

The number of β -particles from Radium E By K. G. EMELÉUS, B.A., Hutchinson Student of St John's College. (Communicated by Professor Sir E. RUTHERFORD, F.R.S.)

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When a radioactive element disintegrates with expulsion of β -rays, and has no other mode of disintegration, it is to be expected that at least one β -particle should be emitted for each atom breaking up: one particle arising from each nucleus and possibly others by absorption of accompanying γ -radiation in the orbital electron system of the atom. In the cases of Radium B and Radium C. Moseley*, by measuring the charge acquired by a chamber exposed to the β -radiation from known quantities of the substances, and also from the rate at which the sources themselves charged up positively when insulated, concluded that about 1.1 β -particles came from each disintegrating atom. By a similar method, Danysz and Duane† found that Radium B and Radium C together gave at least three β -particles. Moseley‡ found however that Radium E appeared to emit little more than half a β -particle, and pointed out that this peculiar result seemed in agreement with some ionization measurements by Geiger and Kovarik§. In order to explain this he supposed that Radium E emitted soft rays, not detected in his experiments. On the other hand, Hahn and Meitner¶ photographed its magnetic spectrum, and found a broad continuous band between $H\rho = 5000$ and $H\rho = 1600$, most intense at 2100: a result recently confirmed by unpublished work of Bothe, employing photographic registration, and of Madgwick, using an electrical method: and even if, as appears probable, the band is continued to smaller values of $H\rho$ than originally found, its intensity is feeble, and Moseley's explanation improbable.

Moseley experienced considerable difficulty in the case of Radium E on account of the small current he had to measure, and probably his result was much less accurate than he estimated it to be. In the present investigation the particles have been recorded individually by an electrical counter¶¶, a far more sensitive method, and it has been shown that about one β -particle is ejected from each atom breaking up.

Two methods suggest themselves. In the first a strong source of pure Radium E is taken, and its β -ray emission found; it is then

* *Proc. Roy. Soc., A.*, 87, 230 (1912).

† J. Danysz and W. Duane, *C.R.*, 155, 500 (1912); *Sill. J.*, (4), 35, 295 (1913); J. Danysz, *Thèses, Univ. Paris* (1913).

‡ *Loc. cit.*

¶ *Phys. Z.*, 9, 321, 697 (1908).

§ *Phil. Mag.*, (6), 22, 604 (1911).

¶ H. Geiger, *Phys. Z.*, 14, 1129 (1913).

allowed to decay, and from the α -ray activity of the resulting Radium F, and the known transformation constants, the quantity of Radium E initially present can be deduced. Unfortunately it was not found possible to reduce the initial quantity of Radium F present sufficiently to permit of an accurate determination of its subsequent increase. Radium F disintegrates at only one-thirtieth the rate of Radium E, and so, for example, if only 3 per cent. of the Radium F in equilibrium with the Radium E on the source were present, it would give almost the same number of α -particles as would result from the Radium F produced by decay of this Radium E.

In the second, which was adopted, the two substances are taken in equilibrium. Then the rates at which they are breaking up are equal, and the ratio of the number of β -particles to the number of α -particles gives the number of β -particles per disintegrating atom

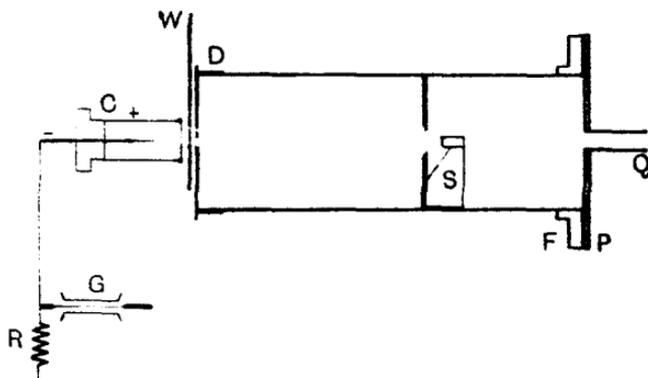


Fig. 1

of Radium E, on the assumption that one atom of Radium F gives one α -particle.

The apparatus is shown in Fig. 1. The counter (C) consisted of a brass tube, $3\frac{1}{2}$ cm. long and $1\frac{1}{2}$ cm. in diameter, polished internally. The particles entered through a mica window, equivalent in stopping power for α -particles to 8 mm. of air at N.T.P., and covering a hole $\frac{1}{2}$ mm. in diameter in a sheet of platinum 0.8 mm. thick, which was waxed on to the annular brass cap of the case with the hole central. The needle was of platinum, with its point accurately centred 1 cm. from the mica, and was soldered in a brass rod insulated from the case by an ebonite stopper; it was in connection with the fibre of a string electrometer (G), and earthed through an enclosed alcohol xyol resistance (R) of about 10^3 megohms. The case was connected to the positive terminal of a motor-generator capable of giving up to 3000 volts. Entry of an α - or β -particle caused a discharge between the point and the case of the counter, and the resulting

momentary change in potential was indicated by a kick of the fibre of the electrometer.

The source (*S*) was supported on the axis of a glass tube, 14 cm. long and 5 cm. in diameter, resting between the pole-pieces of an electromagnet capable of giving a field of up to 500 gauss. The end opposite to the counter was closed by a brass cap (*D*) with a central hole of 4 mm. diameter covered with mica of 1.2 cm. stopping power: the other end carried a brass flange (*F*) and could be closed by bringing against its ground face a flat brass plate (*P*) with an exit tube (*Q*). In front of the source, and soldered to its support, was a brass diaphragm, whose aperture was sufficiently small to prevent β -rays passing out to the counter after a single reflection in the tube. To minimize reflection, the edges of the holes in the cap (*D*) and diaphragm were tapered, with a flat face towards the source. A brass frame bolted on to *D* carried the counter and was insulated from it. Between the counter and *D* was a brass wheel (*W*), by rotation of which 2 mm. of the metal, or mica of various thicknesses, could be put in the path of the particles. The wheel and *D* were earthed and the front of the counter was as close as possible to the wheel without sparks passing, giving a path in the air of 0.45 cm.

The source was part of a 3-year old glass emanation tube, broken into small pieces, and mounted on a piece of brass rod on the brass base (*S*). This was slipped into the tube, which was then closed, and exhausted through *Q*, first by an oil-pump, and finally by a charcoal-liquid air tube. The active material of this source consisted of Radium D + E + F, the quantities of the last two being to within 2 per cent. in their equilibrium ratio*. In addition to the β -radiation from Radium E there is β -radiation from Radium D, but Meitner† has shown that it is very soft, with an absorption coefficient of $\mu = 5500 \text{ cm.}^{-1}$ in aluminium, although her results do not preclude the existence of a small amount of more penetrating radiation. There is also a little γ -radiation from all three bodies, chiefly soft, but negligible for the present purpose, for which the source can be regarded as consisting of Radium E and Radium F in equilibrium.

It was found by preliminary experiments that the number of β -particles recorded by the counter increased rapidly when the potential was raised from 1200 to 1550 volts, but by only a further 3 per cent. between 1580 and 1740 volts; above 1800 volts the point discharged frequently without apparent external stimulus. 1740 volts were used, and at frequent intervals during the course of the counting the number of spurious discharges was found by bringing the metal part of the wheel in front of the counter: these

* St. Meyer and E. v. Schweidler, *Radioaktivität*, p. 365.

† *Phys. Z.*, 16, 272 (1915).

were mainly due to γ -rays and X-rays from other parts of the building, and were reduced to one or two per minute by lead screens.

A count was first made with an air gap in the wheel, giving the total number of α -particles from the Radium F and β -particles from the Radium E entering the counter in a given time. A field of 350 gauss was then applied to deflect the β -particles. The α -particles were not appreciably affected and their number was found by a second count. The field in the neighbourhood of the counter was

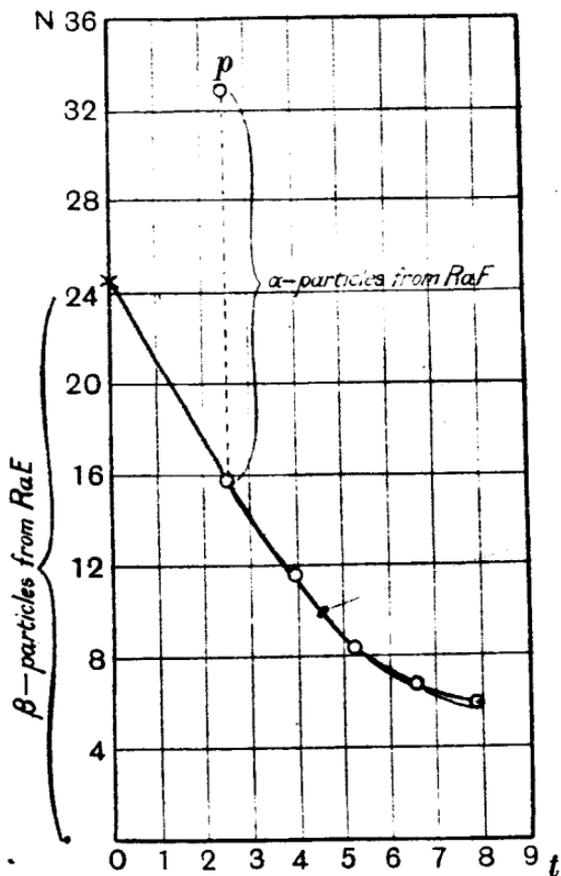


Fig. 2

less than 12 gauss, and this was shown by a subsidiary experiment not to affect the number of α -particles detected. The complete deflection of the β -particles was verified by putting a 1.6 cm. air-equivalent sheet of mica in front of the counter, when nothing was recorded beyond the usual spurious effect. Finally, a set of counts was taken with various thicknesses of mica inserted and without the magnetic field, to allow for absorption of β -rays in the material unavoidably present between the source and interior of the counter.

The results are shown in Fig. 2, where the number of β -particles (N) recorded per minute, corrected for spurious effects, is plotted against the total quantity of absorbing material (t) in their path, expressed in cm. air-equivalent for α -particles. The observed data are given by circles: the cross gives the number of β -particles for zero absorption, found by logarithmic extrapolation; and p gives the result of the first count, with the air gap in the wheel and no magnetic field.

To every 17.1 α -particles from the source there correspond 24.5 β -particles. Not all of the latter have been initially projected towards the counter: some have been emitted in the opposite direction, and have had their direction of motion reversed by collisions in the glass source. This effect has been investigated by Kovarik*, and although his results refer in the first instance to the resulting ionisation, yet it was shown later by the use of a counter that this is proportional to the actual number of reflected particles†. From his data it appears that in the present experiment about 23 per cent. of the β -particles recorded have arisen in this way. Applying this correction, it follows that for each α -particle emitted from Radium F, 1.10 β -particles are emitted from Radium E, and since the two substances are practically in equilibrium this gives the number of β -particles per disintegrating atom. Great accuracy cannot be claimed for this result, because of the uncertainty as to the exact correction to be applied for reflection at the source, and because of the necessary extrapolation to allow for absorption in the air gap and the mica windows, but it should be correct to within 10 per cent.

SUMMARY.

Using an electrical counter, the number of α - and β -particles from a source of Radium D, Radium E and Radium F in equilibrium has been measured: it has been found that after correction for reflection at the source, their numbers were about equal. According to previous work on their absorption, the β -particles from Radium D would not be recorded under the conditions of these experiments. On this assumption the observed β -radiation was due to disintegration of Radium E, and since this was in equilibrium with Radium F, it follows that about one β -particle is emitted per disintegrating atom of Radium E.

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* *Phil. Mag.*, 20, 849 (1910).

† Kovarik and McKeehan, *Phys. Z.*, 15, 434 (1914).