Long-Lived Radioactive Silver

Several reports of a long-lived activity induced in silver by slow neutrons have appeared recently. Mitchell refers[1] to a weak activity of about 3 months half-life: Alexeeva gives the figure 1.2 to 2.0 years[2] (amended in a private communication to 300±90 days); Reddemann and Strassmann quote[3] a half-life equal to 190±40 days, with observations extending for 3 months, and have shown the activity to be chemically identifiable with silver, so that it must be ascribed to either Ag^{108} or Ag^{110}.

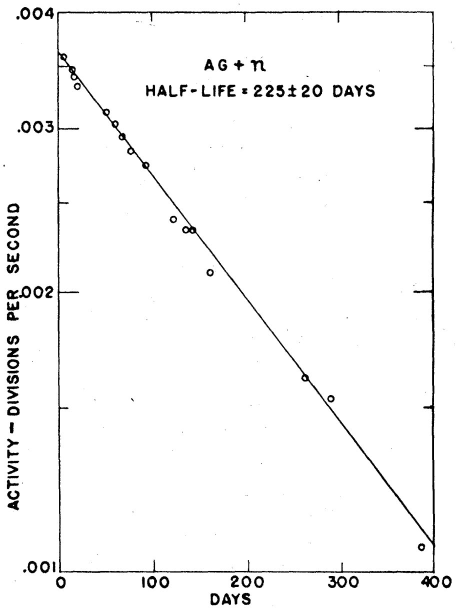

FIG. 1. Decay of radioactive silver.

We wish to add further confirmation to this neutron-induced activity and to give the half-life with somewhat greater precision, after having followed the decay for over a year. Our value is 225±20 days, as may be seen from Fig. 1.

This research has been supported by the Research Corporation, the Chemical Foundation and the Josiah Macy Jr. Foundation.

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[1] A. C. G. Mitchell, Phys. Rev. **53**, 269 (1938).
[2] K. Alexeeva, Comptes Rendus U.R.S.S. **18**, 553 (1938).
[3] H. Reddemann and F. Strassmann, Naturwiss. **26**, 187 (1938).

Cosmic-Ray Particles of Intermediate Mass

A Geiger-counter placed inside a cloud chamber and coupled by means of a coincidence circuit to a second counter placed above the chamber has been employed to increase the probability of observing cosmic-ray particles near the ends of their ranges, and thus to provide information concerning the mass and stability properties of the particles of intermediate mass. One photograph obtained by this method showing a positively charged particle of $H\rho = 1.7 \times 10^5$ gauss cm, which after traversing the counter emerges with an energy low enough for it to be brought to rest in the gas of the chamber, is of special interest and is reproduced in Fig. 1.

The gas in the chamber consisted of $\frac{2}{3}$ helium and $\frac{1}{3}$ argon at a combined pressure of 1 atmosphere, which together with the alcohol vapor corresponds in stopping power to about 0.5 atmosphere of air. Partly for this reason and partly because of a lower light intensity used in these experiments the tracks are somewhat fainter than those normally obtained. The specific ionization of the particle of Fig. 1 before it traverses the counter, although not accurately measurable, is greater than that of a fast electron.

Although four independent mass estimates can be made from the data provided by the photograph, the most accurate value is to be obtained merely from the initial $H\rho$ of the particle and the thickness of matter traversed before it comes to rest. Both of these quantities can be accurately measured; in particular the track is sharp and an accurate curvature measurement is possible.

The details of the computation and a discussion of the errors of measurement will be deferred until the thickness of matter traversed has been accurately measured after breaking the counter. The uncertainty in the final estimate will probably lie more in the theoretical relation between energy loss and velocity than in the experimental measurements themselves. The final determination should be considerably more accurate than any so far made. From the best guess we can make at present as to the thickness of matter traversed in the counter, the mass appears to be about 240 electron-masses. The other three determinations of the mass, (1) by the relation between the specific ionization and the value of $H\rho$ for the upper portion of the track, (2) by the ionization and $H\rho$ below the counter, and (3) by the $H\rho$ and residual range below the counter, all give values consistent with the one above. The initial energy of the particle before it traverses the counter is 10 Mev and the energy with which it emerges is about 210,000 ev. It is perfectly clear that this particle cannot possibly have either electronic or protonic mass (see caption to Fig. 1).

An interesting feature of the photograph is the fact that the particle is actually observed to come to rest in the gas of the chamber. No completely certain evidence of a subsequent disintegration can be found on the photograph. There are, however, three droplets which appear on the left-hand image, which is the direct view, and also on the right-hand mirror image. Stereoscopic observation shows that these droplets line up so as to indicate a short segment of an electron track emanating from the point in the gas at which the particle came to rest and directed toward the counter. Because of the relatively weak light used in these experiments electron tracks are very faint. These droplets may therefore indicate that the particle after coming to rest disintegrated by the emission of a positive electron.

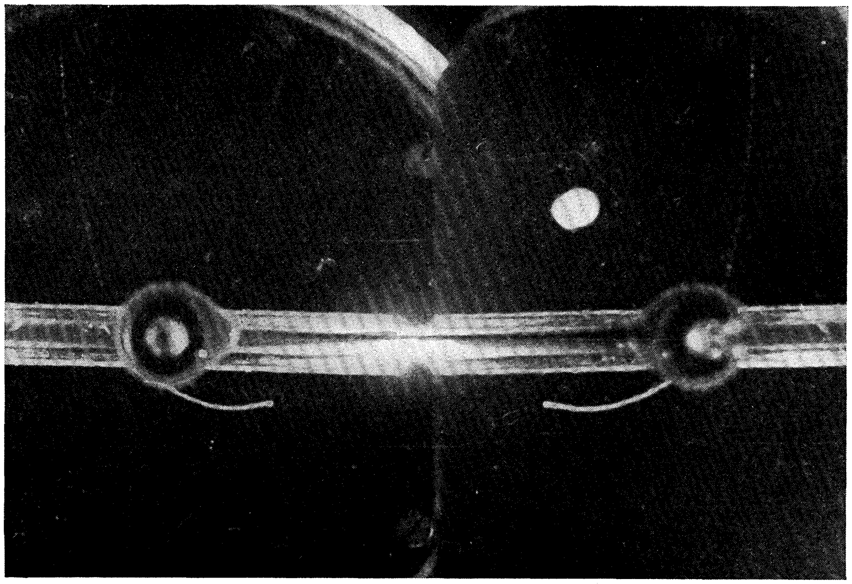

FIG. 1. A positively charged particle of about 240 electron-masses and 10 Mev energy passes through the glass walls and copper cylinder of a tube-counter and emerges with an energy of about 0.21 Mev. The magnetic field is 7900 gauss. The residual range of the particle after it emerges from the counter is 2.9 cm in the chamber (equivalent to a range of 1.5 cm in standard air). It comes to rest in the gas and may disintegrate by the emission of a positive electron not clearly shown in the photograph. It is clear from the following considerations that the track cannot possibly be due to a particle of either electronic or protonic mass. Above the counter the specific ionization of the particle is too great to permit ascribing it to an electron of the curvature shown. The curvature of the particle above the counter would correspond to that of a proton of 1.4 Mev and specific ionization about 7000 ion-pairs/cm, which is at least 30 times greater than the specific ionization exhibited in the photograph. The curvature ($\rho \cong 3$ cm) of the portion of the track below the counter would correspond to an energy of 7 Mev if the track were due to an electron. An electron of this energy would have a specific ionization imperceptibly different from that of a usual high energy particle which produces a thin track, and in addition it would have a range of at least 3000 cm in standard air instead of the 1.5 cm actually observed. Moreover if the particle had electronic mass and emerged from the counter with a velocity such that its specific ionization were great enough to correspond to that exhibited on the photograph, its residual range (in standard air) would be less than 0.05 cm instead of the 1.5 cm observed. A proton of the curvature of the track below the counter would have an energy of only 25,000 ev and a range in standard air of less than 0.02 cm.

Since the particle itself is positively charged it could not have been removed by absorption into a nucleus.

The "intermediate mass" hypothesis offered by the writers[1] to provide an interpretation both of energy loss data and of ionization-range data of the above kind has been given strong support by many experimenters.[2] Various mass estimates have been made from data of the latter type, yielding values ranging from 120 to about 400 electron masses. Our energy loss data have moreover recently been confirmed in all essential details by Blackett.[3] His main conclusion that the penetrating particles always become indistinguishable from electrons when their energies fall below 200 Mev cannot, however, be maintained. In any event this energy value needs to be corrected for the mass, and becomes in fact only 110 Mev for a mass of 240 electrons. A particle of this mass with a curvature corresponding to 100 Mev for an electron would have an actual energy of only 37 Mev and should have a range somewhat less than 1 cm of Pb. Thus, the scarcity of "penetrating" particles with small curvatures (which is clearly evident in our own data) could possibly be understood in terms of the short residual range.

A more detailed discussion, including evidence based on several other photographs of intermediate mass particles, will be given elsewhere.

It is a pleasure to express our indebtedness to Professor R. A. Millikan, and to the Carnegie Institution of Washington, whose grant of funds to Professor Millikan has provided the chief support for these researches. We wish to thank also Dr. J. K. Boggild and Mr. I. C. Kuo for their assistance in operating the apparatus.

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June 16, 1938.

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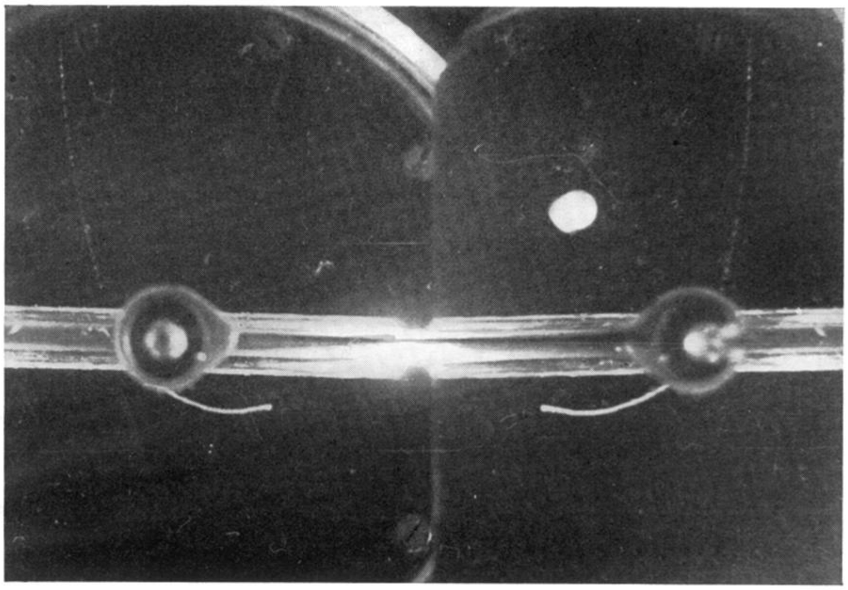
[1] Anderson and Neddermeyer, Phys. Rev. **50**, 263 (1936); Neddermeyer and Anderson, Phys. Rev. **51**, 884 (1937). A discussion of certain fundamental difficulties with identifying the penetrating component with either electrons or protons was given in the former paper and also by Anderson and Neddermeyer, *Report of London Conference*, Vol. I (1934), p. 179.

[2] Street and Stevenson, Phys. Rev. **52**, 1003 (1937); Nishina, Takeuchi and Ichimiya, Phys. Rev. **52**, 1198 (1937); Brode and Starr, Phys. Rev. **53**, 3 (1938); Auger, Comptes Rendus **206**, 346 (1938); Ruhlig and Crane, Phys. Rev. **53**, 266 (1938); Corson and Brode, Phys. Rev. **53**, 773 (1938); Ehrenfest, Comptes Rendus **206**, 428 (1938); Williams and Pickup, Nature **141**, 684 (1938).

[3] Blackett, Proc. Roy. Soc. **A165**, 11 (1938).



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