"Ghost" anomaly in the reactions $^{12}C(d, ^6Li)^8Be$ and $^{13}C(d, ^7Li)^8Be$

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An experimental angular distribution of the "ghost" anomaly in a nuclear reaction with ^8Be has been observed for the first time in the outlet channel.

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The anomaly in the energy spectrum of deuterons and of α particles in the nuclear reactions $^9Be(p,d)^8Be$ and $^{11}B(p,\alpha)^8Be$ at $E_p = 5.205$ MeV, which was first observed by Beckner *et al.*,[1] has been analyzed by many authors.[2–4] This anomaly, which is localized in the excitation region of ^8Be nucleus, $E^* = 750$ keV, has been observed in the reactions $^6Li(^3He, p)^8Be$; $^7Li(\alpha, t)^8Be$; $^6Li(\alpha, d)^8Be$; $^9Be(p, d)^8Be$; $^9Be(d, t)^8Be$; $^{10}B(p, ^3He)^8Be$; $^{10}B(\alpha, ^6Li)^8Be$; and $^{13}C(^3He, ^7Be)^8Be$ in various energy ranges of incident particles. Berkovitz *et al.*[2] have shown that the strongest manifestation of this anomaly is found in the many-nucleon transfer reactions at incident-particle energies of $\sim$5-10 MeV/nucleon. The experimental data obtained previously do not allow us to determine unambiguously the nature of this anomaly. Various authors interpret the same experimental data using completely opposite models.[5] It would seem useful to us, therefore, to investigate the nature of the process in which the "ghost" anomaly appears.

We have studied the energy spectra of ^6Li from the reaction $^{12}C(d, ^6Li)^8Be$ at $E_d = 12.7$ MeV, 13.2 MeV, and 13.6 MeV and the energy spectra of ^7Li ions from the

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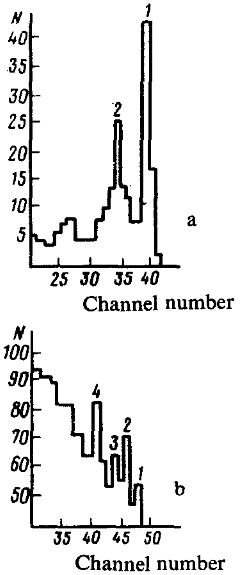

Fig. 1. Energy spectra of ^{6}Li(a) and ^{7}Li(b) from the reactions ^{12}C(d,^{6}Li) ^{8}Be and ^{13}C(d,^{7}Li) ^{8}Be. (a) Peak 1—^{6}Li from the reaction ^{12}C(d,^{6}Li) $^8Be_{gr}$, peak 2—^{6}Li from the reaction ^{12}C(d,^{6}Li) $^8Be_{0.750}$. (b) Peak 1—^{7}Li from the reaction ^{13}C(d,^{7}Li) $^8Be_{gr}$, peak 2—^{7}Li from the reaction ^{13}C(d,$^7Li_{0.477}$)$^8Be_{gr}$, peak 3—^{7}Li from the reaction ^{13}C(d,^{7}Li) $^8Be_{0.750}$, peak 4—^{7}Li from the reaction ^{13}C(d,$^7Li_{0.477}$)$^8Be_{0.750}$.

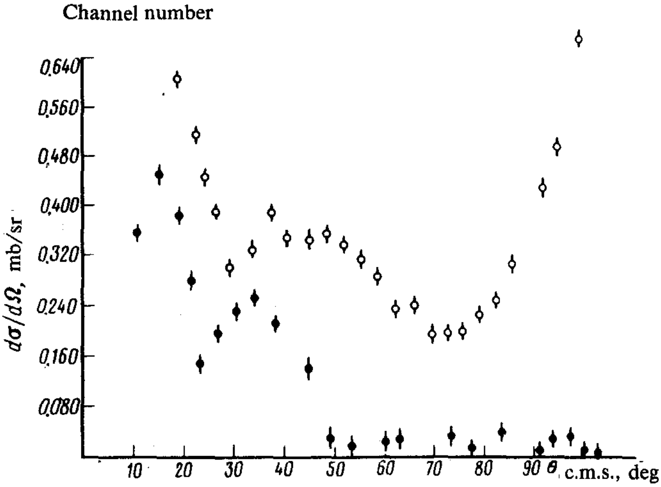

Fig. 2. Differential cross sections of the reactions. O ^{12}C(d,^{6}Li) ^{8}Be, ● ^{12}C(d,^{6}Li) $^8Be_{0.750}$ for $E_d = 13.6$ MeV.

reaction ^{13}C(d, ^{7}Li) ^{8}Be at $E_d = 13.6$ MeV. The self-sustaining ^{12}C films and carbon films 53%, enriched by ^{13}C isotope were used as targets. The targets were ~40-70 μg/cm^2 in thickness.

The angular distributions of ^{6}Li from the reaction ^{12}C(d, ^{6}Li) ^{8}Be and ^{7}Li from the reaction ^{13}C(d,^{7}Li) ^{8}Be were measured using the time-of-flight method to identify the heavy charged particles.[6] Figures 1a and 1b show the energy spectra of ^{6}Li from the reaction ^{12}C(d,^{6}Li) ^{8}Be and the energy spectra of ^{7}Li from the reaction ^{13}C(d,^{7}Li) ^{8}Be. With an energy resolution $\Delta E_{6\mathrm{Li}} = 130$ keV for ^{6}Li and $\Delta E_{7\mathrm{Li}} = 150$ keV for ^{7}Li, we see that the width of the $^8Be^*_{0.750}$ state in the reactions in question is $\leqslant 150$ keV. This allows us to assume the existence of a single level of a ^{8}Be nucleus with an excitation energy $E^* = 750$ keV.

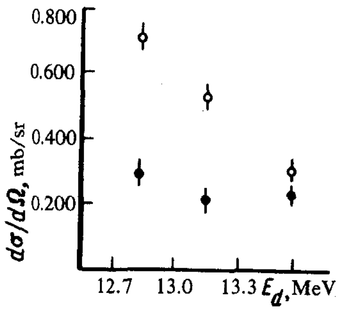

Fig. 3. Energy dependence of the reaction cross sections. ○—$^{12}C(d,^{6}Li)\,^{8}Be_{gr}$, ●—$^{12}C(d,^{6}Li)\,^{8}Be_{0.750}$ for $\theta_{l.s.} = 20°$.

Thus, assuming that the reactions $^{12}C(d,^{6}Li)\,^{8}Be$ and $^{13}C(d,^{7}Li)\,^{8}Be$ are two-particle reactions, we can obtain experimental angular distributions for the processes in which the state of a ^{8}Be nucleus under investigation is formed. Figure 2 shows the angular distributions of ^{6}Li from the reactions $^{12}C(d,^{6}Li)\,^{8}Be$ and $^{12}C(d,^{6}Li)\,^{8}Be_{0.750}$. The relative errors of the measured differential cross sections vary in the range 9% to 20%. Since the energy of ^{6}Li decreases markedly with increasing angle of emission, the differential cross sections of the reactions were measured only in the range of angles $\theta_{l.s.} = 11.5° - 72.5°$.

The angular distribution of ^{6}Li from the reaction $^{12}C(d,^{6}Li)\,^{8}Be$ was studied by us previously.[7] Assuming that direct processes play a key role in the reaction $^{12}C(d,^{6}Li)\,^{8}Be$ at $E_d = 13.6$ MeV, we analyzed the differential cross sections of this reaction in terms of the model for the capture of an α particle using the zero-radius approximation in the distorted-wave method.[8] It was shown that the calculated values of the differential cross sections are in satisfactory agreement with the experimental data.

For the reaction $^{12}C(d,^{6}Li]\,^{8}Be_{0.750}$ the differential cross sections in the region of angles $\theta_{c.m.s.} = 12° - 50°$ are similar in their structure to the angular distribution for the reaction $^{12}C(d,^{6}Li)\,^{8}Be$. This allows us to assume that the formation of the excited state of a ^{8}Be nucleus—$E^* = 750$ keV—occurs in the direct process.

The energy dependence of the cross section for production of the Be nucleus in this state was measured in a narrow range of deuteron energies $E_d = 12.7 - 13.6$ MeV. A comparison of the ground state of a ^{8}Be nucleus from the reaction $^{12}C(d,^{6}Li)\,^{8}Be$ shows that the excited state of this nucleus is similar to its ground state (Fig. 3).

In summary, the existence of an excited state of a ^{8}Be nucleus with $E^* = 750$ keV is justifiable experimentally.

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