Letters to the Editor

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On the Production Process of Mesons

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ACCORDING to present cosmic-ray evidence, it seems that mesons are produced in the upper atmosphere by the primary cosmic radiation, which consists presumably of protons. The cross section for this production is of the order of nuclear dimensions since the primary radiation is absorbed in about 1-m water equivalent of air. The mesons are presumably produced in showers of several particles. Very much smaller cross sections, however, are found for any interaction of the mesons themselves with matter. After being produced in the first 100 g/cm^2 of the atmosphere, a considerable fraction of the mesons are able to penetrate through the total atmosphere and even deep underground. The only interaction with matter seems to be the one which is caused by its charge. Scattering by interactions other than electric is small and perhaps nonexistent. Recent experiments have shown that even the absorption of slow mesons by nuclei takes place with a probability far below the expected one.

Nordheim and Hebb have shown that these facts are in contradiction with any simple theoretical description of meson production.[1] One should expect a similar cross section for processes induced by mesons as for processes in which mesons are created. This result follows immediately from any "interaction term" which is introduced into the Hamiltonian in order to describe the meson creation, if one applies the well-known principle of detailed balancing. This difficulty has been repeatedly emphasized by Oppenheimer.[2]

The striking lack of reversibility suggests the possibility that the process of meson creation is not elementary, but consists of a succession of several elementary processes. The total process will not be reversible if one of the successive steps is much slower than the initial one. The following analogy may perhaps clarify the picture: The cross section for the production of fission in uranium by a nuclear particle is of the same order as the cross section for the fission fragments to collide with another fragment, in accordance with the reversibility of the fission process. Let us imagine, for the sake of argument, however, that the fission fragments were not observable and that the only known effect would be the absorption of a nuclear particle by uranium with the subsequent emission of several electrons due to the beta-disintegrations of the fragments. We would then be faced with an analogous lack of reversibility, since the absorption of electrons by nuclei is extremely weak.

A number of possible combinations of processes suggest themselves for the mechanism of meson production. One could assume that the primary cosmic radiation transforms the nucleons into an "excited" state which, after a time long compared to the excitation process, decays with the emission of several mesons. The relatively long life-time of the "meson-pregnant" state would give rise to the small interaction between mesons and nucleons. Another alternative assumption, which was proposed by R. E. Marshak, would be that the primary radiation produces a number of particles which are mesons of a different kind than the ones observed. They have a limited lifetime after which they decay into the actual mesons observed. The lifetime could be long enough to preclude a strong interaction between the observed mesons and the nuclei.

These examples are meant only to exemplify the type of concepts which one may be forced to introduce into our description of meson production to understand the apparent lack of reversibility. The ideas expressed in this note were suggested by the discussions at the Theoretical Physics Conference on Shelter Island, June 2 to 4, 1947, sponsored by the National Academy of Sciences.

[1] L. Nordheim and M. Hebb, Phys. Rev. **56**, 494 (1939).
[2] Lecture delivered at the New York meeting of the American Physical Society, Shelter Island Conference, 1947.

The Thermal Diffusion Constant of Helium and the Separation of He^3 by Thermal Diffusion

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WE have been investigating the possibility of separating He^3 by thermal diffusion, and as part of the preliminary work we have constructed a hot wire column using a platinum wire 0.018 cm in radius. The radius of the water-cooled outer wall was 0.436 cm and the length 305 cm. The power consumption for a wire temperature of 780°C was 1520 watts and the operating pressure 10 atmospheres. Well helium flowed continuously past the lower end of the column at a sufficient rate so that the concentration here could be considered to have its normal value,[1] 1.6×10^{-7}. As the relaxation time for the above conditions would be of the order of 10^4 years, a linear increase in concentration is observed with time and with a negligible draw-off of gas it was possible to produce an enrichment in He^3 of 860 times in a period of 8 days.

During the course of our experiments it was possible to accumulate 52 cm^3 at N-P of well helium in which a He^3 enrichment of 300 times had been achieved. The He^3 concentration was sufficient to permit accurate mass-spectrometer analyses and hence a determination of α, the thermal diffusion constant, by the two-bulb method employed in this laboratory[2] for other gases. With the hot and cold bulbs at temperatures of 340° and 0°C, respectively, α was found to have a value of 0.059 ± 0.005. This value is considerably lower than 0.076 tentatively assumed by Jones