the main configuration being possibly $(d_{\frac{3}{2}}^2)_n$. Within the approximation considered (Si^{28} core+two nucleons), the first excited state cannot have a $(s_{\frac{1}{2}}^2)_n$ configuration at all, since it could not give rise to a 2^+ state. This gives a qualitative explanation for the fact that the transition probability of the decay to the first excited state, after correction for the statistical factor, is about ten times smaller than that for the ground-state decay.

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Measurement of the Mass of He^5

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A Q value of 15.15 ± 0.04 Mev for the reaction $Li^6(t,\alpha)He^5$ has been obtained through a measurement of the energy of the alpha particles. The mass of He^5 is then 5.01390 ± 0.00004 amu or $He^5\rightarrow He^4+n+0.97\pm0.04$ Mev. The width of the ground state is 0.7 ± 0.2 Mev.

INTRODUCTION

A NUMBER of determinations of the mass of He^5 have been made by measuring the energies of charged particles from nuclear reactions in which He^5 is one of the products. The reactions used were $He^4(d,p)He^5$, $Li^6(d,He^3)He^5$, $Li^6(n,d)He^5$, $Li^7(d,\alpha)He^5$ and $T(He^3,p)He^5$. References to these measurements are given in Table I. As can be seen there, there is a considerable variation in the values obtained for the instability of He^5 for neutron emission and for the width of its ground state. A further experiment thus seemed justified.

From the point of view of accuracy, the last two of the reactions mentioned above have the advantage that the energy of the bombarding particles can be relatively low, most of the energy of the products coming from the Q of the reaction. This reduces the effects, on the mass derived for He^5, of target thickness, errors in bombarding energy, and errors in the angle at which the reaction products are measured. A further reaction with similar advantages, $Li^6(t,\alpha)He^5$, has been used in the present experiment. The Q value was obtained by measuring the energy of the alpha particles with a large proportional counter. This counter was calibrated with alpha particles from ThC′ and ThC.

METHOD

The tritons were accelerated to 235 kev by a 250-kv accelerator. A thick target was formed by melting Li^6F onto a stainless steel backing. The target was one-eighth inch square and held at an angle of 22.5° to the beam. This surface, in conjunction with a one-quarter inch diameter diaphragm 13 inches away, formed a collimating system for the beam. The target chamber is illustrated in Fig. 1. The angle between the observed alpha particles and the triton beam could be varied by rotating the lid of the target chamber, on which the counter was mounted.

The side-window counter, similar to one described by Allen *et al.*,[1] is five inches in diameter and sixteen inches long. It was filled with an argon-CO_2 mixture to a pressure of 70 cm of Hg. The central wire had a diameter of 0.005 inches and was held at a potential of 1600 volts. With these conditions, the gas multiplication was six. Particles entered the counter through a gold-sputtered mica window, 1.1 mg/cm² thick.

TABLE I. Summary of measurements of the instability of He^5.

Reaction	Q (Mev)	Instability (Mev)	Γ (Mev)	Reference
$Li^6(t,\alpha)He^5$	15.15 ± 0.04	0.97 ± 0.04	0.7 ± 0.2	a
$T(He^3,p)He^5$	11.18 ± 0.07	0.90 ± 0.07		b
		0.95 ± 0.07		c
$He^4(n,n)He^4$		0.95 ± 0.05		d
$He^4(d,p)He^5$	-3.10 ± 0.05	0.87 ± 0.05	≥0.32	e,f
$Li^6(n,d)He^5$	-2.57 ± 0.10	1.09 ± 0.1	1.1	g
$Li^7(d,\alpha)He^5$	14.2 ± 0.1	$0.9\ \pm0.1$	0.3 ± 0.1	h
	14.2 ± 0.1	$0.9\ \pm0.1$		i
	14.3	0.8	0.25	j,k
	13.43	1.7		l
	14.26	0.86 ± 0.09	0.66 ± 0.2	m
$Li^6(d,He^3)He^5$	0.91 ± 0.09	0.88 ± 0.09	0.69 ± 0.2	m

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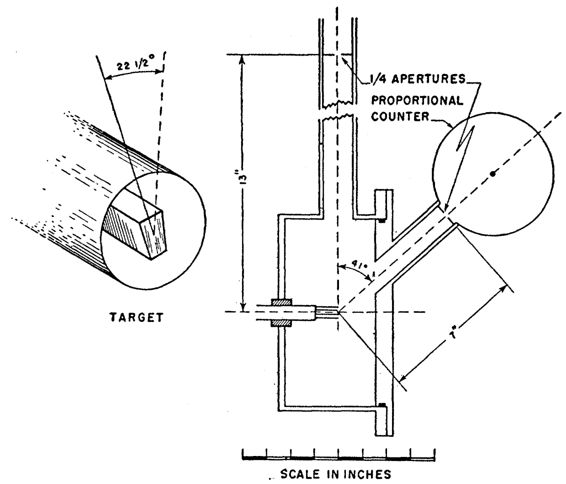

FIG. 1. Target and counter arrangement.

This counter was used to compare the energy of the alpha particles from the reaction with those from ThC′, obtained from a ThB source. The energy of the ThC′ alpha particles is 8.780 Mev.[2] Those from the reaction have the same energy to within a few hundred kev, the exact energy depending on the angle to the beam at which they are observed. ThC alpha particles, which have a mean energy for the two very close upper lines of 6.056 Mev,[2] were used to calibrate the counter for the change in pulse height produced by a known change in particle energy.

The amplified pulses from the counter were displayed on a 30-channel pulse-height analyzer and were compared with pulses of variable known height from a mercury-relay precision-pulse generator.

There were two possibilities open in making a choice of the angle to the beam at which the alpha particles were observed.

(A) At backward angles greater than about 100°, both the spectrum of pulses from the reaction and that from ThC′ could be put onto the pulse-height analyzer simultaneously, and the two peaks separated. This method has the advantage that any shift in the gain of the system has the same effect on both peaks. However, it has the disadvantage that at these backward angles the energy of the alpha particles is quite dependent on the energy of the tritons. An uncertainty in E_B, the beam energy, will then affect the calculated Q. At 124°, the magnitude of this effect is given by $\Delta Q=1.9\Delta E_B$, and at 105°, $\Delta Q=0.7\Delta E_B$ for small changes in E_B. Because of corona from the resistor chain used in measuring the accelerating voltage, the beam energy is uncertain by ±15 kev.

At such backward angles, the reduction in effective bombarding energy, produced by a thick target or by surface contamination, increases the energy of the alpha particles from this reaction. This increase is partly compensated for by the energy losses which the alpha particles suffer in escaping from the target. These two effects are estimated to cancel at about 108°. Since the yield curve of the reaction is not known accurately, there is appreciable uncertainty in these calculations of the effect of target thickness.

(B) At an angle of approximately 97°, the Q-value measurement is insensitive to small changes in E_B, but since the energy of the alpha particles from the reaction is very close to that of the ThC′ alpha particles, the counter will not resolve both groups if they are introduced simultaneously. It is then necessary to take runs with ThC′ alpha particles before and after each reaction run, in order to check the stability of the system. Since no one angle is ideal, measurements were made at several different angles.

Ideally, the ThB source should be at the same position as the target, because the pulse height from the counter depends slightly on the angle of entry of the particles. In practice, the source was placed one centimeter from the target. At this distance, the alpha-particle peak was not displaced appreciably from its position with the source at the target.

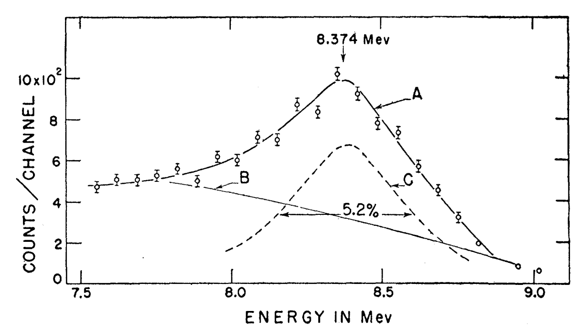

FIG. 2. Upper end of the pulse-height distribution from $Li^6(t,\alpha)He^5$. The data of curve A are the observed data. Curve B gives the estimated background from the $Li^6(t,2\alpha)n$. Curve C is the difference between A and B.

RESULTS

Five measurements were made at angles for which the dependence of the calculated value of Q on E_B is small. Three were at an angle of 89.3±0.5° and two at 94.8±0.4°. (All angles mentioned are in the laboratory system.) The average Q value calculated from these five runs is 15.19±0.05 Mev. Four measurements were made using method (A), two at each of the angles of 124° and 105°. The average Q value calculated from these runs is 15.09±0.07 Mev. The mean value is 15.15±0.04 Mev. As explained above, the runs at 89.3° and 94.8° required the calibration alpha particles to be introduced before and after the run. Any dependence of pulse height on counting rate would then introduce an error. No measurable shift in the height of a peak was detected when the counting rate was doubled, or when the height of the ThC′ alpha-particle

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peak was measured alone or along with the particles from the reaction $Li^7(p,\alpha)He^4$, described below.

The alpha-particle peak is seen in Fig. 2 to be superposed on a continuous background of alpha particles from the reaction $Li^6+T \rightarrow He^4+He^4+n$. A correction of +0.03 Mev has been included in the above Q value to allow for a shift in the peak to a lower energy caused by the shape of the spectrum of alpha particles from the three-body breakup. Although the shape of this spectrum is not known, its possible variation is restricted by requiring that the peak obtained, when it is subtracted from the experimental distribution, shall be symmetrical. A correction to the Q value was made for the energy losses of the tritons and alpha particles in the thick target. The amount of this correction varied from 44 kev at 89.3° to −35 kev at 124°. These values were derived using the measured resolution of the counter and assuming that the variation of the cross section in this region is determined only by the penetrability. A further correction to Q of −6 kev at 90° and −11 kev at 105°−124° was made for the energy losses of the alpha particles in the counter window. The beam energy was taken to be 15 kev higher than that measured, because of corona in the resistor chain. This estimate was based on repeated measurements of the 222-kev resonance[3] in the reaction $Mg^{24}(p,\gamma)Al^{25}$. The uncertainties in the Q-value measurement are listed in Table II. These uncertainties apply to the average Q value.

TABLE II. Uncertainties in the $Li^6(t,\alpha)He^5$ Q-value measurement

Source	Uncertainty in Q kev
1. Measurements of relative pulse heights	±30
2. Angle	±15
3. Correction for continuum from three-body breakup	±20
4. Correction for counter window thickness	± 2
5. Correction for thick target	± 7
6. Target surface contamination (no correction made)	±10
7. Beam energy	± 6
Root mean square of these values is ±0.04 Mev.	

To check possible errors, the Q value of the reaction $Li^7(p,\alpha)He^4$ was measured under similar conditions. This reaction has an accurately known Q value and emits alpha particles with an energy close to that of those from the $Li^6(t,\alpha)He^5$ reaction. Three measurements were made at angles near 90° and four at 124°. The average values obtained were 17.39±0.04 Mev and 17.31±0.06 Mev, respectively. The mean value is 17.35±0.04 Mev. The thick-target correction to the Q-value in this case varied from −10 kev near 124° to 82 kev near 90°. The mean Q value of 17.35 Mev is in agreement with the accepted value of 17.346±0.010 Mev.[4] The four runs at 124° were taken in succession, using the same target. The Q values obtained varied from the mean by ±0.01 Mev. This may be considered as some evidence that there was no appreciable buildup of carbon contamination on the target.

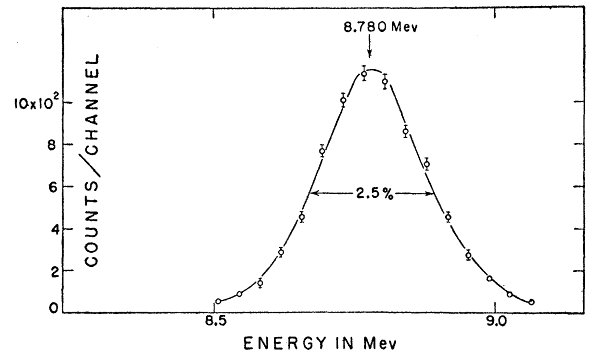

FIG. 3. Pulse-height distribution from ThC′ alpha particles.

Using the above-measured Q value of 15.15 Mev for the $Li^6(t,\alpha)He^5$ reaction and the known Q values[4] of 5.027±0.003 Mev for $Li^6(d,p)Li^7$, 17.346±0.010 Mev for $Li^7(p,\alpha)\alpha$, and 6.251±0.008 Mev for $D(n,\gamma)T$, the He^5 nucleus is calculated to be unstable to disintegration into an alpha particle plus a neutron by 0.97±0.04 Mev. This corresponds to a mass for He^5 of 5.01390±0.00004 amu and a mass defect of 12.94±0.04 Mev. In Table I, this value for the instability of He^5 for neutron emission is given along with values obtained from other reactions.

After subtracting the assumed contribution from the $Li^6(t,2\alpha)n$ reaction, Γ, the full width at half-maximum of the peak of the alpha-particle spectrum from $Li^6(t,\alpha)He^5$, is approximately 5.2 percent. This spectrum is shown in Fig. 2. The width at half-maximum of the peak produced by alpha particles from a thin ThC′ source is approximately 2.5 percent and is illustrated in Fig. 3. The alpha particles from the reaction then have a spread of approximately 375 kev, which corresponds to a Γ of 675 kev for the ground state of He^5. The uncertainty in Γ is estimated to be 200 kev. For the data taken at 94.8°, a spread in the bombarding energy of 40 kev due to the thick target would cause only a 20-kev spread in the energy of the alpha particles, which would affect Γ by 36 kev. For comparison, the various experimental values reported for the width of the state are given in Table I, Column 4.

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