EXCITED STATES OF ^{8}Be FROM THE ^{7}Li(d,n)^{8}Be REACTION

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Summary

The energy spectrum of neutrons from the reaction ^{7}Li(d,n)^{8}Be at 700 keV bombarding energy has been studied with nuclear emulsions at 0, 75, and 135°. Both resolution and statistics compare favourably with those of previous nuclear emulsion measurements of this spectrum. The results do not confirm the suggestions made by earlier workers that levels at 2·2, 4·1, 5·3, and 7·5 MeV in ^{8}Be participate in the reaction, and support the view that the only excited state below 9 MeV in ^{8}Be is the well-known broad level at 2·9 MeV.

I. Introduction

During the past decade there has been a good deal of controversy as to the level scheme of ^{8}Be in the region of excitation energy E_{ex} from 0 to 9 MeV. The experimental evidence, which has been amply reviewed elsewhere (see, for example, Titterton 1954; Holland *et al.* 1955; Nilson *et al.* 1958), may be broadly divided into two groups. Some experiments, especially those with good statistics, indicate that the well-known 2·9 MeV level is the only excited state in the region, whereas others, usually with relatively poor statistics, suggest a multiplicity of levels. In some respects the most convincing of the latter group of experiments are those using nuclear emulsions to study the energy spectrum of neutrons from the reaction ^{7}Li(d,n)^{8}Be. The most recent of these is the work of Gibson and Prowse (1955); using 930 keV deuterons, they claimed evidence for the existence of levels at 2·2, 2·9, 4·1, and 5·3 MeV. The resolution achieved is apparently better than has been achieved in previous studies of the reaction, since the half width of the ground state group is between 400 and 450 keV. However, Trail and Johnson (1954a, 1954b) have used a neutron spectrometer consisting of a proton recoil telescope with thin polyethylene radiator to study the same reaction at a deuteron energy of 2·0 MeV. With much better statistics than the nuclear emulsion measurements they find no evidence for any states below 10 MeV other than the 2·9 MeV level. The resolution achieved, however, was relatively poor, the half width of the ground state group being 1100 keV. It is possible to argue that this lack of resolution precluded the observation of the fine structure suggested by the emulsion measurements; Gibson and Prowse themselves suggest that the groups were not observed because of a decrease in intensity relative to the 2·9 MeV group with increasing bombarding energy.

The aim of the present work, using nuclear emulsions to measure the energy spectrum of neutrons from the ^{7}Li(d,n)^{8}Be reaction, has been to achieve resolution comparable with the best of previous experiments, and hence to endeavour to confirm the existence of the suggested fine structure.

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II. Experimental Procedure

A 30 keV thick target of separated ^{7}Li was bombarded by 700 keV deuterons for an integrated exposure of 40,000 μC. The target thickness was estimated from the energy of scattered protons as measured with a 180° magnetic analyser. Neutrons were detected in pairs of 1-in. square 400μ Ilford C2 nuclear emulsion plates located at 15° intervals around the target, the camera and target arrangements being the same as those described previously (Bird and Spear 1957). The plates were processed using a conventional " temperature development " method. Tracks were measured and analysed using the procedures described in detail by Bird and Spear (1957).

III. Results

Spectra have been obtained at 0, 75, and 135°. In each of the spectra illustrated, recoil protons were accepted for measurement if the recoil angle ψ was less than 25°, the dip angle in unprocessed emulsion, τ, was less than 12·4°, and the recoil proton range corresponded to E_{ex} less than 8·8 MeV. Except in Figure 5, no corrections have been applied for loss of tracks from the emulsion and variation with energy of the neutron-proton scattering cross section.

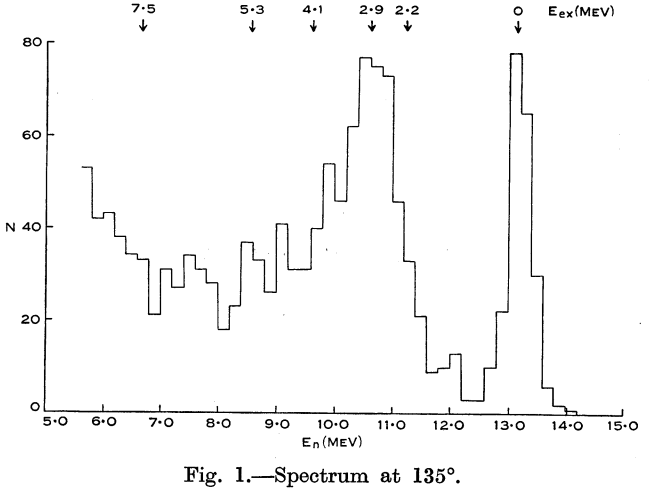

Fig. 1.—Spectrum at 135°.

The best resolution was obtained at 135°, the results for which are shown in Figure 1, where the number of tracks, N, per 200 keV interval is plotted against neutron energy E_n. The arrows indicate the positions at which groups would occur corresponding to excited states in ^{8}Be suggested by previous experiments. The resolution achieved is indicated by a half width of 440 keV for the ground state group, and the statistical accuracy is considerably better than that of Gibson and Prowse as determined from the statistical error bars on their published spectrum. The resolution may be improved further to 400 keV at the expense of statistical accuracy by limiting the acceptance angles ψ and τ more stringently ; the shape of the spectrum is, however, essentially unaltered.

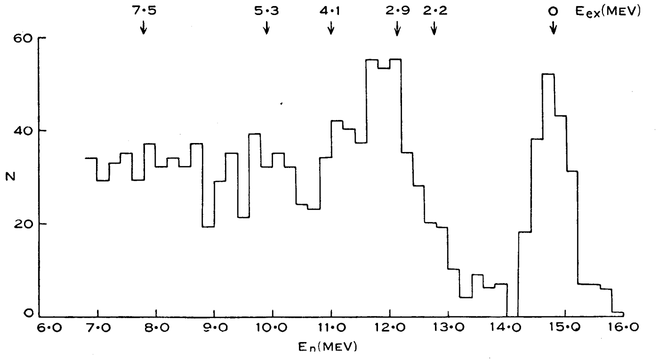

Fig. 2.—Spectrum at 0°.

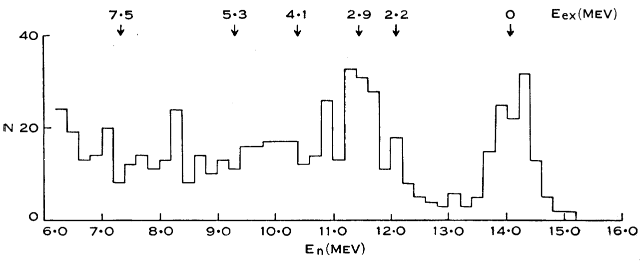

Fig. 3.—Spectrum at 75°.

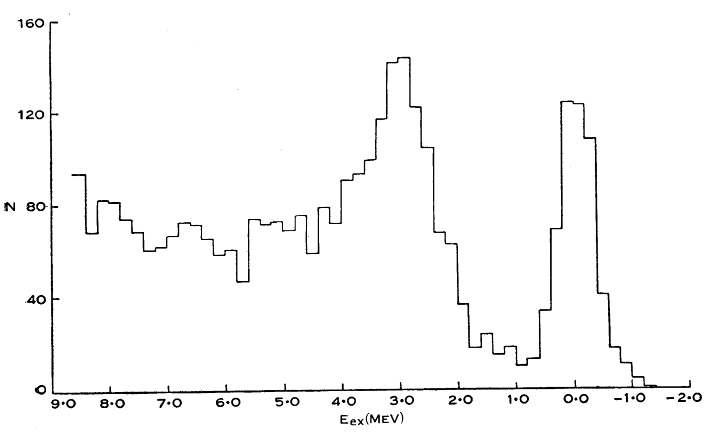

Fig. 4.—Combination of results at 0, 75, and 135°.

The results obtained at 0 and 75° are shown in Figures 2 and 3. The results for all three angles have been combined and plotted in Figure 4 in terms of ^{8}Be excitation energy. In Figure 5 the same results are shown after correcting for loss of tracks from the emulsion and variation with energy of the neutron-proton scattering cross section, statistical error bars being indicated at several points. The half width of the ground state group is approximately 700 keV. The total number of tracks represented in Figure 5 is 3300.

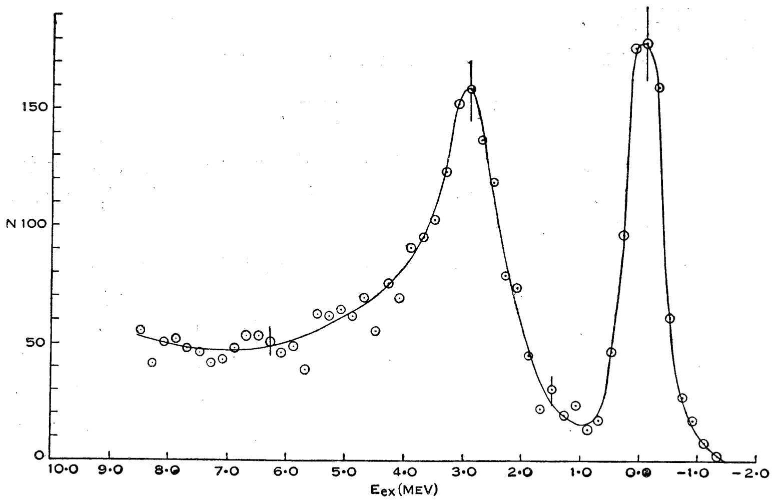

Fig. 5.—Combination of results at 0, 75, and 135° after correcting for loss of tracks from the emulsion and variation with energy of the neutron-proton scattering cross section.

IV. Discussion of Results

In none of the spectra illustrated is there any statistically significant indication of levels at 2·2, 4·1, 5·3, or 7·5 MeV. If such levels participate in this reaction in the way suggested from previous experiments, it is difficult to see why they should not have been observed in the present experiment, especially at 135°, where the resolution is similar to that achieved by Gibson and Prowse, and the statistical accuracy is considerably better.

From a measurement of the energies of α-particles emitted in coincidence with γ-rays in the reaction $^7Li(p,\gamma)^8Be^*(\alpha)^4He$, Inall and Boyle (1953) have suggested that transitions involving excited states at 4·1, 5·3, and 7·5 MeV in ^{8}Be occur with intensities of the order of 1 per cent. of the total radiation. Transitions of such low intensities would not have been detectable in the present work. However, LaVier, Hanna, and Gelinas (1956) used a magnetic spectrograph to study the energy spectrum of α-particles from the same reaction and found no evidence for the existence of such states, although transitions of 0·5 per cent. of the total intensity would have been detectable. Similar negative results have been obtained more recently by Meyer and Staub (1958) from magnetic analysis of the α-particle spectrum, both singly and in coincidence with γ-rays.

If there is no excited state below 10 MeV in ^{8}Be, other than the $2\cdot9$ MeV state, then some explanation is required for the continuum of neutrons for E_{ex} above 3 MeV. Three possibilities are suggested:

(i) A continuum of neutrons from the simultaneous three-particle break-up of ^{9}Be in the reaction

$$^7\mathrm{Li}(d)^9\mathrm{Be}^*(n)^4\mathrm{He}+{}^4\mathrm{He}.$$

This reaction could provide neutrons of energies up to that of the ground state group from ^{7}Li$(d,n)^8$Be.

(ii) A continuum of neutrons from the reaction

$$^7\mathrm{Li}(d,\alpha)^5\mathrm{He}(n)^4\mathrm{He}.$$

If ^{5}He is produced in its ground state, the maximum neutron energy is approximately $4\cdot6$ MeV at 0°. If excited states of ^{5}He are involved, more energetic neutrons may be obtained.

(iii) A contribution due to the overlapping of " tails " from groups corresponding to broad levels at $2\cdot9$ and 11 MeV. After correcting for the effects of experimental resolution, the half width obtained for the $2\cdot9$ MeV level is $1\cdot6\pm0\cdot4$ MeV. Values ranging from $0\cdot8$ to $2\cdot0$ MeV have been obtained from other reactions (Ajzenberg and Lauritsen, " Energy Levels of Light Nuclei, VI ", personal communication). The evidence for the existence of a very broad level at about 11 MeV has been discussed by Ajzenberg and Lauritsen.

V. Conclusion

The results of this experiment do not confirm the deductions made from previous work that excited states at $2\cdot2$, $4\cdot1$, $5\cdot3$, and $7\cdot5$ MeV in ^{8}Be participate in the reaction ^{7}Li$(d,n)^8$Be. They support the view that the only excited state in ^{8}Be below 9 MeV is the $2\cdot9$ MeV state.

VI. Acknowledgments

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