

Soné,

$$\chi_{\text{O}_2} = 104.1 \times 10^{-6} \quad (20^\circ \text{ C}).$$

The values, for oxygen 104.1×10^{-6} , and for NO 48.6×10^{-6} , give results in still closer agreement with Pauli's equation. The ratios of the theoretical and experimental values are, for O₂ 1.019, and for NO 1.067, instead of 1 where for oxygen $n = 2$ and for NO $n = 1$.

We see that oxygen at least has very nearly a magneton of Bohr with the quantum number 2, or 2 magnetons. Experiments are in progress to re-determine the susceptibilities of paramagnetic and diamagnetic gases.

UNIVERSITY OF ILLINOIS,
October, 1921.

THE GROWTH AND DECAY OF PHOTO-THERMIONIC CURRENTS FROM OXIDE-COATED FILAMENTS.

BY H. D. ARNOLD AND HERBERT E. IVES.

AN investigation of the increase of thermionic current caused by illumination. It is found that the current increment due to red light grows and decays exactly as a similar increment due to increasing the temperature of the oxide coated filament. With blue light, on the contrary, the added thermionic current grows and decays at rates different from those due to heating, and at different rates depending on the temperature. At low filament temperatures the added current rises and falls very slowly; at high temperatures it rises and falls abruptly. These properties of the added current due to blue light are considered to differentiate it from a true photo-electric current which, as far as known, rises and falls instantaneously at all temperatures. It is concluded that previously recorded observations on changes in the magnitude of the added current with variation of filament temperature, do not necessarily imply a temperature coefficient of the true photo-electric effect.

RESEARCH LABORATORIES OF THE
AMERICAN TELEPHONE & TELEGRAPH COMPANY
AND WESTERN ELECTRIC COMPANY, INC.

THE ABSOLUTE SIZES OF CERTAIN MONOVALENT AND BIVALENT IONS.¹

BY WHEELER P. DAVEY.

IN a preceding paper² attention was called to the fact that if the dimensions of crystals were used alone, to find the absolute sizes of ions, the solution was indeterminate, for there were $n - 1$ equations with which to solve for n unknowns. At that time a consideration of the diffraction patterns of KCl led to the assumption that K^+ , Rb^+ , and Cs^+ were equal in size respectively to

¹ Abstract of a paper to be presented at the Am. Phys. Soc., November, 1921.

² W. P. Davey, *PHYS. REV.*, Aug., 1921.

$\bar{\text{Cl}}$, $\bar{\text{Br}}$ and $\bar{\text{I}}$, thus giving $n + 2$ equations for n unknowns. The concordant numerical results obtained by the use of these three additional, independent equations amply justified the assumption, at least to an accuracy of one per cent. At that time, values were reported for the "radii" of ions of the alkali metals and of the halogens. It is the purpose of the present paper to report the corresponding dimensions of Ag^+ , Cu^+ and of certain bivalent ions.

Since the dimensions of bivalent metallic ions are most conveniently determined from the crystals of their oxides and sulphides, it was necessary to obtain as accurate a determination as possible of the "radius" of $\bar{\text{O}}$. To this end, four routes were employed, namely (1) $\text{CsI-AgI-Ag}_2\text{O}$; (2) $\text{CsI-CuI-Cu}_2\text{O}$; (3) $\text{KCl-KF-CaF}_2\text{-CaO}$; (4) $\text{KCl-KF-BaF}_2\text{-BaO}$. The first two of these depend primarily upon the assumption that the radii of $\bar{\text{Cs}}$ and $\bar{\text{I}}$ are equal. The last two depend upon the assumption that the radii of $\bar{\text{K}}$ and $\bar{\text{Cl}}$ are equal. The last two routes are longer than the first two, so that the cumulative effect of experimental errors in the data is greater. These last routes, therefore, should not be expected to give as concordant results as the first two routes. They should, however, at least serve as valuable checks upon the validity of the results, since they are arrived at by means of values which are quite independent of those used in the first two routes.

Routes 1 and 2.—The chloride, bromide, and iodide of silver were investigated. The first two were found to be simple cubes of ions of side 2.76 and 2.89 Å, respectively. Silver iodide is a diamond-cube of ions of side 6.53 Å, *i.e.*, the shortest distance between centers of $\bar{\text{Ag}}$ and $\bar{\text{I}}$ is 2.83 Å. These structures are in agreement with those reported by Wilsey¹ and the dimensions agree with his to within one per cent. The chloride and bromide give "radii" for Ag^+ of 1.20 and 1.16 Å, respectively. The dimensions of the two crystals would not have to be in error by more than $\frac{2}{3}$ of one per cent. to account for this difference. The iodide gave a radius for Ag^+ of .85 Å. This discrepancy can not be accounted for on the basis of experimental error. CuCl , CuBr , and CuI crystals are all diamond-cubes of ions, with sides 2.32, 2.49 and 2.63 Å, respectively, giving "radii" for Cu^+ of .76, .76 and .65 Å. Here, as in the case of Ag^+ the values obtained from the chloride and bromide are in agreement with each other, but are larger than that obtained from the iodide. Either the silver and copper ions are of such a shape that they appear to have two dimensions (such as might be obtained by ascribing a "radius" to a tetrahedron), or they occur in two entirely different shapes, thus giving two different dimensions. The latter possibility was predicted by Langmuir² in the case of Ni and Pd atoms. If this possibility is granted in the case of Ni and Pd

¹ R. B. Wilsey, *Phil. Mag.*, 42, 262 (1921).

² I. Langmuir, *Jour. Am. Chem. Soc.*, 1919.

atoms, it should also hold for not only Cu^+ and Ag^+ , but also for Zn^{++} and Cd^{++} ions. It will be shown below that Cd^{++} appears to have two sizes. So far, only one size has been found for Zn^{++} .

Ag_2O and Cu_2O were each found to consist of a body-centered cube of $\bar{\text{O}}$ and a face-centered cube of the metal ion. These two cubes interpenetrate in the manner described by Bragg for Cu_2O (cuprite).¹ The sides of the cubes are 4.69 and 4.26 Å, respectively. The position of the $\bar{\text{O}}$ in Ag_2O is identical with the position of the $\bar{\text{I}}$ in the iodides,—it is in the center of a tetrahedron of Ag^+ . The difference in “radii” between $\bar{\text{I}}$ and $\bar{\text{O}}$ may therefore be determined directly by the difference in the distances between Ag^+ and $\bar{\text{I}}$ and between Ag^+ and $\bar{\text{O}}$, *i.e.*, $\bar{\text{I}} - \bar{\text{O}} = 2.83 - 2.03 = .80$. Since the “radius” of $\bar{\text{I}}$ is 1.98 Å, the “radius” of $\bar{\text{O}}$ is 1.18 Å. A similar calculation, using Cu_2O and CuI gives $\bar{\text{O}} = 1.19$ Å.

Routes 3 and 4.—The structure of CaF_2 was shown by Bragg to be a modified diamond-cube. The side of this cube is 5.49 Å, so that the distance between centers of Ca^{++} and $\bar{\text{F}}$ is 2.38 Å. Since the “radius” of $\bar{\text{F}}$ is 1.13 Å, the “radius” of Ca should be 1.25 Å. Now CaO is a simple cube of ions, of side 2.42 Å.² This gives a “radius” for O of 1.17 Å. BaF_2 has a structure like that of CaF_2 . The side of the cube is 6.20 Å, giving a distance between centers of Ba^{++} and $\bar{\text{F}}$ of 2.69 Å. This gives a “radius” for Ba^{++} of 1.56 Å. Bragg³ gives the distance between centers of Ba^{++} and $\bar{\text{O}}$ as 2.81 Å. This leaves the “radius” of $\bar{\text{O}}$ as 1.25 Å. These two values of 1.17 and 1.25, obtained by routes 3 and 4 check very well with the values of 1.18 and 1.19 obtained by the more direct routes 1 and 2. The “radius” of $\bar{\text{O}}$ will therefore be considered to be 1.19 Å.

The difference in the “radii” of $\bar{\text{O}}$ and $\bar{\text{S}}$ as shown by BaO and BaS is .39 Å, by ZnO and ZnS , .40 Å, by CaO and CaS , .40 Å. The “radius” of $\bar{\text{S}}$ may therefore be taken as 1.59 Å. The following table gives the values for the “radii” of ions which have been determined since the report in the *PHYSICAL REVIEW* of Aug. 1921. Crystal data on SrO and BaO are from Bragg’s published work. All other data are from this laboratory.

¹ W. H. and W. L. Bragg, *X-Rays and Crystal Structure*.

² W. P. Davey, *PHYS. REV.*, May, 1920.

³ W. L. Bragg, *Phil. Mag.*, Aug., 1920.

Ion.	Crystal.	"Radius."
$\bar{\bar{O}}$	CaO - 1.17 BaO - 1.25 Cu ₂ O - 1.19 Ag ₂ O - 1.18	1.19 - Å.
$\bar{\bar{S}}$	CaS - 1.59 ZnS - 1.59 BaS - 1.58	1.59
$^{+}Cu_{(1)}$	Cu Cl - .76 Cu Br - .76	.76
$^{+}Cu_{(2)}$	CuI	.65
$^{+}Ag_{(1)}$	Ag Cl - 1.20 Ag Br - 1.16	1.18
$^{+}Ag_{(2)}$	AgI	.85
^{+}Tl	Tl Cl	1.77
^{++}Mg	MgO	.90
^{++}Ca	CaF ₂	1.25
^{++}Sr	SrO - 1.44 SrF ₂ - 1.40	1.42
^{++}Ba	BaF ₂	1.56
^{++}Zn	ZnO	.76
$^{++}Cd_{(1)}$	CdO	1.11
$^{+}Cd_{(2)}$	CdS	.95
^{++}Ni	NiO	.88
^{++}Sn	SnS	.93
^{++}Pb	PbS	1.33

RESEARCH LABORATORY,
GENERAL ELECTRIC Co.,
SCHENECTADY, N. Y.,
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ON THE UNIVERSAL DISTANCE OF THE ORDER OF 10^{-8} CM. BETWEEN THE
CENTERS OF THE NEAREST ATOMS IN SOLIDS.

BY ALBERT C. CREHORE.

By using the model of the atom described in previous abstracts¹ it has been found that two such atoms may unite to form a diatomic molecule. The distance between the two atoms is of the order of 10^{-8} cm., and the common

¹ PHYS. REV., April, 1921, pp. 541, 544.