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The Ordinals of the Elements and the High-frequency Spectra.
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AFTER having made use of integers of a similar kind already in the year 1885* in trying to find out the laws of the atomic weights, in 1896† I expressly emphasized the great importance, or rather the necessity, of introducing for the qualities of the elements a true independent variable instead of the atomic weight, which no doubt is not a simple quality but of a most complex nature. As such an independent variable I proposed the *ordinals* of the elements supposing, after the simple rule for the atomic weights of the first elements from He to Cl, that He had the number 2 and Cl the number 17. Finally, having found in 1913 that the system of the elements did not consist of any periods in an ordinary sense, but of quadratic groups of $4p^2$ elements‡ (p being the number of the group), I did not doubt that the new numbers (which in the beginning of the series from He onwards were 2 units greater than the old ones) must be the true ordinals of the elements, and therefore ventured to propose that they should be used as rational designations besides the ordinary, as for instance Al (15), Co (29), Ni (30), Ag (49), La (59), Ta (75), Au (81), U (94).

Now for me it has been of the utmost interest to see that Mr. Moseley, in his excellent researches on the high-frequency spectra §, has found a simple relation between some of the lines of these spectra and the ordinals of the elements. But as there is a certain difference between my ordinals and Mr. Moseley's numbers, I have allowed myself to calculate his series of lines more completely and in a somewhat different way.

As we see from the publications quoted, Mr. Moseley in the examined spectra has distinguished several kinds of lines, and of these he has published the wave-lengths of six separate series which, referring to Barkla and Moseley, we will, for the present, designate as $K\alpha$, $K\beta$, $L\alpha$, $L\beta$, $L\phi$, and $L\gamma$.

* "Die Gesetze der Atomgewichtszahlen," *Bihang till Sv. Vetensk.-Akad. Handl* xi. No. 13 (1886).

† "Studien über die Atomgewichtszahlen," *Zeitschr. für anorg. Chemie*, xiv. p. 66 (1897).

‡ "Untersuchungen über das System der Grundstoffe," *Lunds Univ. Årsskrift*, N. F. Afd. 2, Bd. ix. Nr. 18 (1913).

§ Phil. Mag. xxvi. p. 1024; xxvii. p. 703.

Of these series Mr. Moseley has calculated only Kα and Lα after formulæ which we may write

for Kα, $$\frac{10^8}{\lambda}=\nu=\nu_0\cdot\frac{3}{4}(N-1)^2,$$

for Lα, $$\frac{10^8}{\lambda}=\nu=\nu_0\cdot\frac{5}{36}(N-7\cdot4)^2.$$

Here ν_0 is my general constant (109720 instead of 109675?) and N the number of the element, supposing N=13 for Al.

These numbers differ, as we see, from my ordinals with 2 units (Al in my system having the number 15), but the order is the same from Al to Au including Co and Ni, where the element of greater atomic weight precedes the lower one. Only the element designated as Ho, which according to Moseley has the number 66, corresponding to my ordinal 68, must, according to my system, be Dysprosium*.

In my calculation of the different series I have, in close agreement with Mr. Moseley, made use of the general formula

$$\frac{10^8}{\lambda}=\nu=109675\,.\,a^2\,(N-C)^2,$$

or

$$a\,(N-C)=\sqrt{\frac{10^8}{109675\,\lambda}}=r,$$

where we from the observations directly obtain the value of the right member r.

In the left member we know that N varies by one unit from one element to the next, and without making any assumption regarding the true absolute values of N, we can always write for two elements of a series

$$a\,(N_1-C)=r_1$$
$$a\,(N_2-C)=r_2,$$

where r_1, r_2 and the integer difference N_2-N_1 are known for all lines.

* In the abstract of his second paper, which Mr. Moseley has been so kind as to send me, I find that he has himself made the same remark and corrected Ho to Dy.

Then we have

$$a\,(N_2-N_1)=r_2-r_1,$$

and

$$a=\frac{r_2-r_1}{N_2-N_1},$$

and can in this way calculate a series of approximate values of a, independent of the absolute values of N.

Having taken the mean of these values of a I have calculated the values of $\frac{r}{a}$ or N$-$C, and found that in all six series these numbers, and consequently also the values of C (N always being an integer), approach very nearly to whole or half units.

I have then assumed that the values of N$-$C end exactly on ·0 or ·5, and on inverting the reckoning have calculated $\frac{r}{N-C}$ or a for every line in the spectra. If the formula of Mr. Moseley is exact, we shall then find a constant value of a in every series.

On using the N-values of my system the values of C will follow directly on taking for any one element the difference N$-$(N$-$C). These values of C are given at the heads of the columns a(N$-$C). As our N-values are 2 units greater than Moseley's, our C-values will also be greater. As we shall see, the six lines form three pairs Kα and Kβ; Lα and Lβ; Lγ and Lϕ, of which the C-value of the first line in every pair contains 3, the second 3·5 as a factor. I have designated the corresponding a-values by a_1, b_1, a_2, b_2, and a_3, b_3 in the three pairs.

In the following tables the above-mentioned reckoning is given for all the six series, with the exception of the later part of Lβ, where the lines seem not to belong to the same series as the first ones, but to have been interchanged in some way. The last 5 lines (Ta to Au), given by Moseley for Lβ, I have carried over to the series Lϕ, where their wave-lengths answer tolerably well. Probably there will be more lines in the high-frequency spectra than those hitherto measured or published.

As we see, the a-values in the different series are nearly constant. Greater deviations occur only at the beginning and at the end of the series, in Kα for the two first and for the 3 (7) last elements; in Kβ for the two first only. In Lα there are some greater values at the ends of the series, but the differences are of no consequence. Lγ and Lϕ show nearly constant values throughout the whole series. Of Lβ I have already spoken. The results for this series are to be regarded as rather uncertain.

First pair of Lines.

N.	Kα.	a_1 (N−3).	Kβ.	b_1 (N−3·5).
Al (15).........	8·364	0·8701 . 12	7·912	0·9335 . 11·5
Si (16).........	7·142	0·8695 . 13	6·729	0·9313 . 12·5
Cl (19).........	4·750	0·8659 . 16	—	——
K (21).........	3·759	0·8652 . 18	3·463	0·9272 . 17·5
Ca (22).........	3·368	0·8659 . 19	3·094	0·9279 . 18·5
Ti (24).........	2·758	0·8659 . 21	2·524	0·9272 . 20·5
V (25).........	2·519	0·8648 . 22	2·297	0·9267 . 21·5
Cr (26)......	2·301	0·8655 . 23	2·093	0·9276 . 22·5
Mn (27)......	2·111	0·8660 . 24	1·918	0·9278 . 23·5
Fe (28).........	1·946	0·8658 . 25	1·765	0·9277 . 24·5
Co (29).........	1·798	0·8661 . 26	1·629	0·9278 . 25·5
Ni (30).........	1·662	0·8675 . 27	1·506	0·9285 . 26·5
Cu (31).........	1·549	0·8665 . 28	1·402	0·9273 . 27·5
Zn (32).........	1·445	0·8662 . 29	1·306	0·9271 . 28·6
Y (41).........	0·838	0·8681 . 38	—	——
Zr (42).........	0·794	0·8689 . 39	—	——
Nb (43).........	0·750	0·8717 . 40	—	——
Mo (44)......	0·721	0·8674 . 41	—	——
Ru (46)......	0·638	0·8792 . 43	—	——
Pd (48).........	0·584	0·8781 . 45	—	——
Ag (49).........	0·560	0·8772 . 46	—	——

Second pair of Lines.

N.	Lα.	a_2 (N−9).	Lβ.	b_2 (N−10·5).
Zr (42).........	6·091	0·3708 . 33	—	——
Nb (43).........	5·749	0·3704 . 34	5·507	0·3959 . 32·5
Mo (44)......	5·423	0·3705 . 35	5·187	0·3958 . 33·5
Ru (46).........	4·861	0·3702 . 37	4·660	0·3940 . 35·5
Rh (47).........	4·622	0·3696 . 38	—	——
Pd (48).........	4·385	0·3697 . 39	4·168	0·3944 . 37·5
Ag (49).........	4·170	0·3697 . 40	—	——
Sn (52).........	3·619	0·3691 . 43	—	——
Sb (53).........	3·458	0·3690 . 44	3·245	0·3944 . 42·5
La (59).........	2·676	0·3692 . 50	2·471	0·3961 . 48·5
Ce (60).........	2·567	0·3695 . 51	2·360	0·3971 . 49·5
Pr (61).........	2·471	0·3694 . 52	2·265	0·3973 . 50·5
Nd (62).........	2·382	0·3692 . 53	—	——
Sa (64).........	2·208	0·3695 . 55	—	——
Eu (65).........	2·130	0·3695 . 56	—	——
Gd (66).........	2·057	0·3694 . 57	—	——
Dy (68).........	1·914	0·3699 . 59	—	——
Er (70).........	1·790	0·3700 . 61	—	——
Ta (75).........	1·525	0·3705 . 66	—	——
W (76).........	1·486	0·3697 . 67	—	——
Os (78).........	1·397	0·3703 . 69	—	——
Ir (79).........	1·354	0·3707 . 70	—	——
Pt (80).........	1·316	0·3707 . 71	—	——
Au (81).........	1·287	0·3697 . 72	—	——

Third pair of Lines.

N.	Lγ.	a_3 (N−12).	Lφ.	b_3 (N−14).
Pd (48).........	3·928	0·4232 . 36	—	——
La (59).........	2·313	0·4224 . 47	2·424	0·4310 . 45
Ce (60).........	2·209	0·4233 . 48	2·315	0·4314 . 46
Sa (64).........	1·893	0·4221 . 52	1·972	0·4301 . 50
Eu (65).........	1·814	0·4230 . 53	1·888	0·4309 . 51
Gd (66).........	—	——	1·818	0·4307 . 52
Er (70).........	—	——	1·563	0·4313 . 56
Ta (75).........	1·287	0·4225 . 63	1·330	0·4292 . 61
Os (78).........	1·172	0·4226 . 66	1·201	0·4305 . 64
Ir (79).........	1·138	0·4225 . 67	1·155	0·4323 . 65
Pt (80).........	1·104	0·4226 . 68	1·121	0·4321 . 66
Au (81).........	1·078	0·4215 . 69	1·092	0·4313 . 67

On taking the means of the *a*- and *b*-values for the different series, we find :—

Series.	Constant.	Elements which enter in the mean.	Mean value.
Kα.	a_1.	All except the three last (Ru, Pd, Ag).	0·8671
	,,	The constant middle-part from Cl to Zn.	0·8660
Kβ.	b_1.	All measured by Moseley.	0·9283
	,,	All except Al and Si.	0·9275
Lα.	a_2.	All.	0·3698
	,,	The 12 constant, Rh to Gd.	0·3694
Lβ.	b_2.	All here given in the table.	0·3956
	,,	The six first only.	0·3951
Lγ.	a_3.	All.	0·4226
Lφ.	b_3.	All.	0·4310
	,,	The six original φ-lines.	0·4309

We have then the following table for the constants C and *a* or *b* of the series on taking the best values from their most constant parts.

	First pair.		Second pair.		Third pair.	
Designations of series.	Kα (1 *a*)	Kβ (1 *b*)	Lα (3 *a*)	Lβ (3 *b*)	Lγ (4 *a*)	Lφ (4 *b*)
Values of C.	3 1 . 3	3·5 1 . 3·5	9 3 . 3	10·5 3 . 3·5	12 4 . 3	14 4 . 3·5
a (or *b*) ...	0·8660	0·9275	0·3694	0·3951	0·4226	0·4309
a^2	0·7500	0·8603	0·1365	0·1561	0·1786	0·1857
$\frac{a^2}{C}$	0·2500	0·2458	0·0152	0·0149	0·0149	0·0133

As we have already remarked, the six different kinds of lines can be considered as forming three groups with respectively 3 or 3·5 as factors in their C-values, these factors being multiplied respectively by 1, 3, and 4 in the three groups. The analogy would suggest the existence of a fourth pair of series (2 *a*) and (2 *b*) with 2.3=6 and 2.3·5=7 as values of C. But of course the material of observation is not yet sufficiently great or exact to allow any conclusions of this kind.

There can hardly be any doubt that the very interesting form of the *a*-value for Lα, $a=\sqrt{\frac{3}{4}}$ given by Mr. Moseley, is the true one, as it coincides exactly with the mean of a_1. But his value $\sqrt{\frac{5}{36}}=0\cdot3727$ for a_3 seems too great, if we wish to retain the integer value 9 for C in Lα.

In the complete coincidence of the order of Mr. Moseley's numbers and of my ordinals of the elements, I see a very strong support of my system, according to which there should be respectively 4, 16, 36, and 64 elements in the four first groups. But then also we shall get my ordinals instead of the numbers used by Mr. Moseley*, and for Al the number 15, for Au 81, and my *a*-constants 3 and 9, instead of 1 and 7·4 by Moseley.

The apparent regularity of the C-values in the different series seems also to speak for the opinion that my ordinals are the true ones.

Lund, May 11, 1914.

* The same remark is also to be made in regard to the numbers given by Sir E. Rutherford in Phil. Mag. xxvii. p. 868 (1914), for instance Pb=84, U=94.