The gamma background, obtained for each determination of the spectrum by using an absorber, was subtracted. Decay of each experimental point was plotted and the decay curve analyzed for the 3-hour component. The results were plotted with counting rate *vs* pulse height as coordinates. The curve was then compared with a phosphorus-32 curve obtained under identical conditions. This comparison, plus a Kurie plot of the 3-hour holmium, gave a value of 1.0 ± 0.1 Mev for the energy of the more energetic beta particle. An aluminum absorption curve showed the presence of two betas with energies of 0.96 and 0.28 Mev. No attempt was made to measure the energy of the less energetic beta by use of the spectrometer because of absorption difficulties and the 3-hour half-life. A quantitative estimation of total gammas present, made with a previously calibrated scintillation spectrometer,[4] showed only one-fourth the gammas necessary to account for total betas present. An estimation of betas was made by use of aluminum absorption curves with extrapolation to zero absorber. The two betas were present in approximately equal quantities.

There were approximately three times as many 0.35-Mev gammas as 0.70-Mev gammas. The 0.35-Mev gammas exceeded the maximum observed x-rays by a factor of approximately 18. The amount of conversion must be very small. Although this does not give a complete picture of the decay characteristics of this activity, continuation of the investigation at this time is impractical since the ORNL 86-inch cyclotron is shutdown for modifications.

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Nuclear Energy Levels of Be^8 from $Li^7(d,n)Be^8$

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The nuclear energy levels of Be^8 have been investigated by observing the neutron groups emitted when an isotopic target of Li^7 is bombarded by 0.7-Mev deuterons. Evidence of levels in Be^8 was found at 2.98 and 7.53 Mev, and of a probable level at 5.30 Mev.

INTRODUCTION

The photographic plate technique has been used for the study of the spectrum of low-lying states of Be^8 from the reaction

$$_3Li^7+{}_1D^2\longrightarrow Be^8+{}_0n^1+Q, \qquad \text{(A)}$$

which has a Q value of 15.03 Mev. The reaction (A) has been studied by Richards[1] and also by Green and Gibson.[2] Richards measured the energy distribution of the emitted neutrons at right angles to the direction of the incident deuteron beam, while Green and Gibson measured the neutron spectrum at 0° and 120° with respect to the initial direction of deuterons. They found evidence of the neutron group corresponding to the ground state of Be^8, followed by a broad group for the first excited state, and accompanied by two more levels superposed on a continuous background. Recently, Trumpy and Graue[3] have studied the same reaction. They found evidence of energy levels in Be^8 at 2.9, 4.1, and 5.1 Mev. Their analysis suggests two energy levels at 4.1 and 2.92 Mev in place of the broad levels corresponding to the first excited state of Be^8. Erdös *et al.*[4] have resolved the first excited state of Be^8 into three energy levels at 2.2, 2.9, and 3.4 Mev.

Lately, Malm and Inglis[5] have investigated the Be^8 energy levels using the following reaction:

$$_5B^{10}+{}_1D^2\longrightarrow {}_4Be^8+\alpha+Q. \qquad \text{(B)}$$

They measured the energy of the α particles with a proportional counter, extending their investigations from 0 to 7 Mev excitation energy of Be^8. They found a sharp peak corresponding to the formation of Be^8 in its ground state, having a width of 0.06 Mev, which is by far the best resolution so far reported. Their experimental evidence suggests that there is only one broad energy level at 2.9 Mev which corresponds to the first excited state of Be^8. We have studied the reaction (A) in order to onvestigate the energy levels of Be^8 in general and its first excited state in particular.

EXPERIMENTAL ARRANGEMENT

A thin lithium target was used and kept cool during the time of bombardment. It was bombarded by a homogeneous beam of deuterons of mean energy 686 kev from the Nuclear Physics Research Laboratory's 1-Mev H.T. generator. Ilford *C* 2400-micron nuclear

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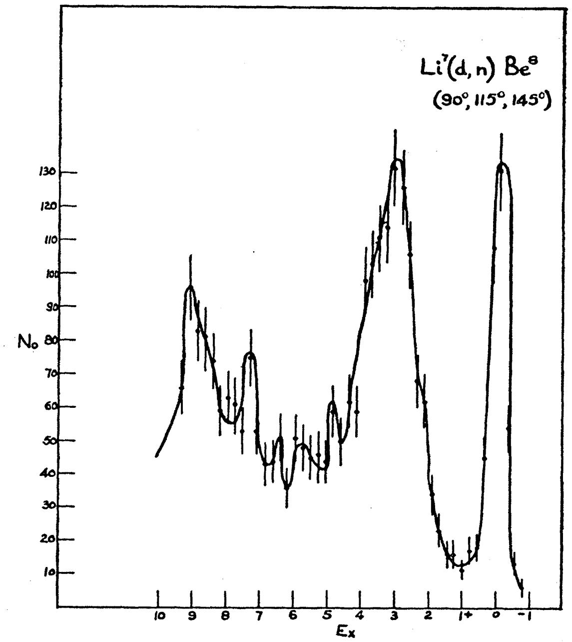

FIG. 1. Number of neutrons from the reaction $Li^7(d,n)Be^8$ as a function of excitation energy, for the three angles combined.

research plates were used for the detection of neutrons. The plates were held lengthwise so as to receive the incoming neutrons tangentially. After an exposure of two hours they were developed by the temperature control method. The proton tracks in the emulsion formed by the collision of incoming neutrons were scanned with a Cooke, Troughton, and Simm's nuclear research microscope with an oil-immersed objective of $\times 45$ and a Kellner eye-piece of $\times 10$. The following criteria were used for the acceptance of a track for measurement: (1) angle (θ) of proton in the forward direction $\leq 10°$; (2) dip of proton track $\leq 4°$. Only those tracks were measured whose range was greater than or equal to 119 microns or 4.99 Mev.

Neutrons spectra were measured at three different angles, 90°, 115°, and 145°, respectively. The energy spectrum of Be^8, obtained by plotting the excitation energy as abscissa against the number of neutron tracks, combined for the three angles, as ordinate at an energy interval of 0.22 Mev, is shown in Fig. 1. It shows a sharp peak corresponding to the ground state, having a half width of 0.5 Mev, followed by a broad peak for the first excited state and a level at 7.53 Mev which is in agreement with the other reported experimental results.[2,6,7]

In addition to these levels there is also an unresolved peak at 5.35 Mev which will be consistent with some[8–10] and in disagreement with other investigators,[5,11,12] but its intensity is so low that we cannot draw any conclusion about it.

ENERGY LEVELS OF Be_4^8

In addition to reaction (A) with which we are mainly concerned, there is a possibility of the following reaction as well:

$$_3Li^7 + {}_1D^2 \longrightarrow {}_2He^4 + {}_0n^1 + Q. \qquad \text{(C)}$$

The reaction (C), being a three-body disintegration of low Q, produces a continuous distribution of neutrons of low energy in the spectrum of Be^8 as seen in Fig. 1.

There is contradictory experimental evidence about the energy levels of Be^8, especially in the region of its first excited state. Except perhaps the asymmetry of the curve at the first excited state of Be^8, shown in Fig. 1, which may be suggestive of another energy level at 4.1 Mev for this state, the main features of our result agree with Malm and Inglis,[5] in contrast to those of Trumpy *et al.* Titterton[13] has discussed the evidence for energy levels in Be^8 at 4.01, 5.3, and 7.5 Mev. Existence of 4.01-Mev level is suggested from $Li^7(d,n)Be^8$,[3] $B^{11}(\gamma,t)Be^8$,[14] $B^{10}(\gamma,d)Be^8$,[15] and $Li^7(p,\gamma)\times Be^8$,[8] reactions, some[14,15] of which have quite limited resolution and statistics, and this level is also not consistent with the experimental results of other[5,6,12,16] investigators, who had much better statistics. The same broad first excited state of Be^8 has also been observed in many different experiments, such as: $B^{11}(p,\alpha)Be^8$,[17] $B^{10}(d,\alpha)Be^8$,[12] $Li^7(p,\gamma)Be^8$,[8] $C^{12}(\gamma,\alpha)Be^8$,[18] $Li^6(He^3,p)Be^8$,[16] and the β decay[19,20] of Li^8 and Be^8 have led to the same value for the energy of this state.

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