black oxide which has a low absorption with a very high molecular weight. It is very probable that absorption, like radioactivity, is an atomic phenomenon. A fuller discussion of this question is given in a later paper by Prof. McCoy and myself.

This work was undertaken at the suggestion of Dr. H. N. McCoy, and carried out under his guidance. It is a pleasant duty, in concluding, to express to him my gratitude for his unfailing interest in the work, and for the many helpful suggestions received.

May, 1906.

[CONTRIBUTION FROM THE KENT CHEMICAL LABORATORY OF THE UNIVERSITY OF CHICAGO.]

THE ABSORPTION OF THE α-RAYS OF URANIUM.

BY HERBERT N. MCCOY AND HENRY M. GOETTSCH.

Received August 4, 1906.

IF k_2 is the absorption coefficient (referred to unit weight upon unit area) of the α-rays of any uranium compound, it is found[1] that

$$A = A_1 \left(1 - e^{-\frac{k_2 w}{s}}\right), \qquad (1)$$

where A is the activity of a *uniform, thin* film of the compound, of weight w and area s, and A_1 is the activity of a film of the same compound of equal area and sufficiently thick to be of maximum activity. If $\frac{A}{A_1} = x$, then

$$k_2 = \frac{2.303\, s}{w} \log \frac{1}{1-x}. \qquad (2)$$

Calling k_1 the *total* activity of unit mass of the active compound,

$$k_1 = \frac{2 k_2 A_1}{s}. \qquad (3)$$

In the paper referred to, results were given for three uranium compounds. The values found for k_2 were constant for each compound, but different for different compounds. The values of k_1 as found from those of k_2 by the above equation, were strictly proportional to the uranium content, P, of the compound. This investigation has now been extended by one of us.[2] Table I gives a summary of both series of measurements.

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[1] McCoy: This Journal, 27, 391 (1905).

[2] Goettsch: Preceding paper.

TABLE I.

Series I (McCoy). $s = 40.15$ sq. cm.

Substance.	A_1.	k_2.	k_1.	P.	k_1/P.
U_3O_8	1.000	335	16.69	0.8482	19.7
$(NH_4)_2U_2O_7$	0.720	417	14.95	0.744	20.1
$UO_2C_2O_4.3H_2O$	0.459	507	11.59	0.576	20.1
				Mean,	20.0

Series II (Goettsch). $s = 39.82$ sq. cm.

Substance.	A_1.	k_2.	k_1.	P.	k_1/P.
U_3O_8	1.000	331	16.63	0.8482	19.60
UO_3	0.876	364	16.01	0.8073	19.82
$Na_2U_2O_7$	0.816	358	14.67	0.7427	19.74
$UO_2(IO_3)_2.H_2O$	0.356	413	7.37	0.3715	19.86
$UO_2NH_4PO_4.3H_2O$	0.431	502	10.86	0.5468	19.93
$UO_2S_2O_3.2H_2O$	0.533	431	11.53	0.5732	20.10
				Mean,	19.84

In Table I the values of A_1 and k_1 are expressed, in each series, in terms of the activity of a thick film of U_3O_8 as unity. If, instead, the activity of 1 sq. cm. of such a standard film of U_3O_8 be taken as the unit,[1] then $\frac{k_1s}{P}$ will represent the total activity of 1 gram of uranium, in terms of this unit. For the first series $\frac{k_1s}{P}$ equals 803; for the second, 789. Considering also the other values found by each of us separately by another method,[2] we have taken 790 as the most probable value of this constant. The *total* activity of 1 gram of uranium is independent of its form of chemical combination and equal to 790 times the activity due to 1 sq. cm. of a film of pure U_3O_8 sufficiently thick to be of maximum activity.

Assuming that this relation holds true for every pure uranium compound, as in all probability it does, we may determine the absorption coefficient, k_2, of any uranium compound from a knowledge of the activity, A_1, of a single thick film, of maximum activity.

$$k_2 = \frac{395\ P}{A_1} \qquad (4)$$

The values of k_2 so found, together with those determined directly, are given in Table II, first column. The highest ab-

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[1] McCoy: Phil. Mag. [6] 11, 176 (1906).

[2] McCoy: *Loc. cit.*

sorption coefficient, that of potassium uranyl butyrate, is more than twice as great as the lowest, that of uranous oxide. The magnitude of the absorption coefficient depends upon the chemical composition of the compound. Absorption is found to be an atomic property; for each element, independent of its form of chemical combination, there is a definite absorption coefficient.

TABLE II.

	k_2. obs.	k_2. calc.	$\Sigma\frac{P}{\sqrt{w}}$.	C.	A_1 obs.	A_1 calc.
UO_2	310	288	0.0866	3580	1.126	1.210
U_3O_8	331	310	0.0930	3560	1.000	1.081
$Na_2U_2O_7$	358	364	0.1093	3280	0.816	0.808
$K_2U_2O_7.H_2O$	362	371	0.1116	3240	0.765	0.745
UO_3	364	335	0.1006	3620	0.876	0.952
$CaU_2O_7.H_2O$	373	367	0.1103	3380	0.785	0.796
$BaU_2O_7.4H_2O$	392	396	0.1186	3310	0.591	0.585
$SrU_2O_7.3H_2O$	406	382	0.1149	3530	0.651	0.692
$UO_2(IO_3)_2.H_2O$	413	396	0.1191	3470	0.356	0.370
$NH_4U_2O_7$	417	414	0.1178	3350	0.714	0.705
$UO_2S_2O_3.2H_2O$	431	469	0.1408	3060	0.533	0.483
$UO_2SO_4.3\frac{1}{2}H_2O$	492	512	0.1535	3200	0.362	0.327
$UO_2(NO_3)_2.2\frac{1}{2}H_2O$	493	530	0.1589	3100	0.436	0.406
$UO_2(NO_3)_2.3\frac{1}{2}H_2O$	502	552	0.1654	3030	0.411	0.374
$UO_2NH_4PO_4.3H_2O$	502	567	0.1619	3100	0.431	0.381
$K_2UO_2Cl_4.2H_2O$	506	454	0.1364	3710	0.352	0.392
$UO_2C_2O_4.3H_2O$	507	519	0.1560	3250	0.455	0.438
$KUO_2(NO_3)_3$	517	517	0.1552	3330	0.369	0.368
$K_4UO_2(CO_3)_3$	531	524	0.1572	3380	0.285	0.291
$K_2UO_2(SO_4)_2.2H_2O$	531	527	0.1582	3360	0.302	0.304
$BaUO_2(C_2H_3O_2)_6.2H_2O$	551	557	0.1669	3300	0.320	0.317
$NaUO_2(C_2H_3O_2)_3$	561	578	0.1742	3220	0.357	0.347
$KUO_2(C_2H_3O_2)_3$	573	570	0.1718	3340	0.339	0.340
$K_2UO_2(C_2O_4)_2.3H_2O$	582	573	0.1723	3380	0.280	0.284
$KUO_2(C_3H_5O_2)_3$	599	629	0.1891	3110	0.297	0.283
$KUO_2(C_4H_7O_2)_3$	633	679	0.2038	3170	0.260	0.242
			Mean,	3330		

If P is the weight of any element in 1 gram of a uranium compound, and *k* is the absorption coefficient of that element, *k*P is the partial absorption due to that element and the sum of all such partial values, or ΣkP, is equal to the absorption coefficient of the compound. That is

$$\Sigma kP = k_2. \qquad (5)$$

The coefficients for uranium and oxygen, k_U and k_O, may be calculated by means of equation (5) from the absorption coefficients of the oxides UO_2 and UO_3, which have 88.2 and 80.7 per cent. of uranium respectively.

$$0.882\ k_U + 0.118\ k_O = 310$$
$$0.807\ k_U + 0.193\ k_O = 364.$$

Therefore $k_U = 225$ and $k_O = 864$. From these values the coefficient of U_3O_8 (84.8 per cent. of uranium) is calculated to be 322, which is in good agreement with the value found, 331.

It is found that the product of the absorption coefficient of any element by the square root of its atomic weight is very nearly constant. Thus for uranium, $225 \times \sqrt{238.5} = 3476$; and for oxygen, $864 \times \sqrt{16} = 3456$. Calling this constant C, and the atomic weight of any element W,

$$k\sqrt{W} = C. \qquad (6)$$

Equations (5) and (6) give

$$k_2 = C\left(\Sigma\frac{P}{\sqrt{W}}\right), \qquad (7)$$

and

$$C = \frac{k_2}{\Sigma\frac{P}{\sqrt{W}}}. \qquad (8)$$

The fourth column of Table II contains the values of C calculated by equation (8). The mean value of the constant, C, for all determinations is 3330. The average deviation from the mean is 4.9 per cent. Column 2 of Table II contains the values of k_2 as calculated by means of equation (7) which now becomes

$$k_2 = 3330\ \Sigma\frac{P}{\sqrt{W}} \qquad (7a)$$

The activity, A_1, of a thick film of any uranium compound may be calculated in a very simple way from its composition. Equations (4) and (7a) give by combination,

$$A_1 = \frac{0.1186\ P_U}{\Sigma\frac{P}{\sqrt{W}}} \qquad (9)$$

The last two columns of Table II give the values of A_1 as directly observed and as calculated by equation (9). The average difference between the values of k_2 or of A_1 as observed and as calculated is 4.9 per cent. There are at least three possible sources of experimental error: (1) the measurement of radioactivity; (2) the presence of UX; (3) the determination of the composition. It is probable that the experimental error involved in the determination of the activity of any film in terms of the standard is not over one per cent. in any case. All of our experiments have been made with uranium from which UX had not been removed. The ionization due to the β-rays of UX is very slight, but has not been deducted. Some of the divergencies from the square-root law of absorption may therefore be due to the effect of the β-rays. Most of the substances studied were analyzed for uranium only and the percentages of the other constituents calculated from the chemical formulas. This procedure involved, of course, appreciable errors in cases of compounds not strictly pure and free from absorbed moisture. The results, here presented, are to be considered as preliminary; we are therefore not able at present to decide whether the square root law is exact or only approximate.

The absorption of the α-rays in the active film itself is closely connected with the "loss of range"[1] of α-rays in their passage through a screen of inert matter, covering the radioactive film. Bragg and Kleeman[2] have found, for α-rays, that the "loss of range" in passing through an atom of such a screen is an additive atomic property, which is independent of the state of chemical combination and proportional to the square-root of the atomic weight. There would, therefore, seem to be a very intimate relationship between "loss of range" and absorption, yet Bragg and Kleeman are of the opinion that the ordinary conception of an absorption coefficient for α-rays is erroneous. But our own results on the determination of absorption coefficients of pure uranium compounds have shown such good agreement with the logarithmic law of absorption that we can not avoid thinking that the law is, at least, very approximately correct.

Recently Marckwald[3] has made the interesting observation that certain very fluorescent double salts of uranium, notably the double nitrate with potassium, send out light rays. He determined this by the photographic method. When the salt was tested in the electroscope by Marckwald, the activity was found to be of the order of magnitude to be expected, judging from the activity of the simple nitrate. Marckwald inclines to the view that the emission of light is to be explained by the con-

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[1] The range is the maximum distance from the active film at which the rays produce gaseous ionization.

[2] Phil. Mag. [6] 10, 318 (1905).

[3] Ber. 39, 200 (1906).

version of a part of the radioactivity into luminous energy. We have found the direct determination of k_1 and k_2 for potassium uranyl nitrate to be impracticable, on account of the impossibility of making uniform thin films. The activity of a thick film was found to be 0.369, which is in almost exact agreement with the calculated value, 0.368 (Table II). It is therefore probable that the proportion of radioactive energy converted into luminous energy is, at most, very small.

Our conclusions may be summarized as follows:

(1) Absorption of radioactivity is, like activity itself, an atomic property, independent of the form of chemical combination.

(2) The absorption by unit weight per unit area is, for any element, inversely proportional to the square-root of its atomic weight.

(3) The radioactivity of a thick film of any pure uranium compound may be calculated from a knowledge of its chemical composition.

A REVISION OF THE ATOMIC WEIGHT OF MANGANESE.

By Gregory Paul Baxter and Murray Arnold Hines.

Received August 2, 1906.

The following table, taken from Clarke's "A Recalculation of the Atomic Weights"[1] gives a brief resumé of previous work upon the atomic weight of manganese which has other than historical interest.

$O = 16.000$

Berzelius: Ann. Physik. Chem. 18, 74 (1830).	$MnCl_2 : 2AgCl$	55.12
Turner: Trans. Roy. Soc. Edinb. 11, 143 (1831).	$MnCl_2 : 2AgCl$	54.92
Dumas: Ann. Chem. Pharm. 113, 25 (1860).	$MnCl_2 : 2Ag$	54.98
von Hauer: J. pr. Chem. 72, 360 (1857).	$MnSO_4 : MnS$	54.91
Schneider: Ann. Physik. Chem. 107, 605 (1859).	$Mn : 2CO_2$	54.03
Rawack: Ibid.	$Mn_3O_4 : H_2O$	54.08
Dewar and Scott: Proc. Roy. Soc. 35, 44 (1883).	$AgMnO_4 : AgMnO$	54.86

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[1] Smith. Misc. Coll., Constants of Nature, Part V, p. 283 (1897).