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Reaction $Li^6(d,t)Li^5(p)He^4$†

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A study is made of the proton and triton continua from the deuteron bombardment of Li^6 in order to obtain information on the mechanism of the three-particle reaction and on the properties of the ground state of Li^5. Because of the great breadth of this state, an unambiguous interpretation is not possible. The most likely mechanism is $Li^6(d,t)Li^5(p)He^4$, with a $Q=0.80\pm0.15$ Mev for the primary reaction (mass defect of $Li^5=12.95\pm0.15$ Mev), and a width of the ground state of Li^5 equal to 2.0 ± 0.2 Mev (in the c.m. system).

SOME of the simplest and most interesting nuclei are so unstable with respect to heavy-particle emission, even in their ground state, that observations on them are restricted to the brief but important roles they play as intermediate states in nuclear reactions, either in a scattering experiment or in a successive disintegration of the type: $A(a,b)B(c)C$. In the latter reaction the emitted particles are characterized by continuous distributions in energy in the laboratory system. In the present investigation the proton and triton distributions encountered in the deuteron bombardment of Li^6 have been examined with magnetic analysis in order to obtain information on the mechanism of the disintegration and on the ground state of Li^5. The proton distribution has been observed previously and assigned to the reaction $Li^6(d,t)Li^5(p)He^4$.[1]

In a study of the triton spectrum it is essential to use Li^6 targets of high purity. The presence of Li^7 in the target is particularly undesirable because of the profuse reaction $Li^7(d,n\alpha)He^4$ which produces a continuum of alpha particles throughout the energy interval of interest. Moreover, it is desirable to minimize the oxygen contamination of the target, as the proton groups from $O^{16}(d,p)O^{17}$ fall in the region of the relatively weak proton continuum under study. For the observations at $\theta=90°$, targets were prepared by allowing a solution of lithium chloride[2] to evaporate at a controlled rate. The target was then heated continuously to prevent the formation of water of hydration. For the other spectra thin metal targets[3] were prepared by evaporation in the vacuum of the target chamber. These latter targets invariably showed a much higher oxygen content, but their greater uniformity compensated for the increased yield from oxygen.

The deuteron beam was obtained from an electrostatic accelerator, and the spectra were recorded in nuclear emulsions in the wide-range magnetic spectrograph used previously in this laboratory. At each angle of observation the complete spectrum was obtained in four exposures covering the range from about $E_p=0.6$ to 6 Mev or, equivalently in magnetic analysis, from $E_t=0.2$ to 2 Mev. Actually the observation of the triton spectrum was not carried below about $E_t=0.7$ Mev because of interference from elastically scattered deuterons.

The spectra are presented in Figs. 1 and 2. As all the sharp peaks have been identified previously, we shall discuss only the broad structure. The various possible three-particle reactions are shown in Fig. 3. Those modes involving the final products, α, He^3, and n, were not studied because of interference from scattered deuterons. In the reactions leading to α, t, and p, only the latter two particles were observed. There is evidence in the figures for the production of both Li^5 and Li^{7*},

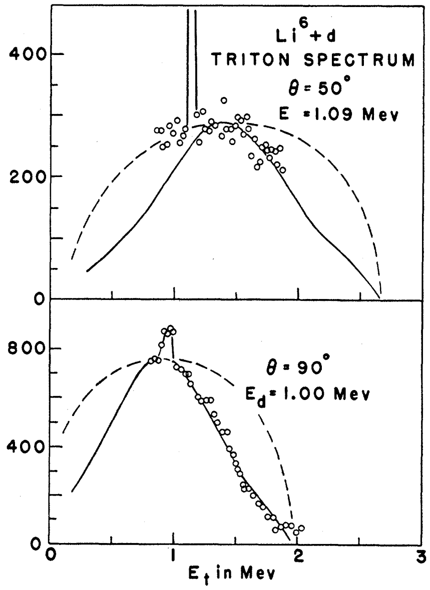

FIG. 1. Triton spectra from the bombardment of Li^6 by deuterons. The dashed curves represent the distributions expected for a simultaneous three-particle disintegration. The solid curves are for the mechanism $Li^6(d,t)Li^5(p)He^4$ with $Q=0.8$ Mev and $\Gamma_{c.m.}=2.0$ Mev. The group at about $E_t=1.1$ Mev is attributed to alpha particles from the reaction $O^{16}(d,\alpha)N^{14}$.

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[1] R. W. Gelinas and S. S. Hanna, Phys. Rev. **86**, 253 (1952).

[2] Prepared from a lithium sulfate sample in which the lithium was enriched to 95.2% Li^6.

[3] Enriched to 95.7% Li^6. Both these samples were obtained from the Stable Isotopes Division, Oak Ridge National Laboratory.

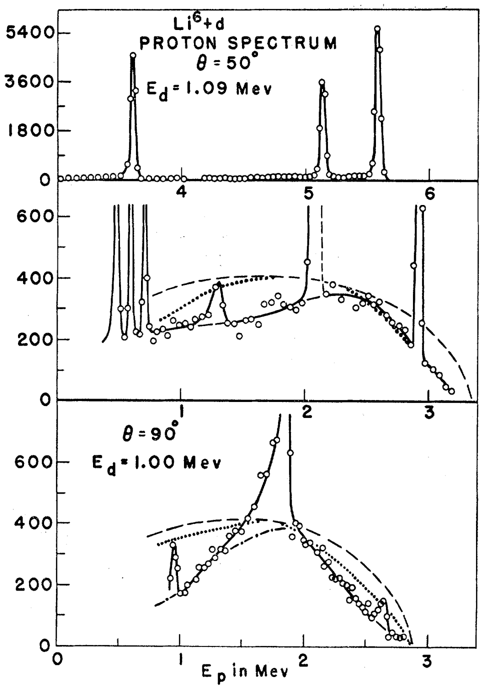

FIG. 2. Proton spectra from the bombardment of Li^6 by deuterons. The unbroken curve is an empirical one drawn through the data. At $\theta=50°$, the peaks at $E_p=5.6$, 5.1, and 1.35 Mev are from $Li^6(d,p)Li^7$; those at 3.6 and 0.68 Mev are from $C^{12}(d,p)C^{13}$; those at 2.9 and 2.1 Mev are from $O^{16}(d,p)O^{17}$; the peak at 0.79 Mev is from $Li^7(d,p)Li^8$; and the one at 0.55 Mev results from the elastic scattering of protons (which contaminate the beam) in the nickel backing of the target. At $\theta=90°$, the peak at $E_p=0.95$ Mev is from $Li^6(d,p)Li^7$; the peaks at 2.7 and 1.8 Mev are from $O^{16}(d,p)O^{17}$. The dashed curves represent the proton distributions expected for $\Gamma=\infty$, i.e., for a simultaneous breakup. The dotted curves are for the successive decay $Li^6(d,t)Li^5(p)He^4$ with $Q=0.8$ and $\Gamma_{c.m.}=2.0$ Mev. The dot-dash curve is for the same reaction with an assumed angular correlation between the triton and the deuteron of the form $1+0.5\cos\theta$.

$E_{ex}=4.61$ Mev, in the reactions:

$$Li^6(d,t)Li^5(p)He^4,$$
$$Li^6(d,p)Li^{7*}(t)He^4.$$

In the latter reaction the weak primary proton group at $E_{ex}=4.61$ Mev is observed. The secondary triton spectrum in this second reaction is presumably submerged in the much stronger triton group from the first reaction. The continuous proton spectrum is attributed solely to the first reaction.

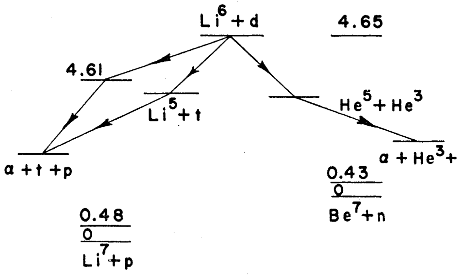

FIG. 3. The possible three-particle disintegrations resulting from the bombardment of Li^6 by deuterons.

This interpretation accords with the known states in Li^7, but it is not by itself unique since the proton continuum could be attributed to a very broad state in Li^7 in the region from $E_{ex}=3$ to 6 Mev. In the absence of any other evidence for such a state,[4] we do not consider this possibility seriously. Two cases are illustrated in the figures. In one, the successive decay $Li^6(d,t)Li^5(p)He^4$ is assumed with a $Q=0.8$ Mev for the primary reaction and a width of 2.0 Mev (in the c.m. system) for the ground state of Li^5. The triton spectrum is obtained from a one-level resonance formula, and the secondary proton spectrum is calculated[5] using the same parameters and assuming isotropic directional correlations among the particles. In the second case, the width of the ground state of Li^5 is assumed to be very large compared to the total energy release in the reaction; this case is of course equivalent to a simultaneous breakup into three particles.

For the tritons the fit for $\Gamma=2.0$ Mev is quite good. In the data at $\theta=50°$, the disagreement below $E_t=1.4$ Mev can probably be traced to an increasing contribution from scattered deuterons which were not completely eliminated in counting the tritons. For the protons the curves for $\Gamma=2.0$ Mev do not fit the data well, although they agree better than do the curves for $\Gamma=\infty$. It is possible to obtain a more satisfactory fit to the data by assuming that the tritons are emitted preferentially in the forward direction as reported earlier[6] and shown by the dot-dash curve in Fig. 2, although the way in which such a fit can be made is not unique. A more detailed calculation, which would include the effect of barrier penetrability, is not presented, as it would not contribute to providing a unique interpretation. It is felt that the present interpretation is favored in light of all other evidence pertaining to the states in Li^5 and Li^7. The mass defect obtained for Li^5 is 12.95 ±0.15 Mev, which may be compared to values of 13.17±0.2, 13.18±0.15, 13.20±0.15, 12.71±0.15, and 13.09 Mev derived[4,7] from the reactions $He^3(d,\gamma)Li^5$, $He^3(He^3,p)Li^5$, $Li^6(He^3,\alpha)Li^5$, $Li^6(p,d)Li^5$, and $Li^6(\gamma,n)$-Li^5, respectively.

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[7] D. M. Van Patter and W. Whaling, Revs. Modern Phys. **29**, 757 (1957).