.45			
$2s2p^4$ - $2p^5$	2D - 2P	$\frac{3}{2}$ - $\frac{1}{2}$	250.79			
		$\frac{5}{2}$ - $\frac{3}{2}$	256.53	212.60	195.69	
		$\frac{3}{2}$ - $\frac{1}{2}$	252.79	207.57	190.03 T	
Silicon ix, phosphorus x and sulphur xi						
Configuration	Term	J - J	Si ix	P x	S xi	
$2s^22p^2$ - $2s2p^3$	3P - 3P	2-2	296.09	269.48	246.90 D	
		1-1	292.78		242.83 D	
		0-1	290.69		239.81 D	
	3P - 3S	0-1	223.73	203.87	186.83 D	
		2-1	227.00	207.67 R	191.26 D	
$2s2p^3$ - $2p^4$	1D - 1P	2-1	227.30	207.35 R	190.35 D	
	1S - 1P	0-1	259.75 R		217.64 R	
	3D - 3P	3-2	261.41	238.53	219.09	
		2-1	258.36 B		214.84	
		1-0	257.27		213.51	
	1P - 1D	1-2	358.29			

Table 2. (cont.)

Chlorine XII and argon XIII							
Configuration	Term	<i>J-J</i>	Cl XII	A XIII			
2s ² 2p ² -2s2p ³	¹ S- ¹ P	0-1	200.96 R	186.38 R			
	¹ D- ¹ P	2-1	175.71 D	162.96 D			
	¹ D- ¹ D	2-2	199.37 D	184.90 D			
	³ P- ³ S	0-1	172.06 D	159.08 D			
		1-1	174.21 D	161.61 D			
		2-1	177.11 D	164.80 D			
	³ P- ³ P	0-1	219.53 D	201.69 D			
		1-2	222.72 D	205.24			
		1-1	223.10	205.77			
		1-0	223.14	205.94			
		2-1	227.83 D	211.00 D			
		2-2	227.47 D	210.46 D			
	³ P- ³ D	0-1	257.43	236.27			
		1-2	262.60	242.22			
		2-3	268.77	248.68			
		2-2	269.21	249.46			
		1-1	262.32	241.90			
		2s2p ³ -2p ⁴	³ D- ³ P	3-2	202.54		
	2-1			197.55			
	1-0			196.33			
³ P- ³ P	2-2		234.64 B				
	0, 1, 2-1		228.29				
	Silicon X, sulphur XII, chlorine XIII and argon XIV						
	Configuration		Term	<i>J-J</i>	Si X	S XII	Cl XIII
2s ² (¹ S)2p-2s2p ²	² P- ² D	$\frac{1}{2}-\frac{3}{2}$	347.39 F	288.27 B	264.78	243.74	
		$\frac{3}{2}-\frac{5}{2}$	356.01 F	299.52	277.17	257.37	
		$\frac{5}{2}-\frac{7}{2}$			277.59	257.98	
	² P- ² P	$\frac{1}{2}-\frac{3}{2}$	253.78	212.10	195.22	180.29	
		$\frac{1}{2}-\frac{1}{2}$	256.38	215.17	198.40	183.41	
		$\frac{3}{2}-\frac{3}{2}$	258.36	218.22	202.10	187.95	
		$\frac{3}{2}-\frac{1}{2}$	261.05	221.42 B	205.47	191.35	
		$\frac{1}{2}-\frac{1}{2}$	271.98	227.51	209.81	194.39	
		$\frac{3}{2}-\frac{1}{2}$	277.23		217.77	203.35	
	² P- ² S	$\frac{3}{2}-\frac{1}{2}$	261.05	221.42 B	205.47	191.35	
		$\frac{1}{2}-\frac{1}{2}$	271.98	227.51	209.81	194.39	
		$\frac{3}{2}-\frac{1}{2}$	277.23		217.77	203.35	
	2s2p ² -2p ³	⁴ P- ⁴ S	$\frac{5}{2}-\frac{3}{2}$	292.15 F	247.20 B	229.15	213.42
			$\frac{3}{2}-\frac{3}{2}$	289.14 F	242.89 B	224.60	208.31
$\frac{1}{2}-\frac{3}{2}$			287.08		221.38	204.64	
² D- ² P		$\frac{5}{2}-\frac{3}{2}$	278.15				
		$\frac{3}{2}-\frac{1}{2}$	278.61				

F = Fawcett *et al.* 1964b

H = Fawcett 1965

D = Deutschman and House 1967

E = Edlen 1936

B = Blend

R = Revised

T = Tentative

Table 3. The $^2P_{1/2}$ $^2P_{3/2}$ interval in the argon XIV isoelectronic sequences in cm^{-1}

Ion	Interval calculated by Edlen 1969	Interval based on new observations	Coronal line interval
Si x	6988.0	6974 ± 50	6988.7 ± 2
P xi	9701.0		
S xii	13135.8	13200 ± 100	13135.3 ± 0.7
Cl xiii	17411.4	17390 ± 50	
Ar xiv	22655.9	22636 ± 30	22657 ± 5

Table 4. Unidentified argon lines between 25 and 47 Å

Wavelength	Intensity	Possible ionization stage
25.60	2	
25.70	1	
26.30	2	
27.79	1	
27.90	1	
30.58	2	xiii
30.68	1	xiii
30.77	1	xiii
30.84	1	xiii
31.18	1	xii xiii
31.48	2	xii xiii
31.56	2	xii xiii
33.03	1	xi xii
33.53	1	xi
36.16	2	x xi
36.31	2	x xi
36.39	2	x xi
36.56	2	x xi
37.10	1	x xi
37.79	3	xi
38.00	3	xi
39.30	2	xi
39.64	3	xi
39.79	3	xi
40.42	1	
40.64	2	
41.08	1	
41.38	3	
43.42	3	
44.19	2	
44.79	3	
45.38	1	
45.49	2	
45.67	3	
46.26	1	
46.39	2	
46.53	3	

(Fawcett 1970), represent an almost complete analysis of the transitions near the ground term with $\Delta n = 0$. The 1S_0 - 1P_1 transitions were incorrectly assigned in both the argon xi and xiii like spectra (Deutschman and House, 1966, 1967). In the latter

case this was due to confusion with the 2P_2 – 2P_2 argon XIV emission lines. The argon XIV like 2P – 2P , 2P – 2S and 2P – 2D multiplets are newly classified in argon, chlorine and sulphur and remeasured with improved wavelength accuracy in silicon. From these tabulated wavelengths the interval between the $^2P_{1/2}$ and $^2P_{3/2}$ ground levels are calculated and listed in table 3 alongside the same intervals predicted by Edlen (1969) and agree within the limits set by measurement accuracy. The same interval derived from the wavelength of the argon XIV solar forbidden line at 4412 Å is $22657 \pm 5 \text{ cm}^{-1}$ and also in agreement hence providing added confirmation of the identification of this coronal line, given by Edlen (1942, 1969), Rohrlich and Pecker (1963) and Jeffries (1969).

The new classifications include additional wavelengths of emission lines due to transitions from doubly excited levels. Taken with earlier data (Fawcett 1970) this enables the location of most of the $n = 2$ doubly excited levels in the period up to chlorine. The reason that these lines were not observed in the argon spectra is because the doubly excited lines are excited more readily at the higher density of the laser produced plasma than in the lower density θ pinch plasma (Gabriel 1970).

Table 4 lists unidentified argon lines and their possible ionization stages. Figures 1 and 2 (plates) show the argon spectrum between 18 and 48 Å in the second order and between 140 and 280 Å in the first order.

5. Theoretical calculations

Hartree–Fock calculations have been applied by Connerade *et al.* (1970) in an attempt to analyse the $n = 2$ to $n = 3$ transitions in Fe XVIII to XXIV observed in solar flare spectra (Neupert *et al.* 1967). The former authors have also applied these calculations to argon X to XVI (private communication). The calculated energy levels are in most cases consistent with this work. As can be seen in their publication on Fe XVIII to XXIV where they attempt to interpret the solar flare spectrum using the computations: many lines are ascribed to the transitions $2p^n$ – $2p^{n-1} 3s, 4s, 5s$ and $2s^2 2p^n$ – $2s 2p^n 3p, 4p, 5p$. This interpretation is inconsistent with the present observations and others in chlorine (Fawcett 1970) which show that these lines are usually weak or not visible on these heavy ion spectra except in the fluorine and oxygen isoelectronic sequences. In our spectra and in the solar flare spectra (Neupert *et al.* 1967, Fawcett 1970), $2s^2 2p^n$ – $2s 2p^{n-1} 3d$ transitions account for most of the recorded emission lines. This point is further substantiated by the work of Feldman and Cohen (1968) who succeeded in producing the iron XVIII to XXIV $2p$ – $3d$ lines in the spectra emitted from a low inductance vacuum spark.

Conclusion

Most of the stronger emission lines due to the configurations investigated are now documented for all elements in the period up to argon including the solar abundant elements, silicon, sulphur and argon.

The analysis of levels near the ground is particularly satisfactory in silicon VII to XII since every allowed emission line is classified. The groundwork is laid for experiments in the period between potassium and iron, throughout which observations are fragmentary. The conditions in the θ pinch plasma have given rise to a spectrum with sharp lines with very small Stark or Doppler broadening and hence provide an opportunity to establish accurate wavelengths in an element well along these isoelectronic sequences. From these, intervals between ground term levels involving

forbidden transitions can be derived for other elements, through extrapolation or with the aid of further observations. A critical examination of the identification of solar forbidden lines in the period between potassium and manganese will then be possible.

The dominance in the spectra of heavy ions of the $2p^n-2p^{n-1}3d$ emission lines and the grouping of their different stages of ionization into separate spectral regions must add to the value of experiments involving the observation of Fe XVIII to Fe XXIV in solar flare spectra.

Acknowledgments

The authors thank Dr G. Tondello for some helpful suggestions, Mr P. Spurrett for operating the θ pinch and Mr R. W. Hayes for taking the spectra of the laser produced plasmas.

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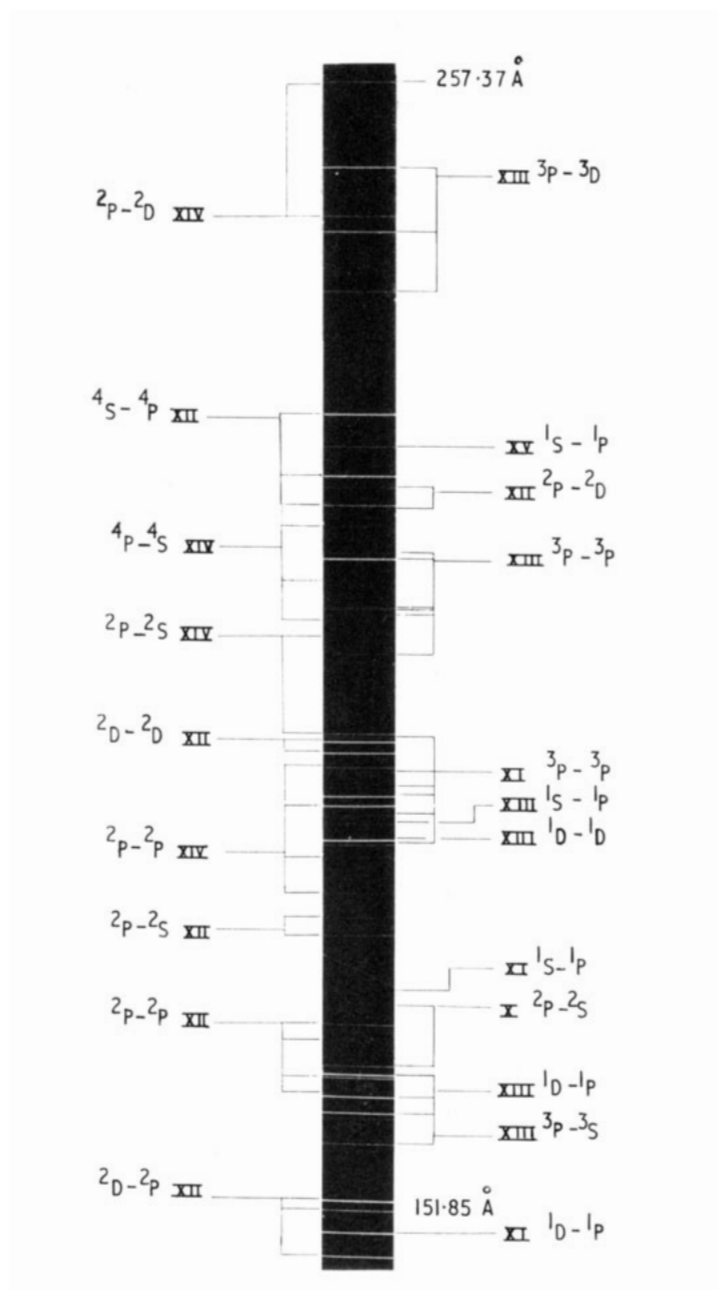


Figure 1. Classification of argon x to xv emission lines.

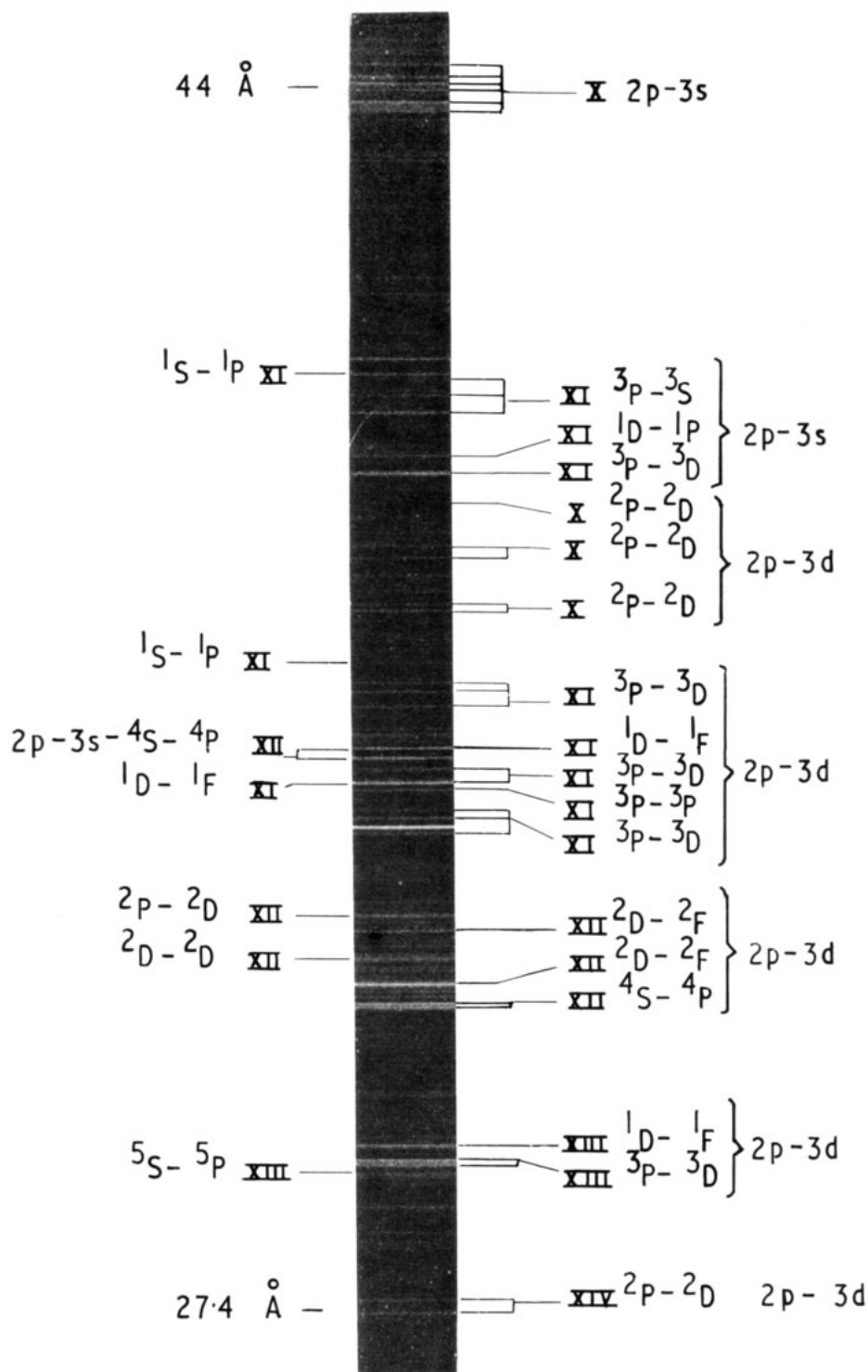


Figure 2. Classification of 2p-3s, 3d argon x to xiv emission lines (second order spectrum).