IONIZATION AND RADIATION POTENTIALS AND THE SIZE OF THE ATOM

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Professor A. S. Eve has recently published an interesting note on a relation between the ionization potential and the size of the atom. (*Nature*, June 30, 1921).

For some time I had been accumulating data for a similar comparison, but from a somewhat different point of view. Eve considers that the size of the atom is determined by the radius of the outer ring. The work (ionization potential) required to lift an electron from this ring by the Bohr model is proportional to $1/a$. The product Ixa should be a constant. Trials of this relation are made for a number of elements using both the cube-roots of the atomic volumes and estimates of the diameters of atoms made by W. L. Bragg from crystal structure and measurements. (*Phil. Mag.*, Aug., 1920). The results obtained by Eve showing the degree of constancy (and departures from constancy)are repeated here in columns 6 and 7 of the table.

The boundary of the atoms, however, should not correspond exactly with the outer ring, but should extend beyond it. If the electron ring were the limit in the solid state, it would require no work to remove an electron from an atom in this state. The photo-electric effect shows that work is required, that it is less than the ionizing potential, but is approximately the same as the radiation potential. I here consider that the limit of the atom is the ring or distance from the center that an electron needs to be lifted to produce the radiation potential. That is, an atom in the solid state of matter is ionized at a potential about equal to the radiation potentials in the gaseous state. The ionizing potential is given by

$$I = A/a,$$

where A is a constant and a is the radius of the electron ring or orbit. If b is the distance from the atomic center then an electron must be lifted to produce radiation, then the radiation potential is given by

$$R = A/a - A/b,$$

where A/b is the work required to remove an electron from position b entirely from the atom in the gaseous state.

$$I - R = A/b,$$

The product $(I - R)b$ or, for comparison with atomic volumes, $(I - R)\sqrt[3]{A.V.}$ should be a constant. The last two columns of the table show the results obtained for the above products. The values of the atomic diameters expressed in Ångstrom units are repeated from Eve's paper which were taken from a list by Bragg.

TABLE 1

E	I	R	D	$\sqrt[3]{A.V.}$	I × D	I × $\sqrt[3]{A.V.}$	(I − R) × D	(I − R) $\sqrt[3]{A.V.}$
H	13.8	10.2		2.45		33.8		8.82
				Group I				
Na	5.13	2.12	3.58	2.87	18.1	14.7	10.74	8.61
K	4.32	1.55	4.15	3.57	17.9	15.4	11.5	9.64
Rb	4.15	1.55	4.50	3.81	18.7	15.9	11.7	9.90
Cs	3.9	1.48	4.75	4.12	18.4	16.0	11.5	9.97
				Range	.8	1.3	1.00	1.37
				Group II A				
Mg	7.61	2.65	2.85	2.4	21.7	18.3	14.14	12.24
Ca	6.09	1.90	3.40	2.96	20.8	18.0	14.28	12.16
Sr	5.67	1.80	3.90	3.25	22.2	18.4	15.2	12.57
Ba	.19	1.56	4.20	3.31	21.8	17.2	15.25	12.03
				Range	1.4	1.2	1.11	.54
				Group II B				
Zn	9.35	4.02	2.65	2.09	24.77	19.5	14.12	11.2
Cd	8.95	3.79	3.20	2.35	28.64	21.0	16.25	12.12
Hg	10.38	4.85		2.45		25.4		13.47
				Range	3.87	5.9	2.13	2.27
				Group III B				
Tl	7.3	1.07	4.50	2.58	32.85	18.8	28.	16.07
				Group IV B				
Pb	7.93	1.26	3.80	2.63	30.13	20.8	25.38	17.54
				Group V A				
As	11.5	4.7	2.52	2.36	29.	27.2	17.14	16.00
				2.52		29.0		17.1
P	13.3	5.8		2.37		31.5		17.78
				2.57		34.2		19.27
				Range		4.3		1.78
						5.2		2.17
				Group VI				
S	12.2	4.78	2.05	2.5	25.	30.4	15.17	18.5
				Group VII A				
I	10.1	2.34	2.8	2.95	28.3	29.8	21.73	22.9
				Inert Gases				
He	25.6	20.5		2.86		73.		14.25
Ne	21.3	16.9	1.3	2.67	27.7	42.8	5.72	13.33
A	15.5	11.5	2.05	3.03	31.77	36.4	8.2	12.1
				Range	4.00	36.6	2.5	2.15

The values of the radiation potentials for strontium and barium have not been directly determined, but Mohler, Foote and Megers (*Sci. Paper, Bureau of Standards*, No. 403, 1920) give estimates from the wave-lengths of the tail lines of the proper spectral series for these elements. Hydrogen is added to the table, although not given by Eve. An inspection of the table brings out the following:

For Group I, the degree of constancy of the products is nearly the same, being slightly in favor of the use of I rather than (I — R). Group II A, shows, on the other hand, that (I — R) gives a better agreement than I. This is still more marked in Group II B. Group V A is considerably more favorable to (I — R). In case of the inert gases the product using I alone does not hold at all, while the product (I — R) gives nearly a constant. The product using (I — R) places hydrogen in good agreement with the first Group. Mercury, which has some of the physical qualities of the inert gases, has a product about equal to that for those gases. In case of the whole table, going from Group to Group, the products using (I — R) are much more constant than is the case with I alone.

*PERIODS AND LOGARITHMIC DECREMENT OF THE GRAVITATION NEEDLE UNDER HIGH EXHAUSTION**

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The Deflections.—After a search for a finer quartz fibre than was used in my last paper, one was found giving a double deflection of $\Delta y = 13.42 \pm .03$ cm. as compared with the former 2.67 cm., for the same case and needle. In spite of this astonishing sensitivity and otherwise admirable behavior of the apparatus, the new result for Δy from 30 successive night observations came out relatively less accurate than the former. At the same time, the observations on any single night (details must be omitted here) rarely differed by more than .1%. It is a case therefore in which the increasing importance of the radiation forces renders further finessing with the fibre of doubtful use in the given environment.

Logarithmic Decrements $\lambda \log \epsilon$.—In the endeavor to cope with this formidable difficulty, I began a study of the vibration of the needle in high vacua of a few thousandths of a millimeter; but the summer vanished before I completed it. The results so far obtained are interesting, however, and are given in the attached chart. The case was exhausted in the beginning to about 2.6×10^{-3} mm. on the McLeod gauge, and then sealed off. Air, however, in the lapse of 11 days very slowly leaked in through the glass cock and rubber tubes; and as the installment prevented me from finding the successive vacua (always beyond the U-gauge limit) I have expressed