moles of Be salt per cm^2 of deposit to be sufficiently thin to make self-absorption negligible for β-particles certainly, and within a few percent for the weakest α-particles, the minimum possible apparent half-life for Be with respect to emission of single particles is $2 \cdot 10^{15}$ years. If one calculates on the basis of the emission of 2 particles at once as Langer and Raitt have done, the minimum life would be $4 \cdot 10^{15}$ years.

The sensitivity of the instrument for low-energy particles has been established previously by using aluminum screen instead of the copper and investigating the photoelectric effect. By means of a monochromator the photoelectric threshold of aluminum was found to be as low as 5000 Angstroms, the counting of the emitted photoelectrons being used to detect the effect. Also, calculation from the geometry of the counter, screen sample, etc., of the expected β-radiation effect due to potassium has always given the observed result within a few percent. It therefore seems probable that any radiation producing as much ionization as a photoelectron of a few volts energy should have been counted.

The $Be(NO_3)_2$ was purified by dissolving in water with $Pb(NO_3)_2$, saturating with H_2S, filtering, adding $Ba(NO_3)_2$, then $(NH_4)_2C_2O_4$ solution, filtering, titrating roughly with Na_2SO_4 solution to remove residual Ba^{++}, and evaporating to dryness.

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W. F. Libby

Department of Chemistry,
University of California,
Berkeley, California,
August 23, 1933.

On the Nature of Cosmic-Ray Showers

The treatment of positive-negative electron pair formation as arising from the ionization of the completed negative energy electron shell around a positive nucleus, has occurred independently to several investigators.[1] This point of view seems to agree well with the experimental facts of the excess absorption of the 2.6 million volt radiation of Th C″ and the recent measurements of excess absorption by Gentner[2] for energies between 1 and 2.6 million.

However, this theory in its simple form is not in agreement with the state of affairs at very high primary energies, as it affords no explanation of shower formation and it requires the total absorption of the primaries (gamma-radiation or electrons) in pair formation, to vary much faster with the atomic number of the absorber, than the absorption of cosmic rays would seem to indicate. Shower formation cannot be a direct secondary effect of a single pair formation where an extraordinarily high probability of new pair formation by electrons of the original pair exists, for Anderson has obtained photographs of high energy electron tracks passing through thick pieces of Pb without shower formation, and suffering relatively small energy losses.

The results of Rossi[3] indicate that a secondary is produced which within a very short range in Pb, loses its energy principally by shower formation. It is here pointed out that a simple and natural explanation of shower formation follows from the assumption that Rossi's secondaries are very high energy protons or heavier nuclei. For, if a positive nucleus has a sufficiently high relative velocity to electrons at rest, so that this velocity is higher than that which electrons have after falling through 1 million volts, then the electrons at rest will be able to ionize the closed negative energy electron shell of the *oncoming* positive nucleus. In order to obtain this relative velocity for a proton, it is necessary for it to have more than 2000 million volts energy. A proton of less than this energy cannot produce showers. An electron with an energy somewhat over a million volts is assumed to have a high effective cross section of pair formation in collision with a nucleus. This assumption is subject to test in the cloud chamber by determining the frequency of pair formation in a thin metal sheet by electrons with energies between 1 and 2 million volts. The calculations of Furry and Carlson[4] are not applicable to this case. When the nuclei are stationary and the electron is moving, it will only form one pair, as it would lose the largest part of its energy in doing so. When the nucleus has the same velocity relative to electrons at rest, the nucleus loses a relatively small amount of energy in a pair formation, so that many pairs can be produced before the speed of the nucleus becomes too low. The density of electrons in Pb is so large, that these pairs can be formed in a very short length of its path. This would appear as a shower formation apparently originating from a small region.

The formation of very high energy positive nuclei from a penetrating primary could be either due to photoelectric ejection of parts of heavy nuclei by a very high energy gamma-radiation or more probably whole nuclei, or parts of them could be projected with high energy by neutrons of enormous energy constituting part of the primary radiation. Much more experimental evidence is needed to elucidate the exact nature of this primary absorption process. Secondary neutrons causing a tertiary positive nucleus projection would seem to explain the non-ionizing links of Blackett and Occhialini.

Benedict Cassen

Kellogg Radiation Laboratory,
California Institute of Technology,
August 29, 1933.

[1] E.g., Beck, Zeits. f. Physik **83**, 498 (1933). Oppenheimer and Plesset, Phys. Rev. **44**, 53 (1933).

[2] Gentner, Comptes Rendus **197**, 403 (1933).

[3] Rossi, Nature **132**, 173 (1933).

[4] Furry and Carlson, Phys. Rev. **44**, 237 (1933).