Energy Dependence of the $^{10}B(n,\alpha)/^{10}B(n,\alpha\gamma)$ Cross-Section Ratio*

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The alpha-particle and lithium-ion recoils from the $^{10}B(n,\alpha)$ reaction were observed in coincidence in face-to-face surface-barrier silicon detectors, using 0.1 atmosphere of $^{10}B_2H_6$ as sample. Neutrons were provided by the ORNL 3-MV pulsed Van de Graaff using the $^7Li(p,n)$ reaction. Cross-section ratios $(n,\alpha_0)/(n,\alpha_1)$ of 0.084 ± 0.005 (160 keV), 0.077 ± 0.004 (110 keV), 0.072 ± 0.003 (30 keV), and 0.067 ± 0.002 (thermal neutrons) were found. These results indicate a small monotonic variation in the ratio, in good agreement with earlier measurements at higher energies. Less accurate results are also given at higher energies.

INTRODUCTION

THE $^{10}B(n,\alpha\gamma)$ reaction is a convenient high-cross-section standard in the 0.1–100 keV energy range for neutron-reaction cross-section measurements.[1] For use as a standard, it is usually necessary to know the relative proportion of the reaction cross section leading to the ground state versus the first excited state of ^{7}Li. Earlier studies of the cross-section ratio[2–7] have been reported for thermal-neutron energy and above 200 keV, but no results have been reported for the energy range between these extremes. The suggestion of a broad resonance near 180 keV in the total cross section[8] calls into question the propriety of smooth interpolation from thermal energy to 300 keV and has renewed interest in the ratio measurement.[9]

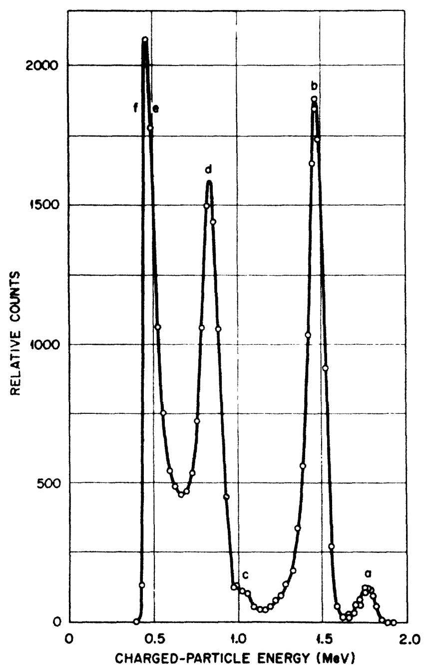

FIG. 1. Pulse-height distribution for thermal neutrons from $^{10}B(n,\alpha)^7Li$, $^7Li^*$ in a single surface-barrier counter. Points indicated on the figure correspond to (a) ground-state alphas, (b) alphas to the first excited state of ^{7}Li, (c) ^{7}Li nuclei from the ground-state reaction, (d) ^{7}Li nuclei from the reaction leading to the first excited state, (e) upper "edge" of pulses due to gammas from $^7Li(p,p'\gamma)$, (f) pulse-height threshold caused by fast discriminator gate.

EXPERIMENTAL

Two face-to-face silicon surface-barrier detectors[10] were used to detect the two charged particles from the reaction in coincidence. After experiencing breakage of self-supporting foils and detector damage with ^{10}B evaporated directly on the gold surface barrier, we tried $^{10}B_2H_6$ (Ref. 11) at 0.1 atm pressure. In this gas the detectors drew high current and became more noisy. This effect was variable (worse for some detectors than for others) and two detectors were found which gave acceptable pulse-height spectra for about two weeks. Exposure to air appeared to reduce the current and noise toward initial values.

Pulsed neutrons were provided at a 500-kc/sec repetition rate by the $^7Li(p,n)$ reaction at the ORNL 3-MV pulsed Van de Graaff. Pulses from the two detectors, passed through fast discriminators to eliminate noise and most γ-ray pulses, operated a 50-nsec coincidence unit whose output started a time-to-pulse-height converter. The bias on the fast discriminators was set low enough (500 keV) to ensure detection of the minimum energy (180-deg) lithium recoils. Two time intervals were chosen, one corresponding to fast-neutron arrival and the other to slow-and thermalized-neutron and other time-independent backgrounds. Summed detector pulses were stored in sections of a multichannel analyzer corresponding to these two time intervals.

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RESULTS AND DISCUSSION

A thermal-neutron spectrum (obtained with a wax moderator) is given in Figs. 1 and 2. The single-counter spectrum (Fig. 1) shows peaks corresponding to the two alpha groups and the two ^{7}Li groups. At higher neutron energies these peaks are spread out by center-of-mass motion. The sum of the (coincident) alpha and ^{7}Li pulses (Fig. 2), however, corresponds to the reaction Q value plus the energy of the incident neutron. The resolution is quite adequate to measure the areas corresponding to capture leading to the ^{7}Li ground and first excited states. The average ratio for four runs was 0.067 ± 0.002, in excellent agreement with recent measurements.[5–7] The thermal spectrum was used routinely to standardize electronic gains and threshold settings.

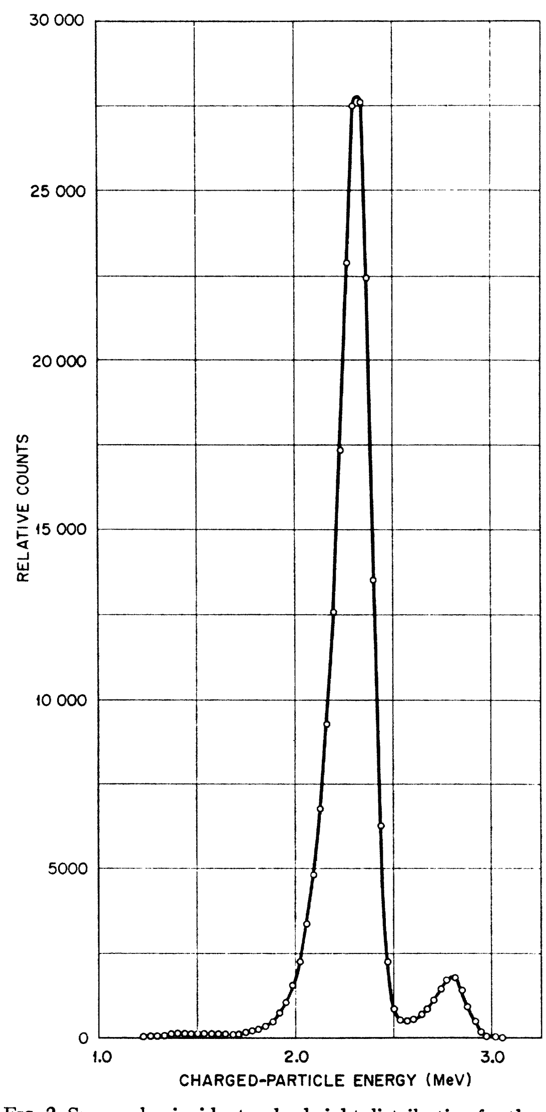

FIG. 2. Summed-coincident pulse-height distribution for thermal neutrons from $^{10}B(n,\alpha)^7Li$, $^7Li^*$ in the spectrometer. The two peaks correspond to the total charged-particle reaction energy from the two reaction branches.

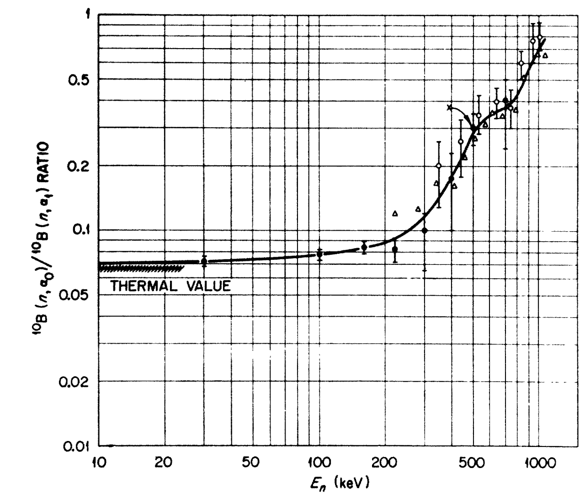

FIG. 3. The energy dependence of the branching ratio (α_0/α_1) in the reaction $^{10}B(n,\alpha)^7Li$, $^7Li^*$. The solid points are due to the present studies; open triangles are from Ref. 4; open circles are from Ref. 2; the cross is from Ref. 3.

At 30 ± 10 keV [forward-angle neutrons from ^{7}Li-(p,n) near threshold] the ratio (0.072 ± 0.003) is barely increased over the thermal value, in agreement with recent Harwell results.[9] At 110 ± 15 keV (0.077 ± 0.004) and 160 ± 15 keV (0.084 ± 0.005), perceptible increases are observed. At energies above 200 keV the pulse-height resolution became progressively worse (mostly because of longer exposure of the detectors to $^{10}B_2H_6$) and difficulty was experienced in determining the ratio. The experiment was terminated at 700 keV, just below the $^7Li(p,n')$ threshold. Values obtained are indicated in Fig. 3 where they are compared with results of other investigators.[1–3]

We feel that the results collectively indicate an effect, albeit small, of the resonance near 530 keV on the cross-section ratio. Our results show that the ratio remains within about 5% of the thermal value for neutron energies up to about 30 keV, after which it rises in a slow, continuous fashion. These new values for the cross-section ratio in the $7<E_n<170$ keV range cause a change of less than 1.5% (less than 0.5% for $E_n\leq100$ keV) in the shape of the $(n,\alpha\gamma)$ cross section assumed for flux calibration in our earlier work on heavy-element capture cross sections.[1]

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