Investigation of the 11 to 13-MeV excitation region of a ^7Be nucleus in the $^3He(\alpha,p_{0,1})^6Li$ reactions

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The results of a measurement of the excitation functions of $^3He(\alpha,p_{0,1})^6Li$ reactions at energies $E_\alpha = 22.2$–26.5 MeV are presented. The observed irregularities in the energy dependence of the differential cross sections are an indication of the possible existence of a ^7Be level with an excitation energy of about 12.2 MeV.

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A study of reactions in the few-nucleon systems and of the mechanisms of inelastic processes is important for obtaining information about the levels of the lightest nuclei and for comparing them with the theoretical predictions based on different modifications of shell calculations.

Several such calculations are known (see Refs. 1 and 2) for a system of seven nucleons, and the theoretical predictions of Ref. 1, in which three- and four-particle correlations are taken into account, are in good agreement with the location of the experimentally discovered levels for several $1p$-shell nuclei. The possibility for the existence of one or a group of levels with $J^\pi = 1/2^-$ and $T = 1/2$ of the ^7Be nucleus with an excitation energy of 12 to 13 MeV follows from Ref. 1. Calculations within the framework of the resonating-group method,[3] which use the phenomenological imaginary potential to determine the inelastic channels and which satisfactorily describe the experimental data for the elastic scattering of $^4He(\tau,\tau)^4He$, also predict a wide ^7Be level at an excitation energy of about 11.6 MeV.

We investigated the indicated range of ^7Be excitation energies by measuring the energy dependence of the differential cross sections for the $^3He(\alpha,p_{0,1})^6Li$ reactions. The measurements were made in the U-120 cyclotron at the Institute for Nuclear Research of the Ukrainian Academy of Sciences. The energy of the α particles was varied in steps of about 600 keV by using aluminum absorbers. The cassette with absorbers was placed in front of the beam collimator, which provided a $\pm 0.25°$ angular spread. A 50-mm-diam gas target was used with approximately 98% ^3He enrichment at a ^3He pressure of 500 Torr. When necessary, the gas was purified by passing it through an activated-charcoal trap at liquid-nitrogen temperature. The windows for entrance and exit of the beam and of the reaction products were made from 2-μm-thick nickel foil. The target was fitted with a 100-mm-long entrance sleeve to reduce the background effect of the entrance foil. A set of 3-mm-diam tantalum diaphragms was placed in the entrance sleeve of the target to compensate for the additional angular spread that results from passage of the α-particle beam through the entrace foil.

We used telescopes made from silicon semiconductors ΔE (50 to 100 μm thick) and E (up to 4 mm thick), to identify the products of the investigated reactions against

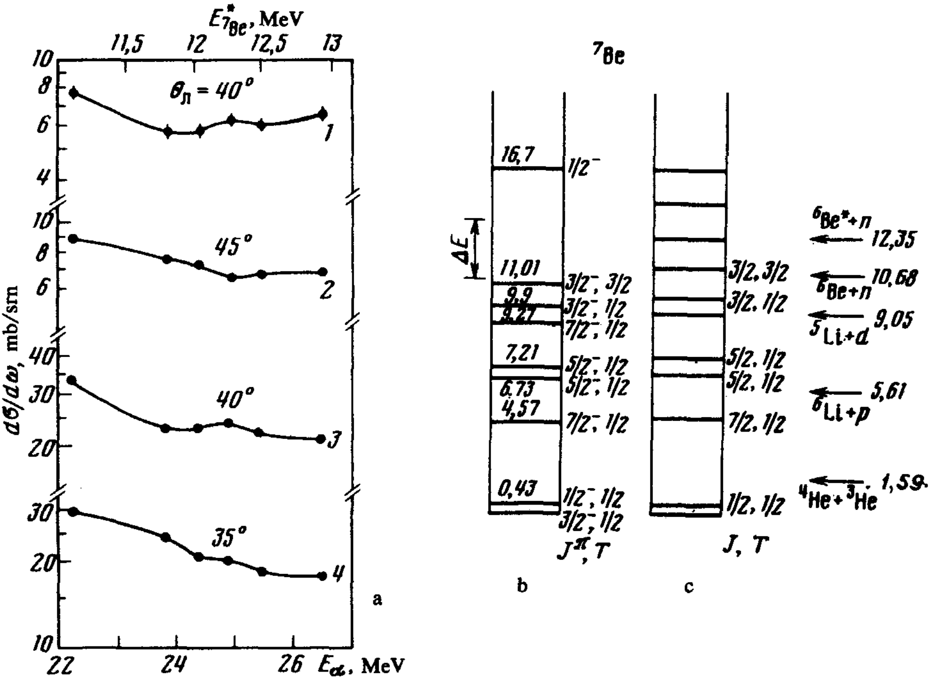

FIG. 1. (a) Excitation functions of the ^{3}He(α,$p_{0,1}$)^{6}Li reaction (curves 1 and 2) and of the ^{3}He(α,p_1)^{6}Li* reaction (curves 3 and 4), (b) the level scheme of the ^{7}Be nucleus.[6] The energy region ΔE investigated by us is indicated by the vertical arrow, and the (c) the theoretical predictions[1] of the ^{7}Be levels.

a background of a large number of processes that occur in the ^{3}He + ^{4}He system. The collimation system of the telescopes provided a $\pm$ 1.1° angular spread. The change of the energy spread in the beam after slowing it down by the absorbers was estimated from the spectrum width of α particles that were elastically scattered by the aluminum target. According to these estimates, the nonmonochromaticity of the beam was better than $\pm$ 150 keV.

After selecting the amplitude and the coincidence, the signals from the ΔE and E detectors were fed to the BAP-6M analog-to-digital converters, and the spectra were stored in the memory of an M6000 computer (16 K memory capacity).

The measured excitation functions of the ^{3}He(α,$p_{0,1}$)^{6}Li reactions for several angles are shown in Fig. 1. The comparatively large differential cross sections of these reactions [and also of the ^{3}He(α,d)^{5}Li reaction[4]] indicate that contribution of the inelastic processes in the ^{3}He + ^{4}He system is large at the investigated energies. Therefore, the theoretical approaches, which ignore the reaction channels in attempting to describe elastic scattering, can hardly be considered justifiable.

The energy dependence of the differential cross sections for (α,p) reactions is quite smooth. The observed irregularity of the differential cross sections in the 12 to 12.5-MeV region of excitation energies of the ^{7}Be nucleus is $\leqslant$20% of the cross section at the adjacent points. An experimental study of this region of ^{7}Be excitation energies in the elastic channel was recently performed in Ref. 5. The observed irregularities in the excitation function at an energy $E_{3He} = 18$–19 MeV for the angles $\theta = 123.8°$ and 135.9° are similar to the results of this paper.

In addition to the presence of one or a group of ^{7}Be levels, which is predicted by the shell calculations, the observed irregularity in the excitation functions may be associated with threshold anomalies: the opening of a $^6\mathrm{Be}_{1.67} + n$ channel (this corresponds to an excitation energy of 12.35 MeV in ^{7}Be) and the "tail" of an $^5\mathrm{Li}^* + d$ channel.

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