Lengths of Enhanced Lines of Metals excited in Various Media and Lines of Constant Wave Number Differences among Enhanced Lines of Bismuth and Lead.

By

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ABSTRACT.

Lengths of enhanced lines of metals excited in various media: In the present experiment the spark spectra of Cu, Zn, Al, Pb, Bi, Cr, Mn and Ni produced in atmospheres of hydrogen, water-vapor, nitrogen, oxygen and halogen were photographed, and the appearance of the enhanced lines excited in these media was examined. It was found that the spark and super spark lines produced in the above mentioned media the lines obtained by the spark in hydrogen were longest, and when that medium was replaced by water-vapor, nitrogen, oxygen and halogen respectively, their lengths were shortened in that order.

Lines having oonstant wave number differences : Lines having constant wave number differences were found among enhanced lines of lead and bismuth.

Spark lines of elments have already been classified by many investigators. Kimura and Nakamura[1] recently introduced a very convenient and simple method of classifying such lines. Their method is simply to compare the lengths of lines in the spectrum of condensed discharge. The results thus obtained in the cases of silicon and of aluminium are in harmony with those obtained by Paschen and Fowler. In the experiment of Kimura and Nakamura, the condensed discharge was sent between metal electrodes placed in air. In the present experiment, however, the sparks were produced in various media namely, hydrogen, water-vapor, nitrogen,

1 Jap. J. phys., **3**, 197 (1924).

oxygen, chlorine. etc., and the change thus called forth in the appearance of enhanced lines was examined. As the electrodes, the following metals were used: Cu, Zn, Al, Pb, Bi, Cr, Mn and Ni.

Apparatus.

In the present experiment two discharged lamps were used, of the form shown in Figs. 1 and 2. The lamp shown in Fig. 1 was made of a glass tube having an internal diameter of about 3 cm., and a length of 15 cm. Both ends of the tube were closed with rubber-plugs containing electrodes placed in glass tubes. The upper plug had another glass tube B. The space surrounding the metal electrode in the glass tube was packed with Indian rubber. The length of the spark gap G was fixed at 6 mm. The lamp has 2 side tubes S and W, the internal diameter of the latter tube, which has a quartz window at W, being 2.2 cm. and its length 4 cm.. The lamp shown in Fig. 2 was made of

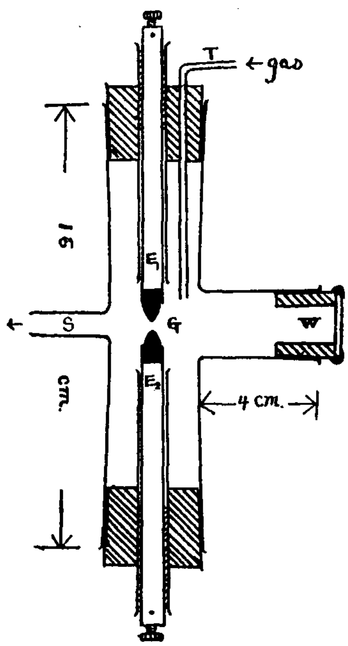


Fig. 1.

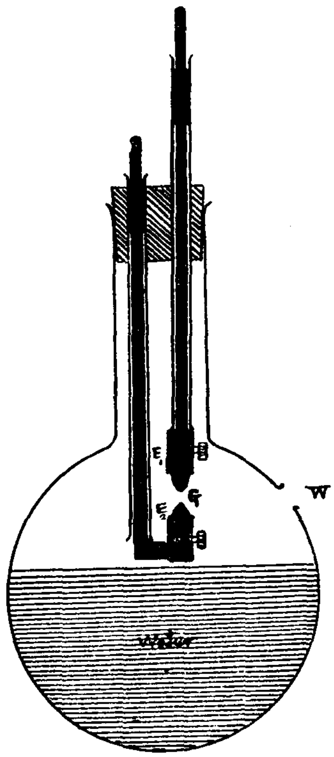


Fig. 2.

a one litre flask having an opening at W. The electrodes were placed in the flask through the rubber-plug, the ends of the electrodes being cut down into the form of truncated cones. A pair of these lamps were placed facing each other as shown in Fig. 3, (b), the distance between S_1 and S_2 being about 30 cm. These two sparks were connected in series with a variable self-induction L, auxiliary spark gap G and a variable condenser C, the latter being charged by a transformer of 1 K. W. capacity giving 30000 V. in the secondary. The capacity of the condenser was varied from about 0·001 to 0·005 microfarads, and the discharge current did not exceed 0·3 amperes.

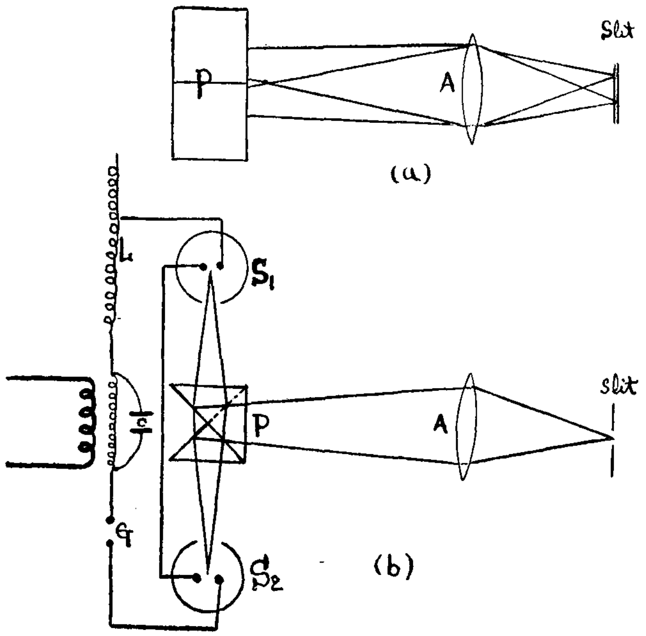


Fig. 3.

A Hilger quartz spectrograph of size E_6 and a Fuess quartz instrument of size B and a prism spectrograph with a large direct vision prism provided with a camera having a photographic lens of 60 cm. focus were used to photograph these spectra.

In the case of the discharge in the media of hydrogen, nitrogen, oxygen and chlorine, two lamps of the form 1 were used, the gas being introduced into one of the lamps through the tube B. Hydrogen was prepared by the action of dilute sulphuric acid on zinc chlorine by the action of hydochloric acid on manganese dioxide, and nitrogen by heating a mixture of ammonium nitrite and sodium sulphite. Oxygen was obtained from a cylinder containing the compressed gas. In the case of the discharge in watervapor, sparks were produced in lamps of the form shown in Fig. 2, the water in one of them being boiled. Two right-angle quartz prisms P and a quartz-fluorite achromatic combination A were so adjusted that the images of the two sparks S_1 and S_2 were formed one above the other on the slit of the spectrograph, as shown in Fig. 3, (a) and (b).

The photographs were taken on Ilford rapid process panchromatic plates and also on Ilford process plates sensitized with paraffine oil for extreme ultra violet. Thus spectra of lights emitted from sparks in air and in a gaseous medium were photographed at the same time on one plate, and the appearances of lines were carefully examined.

Results.

(1) Nitrogen and oxygen.

In air and nitrogen the modes of the appearance of lines in spark spectra of seven elements mentioned above did not show any marked difference. In oxygen, however, certain lines showed a greater broadening than in air. The photographs of lead spectrum taken in oxygen and nitrogen are represented in Figs. 4, b and c, Pl. XII.

(2) Chlorine Bromine and Iodine.

When the sparks were sent between electrodes of zinc, lead and bismuth, placed in chlorine gas their chlorides were soon produced, and the fumes soon obscured the lights. To prevent this, the sparks were intermittently sent and the chlorides deposited on the quartz window were frequently cleared off. The spectra of these lights were markedly different from those in air. These are shown in Figs. 4, a and 5, a, Pl. XII, 6, a and 7, a, Pl. XIII. In the atmosphere of chlorine spark lines increased in intensity while the lengths of super spark lines decreased, and some super spark lines and super-super spark lines disappeared entirely in the spectra. The light in the ultraviolet region extending from λ 3800 to 2800 was wholly absorbed by chlorine. In the case of copper, zinc, aluminium, lead and bismuth, certain lines were found to be broadened out considerably.

In bromine and iodine atmospheres, the lights were strongly absorbed by these gases, so that only a part of the spectra was examined. The result, however, was similar to that of chlorine.

(3) Hydrogen.

In the hydrogen atmosphere the lights emitted from the sparks between various electrodes became faint giving a deep red colour. To photograph these spectra, an exposure six times longer than that given with the air spark was required to get nearly equal photograpnic intensities of the spark lines. In hydrogen, spark lines appeared long, as if they were arc lines in an air spark, and super spark lines short, showing an appearance of spark lines in air spark, and super-super spark lines shortest, but their appearance was like that of super spark lines in air spark, the intensity of super-super spark lines being much enhanced as compared with that of the spark lines. Such spectra of lead and bismuth are represented in Fig. 4,f, Fig. 5, c, Pl. XII, Fig. 6, d and Fig. 7, d, Pl. XIII.

(4) Water-Vapor.

In water-vapor the spark lines looked almost the same as corresponding lines in air, while super spark and super-super spark lines were longer and more intense than those of air spark. The characteristic differences in appearance between the lines of these three types were clearly seen in the spark spectra produced in water-vapor. These are shown in Figs. 4, e; 5, b, Pl. XII, Figs. 6, b; 7, b, Pl. XIII. Certain lines which were not classified by Kimura and Nakamura were observed in these spectra. Their wave-lengths were taken from Kayser's Handbuch and they were classified into spark and super spark, and super-super spark lines according to the method of Kimura and Nakamura as shown in Tables I, II, III and IV.

Table I, Cu.

CuIII			
5768	5635	5566	5486
5760	5618	5563	5439
5652	5608	5543	5268
5642	5574	5487	5204

Table II, Zn.

ZnIII			
5937	5207	3578	2308
5777	5190	2464	2253
5664	4416	2329	
5582	3661	2318	

Table III, Pb.

PbIII				PbIV
6380	4802	3736	2433	5143
5877	3950	3689	2299	
5164	3925	3089	2080	
5005	3854	2804	2060	

Table IV, Bi.

BiII	BiIII	BiIV		
4970	6053	6135	3159	2641
4908	6037	5542	3009	2582
4949	3846	5538	2973	2501
4748	3816	5527	2968	2479
4387	3394	3455	2822	2378
2396		3236	2757	2325
2246		3454	2746	2313
2187		2299	2733	2301
		3296	2730	2294
		3287	2684	2265
		3236	2677	2252

By passing sparks between metal electrodes placed in the seven media mentioned above, changes called forth in the appearance of enhanced lines were thus examined. In hydrogen, the lengths of super spark and super-super sqark lines were remarkably increased as compared with those of corresponding lines excited in air spark, while in water-vapor there was only a slight increase, and in nitrogen and oxygen, none. In halogen lengths and intensities of such lines were decreased and some of them disappeared entirely, while the intensitys of spark lines was enhanced considerably as compared with those excited in air spark. Thus among enhanced lines of higher orders produced in the above mentioned atmospheres, the lines obtained by the spark in hydrogen were longest, and when the medium was replaced by water-vapor, nitrogen, oxygen and halogen the lengths were shortened in that order.

It may be interesting to notice that among the enhanced lines of lead and bismuth lines having constant wave number differeces were found and these are given in the following Tables V and VI.

Table V, Pb.

PbII.

Int	λ	ν vac.	Δ ν
9	5608·9	17828·8	8573·3
8	3786·5	26402·1	
5	2717·1	36793·1	8573·0
10	2203·6	45366·1	
10	4386·8	22788·8	759·5
10	4245·4	23548·3	
8	3017·6	33129·3	766·0
5	2949·4	33895·3	

PbIII.

Int.	λ	ν vac.	Δ ν
4	4571·5	21868·5	
4	3952·1	25295·8	3427·3
4	3176·5	31472·1	6176·3
4	3176·5	31472·1	
4	2864·4	34901·1	3429·0
2	2433·6	41078·9	6177·8
4	-4400·8	-22716·8	
4	-4801·9	-20819·3	1897·5
2	-5163·6	-19361·0	1458·3
3	4272·5	23398·9	
3	3925·2	25296·5	1897·6
3	3736·2	26757·6	1461·1

PbIV.

Int.	λ	ν vac.	ν
3	3242·8	30828·7	211·5
3	3220·7	31040·2	
3	3051·3	32763·4	211·8
2	3031·7	32975·2	
3	3927·7	25453·0	1894·5
3	3655·6	27347·5	
3	3279·2	30486·5	1896·9
3	3087·1	32383·4	

Table VI, Bi.

BiII.

Int.	λ	ν vac	Δ ν
10	5209·4	19190·7	
10	4259·8	23468·7	4278·0
10	3792·8	26358·3	2889·6
6	3111·4	32130·5	
3	2746·3	36401·9	4271·4
3	2544·4	39290·2	2888·3
7	6808·8	14682·8	
7	6599·7	15148·0	465·2
7	6497·7	15385·8	237·8
8	5270·5	18968·3	
8	5144·6	19432·5	464·2
6	5091·2	19636·6	204·1 (?)
7	4391·4	22765·4	
10	4302·2	23237·4	472·0
10	4259·8	23468·7	231·3

Int.	λ	ν vac.	Δ λ
7	6059·0	16499·8	680·5
6	5819·0	17180·3	1159·2(?)
8	5456·2	18339·5	
8	5144·5	19432·8	680·3
4	4970·5	20113·1	1135·9(?)
10	4704·8	21249·0	
—	—	—	—
7	6590·8	15147·8	2332·6
8	5719·1	17480·4	
—	—	—	—
7	5655·7	17676·4	2332·9
6	4993·8	20019·3	
—	—	—	—
7	6497·6	15386·1	3804·2
10	5209.5	19190·3	
—	—	—	—
8	5144·6	19432·5	3805·1
10	4302·2	23237·4	

BiIII.

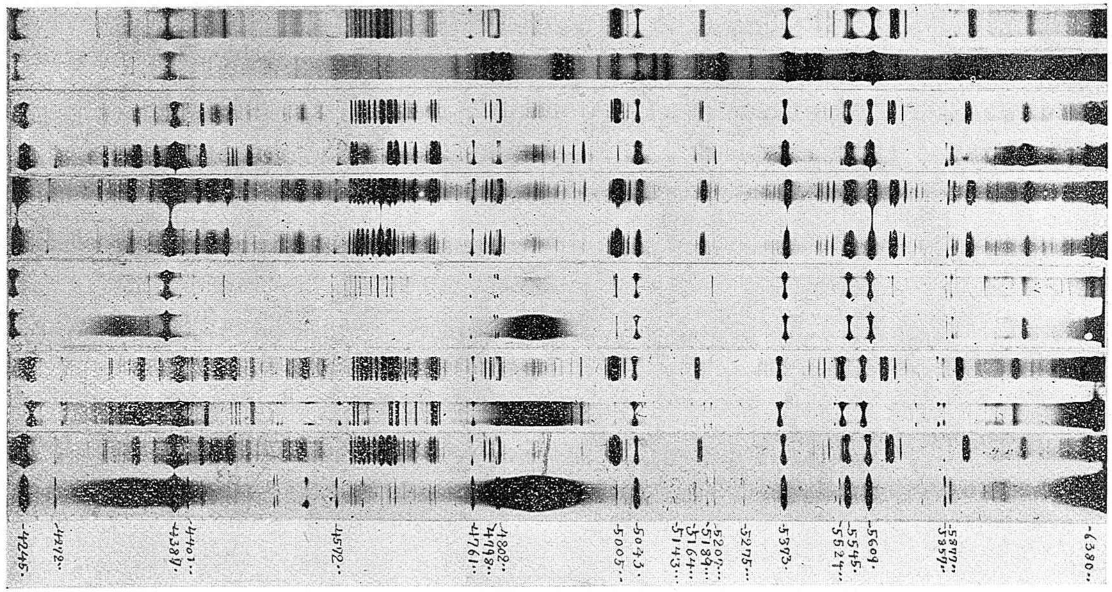
Int.	λ	ν vac.	Δ ν
5	5079·5	19681·5	1156·0
5	4797·7	20837·5	
3	3631·8	27526·7	1154·6
4	3485·6	28681·3	
4	3485·6	28681·3	96·6
4	3473·7	28777·9	
7	2855·7	35007·4	99·6
3	2847·6	55107·0	
2	4752·3	21037·0	2065·6
3	4327·3	23102·6	
3	3756·2	26615·1	2066·2
4	3485·6	28681·3	
5	5079·5	19681·5	7980·0
3	3614·1	27661·5	
3	3039·7	32888·4	7978·9
2	2446·2	40867·3	

BiIV.

Int.	λ	ν vac.	Δ ν
2	3287·3	30411·4	
2	3159·8	31638·4	1227·0
2	2968·8	33673·8	2035·4
3	3041·2	32872·2	1232·4
3	2931·3	34104·6	2035·4
2	2766·3	36140·0	
4	3473·9(III?)	28777·9	
2	2917·4	34267·1	5489·2
2	2693·1	37130·9	2863·8
2	3159·9	31637·4	5483·5
2	2693·1	37120·9	2868·6
2	2500·5	39989·5	
2	2773·1	36046·2	
2	2730·5	36612·5	566·3
1	2676·5	37351·1	738·6
2	3295·9	30332·0	561·5
2	3236·0	30893·5	744·9
2	3159·8	31638·4	

In conclusion, I wish to express my best thanks to Prof. M. Kimura, under whose guidance the present experiments were carried out.

Fig. 4. Pb.



Pb-Spark in

a { Air,
Chlorine,

b { Air,
Oxygen,

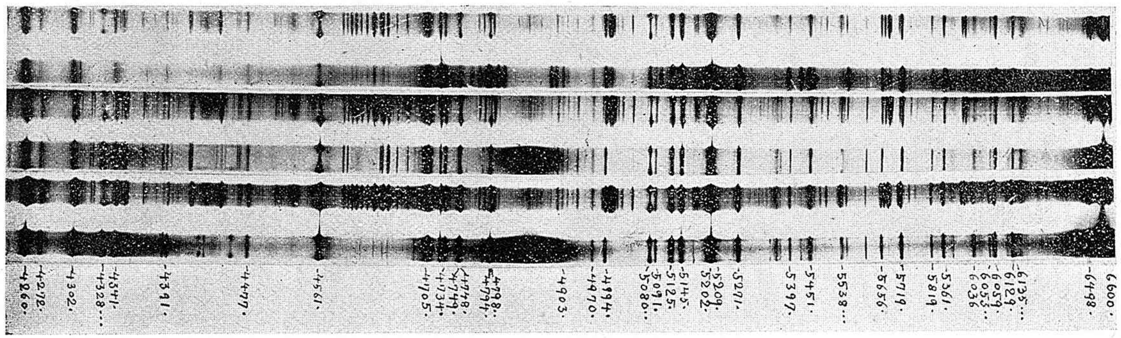
c { Air,
Nitrogen,

d { Air,
(Small Self-induction)
Water-Vapor,

e { Air,
Water-Vapor,

f { Air,
Hydrogen.
(6-Times-Exposure)

Fig. 5. Bi.



Bi-Spark in

a { Air,
Chlorine,

b { Air,
Water-Vapor,

c { Air,
Hydrogen.
(6-Times-Exposure)

Mem. Coll. Sci. Kyoto. Imp. Univ. A. Vol. X. Pl. XIII.

Fig. 6. Pb.

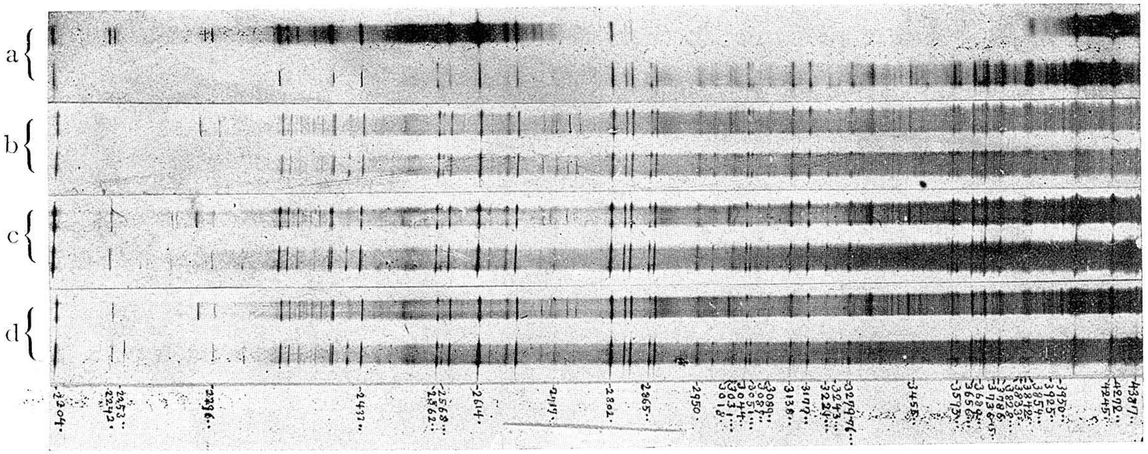


Fig. 7. Bi.