of the reactions taking place between the incident light and the scattering particle. Therefore in pure scattering, the scattered light should be completely polarised in pure absorption and in re-emission unpolarised; and in phenomena intermediate between these two it should be partially polarised, as has been proved by Wood.

The phenomena of negative scattering should also be capable of extension to free electrons, and will thus probably afford an easy explanation of the origin of bright and broad bands in the spectra of Novae, and of winged lines in the solar spectrum.

Department of Physics,
Allahabad University, Aug. 14.

46. ON THE METHOD OF HORIZONTAL COMPARISON IN THE LOCATION OF SPECTRA OF ELEMENTS

M. N. Saha and K. Majumdar

For sometime past workers in spectroscopy in this laboratory are using a new principle in the location of spectra of elements, which, in the absence of a better name, may be styled the method of Horizontal Comparison. To explain the method, we start with Table I, where, in the first row, we have taken the successive elements, B, C, N, O, F, Ne, and Na (atomic numbers 5 to 11). The K- and L_1-rings of these elements are complete but the number of electrons in the L_2-orbit in the normal state varies from 1 to 6 from B up to Ne; in Na there is one more electron in M_1 besides the full quota of 6 in L_2. The optically excited states are obtained by allowing one electron to run through the higher orbits. If x denotes the number of electrons in the L_2-orbit, the different optically excited states can be represented by

$x L_2 M_1$, $x L_2 M_2$, $x L_2 M_3$, $x L_2 M_1$, $x L_2 M_2$, etc.

It is apparent that in the elements B to Na, x varies from 1 to 6.

In the second row, we have put the elements C^+, N^+,....... Mg^+, and in the third row the elements N^{++}, O^{++},...Al^{++}, so that elements in the same vertical column have the same electronic configurations, the nuclear charge increasing by one in each step.

takes place between orbits having the same total quantum number, e.g., $M_1 \leftarrow M_2$. Recently this case has been exhaustively discussed by Prof. M. N. Saha and Dr. P. K. Kichlu[1] who have shown the validity of the law to higher valence elements. The purpose of the present paper is to compare the corresponding lines of the elements in the same horizontal row in table I. We shall at present confine our attention to the transition $x L_2$ $(M_1 \leftarrow M_2)$.

Owing to the variety of the electronic configurations of these elements, the nature of the lines involved is widely different. We shall, therefore, for the sake of simplicity, chose lines which arise from terms of the highest multiplicity. As for example, according to the Hund's theory, we expect the following terms in oxygen,—

$$3L^2M_1 \left\{ \begin{array}{cccc} ^5S & ^3S & ^3D & ^3P \\ & ^1D & ^1P & \end{array} \right.$$

$$3L_2M_2 \left\{ \begin{array}{cccccccc} ^5P & ^3P & ^3F & ^3D & ^3P & ^3D & ^3P & ^3S \\ & ^1F & ^1D & ^1P & ^1D & ^1P & ^1S & \end{array} \right.$$

which will give rise to a very large number of lines. As it is not possible to compare all the lines due to the above transition,—most of them have yet to be discovered,—we have taken only the quintet lines ^5S—^5P, which are also the strongest in the transition. In Chart I are collected the lines (of the highest multiplicity) of the corresponding elements given in Table I, due to the transition $M_1 \leftarrow M_2$. We have chosen from a multiplet only one line which has the average of the frequencies forming the multiplet. In the case where the average frequency does not much differ from the frequency of the strongest line in the multiplet, the latter frequency has been taken.

TABLE I

x→	0	1	2	3	4	5	6
I	B	C	N	O	F	Ne	Na
II	C^+	N^+	O^+	F^+	Ne^+	Na^+	Mg^+
III	N^{++}	O^{++}	F^{++}	Ne^{++}	Na^{++}	Mg^{++}	Al^{++}

The elements in the same vertical column, *e.g.*, C, N^+, O^{++}, follow the arithmetic progression law, when the transition is along the same horizontal level, that is, when the transition

[1] Saha and Kichlu, *Ind. Jour. Phys.*, 2, (1928).

Chart I

$$xL_2 \; (M_1 \leftarrow M_2)$$

$x\rightarrow$	0	1	2	3	4	5	6
(1)	..	$^3P_2-^3D_3$	$^4P_2-^4D_2$	..	$^4P_2-^4P_2$	$^3P_1-^3S_1$	..
(2)	$^2S_1-^2P_2$	$^3P_2-^3S_1$	$^4P_2-^4P_2$	$^5S_2-^5P_2$	$^4P_3-^4D_4$	$^3P_2-^3D_3$	$^2S_1-^2P_2$
(3)	..	$^3P_2-^3P_2$	$^4P_2-^4S_2$	..	$^4P_2-^4S_2$	$^3P_1-^3P_2$	..
I	**B**	**C**	**N**	**O**	**F**	**Ne**	**Na**
(1)	..	..	11475	..	13360	13798	..
(2)	[6000]	10348	12175	12860	15582	15615	16973
(3)	..	10993	13433	..	15747	16399	..
		Fowler, P.R.S., 118, 42 (1928).	Kiess, J.O.S.A. 11. 4 (1925).	Fowler, Report, p. 168.	Dingle, P.R.S., 113, 326 (1927).	Saha, Phil. Mag. 4,223, (1927).	Fowler, Report, p. 99.
II	**C⁺**	**N⁺**	**O⁺**	**F⁺**	**Ne⁺**	**Na⁺**	**Mg⁺**
(1)	..	17602	21446	..	26767	27530	..
(2)	15198	19816	23052	25967	29977	32323	35761
(3)	..	21590	26821	..	33004	34411	..
	Fowler, P.R.S., 105, 306 (1924).	Fowler and Freeman, P.R.S., 114, 665 (1927).	Fowler, P.R.S., 110, 484 (1926).	Jog. Ind. Journ. Phy. 2, 344 (1928).	Kichlu, (Lond.) Phy. Soc., 39, 424 (1927).	Majumdar, Ind. Journ. Phy. 2, 353 (1928).	Fowler, Report, p. 120.
III	**N⁺⁺**	**O⁺⁺**	**F⁺⁺**	**Ne⁺⁺**	**Na⁺⁺**	**Mg⁺⁺**	**Al⁺⁺**
(1)	..	26589	..	..	..	..	..
(2)	24399	29925	[34700]	38545	[44300]	[49000]	53918
(3)	..	32808	..	..	..	..	..
	Bowen, Phy. Rev. 29, 234 (1927).	Fowler, P.R.S., 117, 325 (1928).		Jog. do.			Paschen Annd. Phys. 71, 151 (1923).

It will be evident from the chart that the frequencies in the same horizontal row increase with increase of atomic numbers. The relation has been graphically represented in fig. 1, where we find that the average frequency of the average multiplet increases linearly with the atomic number with the exception of the case where $x=0$.

In a similar manner, we can compare the lines of the elements beginning with Al. The transitions to be compared in this case will be $xM_2 \; (N_1 \leftarrow N_2)$, x varying from 0 to 6.

Table II.

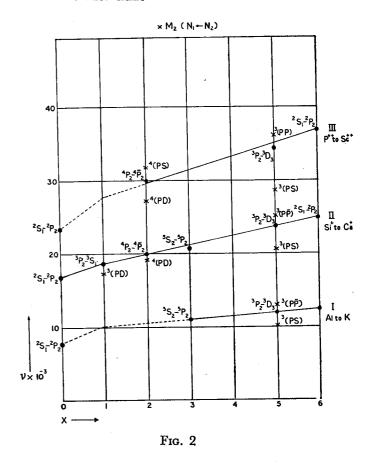| $x\rightarrow$	0	1	2	3	4	5	6
I	Al	Si	P	S	Cl	A	K
II	Si⁺	P⁺	S⁺	Cl⁺	A⁺	K⁺	Ca⁺
III	P⁺⁺	S⁺⁺	Cl⁺⁺	A⁺⁺	K⁺⁺	Ca⁺⁺	Sc⁺⁺

FIG. 1

FIG. 2

The elements are shown in Table II and their respective lines are given in Chart II. The relations between the frequencies and the atomic numbers in the three types of spectra are illustrated graphically in fig. 2. That the relations are linear in this case also (with the exception where $x-0$) is clear.

For comparison, the positions of multiplets other than the average multiplets (for which only the relation is linear) are indicated by a cross ($\times$) in the figures 1 and 2. They show by how much these multiplets differ from the normal relations.

It is now apparent that location of spectra of elements, in such a group as we have considered, can be made, provided we know the spectra of two or more elements in the group. In fact, as already has been mentioned, this method of location has been used with advantage in the classification of a number of elements. The applicability of this method, in addition to that of the irregular doublet law, was shown in the spectrum of ionised sodium[2], which was treated as the mean between the spectra of Ne+ and Mg+. Where irregular doublet law is not applicable for want of data, this method of location is of special importance. Recently Mr. D. K.

Bhattacharyya has applied this method of location in the spectra of ionised sulphur and of doubly ionised sulphur with some amount of success.

This method, though not so accurate as the irregular doublet law, has one advantage over it, inasmuch as the successive changes in the frequencies ($d\nu$) when we pass on from one element to another is much smaller than when we apply the irregular doublet law. In the latter case the changes are sometimes as great as, or even more than, the frequency of the first member in the group. As for example, in passing from C to N+ the $d\nu=9468$ (in C, $\nu=10348$) whereas in passing from C to N, the change is only 1827 (*vide* Chart I). Therefore, if we know the spectrum of only one member, the preceding or the succeeding, in a group, we can approximately locate the position of the spectrum of an element, since the change is not great. By this means, knowing the spectrum of Sc++, that of Ca++ was located and analysed. The details of the results will be published separately.

The correctness of the above-mentioned results enables us to predict with confidence the lines in the spectra of elements which remain to be classified. These have been shown in brackets [   ] in Charts I and II.

The theoretical aspects of these considerations are in progress and will it is hoped, form the subject of a subsequent paper.

---

[2]Majumdar, *Ind. Jour. Phys.*, 2, 348 (1928)

CHART II

xM$_2$ (N$_1$←N$_2$)

x→	0	1	2	3	4	5	6
(1)	..	$^3P_2-^3D_3$	$^4P_2-^4D_2$	..	$^4P_2-^4P_2$	$^3P_1-^3S_1$	..
(2)	$^2S_1-^2P_2$	$^3P_2-^3S_1$	$^4P_3-^4\bar{P}_2$	$^5S_2-^5P_2$	$^4P_3-^4D_4$	$^3P_2-^3D_3$	$^2S_1-^2P_2$
(3)	..	$^3P_3-^3\bar{P}_2$	$^4P_2-^4S_2$		$^4P_2-^4S_2$	$^3P_1-^3\bar{P}_2$	
I	Al	Si	P	S	Cl	A	K
(1)	..	..	..	..	..	10351	..
(2)	7617	[9700]	[10300]	11044	11937	12318	13043
(3)	..	..	..	..	..	13380	..
	Fowler, Report, p. 156.			Fowler, Report, p. 170.	K. Majumdar (unpublished)	Meissner, Zs. f. Phys. 40, 839 (1927).	Fowler, Report, p. 120.
II	Si+	P+	S+	Cl+	A+	K+	Ca+
(1)	..	16453	18144	..	..	20701	..
(2)	15751	18877	20026	20784	..	23881	25414
(3)	..	18425	21197	..	..	24917	..
	Fowler, Phil. Trans. 225, 24 (1926).	Bowen Phys. Rev. 29, 511 (1927).	Bhatta-charyya, Nature, (Communi-cated).	Paschen Annd. Phys. 71, 560 (1923)·		Bowen, Phy. Rev. 31, 497 (1928).	Fowler, Report, p. 127.
III	P++	S++	Cl++	A++	K++	Ca++	Sc++
(1)	..	..	27238	..	..	28258	..
(2)	23678	..	30030	[31200]	[33100]	34475	37039
(3)	..	..	31845	..	..	35811	..
	Millikan & Bowen Phy. Rev. 25, 601, (1925).		Bowen, Phy. Rev. 31, 35 (1928).		Bowen, do.	Bowen, do. Majumdar and Toshniwal, Nature.	Russell, Astro. Journ. 66, 13 (1927).