Further Evidence Against Heavy Beta-Particles

We have shown[1] that Champion's experiments on the collisions of beta-particles with electrons contradict the hypothesis of heavy beta-particles, in the form recently proposed by Jauncey.[2] Earlier, he suggested that heavy electrons in the cosmic rays might lose mass by ionization or by emitting gamma-radiation, and now he employs this suggestion[3] to explain the presence of "ordinary electrons" in his deflection experiments, and in those of Zahn and Spees. We are asked to believe that in the latter experiments practically all the radium E beta-particles start out in heavy form, but that they may revert to the ordinary form in the short time elapsing before they reach the detector. Presumably the same supposition could be employed to question our interpretation of Champion's results, so we wish to show that it does not agree with known facts. The idea that the excess energy is dissipated very quickly in the form of gamma-rays is incompatible with the very low amount of radiation emitted by radium E; this amounts to only 10^4 volts per disintegration.[4] On the other hand, the excess energy cannot be frittered away in ionization processes, for this would contradict the calorimetric experiments of Ellis and Wooster, who found the total energy liberated in the form of heat is $350{,}000\pm 40{,}000$ volts per disintegration. Meitner and Orthmann's repetition gave $337{,}000\pm 20{,}000$ volts.

Before Jauncey proposed the idea we have just considered, he discussed[5] the experiments of Meitner and Orthmann from another point of view, assuming that the lifetime of a heavy electron is long, or that any radiation it may emit escapes detection in experiments on the heat evolution of radium E. His hypothesis that all beta-particles from a given substance have the same total energy means that their *energy distribution* curve is shifted decidedly to lower energies, as compared with the classical one,[6] so that the average kinetic energy of the electrons is less than one-third of the maximum. He states that his hypothesis explains the Meitner-Orthmann result, provided that their experiment records only the kinetic energy of the particles.

We have done the computation over and used the data of Flammersfeld[7] on the shape of the radium E distribution curve. The average kinetic energy turns out to be 153 kev on Jauncey's hypothesis, while on the usual basis it is 331 kev, in excellent agreement with the calorimetric value, given above.

Additional evidence against the heavy particle hypothesis may be derived from data on elastic scattering of radium E beta-particles by electrons. Champion[8] obtained extensive cloud chamber evidence on the angular distribution of scattered electrons and the scattering cross section. His results agree closely with the theory of Möller, which takes into account both exchange effects and retardation. In these experiments the incident beta-particles had kinetic energies ranging from about 380 to about 880 kev. By the use of Jauncey's formulas these figures would become 165 and 570 kev, respectively. The predicted scattering would then be very different from the observed scattering, firstly because the average energy is much lower than the classical one, and secondly, because the incident particle and the one struck would not have the same rest mass.

No doubt many other types of experiment could be cited to show that there is no striking difference between the properties of beta-particles and electrons of the same velocity, calculated of course by the usual formulas. We are well aware that several observers have claimed that the energy loss formulas for electrons break down in the region below 10 Mev. The experiments of Turin and Crane[9] and the calculations of Jaeger[10] indicate that the trouble will be ironed out when more accurate numerical computations of cross sections become available. It is to be expected that present theories, properly applied, will be found to provide an adequate description of the behavior of electrons *outside* of nuclei and at energies for which the de Broglie wavelength is much larger than the classical electron radius.

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[1] Ruark and Jones, Phys. Rev. **53**, 264 (1938).
[2] Jauncey, Phys. Rev. **53**, 197 (1938).
[3] Jauncey, Phys. Rev. **53**, 265 (1938).
[4] Aston, Proc. Camb. Phil. Soc. **22**, 859 (1925).
[5] Jauncey, Phys. Rev. **53**, 106 (1938).
[6] Jauncey uses 2.06 mc^2 for the maximum *kinetic* energy. This is incorrect. In reference 1 we employed 2.44 mc^2 which corresponds to the Konopinski-Uhlenbeck extrapolation of O'Conor's data. The experimental end point is 2.28 ± 0.06 mc^2. Use of this value would not affect the conclusions in reference 1.
[7] Flammersfeld, Physik. Zeits. **38**, 973 (1937).
[8] Champion, Proc. Roy. Soc. **137**, 688 (1932).
[9] Turin and Crane, Phys. Rev. **52**, 63 and 610 (1937).
[10] Jaeger, Nature **140**, 108 (1937).

The Energy of the Neutrons from the Disintegration of Carbon by Deuterons

Recently Bethe and Livingston[1] have constructed new range energy curves for low energy protons which differ considerably from the old data. Because the old data of Blackett and Lees[2] were used in calculating the energy of the neutrons from carbon,[3] according to the reaction

$$C^{12}+H^2\rightarrow N^{13}+n'+Q,$$

it was considered advisable to recalculate the data on the basis of the new range-energy curve.

The neutron energies are determined from that of the recoil protons recoiling in the forward direction (0–8°) to the 0.88 Mev deuterons. They were observed in a cloud chamber at an angle of $90°\pm 10°$ to the direction of the incident deuterons on the target. The stopping power of the methane in the cloud chamber was found to be 1.057 for polonium alpha-particles, and was corrected for the change in stopping power according to the procedure of Livingston and Bethe.[4] This gives a value of 1.16 for protons of 0.5 cm range.

The extrapolated range of the recoil protons is 0.58 ± 0.05 cm as determined from the integral range-number curve. This corresponds to a proton energy of 0.455 Mev according to the new data or to an energy of 0.33 Mev when Blackett's old data are used.