Energy Levels of Light Nuclei
$A = 7$

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Abstract: An evaluation of $A = 5$–10 was published in *Nuclear Physics* 78 (1966), p. 1. This version of $A = 7$ 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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^{7}He

(Not illustrated)

From the known location of the ^{7}Li $T = \frac{3}{2}$ state, the mass excess of ^{7}He is calculated as 26.03 ± 0.15 MeV (calculation of the Coulomb energy difference based on the pair ^{6}He-^{6}Li* ($T = 1$)); ^{7}He is then unstable with respect to decay into ^{6}He + n by 0.36 MeV (1965DE08). See also (1953PE1A, 1960BA51, 1960GO1B, 1961YA04, 1962EL1E, 1963NE02). Some reactions leading to ^{7}He are ^{7}Li(n, p)^{7}He, ^{7}Li(t, ^{3}He)^{7}He and ^{9}Be(n, ^{3}He)^{7}He.

^{7}Li

(Figs. 8 and 10)

GENERAL: See (1957HU1C, 1959BA1M, 1959BA1D, 1959BR1E, 1959FE1B, 1959MA1F, 1959MA1G, 1960KU1B, 1960PE11, 1960PH1A, 1960SH1A, 1960TA1C, 1961BA1D, 1961BA1E, 1961BL1C, 1961CL10, 1961KH03, 1961TA05, 1961TO04, 1962CL1F, 1962CR09, 1962IN02, 1963CH08, 1963CL1B, 1963KL1A, 1963SC30, 1964BE1N, 1964GR1J, 1964MA1G, 1964NE1E, 1964OL1A, 1964SA1F, 1965BE1R, 1965FA1B, 1965JA1L, 1965NE1C, 1965PR1F).

Ground state :

$Q = -45 \pm 5$ mb (1961KA29, 1963VA19, 1964WH01);
$\mu = +3.2564$ nm (1965FU1G).

1. ^{4}He(t, γ)^{7}Li $\qquad Q_{\rm m} = 2.467$

Excitation functions and angular distributions have been studied in the range $E_\alpha = 0.5$ to 1.9 MeV by (1961GR27), $E_\alpha = 0.5$ to 1.3 MeV by (1959HO03). The cross section rises smoothly, as expected for a direct capture process; at $E_\alpha = 1.32$ MeV, $\sigma = 3.58 \pm 0.06$ μb, and the corresponding reduced cross section factor $S = 0.064 \pm 0.016$ keV · b (1961GR27) in good agreement with the value 0.05 calculated by (1961CH1C). Cross sections of (1961GR27) are 2 to 2.5 times higher than those of (1959HO03).

The branching ratio of γ_0/γ_1 (to ^{7}Li(0) and ^{7}Li*(0.48)) is $1/(0.4 \pm 0.05)$, essentially independent of energy and angle. At $E_\alpha = 0.56$ MeV, the angular distribution of γ's is isotropic (±6%), while some preference for forward emission appears at $E_\alpha = 1.6$ MeV. Assuming $\theta^2_\alpha = 1.25$ and 1.05 for the ground and 0.48 MeV states of ^{7}Li, and taking into account only E1 capture from s- and d-waves, (1963TO06) have calculated the total cross section from 0 to 7 MeV and the γ-ray intensity ratios: the calculations are in excellent agreement with the data of (1961GR27). See also (1961TO04).

Table 7.1: Energy levels of ^{7}Li

E_x (MeV ± keV)	$J^\pi; T$	Γ (keV)	Decay	Reactions
g.s.	$\frac{3}{2}^-; \frac{1}{2}$		stable	1, 3, 4, 9, 10, 22, 26, 28, 29
0.4779 ± 0.3	$\frac{1}{2}^-; \frac{1}{2}$	6.2 ± 0.3 meV	γ	1, 3, 4, 9, 10, 13, 15, 17, 20, 21, 22, 26, 27, 28, 29
4.629 ± 8	$\leq \frac{7}{2}^-; \frac{1}{2}$	93 ± 8	α, t	9, 15, 16, 17, 20, 21, 26, 28
(6.56 ± 120)	$(\frac{5}{2}^-); \frac{1}{2}$	≈ 1000		15, 16, 17
7.475 ± 4	$\frac{5}{2}^-; \frac{1}{2}$	89 ± 7	n, α, t	5, 8, 9, 14, 15, 16, 17, 20, 26, 28
(9.7)			γ, n, t	14, 16, 17
11.13 ± 0.05	$(\frac{3}{2}^-; \frac{3}{2})$	268 ± 30	γ, n, t	14, 15, 26
(12.5)			γ, n, p	14, 15
(14)			γ, n, p, t	14, 15
(15.5) [a]			γ, n, p	14
(16.8) [a]			γ, n	14
(17.3)			γ, n	14
(19.6) [a]			γ, t	14

[a] Giant resonance.

2. ^{4}He(t, t)^{4}He $E_b = 2.467$

Angular distributions have been measured for $E_t = 1.2$ to 2.2 MeV (1956HE16), 1.7 MeV (1958AL05), $E_\alpha = 11$ to 28 MeV (1960BR1J). See also (1961TO04).

3. ^{4}He(α, p)^{7}Li $Q_m = -17.347$

At $E_\alpha = 38.5$ MeV, two groups of protons are observed leading to the ground and 0.48 MeV states of ^{7}Li (1958BU38).

4. ^{6}Li(n, γ)^{7}Li $Q_m = 7.253$

Two γ-rays with $E_\gamma = 7.26 \pm 0.03$ and 6.78 ± 0.05 MeV, and relative intensities 10 and 7.5 ± 2.0, corresponding to transitions to the first two states of ^{7}Li are observed (1957BA18). The total radiative capture cross section is 45 ± 10 mb (1964ST25). See also (1961JA19, 1961TO04).

5. ^{6}Li(n, n)^{6}Li $E_b = 7.253$

The total cross section has been measured for $E_n = 4$ eV to 29 MeV (1958HU18, 1960HU08, 1960PE25, 1963BA50, 1964AR25, 1964ST25). A pronounced resonance occurs at $E_n = 262$ keV with a peak cross section of 11.2 b (1960HU08). The elastic contribution is 7.2 b (1961LA1A). No other clearly defined resonance is observed, although the cross section exhibits a broad maximum at $E_n \approx 5$ MeV (1954JO17, 1960HU08). The coherent scattering length (thermal, bound) is 1.8 fm (1964ST25).

Angular distributions are tabulated by (1963GO1M): see also (1961LA1A, 1962BA1W, 1963BA50). All observations near the 0.262 MeV resonance are consistent with p-wave formation of a $J^\pi = \frac{5}{2}^-$ level (^{7}Li*(7.48)). Table 7.2 gives the resonance parameters compared with those for ^{7}Be*(7.18). These states are believed to have a $^4P_{5/2}$ character, in agreement with their large θ_n^2 and θ_p^2 (see ^{7}Be and (1956ME1A, 1957MA57)).

The scattering of polarized neutrons on ^{6}Li has been studied for $E_n = 0.19$ to 0.42 MeV (1961DA04), 0.14 to 0.66 MeV (1962EL01), and 0.2 to 2.0 MeV (1964LA19). The data agree reasonably well with polarizations calculated from the resonance parameters of Table 7.2 with a background of s-wave potential scattering in which channel spin $J_c = \frac{1}{2}$ dominates (1961DA04, 1962EL01, 1964LA19).

See also (1960KO1C, 1960LA1C, 1962MA1R, 1963AL1J, 1964PE1E).

6. (a) ^{6}Li(n, p)^{6}He $Q_m = -2.727$ $E_b = 7.253$
(b) ^{6}Li(n, d)^{5}He $Q_m = -2.430$

The cross section for reaction (a) at $E_n = 14$ MeV is 6.7 mb (1953BA04, 1954FR03). See also (1963BA56).

For reaction (b) see reaction 8 and (1954FR03, 1956RI34).

7. ^{6}Li(n, 2n)^{5}Li $Q_m = -5.662$

The cross section is 33 ± 15 mb at $E_n = 10.2$ MeV, 70 ± 6 mb at $E_n = 14.1$ MeV (1963AS01).

8. ^{6}Li(n, α)^{3}H $Q_m = 4.785$ $E_b = 7.253$

Table 7.2: Resonance parameters for $7.2 - 7.5$ MeV levels in ^{7}Li and ^{7}Be

Reaction	$^6\mathrm{Li} + \mathrm{n}$	$^6\mathrm{Li} + \mathrm{p}$
References	[a]	[b]
E_r (keV, lab)	262	1840
$\Gamma(E_\gamma)$ (keV, c.m.)	154	836
E_λ (keV above g.s.)	7700	7580
$\Gamma_{\mathrm{n,\ p}}(E_\mathrm{r})$ (keV, c.m.)	118	798
radius (n, p) in fm	3.94	4.08
$\gamma^2_{\mathrm{n,\ p}}$ (MeV · fm)	4.85	5.02
$\theta^2_{\mathrm{n,\ p}}$	0.26	0.28
$\Gamma_\alpha(E_\mathrm{r})$ (keV, c.m.)	36	38
radius (α) in fm	4.39	4.39
γ^2_α (MeV · fm)	0.101	0.101
θ^2_α	0.012	0.012

[a] (1959GA08: see (1963MC09)).
[b] (1963MC09).

Excitation functions and angular distributions are summarized in (1958HU18, 1960HU08, 1963GO1M, 1964ST25). Recent measurements are reported for $E_\mathrm{n} < 30$ keV (1961BE24) and for $E_\mathrm{n} = 0.19$ MeV (1963BA2A), 1 to 600 keV (1965SC07), 0.1 to 0.3 MeV (1959PA02), 9 to 340 keV (1959BA46), 1.2 to 8 MeV (1959MU25), 2.0 to 2.65 MeV (1959PU75), 8 to 14 MeV (1963MA61), 14.4 MeV (1964VA19). See also (1960PE24, 1961BE24, 1962BE1P, 1962CA1F, 1963AL1J, 1963CH20, 1963WA1K).

The isotropic thermal cross section is 949 b: in the eV-keV range, the cross section falls off somewhat more slowly than $1/v$ (1958HU18); for $E_\mathrm{n} = 9$ to 90 keV, $\sigma = 3.96E^{-0.367}$ b (E in keV) (1959BA46). The failure to follow the $1/v$ law may reflect a broad s-wave resonance (1959BA46, 1959GA08, 1960LA1C, 1961BE24). Results of (1965SC07) are consistent with strict $1/v$ dependence for $E_\mathrm{n} < 20$ keV. (1956MA83) have analyzed cross section data for $E_\mathrm{n} = 20$ to 565 keV and find no need for an s-wave resonance. The s-wave background contribution is mainly (75%) in the $J_\mathrm{c} = \frac{1}{2}^+$ channel.

A resonance occurs at $E_\mathrm{n} = 258$ keV, with $\sigma_\mathrm{max} = 2.75$ b (1959BA46), 2.80 ± 0.22 b (1959GA08): see also (1965MA1Y). The resonance is formed by p-waves, $J^\pi = \frac{5}{2}^-$, and has a large neutron width and a small α-width (Table 7.2) (1959GA08). Above the resonance the cross section decreases monotonically to $E_\mathrm{n} = 18$ MeV, except for a slight bump near $E_\mathrm{n} = 1.6$ to 2.1 MeV (1959GA08, 1959MU25). A careful search in the range $E_\mathrm{n} = 2.0$ to 2.65 MeV

Table 7.3: ^{7}Li levels from ^{6}Li(d, p)^{7}Li

E_x [a] (MeV $\pm$ keV)	$\Gamma_{c.m.}$ (keV)	θ_n^2 [b]
g.s.		0.048
0.477 ± 2 [c]		0.063
4.630 ± 9	93 ± 8 [e]	(isotropic)
(6.54 ± 20) [d]		
7.464 ± 10	91 ± 8 [e]	0.040

[a] (1952GE07, 1955KH35, 1957BR97, 1961JA23) and C.P. Browne, private communication.
[b] (1960MA32): data of (1955LE24, 1960HA14); PWBA. See also (1962RO23, 1963ME09).
[c] See (1955AJ61).
[d] (1955KH35; see, however, (1960HA14)).
[e] (1957BR97).

($E_x = 9$ to 9.55 MeV) revealed no evidence for a level reported in ^{6}Li(γ, n) (1959PU75). See also (1964GI1F).

In the range $E_n = 8$ to 14 MeV, the reaction ^{6}Li(n, dn)^{4}He shows a large cross section, reaching 0.6 b at $E_n \approx 6$ MeV (1962RO12).

9. ^{6}Li(d, p)^{7}Li $\qquad Q_m = 5.028$

Proton spectra and angular distributions have been studied at $E_d = 1.5$ MeV (1964RI1E), 1.6 MeV (1960AN02), 3.4 to 5.2 MeV (1963ME09), 7 to 7.5 MeV (1957BR97), 8.0 MeV (1953HO48), 14 to 15 MeV (1955LE24, 1959HA29, 1960HA14). Groups corresponding to the ground state and to the states at 0.48, 4.6 and 7.5 MeV have been identified: see Table 7.3. The first two and the last show stripping patterns with $l_n = 1$, while the angular distribution of p_2 ($E_x = 4.6$ MeV) is isotropic. It is noted that stripping to this level is forbidden if it has the character ^{22}F. Ratio of observed θ_n^2 are consistent with assignments ^{22}P to the g.s. and 0.48 and ^{24}P to the 7.5 MeV state (1960HA14, 1960MA32).

The angular correlation between the protons and the 0.48 MeV γ-rays is isotropic (see (1955AJ61)) indicating $J = \frac{1}{2}$ for ^{7}Li*. The mean lifetime is reported to be $(7.7 \pm 0.8) \times 10^{-2}$ psec (1956BU83: see also ^{9}Be(d, α)^{7}Li) see Table 7.4. See also (1959BO1C, 1959HE1C, 1960NE1C, 1961HA1F, 1963BI27). The polarization of p_0 and p_1 protons has been observed at $E_d = 1.6$ MeV by (1961VA03). The circular polarization of the 0.48 MeV γ-rays has been studied by (1964SC1J). See also (1964PA16, 1965HE1B).

10. ^{6}Li(t, d)^{7}Li $\qquad Q_{\rm m} = 0.995$

The reaction has been observed to the ground and 0.48 MeV states at $E_{\rm t} = 0.24$ MeV (1954AL35) and 1.5 and 1.9 MeV (1961HO21). See also (1955CU17, 1961HO1F, 1963BA2B).

11. ^{6}Li(α, ^{3}He)^{7}Li $\qquad Q_{\rm m} = -13.325$

Not reported.

12. (a) ^{6}Li(^{6}Li, p^{4}He)^{7}Li $\qquad Q_{\rm m} = 3.556$

(b) ^{6}Li(^{9}Be, ^{8}Be)^{7}Li $\qquad Q_{\rm m} = 5.587$

^{9}Be(^{6}Li, ^{8}Be)^{7}Li

See (1960MA1H, 1961LE1K, 1962BE16, 1962MC12, 1963BA1Q, 1963CO35, 1963NO02, 1965SA1L), ^{12}C and ^{15}N.

13. ^{7}Li(γ, γ)^{7}Li

Resonance scattering and absorption by ^{7}Li*(0.48) has been studied by a number of observers: the derived mean lifetimes are listed in Table 7.4. See also (1960VA1G).

14. (a) ^{7}Li(γ, n)^{6}Li $\qquad Q_{\rm m} = -7.253$

(b) ^{7}Li(γ, p)^{6}He $\qquad Q_{\rm m} = -9.980$

(c) ^{7}Li(γ, d)^{5}He $\qquad Q_{\rm m} = -9.683$

(d) ^{7}Li(γ, t)^{4}He $\qquad Q_{\rm m} = -2.467$

Reports on the structure of the (γ, n) cross section differ widely. According to (1954GO1A, 1958RY77: E(brems.) $= 24$ MeV), a broad maximum appears at $E_{\gamma} = 16.8$ MeV, with $\sigma_{\rm max} = 2.3$ mb and a width $\Gamma = 9.3$ MeV. Fine structure corresponding to levels at $E_{\rm x} = 9.66 \pm 0.04$, 10.8, 12.4, 14.0 and 17.5 MeV is also reported (1954GO39, 1958RY77). Up to E(brems.) $= 19$ MeV, the work of (1964AL08) confirms the gross structure of (1958RY77): additional levels at $E_{\rm x} = 13.6$, 15.3 and 16.5 MeV are found: see Table 7.5. (1955HE51) and (1959RO62) find, on the other hand, a weak rise at 8 MeV, a pronounced narrow peak at 14 MeV, followed by a deep minimum at 17 MeV and a sharp rise thereafter. It is suggested by (1964AL08) that the discrepancies are to be traced to different spectral sensitivities in the neutron detectors. Evidence is found for enhanced

Table 7.4: Mean life of ^{7}Li*(0.48)

$\tau_{\rm m}$ (sec $\times 10^{13}$)	Reaction	Reference
0.77 ± 0.08	^{6}Li(d, p)	1956BU83
0.75 ± 0.25	^{10}B(n, α)	1949EL07
1.1 ± 0.3	^{7}Li(γ, γ)	1958BE10
1.15 ± 0.14	ibid	1959SW63
$\geq 1.09 \pm 0.07$	ibid	1959SW63
1.4 ± 0.7	ibid	1960BO23
1.0 ± 0.5	ibid	1960BO23
1.25 ± 0.06	ibid	1962MO17
1.48 ± 0.35	ibid	1963MO02
0.93 ± 0.13	ibid	1964BO22
1.07 ± 0.05		mean

emission of slow neutrons from a level near $E_{\rm x} = 17.25$ MeV (1964AL08). With E(brems.) $= 57$ MeV, (1960FA06) find a broad maximum near 19 MeV, $\sigma = 3.2 \pm 0.8$ mb, and a slow tailing off to 57 MeV: see also (1963CO1D). Reported integral cross sections, $\int \sigma {\rm d}E$, are $0 - 24$ MeV: 33 MeV $\cdot$ mb (1954GO1A), 18 MeV $\cdot$ mb (1958RY77); $0 - 25$ MeV: 39 MeV $\cdot$ mb (1960FA06); $0 - 50$ MeV: 93 MeV $\cdot$ mb (1960FA06). (1964GR40) report cross sections for $E_\gamma = 7.4$ to 10.8 MeV: a value $\Gamma_\gamma = 0.9 \pm 0.4$ eV is obtained for ^{7}Li*(7.48). See also (1960KU1C).

The (γ, p) cross section determined by ^{6}He production shows a splitting of the giant resonance into 2 components, at 15.5 and 19.6 MeV: smaller resonances are reported at 12.7, 25.4, 32.0 and 38.0 MeV (1963CL03: see also (1954RU27)). Peaks at 12.5, 13.5 and 14.3 MeV are reported by (1962SH24), while (1963KU25) report 6 peaks in the range $E_{\rm x} = 11$ to 24.5 MeV. According to (1954TI16, 1962GR08) only a single maximum occurs, at ≈ 15.6 MeV, with a width of ≈ 4 MeV. Polarization of photoprotons at $E_\gamma = 335$ MeV is small and consistent with zero (1962LI13). See also (1963FU1D, 1963KI1C).

The ratio $\sigma_{\gamma{\rm p}}/\sigma_{\gamma{\rm d}}$ has been investigated by (1962BE1N, 1962CH26, 1962VO1C). See also (1963KU16).

Peaks reported in the (γ, t) cross section are listed in Table 7.5. See also (1961KO1J, 1963WA07).

See also (1964BI03, 1964MA2B).

15. ^{7}Li(e, e)^{7}Li

Elastic scattering has been studied at $E_{\rm e} = 41.5$ MeV (1963GO04: $\theta = 180°$) and 187 MeV (1955ST85). At the lower energy the magnetic scattering is consistent with that expected from a

Table 7.5: Levels of ^{7}Li(γ, n)^{6}Li, ^{7}Li(γ, p)^{6}He and ^{7}Li(γ, t)^{4}He

(γ, n)		(γ, p)			(γ, t)						
(1954GO39)	(1964AL08)	(1962SH24)	(1963CL03)	(1963KU25)	(1953TI02)	(1953ST27)	(1954ST89)	(1955MI55)	(1960MI02)	(1961SH11, 1961SH21)	(1963KU16) [d]
							4.7				
						5.25	5.5			5.3	
							6.8			6.6	
						7.25		7.6	7.8	(7.5)	
								8.6	8.9	8.3	
9.6 [a]					9.3	(9.25)		9.6	9.8		
10.8				11.0				11.7			
12.4		12.5	12.7								
	13.6	13.5						(13.5)	13.5		
14.0		14.3		14.0							14.1
	15.3		15.5 [b]								
16.8 [b]	16.5			16.0	(16.7)			16.2			16.2
17.5	17.3 [c]			17.9							18.0
			19.6 [b]								19.6
				21.4	(21.5)						(21.5)
					(23.5)						(23.5)
			25.4	24.5							(25.3)
			32.0								
			38.0								

[a] 9.66 ± 0.04 MeV (1958RY77).
[b] Giant resonance.
[c] Resonance for $E_n < 6$ MeV.
[d] And (1963KU25); ± 0.2 MeV, except 25.3 ± 0.3 MeV.

point dipole (1963GO04). The higher energy results yield an r.m.s. charge radius of about 2.1 fm (1957HO1E).

In inelastic scattering studies at $E_e = 41.5$ MeV, $\theta = 180°$, weak broad peaks, ascribed to M1 transfer, are reported at $Q = -6.9, -10.5, -14.0$ MeV (1963BA19: see Table 7.6). At $E_e = 102$ to 177 MeV, excitation of states at 0.48, 4.63 ± 0.05, (5.7 ± 0.1), 6.8 ± 0.1 and 7.5 ± 0.08 MeV is reported. Transitions to the $E_x = 0.48$ MeV state show both longitudinal and transverse E2 contributions (see (1963WI1B)), while the others are mainly longitudinal E2: reported B(E2) are listed in Table 7.6 (1963BE26, 1963BE53, 1964BI03). See also (1959ME1D, 1962BA1D, 1964GU1B, 1964MA2C, 1965CH11).

16. ^{7}Li(n, n)^{7}Li

Elastic angular distributions have been measured for $E_n = 1.5$ to 7.5 MeV (1963BA1V, 1963BA50) and 14 MeV (1964AL1N) and compared with optical model scattering.

At $E_n = 14$ MeV, evidence is reported for states at $E_x = 4.6 \pm 0.25$, ≈ 6.5, 7.5 ± 0.25, and (9.25) MeV (1954AL24). For $E_n = 1.5$ to 7.5 MeV, the excitation of the 4.6 MeV state shows no evidence of direct interaction (1963BA50). A DWBA analysis of the distribution of this group at $E_n = 14$ MeV has been carried out by (1960PE1A). See also (1960HE1F, 1962WO07).

A tabulation of various partial cross sections is given by (1963BA50) and (1964AL1N). See also (1963GL1F, 1963OP1A, 1964VA19).

17. ^{7}Li(p, p)^{7}Li

Elastic scattering and polarization has been studied at $E_p = 40$ MeV (1959CH1B, 1960CH1B), 150 MeV (1962NE12), 155 MeV (1964TA02), 156 MeV (1964JA03) and 160 to 180 MeV (1959JO43, 1960JO14, 1961JO18, 1962RO1F). Analysis in terms of optical parameters is reported by (1961JO18, 1964SA1L).

Inelastic proton groups have been observed corresponding to the excited states of ^{7}Li at 0.48, 4.63, 6.56 and 7.48 MeV: see (1952AJ38). At $E_p = 185$ MeV, proton groups are observed to these states, as well as to states at 5.5 ± 0.3 MeV ($\Gamma \approx 0.4$ MeV) and 9.6 ± 0.2 MeV. The width of the 6.5 MeV state is reported to be ≈ 1 MeV. Angular distributions have been measured for the 4.6 and 6.5 MeV states (1965HA17). A check of the isotropy of the 477 keV radiation ($J = \frac{1}{2} \to \frac{3}{2}$) yields an upper limit $F^2 < 10^{-4}$ for the intensity of a parity non-conserving part of the wave function (1958WI38). Relative intensities of the $Q = -4.6$, -6.6 and -7.5 MeV groups, observed at $E_p = 17.5$ MeV, are consistent with the assignments $^{22}F_{7/2}$, $^{22}F_{5/2}$, $^{24}P_{5/2}$, respectively (1957LE1E, 1957MA04). At $E_p = 150$ MeV, the $E_x = 4.6$ MeV state is strongly excited compared to the $E_x = 0.48$ and 6.5 MeV states, consistent with the assumed rotational character of these levels (1962NE12, 1964JA03). See also (1960HA21, 1960HE1F, 1962RU04, 1963CH08, 1963RI1B, 1964ST15, 1965WE1E).

Table 7.6: Electromagnetic transitions in ^{7}Li from ^{7}Li(e, e′) and Coulomb excitation

E_x (MeV)	J^π	$B(E2\uparrow)$ (fm^4)	$(2J+1)\Gamma_\gamma$	References
0.48 [a]	$\frac{1}{2}^-$	6.8 ± 1		(1963BE26)
		7.3 ± 1.5		(1960ST17)
		7.6 ± 1.1		(1962RI09)
4.63	$(\frac{7}{2}^-)$	15.5 ± 0.8		(1963BE26, 1963BE53)
(5.7) [b]		(4.1 ± 2)		(1963BE26, 1963BE53)
6.8	$(\frac{5}{2}^-)$	12.5 ± 1.2 [c]		(1963BE26, 1963BE53)
7.5	$\frac{5}{2}^-$	$2.5^{+0.5}_{-1.0}$	3.6 ± 2 [d]	(1963BA19, 1963BE26)
(10.5)			38 ± 10	(1963BA19)
(12.5)				(1963BA19)
(14.0)			62 ± 25	(1963BA19)

[a] See also Table 7.4.
[b] Possibly due to ^{7}Li $\rightarrow \alpha +$ t (1964BI03).
[c] $B(M1\uparrow) = 6.9 \times 10^{-3}$ fm^2 (1963BE26).
[d] $\Gamma_\gamma = 0.9 \pm 0.4$ eV (1964GR40).

18. (a) ^{7}Li(p, 2p)^{6}He $\quad Q_m = -9.980$
(b) ^{7}Li(p, pd)^{5}He $\quad Q_m = -9.683$
(c) ^{7}Li(p, α)^{4}He $\quad Q_m = 17.347$

The summed proton energy spectrum, observed at $E_p = 155$ to 450 MeV, shows two peaks, with $Q \approx -11.6$ and $Q \approx -25.4$ MeV, corresponding to formation of ^{6}He(g.s. + 1.80) and an excited state near 15 MeV (see ^{6}He). Angular distributions indicate that the higher energy peak corresponds to the removal of a p-proton while the lower results from removal of an s-proton (1958MA1B, 1959MA1F, 1960HI10, 1961GA09, 1962BE1J, 1962BE1K, 1962DI1A, 1962GA09, 1962GO1P, 1962IN02, 1962IN1A, 1962ST1E, 1962ST1F, 1962TI01, 1963BE1A, 1963BE42, 1963EL1C, 1963JO07, 1963RI1B, 1963TA1D, 1964BA1C, 1964LI1D, 1964TI02, 1965RI1A, 1966TY01).

For reaction (b), see (1962RU04, 1963SH1A, 1964SA1H, 1965JA1L). For reaction (c), see (1962MA40, 1965ZH1A) and ^{8}Be.

19. (a) ^{7}Li(p, d)^{6}Li $\quad Q_m = -5.028$

Table 7.7: ^{7}Li(p, d)^{6}Li, ^{7}Li(d, t)^{6}Li reduced widths [a]

E_x in ^{6}Li (MeV)	J^π	l	$\theta^2_{(p,\,d)}$ [b]	$\theta^2_{(p,\,d)}$ [c]	$\theta^2_{(d,\,t)}$ [d]	$\theta^2_{(d,\,t)}$ [e]
0	1^+	1	0.053	(0.053)	(0.048)	0.11
2.18	3^+	1	0.036	0.027	(0.036)	0.061
3.56	0^+	1		0.028	0.032	0.083
4.57	2^+					
5.36	(2^+)	1			0.025	0.017

[a] PWBA.

[b] (1956RE04, 1960MA32).

[c] (1959BE84, 1960MA32).

[d] (1955LE24, 1960HA14, 1960MA32).

[e] (1959VL24); see also (1962SL04).

(b) ^{7}Li(d, t)^{6}Li $Q_m = -0.995$

(c) ^{7}Li(d, ^{3}He)^{6}He $Q_m = -4.486$

(d) ^{7}Li(t, α)^{6}He $Q_m = 9.834$

Reduced widths derived from PWBA analysis of pickup reactions (a) and (b) are listed in Table 7.7. For reaction (c), $\theta^2 = 0.025$ and 0.008 for ^{6}He(0) and ^{6}He*(1.80) (1957FR1B, 1960MA32).

20. ^{7}Li(d, d′)^{7}Li*

Inelastic deuteron groups are observed corresponding to the ground and 0.48, 4.6 and 7.5 MeV states. At $E_d = 14.8$ MeV, the $Q = -7.46$ MeV group is only weakly excited (1960HA14). At $E_d = 28$ MeV, the $Q = -4.6$ MeV group is strong: the angular distribution is strongly forward. A fit with PWBA requires $l = 0 + 2$ (1962SL02). See also (1952AJ38, 1959AJ76).

Elastic scattering at 28 MeV has been analyzed in the black disc approximation, yielding $R = 4.1$ fm (1962SL02). See also ^{9}Be and (1958EL45, 1958RO49, 1959HA29, 1959SI1A, 1961SL06, 1965JU1A).

21. (a) ^{7}Li(α, α')^{7}Li*

(b) ^{7}Li(^{7}Li, ^{7}Li′)^{7}Li*

(c) ^{7}Li(^{20}Ne, ^{20}Ne′)^{7}Li*

Table 7.8: Branching fraction in ^{7}Be(ϵ)^{7}Li

γ/disintegration (%)	References
10.7 ± 2	(1949WI13)
11.8 ± 1.2	(1949TU06, 1949TU1B)
12.3 ± 0.6	(1949TU1B, 1951DI12)
10.32 ± 0.16	(1962TA11)

Inelastic alpha groups are observed corresponding to the 0.48 and 4.6 MeV states: see (1955AJ61). At $E_\alpha = 13.2$, 31.8 and 48 MeV, the angular distributions of the $Q = -4.6$ MeV group show a prominent peak in the forward hemisphere (1956CO61, 1957SI36, 1960MA15). Analysis by PWBA yields $R = 5.6$ fm, $l = 2$ (1960MA15). See also (1962MA59). For reaction (b), see (1960BL1B).

Coulomb excitation of ^{7}Li*(0.48) in reaction (c) has been studied at $E(^{20}\text{Ne}) = 9$ to 11 (1960ST17), 15.4 (1962RI09) and 16 MeV (1961AN07). The observed intensity leads to a value of the reduced transition matrix element B(E2) $= 7.6\ e^2$fm^4 (1962RI09), $7.3\ e^2$fm^4 (1960ST17) corresponding to a partial half life $\tau = 1.5$ nsec. Comparison with the quoted $\tau_{1/2}$ of the state, 0.08 psec, yields Γ(E2)/Γ(M1) $= 5 \times 10^{-5}$ (1960ST17): see Tables 7.4 and 7.6. See also (1963BE1R).

22. ^{7}Be(ϵ)^{7}Li $\qquad Q_\text{m} = 0.862$

The decay proceeds to the ground and 0.48 MeV states. Reported branching ratios are listed in Table 7.8. The γ-ray energy is 477.8 ± 0.3 keV (see (1955AJ61, 1957DU37)). The weighted mean value of the half life is 53.37 ± 0.11 days (1949SE20, 1953KR16, 1956BO36, 1957WR37); $ft = 2.00 \times 10^3$ for the ground state transition and 3.45×10^3 for the excited state (1965BA2C). Both transitions are super-allowed (1954MA1D, 1956CH1B). The internal conversion coefficient of the 0.48 MeV γ is $5.8 - 16.6 \times 10^{-7}$ indicating an E2/M1 ratio between 0 and 0.8 (1959LE30). Calculations of electron capture and nuclear matrix elements support the conclusion that ^{7}Li is close to LS coupling (1962BA1X). See also (1959BL1C, 1963CH08, 1963KI1D).

23. ^{7}Be(n, p)^{7}Li $\qquad Q_\text{m} = 1.644$

See ^{8}Be.

24. (a) ^{9}Be(γ, d)^{7}Li $\qquad Q_\text{m} = -16.693$

(b) ^{9}Be(γ, np)^{7}Li $\qquad Q_\text{m} = -18.917$

See (1955AJ61) and ^{9}Be.

25. ^{9}Be(n, t)^{7}Li $Q_{\rm m} = -10.435$

See (1957SC12, 1957VA12) and ^{10}Be.

26. ^{9}Be(p, ^{3}He)^{7}Li $Q_{\rm m} = -11.199$

At $E_{\rm p} = 43.7$ MeV, ^{3}He groups are observed corresponding to the ^{7}Li levels at 0, 0.48, 4.6 and 7.5 MeV and to a new state at 11.13 ± 0.05 MeV, with $\Gamma = 268 \pm 30$ keV. From the similarity of the angular distribution and cross section to that in the (p, t) mirror reaction, it is concluded that the level has $J^{\pi} = \frac{3}{2}^{-}$; $T = \frac{3}{2}$ (1965DE08).

27. (a) ^{9}Be(p, pd)^{7}Li $Q_{\rm m} = -16.693$
(b) ^{10}B(p, p^{3}He)^{7}Li $Q_{\rm m} = -17.786$

See (1963SH1A, 1964BA1C, 1964BA1P, 1964SH1C).

28. ^{9}Be(d, α)^{7}Li $Q_{\rm m} = 7.154$

A number of α-groups have been observed with deuteron energies up to 27.5 MeV. These correspond to levels at 480 ± 2 keV (1948BU31, 1953CO02, 1961JA23), 4.62 ± 0.02 MeV (1953GE01: see also (1964MA04)), and 7.5 MeV (1951GO47, 1964MA04). Angular distributions have been studied for the ground and $E_{\rm x} = 0.48$ MeV states at $E_{\rm d} = 0.4$ to 2.4 MeV (1962BI11), 10 MeV (1962WE04) and 13.6 MeV (1962IV1A); those to the 4.6 and 7.5 MeV states at $E_{\rm d} = 27.5$ MeV (1964MA04). The widths of the 4.6 and 7.5 MeV states are, respectively, 93 ± 25 and 80 ± 20 keV (1966HA09). The upper limit to the intensity of an α-particle group to a state at $E_{\rm x} \approx 5.5$ MeV is 5% of the intensity of the group to ^{7}Li*(7.48) (1966HA09: $E_{\rm d} = 11.1$ MeV). See also (1964YA1A).

The (α, γ) angular correlation has been observed for $E_{\rm d} = 0.40$ and 0.84 MeV, (1953UE01, 1954CO17). There is no significant departure from isotropy, in agreement with $J = \frac{1}{2}$ for the 0.48 MeV level. The mean life of this state is reported to be $(7.7 \pm 0.8) \times 10^{-2}$ psec (1956BU83): see Table 7.4.

See also (1959AJ76) and ^{11}B.

29. ^{10}B(n, α)^{7}Li $\qquad Q_{\rm m} = 2.792$

With thermal neutrons, two groups of α-particles are observed, corresponding to ^{7}Li*(0, 0.48); the fraction of transitions leading to the ground state is about 6%: see ^{11}B. The γ-ray energy is 478.5 ± 1.5 keV (1948EL1A), 478 ± 4 keV (1956DA23); the mean life is $(7.5 \pm 2.5) \times 10^{-2}$ psec (1949EL07): see Table 7.4.

See also (1952AJ38, 1955AJ61, 1959AJ76, 1960AN14, 1962LA07, 1963DE1F).

30. (a) ^{11}B(α, 2α)^{7}Li $\qquad Q_{\rm m} = -8.664$

(b) ^{11}B(γ, α)^{7}Li

(c) ^{11}B(p, pα)^{7}Li

For reaction (a) see (1963ME01). For reaction (b) see ^{11}B. For reaction (c) see (1964BA1C).

31. ^{18}O(d, ^{13}C)^{7}Li $\qquad Q_{\rm m} = -5.678$

See (1963DR1B).

^{7}Be

(Figs. 9 and 10)

GENERAL: See (1957FR1B, 1960PH1A, 1960SH1A, 1960TA1C, 1961KU1C, 1961TA05, 1961TO04, 1962GL1A, 1962IN02, 1964AR22, 1964BA2A, 1964GR1J, 1964HO31, 1964LI1F, 1964MO1K, 1964NE1H, 1964PA1K, 1964PH1A, 1964RA1B, 1964SA1F, 1964ST1B).

1. ^{7}Be(ϵ)^{7}Li $\qquad Q_{\rm m} = 0.862$

The decay is complex: see ^{7}Li.

2. ^{4}He(^{3}He, γ)^{7}Be $\qquad Q_{\rm m} = 1.587$

In the range $E_\alpha = 0.42$ to 5.80 MeV the cross section rises from 0.02 to 4 μb. The branching ratio γ_0 (to g.s.)/γ_1 (to 0.4 MeV state) remains at 73/27 for $E_\alpha = 1.1$ to 3.2 MeV (1963PA12) .The zero-energy intercept of the cross section factor $S = 0.47 \pm 0.05$ keV $\cdot$ b (1963PA12). See also (1958BA59, 1959HO03, 1961FA02, 1964PA1A). A direct capture calculation, assuming an α + ^{3}He model with phase shifts obtained from ^{4}He(^{3}He, ^{3}He), gives good agreement with the excitation function of (1963PA12) with $R = 2.8$ fm, $\theta^2_\alpha = 1.25$ and 1.05 for ^{7}Be(0) and ^{7}Be*(0.43), respectively. The capture proceeds mainly by E1, with both s- and d-waves contributing above $E_\alpha = 1$ MeV (1963TO06). See also (1961CH1C, 1961TO04, 1962HE1C). The bearing of this reaction on ^{4}He production in stars is discussed by (1958FO1A, 1964PA1A).

Table 7.9: Energy levels of ^{7}Be

$E_{\rm x}$ (MeV $\pm$ keV)	$J^\pi; T$	Γ (keV)	Decay	Reactions
g.s.	$\leq \frac{3}{2}^-; \frac{1}{2}$	$\tau_{1/2} = 53.37 \pm 0.11$ d	ϵ	1, 3, 5, 10, 14, 15, 17, 19
0.431 ± 1	$\frac{1}{2}^-; \frac{1}{2}$	$\tau_{\rm m} = 0.27 \pm 0.10$ ps	γ	5, 10, 14, 15, 17, 19
4.55 ± 20	$\frac{7}{2}^-; \frac{1}{2}$	100	^{3}He, α	3, 17, 19
6.51 ± 40	$\frac{5}{2}^-; \frac{1}{2}$	1200	^{3}He, α	3, 10, 19
7.185 ± 20	$(\frac{5}{2}^-); \frac{1}{2}$	836	p, ^{3}He, α	3, 7, 9, 10, 19
(9.2 ± 0.5)		broad	p, ^{3}He	3
9.9	$(\frac{3}{2}^-; \frac{1}{2})$	≈ 1800	p, p_1, p_2	7
10.79 ± 40	$(\frac{3}{2}^-; \frac{3}{2})$	298 ± 25		17
(14.6 ± 300)				19

3. (a) ^{4}He(^{3}He, ^{3}He)^{4}He $E_b = 1.587$

(b) ^{4}He(^{3}He, p)^{6}Li $Q_m = -4.021$

Elastic scattering studies have been reported for $E(^3\text{He}) = 3$ to 5.5 MeV (1958MI92), 2.5 to 5.7 MeV (1964BA09), 4 to 12 MeV (1963TO04), 8 to 18 MeV (1964SP04), 29 to 30 MeV (1960BR19, 1960MC1E), $E_\alpha = 11$ to 28 MeV (1960BR1J), 28 to 41 MeV (1961CH09). Two resonances are reported in the f-wave phase shifts: at $E_x = 4.55$ MeV (^{2}F$_{7/2}$) and $E_x = 6.51$ MeV (^{2}F$_{5/2}$); see Table 7.10. In the range $E(^3\text{He}) = 2.5$ to 12 MeV, the s-wave and d-wave phase shifts reflect hard-sphere scattering with $R = 2.8$ fm, although some systematic deviation seems to appear in the s-waves for $E(^3\text{He}) > 5$ MeV (1963TO04, 1964BA09). The $\text{p}_{\frac{3}{2}}$ phase shift exhibits a contribution from the ground state, with $\theta^2_\alpha(\text{g.s.}) = 0.15$, but the $\text{p}_{\frac{1}{2}}$ phase shift cannot be adequately accounted for by ^{7}Be*(0.43) (1961TO04, 1964BA09). The $^4\text{P}_{\frac{5}{2}}$ level ($E_x = 7.18$ MeV) seems to have no influence on the scattering: $\theta^2_\text{p} < 0.02$ (1963TO04). See also (1964PH1A). A broad resonance has been observed at $E_x = 9.2 \pm 0.5$ MeV. It is not clear whether it can be identified with the $(\frac{3}{2}^-)$ state at 9.9 MeV (1964SP04).

At the higher energies, distinct minima are observed in the angular distribution at $\theta = 45°$, $100°$ and $140°$. No evidence of sharp resonances is observed for $E_x > 13$ MeV (1960BR19, 1960BR1J, 1961CH09). Optical model calculations are reported by (1963SQ1A), resonating group calculations by (1963TA10). See also (1963SC1M).

Polarizations have been calculated from the observed phase shifts by (1959PH37, 1963TO04, 1964BA09). Measurement of scattering of α-particles from a polarized ^{3}He target at $E_\alpha = 6.53$ and 7.33 MeV confirms the expected reversal of polarization between these two energies (1962PH1B).

Reaction (b) has been studied for $E(^3\text{He}) = 8$ to 12 MeV by (1963TO04) and at 29 MeV by (1960BR19, 1960MC1E). A peak appears in the excitation function at $E(^3\text{He}) = 9.8$ MeV, corresponding to the ^{4}P$_{5/2}$ level at $E_x = 7.18$ MeV (1963TO04). The resonance corresponding to ^{7}Be*(9.2), observed in the elastic scattering, is strongly present in the yield of ^{6}Li*(2.18) protons but not in the yield of ground state protons (1964SP04). See also (1962TE1D).

4. ^{4}He(α, n)^{7}Be $Q_m = -18.991$

See ^{8}Be.

5. ^{6}Li(p, γ)^{7}Be $Q_m = 5.608$

Gamma transitions are observed to the ground and 0.43 MeV states. The yield shows no evidence of resonance for $E_p = 0.4$ to 1.0 MeV and the branching ratio remains approximately constant at (62 ± 5)% to the ground state, 38% to the 0.43 MeV state, < 4% to the 4.6 MeV state (1955BA59, 1956WA03). The $90°$ differential cross section at 750 keV is 0.02 μb/sr (1956WA03).

Table 7.10: ^{7}Be levels from ^{4}He(^{3}He, ^{3}He)^{4}He and ^{6}Li(p, p)^{6}Li

E_x (MeV)	J^π	Term	R (fm)	θ^2_α	θ^2_p	Refs.
0	$\frac{3}{2}^-$	$^2P_{\frac{3}{2}}$	3.8	0.15		(1964BA09)
0.43	$\frac{1}{2}^-$	$^2P_{\frac{1}{2}}$				
4.54 ± 0.02 }	$\frac{7}{2}^-$	$^2F_{\frac{7}{2}}$	4.4	0.36		(1958MI92)
4.57 ± 0.04 }				0.38		(1964BA09)
6.51 ± 0.04	$\frac{5}{2}^-$	$^2F_{\frac{5}{2}}$	4.4	0.48	< 0.02	(1963TO04)
7.18	$\frac{5}{2}^-$	$^4P_{\frac{5}{2}}$	4.1	0.012	0.28	(1963MC09)
9.2 ± 0.5						(1964SP04)

The angular distributions of γ_0 and γ_1 are the same at $E_p = 0.75$ MeV, $W(\theta) = 1 + (1.05 \pm 0.15)\cos^2\theta$. Neither s- nor d-wave capture yields such a distribution, and p-wave, $J = \frac{3}{2}^-$, is indicated (see, however, ^{4}He(^{3}He, ^{3}He)^{4}He); a direct non-resonant capture process seems also possible (1956WA03). For $E_p = 1$ to 2 MeV, large $\cos^2\theta$ terms appear: the yield shows no resonance behavior in this range (1963MC09). See also (1959GR1A, 1961TO04, 1965LA03).

6. ^{6}Li(p, n)^{6}Be $\qquad Q_m = -5.066 \qquad E_b = 5.608$

The yield of neutrons increases approximately monotonically from threshold to $E_p = 14.3$ MeV (1964BA16). The excitation function for slow neutrons near threshold indicates that both s- and p-wave neutrons contribute significantly (1964HOZZ). The cross section for production of ground state neutrons is 5 ± 1 mb at $E_p = 9$ MeV (1957BO1F), 0.5 mb/sr at $E_p = 10.5$ MeV, $\theta_{c.m.} = 104°$ (1959AJ81).

7. ^{6}Li(p, p)^{6}Li $\qquad E_b = 5.608$

Elastic scattering has been studied from $E_p = 1$ to 3 MeV by (1951BA79), from 0.5 to 2.9 MeV by (1963MC09), from 1.2 to 5.6 MeV by (1964FA1D), from 2.4 to 12 MeV by (1963HA53), and at 31 MeV by (1963DE01). Two resonances are reported at $E_p = 1.84$ and 5 MeV. In the range 0.5 to 2.9 MeV, the data are consistent with p-wave formation of a $\frac{5}{2}^-$ or $\frac{3}{2}^-$ state, with $\Gamma_{c.m.} = 836$ keV, $\theta^2_p = 0.28$, $\theta^2_\alpha = 0.012$ (see Table 7.2); an s-wave background is evident, possibly reflecting a $\frac{1}{2}^+$ state at higher energies (^{7}Be* > 8 MeV). No evidence is found for a previously reported $\frac{3}{2}^+$

state near $E_p = 1$ MeV (1963MC09). The 5 MeV resonance, corresponding to $E_x = 9.9$ MeV, has a width of ≈ 1.8 MeV and exhibits a behavior much like that of the lower resonance, suggesting that it too is formed by p-wave: on this assumption, the reduced width $\gamma_p^2 = 3 \pm 2$ MeV · fm. A weak rise near $E_p = 8$ to 9 MeV may indicate a further level, ^{7}Be* ≈ 13 MeV (1963HA53). See also (1964LE1E).

Polarization of elastically scattered protons has been studied by (1962RO20: 15 MeV), (1963HW01: 39 MeV), while polarization of inelastically scattered protons (to ^{6}Li*(3.56)) has been studied by (1964MA1Y: 150 MeV). See also (1964VE1A).

Inelastic protons (to ^{6}Li*(2.18)) studied from $E_p = 3.6$ to 9.4 MeV show the resonance at $E_p = 5.5$ MeV, Angular distributions suggest p-wave formation with $J^\pi = \frac{3}{2}^-$ or $\frac{5}{2}^-$ (1963HA49). The yield of 3.6 MeV γ-rays (from ^{6}Li*(3.56)) shows a broad maximum at ≈ 6 MeV, probably associated with ^{7}Be*(9.9): $J^\pi = \frac{3}{2}^-$ is suggested. At $E_p \approx 6.3$ MeV there is an abrupt decrease in the inelastic cross section, which is either due to the onset of the (^{6}Be+n) channel or to interference with an other broad state with $J^\pi = \frac{3}{2}^-$ (1964HA37).

8. ^{6}Li(p, d)^{5}Li $\quad Q_m = -3.438 \quad E_b = 5.608$

See ^{5}Li.

9. ^{6}Li(p, α)^{3}He $\quad Q_m = 4.021 \quad E_b = 5.608$

The cross section exhibits a broad, low maximum near $E_p = 1$ MeV and a pronounced resonance at $E_p = 1.85$ MeV (1951BA79, 1956MA91: see (1963MC09)). No other structure is reported up to $E_p = 5.6$ MeV (1963JE03, 1964FA03). From $E_p = 3$ to 12 MeV, $\theta = 70°$, the excitation function shows only a smooth decrease (1962HE03, 1963TE1B). In the range $E_p = 0.5$ to 2.5 MeV, a strong $\cos\theta$ term is observed, indicating interference between the p-wave resonance and s-wave background (1956MA91, 1963JE03). At $E_p > 8$ MeV, the angular distributions are characterized by forward and backward peaks (1956LI37, 1960AL18, 1962HE03, 1963TE1B). See also (1957JA37, 1960BO13, 1960SA28, 1961KH01, 1963BE08, 1964BE37) and ^{6}Li.

10. ^{6}Li(d, n)^{7}Be $\quad Q_m = 3.384$

Two neutron groups are reported, corresponding to the ground and 0.43 MeV states. The γ-ray energy is 428.9 ± 2 keV (corrected for Doppler shift): the ^{7}Li*-^{7}Be* difference is 48.5 ± 1.0 keV (1952TH24). Angular distributions of the n_0 and n_1 groups have been determined at $E_d = 0.56$ to 2.9 MeV (1963BI27), $E_d = 0.6$ to 1.5 MeV (1956NE13), $E_d = 1.8$ to 3.1 MeV (1963CR08) and $E_d = 3.5$ MeV (1952AJ1B). The distributions indicate $l_p = 1$, $J \leq \frac{5}{2}^-$ for both states. Since the n-γ correlations are isotropic (1956NE13) $J = \frac{1}{2}^-$ for the 0.43 MeV excited state is indicated.

Broad maxima are observed in the ratio of low-energy to high-energy neutrons at $E_{\rm d} = 4.2$ and 5.1 MeV (^{7}Be* $= 6.5$ MeV and 7.2 MeV, $\Gamma_{\rm c.m.} = 1.2$ and 0.5 MeV, respectively) (1957SL01). See also (1964PA16, 1965MA1K).

11. ^{6}Li(^{3}He, d)^{7}Be $\qquad Q_{\rm m} = 0.115$

Not reported.

12. ^{6}Li(α, t)^{7}Be $\qquad Q_{\rm m} = -14.206$

Not reported.

13. ^{6}Li(^{6}Li, nα)^{7}Be $\qquad Q_{\rm m} = 1.912$

See (1957NO17, 1962BE16, 1962MC12, 1963BA1Q, 1963CO35) and ^{12}C.

14. ^{7}Li(p, n)^{7}Be $\qquad Q_{\rm m} = -1.644$

The threshold for this reaction is used as a secondary standard for energy calibrations: the value recommended by (1963MA1R) is 1880.36 ± 0.22 keV (see Table 7.11). See also (1960BR20). Studies of target and shape effects at threshold are reported by (1959WE1A, 1963PA11, 1964BO10).

A determination of Q from the cone angle of neutrons above threshold confirms that the observed threshold corresponds to the true onset of the reaction (1963YO04). A second threshold, corresponding to the first excited state of ^{7}Be, yields $E_{\rm x} = 433 \pm 2$ keV (1960MA1G). Neutrons corresponding to ^{7}Be*(4.55) are observed for $E_{\rm p} \gtrsim 7$ MeV (1959AJ81, 1960HI04). At $E_{\rm p} = 10$ MeV, groups n_0, n_1 and n_2 account for nearly all the neutrons observed (1963BO06). See also (1952TH1C, 1957BO1F, 1961NI04, 1962AU01). See also (1959GA08, 1960RO21, 1961TO06, 1962BO33, 1963BO1N, 1964BA16, 1964OL1C) and ^{8}Be.

15. ^{7}Li(^{3}He, t)^{7}Be $\qquad Q_{\rm m} = -0.880$

Angular distributions have been measured for ground-state tritons (1961WO05: $E(^3{\rm He}) = 4.5$ MeV) and for tritons to both ground and first excited states (1963BO1P: $E(^3{\rm He}) = 3.0$ to 4.0 MeV).

Table 7.11: ^{7}Li(p, n)^{7}Be threshold energies [a]

$E_{\rm thresh.}$ (keV)	Reference
1879.4 ± 1.0	(1954JO10)
1881.2 ± 0.9	(1959BO14)
1880.8 ± 1.0	[b]
1880.3 ± 0.5	(1960ST19)
1880.5 ± 0.8	(1961BE13)
1880.48 ± 0.25	[c]
1879.8 ± 0.6	(1962GA12)
1880.36 ± 0.22	mean: (1963MA1R)
1881.27 ± 0.94	(1964BO10)

[a] Revised values as quoted in (1963MA1R), except for the (1964BO10) value.

[b] C.P. Browne, as quoted by (1963MA1R).

[c] A. Rytz, as quoted by (1963MA1R).

16. ^{9}Be(γ, 2n)^{7}Be $\qquad Q_{\rm m} = -20.561$

See (1962FO10) and ^{9}Be.

17. ^{9}Be(p, t)^{7}Be $\qquad Q_{\rm m} = -12.079$

At $E_{\rm p} = 44$ MeV, triton groups are observed corresponding to the ^{7}Be levels at 0, 0.43 and 4.55 MeV, and to a new level at 10.79 ± 0.04 MeV with $\Gamma = 298 \pm 25$ keV. From the similarity of the angular distribution to that in the (p, ^{3}He) reaction to ^{7}Li*(11.13), it is concluded that the level has $J^\pi = \frac{3}{2}^-$; $T = \frac{3}{2}$ (1965DE08). See also (1954CO02, 1956BE14).

18. ^{9}Be(d, tn)^{7}Be $\qquad Q_{\rm m} = -14.304$

See (1955HE83) and ^{11}B.

19. ^{10}B(p, α)^{7}Be $\qquad Q_{\rm m} = 1.148$

Alpha groups corresponding to ^{7}Be(0) and ^{7}Be*(0.43) have been studied by many observers: see (1952AJ38, 1959AJ76). Some reported values for the energy of the first excited state are: 434.4 ± 4 keV (1951BR10), 431 ± 5 keV (1950VA01), 429 ± 3 keV (1952CR30), 428.5 ± 1.8 keV (1952TH24). The mean lifetime of this state is 0.27 ± 0.10 psec (1956BU83: Doppler shift). This value agrees with a shell model calculation by (1955LA1D).

At $E_{\rm p} = 18$ MeV, α-groups are reported correspondingly to ^{7}Be* $= 0$, 0.49 ± 0.10, 4.72 ± 0.08, 6.27 ± 0.10, 7.21 ± 0.10 and 14.6 ± 0.3 MeV. The last group is ten times as intense as any of the others. It is not completely excluded that it may be due to ^{10}B(p, ^{3}He)^{8}Be (1955RE16).

Angular distributions of ground and first excited state α-particles have been obtained at 30 energies in the range $E_{\rm p} = 2.8$ to 7.0 MeV (1964JE01: see also ^{11}C). See also (1964YA1A).

See also (1960RO21, 1962GR21).

20. ^{12}C(d, ^{7}Li)^{7}Be $\qquad Q_{\rm m} = -17.540$

See (1965BE1W).

^{7}B

(Not illustrated)

From the known location of the ^{7}Be $T = \frac{3}{2}$ state, the mass excess of ^{7}B is calculated as 27.99 ± 0.15 MeV (calculation of the Coulomb energy difference based on the pair ^{10}Be-^{10}B* $(T = 1)$); ^{7}B is then unstable with respect to decay into ^{5}Li + 2p by 1.73 MeV, ^{6}Be + p by 2.33 MeV, and α + 3p by 3.70 MeV (1965DE08). See also (1960GO1B, 1965JA1C).

References

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