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On the Number of δ Particles Expelled Concurrently with each α Particle Emitted by Polonium.

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Presented by Prof. J. C. McLennan.

(Read May 16, 1911.)

A problem which has been presented for solution for some time in connection with radio-active transmutations is the manner in which the active deposit particles in radium, thorium and actinium acquire their positive charge and in virtue of which they are attracted in an electric field to the electrode which is negatively charged.

One inference which may be drawn from some observations on the active deposits from actinium which are recorded in a paper published recently by the writer[1] is that the active deposit particles at the instant of their production are uncharged and that their positive charge is acquired by contact with the surrounding ionized gas.

This deduction may be made from the fact that when exposures are made to the emanation in a small chamber at the lowest pressures attainable the amount of active deposit obtained on a charged electrode is practically the same, whether it be charged positively or negatively or whether it be uncharged.

The active deposit particle, it is generally conceded, is produced by the expulsion of an *α* particle from the parent atom.

As the *α* particle has been shewn to carry a positive charge of two elementary units it follows that if the active deposit particle is uncharged when it is created, the expulsion of the *α* particle, from the parent atom, must be accompanied by the emission of two delta particles each bearing one elementary negative unit of electricity.

As the expulsion of *α* particles from polonium is known to be accompanied by the emission of delta particles it was thought that if the number of delta particles accompanying on the average the expulsion of one *α* particle from polonium could be determined the result might possibly throw some light on the problem raised here in connection with the formation of active deposit particles from radioactive emanations.

In the following paper an account is given of some experiments made in connection with such a determination.

The manner in which the experiments were carried out is illustrated by the diagram shewn in Fig. I. A small copper plate N, coated with a thin deposit of polonium on its anterior face, was connected with a

[1] Kennedy. Phil. Mag. 1909, p. 744.

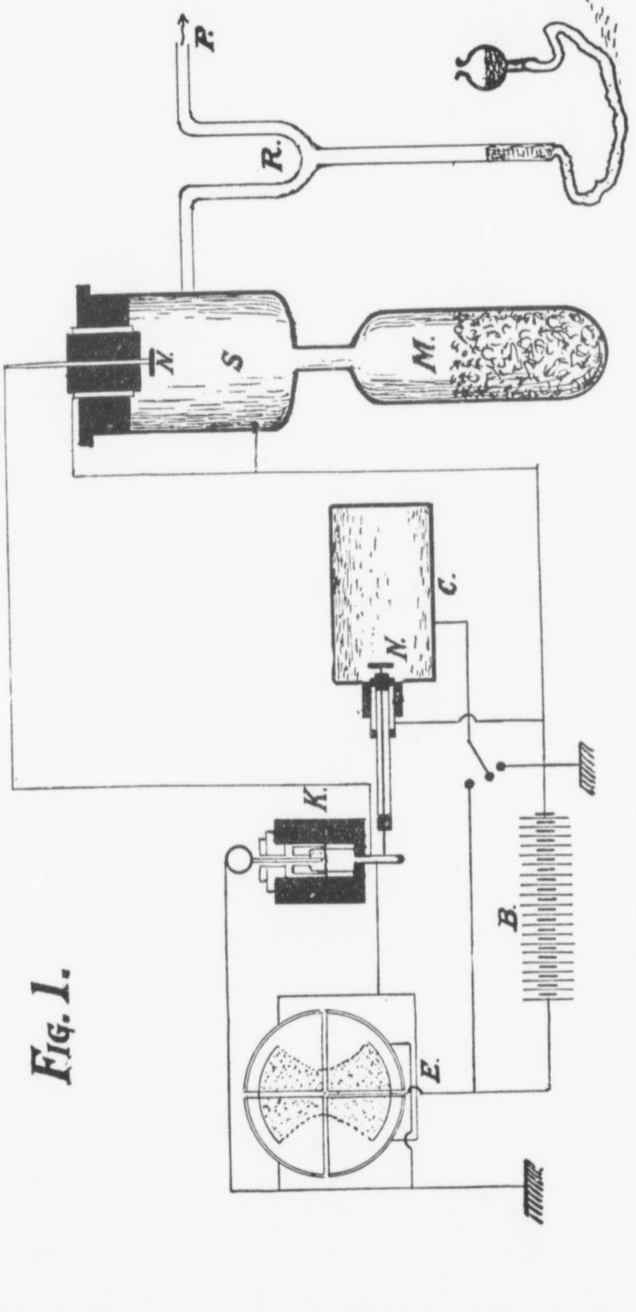

FIG. 1.

quadrant electrometer and exposed in an ionizing chamber C. This vessel which was cylindrical in form was 15 cms. in length and 12 cms. in diameter.

As the range of the α particles in air at atmospheric pressure has been given by Geiger* as 3.86 cms. it is clear that this air chamber was of ample size to insure that all the α rays expelled by the polonium on N. were absorbed by the air in it before they could reach its walls.

With this apparatus the ionization currents were measured with various voltages applied to the receiver and the results of these measurements are shewn by the curve in Fig. II. From the numbers there plotted it will be seen that saturation was obtained with between 200 and 250 volts applied to the receiver C.

The electrical capacity of the system, which included a condenser in this part of the investigation, was then determined and from the known value of the saturation current it was easy to deduce, assuming the charge on an ion to be $4 \cdot 65 \times 10^{-10}$ E. S. U. the number of ions made in the gas per second by all the α particles emitted by the polonium.

As Geiger* has shewn that the number of ions made by each α particle emitted by polonium in its passage through a column of air is approximately $1 \cdot 62 \times 10^5$ it follows since the number of ions produced per second by all the α particles was determinate that the number of α particles expelled per second by the sample of polonium used could at once be calculated.

When the number of α particles emitted per second at any particular time by a sample of polonium is ascertained, one is enabled by the known rate of decay of polonium to calculate the number of α particles emitted per second by the same sample of polonium at any later time.

After the rate at which the deposit on the copper plate N emitted α particles had been determined this plate was placed in a second chamber S made of glass silvered on its inner surface. The rod which carried the plate N was supported in S by a plug of ebonite freshly cleaned. It was protected by a guard tube as shewn in the figure and was connected to the free quadrants of the electrometer.

To the chamber S there was attached a second glass tube partly filled with cocoanut charcoal. This chamber S was also connected to a mercury pump and in this connection a trap R was inserted which enabled one to cut the pump off and push the evacuation to the lowest possible limit by cooling the charcoal chamber with liquid air.

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*Geiger. Proc. Roy. Soc. A 82, p. 486, July 31, 1909.
*Geiger, *loc. cit.*

Table I.

Pressure.	Time.	Electrometer.	Electrometer (volts)
·001 mm	0 min.	0	0
"	6 "	+ 6	+ ·014
"	13 "	11·7	·025
"	18 "	14·8	·032
"	25 "	19·0	·042
"	30 "	22·2	·049
"	45 "	31·6	·072
"	1 hr. 01 "	40·9	·093
"	1 " 22 L	50·1	·111
"	1 " 40 "	58·8	·137
"	1 " 1 "	63·3	·146
"	2 " 27 "	76·4	·179
"	3 " 01 "	91·5	·213
"	4 " 02 "	112·0	·262
"	4 " 25 "	119·0	·279
"	5 " 42 "	129·5	·305
"	6 " 57 "	132·0	·312
"	7 " 24 "	139·0	·328
·95 mm.	0 min.	0	0
"	9 "	+5	+ ·010
"	24 "	8	·015
"	34 "	16·5	·033
"	51 "	22·8	·045
"	1 hr. 03 "	26·0	·053
"	2 " 03 "	42·0	·088
"	2 " 42 "	51·5	·108
"	3 " 09 "	57·0	·121
"	3 " 50 "	58·5	·125
5·6 mm.	0 min.	0	0
"	4 "	−5·3	− ·011
"	16 "	23·0	·045
"	39 "	48·0	·095
"	48 "	55·0	·113
"	1 hr. 05 "	68·0	·135
"	1 " 21 "	76·0	·158
"	1 " 45 "	93·5	·195
"	2 " 27 "	97·0	·202
25·6 mm.	0 min.	0	·0
"	4 "	−11	− ·022
"	8 "	23	·047
"	16 "	41	077
"	28 "	50	·105
"	44 "	58	·123
"	1 hr. 00 "	77	·167
"	1 " 34 "	111	·242
"	2 " 02 "	127	·280
"	2 " 24 "	136	·302
"	2 " 53 "	142	·316
"	3 " 15 "	143	·318

With this arrangement observations were made on the charges acquired (when the earth connection at K was broken and the quadrants made free) by the plate N and its connections under the influence of the radiations emitted. This was done with the air in S at a number of different pressures. A set of these results for 25·6 mm., ·95 mm. and ·001 mm pressure is given in Table I and curves which illustrate them are shewn in Fig. III.

At the pressure 25·6 mm. and 5·6 mm. the charge acquired was negative and in the two cases limiting potentials of approximately ·318 and ·202 volts respectively were reached.

The explanation of this acquisition of a negative charge by the electrode N was taken to be the existence of a volta difference of potential between the copper plate and the silver lining of the vessel S. At the lower pressures, however, as may be seen from the curves, the system acquired a positive charge which as Sir J. J. Thomson* has shewn is due to the delta rays carrying a negative charge from the polonium coated plate in excess of the positive charge carried from the same plate, by the α rays.

To get an accurate measure of the charge thus carried off by the delta rays the pressure was reduced in the vessel S until the McLeod gauge attached to the pump indicated a pressure of ·001 mm. of mercury. An observation was then made on the rate at which the plate N acquired a negative charge. By means of the trap R the vessel was then cut off from the pump, and the liquid air was placed round the vessel M. After it was certain that the charcoal had absorbed as much of the remaining air as possible a set of readings was again taken on the rate at which the plate N charged up.

This rate, however, was found to be practically the same as that obtained just before the liquid air was applied, and from the similarity in these two sets of readings it was considered that any current in the gas at ·001 mm. pressure due to ionization was negligible.

The numbers given in Table I and the graph representing them may therefore be taken to represent a measure of the rate at which the plate N emitted particles carrying negative electricity in excess of those emitted which carried positive charges.

Since the number of α particles leaving N per second was determined in the first part of the investigation it was a simple matter to calculate the rate at which the delta particles were emitted and so deduce the number shot off per α particle. The calculation is as follows:—

Calculation I.—Determination of number of α particles emitted per second.

* J. J. Thomson, Proc. Can. Phil. Soc. 13, 49, 1905.

Potential acquired in 184·6 secs by plate N with saturation current $=\cdot 75$ volts or $\cdot 75/300$ E. S. Units.

Capacity of electrical system=2411 cms.

$$\text{Charge acquired per sec.} = \frac{\cdot 75\times 2411}{300}\times\frac{1}{184\cdot 6}\ \text{E. S. U.}$$

$$\therefore \text{No. of ions} = \frac{\cdot 75\times 2411}{300}\times\frac{1}{184\cdot 6}\times\frac{1}{4\cdot 65\times 10^{-10}}$$

$\therefore N_1$=No. of α particles = emitted per sec.

$$=\frac{\cdot 75\times 2411}{300}\times\frac{1}{184\cdot 6}\times\frac{1}{4\cdot 65\times 10^{-10}}\times\frac{1}{1\cdot 62\times 10^{5}}=433.$$

Calculation II. Determination of number of δ particles emitted per second.

Initial rate of increase in potential of plate N and attached electrical system=·107 volts per hour.

Capacity of electrical system=260 cms.

$$\text{Positive Charge acquired per second} = \frac{\cdot 107}{300}\times\frac{1}{3600}\times 260\ \text{E. S. U.}$$

$\therefore$ No of Elementary units of Electricity gained per sec.

$$=\frac{\cdot 107}{300}\ \frac{1}{3600}\ \frac{260}{4\cdot 65\times 10^{-10}}$$

$$=53170$$

Let N_2 denote the number of delta particles leaving the plate N per second, then if each delta particle carried a negative charge of $4\cdot 6\times 10^{-10}$ E. S. U. and each α particle carried a positive charge of twice this amount we have

$$N_2 - 2N_1 = 53170$$
$$\text{or } N_2 = 53170 + 2N_1$$
$$= 53170 + 866$$
$$= 54036$$

It follows then that $\frac{N_2}{N_1}=\frac{54036}{433}=124\cdot 8$

i.e., approximately 125 delta particles left the polonium coated copper plate for every α particle which it emitted.

In seeking to interpret this result one must remember that in all probability there were just as many α particles shot back per second into the copper plate carrying the polonium deposit as were projected forward away from it. Since α rays are known to produce secondary rays when they impinge on a metal it is therefore highly probable that a very considerable portion of the delta radiation measured in the experiments described above were secondary rays caused by these retrograde α rays.

It follows then that before one can form an estimate of the number of delta particles projected with each α ray from the particles which are the parent atom of the active deposit particles one must ascertain the number of delta particles projected as a secondary radiation from a copper plate, when the latter is bombarded by one α particle.

From experiments which are now being made by the writer it is expected that this number will shortly be obtained. It will then be possible to make an estimate of the number of delta particles ejected concurrently with an α particle in the disintegration of a radioactive atom.

In conclusion, the writer wishes to express his sincere thanks to Professor McLennan for his helpful suggestions and for his interest in the investigation.

FIG. II.

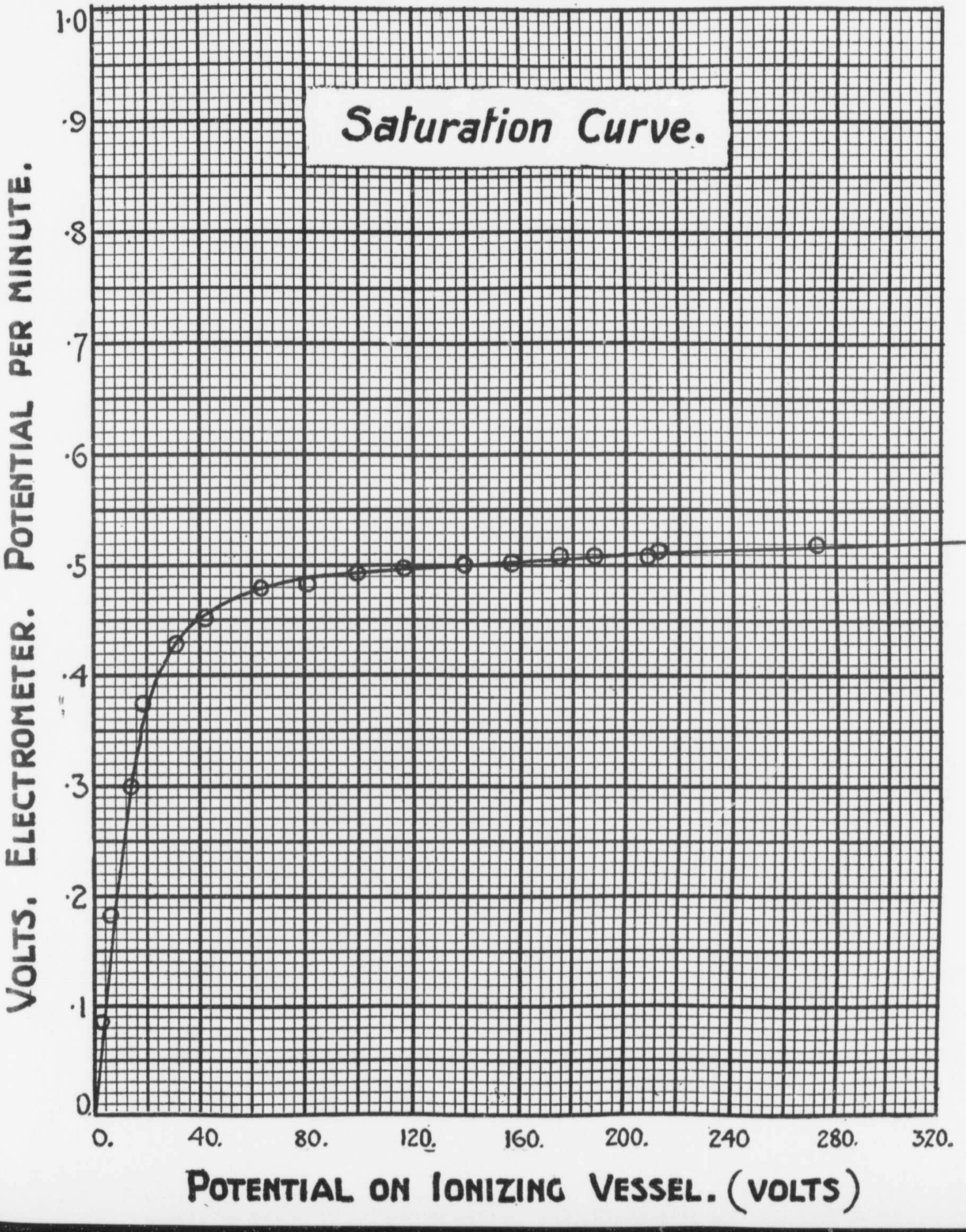
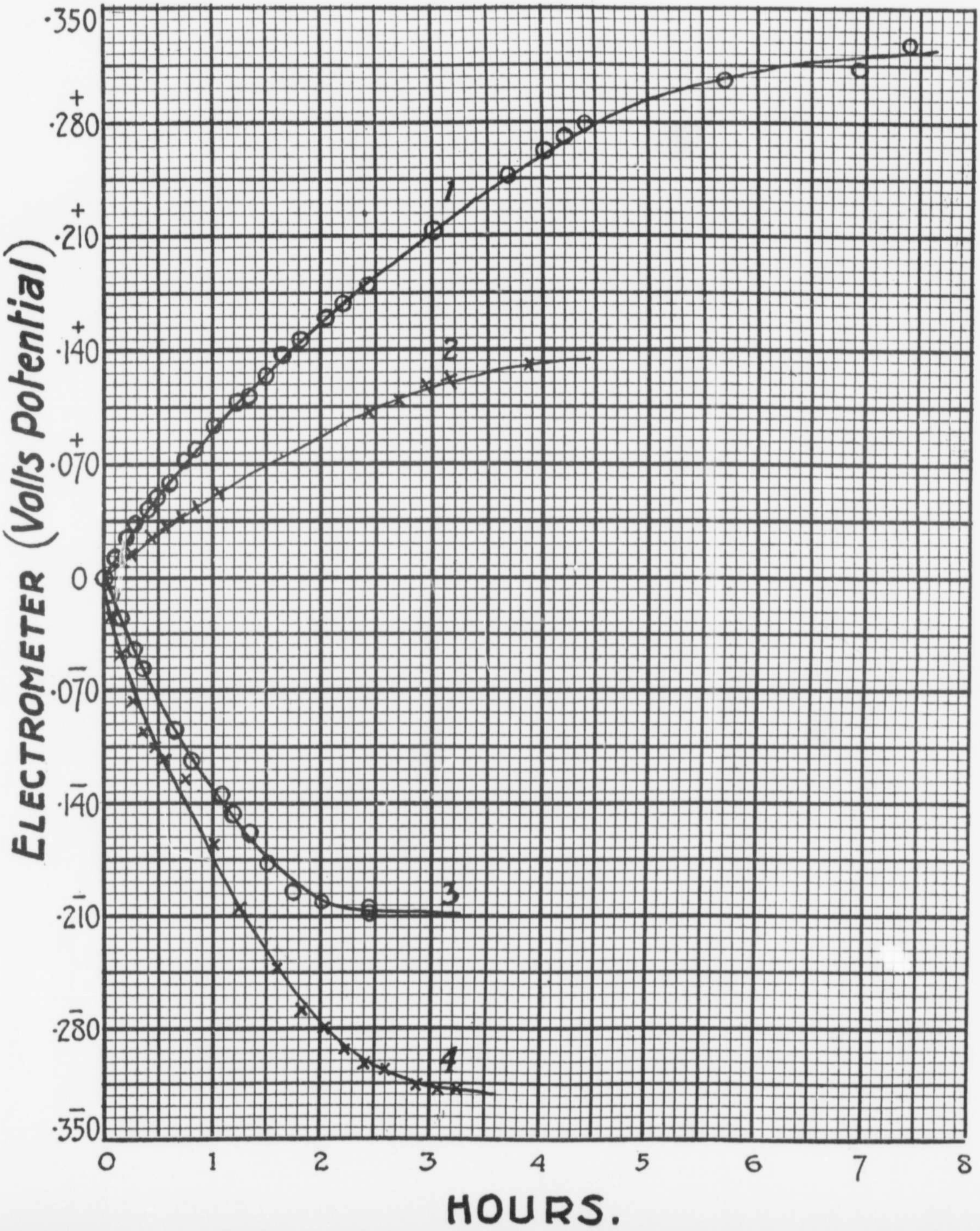

Saturation Curve.
1·0
·9
·8
·7
·6
·5
·4
·3
·2
·1
0.
Volts. Electrometer. Potential per minute.
0.
40.
80.
120.
160.
200.
240
280.
320.
Potential on Ionizing Vessel. (volts)

FIG. III.



·350
+
·280
+
·210
+
·140
+
·070
0
·070
·140
·210
·280
·350
ELECTROMETER (Volts Potential)
1
2
3
4
0
1
2
3
4
5
6
7
8
HOURS.