Study of the Structure of Bromine Lines.

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ABSTRACT.

Examination of the structure of bromine lines. A long lasting discharge tube which gave a very satisfactory spectrum was devised. For the analysis of the lines, an echelon grating consisting of twenty plates of 1·5 cm. thickness was used in combination with a constant deviation or direct vision prism. The structure of about fifty lines thus examined is described and out of them those lines which are similar in structure are picked out and arranged in a table.

Groups of lines having constant frequency differences. It was found that the lines each group in the table stand parallel to one or more other series of complex or single lines.

The structure of the lines of the bromine spectrum was first studied by Kimura, who found that a number of lines have a complex structure, but gave those of only fourteen lines.

The structure of the remaining complex lines was not given, as there were some ambiguities in the position of satellites. To investigate further the structure of these remaining lines, he obtained from Hilger Co. an echelon grating with twenty plates, 1·5 cm. thick, and advised me to continue the study of the problem.

The optical constants of the glass of this echelon grating are given by the maker as follows:

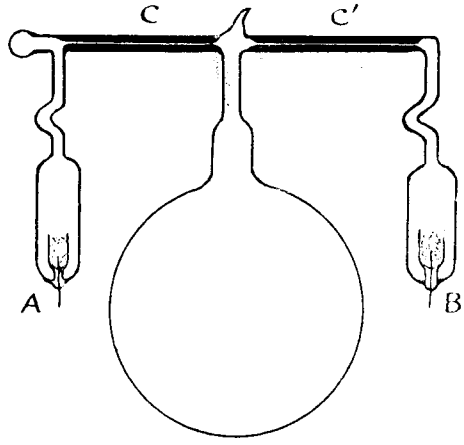
D 1 57508, C-D 0·00394, D-F 0·01003, F-G 0·00829, and from these values, the order separations (d_{max}) were calculated for the lines C, D, F and G. The values of d_{max} are given in table 1.

Table 1.

	d_{max}
C: 6563.1	0.474
D: 5893.0	0.376
F: 4861.5	0.242
G: 4341.0	0.186

As the source of light, a tube of the form used by Kimura was first employed, but the life of the tube was not sufficient for recording the structure of weak lines.

Fig. 1.



The present writer modified it, as shown in Fig. 1, by connecting another capillary C' between the capillary C and the wider tube containing the electrode B.

Each capillary was 8 cm. in length and had a diameter of about 0.5 mm. The tube thus prepared was excited by an induction coil giving a 30 cm. spark, and it was found that it lasted for a couple of days, giving a beautiful pink discharge.

The light emitted in an end-on direction was first analysed with the echelon grating and then by a prism and photographed by means of an achromatic objective of 1 or 1.5 m. focus. In the case of the lines at 6150 and 6351, the prism (one constant deviation) was so arranged that it gave the horizontal dispersion as that of the echelon, but in other cases, the echelon was crossed with a large direct vision prism as used by Kimura.

In either case, the optical part of the arrangement was enclosed in a wooden box, the temperature within this being kept constant to within 0.1 C by a toluol thermostat.

With this arrangement it was very easy to see at a glance the structure of many lines in the spectrum, but the exact positions of satellites relative to a main component could not be determined unless the orders of the satellites and the main component were properly assumed. Besides this, many of the complex lines had components too close together to be

analysed distinctly by the instrument employed in this work so that the numerical data concerning the structure given below are not final.

With the tube described above a number of lines which were not studied by the above-mentioned investigator revealed their structures. In the following list are described the lines examined and their structures, the wave-length of the lines being taken from those of Eder and Valenta (Some marked with a single asterisk are due to Galitzin and Wilip and those with two asterisks are the values roughly determined by the extrapolation method from the lines which appeared in my photograph. The identification of the latter as bromine lines calls for further investigation.)

4425·32. Doublet (?)

4441·94. Doublet (?)

4472·83. Doublet having a separation of 0·040 (?)

4477·96. Doublet (?)

4513·67. Doublet (?)

4525·82. Doublet with components 0·027 apart.

4542·67, 4543·12. Two faint lines, standing very close to each other. Confusion arising from their proximity and faintness could not be avoided, but probably the former line is double, while the latter is single.

4629·66. Triplet; Components at 0·000, − 0·074, − 0·126.

4672·75. Triplet; 0·000, − 0·067, − 0·106.

4678·89. Bright and broad, having satellites on both sides.

4693·48. Stronger and less refrangible component of the two, separated about 0 035, is accompanied by a satellite at about 0·049.

4705·00. Triplet; 0·000, − 0·035, − 0·057. (?)

4728·49, 4728·90. One or both of these two lines have some structure.

4767·28. Close doublet ?

4774·01. Triplet with components at 0·000, − 0·070, − 0·112.

4776·61. Quadruplet; 0·000, − 0·038, − 0·070, − 0·093.

4785·64. Triplet having a similar structure to 4705 with components at 0·000, − 0·033, − 0·056 (?)

4795·28.* Doublet; separation of components 0·064.

4802·54. Doublet; 0·033.

4816·90. Triplet; 0.000, − 0·038, − 0·071.

4838·82. Faint, suggesting some structure.

4866·85. Triplet; 0 000, − 0·075, − 0·111.

4867·94. Quadruplet ? Three components are at 0·000, 0·032,

0·063 and the fourth seems to appear at 0·090.

4921·39. A bright and broad line, with satellites on both sides; − 0·030, 0 000, − 0·033.

4929·00. 4930·82. Structure similar to the foregoing;

4945·77. Complex, perhaps triplet, but too faint to be recognized distinctly.

4959 51. Quadruplet; 0·000, − 0·044, − 0·080, − 0·104 similar to 4776·61 but the components are arranged in reversed order.

4979·95. Doublet; 0.032 separation.

5184·07. Quadruplet, similar to 4959·51; 0·000, − 0·045, − 0·086, − 0·127.

5194·08. Close doublet having a separation of 0 023.

5199·50. Faint but suggesting a similar structure to 5227·91.

5227·91. Triplet; 0 000, − 0·045, − 0·079.

5249·68. Doublet; separation 0·048.

5263·68. Doublet; 0·039.

5272·89. Triplet with components at 0·000, − 0·090, − 0·166 similar structure to that of 4629·66 but the series of components in reversed order.

5332·18. Complex, two components being separated about 0·06, and the more refrangible one suggesting further structure.

5345·53. Doublet: 0 051.

5395·69. Triplet: 0·000, − 0·069, − 0·094.

5423·01. Doublet with about 0·05 separation, more refrangible component being somewhat broad and bright.

5425·21. Doublet with comparatively wide separation 0.089.

5466·43. Doublet; 0·047.

5495·24. Quadruplet; 0·000, − 0 044, − 0·085, − 0 117.

5590·15. Two components (0·031), the more refrangible one having a satellite at − 0·065.

5600 90. Doublet with separation 0 075.

5719·17. Doublet; 0·010.

5831 04, Doublet; 0·056.

5940·83. Doublet; 0·056.

6118·89. Doublet; 0·051.

6149·95. This line as well as the three lines described below are typical examples of the quadruplet, consisting of a series of components of decreasing spacing and intensity. The components are at 0·000, − 0·071, − 0·120, − 0·148.

6351·02. 0·000, − 0·079, − 0·133, − 0·165.
6560 17. 0·000, − 0·084, − 0·142, − 0·178.
6632 02. 0 000, − 0·085, − 0·142, − 0·179.
6682·00.** Doublet; 0·056.
6728·00.** Doublet; 0 059.
7040·00.** Doublet; 0 044.

From the above list lines having nearly the same or similar structures were picked out and arranged in the following table.

Table 2.

Quadruplets.

Group		d (− d_2) 10^2
A	6632.02	0.0, − 19.3, − 31.5, − 40.8
	6560.17	0.0, − 19.6, − 32.9, − 41.3
	6351.02	0.0, − 19.6, − 33.0, − 40.9
	6149.95	0.0, 18.9, − 31.8, − 39.0
B	5495 24	0.0, − 14.6, − 28.3, − 38.8
	4867.94	0.0, − 13.5, − 26.4, − 38.0 (?)
C	5184.07	0.0, − 16.6, − 31.9, − 45.5 (?)
	4959.51	0.0, − 17.8, − 32.5, − 42.2
C	4776.61	0.0, − 16.4, − 30.8, − 41.0

Triplets.

Group		d 10^2
D	5395.69	0.0, − 23.8, − 32.3
E	5272.89	0.0, − 32.2, − 59.7
E′	4629.66	0.0, − 34.6, − 58.8
	5227.91	0.0, − 16.4, − 29.0
	4945.77	
	4816.90	0.0, − 16.5, − 30.6
G	4866.85	0.0, − 31.8, − 47.0
	4774.01	0.0, − 30.8, − 49.0
	4672.75	0.0, − 30.5, − 48.6
H	4785.64	0.0, − 14.4, − 24.4 (?)
	4705.00	0.0, − 16.0, − 25.8 (?)

Doublets.

Group		d (separation) 10^2	Group		d 10^2
J	6118.89	8.6	L	5345.53	17.8
	5194.08	8.6		5249.68	17.3
					at-22.0
K	5263.68	14.1	M	4472.83	20.0 (?)
	4802.54	14.4		5719.17	31.6
	4643.74	14.2		5425.21	30.1
	4525.82	13.2		4795.28	27.9
				4979.95	13.0
				5940.83	15.8
				5466.43	15.9
				5831.04	16.4
				5423.01	17.0
				5332.18	17.0 (?)
				5600.90	23.8

For the lines belonging to Groups C, C′ or E, E′, the frequency seppratıons of the components are constant while their arrangement is in reversed order.

The writer calculated all possible wave-number differnces of the lines in the bromine spectrum and sorted out a large number of groups of lines having constant frequency separations. In particular, those groups of lines, which, when displaced by a certain amount on the wave-number, scale coincide almost with the lines of the groups, B, C, F, G, H, J, K, L, M, etc. mentioned in the above table, way be of some interest.

But the publication of these results should be reserved here, because many of the supposed constant differences may well be due to chance and their significance may be questioned until series or any other physical inter-relationship can be established relating them.

In connexion with the problem whether the whole spectrum can be produced by the same electron or by two electrons or more, Kimura [1] divided the lines into two groups, namely 'spark' type lines and 'arc' type lines, according to the behaviour of the lines in the presence of a spark gap in the discharge circuit. Excepting a few cases, complex lines seem to belong to the 'arc' type, which is different from the case of iodine, in which all the complex lines belong to the 'spark' type.[2]

The present investigation was carried on under the direction of Prof. Kimura. To him I wish to express my hearty thanks for his unfailing interest as well as for his invaluable help.

1 These Memoirs, **4**, 127 (1920).
2 Astrophys. J., **46**, 196 (1917).