The Period of Decay of Radium B and Radium C. By P. BRACELIN. (Communicated by Dr J. CHADWICK.)

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In determining the transformation constant of a radio-active substance by direct experiment, two general methods are available, depending on the precision possible in individual measurements. In the first case, a very accurate determination of the activity of the substance is made at two times, the length of time that elapses between the measurements being relatively unimportant as long as it can be estimated exactly. Alternatively, the decay of the activity may be followed by measurements not so precise individually, and in this case the accuracy of the result is largely influenced by the length of time over which the observations are extended. This requires, over even a small number of half-value periods, that the method of measurement employed is capable of the accurate comparison of widely different activities.

It is a defect in the electroscope method of comparing different ionisation currents that the accuracy obtainable falls off greatly as the ratio of the currents increases, and the error introduced is difficult to allow for. This objection does not apply to galvanometer measurements where, by the use of suitable shunts, it is possible to obtain an accurate comparison of very different intensities of current. The actual strength of the currents measurable even by a sensitive galvanometer demands of course the use of much greater quantities of radio-active material, but, where this is possible, the method seems to be less open to criticism than the use of the electroscope.

In the experiments described below the galvanometer method has been applied to the case of radium C and has been found to give very consistent results. Similar measurements of the decay of radium active deposit have enabled an estimate of the period of radium B to be made.

The apparatus consisted essentially of a parallel plate condenser, one plate being connected through a galvanometer and a megohm resistance to earth, and the other to a source of potential. The plates were enclosed in a glass vessel in communication with a drying tube, a manometer, and an oil pump. Thus dry air at any desired pressure could be obtained, and standard conditions for the different experiments ensured.

The radio-active source was fixed on one of the plates, and the saturation current measured by the galvanometer using a telescope and scale arrangement, which allowed deflections to be estimated

within ·2 mm. with accuracy. The scale was carefully calibrated by means of known currents during each experiment. The resistances of the galvanometer and the shunts employed in conjunction with it were determined by a Post Office box guaranteed correct to 1 in 1000.

The attainment of saturation of α-particle ionisation currents is a difficult matter at atmospheric pressure, but is rendered much easier by working at reduced pressures. Accordingly the experiments were carried out at pressures from 20 to 40 cm. of mercury. In order to be certain that the measurements were performed within the saturation range, the applied potential was varied over the first few readings, starting at a considerably lower value than was afterwards maintained. As these are also the largest currents, this ensures that all the readings are taken at saturation, the applied fields being well below the limit where ionisation by collision was possible. Preliminary experiments with polonium showed also that over a wide range of applied potentials, when saturation was attained, the galvanometer deflection was very free from fluctuations, indicating that the single reading of a particular activity, which it is possible to take when following a decaying ionisation current, was an accurate index of the actual saturation value of the current at that instant.

Radium C. The radium C sources were prepared in the ordinary way by spinning a nickel disc in a solution of radium active deposit in hydrochloric acid at 80° C. The active deposit after removal from the emanation was left for 40 minutes before solution. By this time the radium A present, which would also be deposited by this process on the nickel disc, had decayed to about ·01 per cent. of the original amount. The quantities of radium C used showed an initial activity of the order of 20 mgms. radium, and with these it was possible to follow the decay for a little less than two hours, i.e. six half-value periods.

It is important to check the purity of the sources used, and this was accomplished by measuring the decay over an hour with an α-ray electroscope, five hours after the radium C was collected from solution. It was estimated that 0·5 per cent. radium A deposited initially would cause an increase of 0·2 minute in the observed period over the first two hours, while from 5–6 hours afterwards the difference from the real period would amount to 1·5 minutes. This would easily be detectable by the electroscope measurements. In fact, one experiment in which the RaC was collected about 20 minutes after removal of the deposit from the emanation enabled this to be verified, the period from the galvanometer measurements being estimated at 19·9 minutes and from the electroscope readings as 21·4 minutes. In the experiments from which the transformation

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constant was obtained, the electroscope measurements showed that no perceptible change in the decay period had taken place, giving good grounds for the belief that pure radium C was being used.

The most probable values of the transformation constant λ were calculated by the method of least squares from the results of four experiments, and are given below with their probable errors:

$\lambda \times 10^2$ min.$^{-1}$
$3{\cdot}516 \pm {\cdot}002$
$3{\cdot}521 \pm {\cdot}003$
$3{\cdot}507 \pm {\cdot}003$
$3{\cdot}511 \pm {\cdot}002$

giving a mean value for $\lambda = (3{\cdot}514 \pm {\cdot}007) \times 10^{-2}$ min.$^{-1}$ The corresponding period is $T = 19{\cdot}72 \pm {\cdot}04$ minutes. This is about 1 per cent. greater than the generally accepted value of 19·5 minutes as determined by F. v. Lerch*.

Radium B. The sources of radium active deposit were obtained by exposing a brass disc to decaying radium emanation for about 15 hours, without the application of an electric field. The latter, although of value in concentrating the deposit on the collecting disc, has been found to affect in a variable manner the relative amounts of RaA, RaB, and RaC deposited, and thus to render inaccurate the calculation of the resulting decay based on the assumption of radio-active equilibrium. Three experiments were performed in each of which the decay was followed over nearly three hours.

Under the above conditions, transient equilibrium is attained after about five hours' exposure to the emanation, and after removal of the latter, the amount of radium C present at any instant is given by the formula†

$$\frac{\text{Amount of RaC at time } t}{\text{Initial amount of RaC}} = -(\lambda_2 - \lambda_1)(\lambda_3 - \lambda_1)(\lambda_4 - \lambda_1) \sum_2^4 \frac{e^{-\lambda_n t}}{(\lambda_1 - \lambda_n)(\lambda_3 - \lambda_n)(\lambda_4 - \lambda_n)},$$

where λ_1, λ_2, λ_3, λ_4 are the transformation constants of radium emanation A, B, C respectively.

The initial decay is complicated by the presence of radium A, which also gives α-particles, but after about 30 minutes the effect of the radium A is negligible, and the observed activity ought to be in agreement with the values calculated from the above equation.

The accepted values for λ_1 and λ_2 were taken and the value $3{\cdot}514 \times 10^{-2}$ min.$^{-1}$ for λ_4 as found above. For λ_3 various numerical

* F. v. Lerch, *Ann. der Phys.* vol. 20, 2, pp. 345–54 (June, 1906).

† Cf. Rutherford, *Radioactive Substances and their Radiations*, p. 498.

values were substituted, and it was found that while other values could be discarded, the values $2{\cdot}587 \times 10^{-2}$ min.$^{-1}$ and

$$2{\cdot}596 \times 10^{-2} \text{ min.}^{-1}$$

for λ_3 both gave very good agreement with the experimental results. If anything, the experimental data seem to indicate that values calculated on the basis of $\lambda_3 = 2{\cdot}596 \times 10^{-2}$ min.$^{-1}$ fall a little too quickly and on $\lambda_3 = 2{\cdot}587 \times 10^{-2}$ min.$^{-1}$, rather too slowly, but the calculated values are in too close agreement over the range of time of the experiments to allow of discrimination between them. These values correspond to half-value periods of 26·7 and 26·8 minutes respectively for radium B, and both have support from previous determinations. F. v. Lerch* using pure RaB found a period of 26·7 minutes, and Mme Curie†, by measuring the decay of the active deposit from 7–10 hours after removal from the emanation, fixed on a period of 26·8 minutes. In conjunction with the above measurements, these determinations suggest that the correct value of the period is intermediate between these two values.

The use of a longer period for radium C in calculating the decay of the active deposit requires that the latter decay more slowly than has formerly been thought. Confirmatory evidence on this point has been found by other workers in this laboratory when checking up deposit sources. This was attributed to the disturbing influence of the electric field used in collecting the sources, but it seems probable that part, at least, of this discrepancy has been

Amount of RaC present.

Time in minutes	Lawson and Hess	From present work
0	100	100
60	50·05	50·23
70	41·21	41·50
80	33·73	33·92
85	30·23	30·60
90	27·10	27·51
100	21·81	22·19
110	17·43	17·79
120	13·96	14·20
130	11·06	11·30
140	8·746	8·955
150	6·868	7·075
160	5·400	5·569
170	4·256	4·379
180	3·342	3·437
190	2·628	2·690
200	2·070	2·107

* F. v. Lerch, *loc. cit.*

† Mme Curie, *Radioactivité*, vol. 2, p. 322 (1910).

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due to the shorter estimate of the period of radium C in the calculations.

As these sources are frequently employed in radio-active work, it may be of use to give a comparison of values calculated on the above basis with those given in a table by Lawson and Hess* based on previous calculations.

The difference is negligible over the first hour. As Lawson and Hess give values at minute intervals from zero up to 200 minutes, intermediate values may easily be interpolated from the above.

Summary. Measurements of the saturation currents produced between two parallel plates by a source of radium C of carefully tested purity have been performed by an accurate galvanometer method. From the results a transformation constant

$$\lambda = (3{\cdot}514 \pm {\cdot}007) \times 10^{-2} \text{ min.}^{-1}$$

has been assigned to radium C corresponding to a half-value period of $19{\cdot}72 \pm {\cdot}04$ minutes.

Similar measurements with radium active deposit have enabled a value to be estimated for the period of radium B between 26·7 and 26·8 minutes, which is the limit of accuracy of the experimental data.

I wish to express my thanks to Dr J. Chadwick for suggesting this work, and both to him and to Sir Ernest Rutherford for their interest and advice during its prosecution; also to Mr G. R. Crowe for the preparation of the sources used.

* Lawson and Hess, *Wien. Ber.* 2 A, 127, pp. 626–7 (1918).