$Li^7(\alpha,n)B^{10}$ Reaction*†

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The $Li^7(\alpha,n)B^{10}$ reaction has been investigated by two independent methods. In the first method the energies of the neutron groups were measured with a proton recoil telescope using an integral range technique. In the second method slow neutrons were observed at the threshold energies for each level with an enriched BF_3 counter. The combined results of the two methods give energy levels in B^{10} at excitation energies of 0.74, 1.31, and 1.72±0.06 Mev, with a ground-state Q-value for the reaction of −2.82±0.10 Mev. A comparative experiment with a Li^6 target was carried out so that positive assignment of the levels to B^{10} could be made. This work confirms the existence of a second excited state in B^{10} at 1.3-Mev excitation. The 1.3-Mev level had been observed in an early slow-neutron threshold experiment using the $Li^7(\alpha,n)B^{10}$ reaction, but it has not been found in other reactions leading to the same final nucleus.

I. INTRODUCTION

RECENT experimental investigations of the energy level structure of light nuclei indicate that certain levels are not observed with all reactions leading to the same final nucleus. Some such cases have been explained by using the theory of conservation of isotopic spin.[1] Others have been explained by using the theory of fractional parentage of nuclear states.[2]

Recently the second excited states of three light $N=Z$ nuclei, B^{10}, C^{12}, N^{14}, have been observed in (α,n) reactions.[3–5] These levels have not been observed in other reactions leading to the same final nuclei.[1,6–9] The reactions in which these second excited states were observed proceeded by means of compound nucleus formation, while the reactions in which the levels were not observed were probably stripping processes.

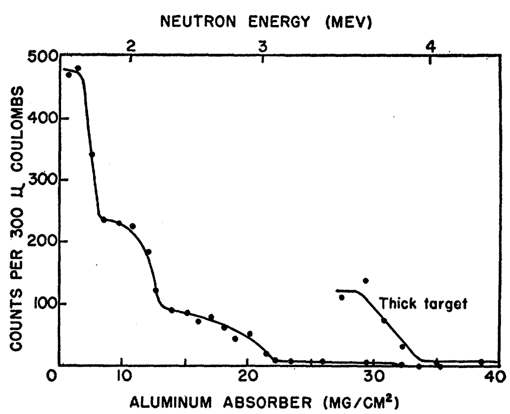

FIG. 1. Integral range curve of recoil protons from $Li^7(\alpha,n)B^{10}$ reaction. Observation at 0°.

The $Li^7(\alpha,n)B^{10}$ reaction was investigated by Haxel and Stuhlinger[3] by means of a slow-neutron threshold experiment. They reported the second excited state in B^{10} at 1.3 Mev. This level has not been observed in any other reaction leading to B^{10}.

The purpose of the present investigation is to study in detail the $Li^7(\alpha,n)B^{10}$ reaction using two independent methods.

II. EXPERIMENTAL METHODS

Two independent methods have been used in this experiment. In the first method the neutrons strike a hydrogenous radiator, giving rise to recoil protons. The energies of the recoil protons were measured by determining their range in aluminum. The aluminum foils were part of a two-counter telescope, with which integral range curves were taken.

In the second method the reaction threshold for each level was determined with an enriched BF_3 counter. The pulses from the counter passed through a single-channel pulse-height analyzer adjusted to reject fast-neutron pulses. The 8.16-Mev alpha-particle beam from the Yale cyclotron was degraded by means of a helium range cell. A detailed description of the experimental methods used in this experiment is given by Quinton and Doyle.[5]

III. RESULTS

Thin targets of Li_2SO_4, LiBr, and metallic lithium were used in this experiment. The Li_2SO_4 was 99% Li^7 loaned by the U. S. Atomic Energy Commission. The

TABLE I. Telescope experiment.

Neutron energy (Mev)	Q value (Mev)	Excitation E^* (Mev)
3.94	−2.82±0.10	...
3.04	−3.54±0.10	0.72±0.08
2.24	−4.14±0.10	1.32±0.08
1.67	−4.53±0.10	1.71±0.08

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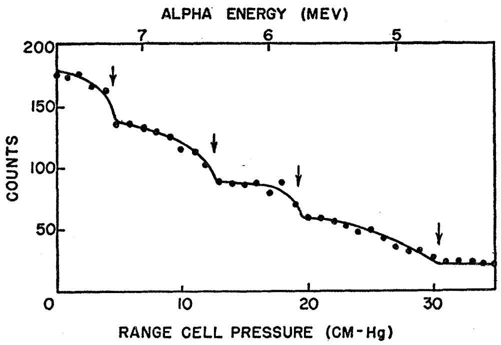

FIG. 2. Slow-neutron threshold curve for $Li^7(\alpha,n)B^{10}$ reaction.

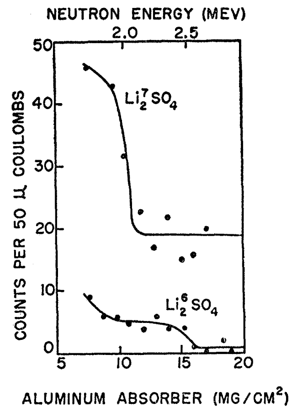

FIG. 3. Integral range curve of recoil protons from $(Li^7)_2SO_4$ and $(Li^6)_2SO_4$ targets in the vicinity of the 1.3-Mev level.

TABLE II. Threshold experiment.

Alpha energy (Mev)	Q value (Mev)	Excitation E^* (Mev)
4.45	-2.83 ± 0.10	...
5.64	-3.59 ± 0.10	0.76 ± 0.08
6.49	-4.13 ± 0.10	1.30 ± 0.08
7.15	-4.55 ± 0.10	1.72 ± 0.08

TABLE III. Summary.

	Average (Mev)	Haxel and Stuhlinger (Mev)	Ajzenberg and Lauritsen (Mev)
Q	-2.82 ± 0.10	-3.00 ± 0.10	-2.79 ± 0.04
E_1^*	0.74 ± 0.06	0.83 ± 0.10	0.72 ± 0.01
E_2^*	1.31 ± 0.06	1.31 ± 0.10	...
E_3^*	1.72 ± 0.06	...	1.74 ± 0.01
E_4^*	...	2.09 ± 0.10	2.15 ± 0.01

Li_2SO_4 and LiBr targets were prepared from solutions while the metallic lithium target was evaporated in vacuum. All the targets were deposited on thick lead backing. Similar level structure was found in experiments with the different targets.

Several runs were made with the proton recoil telescope for each of the targets. The results of nine runs have been combined in Fig. 1. Two runs on a thick lithium metal target were made to establish the ground state end point. Four levels are indicated by the sharp changes of slope. In Table I are listed the neutron energies, Q-values, and excitation energies for these levels.

The BF_3 counter was used to observe the slow-neutron thresholds for the same three targets. A large number of runs was taken with this apparatus to verify the level structure. A typical slow-neutron threshold curve is shown in Fig. 2. The results of eleven such runs have been averaged to give the alpha energies, Q-values, and excitation energies listed in Table II.

To investigate the possibility that the 1.3-Mev level in B^{10} might come instead from an anomalously high cross section for the $Li^6(\alpha,n)B^9$ reaction, a comparative experiment was carried out with the proton recoil telescope. Identical runs were made with similar targets of $(Li^6)_2SO_4$ (99% Li^6) and $(Li^7)_2SO_4$ (99% Li^7). The results of these runs in the vicinity of the 1.3-Mev level are shown in Fig. 3. This comparison shows that the cross section for the $Li^6(\alpha,n)B^9$ reaction is very much less than the cross section for the $Li^7(\alpha,n)B^{10}$ reaction. Therefore, the 1.3-Mev level in B^{10} could not have come from a Li^6 reaction, or from a reaction with any impurity in the target.

IV. DISCUSSION

The results of the proton recoil telescope experiment are in close agreement with the results of the slow-neutron threshold experiment. The same four levels have been observed in each experiment. The comparative experiment further strengthens the assignment of the observed levels to B^{10}.

The results of the two experiments have been combined in Table III and compared with the work of Haxel and Stuhlinger and the assignments of Ajzenberg and Lauritsen.[10] The ground-state Q-value determined in the present investigation is in good agreement with the Q-value calculated for this reaction from known mass defects. The first and third excited states observed here correspond closely to the assignments of Ajzenberg and Lauritsen. The second excited state found in this experiment confirms the level found in the earlier work of Haxel and Stuhlinger with the same reaction. This level has not, however, been reported from any other reaction leading to B^{10}.

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