Evidence for the Existence of a Low-Mass Mesotron[1]

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The photograph in Fig. 1 shows what may be interpreted as an elastic collision between a particle of mass about 10 times that of an electron and an electron in the gas of a cloud chamber. An explanatory diagram is given in Fig. 2. The photograph was taken at an altitude of 8,850m with a random expansion of a cylindrical cloud chamber 87 cm in diameter and 15 cm deep filled with approximately 1 atm of argon and saturated with ethyl-alcohol vapor. No magnetic field was present.

From the range of the electron, which stops in the gas, its velocity immediately after the impact is found to have been about ½ of the velocity of light, and comparison of the ionization along the two tracks near the junction shows the heavier particle to have had about the same velocity. A nonrelativistic treatment will therefore give a reasonable first approximation for the masses involved in the collision. Since the energy transferred to the electron is about 75,000 eV while the binding energy of even the K-shell electrons of argon, the heaviest atom in the chamber gas, is only 3,200 eV, the collision may be considered to be elastic and the laws of conservation of momentum and energy applied.

The following relation results:

$$\frac{M}{m} = \frac{\sin(2\theta + \phi)}{\sin \phi},$$

where M is the mass of the heavy particle, m is the mass of the electron, and θ and ϕ are the angles indicated in Fig. 2.

To measure these angles, which are considerably smaller than the projected angles in the two stereoscopic views in Fig. 1, the two negatives were reprojected through the original camera arrangement upon a screen. The screen was then tilted until the two images coincided, and the true angles in space were measured. When so projected, the right and left images of both tracks coincided near the junction, indicating that the collision was approximately coplanar.

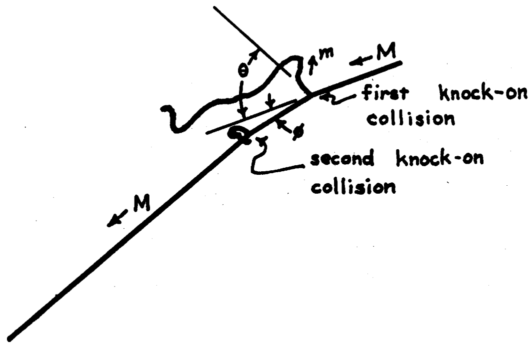

Fig. 2

The values of $\theta = 39°$ and $\phi = 5.0°$, when substituted in the equation above, give a mass ratio of 11.4 for the two particles involved in the collision.

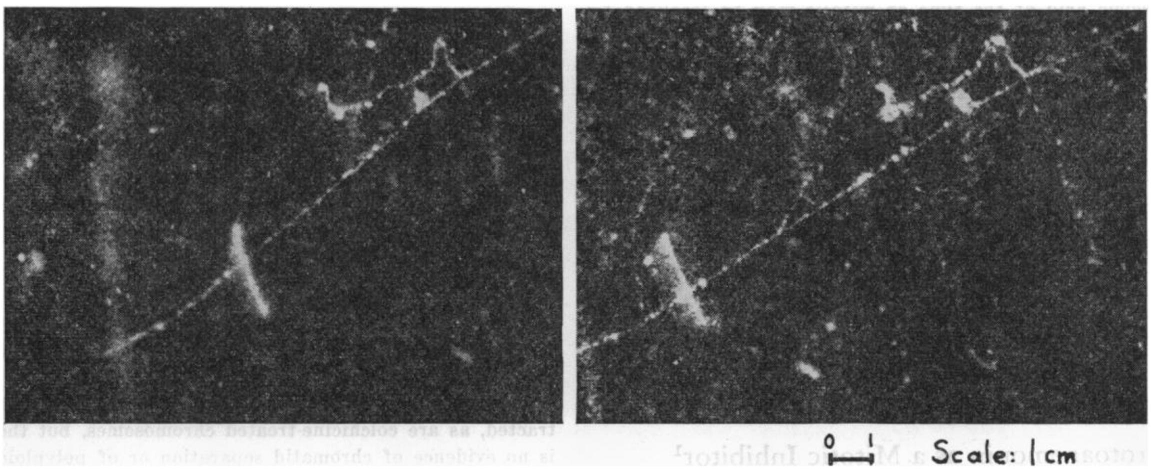

Fig. 1

Although the value of θ may be considered to be doubtful because of the possibility of a single large-angle scattering of the electron immediately after it was accelerated by the knock-on collision, the maximum value of M/m that can be obtained for any value of θ is csc ϕ, which is 11.5 for the value of ϕ given above. This maximum is relativistically correct for the rest mass ratio.

The lower limit for the mass ratio is still uncertain if the value of θ is considered doubtful. However, the possibility that the track could have been produced by

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an electron can be ruled out on the basis of the ionization and degree of multiple scattering of the track. The ionization of the two tracks is roughly equal at the junction point and several times the minimum value for a singly-charged particle. Thus, the tracks indicate about the same velocity for the two particles but show a markedly smaller scattering for the deflected particle, indicating a heavier mass.

Another possible interpretation is that the track was caused by a mesotron or proton that was scattered by a nuclear collision very close to the point where the knock-on collision occurred. The probability of this explanation is reduced considerably by the occurrence along the same track of a second knock-on electron of shorter range with a correspondingly smaller deflection of the heavy particle. Since the value of θ for this second collision is close to 90°, in which range the mass ratio varies rapidly with θ, the uncertainty in the exact direction of the knock-on electron caused by its large scattering makes it impossible to calculate a significant mass ratio. The value of csc ϕ for this collision, however, sets an upper limit of 30 for the mass ratio.

Measurement of Radiocarbon as CO_2 in Geiger-Müller Counters[1]

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The gas counting of radioactive carbon dioxide has been studied as a quantitative procedure in the range 2–12 cm Hg pressure. The results presented below demonstrate that this highly efficient counting method may be carried out with routinely available equipment furnishing up to 2,000 or 2,500 v.

Miller and Brown (*1, 2*) have recently reported a satisfactory counting technique at CO_2 pressures from 10 to 50 cm Hg admixed with 2 cm pressure of CS_2 vapor. They report threshold voltages over the range 1,800–4,500 v, depending on counter diameter and CO_2 pressure. This counting gas mixture was used in the experiments reported here. Using a 4-mil tungsten anode, 15.5-mm I.D. Geiger-Müller counter tube and a CS_2 partial pressure of approximately 2 cm, threshold voltages ranged from 1,450 to 2,200 v for the 2–12 cm pressure range. The measured activity was found to be directly proportional to the partial pressure of the radioactive gas sample admitted to the tube. This indicates that the counting efficiency of the tube for beta particles emitted by carbon 14 is very close to 100% in the effective volume over this pressure range.

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Pure CO_2 was prepared by heating sodium bicarbonate (E. and A. Tested Purity Reagent) at 350°. Water vapor was condensed in a dry-ice trap. Radioactive CO_2 was prepared by addition of perchloric acid to barium carbonate containing carbon 14. Mallinckrodt carbon disulfide (analytical reagent; boiling range, 46°–47°) was used without further purification.

A scaling circuit and 2,500-v stabilized voltage supply was used with a modified Neher-Harper quenching tube and cathode follower. The latter unit contained two 6AG5 tubes, a 5.6-megohm grid resistor, and a variable cathode resistor usually set to 7,000 ohms. The Geiger-Müller tubes were glass envelopes containing as cathode chemically deposited silver covered with colloidal graphite (*1, 2*). Tungsten wire (4 mil) anodes were used.

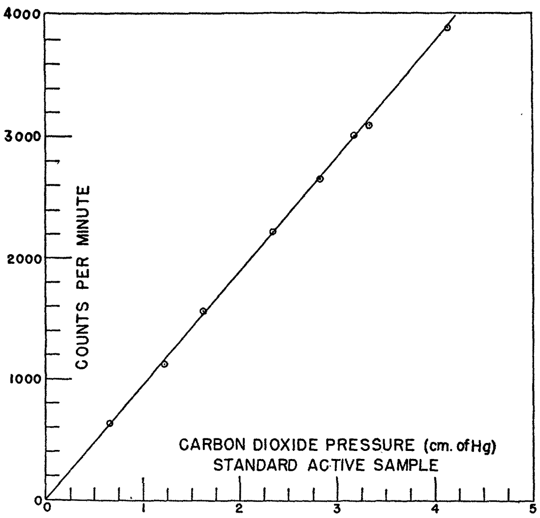

Fig. 1

A "cold finger" attached to the lower portion of the counter tube permitted quantitative condensation of CO_2 and CS_2 at liquid nitrogen temperatures. CO_2 pressures were measured with less than 0.3% error using a constant-volume mercury manometer and "cold finger" having a combined volume of about 18 ml. The resolving time was measured using two external radium sources and was found to be 4.1×10^{-5} min. Corrections using this resolving time were applied to the data.

In Fig. 1 the corrected counts per minute are plotted as a function of the partial pressure of a reference radioactive CO_2 sample using a counter tube having a 15.5-mm I.D. and 15-cm length of cathode surface. The pressures correspond to a temperature of 27.0°. The partial pressure of carbon disulfide in these fillings was 1.85 cm Hg (equivalent to one "doser" volume of vapor in the filling line when the liquid is maintained at 0.0°). In the case of the point closest to the origin, inactive CO_2 was added until the total pressure of CO_2 was 5.8 cm. The average deviation of the experimental points from the straight line drawn in Fig. 1 is 1.1% The range of CO_2 pressures plotted extends to 4 cm Hg. Further measurements made after adding inactive CO_2 up to pressures of about 10 cm Hg checked the line