Energy Levels of Light Nuclei
$A = 6$

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Abstract: An evaluation of $A = 5$–24 was published in *Nuclear Physics* 11 (1959), p. 1. This version of $A = 6$ differs from the published version in that we have corrected some errors discovered after the article went to press. Figures and Introductory tables have been omitted from this manuscript. Reference key numbers have been changed to the TUNL/NNDC format.

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Table of Contents for $A = 6$

Below is a list of links for items found within the PDF document. Figures from this evaluation have been scanned in and are available on this website or via the link below.

^{6}He
(Fig. 3)

GENERAL:

Spin of ^{6}He: In a Stern-Gerlach experiment, (1958CO68) find $\mu(^6\mathrm{He}) < 0.16$ nuclear magnetons if J is taken as 1; it is concluded that $J(^6\mathrm{He}) = 0$.

Theory: See (1955BA1J, 1958SK1A).

1. ^{6}He(β^-)^{6}Li — $Q_\mathrm{m} = 3.536$

The β-spectrum is simple, with an end point E_β(max) $= 3.50 \pm 0.05$ (1952WU22), 3.50 ± 0.02 MeV (1956SC40). Recently reported half-lives are 0.852 ± 0.016 sec (1956VE10), 0.83 ± 0.02 sec (1958HE46), 0.85 ± 0.03 sec (1955RU06). The weighted mean of half-lives cited here and in (1950HO80, 1955AJ61) is 0.813 ± 0.007 sec. Using Q_m, $\log ft$ is 2.92.

The electron-neutrino correlation is found to be $W(\theta) = 1 + \alpha(p/W)\cos\theta$, with $\alpha = -(0.39 \pm 0.02)$, in good agreement with the value $\alpha = -\frac{1}{3}$ for pure axial vector interaction (1958HE46, 1959HE1E, 1959PL52). An earlier report by (1955RU06) appears to have been in error: see (1958AL1G, 1958WU60). See also (1955BA1J, 1955LA1D, 1957LE1E; theor.).

2. (a) ^{3}H(t, n)^{5}He — $Q_\mathrm{m} = 10.371$ — $E_\mathrm{b} = 12.272$
(b) ^{3}H(t, α)2n — $Q_\mathrm{m} = 11.328$
(c) ^{3}H(t, α)^{2}n

At $E_\mathrm{t} = 1.9$ MeV, the α-spectrum, observed at $30°$, extends from 1 to 7 MeV, with peaks at $E_\alpha = 2$ and 5 MeV. The same general shape is observed at other angles and for $E_\mathrm{t} = 0.95$ to 2.1 MeV. These peaks are attributed to a two-stage process involving formation and breakup of ^{5}He in the $\mathrm{P}_{3/2}$ and $\mathrm{P}_{1/2}$ states and are superposed on the three-body spectrum, reaction (b). Structure observed near the end point may indicate a correlation between the two neutrons (1958JA06). At $E_\mathrm{t} = 1.48$ MeV, the neutron spectrum shows a continuum from 0 to 12 MeV with a broad peak at 11.3 MeV, corresponding to formation of ^{5}He in the ground state (1957BA10).

The cross section for neutron production rises monotonically from 0.1 to 2.2 MeV (1951AG30, 1957JA37, 1958JA06). At $E_\mathrm{t} = 1.90$ MeV, the total cross section for production of α-particles is 106 ± 5 mb (1958JA06).

3. ^{3}H(t, t)^{3}H — $E_\mathrm{b} = 12.272$

Table 6.1: Energy levels of ^{6}He

E_x in ^{6}He (MeV)	J^π	Γ (MeV)	Decay	Reactions
0	0^+	$\tau_{1/2} = 0.813 \pm 0.007$ sec	β^-	1, 5, 7, 8, 9, 10, 11, 12
1.71 ± 0.01	(2^+)	$\lesssim 0.1$	α, n, (γ)	7, 10, 11
(3.4)		$(\lesssim 0.3)$		11
(6.0 ± 0.9)				11
(9.3 ± 0.7)			α, n	11

Differential scattering cross sections have been measured at $E_t = 1.58$ to 2.01 MeV by (1956HO12). At $E_t = 1.90$ MeV, θ(lab) $= 30°$, $\sigma(\theta) = 286$ mb/sr ($\pm$5%) (1958AL05). A phase-shift analysis shows that the distributions at $E_t = 1.80$ and 2.01 MeV are adequately accounted for by a ^{1}S phase shift corresponding to a hard sphere of radius 2.35×10^{-13} cm. There is no evidence of p-waves or of resonance in this region (1955FR1C).

4. ^{3}H(α, p)^{6}He $\qquad Q_m = -7.540$

Not reported.

5. ^{6}Li(n, p)^{6}He $\qquad Q_m = -2.753$

See ^{7}Li.

6. ^{6}Li(t, ^{3}He)^{6}He $\qquad Q_m = -3.518$

Not reported.

7. ^{7}Li(γ, p)^{6}He $\qquad Q_m = -10.006$

A γ-emitting level at $E_x = 1.6 \pm 0.2$ MeV is reported by (1954TI16). This evidence, based on the colinearity of p and ^{6}He tracks in photoplates, appears to conflict with other indications that this state decays predominantly to ^{4}He+2n (1954AL35: see, however, (1956MA1R, 1956MA50)). See ^{7}Li(t, α)^{6}He.

8. ^{7}Li(n, d)^{6}He $\qquad Q_{\rm m} = -7.779$

See ^{8}Li.

9. ^{7}Li(p, 2p)^{6}He $\qquad Q_{\rm m} = -10.006$

The summed proton spectrum at $E_{\rm p} = 185$ MeV shows two peaks, attributed to formation of ^{6}He$_{\rm g.s.}$ by removal of a p-proton from ^{7}Li and ^{6}He* ≈ 15 MeV, formed by removal of an s-proton (1957TY35, 1958MA1B, 1958TY49).

10. ^{7}Li(d, ^{3}He)^{6}He $\qquad Q_{\rm m} = -4.512$

At $E_{\rm d} = 14.5$ MeV, the ground state and the 1.71-MeV level are observed. The angular distributions analyzed by pick-up theory indicate even parity for both states. Peak differential cross sections are 8.0 mb/sr at $\theta_{\rm c.m.} = 17°$ and 2.0 mb/sr at $\theta_{\rm c.m.} = 16.5°$ for the ground and 1.7-MeV states, respectively (1955LE24); $\theta^2 = 0.055$ and 0.017 (1957FR1B).

11. ^{7}Li(t, α)^{6}He $\qquad Q_{\rm m} = 9.807$

$Q_0 = 9.79 \pm 0.03$ (1954AL35);

$Q_0 = 9.79 \pm 0.14$ (1956MA09).

The energy of the first excited state is 1.71 ± 0.01 MeV, $\Gamma \lesssim$ 100 keV (1954AL35, 1955AL1C). Preliminary results may indicate a state at 3.4 MeV, $\Gamma < 0.3$ MeV (1954AL35, 1955AL1C). (1956MA1R, 1956MA50) report evidence for a state at (6.0 ± 0.9 MeV) and for one or more states at 9.3 ± 0.7 MeV (3.8-MeV tritons from ^{9}Be(d, t)^{8}Be were used). Angular distributions at $E_{\rm t} = 240$ keV are consistent with $J = 0$ and 2 for the ground state and the 1.7-MeV level, respectively (1954AL38: see ^{10}Be). At $E_{\rm t} = 0.84$ MeV, $\theta = 90°$, the cross sections for formation of ^{6}He(0) and ^{6}He*(1.7) are 16 and 26 mb/sr, respectively (1956MA09).

The absence of ^{6}He recoils corresponding to the 1.7-MeV state implies that this state decays predominantly into ^{4}He + 2n (1954AL35). See also (1955CU17, 1956BA1E) and (1952AJ38).

12. ^{9}Be(n, α)^{6}He $\qquad Q_{\rm m} = -0.628$

See ^{10}Be.

^{6}Li

(Fig. 4)

GENERAL:

Theory: See (1954MO1C, 1955AD1A, 1955AU1A, 1955BA1J, 1955IR1A, 1955LA1C, 1955OT1A, 1956FE1A, 1956ME1A, 1956NE1B, 1957FR1B, 1957LE1E, 1957LY1A, 1957SO1A, 1957TA1A, 1958PI1A, 1958SK1A).

1. (a) ^{3}H(^{3}He, d)^{4}He $\quad Q_{\rm m} = 14.319 \quad E_{\rm b} = 15.790$

   (b) ^{3}H(^{3}He, p)^{5}He $\quad Q_{\rm m} = 11.136$

   (c) ^{3}H(^{3}He, p)^{4}He + n $\quad Q_{\rm m} = 12.093$

The relative intensities (43 ± 2, 6 ± 2, 51 ± 2) of reactions (a), (b) and (c), do not vary for $E(^{3}\mathrm{He}) = 225$ to 600 keV. The deuterons are isotropic (c.m.) at $E_{\rm t} = 360$ keV. The total cross section, reported for $E(^{3}\mathrm{He}) = 100$ to 800 keV, varies from 0.5 mb to 0.18 b, without showing resonance behaviour, the main variation being accounted for by the Coulomb barrier effect (1953MO61). See also (1953AL1A) and (1957JA37).

2. ^{3}He(α, p)^{6}Li $\quad Q_{\rm m} = -4.004$

See (1958CH35).

3. ^{4}He(d, γ)^{6}Li $\quad Q_{\rm m} = 1.471$

An upper limit for capture radiation at $E_{\rm d} = 1.055$ MeV (2.18-MeV state) is 0.1 mb (1954SI07). A search for resonant capture radiation at $E_{\rm d} = 3.1$ MeV (^{6}Li* $= 3.56$) yields $\Gamma_{\rm d\alpha} < 0.2$ eV. It is concluded that the intensity of parity non-conserving parts of the wave functions, $F^{2} \lesssim 10^{-7}$ (1958WI15).

4. ^{4}He(d, d)^{4}He $\quad E_{\rm b} = 1.471$

Differential cross sections have been measured for $E_{\rm d} = 0.88$ to 3.51 MeV (1949BL66), $E_{\rm d} = 1.0$ to 1.2 MeV (1953LA28), $E_{\rm d} = 0.28$ to 4.62 MeV (1955GA26), $E_{\rm d} = 6.5$ MeV (1947GU1A), $E_{\rm d} = 7.94$ MeV (1951BU1C), $E_{\rm d} = 10.3$ MeV (1951AL26), $E_{\rm d} = 13.7$ and 19.0 MeV (1954FR22): see (1957JA37).

Table 6.2: Energy levels of ^{6}Li

E_x in ^{6}Li (MeV)	$J^\pi; T$	Γ (keV)	Decay	Reactions
0	$1^+; 0$		stable	4, 6, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22, 23
2.184 ± 0.003	$3^+; 0$	21	α, d	4, 11, 12, 13, 14, 18, 19, 20, 22, 24
3.560 ± 0.006	$0^+; 1$	< 5	γ	12, 18, 20, 22
4.52 ± 0.08	$2^+; 0$	≈ 600	α, d	4, 12, 13, 14, 19, 20
5.35 ± 0.07	; (1)	< 100		20
5.5 ± 0.4	$1^+; 0$	≈ 1000	α, d	4, 20
6.63 ± 0.08	; (1)	< 200		20
7.40 ± 0.10	; (0)	≈ 500	α, d, p, n	13, 19, 20
(8.37 ± 0.08)	; (1)	(< 200)		20
(9.3 ± 0.2)		(≈ 500)		20

At $E_d = 1.07$ MeV, a strong resonance is observed (see Table 6.3) attributed to d-wave formation of a $J = 3^+$ state. The best fit is obtained with the p-wave phase shift set equal to zero. If an interaction radius of $R = 3.5 \times 10^{-13}$ cm is used, the s-wave phase shift requires a contribution from the ground state, whose width is thus determined to be $\theta^2 = 0.51$; for a radius $R = 5.0 \times 10^{-13}$ cm, hard-sphere scattering alone suffices (1955GA74).

The anomaly in the region 3.5 to 4.5 MeV requires two levels, $J = 1^+$ and 2^+ (see Table 6.3) formed by d-waves. Again the p-wave phase shift differs from the hard sphere value, suggesting an odd parity state at higher energy. There is no indication of the 3.56-MeV ^{6}Li level, consistent with its assumed $J = 0^+$, $T = 1$ character. The three states found here are presumed to be the components of a ^{3}D term; their spacings indicate a coupling rather close to the L-S limit (1955GA74: see (1953IN1A)).

5. (a) ^{4}He(d, p)^{5}He $\qquad Q_m = -3.184 \qquad E_b = 1.471$
   (b) ^{4}He(d, n)^{5}Li $\qquad Q_m = -4.023$
   (c) ^{4}He(d, pn)^{4}He $\qquad Q_m = -2.226$

Ground-state protons from reaction (a) and ground-state neutrons from (b) have been studied by (1957WA01: $E_d = 14.8$ MeV) and by (1956BO1F, 1956BO43: $E_d = 13.5$ MeV), respectively; see ^{5}He, ^{5}Li. The cross section for (a) is 25 ± 5 mb/sr at $\theta = 18°$ (c.m.) and 15 ± 5 mb/sr at $24°$ (c.m.) (1957WA01).

Table 6.3: Levels of ^{6}Li from ^{4}He(d, d)^{4}He (1955GA74) [a]

E_{res} (MeV)	Γ (keV)	E_x (MeV)	l_d	J^π	E_λ [b] (MeV)	θ^2_d
		0	0	1^+	-2.26	0.51
1.070 ± 0.003	35 ± 5	2.183	2	3^+	2.333	0.80
4.57 ± 0.08	900	4.52	2	2^+	7.05	1.0
$5.1 - 6.5$	1000	$4.9 - 5.8$	2	1^+	$5.5 - 9.7$	$0.2 - 1.0$

[a] Interaction radius $= 3.5 \times 10^{-13}$ cm.
[b] Measured from ^{6}Li ground state.

Cross sections for production of low-energy neutrons have been measured in the range $E_d = 3$ to 6 MeV by (1955HE90). It is argued that reaction (c) probably involves production of the ^{1}S state of the deuteron and hence is isobaric spin forbidden in the present case: the low energy neutrons are therefore attributed to reaction (a) (1955HE90). See also (1951AL26, 1951BU1C, 1957JA37).

6. ^{6}He(β^-)^{6}Li $\qquad Q_m = 3.536$

See ^{6}He.

7. ^{6}Li(γ, n)^{5}Li $\qquad Q_m = -5.494$

The cross section is 0.3 ± 0.2 mb at $E_\gamma = 6.2$ MeV (1956ED15) and 0.5 ± 0.2 mb for $E_\gamma = 14.8$ to 17.6 MeV (1951TI06). See also (1957BA1H, 1957FO1A, 1958BE1C, 1958PR66, 1958RY77).

8. ^{6}Li(γ, p)^{5}He $\qquad Q_m = -4.655$

This reaction has been observed with photoplates for E_γ(max) $= 30$ to 80 MeV. The angular distribution is of the form $a + b \sin^2\theta(1 + \cos\theta)^2$ (1956KL19). For 17.5-MeV bremsstrahlung, no n-p correlation is observed; this result argues against a (^{4}He + d) model for ^{6}Li (1958PR66). See also (1955TI1A, 1958RY77).

9. ^{6}Li(γ, d)^{4}He $\qquad Q_m = -1.471$

The cross section is $\lesssim 5$ μb in the range $E_\gamma = 2.6$ to 17 MeV (1952GL1A, 1952TI1A, 1953JE1A, 1954TI25, 1955TI1A). Electric dipole absorption is forbidden by isobaric spin selection rules (1953GE1B); the relative weakness of both electric and magnetic interaction may be made plausible on a simple (^{4}He + d) model for ^{6}Li (1953JE1A: see also (1954VA1A, 1955DA1A, 1955DA1C, 1958PR66)).

10. ^{6}Li(γ, t)^{3}He $\qquad Q_\mathrm{m} = -15.790$

The cross section is < 10 μb at $E_\gamma = 17.6$ MeV (1954TI25).

11. (a) ^{6}Li(e, e$'$)^{6}Li
(b) ^{6}Li(e, p)^{5}He $\qquad Q_\mathrm{m} = -4.655$
(c) ^{6}Li(e, d)^{4}He $\qquad Q_\mathrm{m} = -1.471$

Elastic scattering of 187-MeV electrons yields an r.m.s. radius of 2.78×10^{-13} cm $\pm$2%: for the uniform model, $R_0 = 1.98 \times 10^{-13}$ cm (1955ST85, 1956HO93). At $E_\mathrm{e} = 426$ MeV, the data are fitted by an r.m.s. radius of $(2.2 \pm 0.2) \times 10^{-13}$ cm. Inelastic scattering has been observed to the 2.18-MeV state and to higher states (1957HO1D, 1957HO1E). See also (1957EH1A, 1957ME1B).

Reactions (b) and (c) have been observed and angular distributions measured at $E_\mathrm{e} = 500$ MeV (1957KE1A).

12. ^{6}Li(p, p$'$)^{6}Li*

At $E_\mathrm{p} = 7.0$ to 7.5 MeV, and three angles, proton groups are observed corresponding to the ground state, to a state at 2.188 MeV ($\Gamma_\mathrm{c.m.} = 25$ keV) and to a state at 3.559 MeV ($\Gamma < 5$ keV): (see Table 6.4). No other sharp levels ($\Gamma < 100$ keV) are seen below $E_\mathrm{x} = 5$ MeV: the intensity limit of groups corresponding to such states is 3% of the intensity of the group corresponding to the 2.18-MeV state. A group of ≈ 1 MeV breadth would have escaped detection unless its intensity were ≈ 3 times that of the 2.18-MeV state group (1957BR12). At $E_\mathrm{p} = 14.8$ and 19.0 MeV, the angular distributions of the protons to the 2.18-MeV state peak at $\approx 40°$. The protons from the 3.56-MeV state appear weakly, if at all, on the side of the broad group from the 4.5-MeV level ($\Gamma \approx 1.8$ MeV) (1956SH1B). For a theoretical discussion of the data see (1957LE1E). See also (1952AJ38, 1952FR1B, 1958CH26).

13. ^{6}Li(d, d$'$)^{6}Li*

Table 6.4: Levels of ^{6}Li from ^{6}Li(p, p$'$)^{6}Li, ^{6}Li(d, d$'$)^{6}Li, ^{7}Li(d, t)^{6}Li and ^{9}Be(p, α)^{6}Li (1957BR12)

Reaction	$E_{\rm x}$ (MeV)	$\Gamma_{\rm c.m.}$ (keV)
^{6}Li(p, p$'$)^{6}Li	2.188	25.4
^{6}Li(p, p$'$)^{6}Li	3.559	< 5
^{6}Li(d, d$'$)^{6}Li	2.186	24.5
^{7}Li(d, t)^{6}Li	(2.18)	< 27
^{9}Be(p, α)^{6}Li	2.192	29
^{9}Be(p, α)^{6}Li	3.561	
Mean:	2.188 ± 0.006	24
	3.560 ± 0.006	< 5

At $E_{\rm d} = 7.0$ and 7.5 MeV ($\theta = 60°$ and $90°$), deuteron groups are observed corresponding to the ground state and to a level at 2.186 MeV ($\Gamma_{\rm c.m.} = 24$ keV: see Table 6.4). At $E_{\rm d} = 7.5$ MeV, $\theta = 60°$, an upper limit of 0.9% of the intensity of the 2.18-MeV group is given for a group corresponding to the 3.56-MeV state. The fact that the 2.18-MeV state was observed in this experiment but that the 3.56-MeV state was not is consistent with the assignments $T = 0$ and $T = 1$, respectively, for these states. No other sharp groups with $E_{\rm x} < 5$ MeV were observed: their intensity limits are 1% of the intensity of the 2.18-MeV state. A 1-MeV broad group would have escaped detection unless its intensity were > 2 times that of the 2.18-MeV state group (1957BR12). At $E_{\rm d} = 15$ MeV, the angular distribution of the deuterons to the 2.18-MeV state has been measured by (1956HA90). Comparison is made with predictions based on nuclear and electric interactions (1956HA90).

Excitation of ^{6}Li states at 2.2, ≈ 4.5, and $76. \pm 0.3$ MeV is observed in deuteron bombardment, $E_{\rm d}$(max) $= 13.8$ MeV, of Li-loaded emulsions. Observed stars are reported to correspond to d $+\, \alpha$ decay of the first two states and decay into $\alpha +$ p $+$ n of the last (1956SO21). At $E_{\rm d} = 17.5 \pm 0.25$ MeV, these three states and two additional states at 5.9 and 8.3 MeV are reported (1956SO33).

14. ^{6}Li(α, α')^{6}Li

Angular distributions of elastic and inelastic scattering have been studied at $E_{\alpha} = 31.5$ MeV by (1956WA29). Inelastic groups corresponding to the 2.18 and 4.52-MeV levels are observed; the isobaric spin-forbidden group corresponding to the 3.56-MeV level is $< 4\%$ as intense. The angular distributions of the inelastic groups are well described by the direct interaction theory of (1953AU1A) with $R = 6.6$ and 5.8×10^{-13} cm, respectively (1956WA29).

15. ^{6}Li(p, ^{3}He)^{4}He $\qquad Q_{\rm m} = 4.022$

Angular distributions observed at $E_{\rm p} = 15$ and 18.5 MeV indicate a deuteron pickup process. An analysis based on Born approximation theory leads to deuteron reduced widths for the ground state of ^{6}Li of $\theta^2_{\rm d} = 0.30$ and 0.45 (1956LI37). See also ^{7}Be.

16. (a) ^{6}Li(n, t)^{4}He $\qquad Q_{\rm m} = 4.787$

(b) ^{6}Li(n, d)^{5}He $\qquad Q_{\rm m} = -2.428$

Angular distributions at $E_{\rm n} = 1.5$ and 2.0 MeV reported by (1954WE11) and $E_{\rm n} = 14$ MeV by (1954FR03) are analyzed by (1955DA1A, 1955DA1B, 1955DA1C, 1955SA1C) in terms of pickup theory in Born approximation, using a (^{4}He + d), two-body model for ^{6}Li. (1956LI37) calculate $\theta^2 = 0.5$ from the data of (1954FR03) on reaction (a). See also ^{7}Li.

17. ^{7}Li(γ, n)^{6}Li $\qquad Q_{\rm m} = -7.252$

See ^{7}Li and (1955TI1A, 1958TI1A).

18. ^{7}Li(p, d)^{6}Li $\qquad Q_{\rm m} = -5.026$

At $E_{\rm p} = 17.5$ MeV, angular distributions of the deuterons to the ground state and the 2.18-MeV level, analyzed by pickup theory, indicate $l_{\rm n} = 1$ and hence even parity, $J \leq 3$ for both states. The absolute differential cross section (at $\approx 20°$ (c.m.)) for the formation of the ground state is 17 ± 4 mb/sr, in good agreement with the value computed from the observed cross section for the inverse reaction. The cross section for the formation of the excited state is about half that for the ground state. The derived reduced widths (^{7}Li) are $\theta^2_{\rm n} = 0.05$ and $\theta^2_{\rm n} = 0.035$ for ^{6}Li(0) and ^{6}Li*(2.2), respectively. The ratio is in good agreement with that calculated from shell theory in intermediate coupling with $1.4 \leq a/K \leq 2.1$, near the L-S limit (1956RE04). See also (1957SI36). At $E_{\rm p} = 18$ and 31.8 MeV, a deuteron group has also been observed leading to the 3.56-MeV state (1952FR1B, 1957SI36). See also (1955HI1A, 1957MA04, 1958EL1A).

19. ^{7}Li(d, t)^{6}Li $\qquad Q_{\rm m} = -0.994$

Table 6.5: States in ^{6}Li from ^{7}Li(^{3}He, α)^{6}Li (1955AL1C)

E_x in ^{6}Li (MeV)	Γ (keV)	T
0		
2.19	< 100	
3.56 ± 0.06	< 100	
4.3 ± 0.2		
5.35 ± 0.07	< 100	$(T = 1)$
(5.6 ± 0.2)	(≈ 2000)	$(T = 0)$
6.63 ± 0.08	< 200	$(T = 1)$
7.40 ± 0.10	≈ 600	$(T = 0)$
(8.37 ± 0.08)	(< 200)	$(T = 1)$
(9.3 ± 0.2)	(≈ 600)	

At $E_d = 14.5$ MeV, the angular distributions of the tritons analyzed by pickup theory, indicate $l_n = 1$, and hence even parity, for the ground state and the 2.18-MeV state. Peak cross sections are 32.4 and 16.0 mb/sr at $\theta_{c.m.} = 11°$ and $16°$, respectively (1955LE24). The corresponding reduced widths are $\theta^2 = 0.11$ and 0.061 (1957FR1B: compare ^{7}Li(p, d)^{6}Li). See also (1953HO48, 1956HA90, 1957BR12, 1958EL1A). At E_d(max) $= 13.8$ MeV, stars are observed in Li-loaded emulsions corresponding to excitation of ^{6}Li states at 2.2, ≈ 4.5 and 7.5 MeV with subsequent disintegrations into (α + d) (1956SO21). At $E_d = 17.5$ MeV, the decay of additional states at 5.2, 5.9, 6.7, 8.3, 9.5 and 10.1 MeV is also reported (1956SO33). A search in the region $E_x = 4.4$ to 8.5 MeV has revealed only the 5.4-MeV level; no other level appears with $\Gamma < 80$ keV (1958HA10, 1958HA1G).

20. ^{7}Li(^{3}He, α)^{6}Li $\qquad Q_m = 13.325$

Alpha-particle groups observed at $E(^3\text{He}) = 700$ to 900 keV are listed in Table 6.5. ^{6}Li-recoils corresponding to the 3.56-MeV state are observed, indicating that the state decays by γ-emission. The states at 2.2, 4.3 and (5.6) MeV are presumably those observed in ^{4}He(d, d)^{4}He. The small width of the 5.35 and (8.37)-MeV states suggests that they have $T = 1$ (1955AL1C).

21. ^{9}Be(γ, t)^{6}Li $\qquad Q_m = -17.687$

See (1955AJ61).

22. ^{9}Be(p, α)^{6}Li $\qquad Q_{\mathrm{m}} = 2.125$

At $E_{\mathrm{p}} = 7.2$ to 7.5 MeV ($\theta = 30°$ and $60°$), alpha-particle groups are observed to the ground state and to levels at 2.188 ($\Gamma_{\mathrm{c.m.}} = 24$ keV) and 3.560-MeV (see Table 6.4). No other sharp levels with $E_{\mathrm{x}} < 5$ MeV are seen with an intensity greater than 5% of the intensity of the groups to the 2.18 and 3.56-MeV states (1957BR12). The 3.56-MeV state is observed to decay by γ-radiation: $E_\gamma = 3.572 \pm 0.012$ MeV. The internal pair spectrum is consistent with an M1 transition (1954MA26). Both the γ-ray angular distribution and the (α-γ) correlation are isotropic at $E_{\mathrm{p}} = 2.56$ MeV, consistent with $J = 0$ for ^{6}Li*(3.56) (1956ST93). Determination of the Doppler shift establishes that the lifetime is $< 3 \times 10^{-14}$ sec (1957RO1B), $< 3.3 \times 10^{-14}$ sec (1957LE1D: see (1958WA1C)), consistent with M1 radiation but not with E2. The fact that the ground-state and 2.18-MeV state α-particles do not show resonance at $E_{\mathrm{p}} = 2.56$ MeV is consistent with the assumption that the first two levels have $T = 0$: see ^{10}B (1954MA1C). See also (1956RA32).

23. ^{10}B(γ, α)^{6}Li $\qquad Q_{\mathrm{m}} = -4.459$

See ^{10}B.

24. ^{10}B(n, dn$'$2α) $\qquad Q_{\mathrm{m}} = -5.930$

At $E_{\mathrm{n}} = 12.2$ to 19.5 MeV, this reaction proceeds partly through the 2.18-MeV state of ^{6}Li (1956FR18).

^{6}Be

(Not illustrated)

Mass of ^{6}Be: From the Q-value of the ^{6}Li(p, n)^{6}Be reaction (1957BO1F), and using the Wapstra masses (1955WA1A) for ^{6}Li, ^{1}H and n, the mass excess $(M - A)$ of ^{6}Be is 20.3 ± 0.2 MeV (see also (1955AJ61)).

1. (a) ^{3}He(^{3}He, 2p)^{4}He $\qquad Q_{\mathrm{m}} = 12.858 \qquad E_{\mathrm{b}} = 10.4$
   (b) ^{3}He(^{3}He, p)^{5}Li $\qquad Q_{\mathrm{m}} = 11.062$

The total cross section shows a monotonic increase for $E(^3\mathrm{He}) = 100$ to 800 keV. At $E(^3\mathrm{He}) = 200$ keV, it is at least 2.5 μb. Below $E(^3\mathrm{He}) = 350$ keV, the cross section fits the simple Gamow exponential form. At higher energies, partial waves of $l \geq 2$ appear to be required (1954GO18). See also (1953AL1A).

2. (a) ^{3}He(α, n)^{6}Be $Q_{\rm m} = -9.2$

(b) ^{4}He(^{3}He, n)^{6}Be $Q_{\rm m} = -9.2$

Not observed.

3. ^{6}Li(p, n)^{6}Be $Q_{\rm m} = -5.2$

At $E_{\rm p} = 9$ MeV, a neutron group is observed with $Q = -5.2 \pm 0.2$ MeV; the reported ground-state width is < 300 keV (1957BO1F).

4. ^{6}Li(^{3}He, t)^{6}Be $Q_{\rm m} = -4.5$

Not observed.

References

(Closed December 01, 1958)

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