the neutron in the nucleus), their angular distribution will be confined to a relatively narrow cone about a direction opposite to that of the neutrino momentum. The width of this angular distribution is of the order of $\Delta \cos \vartheta \sim mE_0/pq \sim 0.4$.

Thus an experimental measurement of the angular distribution of the high-energy neutrons arising from the capture of polarized μ^--mesons by light nuclei may make it possible to distinguish between two classes of interaction between μ^--mesons and nucleons. One class comprises the scalar, vector, and pseudoscalar ($\beta = 1$) interactions, the other the tensor and axial-vector ($\beta \approx -1/3$) interactions.

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ON THE POSSIBLE EFFICIENCY OF THE CATALYSIS OF NUCLEAR REACTIONS BY MESONS

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THERE exists at present experimental evidence[1] of the ability of negative mesons to catalyze a nuclear reaction between two singly charged ions (p, d, t) by bringing the reacting nuclei closer together (see Zel'dovich and Sakharov,[2] where additional references are given). The meson is not lost in the nuclear reaction.

For μ-mesons in a liquid mixture of p and d, the reaction probability is no greater than several hundredths per meson entering the mixture. This small probability is determined by the ratio between the mean time for creating a mesomolecule ($pd\mu$, $dd\mu$) and the lifetime of the μ meson, which is 2×10^{-6} sec. One is naturally led to enquire whether there exist in nature some long-lived mesons, and whether such mesons may not in practice make possible a self-maintaining nuclear reaction of hyperon isotopes.

The second of these questions can definitely be answered in the negative. For all imaginable reactions there exists the probability that the meson will be bound to the helium nucleus produced in the nuclear reaction. Owing to the positive charge of the $He\mu$ system, other nuclei, including those of hydrogen, cannot come very close, so that the bound meson leaves the reaction and can no longer perform its catalyzing action.

The probability of binding was calculated by a method developed by Migdal[3] in treating the probability that an atom is ionized during β-decay. At the time the nuclear reaction is taking place, the two nuclei involved are close together and the wave function of the meson in the adiabatic approximation is that of the mesohelium ion $\psi_i(r)$, where r is the distance between the meson and the point at which the two nuclei meet.

The helium nucleus produced in the reaction has a definite energy E_0 (which is 0.8 Mev for $d + d \rightarrow He^3 + n$, and 3.5 Mev for $d + t \rightarrow He^4 + n$) and a corresponding velocity. To account for this, the meson wave function should be multiplied by $e^{ipz/\hbar}$, where the z axis is along the direction of motion of the nucleus, and the momentum p is the product of the nuclear velocity by the reduced mass $m = M\mu/(M + \mu)$, where μ is the meson mass and M is the mass of the helium nucleus. Expanding $\psi_i(r)\, e^{ipz/\hbar}$ in meson eigenfunctions in the field of the helium nucleus, we obtain the probability for one or the other final meson states after the nuclear reaction.

In particular,

$$K = \left| \int \psi_i^2(r) e^{ipz/\hbar} dv \right|^2$$

gives the probability that the meson remains bound to the helium in the ground state inserting $\psi_i \sim e^{-br}$, we obtain

$$K = (1 + p^2/4\hbar^2 b^2)^{-4}.$$

Writing p^2 in terms of E_0,

$$p^2 = m^2 v^2 = 2m^2 E_0/M; \qquad b = mZe^2/\hbar^2, \qquad \text{where } Z = 2.$$

We note that $p^2/\hbar^2 b^2$ does not depend on the meson mass, and is equal to the ratio of the recoil nucleus energy E_0 to $\epsilon = MZ^2e^4/2\hbar^2 = \mathrm{Ry}Z^2M^2/m_e$. For He^3, $\epsilon = 0.3$ Mev, $E_0 = 0.8$ Mev, and $K = 0.13$; for He^4, $\epsilon = 0.4$ Mev, $E_0 = 3.5$ Mev, and $K = 0.01$. Thus a nondecaying meson could give on the average 8 neutrons from the d + d reaction, or 100 neutrons from the d + t reaction. In d + t mixtures, however, in addition to $d + t \rightarrow He^4 + n$, there would also be the reactions $d + d \rightarrow He^3 + n$, and $t + t \rightarrow He^4 + 2n$, which would decrease the neutron yield.

The binding of a meson to helium can easily be observed in a hydrogen bubble chamber, since singly charged $(He\mu)^+$ should give a longer track with lower ionization and smaller curvature (in a magnetic field) at a given energy than does He^{++}.

It is easy to see that μ mesons (or heavier mesons) will not be stripped from the helium nucleus by electron collisions.

The probability that a meson enters an excited state (with a wave function ψ_f) near the helium nucleus is small compared with the probability that it remains in the ground state.

Since the integral $\int \psi_f^* \psi_i e^{ipz/\hbar} dv$ contains the rapidly oscillating function $e^{ipz/\hbar}$, its magnitude is determined by the singularity of $\psi_f^* \psi_i$. The Coulomb functions ψ_f and ψ_i have a singularity at the origin. The formation of excited mesohelium in a state with $\ell \neq 0$, for which $\psi_f(0) = 0$, has a probability which is inversely proportional to a higher power of the momentum p than the probability for states with $\ell = 0$. States with $\ell = 0$, $n > \ell$ have probability proportional to $|\psi_f(0)|^2 \sim 1/n^3$, and therefore contribute less than 20% to the probability of forming the ground state with $n = 1$.

Finally, in the $pd\mu$ case, Alvarez[1] observed a process in which the total energy of the reaction was given to the meson. Calculation,[2] however, leads to the result that emission of this energy in the form of a photon is equally probable. In this case the energy of the recoil nucleus is only 5 kev, and the meson must remain with the He^3 nucleus. It would seem that the tracks of such nuclei could not be observed in bubble chambers.

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