Predominance of the direct reaction mode in ^{58}Ni(^{6}Li, d)^{62}Zn

F. Jundt, J. P. Coffin, H. W. Fulbright,* and G. Guillaume

Laboratoire de Physique Nucléaire et d'Instrumentation Nucléaire, Centre de Recherches Nucléaires et Université Louis Pasteur, Strasbourg, France

(Received 12 May 1975)

Measurements of the angular distribution of deuterons from the ^{58}Ni(^{6}Li, d)^{62}Zn reaction have been extended to large angles. A decrease of about two orders of magnitude is seen between 30 and 170°, in general agreement with distorted-wave Born-approximation (DWBA) predictions. The case for using simple DWBA analysis to extract α particle spectroscopic factors is thus strengthened.

[NUCLEAR REACTIONS ^{58}Ni(^{6}Li, d), $E = 28$ MeV; measured $\sigma(\theta)$.]

During the past several years many (^{6}Li, d) reactions have been studied with even-even f-p shell nuclei.[1-3] When the results have compared with predictions of zero-range and exact finite-range distorted-wave Born-approximation (DWBA) calculations good agreement has been found, suggesting the predominance of the direct mode of reaction.[3-5] However, in the past observations have been confined to angles under 80°, partly because that was the region of greatest interest and partly because of practical difficulties associated with the small cross sections involved, usually well under 50 μb/sr. Although the agreement between the data and DWBA theory is quite good in the angular range studied, the suggestion has often been heard that the compound nucleus mode of reaction may also contribute significantly, therefore that the yield of the reaction at large angles would be found to rise considerably, in contradiction to expectations from DWBA theory, as it does, for example, in the case of the ^{12}C(^{6}Li, d)^{16}O reaction.[6] To test this suggestion, we have measured the large-angle yield of the ^{58}Ni(^{6}Li, d)^{62}Zn reaction, already well studied at Rochester at angles up to 70° with a 28 MeV beam.[3]

The measurements were made with 28 MeV ^{6}Li ions from the Strasbourg MP tandem Van de Graaff accelerator. The deuterons were counted with a counter telescope system. The over-all experimental energy resolution was about 175 keV. The yield was small, principally because of the small solid angle of the detector and the quite small values of the cross sections at large angles, therefore, we had to be content to take data at only six angles, the largest being 170°. However, those data proved sufficient.

Low-lying states of ^{62}Zn were seen strongly and clearly in the earlier work at small angles at the following excitation energies (MeV): 0.0, 0^+; 0.96, 2^+; 2.17, 4^+; 3.18, 3^-; 3.86 (1^-); 4.04 (1^-).[7] Others seen about an order of magnitude more weakly lie at: 1.80, 2^+; 2.34, 0^+; and 2.88, 2^+. In

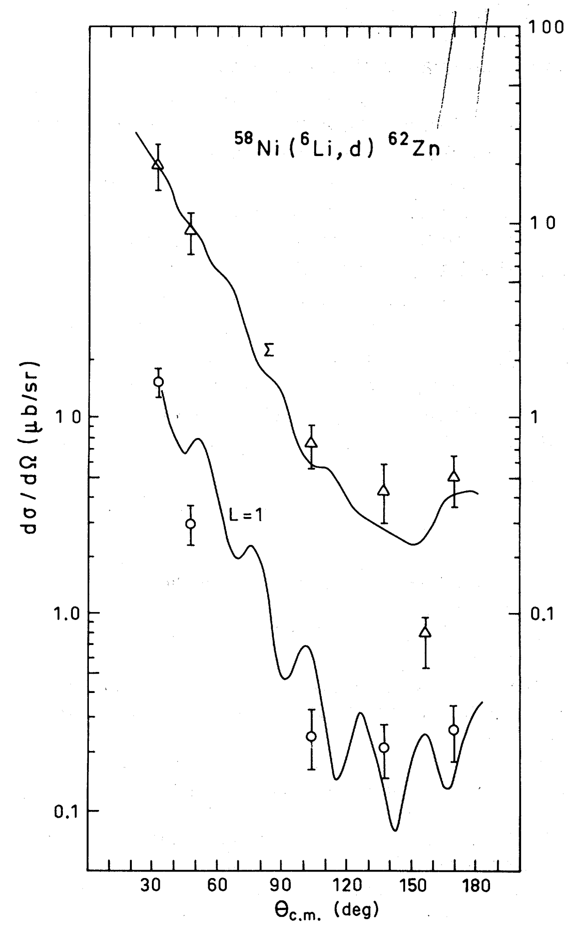

FIG. 1. Yield from the ^{58}Ni(^{6}Li, d)^{62}Zn reaction at large angles. Upper: Points obtained by summing spectra for all low-lying states up to 3.18 MeV excitation, as described in the text, with corresponding summed zero-range DWBA curve. Lower: Summed results for the states at 3.86 and 4.04 MeV, with DWBA curve. The single normalization factor used for all data points was obtained by normalizing the 30° point of the integrated spectrum to the results of Ref. 3. The states at 3.86 and 4.04 MeV are both unbound against α emission and the corresponding curve was calculated for an arbitrarily chosen binding energy of 0.5 MeV.

the present experiment the three states at 1.80, 2.34, and 2.17 MeV could not be resolved, but appeared as one line. The same was true of the pair of states at 3.86 and 4.04 MeV. Groups corresponding to higher excitations could not be resolved adequately from each other or from the background, hence were not included in the analysis. Because the number of counts in individual spectral lines was insignificantly small at some angles, it was not feasible to treat them all individually. (The line from the unresolved 3.86 and 4.04 MeV states was the sole exception). Instead, for each angle of observation all the counts from the lines involved were added together by simply integrating that entire part of one spectrum, i.e., the 3.18 MeV group and all counts at higher energies, through the ground-state group, with no attempt to eliminate counts due to target impurities. The results were then compared with a composite DWBA curve constructed by adding together the appropriate individual DWBA curves, suitably normalized at 30° according to the results in Ref. 3. In addition, the $L=1$ results for the line from the 3.86 and 4.04 MeV states were treated separarately, but with the same normalization.

The two comparisons are shown plotted in Fig. 1 along with zero-range DWBA results calculated as described in Ref. 3 with the well parameters given there. In both cases the general trend with increasing angle is downward, just as is the trend of both DWBA curves.[8] Of course, one must not assume that these particular DWBA curves necessarily predict correctly the fine features of angular distributions at such large angles, however well they may have done so at smaller angles. Nonetheless, all of the individual curves, for $L=0$, 1, 2, 3, and 4, show a falloff of about two orders of magnitude between 30 and 180°, so one is probably justified in believing that the consistency of the data with this trend suggests predominance of the direct reaction mode. In any case there is no rise at large angles to suggest the presence of a substantial compound nucleus contribution.

This result is consistent both with the general success in obtaining good fits with simple zero-range DWBA theory and with the failure to detect any example of the formation of a state of unnatural parity via this reaction in the f-p shell. Our conclusion is that the belief that significant α particle spectroscopic factors can be obtained via DWBA analysis of (^{6}Li, d) data in the f-p shell has been strengthened.

One of us (H.W.F.) wishes to thank Professor André Gallmann for making it possible for us to carry out this work at Strasbourg.

---

*Permanent address: University of Rochester, Rochester, New York 14627.

[1]H. H. Gutbrod and R. G. Markham, Phys. Rev. Lett. 29, 808 (1972).

[2]U. Strohbusch, C. Fink, B. Zeidman, R. G. Markham, H. W. Fulbright, and R. Horoshko, Phys. Rev. C 9, 965 (1974).

[3]H. W. Fulbright, U. Strohbusch, R. G. Markham, R. A. Lindgren, G. C. Morrison, S. C. McGuire, and C. L. Bennett, Phys. Lett. 53B, 449 (1975); (unpublished).

[4]R. M. DeVries, H. W. Fulbright, R. G. Markham, and U. Strohbusch, Phys. Lett. 55B, 33 (1975).

[5]U. Strohbusch, G. Bauer, and H. W. Fulbright, Phys. Rev. Lett. 34, 968 (1975).

[6]K. Bethge, K. Meier-Ewert, K. Pfeiffer, and R. Bock, Phys. Lett. 24B, 663 (1967); K. Meier-Ewert, K. Bethge, and K. O. Pfeiffer, Nucl. Phys. A110, 142 (1968).

[7]For the last two cases, $J^{\pi}=1^-$ was assigned in Ref. 3 because of the $L=1$ character of their angular distributions in this reaction.

[8]The ground state group from a small amount of carbon present in the target is believed to have produced the principal contribution to the neglected background. It fell within the integrated spectrum only at $\theta=47°$ and it never affected the $L=1$ data.