Magnetic Analysis of the $Li^6(d,p)Li^7$ and $Li^7(d,p)Li^8$ Reactions

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The energy release of the $Li^6(d,p)Li^7$ reaction has been measured as 5.006 ± 0.014 Mev, using a semicircular magnetic analysis. The hitherto unobserved protons from the $Li^7(d,p)Li^8$ reaction have been found and their energy measured. The Q for this reaction has been determined as -0.193 ± 0.008 Mev.

I. INTRODUCTION

THE various nuclear reactions of the lithium isotopes have been studied in considerable detail, the most comprehensive investigation being that of Rumbaugh, Roberts, and Hafstad.[1] These studies have shown that the reactions $Li^6(d,p)Li^7$ and $Li^7(d,p)Li^8$ occur. The first of these reactions was detected from the protons emitted. The protons from the second reaction were not found, and the reaction was inferred from the observed production of radioactive Li^8.

Two proton groups result from the $Li^6(d,p)Li^7$ reaction, and the difference in energy of these groups has been measured[2] to obtain the energy of the well-known, low lying level in Li^7. In the present experiment, the energy release of this reaction has been determined using a semicircular magnetic analyzer. This apparatus has also been used to search for the protons that result from the $Li^7(d,p)Li^8$ disintegration and to measure the Q for the reaction.[3]

II. APPARATUS AND EXPERIMENTAL PROCEDURE

The essential details of the experimental arrangement have been described previously.[4] The thin targets used were prepared by the evaporation of Li_2SO_4 onto platinum sheets. This compound was chosen since it can be obtained from the Atomic Energy Commission enriched in Li^6. The natural compound was used for the studies with Li^7, and the enriched targets were used for the Li^6 reaction. The oxygen in the target was not a complication in the present experiment, inasmuch as the proton groups that result from the deuteron bombardment of oxygen have energies that are considerably different from those of the protons that were being investigated.

As in our previous work,[2] the studies of the energies of the protons from the $Li^6(d,p)Li^7$ were simplified by the fact that, at the bombarding energy used, these protons have a $H\rho$ in the magnetic field which is close to that of polonium alpha-particles. This makes it possible to compare their energies directly. The energy of the incident deuteron beam was determined from measurements on the deflection of the deuterons elastically scattered from a thin film of platinum evaporated onto copper.

Protons from the $Li^7(d,p)Li^8$ reaction have an energy that is considerably less than the energy of the deuterons which are elastically scattered from the platinum support of the lithium target. While it is possible to count the proton tracks on the photographic plates even in the presence of the heavy deuteron background, most of the plates were taken with a thin aluminum foil placed directly in front of the emulsion surface. The foil was of such a thickness as to stop completely the scattered deuterons.

III. RESULTS

A large number of observations have been made on the two proton groups from $Li^6(d,p)Li^7$. No evidence has been found for any structure in either of the groups. From these measurements, we have obtained 5.006 ± 0.014 Mev for the Q-value of the reaction leading to the formation of Li^7 in the ground state. Of the factors entering into the uncertainty in this value, 11 kev are due to uncertainties in the constants used in the conversion of observed $H\rho$ into particle energy, and 9 kev are due to experimental errors, most of which arise from an uncertainty in the angle of observation. The origin of these corrections has been discussed in an earlier paper.[5] Using the value 5.006 ± 0.014 the mass difference between Li^7 and Li^6 is calculated to be 1.001213 ± 0.000016, in good agreement with the mass-spectrograph values reported by Bainbridge.[6]

A low energy proton group was found when Li^7 was bombarded by deuterons, and the measurement on the variation of the energy of this group with changes in the incident energy has shown that it arises from the $Li^7(d,p)Li^8$ reaction. The Q-value for the reaction has been determined to be -0.193 ± 0.008 Mev. This is in remarkably good agreement with the value obtained by Rumbaugh, Roberts, and Hafstad who calculated the Q-value to be -0.200 Mev on the basis of a comparison of the observed yield function for radioactive Li^8 with the predictions of the Breit formula. From this value, the Li^8-Li^7 mass difference is calculated to be 1.006797 ± 0.000010.

[1] Rumbaugh, Roberts, and Hafstad, Phys. Rev. **54**, 657 (1938).
[2] Buechner, Strait, Stergiopoulos, and Sperduto, Phys. Rev. **74**, 1569 (1948).
[3] A preliminary account of this portion of the work was presented at the June, 1948, meeting of the American Physical Society, Phys. Rev. **74**, 1257 (1948).
[4] Buechner, Strait, Sperduto, and Malm, Phys. Rev. **76**, 1543 (1949).
[5] W. W. Buechner and E. N. Strait, Phys. Rev. **76**, 1547 (1949).
[6] K. T. Bainbridge, Preliminary Report No. 1, Nuclear Science Series, National Research Council (1948).

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Investigations of the Capture of Protons and Deuterons by Deuterons

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The capture of protons and deuterons by deuterons has been studied up to energies of 1.5 Mev. An upper limit of $\sim 10^{-31}$ cm^2 has been found for the $D(d\gamma)$ reaction near 1 Mev. The gamma-radiation from $D(p\gamma)$ has been found to have an angular distribution obeying a $\sin^2\theta$ law. The cross section of the reaction is given empirically from 0.5 to 1.5 Mev by $\sigma = 0.74E^{0.72} \times 10^{-29}$ cm^2 for E in Mev.

The discovery at Los Alamos[1] of 20 Mev gamma-radiation with an angular asymmetry in yield from the capture of protons by tritons led us to investigate the possibility of the emission of similar radiation in the capture of deuterons by deuterons. The excitation of the He^4 nucleus produced in this capture was expected to be 24 Mev, slightly higher than that expected and observed in the capture of protons by tritons. Because of the large number of neutrons produced in the bombardment of deuterons by deuterons a triple coincidence counter arrangement was employed. Thick targets of heavy ice were bombarded by deuterons from the electrostatic generator at an energy of 1.24 Mev. Observations were made at angles from 0° to 135° with the incident beam.

Copious radiation was observed which produced electron secondaries having ranges in aluminum as measured by the coincidence method corresponding to energies up to 8 Mev. This radiation was considerably enhanced by the introduction of paraffin and various materials such as cadmium between target and counter and could be accounted for completely as radiation caused by the capture of neutrons in materials near the experimental set-up. Above 8 Mev it was possible to set an upper limit of 2×10^{-11} quanta per proton for the yield. On the assumption that the effective target width is about 0.5 Mev, the average cross section of the $D(d\gamma)He^4$ reaction near 1 Mev is calculated to be $< 10^{-31}$ cm^2. This upper limit is considerably less than that observed[2] in the $T(p\gamma)He^4$ reaction which has a cross section of $\sim 3\times 10^{-28}$ cm^2 at 1.24 Mev rising to $\sim 10^{-27}$ cm^2 at 2.6 Mev. An explanation of the low yield in the $D(d\gamma)$ reaction has been given by Professor R. F. Christy in terms of arguments based on the identity of the incident and target deuterons. The odd ^1P state in He^4 apparently responsible for the radiation in the $T(p\gamma)$ reaction cannot be produced by any combination of deuterons and deuterons.

In the course of the above investigation it was decided to investigate also the bombardment of deuterons by protons. Preliminary measurements with the triple coincidence arrangement indicated gamma-ray emission and since no neutrons were observed measurements were continued with the standard double coincidence

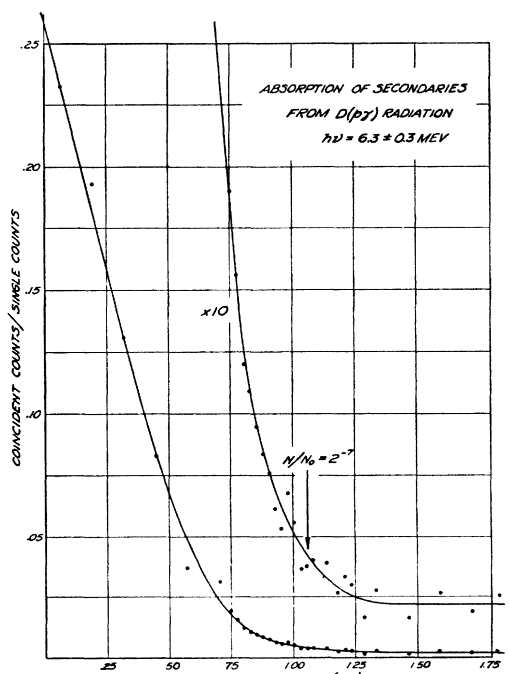

FIG. 1. Coincident counter measurements of the absorption of the secondaries produced in aluminum by the radiation from $D(p\gamma)$. The coincidence counts drop to 2^{-7} at 1.06 ± 0.05 cm of aluminum indicating a gamma-ray energy of 6.3 ± 0.3 Mev.

[1] Argo, Gittings, Hemmendinger, Jarvis, Mayers, and Taschek, Phys. Rev. **76**, 182 (1949). We are grateful to these authors for communicating to us the details of their investigations.

[2] R. F. Taschek, Phys. Rev. **76**, 584 (1949).