LXXXVI. The recoil of radium D from radium C

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less completely masked by the spectrum of the gas with which it is mixed, may still be taking a very important part in carrying the current in the dark space. It is doubtful, however, whether this conclusion can be carried further so as to include the positive column.

Until more is known definitely of the manner in which an atom emits its spectrum, it will be very difficult to suggest a cause for the masking effect of one spectrum upon another. But it is interesting to note in this connexion the discovery of multiply-charged atoms. Sir J. J. Thomson has observed that in the positive-ray tube the heavier atoms can lose more corpuscles than the lighter atoms. As the masking effect only occurs when there is an appreciable difference between the atomic weights, it may be that it is connected with the property of the heavier atoms to become more completely ionized. If these multiply-charged atoms occur in the positive column, they would form the more strongly attractive centres, and recombination with subsequent spectral emission would be more frequent in their case.

In conclusion, I desire to thank Sir J. J. Thomson for suggesting this research, and for the kind interest taken in its progress.

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LXXXVI. *The Recoil of Radium D from Radium C.*
By A. B. WOOD, *M.Sc.*, and W. MAKOWER, *M.A., D.Sc.**

MANY attempts have been made to detect the photographic action of the recoil stream emitted by radioactive surfaces, but hitherto they have been unsuccessful in detecting any *direct* action. The position at which the recoil stream from radium A impinges on a photographic plate has, however, been fixed by allowing the radium B reaching the plate to decay *in situ*, and obtaining a photographic record by means of the α radiation subsequently emitted by the radium C produced †. It seemed possible that the failure to procure any direct photographic evidence of a recoil stream might be due to the extreme facility with which this type of radiation is absorbed by matter; for an ordinary photographic film contains so much gelatin that most of the recoil particles striking the plate are absorbed by the gelatin before colliding with a grain of

* Communicated by the Authors.

† Walmsley and Makower, *Phil. Mag.* Feb. 1915.

silver halide, so that no photographic action can be expected. In order to overcome this difficulty experiments were made by Wood and Steven * to detect photographically the recoil stream from polonium by means of Schumann plates, in which the amount of gelatin is reduced to a minimum. This attempt was unsuccessful; but the failure to obtain any photographic record may well have been due to one or both of the following causes. The experiments were performed by allowing a confined beam of the recoil stream and α radiation from polonium to pass through a strong magnetic field, and it was hoped thus to separate the recoil stream from the α rays; but unless the recoil particles and α particles carry different charges, it is of course impossible to do this. There is, however, no evidence to indicate what charge is carried by a particle of radium G recoiling from polonium when it disintegrates, unless it be justifiable to argue from the analogy of the recoil of radium B from radium A, in which case the recoil particle carries a single charge in contact with the double charge carried by the α particle. But even if it were possible to separate the recoil stream from the α rays by means of a magnetic field, it seems doubtful whether any photographic action could be expected with the sources of polonium available except with an exposure of prohibitive duration. Further experiments therefore seemed desirable.

In order to obtain as strong a source of radiation as possible, a length of about one centimetre of platinum wire 14 mm. in diameter was exposed in a fine capillary tube to about 300 millicuries of radium emanation which had been reduced to a sufficiently small volume by condensation in liquid air. After an exposure of three hours the emanation was pumped out of the capillary, and the wire removed and subsequently mounted in the apparatus used by Walmsley

Fig. 1.

and Makower to measure the magnetic deflexion of the recoil stream from radium A†. The arrangement is shown in fig. 1, which is reproduced from the paper just quoted.

* Wood and Steven, Proc. Phys. Soc. 27th April 1915.

† *Loc. cit.*

The wire mounted at O at right angles to the plane of the paper acted as a line source 3 cm. distant (l_1) from a slit S of width 0.14 mm., and the radiation which passed through was allowed to impinge on a Schumann plate placed at P. The distance SP (l_2) was 2.8 cm. The whole apparatus was enclosed in a brass box which could be completely evacuated, and was situated between the pole-pieces of a strong electromagnet, which when excited produced a uniform field of about 13,000 gauss at right angles to the plane of the paper.

To carry out an experiment the active wire, upon which was deposited some 30 milligrams of active deposit, was placed in a tube which could be evacuated and heated to drive off any adhering emanation. The wire was then left for twenty minutes, during which time the radium A on it had decayed to a small fraction of its original value. It was then mounted at O, and the box containing it was exhausted as rapidly as possible. An interval of eight minutes was then allowed to elapse, during which the radium A still remaining on the wire decayed to an insignificant amount. During this time the radiation from O struck the centre of the Schumann plate P and produced a photographic impression. The magnetic field was then excited and kept at a constant value for 75 minutes. The photographic record obtained in this way is shown in fig. 2.

Fig. 2.

On the left of the photograph is a strong line giving the undeflected position of the beam of α rays coming through the slit before exciting the electromagnet. On the right is another somewhat stronger line fixing the position of the beam of α rays when deflected by the magnetic field. Between these two lines is a much fainter one due to the deflected recoil stream. It is evident that this line must have been produced by the *direct* action of the recoil stream, since radium D emits no α rays and its period of transformation is so long that any photographic action due to this or any subsequent disintegration product is precluded.

It is interesting to note that the line due to the recoil stream does not appear to be accurately midway between the two α ray lines, which is remarkable if radium D carries a single positive charge when it recoils from radium C; but careful consideration of the experimental conditions under which the photograph was taken leads to the conclusion that a slight dissymmetry such as is observed is to be expected. For when the wire is exposed to the emanation, there is deposited on its surface radium A, which subsequently disintegrates into radium B and then into radium C. During the process of disintegration of the radium A, which is accompanied by the expulsion of α particles, the radium B is shot into the wire by recoil, with the result that the radium C subsequently formed is situated, not on the surface of the wire, but at varying depths below its surface. The recoil stream of radium D subsequently emerging from the wire is therefore heterogeneous; for the particles of radium D must have traversed different thicknesses of platinum and so escape with all possible velocities. The densest part of the recoil line in the photograph is therefore produced in the region corresponding with the most probable velocity of emission of the particles*. In support of this view it will be noticed that the left-hand edge of the recoil line is much sharper than the right-hand edge, indicating that there are no particles travelling with velocities greater than that corresponding with the left-hand edge of the line. On the right-hand side the line gradually fades away, indicating the presence of recoil particles of all possible velocities. If instead of fixing attention on the regions of maximum density in the lines, the positions of the left-hand edges of the three lines are measured, it is found that the recoil line is much more nearly midway between the two α ray lines. But since even the left-hand edge of the recoil line is not perfectly sharp, and since the displacement of the line from the centre is small, it is not possible to make this measurement with very great accuracy.

From these considerations there seems to be no room for doubt that the particles of radium D which leave the *surface* of the wire traverse the magnetic field in a path the radius of curvature of which is double that of the α rays from radium C. Thus the radium D is projected with a single positive charge, just as is the case when radium B recoils from radium A. It should, however, be noticed that no

* If this view of the displacement of the recoil line is correct, the efficiency of recoil of radium D from radium C should be low, and experiments are in progress to test this point.

general conclusions as to recoil phenomena can be deduced from this fact since radium B and radium D are isotopic elements, and must therefore be expected to behave alike. Possibly in other cases of radioactive disintegration the recoil streams may consist of particles with multiple charges; but unfortunately there are no other cases which lend themselves to easy experimental investigation.

We are indebted to Sir Ernest Rutherford for putting at our disposal the large quantities of radium emanation without which successful experiments would have been impossible. We have also to thank Mr. C. W. Gamble, of the Manchester School of Technology, for helping us to make the Schumann plates used in these experiments.

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LXXXVII. *The Variation of the Emanation Content of Certain Springs.* By R. R. RAMSEY, Ph.D., Associate Professor of Physics, Indiana University, Bloomington, Ind., U.S.A.*

WHILE measuring the radioactivity of springs in the neighbourhood of Bloomington, Indiana, I found that measurements made at one time did not agree with those made at another time. The discrepancy was so great, that I set out to determine if the difference was due to errors or due to an actual change of the value. I selected two springs^c and have tested them once a week during the last nine months.

The method of measurement was the Schmidt shaking method (*Phys. Zeit.* vol. vi. p. 561, 1905). This method has been found to have an accuracy of about 5 per cent. when measurements are made at the spring, and an accuracy of about 3 per cent. when measurements are made in the laboratory (*Am. Journ. Sci.* vol. xl. p. 311, 1915).

An emanation electroscope was used. This electroscope was at first calibrated by means of Duane and Laborde's† empirical formula, which holds for an electroscope of one litre capacity. Later, the electroscope was calibrated by means of emanation standard E 54, which is certified by the Bureau of Standards to be accurate to within 3 per cent. The two methods of calibration agreed within 5 per cent.

* Communicated by the Author.

† *Le Radium*, vol. xi. p. 5 (1914); *Ann. der Phys.* vol. xxxviii. p. 959 (1912); *Compt. Rendus*, vol. cl. p. 1421 (1910); *Journ. de Phys.* vol. iv. p. 605 (1905); Indiana Acad. Proc. 1914.