For the first experiments I used a Geiger point counter which gave only about 1 stray count in 5 minutes. It was controlled by use of a very weak polonium source of known activity. Recoil protons of a few centimeters range in air could easily be counted. Heavy water (80 percent) in a cup of about 1 cm^2 surface did certainly not give 0.05 count per minute more than ordinary water.[12] For instance, the mean value of counts per minute over 6 hours was $0.20_5 \pm 0.02$ for heavy and $0.19_4 \pm 0.02$ for ordinary distilled water. If protons of 2.4 MV, corresponding to a range of about 11 cm in air, were given off from H^2, they could penetrate a layer of about 90 microns of water. Then the experiments show that the constant of transformation of H^2 would be: $\lambda < 2 \cdot 10^{-23}$ and its "period" $T > \cdot 10^{15}$ years.[13] An ionization chamber with linear amplifier which can probably detect a hundred times smaller yield will be used in the near future.

Of course such experiments cannot prove that the neutron mass is not so small as Livingston, Henderson and Lawrence assume, but it appears now more improbable that it is so small. Perhaps another explanation for their experiments can be found.

I am much indebted to Professor Hugh S. Taylor and Dr. T. N. Selwood for providing the heavy water and to Mr. J. B. Kuper and Mr. M. B. Sampson for their valuable help in these experiments.

Rudolf Ladenburg

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Princeton University,
January 15, 1934.

[12] Professor H. C. Urey and Dr. J. R. Dunning have kindly informed me that they have carried out similar experiments; it is probable that such experiments have also been done elsewhere.

[13] Such a lifetime for a nucleus which emits spontaneously a proton would only be possible, if the potential barrier of a reasonable thickness (5×10^{-13} cm) had a height of some billion volts—provided that the Gurney-Condon-Gamow theory of α-ray disintegration is applicable.

On the Interior Magnetic Field in Iron

In an effort to determine the magnitude of the deflecting field in magnetized iron, the following experiment was recently performed: Beta-rays from radium C ($H\rho = 5900$) were focussed in a field of 1900 gauss, and after passing through 0.36 mm of transformer iron, were registered on a photographic film, 1.53 mm from the latter. Both the iron sheet and the film were parallel to the direction of the field, and normal to the incident beta-rays. To prevent darkening of the film due to the continuous spectrum, and to secondary and scattered beta-rays from the walls of the spectrograph, a sheet of brass 2 mm thick was placed 1.88 mm above the film. A 1 mm slit in this sheet allowed the beta-rays to strike the iron, which was waxed to its lower side, only in a definite line, parallel to the radon tube which was used as the source of beta-rays. The brass sheet was soldered to two pieces of brass, which rested directly on the film. One of these supporting pieces was pierced with a thin slit, through which some of the beta-rays passed to darken the plate in a line parallel to the source. The sharp edge of this line served as a fiducial mark.

Photographs were taken with the apparatus as described, and with an equal thickness of copper in place of the iron. The field was kept constant to within less than one percent with the aid of a ballast lamp. Small variations in the field could not shift the line on the plate, since its position was determined by the stationary slit. Exposures of 110 millicurie hours gave maximum contrast as measured by a Mohl microphotometer. The shape of the microphotometer traces was very nearly the same for the copper and iron photographs, and agreed very well with a curve calculated on the basis of the theory of beta-ray scattering.[1]

If the field in the iron were assumed to be equal to the induction B, which in this case was 17,000 gauss, the point of maximum density on an iron photograph should have been 0.15 mm further from the fiducial mark than the corresponding point on a copper photograph. (The induction was calculated from the magnetization curve of the iron used, after allowing for the demagnetizing effect of the free poles developed at the ends of the sheet,[2] and was later measured with a fluxmeter.) Since it was difficult to locate the maximum point with precision, the shift could be more easily detected at a point 1/3 of the distance down from the peak of the microphotometer trace. Here the trace was quite smooth, and in addition, the expected shift was considerably increased because of the greater distance from iron to film, the inclination of the film to the beta-rays, and the greater path in the iron. 1/3 down on the trace (corresponding to a point on the film 1.2 mm from the center of the line), the expected shift was 0.27 mm. The traces were measured on a comparator equipped with micrometer screws at right angles, and similar curves were plotted with the aid of the readings obtained in this manner. All measurements were made on these enlarged traces ($\times 5$); the shift 1/3 down should have been 0.92 cm. Points on these curves could be reproduced to within 1 mm.

Fig. 1 shows the distance from the mean abscissa of a trace to the fiducial mark, as a function of the half width of the curve at the corresponding ordinate. The curves in this figure are essentially the center lines of the microphotometer traces, corrected for variations in exposure time. Their inclination is due to the "straggling" of the beta-rays by the metal sheets. The dotted lines show the calculated positions of iron curves for various values of the interior field.

The data obtained so far are in definite disagreement with the classical theory of magnetism, which postulates an interior field $= B$. The experimental results indicate that the deflecting field in iron is less than 1/3 of B. This is

[1] Rutherford, Chadwick and Ellis, *Radiations from Radioactive Substances*, 219 (1930).

[2] DuBois, *The Magnetic Circuit*, 34, 41 (1896).

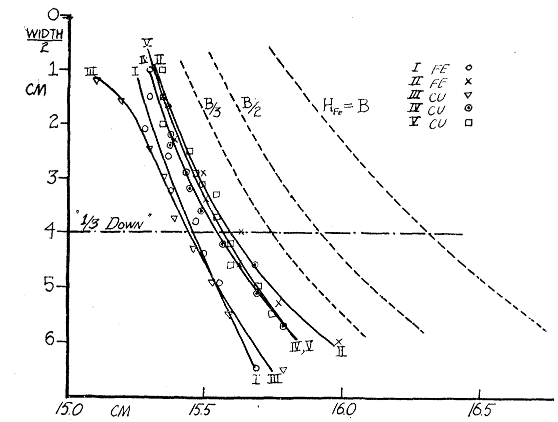

FIG. 1.

consistent with the findings of Mott-Smith,[3] and Rossi,[4] in conjunction with the later work of Curtiss.[5] The data are also in accord with the view that the interior field is equal to the field in a spherical cavity, and not to that in the usually assumed, pill-box shaped cavity. In this case, the equation is $H_{Fe}=(2+\mu)H_{air}/3$.

In the hope of evaluating H_{Fe}, the experiments are being continued, by using a piece of cobalt iron ($B=25{,}000$) and a greater distance from iron to film. The expected shift could also be tripled, and the scattering reduced, by using the beta-rays of thorium C″, a thicker sheet of iron, and a reversal of the induction. In this case, no focussing field would be necessary, since the iron sheet would filter out a nearly homogeneous beam of beta-rays of initial $H\rho=10^4$.

The author expresses with pleasure, his indebtedness to Dr. James Thompson for the loan of several radon tubes, and to Professors A. H. Compton and J. B. Hoag for suggestions and encouragement during the course of the experiment.

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University of Chicago,
January 16, 1934.

[3] L. M. Mott-Smith, Phys. Rev. **39**, 403 (1932).
[4] B. Rossi, Nature **128**, 300 (1931).
[5] L. F. Curtiss, Bur. Standards J. Research **9**, 815 (1932).

Disintegration of Beryllium by Deutons

We reported recently[1] that neutrons were produced in large numbers when beryllium was bombarded with deutons having energies between 400,000 and 800,000 electron-volts. This has since been confirmed by Livingston, Henderson and Lawrence,[2] by using deutons of considerably higher energy. In our early measurements of neutrons the ionization chamber was protected by a lead armor 5 cm thick, in order to minimize the effect of other types of radiation. Realizing that nuclear γ-radiation might be produced in the disintegration, we later made provision for reducing the thickness of lead in the direct path of the radiation to $\frac{1}{4}$ inch. With this arrangement we have measured the absorption of the beryllium radiation in lead and in paraffin, using in each case a lead and a paraffin lined ionization chamber. The paraffin lined chamber is more than twice as sensitive to neutrons as the lead lined chamber, and only 0.6 times as sensitive to γ-radiation as the lead lined chamber. Thus by comparing the absorption curves obtained with the two chambers, a mixture of neutrons and γ-rays can be to some extent analyzed.

Four absorption curves, obtained by using the two kinds of absorber and the two chambers, are shown in Fig. 1. Consider first the curves (II and IV) for the lead absorber, at thicknesses greater than 4 cm. The slope is the same for the lead and the paraffin chambers, indicating that the radiation is of a single type, either entirely neutrons or entirely γ-rays. The large displacement of curve II (paraffin chamber) above curve IV (lead chamber) shows clearly that this radiation is neutrons. The slope of curves II and IV, beyond 4 cm absorption is therefore taken to be the absorption coefficient for the neutrons in lead. At thicknesses of absorber less than 4 cm, curve IV shows a steep rise, which clearly indicates the presence of a component of

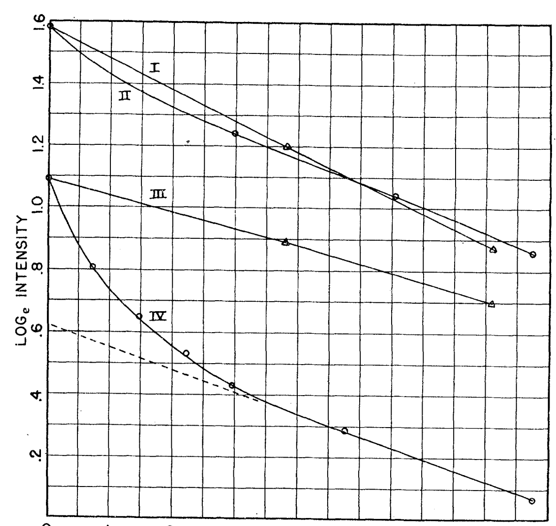

FIG. 1. Absorption of the beryllium radiation. I. Paraffin lined chamber, paraffin absorber; II. Paraffin lined chamber, lead absorber; III. Lead lined chamber, paraffin absorber; IV. Lead lined chamber, lead absorber.

radiation which is much more absorbable than the neutrons, and which is almost entirely screened out by 4 cm of lead. That this component is γ-radiation is indicated by the fact

[1] Crane, Lauritsen and Soltan, Phys. Rev. **44**, 692 (1933).
[2] Livingston, Henderson and Lawrence, Phys. Rev. **44**, 782 (1933).