NONCONSERVATION OF ISOSPIN IN DIRECT REACTIONS*

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New data on the isospin-forbidden reaction $^{12}C(d, \alpha_2)^{10}B(1.74)$ disagree with Noble's proposed direct reaction via a 2^+ doublet in ^6Li. In contrast to other studies, we find no convincing evidence that direct reactions contribute a major portion of the large isospin-forbidden cross sections.

Direct nuclear reactions should conserve isospin (T) since the collision times are so short that the Coulomb forces will not appreciably mix states of different T.[1] However, in 1966 Meyer-Schützmeister, von Ehrenstein, and Allas[2] reported that the T-forbidden reaction $^{12}C(d,\alpha_2)^{10}B(1.74)$ proceeded chiefly by direct reaction for $E_d > 11.5$ MeV. Their data stimulated a number of theoretical attempts[3] to account for the large direct-reaction contributions, but none was quantitatively successful. In 1968 Jänecke, Yang, Polichar, and Gray[4] extended the data on the T-forbidden $^{12}C(d,\alpha_2)^{10}B(1.74)$ to $13 < E_d < 21$ MeV and claimed confirmation of the direct-reaction character reported in Ref. 2 even though only one of their 45 measurements is at an angle greater than $\theta_{c.m.} = 45°$. Our Fig. 1 (which is the same as Fig. 4 of Ref. 4) shows the excitation function at small angles based upon Refs. 2 and 4. The obvious resonantlike character of the excitation function is of course hard to reconcile with a direct-reaction mechanism. However, Ref. 4 makes the attempt by postulating certain clusterlike, quasibound, two-particle, two-hole states in the region of the giant resonance. More recently Noble[5] made an ingenious attempt at explanation in terms of a second-order direct reaction in which the incoming deuteron picks up an alpha particle from the target and forms ^6Li in one of two nearby T-mixed 2^+ states. The virtual ^6Li decays through the $T=1$ channel into an outgoing alpha and a singlet deuteron ($J^\pi = 0^+$, $T=1$). The latter is then captured to form the residual nucleus in the $T=1$ state. This mechanism, according to Noble, predicts two peaks (corresponding to the ^6Li doublet) and for reasonable T mixing in the excited ^6Li could yield the observed cross sections. He also predicts similar behavior for $^{16}O(d,\alpha_1)^{14}N(2.31)$ and this behavior would be expected for $^{14}N(\alpha,\alpha_1)^{14}N(2.31)$ to the extent that the target, ^{14}N, has the cluster configuration, $^{12}C + d$.

Our interest in the problem arose because extensive measurements in this laboratory over the last five years[6] have shown no direct-reaction character in the T-forbidden reactions $^{16}O(d,\alpha_1)^{14}N$ and $^{14}N(\alpha,\alpha_1)^{14}N$. One of us (H.V.S.) therefore repeated and extended some of the earlier measurements.[2,4] Our experimental arrangements are similar to those of Ref. 6. The carbon target was methane gas in a scattering chamber which allows simultaneous observation at numerous angles. Some of the data from

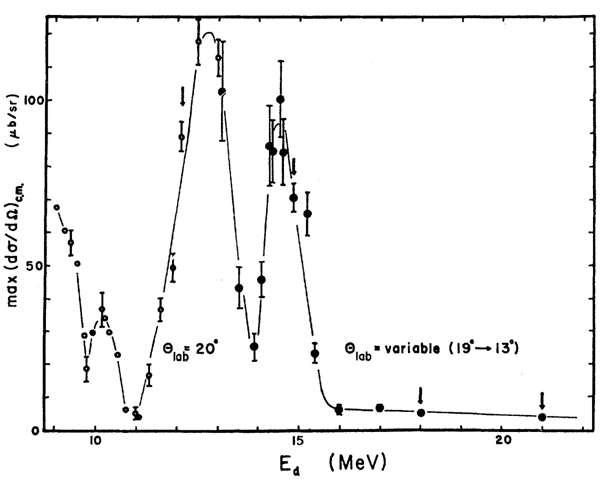

FIG. 1. Excitation function at forward angles (from Ref. 4) for the T-forbidden reaction $^{12}C(d,\alpha_2)^{10}B(1.74)$. Below $E_d = 13.1$ MeV the data are from Ref. 2.

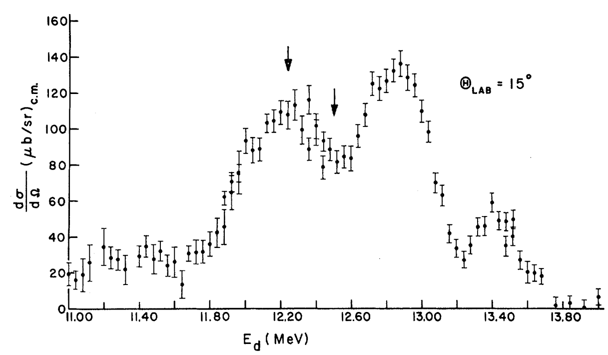

FIG. 2. Detail on excitation function (present data) for the T-forbidden reaction $^{12}C(d,\alpha_2)^{10}B(1.74)$. Note that the broad peak at $E_d \sim 12.5$ MeV in Fig. 1 here splits into at least three components. Arrows are at energies which correspond to angular distributions shown in Fig. 3.

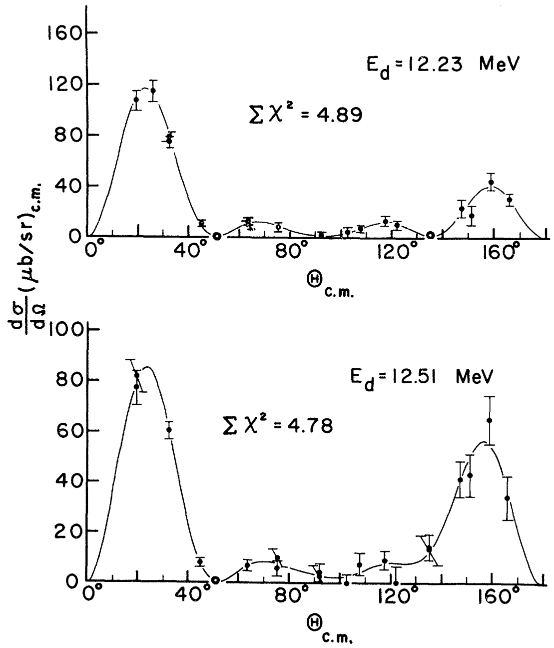

FIG. 3. Angular distributions for the energies indicated by arrows in Fig. 2. The calculated curves are parametrizations in terms of partial waves (Ref. 7) with $l \leq 5$. Over 80% of the total cross section arises from the $l=4$ and $l=5$ partial waves. Open circles correspond to two overlapping data points.

this experiment which are relevant to the direct-reaction question are shown in Figs. 2 and 3. Comparing Figs. 1 and 2 for $11 < E_d < 14$ MeV, we see that the first broad peak reported by Ref. 4 consists of at least three separate peaks. Therefore Noble's second-order ^{6}Li mechanism, which predicts a total of two peaks (including the one at $E_d \approx 14.8$ MeV), does not correspond to our observations.

Furthermore we find that the angular distributions and excitation functions can be interpreted in terms of a few resonant states of the compound nucleus ^{14}N and without introducing any large direct-reaction amplitudes. Figure 3 shows two typical angular distributions and the curves calculated from a partial-wave parametrization,[7] in which only partial waves $l \leq 5$ are needed to describe the data. The four-lobed character of the angular distribution suggests strong $l=4$, and indeed the partial-wave parametrization indicates that the cross section is dominated by two partial waves, $l=4$ and $l=5$, which arise from nearby states ($J=4^+$ and 5^-) in the compound nucleus ^{14}N. The interference between these partial waves gives the asymmetry about 90° which others have attributed to direct reaction. These two partial waves account for 83.5 % of the total cross section at $E_d = 12.23$ MeV and 81.5 % at $E_d = 12.53$ MeV.

While this parametrization is unique in the l_{max}, other solutions are possible for the lower l's.[7] We have not yet explored all such solutions, but the results thus far are all consistent with a simple compound-nucleus interpretation of the T-forbidden reaction ^{12}C(d, α_2)^{10}B(1.74).

In conclusion, our data and analysis indicate the following: (1) The second-order ^{6}Li mechanism proposed by Noble[5] is not important at these deuteron energies. (2) No convincing evidence exists that direct reactions contribute the major portion of the large T-forbidden cross sections seen in ^{12}C(d, α_2)^{10}B(1.74), ^{16}O(d, α_1)^{14}N(2.31), or ^{14}N(α, α_1)^{14}N(2.31).

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