add the following data for three orange red samples.   Biotites from contact ores of Parry Sound, Ontario, and from Thompkins Cove, Hudson River, New York, had about 3 per cent of TiO_2; that from olivine gabbro at Duluth, Minnesota, had about 6 per cent TiO_2.   The most titaniferous biotite analyzed (color unknown) is probably one from shonkinite at Katzenbuckel,[12] containing 12.02 per cent. It should be added, however, that the manganiferous biotites are also red brown.

NOTE ON SPECIFIC GRAVITY: From Doelter's data[13] and a few new cases, a curve was drawn for average specific gravity variations with total iron oxide content.   The iron determines the gravity with an error probably less than .01 in nearly all cases.   The curve ranges from 2.70 with no iron, to 3.3 with 40 per cent iron oxides, and is nearly straight.   The accuracy of such work, however, is probably less than that based on indices of refraction. No further work was therefore attempted.

[12] Rosenbusch, H., Gesteinslehre, p. 201. (Stuttgart, 1910).
[13] *Op. cit.*

FURTHER NOTES ON ATOMIC VOLUME ISOMORPHISM

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In two previous notes on this subject,[1] the writer has pointed out how certain peculiar isomorphous replacements can be explained by the atomic volume relations, but values were there given for but few of the elements. Several requests for data on others having been received, a more complete list is here presented. Radii are stated in 10^{-8} cm., and volumes, based on the assumption that the atomic domains are spheres, are derived from them by the formula $V = 4/3\pi r^3$. For some purposes it will be better to consider the domains to be polyhedrons,[2] and then other formulas will apply, but these are to be discussed elsewhere.

In deriving dimensions from compounds, some of the constituents must be assumed to have a definite, fixed diameter; and since most of the best X-ray measurements have been made on oxides and halides, it is customary to apply this assumption to

[1] *Am. Min.*, 8, 1-8, 94-95, (1923).
[2] *Am. Min.*, 9, 45-54, (1924).

oxygen and the halogens. By comparing the atomic distances in oxides with those in the free forms of the corresponding metals, Bragg[3] fixed the radius of oxygen at 0.65, and there is no reason to question the general correctness of this value. By a fortunate chance, the corresponding spherical volume is near unity, so that oxygen may perhaps be considered a sort of standard of volume, as it is of atomic weight.

As pointed out, however, by Wyckoff,[4] Bragg's values for the halogens lead to many discrepancies between theoretical and calculated interatomic distances. They were based on comparison of the radii of the alkali and alkaline earth metals with the distances of metal from halogen in a considerable number of halides; but as these metals give evidence of being decidedly larger in the free state than in combination, such derivation of atomic radii is open to criticism. It is preferable to start with a presumably less variable metal, and silver will here be used. Assuming spherical shape, the radius of the silver atom in the free state is 1.43. The distance between silver and chlorine in cerargyrite has been accurately measured, and is 2.77, so the radius of chlorine would appear to be 1.34. As the variability in size of the silver atom may be appreciable,[5] this may well be rounded off to 1.35. This compares favorably with the mean value obtained by Richards[6] in his studies of the compressibility of the constituents of the alkali halides, namely 1.40, and is here adopted as the basis of a new series of calculations of atomic dimensions.[7]

The average values of the radii and volumes of most of the chemical elements, excluding the rare earths and some of the radioactives, concerning which there is little basis for inferences as to dimensions, are presented in table 1. As the variation from one compound to another may reach $\pm 35\%$ of the mean (though usually less) and as in but few cases have measurements been made with an accuracy sufficient to yield values certain to the second place, the radii are stated only to the nearest five in that place.

[3] *Phil. Mag.*, **40**, 169-189, (1920).

[4] *Proc. Nat. Acad. Sci.*, **9**, 33-38, (1923).

[5] Thus in Ag_2O, if the radius of O is 0.65, that of Ag is 1.40, a difference of 0.03.

[6] *J. Am. Chem. Soc.*, **45**, 422-437, (1923).

[7] The newly calculated values for the halogens and for the alkali metals agree with those given by Richards well within the limits of error of the respective methods. These values also approach more closely than do those of Bragg to the radii according to Davey, *Phys. Rev.*, **22**, 211-220, (1923).

Interpolated and theoretical values are placed in parentheses. In some cases the volumes here given differ from those of the previous notes, owing to the use of the new value for Cl, as well as to the inclusion of data from recent X-ray measurements, the introduction of which has made some changes in the averages. Future work will no doubt lead to further changes, altho these seem likely to be in most cases but slight.

TABLE 1. AVERAGE DIMENSIONS OF ATOMS OF THE ELEMENTS

ELEMENT	RAD.	VOL.	ELEMENT	RAD.	VOL.	ELEMENT	RAD.	VOL.
1.H	0.95	3.6	25.Mn	1.50	14.1	49.In	(1.5)	14.1
2.He	(1.0)	4.2	26.Fe	1.30	9.2	50.Sn	1.40	11.5
3.Li	1.25	8.2	27.Co	1.30	9.2	51.Sb	1.50	14.1
4.Be	1.15	6.4	28.Ni	1.35	10.3	52.Te	1.40	11.5
5.B	(1.0)	4.2	29.Cu	1.10	5.6	53.I	1.70	20.6
6.C	0.70	1.4	30.Zn	1.35	10.3	54.Xe	(2.0)	33.5
7.N	0.65	1.2	31.Ga	(1.3)	9.2	55.Cs	2.20	44.6
8.O	0.65	1.2	32.Ge	1.20	7.2	56.Ba	2.10	38.8
9.F	0.85	2.6	33.As	1.30	9.2	....	....	
10.Ne	(1.2)	7.2	34.Se	1.20	7.2	72.Hf	(1.7)	20.6
11.Na	1.50	14.1	35.Br	1.50	14.1	73.Ta	1.40	11.5
12.Mg	1.45	12.8	36.Kr	(1.7)	20.6	74.W	1.35	10.3
13.Al	1.40	11.5	37.Rb	1.95	31.1	75.—	(1.4)	11.5
14.Si	1.15	6.4	38.Sr	1.90	28.7	76.Os	1.35	10.3
15.P	(1.1)	5.6	39.Yt	(1.8)	24.4	77.Ir	1.35	10.3
16.S	1.05	4.9	40.Zr	1.60	17.2	78.Pt	1.40	11.5
17.Cl	1.35	10.3	41.Cb	(1.3)	9.2	79.Au	1.45	12.8
18.A	(1.6)	17.2	42.Mo	1.35	10.3	80.Hg	1.60	17.2
19.K	1.80	24.4	43.—	(1.4)	11.5	81.Tl	1.95	31.1
20.Ca	1.75	22.4	44.Ru	1.35	10.3	82.Pb	1.80	24.4
21.Sc	(1.7)	20.6	45.Rh	1.35	10.3	83.Bi	1.55	15.6
22.Ti	1.45	12.8	46.Pd	1.40	11.5	....	....	
23.V	1.30	9.2	47.Ag	1.40	11.5	90.Th	1.80	24.4
24.Cr	1.25	8.2	48.Cd	1.65	18.8	91.Bv	(1.6)	17.2
						92.U	(1.4)	11.5

The relation between some of the peculiar cases of isomorphism and the elementary dimensions can best be brought out by re-stating these data in another form, and this is done in tables 2 and 3 In the first of these the elements are arranged in a periodic table in the order of their atomic number, the form used having the advantage of not requiring the usual but meaningless grouping of Cu, Ag and Au with the alkalies, Mn with the halogens, etc.

The letters used at the heads of columns refer to the more important system of crystallization of the elements; here: C=

TABLE 2. ELEMENTS ARRANGED IN AN ATOMIC-NUMBER PERIODIC TABLE

Crystn.	C	HC	CH	CH	C	C	C	CH	CH	C	C	H	T	CT	CH	OH	O	C
H	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	He
Li	Be	B	C	...	...	...	...	...	...	...	...	...	...	...	N	O	F	Ne
Na	Mg	Al	Si	...	...	...	...	...	...	...	...	...	...	...	P	S	Cl	A
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Yt	Zr	Cb	Mo	43	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	(RE)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	Hf	Ta	W	75	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	85	Rd
87	Ra	Ac	Th	Bv	U	...	...	...	...	...	...	...	...	...	...	...	...

TABLE 3.. ELEMENTS ARRANGED IN AN ATOMIC-DIMENSION PERIODIC TABLE

rad.	vol.																		
0.65	1.2															N	O		
0.70	1.4				C														
0.75	1.8																		
0.80	2.1																		
0.85	2.6																	F	
0.90	3.1																		
0.95	3.6	H																	
1.00	4.2			(B)													S		(He)
1.05	4.9																		
1.10	5.6										Cu					(P)			
1.15	6.4		Be		Si									Ge		Se		(Ne)
1.20	7.2																		
1.25	8.2	Li				Cr		Fe	Co				(Ga)	As				
1.30	9.2				V	Mo						Zn				Cl		
1.35	10.3			(Cb)W		Ru	Rh	Ni		Zn								
1.40	11.5		Al	Ta	(U)	(43)	Os	Ir	Pd	Ag			Sn		Te			
1.45	12.8		Mg	Ti		(75)			Pt	Au								
1.50	14.1	Na				Mn							In		Sb		Br	
1.55	15.6														Bi			(A)
1.60	17.2			Zr	(Bv)						Hg							
1.65	18.8										Cd							
1.70	20.6		(Sc)	(Hf)												I	(Kr)
1.75	22.4	Ca																
1.80	24.4	K	(Yt)	Th									Pb				
1.85	26.5																	
1.90	28.7	Sr	(RE)														
1.95	31.1	Rb										Tl					
2.00	33.5																(Xe)
2.05	36.1																
2.10	38.8	Ba															
2.15	41.6																
2.20	44.6	Cs															

Noteworthy radius differences between and up columns.

Cs—Rb =0.25	Rb—K =0.15	K—Na =0.35	Na—Li =0.25	Li—H=0.30
Ba—Sr =0.20	Sr—Ca =0.15	Ca—Mg =0.30	Mg—Be =0.30	
(RE—Yt =0.10)	(Yt—Sc =0.10)	Sc—Al =0.30	Al—B =0.40	
	Zr—Ti =0.15	Ti—Si =0.15	Si—C =0.45	
	Sb—As =0.20	As—P =0.20	P—N =0.45	
	Te—Se =0.20	Se—Sl =0.15	S—O =0.40	
	I—Br =0.20	Br—C =0.15	Cl—F =0.50	
	Xe—Kr =0.30	Kr—A =0.10	A—Ne =0.40	(Ne—He=0.20)
(decreasing)	(increasing)	(decreasing)	(increasing)	(decreasing)

Cubic, T=Tetragonal, H=Hexagonal, including Trigonal, and O=Orthorhombic.

In most of the columns of table 3 the order of increasing size of the elements is the same as that of increasing atomic number (table 2) on which the usual periodic table is based. Exceptions appear to occur in several places, but in none of these have the measurements been made with sufficient certainty to show the

reality of the reversal. The atomic weight periodic table contains, however, at least three reversals (the high weights of A, Co and Te), so that it is not impossible that the atomic dimension table also contains some.

The dimensional source of the isomorphism of Na and Ca (and of K and Ba) as urged in the writer's previous articles, is less evident when the new values for these elements are used. However, the values for the alkaline earth metals are very imperfectly known, and moreover, the ability to vary 10% in radius which is evidently possessed by many of the elements (some indeed appearing to vary as much as 35%) would enable even the listed dimensions of Na and Ca to overlap. Other instances of cross-column isomorphism with valence dissimilarity show closer dimension similarity: for example, Mg/Al, Ca/Yt, Ti/Cb, V/Mo, Zn/Ga, Ge/As, Sn/Sb, P/S, and Sb/Te.

SUMMARY—In this paper new atomic radius and volume data are calculated and tabulated in a form which it is hoped may prove useful to mineralogists working on isomorphism as a phenomenon connected with atomic dimensions. For deriving radii from compounds, the radius of oxygen is taken to be 0.65, following Bragg; but the value for chlorine is based on silver and silver chloride, and comes out as 1.35. Average values are given for the radii, and for the volumes on the spherical basis, of most of the elements, and the bearing of the data on certain peculiar cases of isomorphism is discussed.

A SIMPLE ROTATION APPARATUS

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Numerous types of rotation apparatus for the measurement of axial angles and the determination of the angles between faces on small crystals have been devised for microscopic work. All such devices, however, add in varying amounts to the cost of microscopic equipment. Therefore, it is assumed that users of microscopes might be interested in a very simple rotation apparatus that can be quickly constructed for a negligible cost and will give fairly accurate results.

This device, shown in the accompanying sketch, may be easily clamped to the stage of any microscope and as easily removed. It consists of a base of wood 2 cm. wide, 4.5 cm. long and 4 mm.