The Spark and the Vacuum Arc Spectra of Some Metals in the Extreme Ultra-Violet.

By

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1. Introduction.

In connexion with the recent progress in the study of photo-electricity, the investigation of arc and spark spectra in the region of ultra-violet emitted by the vapours of various kinds of metals has become of increasing importance.

Owing to the researches of Schumann, Lyman and others, the limit of the spectrum in the extreme ultra-violet has been considerably extended, the excellent literature of these investigations is given by Lyman[1].

The present experiment deals only with the region which can be examined by a quartz spectrograph, the lower limit of wave-length being at about 1839 Å.U., but as most of the wave-length tables given in Kayser's Spectroscopie end at about λ 2100 Å.U., and further, as the rècent investigations on the spectra in the extreme ultra-violet are not so numerous, we may state that even in this easily accessible region between λ 2200 and λ 1830, our knowledge of the arc and spark spectra of various metals are far from being complete.

Below we give very brief resumè of the results obtained by a few recent observers.

The results obtained by Lyman for the elements *Al, Ca, Sr, Ba.* and *Mg* are given in the appendix of his monograph above cited, they are mostly confined to the spark spectra of these elements.

In 1909, Handke[2] published the results of his experiments obtained by using a vacuum prism spectrograph of the Schumann type. The elements investigated were *Ag, Al, Au, Cu, Hg, Mg, Sn, Zn.* A

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[1] The Spectroscopy of the Extreme Ultra-Violet, 1914.

[2] Diss. Berlin, 1909.

similar instrument was employed by Wolff[1] who investigated the vacuum arc spectra of *Zn*, *Cd* and *Hg*.

In 1914, L. and E. Bloch[2] published the preliminary report of their investigations on the extreme ultra-violet lines in the spectra of some kinds of metals. In this experiment, they employed a quartz spectrograph having a large Cornu prism. The spectrograph was specially modified for photographing the extreme ultra-violet region, the lower limit of wave-length being at about 1850 Å.U. It is stated in their paper that by employing a vacuum spectrograph, they obtained the photograph extending down to 1400 Å.U.

In all the papers above cited, excepting that of Wolff, the spark spectrum only is investigated. Quite recently Saunders[3] has published his investigations on both the spark and the vacuum arc spectra of several metals in the extreme ultra-violet. Although the arc spectra present a very few lines in the extreme ultra-violet, they are of interest in connexion with series relations.

Previous to these investigations, Eder[4] examined the spark spectra of a greater number of elements in the ultra-viotet region, but excepting the case of aluminium, the region investigated extended only down to 2100 Å.U.

For some kind of metals, further data are to be found in Eder and Valenta's[5] "Atlas Typischer Spectren." Excellent photographs of various spectra in the extreme ultra-violet are reproduced in Tables LII and LIII. But it is to be remarked that in every photograph the intensity begins to fall off very rapidly in the region near λ 1900 Å.U.

With a view to extending the aforesaid investigations and also comparing the spark spectra with those of the vacuum arc for some elements in the region above cited, the present investigation was undertaken.

2. Arrangements.

Two quartz spectrographs made by Hilger, each furnished with a Cornu prism having faces of 65 × 41 mm. (length of three equal sides × height) and of 21 × 13 mm. respectively were at our disposal. The larger one gives a dispersion of 5 Å.U. per mm. at λ 2100 Å.U.,

1 Ann. d. Phys., **42**, 836 (1912).
2 Jour. de Phys., **4**, 622 (1914). C. R. **158**, 784, 1416 (1914).
3 Astrophys. Jour., **43**, 234 (1916).
4 Ber. d. k. Akad. d. Wiss., Wien **122**, 607 (1913).
5 Atlas Typischer Spectren, 1911.

while the smaller one a dispersion about 15 Å.U. per mm. at λ 2100 and 7 Å.U. per mm. at λ 1900 Å.U.

Without a special modification it was impossible for us to photograph the region below λ 2100 Å.U. with the larger instrument, while with the smaller one, the spectra down to λ 1830 Å.U. appeared with considerable intensity.

For the production of spark, we have employed the sparking apparatus of Hilger, consisting of a ¼ K.W. rotary converter and a transformer raising the potential up to about 10000 volts, a condenser being inserted in parallel with the spark.

As the electrodes, we used in most cases metal rods of 2 or 3 mm. diameter, the spark gap being 3 or 4 mm.

For the purpose of obtaining the vacuum arc spectra, we employed the lamp using a Wehnelt cathode as originally designed by Janicki[1] and afterwards modified by Wali-Mohammad[2].

In order to obtain the photographs of spectra extending to the extreme ultra-violet part, some further modifications were necessary. The lamp is shown in Fig. 1.

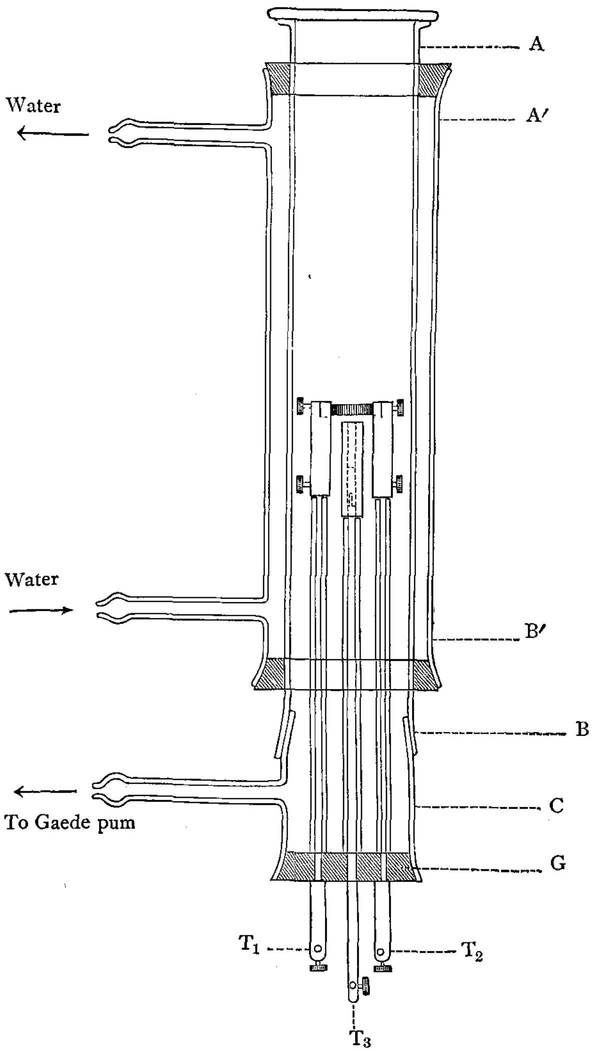
The glass tube *AB* is about 20 cm. long and has a diam, of 35 mm. The upper end of the tube has a rim of 3 mm., to which a quartz circular disc of diam. 4 cm. and thickness 2 mm. is attached and sealed air-tight with sealing wax.

The lower end *B* is protruded, and comes in contact with the conical ending of *C*, both surfaces being well ground to fit each other. The lower tube is about 5 cm. long. The outer side of the tube *AB* is covered by another glass tube *A'B'* with a gap of 1 mm. between them, the outer diameter of *A'B'* being 40 mm. The upper and lower ends of the gap between *AB* and *A'B'* were stopped by rubber tubes, and the inner tube *AB* was cooled by the water current.

1 Ann. d. Phys., **29**, 833 (1909).

2 Diss. Göttingen, (1912).

Fig. 1.

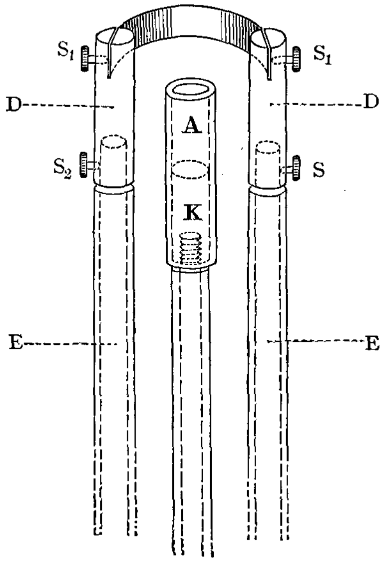


The central portion of Fig. 1, showing the anode and the cathode, is given enlarged in Fig. 2.

The cathode consists of a platinum foil 0·02 mm. thick, 30 mm. long and 5 mm. broad.

By cutting the tops of the two brass rods *D* (of 3 mm. diam.), narrow slits were made and both ends of the platinum strip were inserted in them, the strip being slightly curved around the anode A.

Fig. 2.



The small screws S are to secure good contact of the platinum foil with D. With the screw S, D was fixed to the brass rod B of 2 mm. diameter, leading to the terminals T_1 and T_2 on the ebonite stop G as shown in Fig. 1. The rod E was covered by a glass tube for the purpose of insulation.

To make the Wehnelt cathode, a mixture of barium nitrate and calcium nitrate was dissolved in water and a small quantity of the deposit was put on the platinum foil and heated with a Bunsen burner. The nitrates are then reduced and the strip become covered with a layer of oxide. When lighting the lamp, the cathode was heated to incandescence by a current of 13 to 17 amp. at 40 volts.

As the anode, the metal to be examined was put in a small tube of fused silica A in Fig. 2, either in solid or in powdered state. The dimensions of the tube varied according to the kind of the metal, but in most cases, the external diameter was about 5 mm. and the internal diameter 4 mm. the length of the tube being 2 or 4 cm. The bottom of this silica tube was stopped by the brass rod K which was wrapped in a thin asbestos sheet to fit tightly into the silica tube, the lower end of K was screwed into the terminal T_3 in Fig. 1.

Between the terminals T_1 (or T_2) and T_3, a potential difference of 220 volts was applied with a suitable resistance in series. The process of lighting the lamp may be briefly described as follows. After evacuating the tube for several minutes with a rotary oil pump, the Gaede mercury pump is started and the water current is passed. Then the Wehnelt cathode is made incandescent by the heating current and finally the switch for the main current is closed. The strength of the main current varied from 0·1 to 2·5 amp. at 220 volts. The state of evacuation was sometimes tested by a discharge in a Geissler tube connected to a side tube.

In the previous investigation carried out by one of the authors[1], the light from the anode was totally reflected by a right-angled prism placed at the top, but in the present experiment it was not desirable to let the ray pass through a large quartz prism owing to its absorption, so that the small spectrograph was placed with its collimator vertical and the lamp was brought with its upper end just below the slit of the collimator.

By cutting suitable windows in the slide put before the slit of the collimator, the spark spectrum of iron, or sometimes that of silver, was photographed in the middle part of each spectrum as shown in the reproduction Figs. 8, 9 in Pl. II.

It was so arranged that after photographing the vacuum arc spectrum of a certain element, the lamp was removed and the iron electrodes of the spark was brought in its place. By interchanging the window in the slide before the slit we were able to photograph the comparison spectrum of iron without touching the photographic plate.

The measurements were carried out by means of a photo-measuring instrument of 15 cm. travel reading to 1 μ, constructed by Hilger. As the spectra of the elements under investigation appeared on the photograph closely in contact with the standard spectrum of iron, we were able to measure both spectra without touching the photographic plate.

As it was of primary importance to use pure materials for the electrodes, great care was taken to avoid impurities. But on account of the war, there was much difficulty in obtaining the pure metals. Of the metals we have investigated *Al, Bi, Cd, Co, Sb* were those prepared by "Kahlbaum", and the others were of "Merck", and were of the guaranteed purity. We are obliged to Professor Chikashige of the Chemical Institute for the loan of several samples of pure metals for which we express our deepest thanks.

The Schumann plates prepared by Hilger were used in photographing the spectra.

3. Results of the Experiment.

The spark spectra of the following elements were investigated: *Ag, Al, Au, Bi, Cd, Co, Fe, Mn, Ni, Pt, Sb,* and *Tl.*

[1] Takamine, Proc. Tokyo Math.-Phys. Soc., **8**, 31, (1915).

By using the lamp described in the preceding section as the source of light, we have tried to examine also the vacuum arc spectra of the above elements. But we did not succeed in obtaining a sufficiently strong source for some elements such as *Fe* or *Pt*; further, some elements showed no intense line in the region of extreme ultra-violet, so that we describe below the vacuum arc spectra of only three elements *Bi*, *Sb* and *Tl*.

For the measurement of wave-lengths, we have taken the values given by Bloch for the following five lines in the spark spectrum of silver as standards, and interpolated the other lines. The values given by Bloch are expressed in the international Ångström unit, and not reduced to vacuum.

Standard silver lines:

Intensity	λ
5	1993·65
5	1956·88
5	1916·28
4	1879·60
2	1855·61

Owing to the small dispersion of the instrument, the accuracy of our measurement was only to the first decimal of an Ångström unit. In the region under investigation, one division of the drum of the photo-measuring microscope corresponded approximately to 0·1 Å.U. but as in the case of measuring thick or diffuse lines the error of pointing may sometimes amount to 2 or 3 divisions, thus incurring an error of 0·2 or 0·3 Å.U. in unfavourable cases.

We have taken about 90 plates in all, on each of which more than 10 different exposures could be given by displacing the plate. The time of exposure was several minutes in most cases for the spark spectra, and 10 to 20 minutes for those of the vacuum arc.

After each measurement, the lines were carefully examined to eliminate the air lines and also those lines which could be identified as due to impurities. In the case of the vacuum arc spectra, zinc lines sometimes appeared on the photograph, especially when the platinum foil burned out during the exposure. But there was no great difficulty in identifying these lines.

The results of the measurement are given below separately for each element, and the values obtained by Bloch, Handke and others are also given for comparison. It is to be remarked that the results of Handke, and also of Saunders, which were expressed in wave-length reduced to vacuum, are changed to those in air for the sake of comparison.

(1) *Ag*

As stated in the paper of Bloch, the spark spectrum of silver shows many lines in the extreme ultra-violet which are evenly distributed, so that the spectrum may conveniently be chosen as the wave-length standard.

In the region between λ 2000–1855 Å.U., our results agree quite well with those of Bloch, excepting the following faint lines which appeared on all of our photograms:

Spark spectrum of *Ag* (No. 1).

Intensity	λ	
1	1989·6	
1	88·5	
2	30·6	
4	1862·7	(Handke 1862·3 [Int. 5])

The figures given by Handke show some discrepancies as already noted by Bloch.

Below λ 1855 Å.U., we have found the following lines:

Spark spectrum of *Ag* (No. 2).

Takamine and Nitta		Handke		T and N		Handke	
Int.	λ	Int.	λ	Int.	λ	Int.	λ
1	1852·9	5	1852·8		—	3	1835·0
1	48·7	5	48·8	2	1832·6	3	33·4
	—	5	46·1	1	30·6	4	31·2
3	38·6	5	38·9		—	5	28·0
2	37·0	4	37·5	3	26·3	4	26·5

(2) *Al*

It is well known that the spark lines of this element are convenient for the orientation of lines in the region of the extreme ultra-violet. Our results are slightly different from those of the former investigators.

Instead of the single line at λ 1862, we obtained a double line; and a faint new line was observed at 1855 as shown in the following table:

Spark spectrum of *Al*.

Int.	λ
8	1989·8
7	35·2
2	30·3
4	1862·1
1	61·5
3	57·4
1	55·3
6	54·0

(3) *Au*

The only investigation hitherto published extending below λ 2000 is that of Handke, who measured the wave-lengths of spark lines in a wider range than ours. As in the case of silver, there are many discrepancies.

Spark spectrum of *Au.*

T and N		Handke	
Int.	λ	Int.	λ
8	2000·2		
2	1996·0		
8	91·8		
4	89·2		
1	84·5		
8	77·5		
2	72·7	2	1972·7
	—	2	58·2
1	57·5	2	57·5
	—	2	56·0
1	55·7	3	55·6
1	54·5		—
3	51·8	4	51·8
1	48·0	3	48·3
	—	3	47·5
1	46.0		—
1	44·1	3	44·0
	—	2	42·9
1	38·8	1	39·0
2	37·5	3	38·0
2	35·0	3	35·4
1	34·0	2	34·5
2	31·5	3	31·8
1	30·6		—
1	29·1	2	29·3
	—	1	27·0
	—	1	26·0
	24·5	7	25·4
6	20·7	7	21·8
6	18·8	6	19·4

T and N		Handke	
Int.	λ	Int.	λ
	—	2	1918·0
	—	1	10·9
	—	3	09·4
	—	1	07·6
3	1904·1	5	05·0
	—		00·3
	—	2	1899·4
4	1890·2	6	90·5
4	86·0	6	87·0
1	84·6		—
1	80·3	2	80·8
4	79·2	4	79·7
	—	1	74·5
2	71·3	6	72·0
	—	2	65·6
4	61·8	5	62·1
	—	4	59·6
2	58·4	3	58·5
1	57·0	4	56·7
	—	4	52·7
1	52·0	4	52·0
1	50·9	4	50·4
2	49·6	3	49·2
	—	1	46·7
	—	4	45·3
1	44·0		—
		1	41·5

The region below λ 1925 Å.U., with the comparison spectrum of *Ag* spark, is reproduced in Fig. 3, Pl. I.

(4) *Bi*

In the region between λ 2061·7 and 1902·6, Eder and Valenta[1] gave seven lines, to which Bloch added two new lines. Besides the lines obtained by them, we found two more lines. It may be remarked that the line λ 1902·4 appeared with considerable intensity in our photograph, a few seconds exposure being sufficient to photograph the line.

Spark spectrum of *Bi.*

T and N		Eder and Valenta		Bloch	
Int.	λ	Int.	λ	Int.	λ
1	1990·2		—		—
4	88·9	1	1988·6		—
2	73·3		—	3	1973·15
2	59·7		—	3	59·63
5	53·9	1	54·5		—
2	10·2		—		—
10	02·6	1	02·6		—

The extreme ultra-violet part of the vacuum arc spectra of bismuth has not hitherto been investigated. We have found three lines below λ 2000, which appear also in the spark spectrum.

Vacuum arc spectrum of *Bi.*

Int.	λ
2	1959·7
2	53·9
3	02·6

A reproduction of the vacuum spectra of *Bi* with the comparison spectrum of *Fe* spark is shown in Fig. 8, Pl. II.

(5) *Cd*

The former observations on the spark spectrum of this element are

1 Atlas Typischer Spectren, 148 (1911).

those of Eder and Valenta, Bloch, Saunders, and McLennan and Edwards[1]. The last mentioned authors have employed a spectrograph consisting of a train of fluorite prisms. In the following table, our measurements are compared with those of earlier investigators.

Spark spectrum of *Cd.*

T and N		Bloch		McLennan & Edwards	
Int.	λ	Int.	λ	Int.	λ
6	1994·8	3	1994·78	3	1995·1
1	89·1		—	1	89·2
	—		—	1	79·8
3	77·4	2	76·85	2	77·1
1	75·0		—		—
	—		—	1	70·4
{3	65·8	1	65.44	4	65·4
{1	65·3		—		—
1	62·4		—		—
1	61·6		—		—
1	56·7	1	56·81		—
	—		—	1	45·6
2	44·1	1	43·85		—
2	42·5	1	42·61	6	42·9
4	39·2	2	38·91	4	39·2
3	30·4		—		—
3	21·4	2	21·55	4	21·9

T and N		Bloch		M and E	
Int.	λ	Int.	λ	Int.	λ
2	1919.6	1	1919·30	3	1919·6
1	14·4	1	14·50		—
2	00·6	2	00·70	6	01·1
	—	1	1898·28	2	1899·2
1	1896·7	1	96·64		—
	—	1	87·78		—
2	84·2	1	84·08	2	83·1
	—		—	1	77·8
6	73·2	4	73·37	6	73·8
1	67·7	1	67·73		—
1	65·3	1	65·34		—
4	55·8	3	56·10	6	56·4
4	55·2	2	55·32	6	55·3
3	50·7		—	7	50·6
2	43·7		—	7	44·1

(6) *Co*

For the spark spectrum of this element in the extreme ultra-violet we have only the data given by Bloch in the region λ 2174–1873 Å.U. We have not measured the part above 2000, but as shown in the following table, we have found many lines below 1930 Å.U.

1 Trans. Roy, Soc. Canada, **9**, 167 (1915).

Spark spectrum of *Co.*

T and N		Bloch	
Int.	λ	Int.	λ
4	1999·0		—
2	99·3		—
2	96·2	1	1996·44
2	94·7	1	94·67
2	93·3	1	92·52
2	90·8		—
5	89·0	3	88·85
3	86·5	1	86·38
2	84·3	1	84·16
2	83·2	1	83·24
2	80·3	1	80·62
4	79·1	1	79·32
2	78·0	1	78·18
3	76·3	3	76·25
5	74·2	3	74·13
2	72·0		—
3	71·1	1	71·09
5	69·6	4	69·25
2	68·3	2	68·15
4	62·8	2	62·84
3	60·6	1	60·61
2	58·6	5	58·58
6	56·7	5	56·58
5	55·3	3	55·04
4	54·3	4	53·99
3	53·4	1	53·06
2	52.4	1	52·30
2	51·3	1	51·31
1	50·5		—
6	49·8	3	50·09
1	49·4	4	48·31
1	48·5		—
1	46·2	2	46·00
1	44·8	1	44·43
2	43·7	1	43·46

T and N		Bloch	
Int.	λ	Int.	λ
1	1942·0		—
2	41·6	2	1941·64
8	40·2	6	40·52
2	39·4	3	39·41
1	37·0		—
4	36·6	1	36·85
1	36·2	2	36·26
1	35·5		—
2	34·5	2	34·21
2	34·0		—
2	33·8		—
1	33·0	1	32·41
1	30·3	1	30·20
1	29·7		—
2	29·0	2	29·06
6	28·0	4	27·86
2	27·1	1	26·97
1	25·5		—
2	24.9		—
1	24·0		—
1	23·5		—
1	22·6	1	22·62
1	22·0		—
1	20·2		—
3	18·3	3	18.44
3	16·8	2	16·98
1	15·7		—
1	14·5		—
1	13·5		—
1	12·5		—
1	11·5		—
3	10·1	1	10·16
1	09·2		—
3	08.3		—
1	07·7	1	07·85

T and N		Bloch	
Int.	λ	Int.	λ
1	1907·5		—
1	06·0		—
1	05·1		—
1	03·0		—
1	01·0	1	1900·83
1	00·1		—
1	1899·6		—
1	96·1		—
3	95·2	1	1895·47
1	93·7		—
2	91·4		—
1	90·1		—
1	89·7		—
2	88·2		—
1	87·7		—
1	86·3		—
1	84·9		—
1	84·0		—
1	82·4		—
3	81·2	1	81·52
1	80·7		—
1	80·0		—
2	78·5		—
2	76·6		—
1	74·5		—
2	74·3		—
1	73·7		—
	—	1	72·94
1	72·0		—
4	71·2		—
1	67·9		—
3	66·6		—
2	63·0		—
2	62·4		—
2	62·1		—

T and N	
Int.	λ
3	1861·5
2	59·9
2	54·2
1	53·7
2	53·4
3	52·0
1	50·8
1	49·0
1	47·0
1	46·3
4	45·1
1	44·0
1	43·5
2	42·5
1	39·0
3	38·4
1	36·3
1	34·7
1	34·0
1	28·0

Fig. 4, Pl. I. is the reproduction of *Co* spectrum with *Ag* comparison. It may be noted that this portion is not clearly shown in the publication of Bloch.

(7) *Fe*

As in the visible and ordinary ultra-violet part, so also in the extreme ultra-violet the spark spectrum of iron is very rich in lines and hence suited for comparison of wave-length.

In the region between λ 2000 and 1915 Å.U., our results agree quite well with those of Bloch. The slight differences being that, (i) the line 1943·64 (intensity 1) recorded by Bloch did not appear in our photograph; (ii) instead of the close doublet 1939·37 (intensity 2) and 1939·13 (intensity 4), we obtained 1939·3 (2) and 1938·3 (3).

Beyond the line λ 1875, which is the most refrangible line in the measurement of Bloch, we have found some more lines.

In the following table, we give the results of our measuremen for the region below λ 1915:

Spark spectrum of *Fe*.

T and N Int.	T and N λ	Bloch Int.	Bloch λ
4	1914·3	5	1914·43
6	13·3	6	13·40
1	12·3		—
1	11·0	1	10·75
1	10·0	1	10·00
1	09·0		—
2	06·8	3	06·97
1	06·0	1	06·06
1	04·2	1	04·22
1	03·5		—
1	03·0	3	02·98
1	02·0	1	01·30
2	00·8	2	00·44
1	1899·5		—
1	98·3	1	1897·96
1	97·3		—
2	96·2	1	96·18
6	94·9	6	94·90
2	93·8	2	93·44
2	92·5		

T and N Int.	T and N λ	Bloch Int.	Bloch λ
3	1891·6	2	1891·53
2	91·0		—
3	90·2	4	90·07
2	88·3	2	88·15
3	87·4		—
3	86·9	2	86·55
2	85·8		—
3	84·8		—
3	82·0	1	81·54
2	81·1		—
2	80·7	1	80·39
1	80·0		—
3	77·4	1	77·41
3	76·9	1	76·86
1	76·1		—
1	71·8		—
2	70·7		—
3	69·5		—
1	66·5		—
1	65·8		—

T and N Int.	T and N λ
2	1864·6
2	62·5
1	62·0
1	61·3
3	59·4
1	58·0
1	57·1
1	56·0
2	54·0
1	51·7
1	50·0
1	48·7
1	47·5
2	43·7
1	42·5
2	41·0
1	39·9

The most refrangible part of the above spectrum is reproduced in Fig. 5, Pl. I.

Comparing the results obtained for the iron spectrum with that of the manganese spectrum, we see that the two lines λ 1958·59 and 1914·43, which were suspected by Bloch as due to *Mn*, are really due to iron.

(8) *Mn*

We could not find any former observations for this element below λ 2100 Å.U. We have found the following lines in the spark spectrum below λ 2000 Å.U., but all of them are of feeble intensity.

Spark spectrum of *Mn*.

Int.	λ	Int.	λ	Int.	λ
4	1993·7	2	1951·0	1	1897·1
5	92·8	2	47·9	2	93·2
2	90·9	3	44·2	2	92·0
2	90·0	4	42·6	1	77·3
4	89·2	3	40·9	1	76·0
2	86·4	2	38·8	1	75·3
4	85·4	2	36·0	1	72·2
1	85·0	2	34·5	1	67·5
2	82·5	2	33·0	1	65·3
2	78·7	2	30·8	1	64·0
2	75·4	3	25·8	4	62·2
1	71·0	2	24·7	1	61·2
3	69·8	3	22·3	1	60·2
2	69·0	4	20·2	1	57·5
2	63·7	2	18·7	4	54·2
2	62·8	2	18·0	1	53·0
2	61·6	1	17·0	1	52·5
4	58·2	6	14·8	1	51.1
2	55·7	3	11.1	1	50·1
2	54·2	2	08·5	1	44·6
3	53·1	1	1899·2	1	43·3
3	52·2	1	98·5	1	42·5

(9) *Pt*

For this element also, we were unable to obtain the data of any former observers in the region below λ 2000 Å.U. Our results are tabulated below :

Spark spectrum of *Pt.*

Int.	λ	Int.	λ	Int.	λ	Int.	λ
2	1999·2	3	1958·3	3	1925·5	3	1878·6
2	96·9	4	54·6	1	19·7	1	72·5
3	95·2	2	52·7	2	18·1	1	71·5
1	91·7	2	51·4	2	17·5	1	71·0
1	91·0	4	49·5	1	14·5	2	70·6
5	89·8	2	48·3	1	13·5	1	69·7
1	88·7	2	46·2	2	12·1	5	66·5
5	87·5	5	43·8	5	11·2	1	65·4
1	84·2	3	41·3	2	08·7	1	62·3
5	83·2	6	39·2	3	03·9	1	60·2
4	79·3	4	37·1	1	03·2	1	56·8
2	78·5	2	34·0	2	01·6	1	55·5
1	76·5	2	33·7	1	1898·7	1	51·7
4	71·5	2	33·0	1	98·0	1	45·5
1	70·0	1	31·8	2	97·0	1	44·6
2	69·5	1	31·5	4	95·8	1	42·0
3	68·9	2	30·3	3	94·6	1	39·5
2	65·3	4	29·3	3	93·9	1	37·6
1	63·0	4	28·5	1	91·0		
1	62.0	4	27·7	6	89·2		
1	61·3	1	26·3	3	82·4		

Reproductions are shown in Figs. 6, 7, Pl. I.

(10) - *Sb*

The ultra-violet part of the spark spectrum of this element was examined by Schippers and the arc spectrum by Kayser and Runge; the shortest wave-lengths measured in both cases being above 2000 Å.U. Schumann has photographed the more refrangible part but he did not measure the wave-lengths. L. and E. Bloch were the first to measure the lines from λ 2068 to 1871 Å.U. We have added several more lines as shown in the following table.

So far as we are aware, the vacuum arc spectrum of *Sb* in this region was investigated for the first time. It is remarkable that the vacuum arc of this element, which is of very feeble intensity in visible light, produces a number of fairly strong lines in the ultra-violet part extending down to 1850 Å.U.

Spark spectrum of *Sb* Vacuum arc spectrum of *Sb*.

T and N		Bloch		T and N	
Int.	λ	Int.	λ	Int.	λ
5	1989·3		—	5	1989·3
5	85·0	3	1985·36	5	85·0
4	77·7	3	77·64	3	77·7
3	71·9		—	2	71·9
3	70·9		—	3	70·9
2	56·0		—	1	56·0
6	49·8	5	49·64	6	49·8
2	45·7		—		—
2	37·0		—	2	37·0
5	31·1	4	30·83	4	31·1
5	26·6	4	26·61	4	26·6
5	22·6		22·68		—
2	1899·7		—	2	1899·7
2	98·9		—		—
3	91·3		—	1	91·3
3	90·3		—	1	90·3
2	82·6		—		—
2	81·8		—		—
4	78·1	2	1877·91		—
1	75·8		—		—

Spark spectrum of *Sb*. (Continued).

T and N		Bloch	
Int.	λ	Int.	λ
1	74·5		—
6	70·4	1	70·58
3	67·3		—
1	63·3		—
2	61·4		—
3	58·0		—

Vacuum arc spectrum of *Sb*. (Continued).

T and N	
Int.	λ
1	74·5
2	70·4
1	67·3
1	63·3
1	61·4
1	58·0

The vacuum arc spectrum of *Sb*, with *Fe* spark as comparison, is reproduced in Fig. 9, Pl. II.

(11) *Tl*

Both the spark and vacuum arc spectra of this element have been investigated by Saunders[1], the most refrangible line recorded by him being 1812 Å.U. We have found several new lines in the spark spectrum in the region λ 2000–1860 Å.U.

In the vacuum arc spectrum we have found two lines which appear also in the spark spectrum. The element is very convenient for a lamp using a Wehnelt cathode, since the vaporisation of the anode material is exceedingly small.

1 Astrophys. Jour. **43**, 234, (1916).

Spark spectrum of *Tl*.

T and N		Saunders	
Int.	λ	Int.	λ
2	1994·6		—
1	89·8		—
3	89·0		—
3	71·8		—
4	37·1		—
2	30·4		—
8	08·2	5	1908·05
6	1892·3	3	1892·08
4	90·2		—
4	80·7	2	80·57
2	71·2	1	70·85
2	60·0		—
		1	37·34
		2	27·38
		4	14·11

Vacuum arc spectrum of *Tl*.

T and N		Saunders	
Int.	λ	Int.	λ
3	1971·8		—
2	08·2	10	1908·05
	—	1	1892·08
	—	1	14·11

Summary.

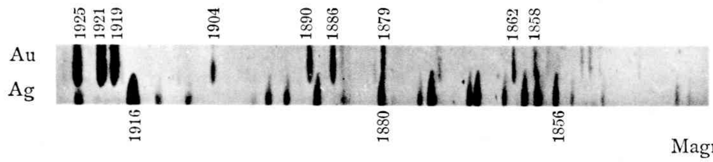
1. The spark spectra of *Ag, Al, Au, Bi, Cd, Co, Fe, Mn, Pt, Sb* and *Tl*, in the extreme ultra-violet were investigated by means of a quartz spectograph using Schumann plates. Relying on the data given by L. and E. Bloch for *Ag* and *Fe* spark, the wave-lengths of the spectrum lines were measured for the above elements in the region λ 2000–1830 Å.U.

A number of new lines were found for each element, especially in the most refrangible part. The spark spectra of *Mn* and *Pt* in this region were investigated for the first time.

2. Employing a vacuum arc lamp provided with a Wehnelt cathode, the vacuum arc spectra of *Bi, Sb* and *Tl* were photographed with the same apparatus and several new lines were found for each element in the region λ 2000–1850 Å.U.

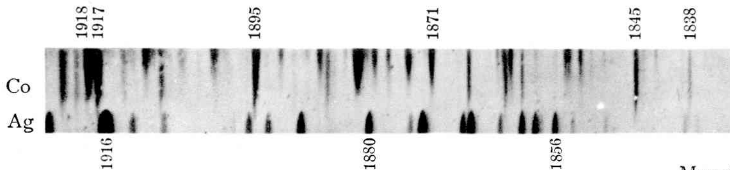
Plate I

Fig. 3



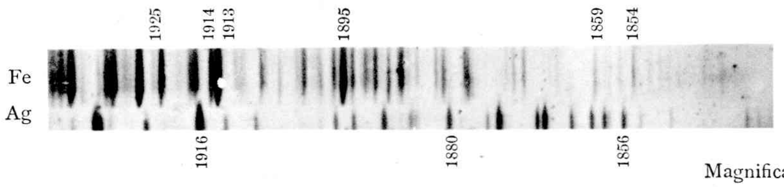
Magnification : 10

Fig. 4



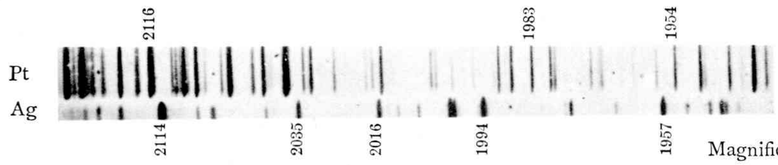
Magnification : 10

Fig. 5



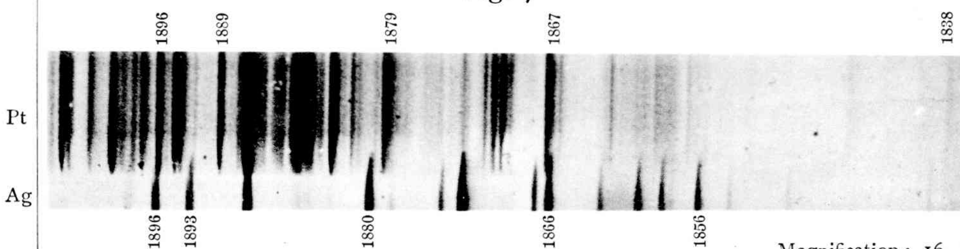
Magnification : 12

Fig. 6



Magnification : 7

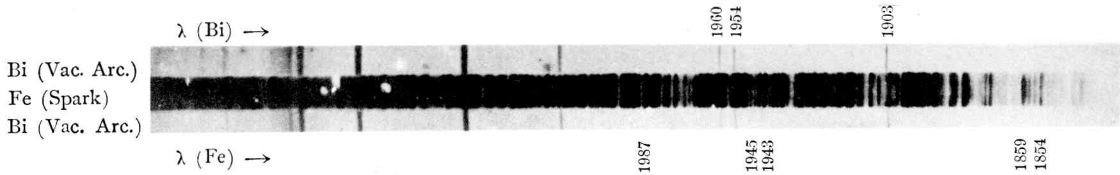
Fig. 7



Magnification : 16

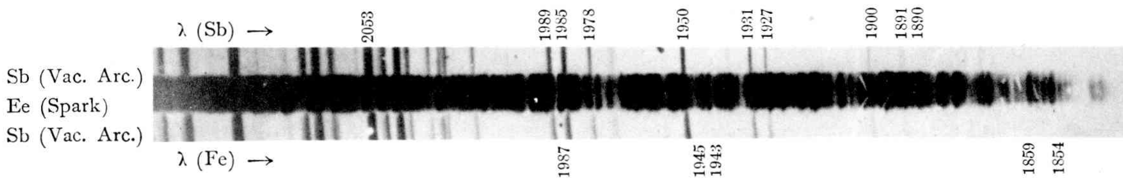
Plate II.

Fig. 8



Magnification : 7

Fig. 9



Magnification : 9