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Abstract

Full Text

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PHYSICS

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FEATURES OF THE FORMATION OF Li_3^8 IN THE INTERACTION OF 660 MeV PROTONS WITH C_6^{12} NUCLEI

(Presented by Academician B. P. Konstantinov on 12 III 1963)

The study of the process of formation of fast multiply charged particles in the disintegration of light nuclei by high-energy protons is acquiring special interest in connection with the development of the theory of direct nuclear reactions. In this connection, in addition to information on the mechanism by which such processes proceed, one may hope to obtain from experimental data certain information on the structure of the target nucleus in its ground and excited states and, possibly, on reactions with unstable nuclei playing the role of intermediate particles. Moreover, investigation of the indicated reactions may prove essential for clarifying a number of questions connected with the mechanism of fragmentation in heavy nuclei. Indeed, one may suppose that, during the development of a nuclear-cascade process in a nucleus, fast nucleons, in interacting with clusters in the diffuse region of the nucleus, along with possible quasi-elastic scattering, produce peculiar nuclear reactions in which fragments are also formed.

In the investigation carried out by us, the task was to study the angular distribution and energy spectra of Li_3^8 fragments emitted at various angles to the beam of incident protons in the disintegration of C_6^{12} nuclei; for this purpose a vacuum chamber was used. Thin films (polystyrene 1.24 mg/cm² and polyethylene 4 mg/cm²) were irradiated in the chamber with a proton flux of 10^{13} cm⁻² on the extracted beam of the phasotron of the Joint Institute for Nuclear Research (proton energy 660 MeV). The Li_3^8 fragments were recorded with a low-sensitivity P-90 nuclear emulsion at angles from 20 to 160° to the proton beam.

As a result of processing the experimental material, range spectra were obtained for particles producing T-shaped tracks (which, in principle, may be produced by Li_3^8 , Li_3^9 , B_5^8 nuclei) at angles of 20, 47, 90, and 137°. Analysis of the ionization characteristics of the T-shaped tracks, carried out by the scale method (¹), showed that almost all the observed T-shaped tracks (with ranges greater

Fig. 1. Range distributions (1) and energy spectra of Li_3^8 (2) from C^{12} at different angles relative to the incident protons

Figure 1: Fig. 1. Range distributions (1) and energy spectra of Li_3^8 (2) from C^{12} at different angles relative to the incident protons

than 35μ) are due to the Li_3^8 nucleus (a very small fraction of the T-shaped tracks is produced by the Li_3^9 nucleus). In Fig. 1 the experimental range and energy distributions of Li_3^8 are presented. The latter were reduced to zero target thickness by recalculating the ranges by the method described in work (2), using methods of best agreement (3).

The angular distribution of Li_3^8 fragments is shown in Fig. 2 for the entire energy spectrum.

The fact noted above of the absence of the B_5^8 isobar is of great significance for interpreting the data obtained, in connection with the possibility, discussed in the literature (4), of quasi-elastic knockout of large groupings of nucleons from light nuclei. From this point of view, the absence of the B_5^8 isobar means a substantial asymmetry of the structure of the C_6^{12} nucleus with respect to the mirror clusters B_5^8 and Li_3^8 .

On the other hand, against the assumption of quasi-elastic knockout of clusters by the incident proton there argues the insignificant change in the most probable energy of Li_3^8 when the observation angle is changed and when going over to a higher energy of the incident particles. This is clearly seen from a comparison of Fig. 1 and Fig. 3 from work (5), in which the formation of Li_3^8 from C^{12} at a proton energy of 2.2 BeV was studied.

Fig. 1. Range distributions (1) and energy spectra of Li_3^8 (2) from C^{12} at different angles relative to the incident protons

One may also note the small change in the angular distribution of Li_3^8 when going over to a proton energy of 2.2 BeV (unfortunately, the data for such a comparison from work (5) can be obtained only for the ratios of the yields of Li_3^8 at angles $30^\circ/150^\circ$ and $55^\circ/125^\circ$).

From the point of view of a cascade mechanism of interaction of fast protons with carbon nuclei, the formation of Li_3^8 occurs as a result of 2-3-fold

collisions of the incident proton with the nucleons of the C^{12} nucleus and the subsequent decay of the excited residual nuclei Be_4^{10} , Be_4^9 , etc. Calculations of such a cascade process, carried out by P. I. Fedotov⁶ by the Monte Carlo method, show that the residual nuclei acquire a comparatively small momentum (an average longitudinal momentum of about $130 \text{ MeV}/c$) and an excitation energy of about 30 MeV.

From the spectra of Li_3^8 shown in Fig. 1 one can estimate the average longi-

Fig. 2

Figure 2: Fig. 2

tudinal momentum in the forward direction. It turns out to be approximately 280 MeV/c, which considerably exceeds the value obtained in the calculation mentioned above. According to the observed distributions, the maximum momentum of Li_3^8 proves to be about 900 MeV/c.

Fig. 2. Angular distributions of Li_3^8 for the entire energy spectrum $N(\theta)$ (in arbitrary units)

It seems natural to assume that the process proceeds in such a way that the softest part of the Li_3^8 spectrum owes its origin to reactions $(N, 2N)$ on an intermediate particle of the Be_4^9 type and to the decay of residual nuclei formed in similar reactions on the C^{12} nucleus itself. At the same time, the large momentum transfers could be explained in processes involving π -mesons (with their absorption as intermediate particles by nucleon associations, or in reactions with the formation of π -mesons in the interaction of the incident proton with a grouping of nucleons).

In conclusion, the authors express their deep gratitude to Prof. V. P. Dzheleпов for supporting this work; to R. G. Vasil'ev, V. N. Kuz'min, E. S. Rozhkova, and R. M. Yakovlev for help in carrying out the experiment; and to P. A. Gorichev for discussing a number of questions touched upon in this article.

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