elevation (3 m water). It must be remembered that this estimate is very rough. Further experiments and calculations are in progress.

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[1] S. A. Korff and W. E. Danforth, Phys. Rev. **55**, 980 (1939).
[2] C. Kittel and G. Breit, Phys. Rev. **56**, 747 (1939).
[3] H. v. Halban, L. Kowarski and M. Magat, Comptes rendus **208**, 572 (1939).

The Absorption of Mesotrons in Air and in Condensed Materials*

It has been pointed out by several authors that the absorption of mesotrons in air is considerably larger than the absorption by equal masses of condensed materials. This fact has been interpreted as evidence for a spontaneous decay of the mesotron. A lifetime of about 2×10^{-6} sec. is required in order to account for the difference.

The great theoretical importance of this conclusion justifies a careful investigation of possible alternative explanations of the observed difference in absorption. I have therefore considered the following effect which seems to explain the observations, at least to some extent, without assuming a decay of the mesotron.

The ionization loss of energy by a fast particle passing through matter is partly due, as is well known, to close impacts between the particle and the material electrons; a large fraction of the loss, however, is due to impacts at distances greater than the atomic radius. For a mesotron with energy of the order of some billions of ev the ionizing effects of the particle can reach to distances of over 10^4 times the interatomic distances.

In a rarefied gas the action of the field of the passing particle on every molecule is independent of the perturbation due to the surrounding molecules. This is no longer true for a condensed material in which the electric field of the passing particle is largely affected by the reaction of the electric polarization of the substance. A calculation of this effect based on the classical theory of the ionization loss shows that it is by no means negligible.

Simple formulas can be obtained if the dielectric properties of the medium are schematized by assuming all the electrons (n per unit volume) to be elastically bound with the same frequency ν_0. The dielectric constant for low frequencies would then be $\epsilon=1+ne^2/\pi m\nu_0^2$. With these assumptions it can be proved that the energy loss per unit path for a particle moving with velocity v is less than the loss calculated with the ordinary theory by the following amount:

$$\frac{2\pi ne^4}{mv^2}\log\epsilon \quad \text{for} \quad v<c/\sqrt{\epsilon},$$

$$\frac{2\pi ne^4}{mv^2}\left[\log\frac{\epsilon-1}{1-v^2/c^2}+\frac{1-\epsilon v^2/c^2}{\epsilon-1}\right] \quad \text{for} \quad v>c/\sqrt{\epsilon}.$$

The result is not essentially dependent on the special assumption as to the dielectric properties of the substance.

While these formulas give a relatively unimportant change in the stopping power of gases and solids for slow particles like protons or α-particles, the difference in behavior becomes rather large when the velocity approaches that of light. Let us consider for example the energy loss of a mesotron of 3×10^9 ev in two different media: A condensed material for which we take $\epsilon=2$; and air for which we take $\epsilon=1.00054$. Neglecting the present effect one would expect the energy loss to be approximately 2.3 Mev·cm²/g for both media. The reduction of loss due to the interaction is negligible in the case of air; it is instead about 0.5 Mev·cm²/g for the condensed substance. This reduces the loss in the latter case to only 1.8 Mev·cm²/g.

The effect of this difference on the absorption of cosmic rays can be estimated if we assume the number of mesotrons with energy $>W$ to vary as $W^{-1.9}$. The ratio of the mesotron intensity observed under equal amounts of air and of condensed materials should then be $(2.3/1.8)^{1.9}=1.6$. According to Ehmert the experimental value of the ratio is about 2.

It seems therefore that the theory accounts for the order of magnitude of the effect even without any contribution from the decay of the mesotron.

Whether all the effects, and especially the somewhat greater differences of absorption reported as results of observations with relatively thin absorbers, can be interpreted on the outlined basis is doubtful. Indeed the theoretical result seems to be near one-half of the experimental difference. But in any case the interactions between atoms represent an important factor to be taken into account in the interpretation of experiments of this type.

I hope to be able to give soon the details of the theory and of its applications in a more extensive publication.

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Helium of Mass Three as an Agent in Nuclear Reactions

Recently Alvarez and Cornog[1] have demonstrated the existence of stable He³. It seems worth while to call attention to the important applications this isotope may have in extending the scope of nuclear physics to the study of nuclear types not previously obtainable.

One observes first that the average binding energy per particle in He³ is very low (2.72 mMU), so that as a general rule processes induced by it will be exothermic. In addition, with large cyclotrons it is convenient to obtain beams of He^{3++} ions having exceedingly high energies so that the penetration of Coulomb potential barriers up to large atomic numbers is possible.

Recent work at Princeton[2] on the systematic production and study of light odd nuclei having one more proton than neutron was undertaken because of the usefulness of these