MECHANISM OF π^- MESON CAPTURE BY LIGHT NUCLEI

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The capture of stopped π^- mesons by light nuclei with formation of protons, deuterons, and tritons is considered on the basis of the dispersion theory of direct nuclear reactions. It is shown that capture of π^- mesons by α particles is the dominant mechanism.

RABIN, Vaĭsenberg, and Kolganova[1] have observed that a considerable number of protons, deuterons, and tritons with energies above 25 MeV are emitted in the capture of stopped π^- mesons by light nuclei (mainly C^{12} and O^{16}). Since this energy is much higher than the nuclear temperature, which corresponds to an excitation energy of 140 MeV, we are here apparently dealing with a genuine direct reaction, i.e., with a process in which the energy of the π meson is transferred to a small group of nucleons in the nucleus. This group may be a two-proton complex (which we shall call He^2), He^3, or an α particle. In a direct process, the capture of the π^- mesons by such associations emitted virtually by the nucleus proceeds in the same way as the reaction with free particles and is described by Feynman graphs. The simplest graph in this case is the pole graph shown in Fig. 1. For the nuclei C^{12} and O^{16}, the pole lying closest to the physical region is that corresponding to the α particle. It should be noted that the results of Ammiraju and Lederman[2] also indicate that this graph gives the dominant contribution.

Using the formulas for pole graphs derived in [3], we can express the relative emission probabilities for protons, deuterons, and tritons in the capture of π^- mesons by C^{12} and O^{16} through the capture probabilities for free α particles or He^3 nuclei. We have carried out such a calculation for C^{12} under the assumption that the particle giving rise to the pole is an α particle and that the amplitude of the reaction with the α particle is constant. With these assumptions, we obtain the following relation for the capture probabilities λ_F^C of a π meson by a C^{12} nucleus with emission of the particle F:

$$\lambda_F^c/\lambda_p^c \approx \lambda_F^\alpha/\lambda_p^\alpha, \tag{1}$$

where λ_F^α is the probability for capture by the α particle. The experimental data on the capture of π^- mesons by α particles are rather scarce at the moment. The best work seems to be that of Schiff, Hulderbrand, and Giese,[4] according to which

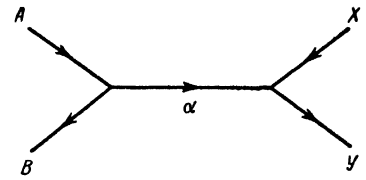

FIG. 1. Pole graph.

$$\lambda_d^\alpha/\lambda_p^\alpha \approx 1/3, \quad \lambda_t^\alpha/\lambda_p^\alpha = 0.5-0.7, \quad (\lambda_d^\alpha + \lambda_t^\alpha)/\lambda_p^\alpha \approx 1. \tag{2}$$

According to the data of Rabin, Vaĭsenberg, and Kolganova[1]

$$\lambda_d^c/\lambda_p^c = 0.75 \pm 0.07, \quad \lambda_t^c/\lambda_p^c = 0.14 \pm 0.10,$$
$$(\lambda_d^c + \lambda_t^c)/\lambda_p^c = 0.93 \pm 0.11. \tag{3}$$

Thus the summed relative yield of deuterons and tritons is in good agreement with formula (1). As far as the other quantities are concerned, there is a discrepancy, although the order of magnitude of the deuteron yield is given correctly by (1) [using the particular values (2)].

Besides the relative yields, we can also compute the energy spectrum of the emitted particles, using the pole graph of Fig. 1.

The spectrum of the deuterons corresponding to capture by an α particle is shown in Fig. 2 (solid curve), together with the experimental data of [1]. The agreement between the experi-

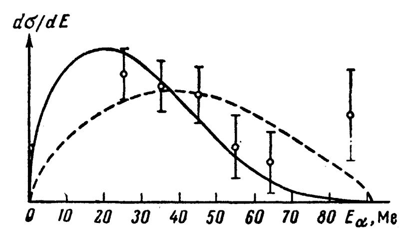

FIG. 2. Energy spectrum of deuterons (the spectrum is normalized by the area under the curve).

mental and theoretical data must be considered satisfactory within the experimental errors. This is an indication that the major contribution to the formation of energetic deuterons in the capture of π^- mesons by C^{12} and O^{16} comes from capture by an α particle, since capture by He^2 would give a monoenergetic spectrum and capture by He^3 would give the dashed curve. We can therefore conclude from a comparison with the already available experimental data that the basic mechanism of the "direct capture" of π^- mesons by C^{12} and O^{16} corresponds to a pole graph in which an α particle is transferred.

We should like to emphasize that the experimental study of direct reactions in π^- and K^- capture by nuclei can provide valuable information on the reduced vertex parts [5] of direct reaction graphs and on the validity of our ideas concerning the nature of the direct processes.

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