XXVII. The rise of γ -ray activity of radium emanation

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apart of their centres have already been stated ; and both modified models have mean areas of projection which are very easily calculated. The upper limit thus determined proves to be 2.12 times the collision area of the argon atom ; the lower limit is 1.90 times the same area. Using the known value 0.648×10^{-15} cm.² for the collision area of the argon atom, we find that the mean area of projection of the model consisting of two argon atoms with an intermediate neon lies between

$$1.37 \times 10^{-15} \text{ cm.}^2$$

$$\text{and} \quad 1.23 \times 10^{-15} \text{ cm.}^2$$

We may venture to predict with some confidence that the mean collision area of the CS₂ molecule, when determined, will be found to be between the above values. A more exact estimate could of course be made, but the degree of accuracy at present attainable in determining molecular dimensions from viscosity measurements is not sufficient to render the additional calculation worth while.

Summary.

On the assumption of the validity of the Lewis-Langmuir view of molecular constitution, the probable behaviour during encounters has been examined for the molecules of carbon oxysulphide and carbon bisulphide. In the former case it is shown that the molecular dimensions as derived from the application of the kinetic theory to the viscosity measurements of C. J. Smith, are in striking accordance with the results of the above examination. In the latter case comparison is not yet possible, on account of the absence of necessary data.

Imperial College of Science and Technology,
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XXVII. *The Rise of γ -Ray Activity of Radium Emanation.* *By F. P. SLATER, M.Sc. (Vict.), B.A. (Cantab.).**

IN a previous paper† it has been shown how the initial rise of γ -ray activity, starting from pure radium emanation, depended on the nature of the walls of the tube containing the gas, the reason being that a small but

* Communicated by Prof. Sir E. Rutherford, F.R.S.

† Slater, Phil. Mag. vol. xlii. p. 904 (1921).

detectable γ radiation was excited in the walls by the impact of the α particles emitted by the emanation. The amount of this excited radiation was, however, very small when the walls of the tube were composed of atoms of low atomic weight, and for a lining of pure paper the γ -ray activity of the emanation and its products was found to rise practically from zero. Under such conditions the γ radiations from the tube are due only to the products radium B and radium C.

Taking the number of emanation atoms disintegrating per second at initial time as unity, the number of radium-B atoms disintegrating per second at any subsequent time t is

$$\lambda_2 \lambda_3 \sum_{\lambda=1,2,3} \frac{e^{-\lambda_1 t}}{(\lambda_2 - \lambda_1)(\lambda_3 - \lambda_1)},$$

where λ_1 , λ_2 , λ_3 are the transformation constants of the emanation and the products A, B, and C respectively. This quantity is tabulated for various times up to 220 minutes at the end of this paper (Table II.).

Similarly, the number of radium-C atoms disintegrating per second at time t is

$$\lambda_2 \lambda_3 \lambda_4 \sum_{\lambda=1,2,3,4} \frac{e^{-\lambda_1 t}}{(\lambda_2 - \lambda_1)(\lambda_3 - \lambda_1)(\lambda_4 - \lambda_1)}.$$

Tables for this quantity for various times up to 258 minutes have been given by Moseley and Makower* and by Rutherford†.

The rise in γ -ray activity of a tube filled initially with pure emanation can therefore be represented by

$$K \lambda_2 \lambda_3 \sum_{\lambda=1,2,3} \frac{e^{-\lambda_1 t}}{(\lambda_2 - \lambda_1)(\lambda_3 - \lambda_1)} + (1-K) \lambda_2 \lambda_3 \lambda_4 \sum_{\lambda=1,2,3,4} \frac{e^{-\lambda_1 t}}{(\lambda_2 - \lambda_1)(\lambda_3 - \lambda_1)(\lambda_4 - \lambda_1)},$$

where K is the fraction of the ionization, measured under given absorption conditions, due to radium B when in radioactive equilibrium with radium C.

Thus it is necessary to determine " K ." Since the γ rays

* Moseley and Makower, *Phil. Mag.* vol. xxiii. p. 302 (1912).

† Rutherford, 'Radioactive Substances,' p. 499.

from radium B are less penetrating than those from radium C, "K" depends on the thickness of matter through which the radiations pass before entering the ionization chamber. Rise curves have been experimentally determined for different thicknesses of absorption material, both lead and aluminium being used. The values of K for various thicknesses have been deduced by trial, and are shown in fig. 1.

Fig. 1.

A comparison of the experimental and calculated rise curves of the γ -ray activity through 12.0 mm. of lead is given in fig. 2. After six minutes from the introduction of pure emanation, the calculated and experimental curves agree very closely.

From these curves the absorption coefficient of the radium B- γ -rays can be deduced, and the values found are given in Table I. along with comparative determinations by Makower and Moseley (*loc. cit.*) and Rutherford and Richardson*.

The values of the absorption coefficients for the thicknesses of aluminium are somewhat doubtful, since the supposition of homogeneity of the radium-C γ rays is not justifiable through such small thicknesses. The increasing

* Rutherford and Richardson, Phil. Mag. vol. xxv. p. 722 (1913).

value of μ (cm.^{-1}) with decreasing thickness of absorption material (see Table I.) is to be expected, since Rutherford and Richardson (*loc. cit.*) showed that radium B emits certainly two types of radiation having absorption coefficients in aluminium of 0.51 cm.^{-1} and 40.0 cm.^{-1} , and possibly a third type ($\mu = 230.0^{-1}$ in aluminium).

Fig. 2.—Rise of γ activity from Radium emanation through 12.0 mm. of lead.

The absorption coefficients in lead only, given in Table I., are corrected for obliquity of the rays entering the electroscope, and King's correction is used as given in Case II. of his paper *,

$$\frac{I_t}{I_0} = \frac{f(\mu t) - \cos \theta f[\mu t \sec \theta]}{1 - \cos \theta}$$

where I_t and I_0 are the intensities of the radiation emerging through a plate of thickness t cm. and incident radiation respectively, μ the absorption coefficient expressed in cm.^{-1} , and θ the semi-angle of the cone of rays entering the electroscope.

* King, Phil. Mag. vol. xxiii. p. 248 (1912).

TABLE I.

Absorbing medium is Lead, except where otherwise shown.

Thickness of Absorbing Plate.	Value of μ (cm. ⁻¹) for Radium-B rays.	Moseley and Makower.	Rutherford and Richardson.
16.0-20.0 mm.	2.7 cm. ⁻¹	—	Varying from
10.0-15.0 „ ..	2.8 cm. ⁻¹	—	11.0 cm. ⁻¹
4.0- 6.0 „ ..	4.1 cm. ⁻¹	4.0 cm. ⁻¹ (lead).	to 2.8 cm. ⁻¹ in lead.
1.5- 2.0 „ ..	6.2 cm. ⁻¹	6.0 cm. ⁻¹ (lead).	
3.0- 4.0 „ (Aluminium).	1.7 cm. ⁻¹ (Al).		
0.75 mm. (Aluminium) ...	10.0 cm. ⁻¹ (Al) ?		

TABLE II.

Rise of Radium B from Radium Emanation.

Maximum = 0.97480 is taken as unity.

Time in mins.	Calculated rise of Radium B.	Time in mins.	Calculated rise of Radium B.	Time in mins.	Calculated rise of Radium B.
1	0.00269	14 ..	0.2260	110	0.9502
2	0.01016	16	0.2649	120	0.9643
3	0.02129	18	0.3023	130	0.9750
4	0.03513	20	0.3379	140	0.9835
5	0.05115	30	0.4942	150	0.9886
6	0.06862	40	0.6135	160	0.9929
7	0.08718	50	0.7066	170	0.9956
8	0.10647	60	0.7780	180	0.9979
9	0.12622	70	0.8329	190	0.9992
10	0.14624	80	0.8748	200	0.9998
11	0.16637	90	0.9058	210	0.9999
12	0.18641	100	0.9315	214	1.0000
				220	0.9999

Summary.

Curves showing the rise of γ -ray activity from pure radium emanation measured through a wide range of absorption thickness of matter have been determined and utilized in deducing the absorption coefficients of the heterogeneous γ radiation from radium B.

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