The Nature of the Primary Cosmic Radiation and the Origin of the Mesotron

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DURING the past year, our counter measurements of the vertical intensity and the production of mesotrons at high altitudes have been continued.[1] In these measurements various arrangements of counters in three-, four- or fivefold coincidences have been used. The vertical intensity has been obtained with lead thicknesses of 4, 6, 8, 10, 12 and 18 cm interposed between the counter tubes. The combined results of these experiments are plotted as Curve *A* of Fig. 1. It is seen from these measurements that the intensity of the hard component increases continuously to the highest altitudes reached. In our previous paper a single point of low statistical weight indicated a maximum in the mesotron curve which is not confirmed in our subsequent experiments. In the original experiments with 8 and 10 cm of lead we considered the possibility of a contribution at very high altitudes to the observed intensity from primary electrons with sufficient energy to penetrate the lead ($E>10^{10}$ ev). This consideration led us to carry out the experiments with greater and with smaller lead thicknesses. The close agreement between the points obtained with the various thicknesses to pressures of 2 cm Hg (less than 1 radiation unit from the top of the atmosphere) is evident from the figure. This shows that measurements of the hard component made at very high altitudes with lead thicknesses even as small as 4 cm are not appreciably affected by electrons.

Further evidence that the traversing particles are not electrons was obtained by an arrangement of side counters registering showers generated in the lead by the traversing particles. A typical arrangement is shown in the figure in which counters 1, 2, 3, 4 and 2, 3, 4, 5 register the vertical intensities for 4 and 6 cm of lead, respectively, and counters 1, 2, 6, 4 and 2, 6, 4, 5 register particles accompanied by showers. If the traversing particles are electrons, there is a high probability of generating in the first 2 cm of lead a shower of many particles. In no case were more than a few percent of the traversing particles accompanied by shower counts in the side counters.

Because of the constancy of the penetrating power of the particles which we measure, and because they are not shower producing, we conclude that there are no electrons of energies between 10^9 and 10^{12} ev present at the highest altitudes reached. Since the energy required for electrons to penetrate the earth's magnetic field of 51° geomagnetic latitude is about 3×10^9 ev, and since our measurements were carried out to within the first radiation unit from the top of the atmosphere, it seems difficult to assume the presence of electrons ($E<10^{12}$ ev) in the primary cosmic radiation and, hence, they must be replaced by some penetrating type of charged particles. The mesotrons themselves cannot be the primaries because of their spontaneous disintegration. Hence, it is probable that the incoming cosmic radiation consists of protons. The following facts support this assumption.

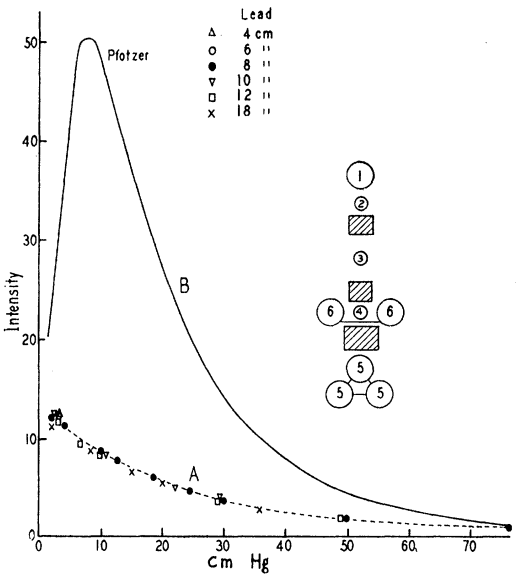

FIG. 1. Curve *A*: Intensity of the hard component for various lead thicknesses as a function of pressure in cm Hg. Curve *B*: Total vertical intensity of cosmic rays obtained by Pfotzer as a function of pressure.

1. Another experiment which we have performed at high altitudes shows that mesotrons which can penetrate 18 cm of lead are produced in multiples mainly by ionizing nonshower producing particles.[2]

2. The number of incident particles as determined by Bowen, Millikan and Neher[3] from their ionization chamber measurements at high altitudes is approximately the same as the number of penetrating particles which we observe close to the top of the atmosphere.

3. The measurements of the east-west asymmetry of cosmic rays have led Johnson[4] to suggest that the primaries of the hard component are probably protons. (In order to make it certain that all the incoming cosmic rays are positively charged, an east-west experiment for penetrating particles should be carried out at high altitudes.)

We hope to continue these observations with lower thicknesses of lead to compare with the measurements without absorption screen made by Pfotzer. Since we have assumed that the primary cosmic radiation consists of protons, the electrons known to exist in large numbers in air at high altitudes (curve *B*) must be of secondary origin. Furthermore, as seen from our experiments, the average energy of these electrons is low ($E<10^9$ ev). These facts suggest that the electrons in the atmosphere arise mainly from the decay of the mesotron and knock-on processes.

The writers wish to express to Professor A. H. Compton their appreciation for his support of these experiments and his continued interest in them.

[1] M. Schein, W. P. Jesse and E. O. Wollan, Phys. Rev. **57**, 847 (1940).
[2] This process is in addition to the process already reported of the production of mesotrons by non-ionizing radiation.
[3] I. S. Bowen, R. A. Millikan and H. V. Neher, Phys. Rev. **53**, 217 (1938).
[4] T. H. Johnson, Rev. Mod. Phys. 11, 208 (1939).