"Data on the oldest obtainable uranium leads from minerals unaltered as far as possible are especially desirable, to test the applicability of the actinium D: radium G ratio formula beyond a billion years. (The Manitoba uraninite, for instance, discovered by H. V. Ellsworth, with a lead/uranium = 0.27 should prove worth while.) They might also be interesting in another respect: In case the experimental curve should deviate in that range from our theoretical it might indicate the existence of a second actinouranium isotope (still a possibility as we mentioned in paper 1), not yet in equilibrium with our present isotope. The Rutherford-Soddy disintegration theory allows one to calculate in a simple way the ratio of actinium D to radium G for different possible cases; it would be, however, premature to discuss these points at the present time."

Assumption of the genetic scheme:

$$AcU^{239} \xrightarrow{\alpha,\ \beta,\ \beta} AcU_7^{235} = 7.10^8 a$$

with a half-life value of the order of 10^8 years for AcU^{239} and a reasonable concentration in uranium during the early history of the earth's crust would account for the observed facts, i.e., the present absence of AcU^{239} and an excessively high Pb^{207} : Pb^{206} ratio in very old minerals.

The *second* discrepancy is between the activity ratio, R, of Nier = 4.6 percent and the directly determined values of 4.0–4.1 percent (Grosse (1932) = 4.0, E. Gleditsch and Foyn (1934) = 4, Francis and Da Tchang (1934) = 4.1) from the Pa : U ratio. However, the magnitude of this disagreement, i.e., $\backsimeq$10 percent of the actual value, is not discomforting if one remembers that in a number of careful investigations previous to 1932 a much greater spread (B. B. Boltwood (1908) 8 percent; O. Hahn and L. Meitner (1919) 3 percent; G. Kirsch (1920) 4.2 percent; W. G. Guy and A. S. Russell (1923) 3.1 percent; A. S. Russell and W. P. Widdowson (1923) 2.9 percent; A. Piccard and E. Kessler (1923) 5 percent) was observed.

Although in a number of cases the errors were due to incomplete separation of protoactinium, we are reasonably sure this was not the case in our own Pa $-$ ZrP_2O_7 precipitations, which were checked for quantitative separation. Errors may have also been introduced by the different corrections required, such as range of particles or thickness of film. In our own measurement inaccuracies *may have* been introduced by inadequate correction for the self-absorption of α-particles in the ZrP_2O_7 film. It is perhaps significant that the results in Mme. Curie's laboratory average 4.0 percent for the tantalum method and 4.2 percent for the ZrP_2O_7-method. Further careful determinations will be required to decide the best value, but we believe no fundamental disagreement with Nier's value exists.

If Nier's value is correct it follows that the AcU^{235}-content of uranium equals 0.7_1 percent by weight and the weight of protoactinium associated in any uranium mineral with 1 g of Ra is increased to 0.9_3 g.

ARISTID V. GROSSE

Department of Chemistry,
University of Chicago,
Chicago, Illinois,
February 20, 1939.

[1] A. O. Nier, Phys. Rev. **55**, 150 (1939).
[2] A. O. Nier, Phys. Rev. **55**, 153 (1939).
[3] A. V. Grosse, see Abstracts of Rochester or 94th Meeting of the American Chemical Society, page 23.
[4] A. V. Grosse, J. Phys. Chem. **38**, 487 (1934).

On the Mass of the Mesotron

Since we published[1] the results of mass determination of the mesotron, the existence of which had theoretically been foreseen by Yukawa, we have been continuing the same experiments with the Wilson cloud chamber.

During last September we obtained a photograph shown in Fig. 1. A lead bar 5 cm thick was mounted in the middle

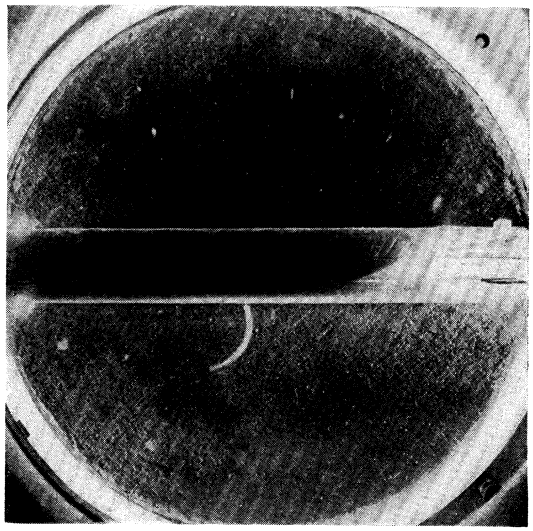

FIG. 1. Wilson track of a mesotron. $H = 12{,}600$ oersteds. $H\rho = 3.88 \times 10^4$ oersted·cm. Observed range = 6.15 cm.

of the chamber 40 cm in diameter, which is filled with air and alcohol vapor, and placed in a magnetic field of about 12,600 oersteds. The operation of the chamber was controlled by two Geiger-Müller tube counters mounted immediately above the chamber. The distance between the counters was about 15 cm. Above the counters was placed a lead block 20 cm thick.

A negatively charged particle of $H\rho = (3.88 \pm 0.08) \times 10^4$ oersted-cm seems to have been created within the lead bar by a certain non-ionizing agent and was brought to rest in the gas of the chamber, the observed range being 6.15 cm. By taking into account the pressure of the gas, which was between 1.23 and 1.30 atmospheres at 25°C, and a possible inclination of the track with respect to the plane of the chamber, we estimate its range in air of 15°C and 760 mm to lie between 7.3 and 8.1 cm. According to the range-energy curve for the proton given by Livingston and Bethe[2] we calculate the mass of the particle by using the above values of $H\rho$ and range and obtain

$$M_m = (170 \pm 9)m, \qquad (1)$$

where m is the mass of the electron.

At the end of the range the photograph shows no sign of an electronic track, which would prove the disintegration of the mesotron.

We have recently re-examined the old photograph mentioned in our preceding paper[1] and obtained the following values. A positively charged particle of $H\rho = (7.4 \pm 0.1)$

$\times 10^5$ oersted·cm passes through a lead bar 3.5 cm thick at an angle of about 47°, the length of the path inside lead thus being 4.8 cm. After traversing the lead bar, $H\rho$ becomes $(5.0\pm0.1)\times 10^5$ oersted·cm.

On assuming the mass of the particle, we can calculate its initial and final energies and thus find the loss of energy due to collisions within lead. On the other hand this energy loss can be calculated theoretically, for example, according to Bloch's formula,[3] if we use the assumed mass and the initial energy. The mass of the particle can be adjusted in such a way as to bring both values of the energy loss to agreement. In this manner we formerly obtained with the old data of preliminary measurements

$$M_m = (180\sim 260)m. \tag{2}$$

In these calculations we assumed for Bloch's formula the maximum energy W transferred in a direct collision from the particle to a free electron to be $2mv^2$ according to the nonrelativistic theory, where v is the velocity of the particle. In our case, however, we ought instead to have used a relativistic value

$$W = \frac{2mM_m(1+\eta)E}{m^2+2mM_m\eta+M_m{}^2}, \tag{3}$$

as was given by Bhabha,[4] where E is the initial energy of the particle, $\eta=(1-v^2/c^2)^{\frac{1}{2}}$, and c is the velocity of light. If we do this and use the above data of the new measurements, we obtain

$$M_m = (180\pm 20)m, \tag{4}$$

which is in better agreement with the value (1).

A more detailed paper will be published in the Scientific Papers of this Institute.

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Institute of Physical and Chemical Research,
Tokyo, Japan,
January 31, 1939.

[1] Y. Nishina, M. Takeuchi and T. Ichimiya, Phys. Rev. **52**, 1198 (1937).
[2] M. S. Livingston and H. A. Bethe, Rev. Mod. Phys. **9**, 268 (1937).
[3] Cf. W. Heitler, *The Quantum Theory of Radiation* (Oxford, 1936), formula (1), p. 218.
[4] H. J. Bhabha, Proc. Roy. Soc. **A164**, 255 (1938).

The γ-Rays of Radium E

At the Chicago meeting of the American Physical Society, Professor Jauncey[1] put forward an interesting interpretation of the results of experiments of Gray and Hinds[2] on the so-called γ-rays of radium E. He believes that these rays may be due to what he terms internal scattering, a process in which a β-ray in escaping from the disintegrating atom dislodges an orbital electron, and thus gives rise to characteristic x-radiations, the γ-rays of radium E.

I have no doubt that this process takes place but to a much smaller extent than imagined by Jauncey. As a result of internal scattering, x-rays characteristic of an atom of atomic number 83 would be emitted and would consist of K, L and M radiations. The M radiation would not enter the measuring instrument under the conditions of our experiment. The L radiation would correspond to what are called the soft γ-rays of radium D. The absorption of these soft γ-rays in aluminum has been found by us. In Fig. 1, three curves are shown. Curve A gives the absorption of the γ-rays of radium E in aluminum. Curve B has been obtained on the assumption that 20 percent of the initial ionization is due to L radiation of atomic number 83. When this is allowed for and subtracted from the ionization intensities in curve A, we get the ionization due to remaining radiation, or curve B.

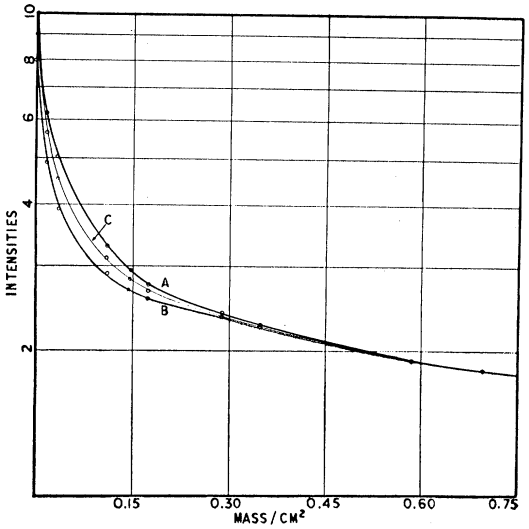

FIG. 1. Absorption of γ-rays of radium E in aluminum.

The slope of any such absorption curve should continually decrease but this is not true in the case of curve B, for it will be seen that the slope increases at about 0.30 g/cm². Consequently L radiation provides less than 20 percent of the initial ionization. Curve C has been obtained by assuming that 10 percent of the initial ionization is due to L radiation. I would say that not more than 10 percent can be due to L radiation. As far as K radiation is concerned it can also be shown that only a small fraction of the harder radiation can be characteristic of an atom of atomic number 83.

Evidently our results have not been interpreted correctly. We believe the spectrum of the γ-rays to be a continuous one. The absorption curve of these rays can be approximately given by a number of exponential terms. We found a fairly close fit by using five, and no special significance was attached to the wave-lengths deduced from these terms. They do give one, however, a very good idea of the type of radiation present and indicate that radium E emits a large number of slow β-rays.

This is shown by the curves in Fig. 2. Curve A gives the variation in intensity of the x-rays produced in aluminum as the mass of the absorbing material is increased. The intensity is a maximum at about 0.05 g/cm² and is 50 percent at about 0.006 g/cm². It is convenient to think of

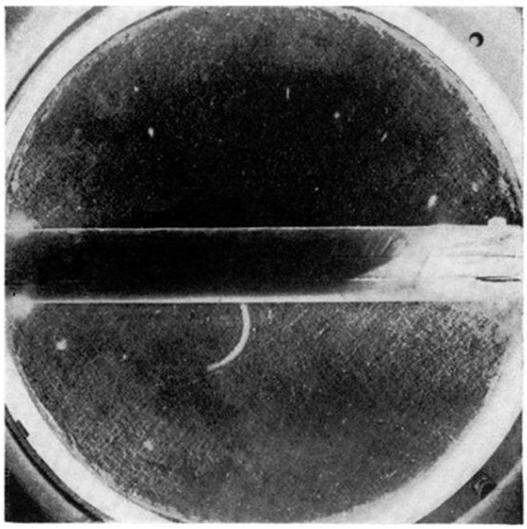

FIG. 1. Wilson track of a mesotron. $H = 12{,}600$ oersteds. $H\rho = 3.88 \times 10^4$ oersted·cm. Observed range = 6.15 cm.