Li(d,α) Reactions at Deuteron Energies between 175 and 300 keV

MEL MANALIS AND JOEL E. HENKEL
University of New Hampshire, Durham, New Hampshire
(Received 6 August 1964)

The differential cross section for the reaction $Li^7(d,\alpha_0)He^5$ (ground state) was measured to be 0.31±0.10, 0.64±0.22, 1.04±0.36, 1.41±0.49, and 1.71±0.60 mb/sr for incident deuteron energies of 175, 214, 248, 280, and 300 keV, respectively, relative to that for the reaction $Li^6(d,\alpha)He^4$. The energy dependence of the measured cross sections agreed with that for the probability of formation of the compound nucleus, calculated from continuum theory.

INTRODUCTION

THE deuteron-induced alpha-particle reactions in lithium have been investigated extensively.[1–10] The differential cross section at 90 deg in the laboratory system for the alpha-particle group from the reaction $Li^7(d,\alpha_0)He^5$ (ground state) has been measured in the deuteron energy ranges 150 to 200 keV and 650 to 3000 keV.[2] No experimental data on the cross section for this reaction are available in the deuteron energy range 200 to 650 keV. Hence, it was of interest to determine the cross section for this reaction in the deuteron energy range 175 to 300 keV.

METHOD

In this experiment thick targets of natural lithium were bombarded with deuterons from a 400 keV. (HVEC, PN-400) van de Graaff generator at energies between 175 and 300 keV. The target was composed of a fine, dry $LiCO_3$ powder which was packed tightly into a cylindrically shaped depression extending $\frac{1}{32}$ in. into an aluminum target holder which was set at 45° to the deuteron beam. The particles emitted at 90° to the beam were detected by a surface barrier (Molechem B-50-40) solid state detector which was coupled to an RCL 256-channel P.H.A. Figure 1 shows the pulse

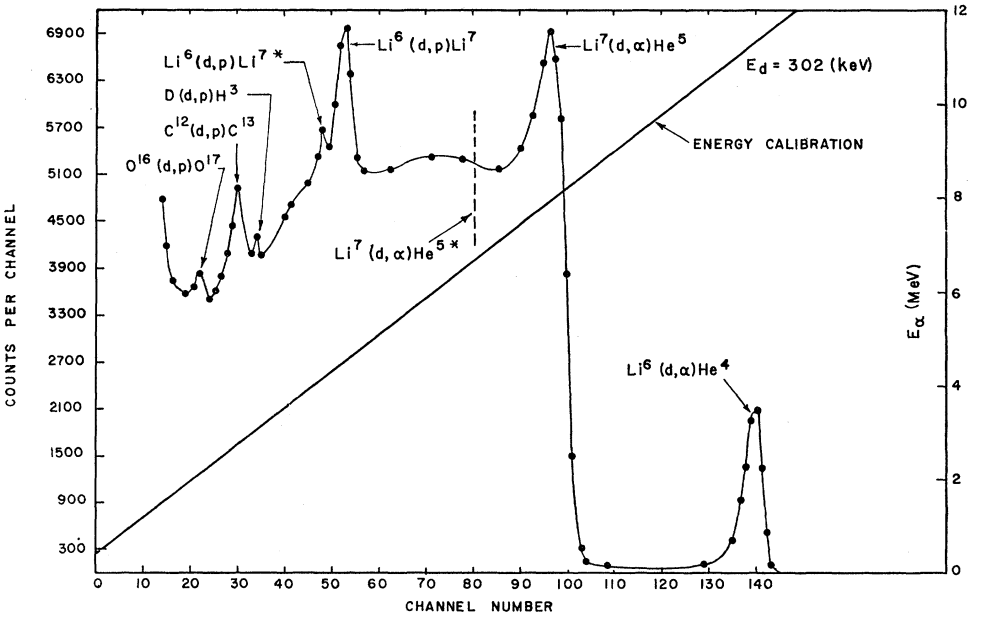

FIG. 1. Pulse-height spectrum for Li(d,α) reactions.

[1] J. H. Williams, W. G. Sheperd, and R. O. Haxby, Phys. Rev. **52**, 390 (1937).
[2] L. H. Rumbaugh, Phys. Rev. **54**, 657 (1938).
[3] W. E. Bennett, T. W. Bonner, H. T. Richards, and B. E. Watt, Phys. Rev. **71**, 11 (1947).
[4] Ward Whaling, and T. W. Bonner, Phys. Rev. **79**, 258 (1950).
[5] L. M. Baggett, and S. J. Bame, Jr., Phys. Rev. **85**, 434 (1952).
[6] F. Hirst, I. Johnstone, and M. J. Poole, Phil. Mag. **45**, 762 (1954).
[7] A. C. Riviere, Nucl. Phys. **2**, 81 (1956/1957).
[8] Gustav Weber, Phys. Rev. **110**, 529 (1958).
[9] P. Paul and D. Kohler, Phys. Rev. **129**, 2698 (1963).
[10] Peter Fessenden and D. R. Maxson, Phys. Rev. **133**, B71 (1964).

height spectrum for Li(d,α) reactions at $E_d=302$ keV. The slanting line gives the energy calibration.

ANALYSIS OF DATA

Figure 2 shows the allowed channels for decay of the Be^{9*} compound nucleus, which can be expected to contribute to the $Li^7(d,\alpha)$ reactions under investigation.

It is evident from Fig. 1 that the $Li^7(d,\alpha)$ reactions form an alpha continuum due to the competing (d,α) reactions shown in Fig. 2. Kinematic limits for the energy of the alpha particles from the secondary reactions were calculated to see if these limits could separate the reactions. It was found that these limits overlap in energy, preventing such an analysis.

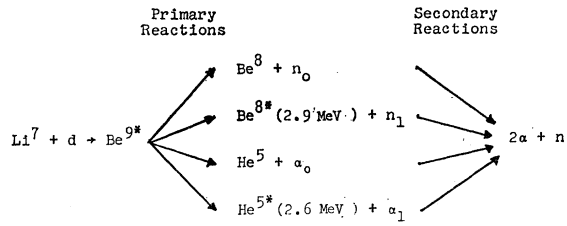

FIG. 2. Allowed channels for decay of the Be^{9*} compound nucleus.

In order to extract the cross section for $Li^7(d,\alpha_0)He^5$ reaction, a method which uses the theoretical line shape for this reaction, given by Weber,[8] was used. The

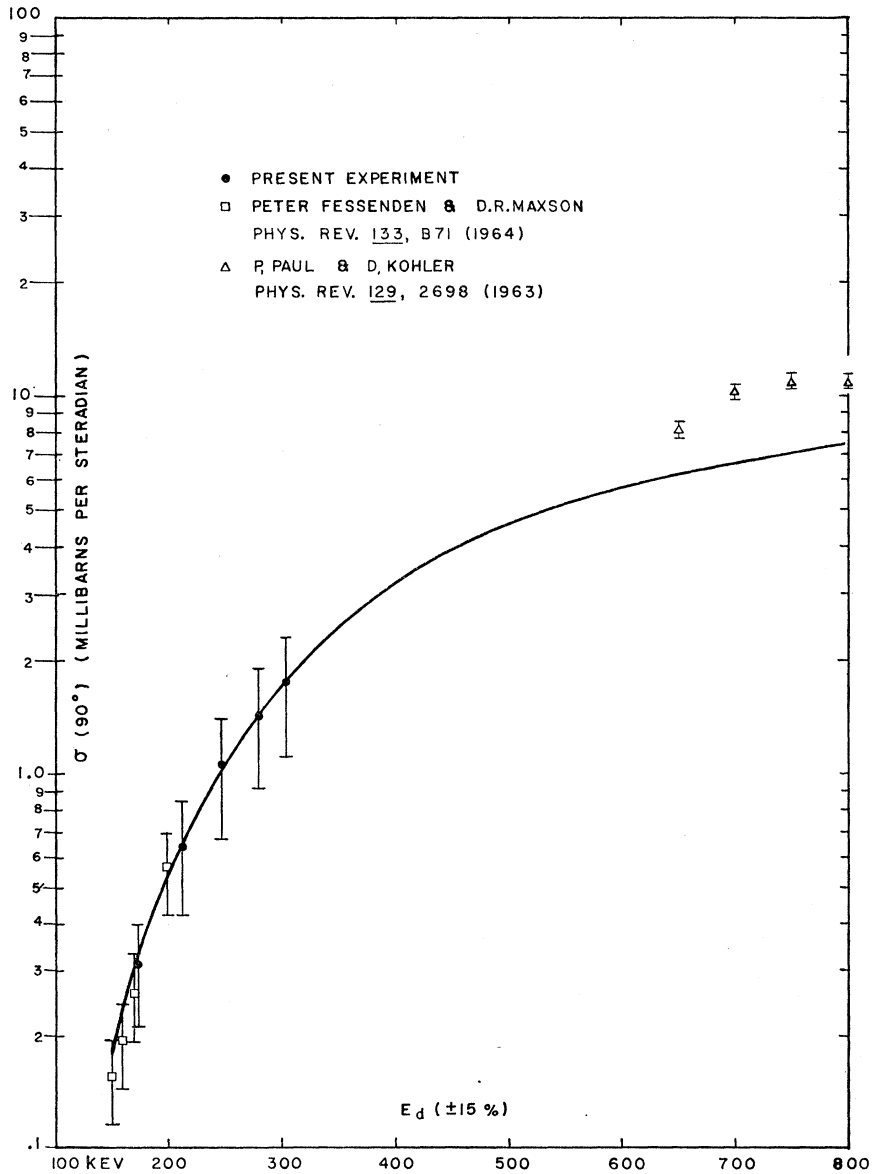

FIG. 3. Cross section for $Li^7(d,\alpha)He^5$. $\theta_{lab}=90°$.

observed line shape for the $Li^6(d,\alpha)He^4$ reaction was folded in to correct the theoretical curve for instrumental resolution. The corrected theoretical line shape was then superimposed on the experimental curve, normalizing to the $Li^7(d,\alpha)He^5$ peak. Since the cross section for a reaction is proportional to the integrated area under the experimental spectrum, the areas under the $Li^7(d,\alpha)He^5$ peak and the $Li^6(d,\alpha)He^4$ peak, corrected for abundance, were calculated. The known value for the cross section of $Li^6(d,\alpha)He^4$ [6] was then used to determine the cross section for the $Li^7(d,\alpha)$ reaction. Figure 3 shows the cross sections determined in our laboratory along with the values of Fessenden and Maxden[10] and Paul and Kohler.[9]

A correction to the deuteron energy was made to account for deuteron energy loss in the thick target. An effective deuteron energy was obtained for each maximum energy by calculating the mean energy using the known excitation function for the $Li^6(d,\alpha)He^4$ as a weighting function and assuming that all deuterons from zero to the maximum energy cause reactions. Assuming that the excitation function for the $Li^7(d,\alpha)He^5$ reaction is similar to that for $Li^6(d,\alpha)He^4$, effective energies were found.

The theoretical cross section for the formation of the compound nucleus Be^{9*}, based on continuum theory, was calculated. This curve was then normalized to the experimental data at 175 keV. In Fig. 3 the experimental points show excellent agreement with the theoretical cross section given by the solid line. Since the experimental points did not fall away from the theoretical curve as energy increased, we conclude no other channels open, up to 300 keV. The data of Paul and Kohler at energies above the region of our experiment show evidence of the well-known resonances at 800 to 1040 keV.

CONCLUSIONS

The differential cross section for the $Li^7(d,\alpha)$ reaction at 90 deg was determined by a relatively simple thick target method, using solid state detectors. The energy dependence of the cross section was found to agree with that for the formation of the compound nucleus, in the energy range 175–300 keV.

ACKNOWLEDGMENTS

The authors gratefully acknowledge helpful discussions with J. A. Lockwood and P. Fessenden.

PHYSICAL REVIEW VOLUME 136, NUMBER 6B 21 DECEMBER 1964

Configuration Mixing Effects in Stripping*

N. AUSTERN
University of Pittsburgh, Pittsburgh, Pennsylvania
(Received 6 August 1964)

The bound "single-particle wave function" into which the stripped particle is inserted is a true single-particle wave function, in the shell-model sense, only if the target nucleus is a closed-shell nucleus. In all other cases the radial shape of this function is altered by configuration mixing effects, and important changes of cross-section magnitudes may ensue. These effects are discussed in the present article, and a detailed comparison is given with the customary phenomenological procedure wherein the configuration mixing effects are estimated in terms of the Q of the reaction.

1. INTRODUCTION

RECENTLY there has been considerable interest in the subject of configuration mixing effects in deuteron stripping, and in other single-nucleon transfer reactions.[1–3] The present article presents some discussion of what these effects are, and of some circumstances under which they may or may not be important.

What is under discussion is the recognition and removal of certain simplifying assumptions which are tacitly made when the usual theory is constructed. Both nuclear structure theory and the distorted-waves stripping theory rely heavily on the use of product wave functions for nuclear bound states. Each theory goes on to improve the wave functions; however, the sorts of improvements which they carry are different. For this reason there is some vagueness when the two theories are used together for practical calculations. Stripping calculations are very sensitive to shapes of radial wave functions; nuclear structure calculations usually ignore radial shapes, and concentrate instead upon building linear combinations of angular momentum states. It is important for the reaction analysis that determination of a best linear combination for a bound-state wave function also implies determination of a best radial shape. It is this relationship which is generally overlooked, or which is treated very crudely.

A sufficient illustration of the dynamics we wish to

* Supported in part by the U. S. National Science Foundation.
[1] J. L. Yntema, Phys. Rev. **127**, 1659 (1962); **131**, 811 (1963).
[2] E. Rost, B. F. Bayman, and R. Sherr, Bull. Am. Phys. Soc. **9**, 458 (1964).
[3] R. Sherr, E. Rost, and M. Rickey, Phys. Rev. Letters **12**, 420 (1964).