und wird in Kurve I veranschaulicht. Herr R. N. Ghosh hat im hiesigen Laboratorium die Abhängigkeit der Ionisierungsspannungen von der äusseren Struktur ausführlich studiert und er kommt zum Schlusse, dass sie mit zunehmender Anzahl der Gruppen-elektronen immer zunehmen. Wenn ein Niveau ganz besetzt ist, erreicht die Ionisierungsspannung ein Maximum. Wenn es eine statische M_{32} M_{33}-Spaltung gibt, muss die Ionisierungsspannung bei Erfüllung der M_{32}-Niveau, also bei Cr oder Mn, ein Maximum erreichen. Zur Illustration fügen wir die folgende Kurve bei, die der Arbeit von R. N. Ghosh entnommen ist.

Es erhellt aus dieser Kurve, dass für Elemente wie O und Fl, für welche das Niveau ungefähr voll besetzt ist, die Ionisierungsspannung sehr gross ist; und diese Elemente nehmen leichter ein oder zwei neue Elektronen auf, als dass sie eines abgeben. Sie haben die negativen Valenzen zwei und eins. Zu positiver Valenz sind sie unfähig. Bei Ne ist die Schale ganz erfüllt, also es ist sehr schwer von Ne ein Elektron abzureissen oder anzuregen, und noch schwerer, ein neues Elektron dort anzuheften. Es ist weder zu positiver noch auch zu negativer Valenz fähig.

In allen Elementen, von B bis Fl, haben wir optische Terme, die zur Kombination

$$L_1(x+1)L_2 \text{ (normal } 2L_1xL_2)$$

gehören. Das L_1-Elektron kann leicht zu L_2 übergehen.

Übergangsgruppe II, III, IV. Ihr Aufbau ist ganz analog der Gruppe Sc bis N. Aber die optische Analyse zeigt kleine Unterschiede. In Gruppe I ist die Struktur des äusseren Niveaus
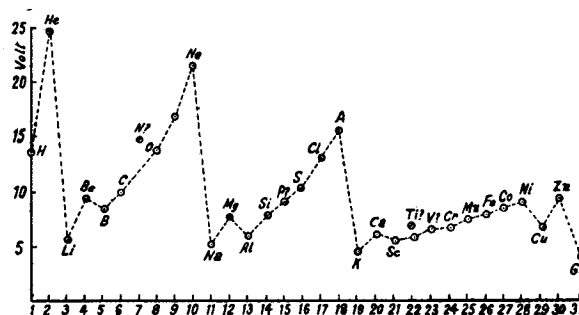

Fig. 4. Ionisierungsspannungs-Kurve.

$$\left.\begin{array}{l} xM_2N_1 \\ (x-1)\ M_32N_1 \end{array}\right\}$$

In Gruppe II ist es bei einigen Elementen

$$\left.\begin{array}{l} (x+1)M_3 \\ xM_3.\ N_1 \end{array}\right\}$$

Vergleicht man z. B. Ni und Pd

$$\begin{array}{llll} Ni & .. & \left.\begin{array}{l} 8M_32N_1 \\ 9M_3N_1 \end{array}\right\} & \\ Ni & .. & & \end{array} \qquad \begin{array}{ll} Pd & .. \\ Pd & .. \end{array} \left.\begin{array}{l} 9N_3O_1 \\ 10N_3 \end{array}\right\}$$

Ag^+ ist palladiumähnlich, der tiefstliegende Term rührt von 10 N_3 her, daher überschreitet für Ag der normale 10 N_3O_1 in seinem Energiewert das $9N_32O_1$, wenn as existiert, bedeutend. Daher ist Ag gegen Cu immer einwertig.

Auch für die seltenen Erden und die Übergangsgruppe III kann man Strukturen angeben; aber die Untersuchung ihrer optischen Spektren ist nur teilweise durchgeführt, und deshalb sind die Strukturen hier nicht gegeben.

Allahabad (Indien), 7. April 1927.

38. ON THE DETAILED EXPLANATION OF SPECTRA OF THE METALS OF THE SECOND GROUP*

The explanation of the spectra of elements is now making very rapid strides, thanks to the work on the arrangement of electrons inside the atom on the one hand, and development of the principles of non-mechanical vector addition of quantum numbers on the other hand, which we owe to Landé, Russell, Pauli, Heisenberg, Hund[1], and others. The latter authors have so far confined their attention to the fundamental levels of the atom, though in some papers the higher levels have been accounted for on similar lines. In the present paper, an attempt has been made to show that these principles can be extended for finding out all the higher terms, and in the case of metals of the second group all details of their spectra are explained in a very satisfactory way. The following is a brief sketch of the method of working:—In accordance with Pauli's Principle, we assign to each electron the characteristics of a doublet spectrum. Applied to alkalies, the explanation of the spectrum is very easy. The vibrating electron always comes after a sublevel has been completely closed, hence the atomic residue contributes nothing towards the resultant spectrum. The electron may be supposed to run through all the higher levels, beginning from X_1. We thus get ^2S, ^2P, ^2D, ... terms,—*i.e.* a completely developed doublet spectrum. The higher terms arise when the electrons run through the possible higher levels. In the case of alkaline

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earths, there are two outermost electrons. In the normal case, both are in some X_1-level. But when the atom is excited, one may be supposed to be at rest; the other runs through all the higher levels. The spectrum observed is due to the combination of the orbits of these two electrons. The rules for combination of orbits were first given by Pauli and developed by Hund and Heisenberg. For the sake of lucidity, I have attached a complete structure diagram. The rules of addition of quantum numbers are also summarized below. It may be added that I claim no originality in this paper except the method of representation, which I have found to be very convenient.

Principles of Orbit Combination

The principles which have so far been developed may be thus briefly summarized:—

Each spectral term may be denoted by the symbol n^r_{kj} (Landé), where r denotes the multiplicity $r = (1, 2, 3, \ldots$ for singlets, doublets, triplets, etc.), k=azimuthal quantum number (1, 2, 3, ... for s, p, d, f, ...), j=inner quantum number which is the vector sum of r and k. But for purposes of addition, we do not use r, k as they occur above, but have to use certain associated numbers. Different authors use different symbols with different values: thus Landé uses R, K, J; Sommerfeld uses j_s, j_a, j; and Pauli uses $[i, j, k]$. A comparison between the different systems of symbols is given in a recent paper by Otto Laporte, who finds that the Sommerfeld system is superior to the other two. In the following we adopt the Sommerfeld systems with a slight change. We shall write

i_r, in place of Sommerfeld's j_s,
i_k, in place of Sommerfeld's j_a
i_j, to denote the effective inner quantum number.

Thus

$i_r = 0, \frac{1}{2}, \frac{2}{2}, \frac{3}{2}$ for singlets, doublets, triplets, etc.

$i_k = k-1,\ 0, 1, 2, 3,$ for s, p, d, f,......

i_j is calculated from the rule:—

$i_j =$ Vector sum of i_k and i_r in the quantum sense— i.e. it must have all successive whole or half-numbered values lying between $|i_r + i_k|$ and $|i_r - i_k|$.

For purposes of description, Landé's notation n^r_{kj} may be retained.

Table I. contains a full chart of (i_r, i_j, i_k) values for different systems.

The corresponding magnetic quantum number $i_m = \pm i_j$, $\pm i_j - 1$, $\pm i_j - 2$, and thus i_m is the vector sum of i_{mr} and i_{mk}, where

$$i_{mr} = \pm i_r, \qquad \pm i_r - 1,$$
$$i_{mk} = \pm i_k, \qquad \pm i_k - 1.$$

TABLE 1

Showing values of i_r, i_k, i_j

i / i_k	ODD MULTIPLETS						EVEN MULTIPLETS						i_v / i_k
	0	1	2	3	4	5	$\frac{1}{2}$	$\frac{3}{2}$	$\frac{5}{2}$	$\frac{7}{2}$	$\frac{9}{2}$	$\frac{11}{2}$	
$s = 0$	0				Singlet i_r 0		$\frac{1}{2}$				Doublet $i_r = \frac{1}{2}$		$s = 0$
$p = 1$		1					$\frac{1}{2}$	$\frac{3}{2}$					$p = 1$
$d = 2$			2					$\frac{3}{2}$	$\frac{5}{2}$				$d = 2$
$f = 3$				3					$\frac{5}{2}$	$\frac{7}{2}$			$f = 3$
$s = 0$		1			Triplet $i_r = 1$			$\frac{3}{2}$			Quartet $i_r = \frac{3}{2}$		$s = 0$
$p = 1$	0	1	2				$\frac{1}{2}$	$\frac{3}{2}$	$\frac{5}{2}$				$p = 1$
$d = 2$		1	2	3			$\frac{1}{2}$	$\frac{3}{2}$	$\frac{5}{2}$	$\frac{7}{2}$			$d = 2$
$f = 3$			2	3	4			$\frac{3}{2}$	$\frac{5}{2}$	$\frac{7}{2}$	$\frac{9}{2}$		$f = 3$
$s = 0$			2		Quintet $i_r = 2$				$\frac{5}{2}$		Sextet $i_r = \frac{5}{2}$		$s = 0$
$p = 1$		1	2	3				$\frac{3}{2}$	$\frac{5}{2}$	$\frac{7}{2}$			$p = 1$
$d = 2$	0	1	2	3	4		$\frac{1}{2}$	$\frac{3}{2}$	$\frac{5}{2}$	$\frac{7}{2}$	$\frac{9}{2}$		$d = 2$
$f = 3$		1	2	3	4	5	$\frac{1}{2}$	$\frac{3}{2}$	$\frac{5}{2}$	$\frac{7}{2}$	$\frac{9}{2}$	$\frac{11}{2}$	$f = 3$

The change in energy level in weak fields is given by

$$\frac{E}{Oh} = (i_{mr} + i_{mk})g,$$

where

$g=$Landé's splitting-up factor,

$O=$Larmor's precession factor$= \dfrac{eH}{4\pi cm}$.

The change in strong fields is given by

$$\frac{E}{Oh} = 2i_{mr} + i_{mk}.$$

We shall have no occasion to use the strong field or weak field magnetic quantum numbers[2].

The doublet spectrum is supposed to be the fundamental spectrum from which all other complicated spectra can be synthesized. When the constitution is such that there is only one electron left after a sublevel is closed, this electron as it runs through the following levels gives rise to the corresponding doublet terms. Thus we have for Potassium:

STRUCTURE DIAGRAM OF POTASSIUM (19)
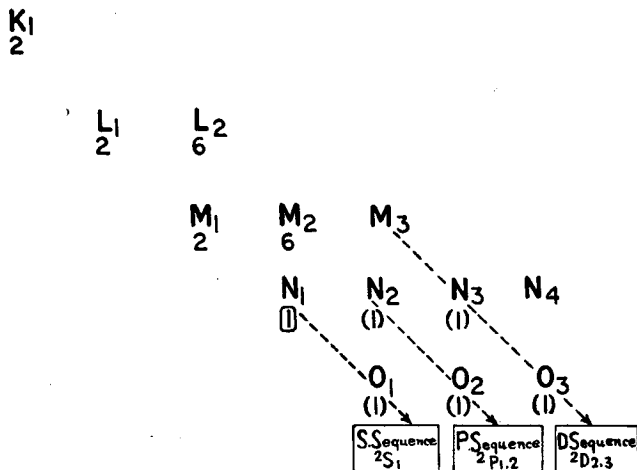
ORIGIN OF NORMAL TERMS IN THE SPECTRUM OF K

Russell and Saunders' symbol has been used throughout (*vide* Ap. Journ. vol. lxi. p. 38). (1) denotes the running electron.

Thus the alkali spectrum is most simply explained on the assumption that it is due to the movement of the running electron in the successive higher levels.

[RULES OF SYNTHESIS.]

Alkaline Earths.

In the case of the next group of elements, viz. the alkalies, a second electron is added. If we take Mg, we have the constitution:—

$$\text{Mg} = \begin{pmatrix} K & L & M_1 & M_2 \cdots \\ 2 & 8 & 1,(1) \rightarrow (1) \end{pmatrix}$$

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[2]The preliminary introduction is taken from Laporte's article in the Journ. Opt. Soc. America, July 1926.

The optical spectrum is due to the two outer electrons shown under M_1. In most cases, one electron remains fixed at M_1, the other runs through the successive levels. The level observed is the vector sum of the levels of these two electrons. As mentioned above, these rules have been developed by Russell, Pauli, Heisenberg, and Hund. Let N^R_{KJ} denote the resultant levels, and let I stand for the Sommerfeld quantum numbers. Then to get a complete knowledge of N^R_{KJ}, we must have a knowledge of the corresponding values of I_K, I_J, I_R, We have

$I_R=$vector sum of $(i_r)_1$ and $(i_r)_2$;
$I_K=$vector sum of $(i_k)_1$ and $(i_k)_2$.

The determination of I_J presents the most formidable difficulties. It cannot be defined as the vector sum of $(i_j)_1$ and $(i_j)_2$. We have to write out all the possible magnetic levels for each of the components (1) and (2) and then add them, taking one from each group. Thus:—

The magnetic levels of electron (1) are

$$(i_m)_2 = \pm(i_1)_1, \ \pm(i_j)_1-1, \ \pm(i_j)_1-2, \ \ldots$$

The magnetic levels of electron (2) are

$$(i_m)_2 = \pm(i_j)_2, \ \pm(i_j)_2-1, \ \pm(i_j)_2-2 \ \ldots$$

Thus the above procedure, without any further restriction, would give us

$\{2(i_j)_1+1\} \ \{2(i_j)_2+1\}$ values of I_m.

After arranging these values symmetrically, we have to obtain the values of I_j. This will completely define the resultant term 1_j.

Applying this rule to Mg, when we have both electrons in the M_1 orbit,

	$i_r.$	$i_k.$	$i_j.$	$i_m.$	
for electron (1):	$\frac{1}{2}$	0	$\frac{1}{2}$	$\frac{1}{2}$	$-\frac{1}{2}$
,, ,, (2):	$\frac{1}{2}$	0	$\frac{1}{2}$	$\frac{1}{2}$	$-\frac{1}{2}$
Resultant:	0 $\frac{2}{2}$	0	0	0	

$$I_R \qquad I_K \qquad \begin{array}{ccc} 1 & 0 & \bar{1} \\ I_J = 0\} \\ I_J = 1\} \end{array}$$

The resultant orbit has therefore $I_R=0$ and $\frac{2}{2}$, *i.e.* it belongs to a singlet or triplet system. $I_K=0$, *i.e.* K=1. It is an *s*-orbit $I_J=0$, 1. It has the inner quantum number $=0$ or 1.

Since $^3S_1$ is not observed, Pauli lays down a principle which excludes it, viz.: no two electrons in a closed orbit can have identical values of i_m.

This rule excludes $^3S_1$, for it arises from $(i_m)_1=\frac{1}{2}$, $(i_m)_2=\frac{1}{2}$, or both $=-\frac{1}{2}$.

From this principle also follows Stoner's rule: The number of electrons in a closed group $=2[j$ used in Landé's sense]. For the resultant magnetic moment due to the component electrons $= 0$, and this can take place if we assign to each the different possible value of $(i)_m$ for a subgroup. The number $= 2j$ or $(2i_j+1)$, and to every

positive value there is a corresponding negative value. Hence the resultant $= 0$, when there are $2j$ electrons, and each is contained in a different magnetic level. But I do not think that Stoner's subdivision of each higher level L_2 or M_2 into $L_{21} L_{22} M_{21} M_{22}$ is quite justified. See a paper by Saha and Ray in the *Physikalische Zeitschrift*.

Origin of Higher Terms.

But Pauli's principle cannot be applied where the electrons are in different levels. Thus let electron (1) be in the M_1-orbit, electron (2) in the N_1-orbit. Here Pauli's rule will not hold; we shall get 2^1S_0, 2^3S_1-terms. Similarly, as the electron (2) runs through the higher X_{11} levels it gives rise to the higher members of the $^1S_0$ and $^3S_1$ series, viz. 2^1S_0, 2^3S_1, etc.

Combination of M_1 and M_2 Levels.

We have

	$i_r.$	$i_k.$	$i_j.$	$i_m.$
for electron (1):	$\frac{1}{2}$	0	$\frac{1}{2}$	$\frac{1}{2}$ $-\frac{1}{2}$
„ „ (2):	$\frac{1}{2}$	1	$(\frac{1}{2}, \frac{3}{2})$	$(\frac{3}{2}, \frac{1}{2}, -\frac{1}{2}, \frac{3}{2})$ $(\frac{1}{2}, -\frac{1}{2})$

0	$\frac{2}{2}$	1	0	$I_j = 0$
			$1\ 0\ \bar{1}$	$I_j = 1$
I_r	I_k		$2\ 1\ 0\ 1\ \bar{2}$	$I_j = 2$
			$1\ 0\ \bar{1}$	$I_j = 1$

The resultant orbit will be $^1P_1$, $^3P_{0,1,2}$. The number of magnetic levels for these terms is $3 + (1 + 3 + 5) = 12$. The possible numbers of combinations of $(i_m)_1$ and $(i_m)_2$ are 2 and 6, and if we write them out, and add for the resultant I_m, and write out the corresponding values of J, we get the P terms $(^2S\frac{1}{2}, ^2P\frac{1}{2})$ give us $^1P_1$, $^3P_0$, and $(^2S\frac{1}{2}, ^2P\frac{3}{2})$ give us $^3P_1$, $^3P_2$.

Combination of N_1 and N_3 Levels.[3]

We need not repeat the summation for i_r. Now $I_k = 2$, or the resultant are D-terms, $^1D_2$, $^3D_{1,2,3}$. The values of i_j are $\frac{1}{2}$ and $(\frac{5}{2}, \frac{3}{2})$ respectively. $(\frac{1}{2})$, $(\frac{3}{2})$ give us $^1D_2$, $^3D_1$, and $(\frac{1}{2})$, $(\frac{5}{2})$ give us $^3D_{2,3}$. In this way we get by combination with levels N_2 the higher Rydberg terms of $^1P_1$ and $^3P_{0,1,2}$. Combination with N_4 gives us the first F-terms.

We thus get a general explanation of the regular term-sequences in the spectrum of Mg, and *mutatis mutandis* for Ca, Sr, and Ba as well. But the procedure is capable of yielding still further results. It is known to spectroscopists that, in spite of the similarity amongst the spectra of these elements, there are certain outstanding differences. For the spectrum of Mg, the highest value for the sequence $D = 15268 \cdot 7$, while the highest D-values for Ca, Sr, and


Ba are much higher; in fact they sometimes exceed the P-values, as the following table shows:—

		D.		P.
Mg	$^1D_2$	$15268 \cdot 7$	$^1P_1$	$26620 \cdot 7$
	$^3D_2$	$13714 \cdot 7$	$^3P_1$	$39801 \cdot 4$
Ca	$^1D_2$	$27455 \cdot 3$	$^1P_1$	$25652 \cdot 4$
	$^3D_2$	$28955 \cdot 2$	$^3P_1$	$34094 \cdot 6$
Sr	$^1D_2$	$25786 \cdot 8$	$^1P_1$	$24238 \cdot 1$
	$^3D_2$	$27717 \cdot 7$	$^3P_1$	$31432 \cdot 2$
Ba	$^1D_2$	$30634 \cdot 1$	$^1P_1$	$23969 \cdot 2$
	$^3D_2$	$32814 \cdot 1$	$^3P_1$	$29392 \cdot 8$

These large D-values can be easily explained if we compare the Structure Diagrams of Mg and Ca.

STRUCTURE DIAGRAM OF Mg (12)
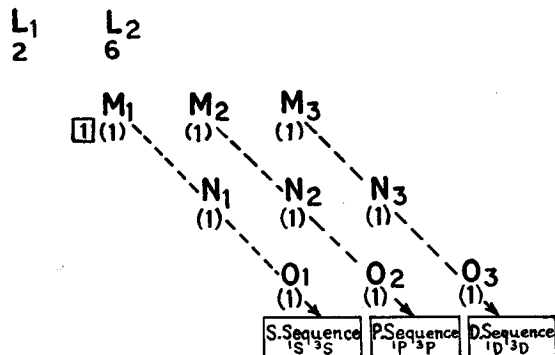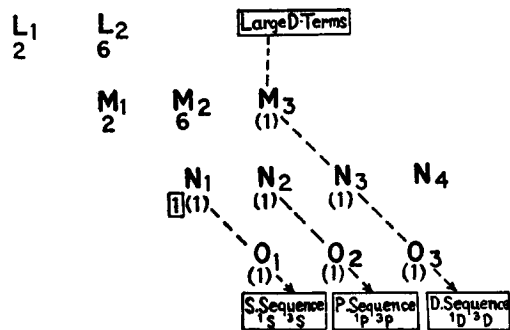

ORIGIN OF NORMAL TERMS IN MAGNESIUM

STRUCTURE DIAGRAM OF CALCIUM (20)

ORIGIN OF NORMAL TERMS IN THE SPECTRUM OF Ca

A comparison of the two structure diagrams shows that the successive positions of the running electron in Mg are M_1 ($^1S_0$), M_2 (^1P and ^3P), M_3 (^1D and ^3D), and we have approximately $^1P = \dfrac{N}{2^2}$, $^1D = \dfrac{N}{3^2}$. But in Ca the positions

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[3]Fowler, Report on Series in Line Spectra, ch. xiv.

				Transitional group I.		Transitional group II.		Rare earths I.	Transitional group III.

K₁ 2

1 H
2 He   2K₁

3 Li   2K₁   L₁
4 Be   2L₁
5 B   2L₁   L₂
6 C   2L₂
7 N   3L₂
8 O   4L₂
9 F   5L₂
10 Ne   6L₂

L₁ 2   **L₂ 6**

Transitional group I.
21 Sc   M₃   2N₁ }
     2M₃ N₁ }
22 Ti   2M₃ 2N₁ }
     3M₃ N₁ }
23 V   3M₃ 2N₁ }
     4M₃ N₁ }
24 Cr   5M₃ N₁ }
     4M₃ 2N₁ }
25 Mn 5M₃ 2N₁ }
     6M₃ N₁ }
26 Fe   6M₃ 2N₁ }
     7M₃ N₁ }
27 Co   7M₃ 2N₁ }
     8M₃ N₁ }
28 Ni   8M₃ 2N₁ }
     9M₃ N₁ }

Transitional group II.
39 Y   2N₃ O₁ }
     N₃ 2O₁ }
40 Zr   3N₃ O₁ }
     2N₃ 2O₁ }
41 Nb 4N₃ O₁ }
     3N₃ 2O₁ }
42 Mo 5N₃ O₁ }
     4N₃ 2O₁ }
43 Ma   6N₃ O₁ }
     5N₃ 2O₁ }
44 Ru 7N₃ O₁ }
     6N₃ 2O₁ }
45 Rh 8M₃ O₁ }
     7M₃ 2O₁ }
46 Pd   10N₃ }
     9N₃ O₁ }

Rare earths I.
57 La
58 Ce
59 Pr
60 Nd
62 Sm
63 Eu
64 Gd
65 Tb
66 Dy
67 Ho
68 Er
69 Tu
70 Yb

Transitional group III.
71 Lu
72 Hf   2O₂ 2P₁ }
     3O₂ P₁ }
73 Ta   3O₂ 2P₁ }
     4O₂ P₁ }
74 W   4O₂ 2P₁ }
     5O₂ P₁ }
75 Re   5O₂ 2P₁ }
     6O₂ P₁ }
76 Os   6O₂ 2P₁ }
     7O₂ P₁ }
77 Ir   7O₂ 2P₁ }
     8O₂ P₁ }
78 Pt   9O₂ 2P₁ }
     9O₂ P₁ }

11 Na   6L₂   M₁
12 Mg   6L₂   2M₁
13 Al   2M₁   M₂
14 Si   2M₂
15 P   3M₂
16 S   4M₂
17 Cl   ·5M₂
18 A   6M₂

M₁ 2   **M₂ 6**   **M₃ 10**

29 Cu   10M₃ N₁ 9M₃ 2N₁
30 Zn   10M₃   2N₁
31 Ga   2N₁   N₂
32 Ge   2N₁·   2N₂
33 As   3N₂
34 Se   4N₂
35 Br   5N₂
36 Kr   6N₂

19 K .... 6M₃ N₁
20 Ca 6M₃ 2N₁

N₁ 2   **N₂ 6**   **N₃ 10**   **N₄ 14**

47 Ag   10N₃O₁
48 Cd   2O₁
49 In   2O₁   O₂
50 Sn   2O₂
51 Sb   3O₂
52 Te   4O₂
53 I   5O₂
54 Xe   6O₂

37 Rb .... 6N₂ O₁
38 Sr 6N₂ 2O₁

O₁ 2   **O₂ 6**   **O₃ 10**

79 Au
80 Hg   10O₃   2P₁
81 Tl   2P₁   P₂
82 Pb   2P₂
83 Bi   3P₂
84 Po   4P₂
85 Rad Te   5P₂
86 Nt   6P₂

55 Cs .... 6O₂ P₁
58 Ba 6O₂ 2P₁

P₁ 2   **P₂ 6**   **P₃ 10**

87 Eka Cs   Q₁
88 Ra 2Q₁

Q₁ 2   **Q₂ 6**

(Explanation of the Chart.)

[The chart is a modification of the earlier schemes of Bohr and Stoner. The L_{21} and L_{22} levels of Stoner are compounded into one L_2-level. (For explanation, see a paper by Saha and Ray in the *Physikalische Zeitschrift*.) The chart explains the formation of (1) the regular groups, (2) the transitional groups, (3) the rare earths, and gives the electronic composition of the outer shells of the electrons, as obtained from Hund's interpretation of complex spectra (*Zs. j. Phys*, vols. xxxiii & xxxiv.). The same chart explains the periodic classification, and the spectra of elements. The distinctive nature of the small groups of two, consisting of an alkali and alkaline earth, is clearly brought out. They are formed when any X_1-level (X=K, L, M, N...) is filled, just as the regular groups are obtained when X_2 is filled, transitional groups when X_3 is being filled, as rare earths when X_4 (X=N) is being filled.

For the explanation of spectra with the same chart, see the text.]

are N_1 ($^1S_0$), N_2 (^1P, ^3P), and then M_3 not N_3, which is on a higher level. Now the ^1D-term corresponding to N_3 has the normal value, i.e. Ca $\dfrac{N}{3^2}$, but the ^1D-term corresponding to M_3 must have a higher value, i.e. Ca$\dfrac{N}{2^2}$. This diagram, therefore, symbolically explains the origin of the large D-terms in Ca and also in Sr and Ba. In the spark spectrum of Ca$^+$, it explains why the first of ^2D-terms is larger than ^2P, while in the spectrum of Mg$^+$, ^2P is $> {}^2D$.

Concluding Remarks.

The foregoing work shows that the above scheme of electron arrangement, which is a modification of Stoner's scheme, combined with the rules of synthesis of complicated spectra from the elementary component doublet spectra, gives a very satisfactory explanation of the fundamental as well as of all the higher terms regular and anomalous, of the alkaline earths. Even the detailed differerences (e.g. occurrence of large D-terms in Ca, Ba, Cr, and its absence in Mg) are readily explained. But the theory goes still further. It gives us a clue to the origin of dashed terms. They arise when the stationary electron is in the metastable orbit, and the running electron is in the same orbit or in the higher homologous orbit. We can also obtain some clue regarding the term values. If the orbit arises when both electrons are in the same shell, or the running electron in the previous unclosed shell, the values are large. No matter whether we get S, P, D, F, or G terms, the order of the value will be the same, when the origin of these terms is common. The origin of dashed terms is taken in a subsequent paper.

Thus note that when both electrons in Ca are in M_3-levels, we get ^3F, $^3\overline{P}$, ^1G, ^1D, $^1S_0$ terms. Their order of value is the same.

But if the running electron is in a higher shell, it will give rise to higher Rydberg terms; the values will decrease approximately as $\dfrac{N}{m^2}$, $m = 1, 2, 3$ respectively.

The investigation also shows that differences are expected between the spectra of Ca and Ba. These points are being investigated. It is also apparent that for the calculation of the higher Rydberg terms Pauli's rule is not necessary, and we no longer need the complex calculation involving the magnetic quantum numbers.

In conclusion, the author wishes to express his thanks to Mr. K. Mazumder, who has drawn the charts and tables for him.

39. ON THE EXPLANATION OF SPECTRA OF METALS OF GROUP II*

(PART II)

P. K. KICHLU AND M. N. SAHA

In a previous paper one of us[1] has discussed the origin of the higher Rydberg sequence terms in the normal spectra of elements of group II. It is well known that besides these normal terms all these elements give a number of anomalous terms. They were noticed by Rydberg[2] in 1894 in the spectra of Ca and Sr, and Popow[3] discovered similar groups in the spectra of Ba and Al in 1915. In 1921, Götze[4] interpreted these groups as a transition between the normal p-group and another group which he called p' (sometimes also called $\bar{p}$, which notation we shall follow. That the $\bar{p}$-group was essentially of the same nature as the ordinary p was made clear from investigation of the Zeeman effect of these groups.

Since this time numerous groups of dashed (or barred) terms have been discovered in the spectra of elements of higher groups; but the first indication of the origin of these terms was given by Russell and Saunders[5], and independently by Wentzel.[6] Russell and Saunders discovered other groups of $p\bar{p}$ and $d\bar{d}$ combinations in spectra of Ca, Sr, and Ba. These $\bar{p}$ and $\bar{d}$ terms are sometimes negative, and the abovementioned authors noted that if a certain number was added to these terms they formed approximately a Rydberg sequence. This number was approximately 13700 in the case of Ca, which is about the same as the difference between the values of the fundamental ^2S-term of Ca$^+$ and the next term in order of value, viz. ^2D. From this fact the above-mentioned authors concluded that the anomalous

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[1]M. N. Saha, Phil. Mag., June 1927.
[2]Rydberg, Wied. Ann. lii. p. 119 (1891).
[3]Popow, Ann. der Physik, Bd. xlv. p. 147 (1914).
[4]Götze, Ann. der Physik, Bd. lxvi. p. 285 (1921).

[5]Russell and Saunders, Astrophysical Journal, lxi. p. 38 (1925).
[6]Wentzel, Phys. Zeits. xxiv. p. 106 (1923); xxv. p. 182 (1924).