

THE MAGNETIC SPECTRA OF THE β -RAYS OF RADIUM
DE AND OF RADIUM AND ITS PRODUCTS,
DETERMINED BY THE STATISTICAL
METHOD.

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INTRODUCTION.

THE investigation of the magnetic spectrum of the β -rays of radium DE was undertaken as a preliminary to the study of the ionization of a single β -particle and the dependence of this ionization upon velocity.¹ The band in the magnetic spectrum of radium E seemed well adapted to such an investigation. The spectrum of the β -rays from radium and its products was also obtained although in less detail. The results in the latter case differ materially from those obtained by Chadwick² using the same method, the maximum occurring for a value of H_p nearly twice as great as that found by him. In this connection the work of Rutherford and Robinson³ on the fine structure of the spectrum of radium C is of interest. They found a great number of lines near $H_p = 4,000$ gauss-centimeters, in the region where our maximum was obtained. The results obtained with radium DE agree well with the photographic results of von Baeyer, Hahn, and Meitner⁴ using the same source of radiations.

APPARATUS AND METHOD.

The source of the β -particles was in one experiment radium DEF chemically separated from radium, minute in quantity but very concentrated, placed on an aluminum foil and held in place by a thin aluminum leaf. In the other experiment the source was a radium salt contained in a spherical glass bulb about 5 millimeters in diameter.

A casting of lead was made of the form shown in Fig. 1, in which *O*, *O* represent the only open spaces in the casting. *S* was the position of the source, and when this was radium it was surrounded by the cylinder of

¹ The present report is presented by itself because one of us is leaving the laboratory and will continue the original plan at a later date.

² J. Chadwick, *Verh. d. D. Phys. Ges.*, 16, 383, April 30, 1914.

³ E. Rutherford and H. Robinson, *Phil. Mag.* (6), 26, 717, October, 1913.

⁴ O. v. Baeyer, O. Hahn, and L. Meitner, *Ph. ZS.*, 12, 378, May 15, 1911.

lead, *C*. *H* was a hemispherical counting chamber insulated by ebonite from the lead. *P* was the point connected to a string electrometer and through a high resistance to earth. The square *F, F*, which was 6 cm. \times 6 cm., was cut out for the pole pieces of the magnet. These were 3.6 cm. apart in the apparatus used for radium. The radius of curvature of the rays was 6.34 cm. For the high values of H_p the same apparatus and pole pieces were used with another and stronger magnet. In the experiment with radium DEF similarly shaped apparatus was used, but this was smaller, the separation of the pole pieces being 2.5 cm. and the radius of curvature being 2.8 cm. In this smaller apparatus the counting chamber was cylindrical. A larger apparatus was needed in

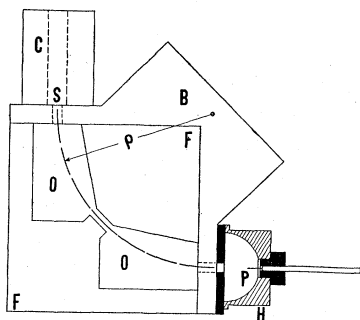


Fig. 1.

the case of radium than in the case of radium DEF because the γ -ray effect from the radium was too marked in the smaller apparatus. The increased amount of lead protecting the counting chamber was sufficient to make the γ -ray effect comfortably small with the strength of radium used (0.2 mg. radium metal).

The magnetic field strength was obtained with a Grassot fluxmeter calibrated by means of a standardized mutual inductance. The field was found approximately uniform, the greatest variation not exceeding 5 per cent. The error in H_p due to such non-uniformity is less than this limit.

The visual method of determining the number of β -particles has already been described by us in connection with our former researches.¹ It may suffice to state that each point was carefully standardized in a special standardizing counting chamber, both for α -particles, whose number was known from the electrical and scintillation methods, and also for β -particles from a standard radium DEF plate (prepared from emanation) used for this purpose throughout all of our researches. The

¹ A. F. Kovarik and L. W. McKeehan, *Phys. Rev.* (2), 6, 426, December, 1915.

voltage used was about 1,700 volts, varying somewhat for the different points. A point made of steel gave the best satisfaction. Such a point, used in counting many thousand β -particles is shown in Fig. 2, the diameter of the cylindrical part being 0.734 millimeter. The photograph was taken after the point ceased to behave properly, but whatever change caused its failure did not alter its appearance.

The hemispherical vessel, having a distribution of the field between the wall and the discharging point different from that in a cylindrical vessel, required, for the same point, a somewhat different—in this case



Fig. 2.

a higher—voltage than the cylindrical vessel, in order to give the constant maximum number of β -particles counted.

During the experiments a new method of counting was developed, but in these experiments it was used only as a check on the visual counting. The point, instead of being connected to earth through a high resistance, as is usually done, was connected to a condenser of a fairly high capacity. In this case the capacity was 0.5 microfarad. The charge collected in the condenser is due to the ions produced in the discharge to the point, and is proportional to the number of such discharges. The condenser was discharged through a ballistic galvanometer and the throw recorded. The throw per β -particle depends upon the point, and also upon the potential on the counting chamber. The throw per discharge for the α -particles, the β -particles, and for the γ -rays is characteristically different; the phenomena observed will be the subject of a later investigation. In testing the method, wires leading to the string electrometer and to earth through the high resistance were placed in proximity to the wire leading from the point to the condenser. With every discharge an induction effect produced a motion of the electrometer fiber, and this effect could be magnified by increasing greatly the high resistance leading to earth. The deflection of the fiber was, of course, in the opposite direction to that obtained when the wire was connected directly to the point. In this manner the galvanometer throw corresponding to a known number of discharges was obtained. The throw per discharge was constant within 2 per cent. for a given point, potential, and type of rays. In using this method one must frequently redetermine the throw per discharge, because this quantity changes if the point itself is becoming more or less sensitive, that is if the point's lasting qualities are poor.

RESULTS.

The results are presented in the form of curves (Figs. 3 and 4) giving the relation between H_p as abscissa and the relative frequency of occurrence of β -particles of the corresponding velocity as ordinate. The frequency at the maximum of each curve is arbitrarily represented by 100. The observed maximum frequencies, which depend upon the experimental dispositions and the strength of the material used, were

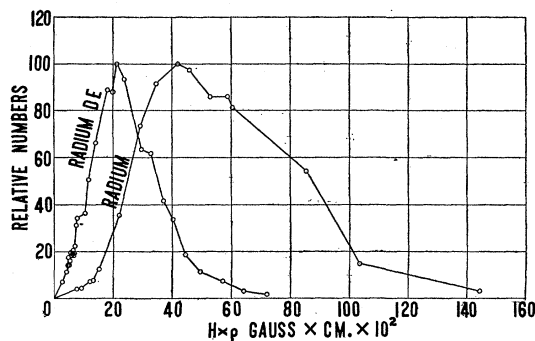


Fig. 3.

about 20 and 60 per minute for radium DE and radium with its products, respectively. The corrections necessary on account of the γ -rays and stray radiations amounted to 0.64 and 12.6 per minute in the two cases and were independent of the magnetic field strength. They were obtained by reversing the field.

Since the steps in H_p are in many places not sufficiently short to discover the finer details of the spectra, it is not intended, by drawing lines between the observed points, to preclude the possibility of variations in these regions. The photographic spectra already alluded to make it, in fact, practically certain that there are many such variations.

A portion of the curve for radium DE is repeated in Fig. 4 on a larger scale to show the series of maxima in the soft radiation. Besides the two maxima observed photographically by other experimenters and attributed to radium D, there are indications of two more maxima lying upon the edge of the radium E band and, perhaps for that reason, not photographically detected. The radium DE specimen was tested for the presence of radium—or rather for the radium C β -rays—by absorption experiments, and the amount present was so small that all the features of the curve are believed due to radium D and radium E. Each of the points plotted is an average of counts extending over a total time of about one hour. In order to check the working of the point without removing it from the apparatus—a procedure which may

damage a satisfactory point—a reading near the maximum was repeated at intervals throughout the experiments. This check reading was at $H_p = 2,000$ gauss-centimeters, requiring a magnetizing current of 0.46 ampere.

The curve for radium was extended in both directions as far as possible, but the extreme points are subject to large experimental errors, since the γ -ray correction mentioned above is at these points much larger

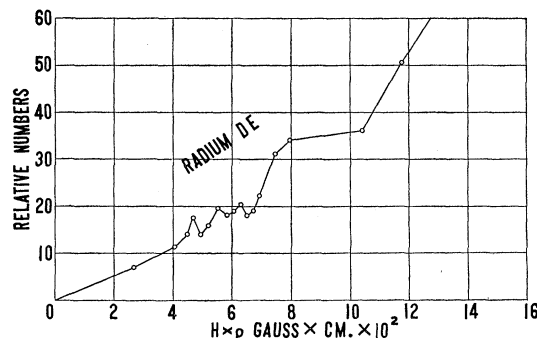


Fig. 4.

than the β -ray effect. Each of the points plotted is an average of counts extending over about half an hour. The check readings were obtained for magnetizing currents of 0.40 ampere ($H_p = 2,190$) with the smaller magnet, and 1.00 ampere ($H_p = 4,020$) with the larger magnet.

SUMMARY.

1. The magnetic spectra of the β -rays of radium DE and of radium and its products have been mapped by the statistical method.
2. The spectrum for radium DE agrees with the photographic spectra (O. v. Baeyer, O. Hahn, and L. Meitner) hitherto published. The principal maximum lies near $H_p = 2,000$ gauss-cm.
3. The spectrum for radium is different from that given by Chadwick, who also used the statistical method. The principal maximum lies near $H_p = 4,000$ gauss-cm.
4. A ballistic galvanometer method of counting is described.

In conclusion we desire to express our appreciation of the financial assistance afforded us under the provisions of the Minnesota Research Fund. We also desire to express our thanks to Mr. H. J. Vennes for his assistance throughout these experiments.

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