Energy Levels of Light Nuclei
$A = 7$

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Abstract: An evaluation of $A = 5$–10 was published in *Nuclear Physics A*227 (1974), 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}H

(Not illustrated)

A search for ^{7}H in ^{7}Li(π^-, π^+)^{7}H was unsuccessful (1965GI10). See also (1968CE1A).

^{7}He

(Fig. 10)

Mass of ^{7}He: From the Q of the ^{7}Li(t, ^{3}He)^{7}He reaction, the atomic mass excess of ^{7}He is 26.11 ± 0.03 MeV. ^{7}He is unbound with respect to ^{6}He + n by 0.44 ± 0.03 MeV (1968ST1J): $\Gamma < 0.2$ MeV (1973LI02).

GENERAL:

See (1960GO1B, 1965BO1C, 1965LA1B, 1967CO1K, 1970LO1E, 1972CA37, 1972GA1L, 1972PN1A, 1973JU2A) and (1966LA04).

1. ^{7}Li(t, ^{3}He)^{7}He $\quad Q_{\rm m} = -11.18$

$Q_0 = -11.18 \pm 0.03$ (1968ST1J).

The ^{3}He particles to the ground state of ^{7}He have been observed at $E_{\rm t} = 22$ MeV. The width of the ground state is 160 ± 30 keV; for a radius of 2.2 fm and $l_{\rm n} = 1$, this width is 0.22 of the Wigner limit. The angular distribution is peaked in the forward direction. No other states of ^{7}He were observed for $E_{\rm x} < 2.4$ MeV (1967ST04, 1968ST1J). See also (1968CE1A).

2. ^{7}Li(n, p)^{7}He $\quad Q_{\rm m} = -10.42$

At $E_{\rm n} = 14.8$ MeV, a proton group is reported corresponding to $^{7}{\rm He}_{\rm g.s.}$: $\Gamma < 0.2$ MeV (1973LI02). See also (1967ME11, 1971KO24) and ^{8}Li.

3. ^{9}Be(n, ^{3}He)^{7}He $\quad Q_{\rm m} = -17.20$

Not reported.

^{7}Li

(Figs. 8 and 10)

GENERAL: (See also (1966LA04).)

Shell model: (1961KO1A, 1965CO25, 1965KU09, 1965VO1A, 1966BA26, 1966HA18, 1966WI1E, 1967BO1C, 1967BO22, 1967CO32, 1967FA1A, 1969GU03, 1969TA1H, 1969VA1C, 1970ZO1A, 1971CO28, 1972LE1L, 1973HA49, 1973KU03).

Cluster model: (1965NE1B, 1968HA1G, 1968KU1B, 1969ME1C, 1969SM1A, 1969VE1B, 1969WI21, 1970BA1Q, 1972HA06, 1972HI16, 1972JA23, 1972KU12, 1972LE1L, 1973KU03, 1973KU12).

Rotational and deformed models: (1965VO1A, 1966EL08).

Special levels: (1966BA26, 1966EL08, 1967BO22, 1967CO32, 1967FA1A, 1969GU03, 1969HA1G, 1969HA1F, 1970FR1C, 1971CO28, 1972BB26, 1973AS02, 1973FE1J, 1973MA1K).

Electromagnetic transitions: (1965CO25, 1965KU09, 1966BA26, 1966EL08, 1967BO22, 1968EL06, 1968KU1D, 1969HA1G, 1969HA1F, 1969VA1C, 1973AS02, 1973HA49, 1973HA1V, 1973SU1C).

Astrophysical questions: (1967DA1C, 1967MI1A, 1968HA1C, 1969BA2A, 1970BA1M, 1972CL1A, 1972KO1E, 1972RA30, 1973AU1H, 1973LA19, 1973RE1G, 1973SA1J, 1973SC1T, 1974AU1A).

Special reactions: (1965GR1C, 1965ZH1A, 1967AU1B, 1968YI01, 1969GA18, 1969YI1A, 1972HA06, 1972RA30, 1972VO06, 1973KO1D, 1973KU03, 1973LA19, 1973OS1C, 1973PF02).

Muon capture: (1965LO1B, 1969WU1A, 1970FA15, 1971DE2D, 1973MU11).

Pion capture and reactions: (1966DA1A, 1966DE1G, 1968BO32, 1968BO1T, 1968KU1B, 1968LO1A, 1968NO1A, 1968PE1B, 1968WI1B, 1969BU1C, 1969KO30, 1969MI10, 1969MI1G, 1969MO1E, 1970BA1E, 1970BO1V, 1970JA23, 1971CA01, 1971CA1J, 1971FA09, 1971KO02, 1972GO1L, 1972HU1A, 1972SW1A, 1973BA2R, 1973BA2V, 1973BA2G, 1973DO1F, 1973NY04, 1973PE1E, 1973SQ01).

Kaon reactions: (1973BA1Y).

Other topics: (1965CO25, 1965VO1A, 1966DE1E, 1966HA18, 1966WI1E, 1966YO1B, 1967BO1C, 1967CA17, 1967FA1A, 1968EL06, 1969GU03, 1969HE1N, 1969HO1M, 1970HO1J, 1970ZO1A, 1971BA2Y, 1971CH1H, 1971GR16, 1971ZA1D, 1972AB14, 1972AN05, 1972BB26, 1972CA37, 1972DA21, 1972FR09, 1972GA1L, 1972LE1L, 1972PN1A, 1973BA1Y, 1973CL09, 1973JU2A, 1973KU03, 1973MA48, 1973RO1R).

Ground state properties: (1965CO25, 1965HU13, 1965KU09, 1965MO17, 1965PR04, 1965VO1A, 1966BA26, 1966CA1F, 1966EL08, 1966WI1E, 1967BO22, 1967PA1G, 1967SH05, 1967SH14, 1968PE1B, 1969GU03, 1969PE1D, 1969VA1C, 1972FR09, 1972LE1L, 1973DO1F, 1973MA1K).

$\mu = +3.2564$ nm (1969FU11, 1971SH26);

Table 7.1: Energy levels of ^{7}Li

E_x (MeV $\pm$ keV)	$J^\pi; T$	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
g.s.	$\frac{3}{2}^-; \frac{1}{2}$	—	stable	1, 4, 6, 12, 13, 16, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 35, 36, 27, 28, 29, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54
0.477611 ± 0.012	$\frac{1}{2}^-; \frac{1}{2}$	$\tau_m = 105 \pm 5$ fsec	γ	6, 12, 13, 16, 18, 19, 20, 22, 23, 24, 27, 30, 33, 35, 38, 42, 43, 45, 47, 49, 50, 51, 53, 54
4.633 ± 8	$\frac{7}{2}^-; \frac{1}{2}$	$\Gamma = 93 \pm 8$ keV	t, α	3, 12, 18, 19, 20, 21, 22, 23, 24, 33, 35, 38, 39, 42
6.675 ± 54	$\frac{5}{2}^-; \frac{1}{2}$	875^{+200}_{-100} keV	t, α	3, 18, 20, 21, 24, 35
7.467 ± 4	$\frac{5}{2}^-; \frac{1}{2}$	89 ± 7 keV	n, t, α	2, 3, 7, 11, 12, 18, 20, 24, 33, 35, 42
9.61 ± 81	$\frac{7}{2}^-; \frac{1}{2}$	broad	n, t, α	2, 3, 12, 35
10.25 ± 100	$\frac{3}{2}^-; \frac{1}{2}$	1.40 ± 0.10 MeV	n, α	7, 18
11.245 ± 31	$\frac{3}{2}^-; \frac{3}{2}$	258 ± 33 keV	n, p	7, 8, 18, 33
16.8		9.3 MeV	γ, n	17

$\mu = 3.255985\ (2)$ nm [quoted in (1973CO1P)];

$Q = -0.058 \pm 0.010$ b (1966IS01);

$Q = -0.04$ b (1969FU11); see also (1971SH26, 1972BA77).

B(E2: $\frac{3}{2}^- \rightarrow \frac{1}{2}^-$) $= 8.3 \pm 0.6\ e^2 \cdot \text{fm}^4$ (1972HA06, 1973HA47);
$= 7.4 \pm 0.1\ e^2 \cdot \text{fm}^4$ (1972BA77) [see also (1973HA47)].

1. ^{3}H(α, γ)^{7}Li $\qquad Q_m = 2.4668$

Excitation functions and angular distributions have been studied for $E_\alpha = 0.5$ to 1.9 MeV (1959HO03, 1961GR27). The cross section rises smoothly as expected for a direct capture process: at $E_\alpha = 1.32$ MeV, $\sigma = 3.58 \pm 0.06\ \mu$b and the corresponding reduced cross section factor $S = 0.064 \pm 0.016$ keV $\cdot$ b (1961GR27). Cross sections of (1961GR27) are 2 to 2.5 times higher

Table 7.2: ^{7}Li levels from ^{3}H + ^{4}He

E_x (MeV ± keV)	J^π	l_α	LS term	R (fm)	θ^2_α [a]	θ^2_{n0}	θ^2_{n1} [b]	Refs.
4.65 ± 50	$\frac{7}{2}^-$	3	$^2F_{7/2}$	4.0	0.57 ± 0.04			(1967SP10)
4.65 ± 20	$\frac{7}{2}^-$	3	$^2F_{7/2}$	4.4	0.37			(1968IV01)
6.64 ± 100	$\frac{5}{2}^-$	3	$^2F_{5/2}$	4.0	1.36 ± 0.13	0.000 ± 0.002		(1967SP10)
6.79 ± 90	$\frac{5}{2}^-$	3	$^2F_{5/2}$	4.4	0.52			(1968IV01)
7.47 ± 30	$\frac{5}{2}^-$	3	$^4P_{5/2}$	4.0	0.011 ± 0.001	0.26 ± 0.02		(1967SP10)
9.67 ± 100	$\frac{7}{2}^-$	3	$^4D_{7/2}$	4.0	0.53 ± 0.22		2.3 ± 0.7	(1967SP10)

[a] $\gamma^2/(\frac{3}{2}\hbar^2/\mu a^2)$.
[b] To ^{6}Li*(2.19).

than those of (1959HO03). See (1966LA04) for further comments and (1972BA77, 1972HA06, 1972SM02).

2. ^{3}H(α, n)^{6}Li $\qquad Q_m = -4.784 \qquad E_b = 2.4668$

The cross section for this reaction has been measured for $E_\alpha = 11$ to 18 MeV: the data show the effect of ^{7}Li*(7.47) and indicate a broad resonance near $E_\alpha = 16.8$ MeV [^{7}Li*(9.6)]. The level parameters derived from this reaction and from reaction 3 (1967SP10) are displayed in Table 7.2. See also (1972BB26; theor.).

3. ^{3}H(α, α)^{3}H $\qquad E_b = 2.4668$

The elastic scattering has been studied for $E_\alpha = 3.6$ to 18.2 MeV. The excitation curves show the effects of ^{7}Li*(4.63, 6.68, 7.47, 9.61). The derived level parameters are displayed in Table 7.2. Polarization parameters are calculated (1967SP10, 1968IV01). Polarization measurements are reported for $E_t = 6.0$ to 12.3 MeV (1968KE03, 1971AR1K) and angular distributions have also been measured for $E_\alpha = 2.13$ to 2.98 MeV (1971CH42). See also (1970LI06) and (1968BR1H, 1971KU22, 1972BB26, 1972CL1C, 1972NE17, 1973KO1Q; theor).

4. ^{4}He(α, p)^{7}Li $\qquad Q_m = -17.348$

See (1958BU38).

5. ^{6}He(p, t)^{4}He $Q_m = 7.511$ $E_b = 9.978$

See (1971PO1A).

6. ^{6}Li(n, γ)^{7}Li $Q_m = 7.2506$

$Q_0 = 7250.0 \pm 0.5$ keV (1968SP01);
$Q_0 = 7250.3 \pm 0.9$ keV (1972OP01);
$Q_0 = 7251.0 \pm 1.0$ keV (1967RA24);
$Q_0 = 7250.6 \pm 1.5$ keV (E.T. Jurney, private communication).

The total radiative capture cross section for thermal neutrons is 38.5 ± 3.0 mb (E.T. Jurney, private communication). Two γ-rays with $E_\gamma = 7247 \pm 2$ and 6769 ± 2 keV are observed corresponding to transitions to ^{7}Li*(0, 0.48) with branching ratios of 61 ± 3 and 39 ± 2%, respectively† . Gamma rays with $E_\gamma = 4.63$, 4.15 and 2.62 MeV corresponding to the decays of, and the transition to, ^{7}Li*(4.63) are not observed: upper limits ar 2, 2 and 6%, respectively (1967TH05), 1% (E.T. Jurney, private communication). See also (1968SP01). For astrophysical implications of this reaction see (1968FO1A).

7. ^{6}Li(n, n)^{6}Li $E_b = 7.2506$

The total cross section has been measured for $E_n = 4$ eV to 29 MeV: see (1960HU1A, 1964ST25, 1966LA04). Recent measurements have been carried out at $E_n = 10$ to 1236 keV (1968HI1E), 50 to 650 keV (1968FA1D), 100 to 1500 keV (1972ME17), 0.7 to 30 MeV (1973GO2B, and C.A. Goulding, private communication) and 2.5 to 15 MeV (1971FO1A). A pronounced resonance occurs at $E_n = 255$ keV with a peak cross section of about 11.0 b (1972ME17, 1960HU1A, 1968HI1E). See also (1968FA1D). The elastic contribution is 7.2 b (1961LA1A). No other clearly defined resonance is observed although the total cross section exhibits its a broad maximum at $E_n \approx 5$ MeV (1954JO17, 1960HU1A). The coherent scattering length (thermal, bound) is $1.8 + 0.25$i fm (1969BA1P, 1973MU14).

Angular distributions are tabulated by (1970GA1A) and in reaction 11 of ^{6}Li. All observations near the 255 keV resonance are consistent with p-wave formation of a $J^\pi = \frac{5}{2}^-$ level [^{7}Li*(7.47)]. Table 7.3 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 (1959GA08, 1963MC09).

The excitation function for 3.56 MeV γ-rays exhibits an anomaly, also seen in the (n, p) reaction [reaction 6]. The data are well fitted assuming $E_{res} = 3.50$ and 4.60 MeV [$E_x = 10.25 \pm 0.10$ and

† $E_\gamma = 477.6 \pm 0.5$, 6770.4 ± 1.5 and 7246.6 ± 1.5 keV, and the branching ratios are 61 ± 1 and 39 ± 1% to the ground state and to $E_x = 477.6 \pm 0.5$ keV (E.T. Jurney, private communication).

Table 7.3: Resonance parameters for $7.5 - 7.2$ MeV levels in ^{7}Li and ^{7}Be

Reaction	^{6}Li + n		^{6}Li + p
Refs.	a	b	c
E_r (keV, lab)	262	255	1840
$\Gamma(E_r)$ (keV, c.m.)	154	65	836
E_λ (keV above g.s.)	7700		7580
$\Gamma_{n,p}(E_r)$ (keV, c.m.)	118	46.8	798
radius (n, p) in fm	3.94		4.08
$\gamma^2_{n,p}$ (MeV · fm)	4.85		5.02
$\theta^2_{n,p}$	0.26		0.28
$\Gamma_\alpha(E_r)$ (keV, c.m.)	36	18.5	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)). See also (1965SC07).
[b] (1972ME17).
[c] (1963MC09).

11.19 ± 0.05 MeV]. $T = \frac{1}{2}$ and $\frac{3}{2}$, $\Gamma_{cm} = 1.40 \pm 0.10$ and 0.27 ± 0.05 MeV, respectively. Both states have $J^\pi = \frac{3}{2}^-$. The reduced widths for the $T = \frac{3}{2}$ state [^{7}Li*(11.19)] are $\theta^2_n = 2 \times 10^{-4}$, $\theta^2_{n''} = 0.16$ [to ^{6}Li*(3.56)] and $\theta^2_p = 0.09$ (1969PR04). Cross-section measurements are also reported at $E_n = 1$ to 100 keV (1970AS1E), 4.8, 5.7 and 7.5 MeV (1968HO03), 10 MeV (1967CO01) and 14 MeV (1966ME1C). See also (1966AG1A, 1971RE07, 1973LA26; theor.).

Polarization measurements are reported at $E_n = 3.4$ MeV (1968WO1F) and at 4.4 MeV (1966ST09). See also (1967BE1F; theor.) and (1966LA04) for earlier measurements.

8. ^{6}Li(n, p)^{6}He $\quad Q_m = -2.727 \quad E_b = 7.2506$

The excitation function, measured from threshold to $E_n = 8.9$ MeV, exhibits an anomaly at $E_n = 4.6$ MeV: see reaction 6 (1969PR04).

See also (1966JE1B, 1971CU1B, 1971PR09, 1972ED01, 1973BO1Y).

9. ^{6}Li(n, d)^{5}He $\quad Q_m = -2.36 \quad E_b = 7.2506$

See (1969LI1F, 1973BO1Y) and (1966LA04).

10. ^{6}Li(n, 2n)^{5}Li $\quad Q_m = -5.66 \quad E_b = 7.2506$

See (1963AS01).

11. ^{6}Li(n, α)^{3}H $\quad Q_m = 4.7839 \quad E_b = 7.2506$

$Q_0 = 4.794 \pm 0.012$ (1967DE15).

Excitation functions and angular distributions are summarized in (1960HU1A, 1964ST25, 1966LA04, 1970GA1A). More recent cross-section measurements are reported by (1967CO1N: $E_n = 10.7$ to 102 keV), (1966BA1V: 25, 67 and 100 keV), (1970FO1E: 81.8 to 517 keV) [see below for thermal measurements]. Recent angular distributions are given in (1971OV1A: 0.10 to 1.80 MeV) and in (1966RO1L: 0.25, 0.39 and 0.60 MeV).

The isotropic thermal cross section is 938 ± 6 b (1970ME1F), 940 ± 4 b (1970SO1A) [the value listed in (1966LA04) is in error: it should have been 945 b]. Below 5 keV, the total cross section is given by $\sigma = (149.5/\sqrt{E}(\text{eV})) + 0.696$ b (1970SO1A). (1970SO1A) have also measured the ratio of (n, α) cross sections for ^{6}Li and ^{10}B in the range $E_n = 10$ eV to 80 keV.

A resonance occurs at $E_n = 258$ keV, with $\sigma_{max} = 2.75$ b (1959BA46), 2.80 ± 0.22 b (1959GA08). The resonance is formed by p-waves, $J^\pi = \frac{5}{2}^-$, and has a large neutron width and a small α-width: see Table 7.3 (1959GA08). Above the resonance the cross section decreases monotonically to $E_n = 18$ MeV, except for a slight bump near $E_n = 1.6$ to 2.1 MeV (1959GA08, 1959MU25). See also (1970MC1A, 1971MA1Y, 1972ZV1A, 1973BO1Y, 1974BA1K), (1966JE1B, 1968GI1D, 1970DE1H) and (1966BL1C, 1966MA1L, 1968FA1D, 1968SE1A, 1972LA1F). For astrophysical implications, see (1964FO1A, 1965BU1C).

12. (a) ^{6}Li(d, p)^{7}Li $\quad Q_m = 5.0260$

(b) ^{6}Li(d, np)^{6}Li $\quad Q_m = -2.22464$

$Q_0 = 5.024 \pm 0.007$ (1967SP09).

Angular distribution measurements have been recently carried out at $E_d = 1$ to 2 MeV (1966BR25; p$_0$, p$_1$), 1.48 to 2.94 MeV (1968TU1A; p$_0$, p$_1$), 1.5 MeV (1965RI09; p$_0$, p$_1$, p$_2$), 2.9 MeV (1966RO1J; p$_0$, p$_1$), 4.5 to 5.5 MeV (1970PO03; p$_0$, p$_1$) and 12 MeV (1967SC29; p$_0$, p$_1$). See also (1969HO39, 1969VI06) and (1966LA04) for earlier references. The p$_0$ and the p$_1$ [$E_x = 477 \pm 2$ keV (1959AJ76)] groups show stripping patterns with $l_n = 1$. The p$_2$ [$E_x = 4.630 \pm 0.009$ MeV, $\Gamma_{cm} = 93 \pm 8$ keV (1966LA04)] angular distribution is isotropic (1960HA14). In addition the excitation of ^{7}Li*(7.47) with $E_x = 7.464 \pm 0.010$ MeV, $\Gamma_{cm} = 91 \pm 8$ keV, is also reported

(1957BR97). See also (1966LA04). Ratios of observed θ_{n}^2 [see Table 7.3 in (1966LA04)] are consistent with assignments ^{22}P to ^{7}Li*(0, 0.48) and ^{24}P to ^{7}Li*(7.47) (1960HA14, 1960MA32). At $E_{\mathrm{d}} = 12$ MeV spectroscopic factors for ^{7}Li*(0, 0.48) [$S = 0.90$, 1.15] derived by DWBA are in good accord with the shell model calculations of (1967CO32, 1967SC29). The angular correlation between p_1 and the 0.48 MeV γ-rays is isotropic (1959AJ76): ^{7}Li*(0.48) has $J^\pi = \frac{1}{2}$.

Using vector polarized deuterons with $E_{\mathrm{d}} = 10$ MeV, (1970FI07) determined the probabilities p_{j} for transfer of a neutron with total angular momentum j. The results are in quite good agreement with the shell-model calculations of (1965CO25, 1967CO32). The circular polarization of the 0.48 MeV γ-rays has been determined by (1966SC1E). See also ^{8}Be (1966AU1A, 1966BE1E, 1968BE1P, 1969LE22) and (1967OG1A).

A kinematically complete study of reaction (b) at $E_{\mathrm{d}} = 10$ MeV shows pronounced final state interactions vua ^{7}Li*(7.47) and possibly ^{7}Li*(9.6) [$\Gamma = 0.5 \pm 0.1$ MeV] (1971VO07). See also ^{8}Be.

13. ^{6}Li(t, d)^{7}Li $\qquad Q_{\mathrm{m}} = 0.9930$

See (1954AL35, 1961HO21, 1967BI1E).

14. ^{6}Li(α, ^{3}He)^{7}Li $\qquad Q_{\mathrm{m}} = -13.3279$

Not reported.

15. (a) ^{6}Li(^{6}Li, pα)^{7}Li $\qquad Q_{\mathrm{m}} = 3.552$
(b) ^{6}Li(^{9}Be, ^{8}Be)^{7}Li $\qquad Q_{\mathrm{m}} = 5.586$

See (1966LA04), ^{12}C in (1968AJ02) and ^{15}N in (1970AJ04).

16. ^{7}Li(γ, γ)^{7}Li

For a listing of lifetime measurements of ^{7}Li*(0.48), see Table 7.4 in (1966LA04): $\tau_{\mathrm{m}} = 0.107 \pm 0.005$ psec.

17. (a) ^{7}Li(γ, n)^{6}Li $\qquad Q_{\mathrm{m}} = -7.2506$
(b) ^{7}Li(γ, 2n)^{5}Li $\qquad Q_{\mathrm{m}} = -12.91$

(c) ^{7}Li(γ, p)^{6}He $Q_{\rm m} = -9.978$

(d) ^{7}Li(γ, pn)^{5}He $Q_{\rm m} = -11.84$

(e) ^{7}Li(γ, d)^{5}He $Q_{\rm m} = -9.61$

(f) ^{7}Li(γ, t)^{4}He $Q_{\rm m} = -2.4668$

Reports on the structure of the (γ, n) cross section [reaction (a)] differ widely. The total photoneutron cross section rises sharply from 10 MeV to reach a broad plateau of about 1.5 mb from 14 to 20 MeV, decreases more slowly to about 0.5 mb at 25 MeV and then remains approximately constant to 30 MeV. There are indications of weak structure through the entire region particularly at $E_{\gamma} = 7.5$ and 10.5 MeV (1973BR1M; monoenergetic photons). See also (1954GO1A, 1958RY77, 1966BR1M). There are many reports of fine structure [see Table 7.5 in (1966LA04) and (1965HA19, 1965WA19, 1966BA1W)]. See also (1970HA1F) and (1968KA1D, 1968RA1E, 1969MU1C). The integrated cross sections from threshold to 32 MeV are 20 MeV · mb and 10 MeV · mb for the total neutron yield and for reaction (b), respectively (1966BR1M). See also (1971KA70, 1973AH1A).

The cross section for the (γ, p) reaction (reaction (c)) shows a maximum at ≈ 15.6 MeV with a width of ≈ 4 MeV (1954TI16, 1962GR08) [however a number of authors claim the existence of many additional peaks: see (1966LA04)]. The energy distribution of the photoprotons has been measured with bremsstrahlung radiation $E_{\rm bs} = 50$ to 34 MeV (1970SA14) and 100 MeV (1968MA19) and at $E_{\gamma} = 60$ MeV (1973GA16). The polarization of the protons produced in the interaction between high-energy γ-rays and ^{7}Li has been studied by (1969AN20, 1970TO09). See also ^{6}He and (1966MA17, 1967DE11, 1969AN1H, 1969MU1C, 1970AN05, 1970WO10, 1971AN04, 1973DO13) and (1970HA1F).

For reaction (d) see (1967SM1A). For reaction (e) see (1967DE11, 1969AN1H, 1971AN04, 1972AN1L). A number of peaks have been reported in the (γ, t) cross section: see Table 7.5 in (1966LA04) and (1970SE1D). See also (1965DA06, 1966DZ07, 1966MA17, 1967DE11, 1969HU1E, 1970DE1Q, 1970SE1A). See also (1967SH1E, 1973AR1L, 1973CO1N) and (1968EL06, 1970RA1H, 1973AS02; theor.).

18. (a) ^{7}Li(e, e$'$)^{7}Li*

(b) ^{7}Li(e, ep)^{6}He $Q_{\rm m} = -9.978$

The electric form factor measurements for $E_{\rm e} = 100$ to 600 MeV are well accounted for by a simple harmonic oscillator shell model with a quadrupole contribution described by an undeformed p-shell: $R_{\rm rms} = 2.39 \pm 0.03$ fm, $|Q| = 42 \pm 2.5$ mb (1967SU1A). From results obtained for $E_{\rm e} = 24.14$ to 97.19 MeV, $R_{\rm rms} = 2.35 \pm 0.10$ fm (model independent), 2.29 ± 0.04 fm (shell model) (1969MO1J, 1972BU01). A study of the ratio of the electric charge scattering from ^{6}Li and from ^{7}Li as a function of (momentum transfer)^2 yields $\langle r^2\rangle_6^{1/2}/\langle r^2\rangle_7^{1/2} = 1.001 \pm 0.008$. The r.m.s. radius of the ground-state magnetization density distribution, $\langle r^2\rangle_{\rm M}^{1/2} = 2.98 \pm 0.05$ fm. From the ratio of

Table 7.4: Levels of ^{7}Li(e, e′)^{7}Li* [a]

E_x (MeV)	$J^\pi; T$	$\Gamma_{\gamma 0}$ (eV)	Type	$\Gamma_{\gamma 0}/\Gamma_W$	Refs.
0.48	$\frac{1}{2}^-; \frac{1}{2}$	$(2.8 \pm 1.6) \times 10^{-7}$	E2	18	(1971VA20)
		$(6.30 \pm 0.31) \times 10^{-3}$	M1	2.8	(1971VA20)
4.63 ± 0.05	$\frac{7}{2}^-; \frac{1}{2}$		E2 [e]		(1963BE26, 1963BE53, 1968HU1C, 1969HU05)
6.6 ± 0.1 [b]	$\frac{5}{2}^-; \frac{1}{2}$		E2		(1968HU1C, 1969HU05)
7.5 ± 0.08	$\frac{5}{2}^-; \frac{1}{2}$	0.6 ± 0.3	E2		(1963BA19, 1963BE26)
		0.9 ± 0.4 [f]			(1964GR1A) [g]
[c]					
11.25 [d]	$\frac{3}{2}^-; \frac{3}{2}$	1.3 ± 0.4	M1	0.043	(1967AR1A)

[a] For a summary of B(E2↑) measurements, see Table 7.6 in (1966LA04) and ^{7}Li, the "GENERAL" section.
[b] $\Gamma_{\mathrm{c.m.}} = 875^{+200}_{-100}$ keV (1968HU1C, 1969HU05).
[c] The excitation of ^{7}Li*(10.5, 12.5, 14.0) is reported by (1963BA19).
[d] $\Gamma_{\mathrm{cm}} = 200 \pm 100$ keV (1967AR1A).
[e] Purely longitudinal (1968HU1C, 1969HU05).
[f] $0.1 \rightarrow 0.5$ eV, from ^{7}Li(γ, n) (B.L. Berman, private communication).
[g] From ^{7}Li(γ, n).

the transverse inelastic and elastic cross sections at $180°$, B(M1,↑; 0.48) $= 2.50 \pm 0.12\ \mu_N^2$. The cross section of the longitudinal excitation of ^{7}Li*(0.48) has been found from the scattering through angles of $90°$ to $150°$, B(C2,↑; 0.48) $= 7 \pm 4$ fm^4. The harmonic oscillator length parameter of the 1p shell is found to be $a_{1p} = 1.90 \pm 0.03$ fm (1971VA20).

The magnetic form factor has been measured for $E_e = 70$ to 200 MeV. The ratio of the magnetic octupole moment to the dipole moment $\Omega/\mu = 2.30 \pm 0.50$ fm^2 (1966RA29).

Inelastic scattering studies show peaks corresponding to ^{7}Li*($0+0.48$, 4.63, 6.68, 7.47, 11.25): see (1967AR1A, 1968HU1C, 1969HU05), (1966LA04) and Table 7.4. See also the review by (1972THZF). For reaction (b) see (1970WO10).

See also (1970WA1N), (1966GO1C, 1966GU1C, 1968GO1J) and (1966MU1A, 1967BO22, 1967EL1B, 1967KA1A, 1968BO1R, 1968KU1D, 1968KU1B, 1969HA1N, 1969KR16, 1969KU1C, 1969VI02, 1969WI21, 1972DR1B, 1973HI03; theor.).

19. (a) ^{7}Li(n, n′)^{7}Li*
(b) ^{7}Li(n, nt)^{4}He $\qquad Q_m = -2.4668$

Angular distributions have recently been measured at $E_n = 1.12$ to 2.30 MeV (1968KN1B; n_0, n_1), 3.35 and 4.83 MeV (1968HO03; n_0), 5.74 and 7.50 MeV (1968HO03; $n_0 + n_1$) and 14 MeV (1966RE1B; $n_0 + n_1$, n_2). See (1966LA04) for a listing of earlier references and (1970GA1A). At

$E_n = 14$ MeV no states other than ^{7}Li*(0, 0.48, 4.63) are populated (1968HA1J): see, however, (1954AL24, 1966RE1B). See also (1966HU1B, 1967CO01) and (1969WA11; theor.). See also ^{8}Li. For reaction (b) see (1972AN1Q) and ^{5}He.

20. ^{7}Li(p, p′)^{7}Li*

Angular distributions are reported at $E_p = 1.0$ to 2.0 MeV (1966BA1Q; p_0, p_1), 24.4 MeV (1967CR1E; p_0, p_1, p_2), 33.6 MeV (1970KU1D; p_0), 49.8 MeV (1971MA13, 1971MA44; p_0, p_1, p_2), 100 MeV (1966MA38, 1968LI1C; $p_0 + p_1$, p_2), 144 MeV (1972JA07; p_0), 152 MeV (1966RO1C; p_0), 155 MeV (1968GE04; p_0, p_1, p_2) and 185 MeV (1967JO1F; p_1). (1967CR1E) report that the p_2 group is strongly excited and that the angular distribution is consistent with the predictions of the collective model for an $l = 2$ transition. Earlier measurements are reported in (1966LA04).

Inelastic proton groups have been observed corresponding to ^{7}Li*(0.48, 4.63, 6.68, 7.47): see (1952AJ38). At $E_p = 185$ MeV proton groups are observed to these states [$E_x = 4.62 \pm 0.04$, 6.55 ± 0.20, 7.5 ± 0.2 MeV: (1967JO1F)] as well as to states at $E_x = 5.5 \pm 0.3$ MeV ($\Gamma \approx 0.4$ MeV) (1965HA17: not seen by (1967JO1F)) and 9.6 ± 0.2 MeV (1965HA17), 9.4 ± 0.2 MeV (1967JO1F). The width of ^{7}Li*(6.7) is ≈ 1 MeV (1965HA17). At $E_p = 50$ MeV (1968MA02) report ten states of ^{7}Li with $E_x < 13.6$ MeV.

$\tau_m(0.48) = 0.106 \pm 0.014$ psec (1966PA11: Doppler shift measurement), a value consistent with intermediate coupling with LS coupling predominating ($a/K < 3.6$): see also Table 7.4 in (1966LA04). Analysis of the 155 MeV data yields B(E2↑) $= 10.5 \pm 2$, 28 ± 6 and 4.5 ± 2.3 fm^4 for ^{7}Li*(0.48, 4.63, 6.68); Γ(E2↓) = 0.43, 0.025 and 0.029 μeV (1965JA1A).

A comparison of σ_t for ^{7}Li(p, p′)^{7}Li*(0.48) and ^{7}Li(p, n)^{7}Be*(0.43) has been carried out for $E_p = 23$ to 52 MeV: the spin-flip, isospin-flip part of the effective interaction is approximately independent of energy while the pure central part appears to decrease with increasing energy (1967LO07). See also (1966MA1N, 1968GL1A, 1968NE1B, 1969MA1P, 1969NE1A, 1969TI02, 1969WA11, 1970KI1E, 1973KA04; theor.).

21. (a) ^{7}Li(p, 2p)^{6}He	$Q_m = -9.978$
(b) ^{7}Li(p, pn)^{6}Li	$Q_m = -7.2506$
(c) ^{7}Li(p, pd)^{5}He	$Q_m = -9.61$
(d) ^{7}Li(p, pα)^{3}H	$Q_m = -2.4668$
(e) ^{7}Li(p, α)^{4}He	$Q_m = 17.348$
(f) ^{7}Li(p, 2d)^{4}He	$Q_m = -6.500$

For reaction (a) see ^{6}He. See also (1966LA04), (1973CO2B) and (1965BE1E, 1966JA1A, 1967EL1C, 1967JA1E, 1968JA1G, 1969KO1J; theor.). For reaction (b) see (1970TH1F). For reaction (c) see reaction 20 in ^{6}Li and (1973CO2B, 1973KO1M). The momentum distribution of the α-particles in reaction (d) has the shape expected for the knockout of an $L = 1$ α-cluster from ^{7}Li (1970JA17). The reaction proceeds sequentially via ^{7}Li*(4.63) (1967JO1C, 1970JA17) and via ^{7}Li*(6.68) (1970JA17). See also (1969HO1K, 1971GA1J, 1973CO2B), (1972RA1E) and (1972JA23; theor.). For reaction (e) see ^{8}Be. For reaction (f) see (1972FU07, 1973CO2B) and reaction 20 in ^{6}Li.

22. ^{7}Li(d, d′)^{7}Li*

Angular distributions have been measured at $E_d = 11.8$ MeV (1968LU02; d_0, d_1), 12 MeV (1971BI11; d_0), 14.7 MeV (1969MA13; d_0, d_1, d_2) and 28 MeV (1962SL02; d_0, d_2). See also (1970EL16; theor.) and (1966LA04).

23. ^{7}Li(^{3}He, ^{3}He′)^{7}Li*

Angular distributions are reported at $E(^3\text{He}) = 8.7$ and 9.7 MeV (1969MA1J; elastic), 11 MeV (1970SC23; elastic), 21, 24 and 27 MeV (1966VA1B, 1967BL1E: to ^{7}Li*(0, 0.48, 4.63)) and 25.2 MeV (1968BR1G: to ^{7}Li*(0, 0.48, 4.63). See also (1967CO1J).

24. (a) ^{7}Li(α, α')^{7}Li*
(b) ^{7}Li(α, 2α)^{3}H $\quad\quad Q_m = -2.4668$

Angular distributions (reaction (a)) are reported at $E_\alpha = 3.6$ MeV (1972BO07; α_0, α_1), 12.0 to 18.0 MeV (1970BI1B, 1971BI12; α_0), 25 MeV (1969DO1H; $\alpha_0 + \alpha_1$, α_2) and 29.4 MeV (1968MA25, 1969MA13; α_0, α_1, α_2). See also (1972BE1Z).

Reaction (b) has been studied at $E_\alpha = 23.6$ MeV (1968BE1Q), 25 MeV (1969DO02, 1969DO03, 1969DO1H), 29.4 MeV (1968MA25), 50 MeV (1970LA14, 1973LA1Q), 55 MeV (1968PI04, 1969PI11, 1970PI1D), 64.3 MeV (1970JA17) and 104 MeV (1969VE1B). ^{7}Li*(4.63) is strongly involved in the sequential decay: see (1968MA25, 1969DO1H, 1970JA17, 1970LA14). The population of ^{7}Li*(7.48) is reported by (1970LA14), and (1968MA25) suggests that ^{7}Li*(6.68) is also involved in the sequential decay. At $E_\alpha = 55$ MeV, the effective number of α clusters, $N_{\text{eff}} = 4^{+4}_{-2}$% (1969PI11). See also (1969BA2C), (1969HO1K, 1971GA1J) and (1968BA1H, 1972AV04; theor.). See also (1966LA04).

25. ^{7}Li(^{7}Li, ^{7}Li)^{7}Li

The elastic angular distribution has been studied for $E(^7\text{Li}) = 4.0$ to 6.5 MeV (1966PI02).

26. ^{7}Li(^{10}B, ^{10}B)^{7}Li

See (1969RO1G) and ^{10}B.

27. (a) ^{7}Li(^{12}C, ^{12}C)^{7}Li
(b) ^{7}Li(^{13}C, ^{13}C)^{7}Li

The elastic scattering has been studied at $E(^7\text{Li}) = 20$ MeV (1969BE90) [on ^{13}C] and at 34 [^{13}C] and 36 [^{12}C] MeV (1973SC26). See also ^{12}C in (1975AJ02) and ^{13}C in (1976AJ04). The inelastic scattering angular distributions involving $^7\text{Li}^*_{0.48} + {}^{12}\text{C}_{\text{g.s.}}$ and $^7\text{Li}^*_{0.48} + {}^{12}\text{C}^*_{4.43}$ have been measured at $E(^7\text{Li}) = 36$ MeV (1973SC26).

28. ^{7}Li(^{16}O, ^{16}O)^{7}Li

See (1969BE90, 1971OR02).

29. ^{7}Li(^{20}Ne, ^{20}Ne′)^{7}Li*

See (1966LA04).

30. ^{7}Be(ϵ)^{7}Li $\qquad Q_{\text{m}} = 0.862$
$Q_0 = 0.851 \pm 0.012$ (1973MU19).

The decay proceeds to the ground and 0.48 MeV states. The branching ratio to ^{7}Li*(0.48) is 10.32 ± 0.16% (1962TA11), 10.4 ± 0.3% (1972SZ02), 10.42 ± 0.18% (1973PO10). [See also Table 7.8 in (1966LA04)]. The weighted mean value of the half-life is 53.44 ± 0.09 days (1949SE20, 1953KR16, 1956BO36, 1970JO21). Both transitions are superallowed. Log $ft = 3.30$ and 3.54 for the decays to ^{7}Li*(0, 0.48) respectively‡ .

The energy of the γ-ray is 477.57 ± 0.05 keV (1967BL03), 477.4 ± 0.2 keV (1965RO09), 477.593 ± 0.012 keV (1971HE20) [$E_{\text{x}} = 477.611 \pm 0.012$ keV]. A measurement of the bremsstrahlung

‡ G. Fox and B. Zimmerman, private communication.

spectrum to ^{7}Li*(0.48) measured in coincidence with the 478 keV γ-ray, leads to a transition energy of 395 ± 25 keV (1971LA03), 388 ± 8 keV (1972PE05). See also (1973MU19).

For discussions of astrophysical considerations, see (1969BA1U, 1969FO1D, 1969YI1B, 1971CA1B, 1972BA2M, 1972KO1A, 1973BA2C). See also (1967GE1A, 1969HE1M, 1973HE1M), (1972EM03) and (1965PR04, 1966EL08, 1966BA26, 1968FI02, 1969LE1D, 1969SU15, 1970DA21, 1970FA14, 1970KO41, 1973HA49, 1973MU12, 1973WI11; theor.).

31. ^{9}Be(γ, d)^{7}Li $\quad Q_{\rm m} = -16.6965$

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

32. ^{9}Be(n, t)^{7}Li $\quad Q_{\rm m} = -10.4389$

See ^{10}Be and (1966LA04).

33. ^{9}Be(p, ^{3}He)^{7}Li $\quad Q_{\rm m} = -11.2027$

At $E_{\rm p} = 43.7$ angular distributions have been obtained for the ^{3}He particles corresponding to ^{7}Li*(0, 0.48, 4.63, 7.47). The 7.47 MeV state is strongly excited while the mirror state in ^{7}Be is not appreciably populated in the mirror reaction (see reaction 17 in ^{7}Be). The angular distribution indicates that the transition to ^{7}Li*(7.47) involves both $L = 0$ and 2, with a somewhat dominant $L = 0$ character (1966CE05). Reanalysis of the data of (1965DE08) places the $J^\pi = \frac{3}{2}^-$; $T = \frac{3}{2}$ level at $E_{\rm x} = 11.28 \pm 0.04$ MeV, $\Gamma = 260 \pm 50$ keV (1967MC14). See also (1969BA1Z, 1969IN1A).

34. ^{9}Be(p, pd)^{7}Li $\quad Q_{\rm m} = 16.6965$

See (1966LA04).

35. (a) ^{9}Be(d, α)^{7}Li $\quad Q_{\rm m} = 7.1511$

(b) ^{9}Be(d, t)^{4}He^{4}He $\quad Q_{\rm m} = 4.684$

$Q_0 = 7.157 \pm 0.008$ (1967SP09).

Angular distributions have been measured recently at $E_d = 0.3$ to 1.0 MeV (1968BE1E; α_0, α_1), 0.9 to 2.2 MeV (1971SA27; α_0, α_1), 11.4 and 12.4 MeV (1966DO1A; α_0, α_1). For older measurements see (1966LA04). A study at $E_d = 11$ MeV finds $\Gamma_{cm} = 93 \pm 25$ and 80 ± 20 keV, respectively, for ^{7}Li*(4.63, 7.47). No evidence was observed for ^{7}Li*(5.5, 8.6, 9.7, 12.5) or for the $T = \frac{3}{2}$ state ^{7}Li*(11.25) (1966HA09). See also (1964MA57, 1966JA05) and (1966ME1E; theor.). In a kinematically complete study of reaction (b) at $E_d = 26.3$ MeV, ^{7}Li*(4.6, $6.5 + 7.5$, 9.4) are strongly excited. No sharp α-decaying states of ^{7}Li are observed with $10 < E_x < 25$ MeV. Parameters for ^{7}Li*(9.6) are $E_x = 9.36 \pm 0.05$ MeV, $\Gamma = 0.8 \pm 0.2$ MeV (1973SO08). See also ^{8}Be.

36. ^{9}Be(^{3}He, αp)^{7}Li $\qquad Q_m = 1.657$

See (1967ST1D).

37. ^{9}Be(^{6}Li, 2α)^{7}Li $\qquad Q_m = 5.677$

See (1966SA04, 1968JA08) and ^{11}B in (1975AJ02).

38. (a) ^{10}B(n, α)^{7}Li $\qquad Q_m = 2.791$
(b) ^{10}B(n, t)^{4}He^{4}He $\qquad Q_m = 0.3237$
$Q_0 = 2.8008 \pm 0.0076$ (1967DE15).

At $E_n = 14.4$ MeV angular distributions have been measured for the $n_0 + n_1$ and for the n_2 groups (1969AN25). The half-life of ^{7}Li*(0.48) is 92 ± 11 fsec (1967CA02). See also (1966LA04), ^{11}B in (1975AJ02), (1969VA1F, 1970NE03, 1972SE1K) and (1972HA04; theor.). For reaction (b) see (1967VA12).

39. ^{10}B(α, ^{7}Be)^{7}Li $\qquad Q_m = -16.202$

See reaction 19 in ^{7}Be (1969FO06).

40. ^{11}B(γ, α)^{7}Li $\qquad Q_m = -8.666$

See ^{11}B in (1975AJ02) and (1969MU10).

41. ^{11}B(p, pα)^{7}Li $Q_{\rm m} = -8.666$

See (1964BA1C).

42. (a) ^{11}B(α, 2α)^{7}Li $Q_{\rm m} = -8.666$
(b) ^{11}B(α, ^{8}Be)^{7}Li $Q_{\rm m} = -8.758$

For reaction (a) see (1966GE12, 1969FU09). Angular distributions have been measured in reaction (b) at $E_\alpha = 28.4$ and 29.0 MeV for the transitions to ^{8}Be*(0, 2.9) and ^{7}Li*(0, 0.48) (1968KA24). At $E_\alpha = 65$ MeV ^{7}Li*(0, 4.63) are strongly populated and ^{7}Li*(7.47) is weakly excited. The intensity of the group to ^{7}Li*(0.48) is < 15% of the group to ^{7}Li(0) (1973WO06). See also (1966GE12).

43. ^{11}B(d, ^{6}Li)^{7}Li $Q_{\rm m} = -7.192$

At $E_{\rm d} = 19.5$ MeV, angular distributions have been measured for the transitions to ^{6}Li(0) and ^{7}Li*(0, 0.48) (1971GU07). At $E_{\rm d} = 40$ MeV the cross section for the transition to ^{6}Li*(3.56) + ^{7}Li(0) is half that for ^{6}He(0)+^{7}Be(0) [to ± 10%] in agreement with isospin conservation (1972GO1P). See also (1972GA1E).

44. ^{11}B(^{16}O, ^{20}Ne)^{7}Li $Q_{\rm m} = -3.936$

See (1968OK06).

45. ^{12}C(d, ^{7}Be)^{7}Li $Q_{\rm m} = -17.543$

At $E_{\rm d} = 39.8$ MeV, angular distributions have been measured for the transitions to ^{7}Li(0) + ^{7}Be(0), ^{7}Li*(0.48) + ^{7}Be(0), ^{7}Li(0) + ^{7}Be*(0.43), and ^{7}Li*(0.48) + ^{7}Be*(0.43). Asymmetries exceeding 20% are observed in the ratio of the cross sections to ^{7}Li(0) and ^{7}Be(0) (1971HO1K, 1971YO06). See also (1971SI28; theor.).

46. ^{12}C(^{3}He, ^{8}B)^{7}Li $Q_{\rm m} = -22.899$

This reaction has been studied at $E(^{3}{\rm He}) = 40.7$ MeV (1971DE37).

47. ^{12}C(^{6}Li, ^{11}C)^{7}Li $\qquad Q_{\rm m} = -11.471$

At $E(^{6}\rm Li) = 36$ MeV, angular distributions have been obtained for the transitions involving $^{7}\rm Li_{g.s.} + {}^{11}C_{g.s.}$ and $^{7}\rm Li^{*}_{0.48} + {}^{11}C_{g.s.}$ (1973SC26).

48. ^{13}C(p, ^{7}Be)^{7}Li $\qquad Q_{\rm m} = -20.264$

At $E_{\rm p} = 45.0$ MeV angular distribution has been measured for the transition to ^{7}Be(0)$+$^{7}Li(0) (1971BR07).

49. ^{13}C(d, ^{8}Be)^{7}Li $\qquad Q_{\rm m} = -3.589$

At $E_{\rm d} = 14.6$ MeV, angular distributions are reported for the transitions to ^{8}Be(0) and ^{7}Li*(0, 0.48) (1967DE03).

50. ^{13}C(^{6}Li, ^{12}C)^{7}Li $\qquad Q_{\rm m} = 2.304$

At $E(^{6}\rm Li) = 34$ MeV angular distributions have been measured for the transitions involving $^{7}\rm Li_{g.s.} + {}^{12}C_{g.s.}$, $^{7}\rm Li^{*}_{0.48} + {}^{12}C_{g.s.}$, $^{7}\rm Li_{g.s.} + {}^{12}C^{*}_{4.4}$, and $^{7}\rm Li^{*}_{0.48} + {}^{12}C^{*}_{4.4}$ (1973SC26).

51. ^{14}N(n, 2α)^{7}Li $\qquad Q_{\rm m} = -8.823$

At $E_{\rm n} = 14.1$ MeV, ^{7}Li*(0, 0.48) are produced with about equal probability (1971SC16).

52. ^{16}O(α, ^{13}N)^{7}Li $\qquad Q_{\rm m} = -22.566$

See (1972RU03).

53. ^{16}O(^{6}Li, ^{15}O)^{7}Li $\qquad Q_{\rm m} = -8.419$

At $E(^{6}\rm Li) = 36$ MeV, angular distributions have been determined for the transitions involving $^{7}\rm Li_{g.s.} + {}^{15}O_{g.s.}$ and $^{7}\rm Li^{*}_{0.48} + {}^{15}O_{g.s.}$ (1973SC26).

54. (a) ^{17}O(d, ^{12}C)^{7}Li $\qquad Q_{\rm m} = -2.580$

(b) ^{18}O(d, ^{13}C)^{7}Li $\qquad Q_{\rm m} = -5.680$

(c) ^{19}F(d, ^{14}N)^{7}Li $\qquad Q_{\rm m} = -6.122$

At $E_{\rm d} = 14.6$ to 15.0 MeV, angular distributions have been measured for the transitions to ^{12}C(0) + ^{7}Li*(0, 0.48) [reaction (a)], ^{13}C(0) + ^{7}Li*(0, 0.48) [reaction (b)] and ^{14}N(0) + ^{7}Li*(0, 0.48) [reaction (c)] (1967DE03).

^{7}Be
(Figs. 9 and 10)

GENERAL: (See also (1966LA04).)

Shell model: (1961KO1A, 1965VO1A, 1966BA26, 1966HA18, 1967FA1A, 1968GO01, 1969TA1H, 1971CO28, 1971NO02, 1972LE1L, 1973HA49).

Cluster model: (1965NE1B, 1968HA1G, 1971NO02, 1972HI16, 1972KU12, 1972LE1L).

Rotational and deformed models: (1965VO1A, 1966EL08).

Special levels: (1966BA26, 1966EL08, 1967FA1A, 1969HA1G, 1969HA1F, 1971CO28, 1971NO02, 1972BB26, 1973AS02, 1973FE1J).

Electromagnetic transitions: (1966BA26, 1966EL08, 1969HA1G, 1969HA1F, 1973AS02, 1973HA49).

Astrophysical questions: (1968BA2F, 1968HA1C, 1970BA1M, 1972KO1E, 1972PA1C, 1972UL1A, 1973LA19, 1973RA37, 1973SC1T).

Special reactions: (1965FU1A, 1966GA15, 1966MI1C, 1967AU1B, 1967FU1E, 1967WI06, 1967WI20, 1968BE1F, 1968DI1B, 1968HU1D, 1968MI1D, 1968RA34, 1968SH1H, 1968YI01, 1969DI18, 1969HI1A, 1969YI1A, 1970BR13, 1970MA1E, 1971AR02, 1971BA58, 1971BI22, 1971BR36, 1971DM01, 1971EP02, 1971HE24, 1971MO1H, 1971NO09, 1971ST30, 1972AM04, 1973ER1G, 1973HO11, 1973JO07, 1973LA19, 1973MI02, 1973VO1G).

Reactions involving pions: (1968BE1F).

Other topics: (1965BO1C, 1965VO1A, 1966DE1E, 1966HA18, 1966YO1B, 1967CA17, 1967FA1A, 1968BE1F, 1968GO01, 1969HE1N, 1969VI1C, 1970DE1P, 1971ZA1D, 1972AB14, 1972AN05, 1972BB26, 1972CA37, 1972LE1L, 1972PN1A, 1973JU2A, 1973RO1R).

Ground-state properties: (1965VO1A, 1966BA26, 1966EL08, 1969PE1D, 1972LE1L, 1973MA1K).

1. ^{7}Be(ϵ)^{7}Li $\qquad Q_{\rm m} = 0.8618$

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

2. ^{4}He(^{3}He, γ)^{7}Be $\qquad Q_{\rm m} = 1.5864$

In the range $E_{\alpha} = 0.38$ to 5.80 MeV the cross section rises from 8×10^{-3} to 4 μb (1963PA12, 1969NA24). The capture proceeds mainly by E1, with both s- and d-waves contributing above

Table 7.5: Energy levels of ^{7}Be

E_x (MeV $\pm$ keV)	$J^\pi; T$	τ or $\Gamma_{c.m.}$	Decay	Reactions
g.s.	$\frac{3}{2}^-; \frac{1}{2}$	$\tau_{1/2} = 53.44 \pm 0.09$ d	ϵ	1, 2, 4, 5, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31
0.42920 ± 0.10	$\frac{1}{2}^-; \frac{1}{2}$	$\tau_m = 192 \pm 20$ fsec	γ	5, 10, 11, 12, 13, 14, 15, 16, 17, 18, 22, 23, 24, 25, 28, 29, 30, 31
4.57 ± 50	$\frac{7}{2}^-; \frac{1}{2}$	$\Gamma = 175 \pm 7$ keV	^{3}He, α	3, 12, 13, 14, 15, 16, 17, 19
6.73 ± 100	$\frac{5}{2}^-; \frac{1}{2}$	1.2 MeV	p, ^{3}He, α	3, 9, 10, 16, 17
7.21 ± 60	$\frac{5}{2}^-; \frac{1}{2}$	0.5 MeV	p, ^{3}He, α	3, 6, 9, 10, 13, 17
9.27 ± 100	$\frac{7}{2}^-; \frac{1}{2}$		p, ^{3}He, α	3, 13
9.9	$\frac{3}{2}^-; \frac{1}{2}$	≈ 1.8 MeV	p, ^{3}He, α	3, 6
$\gtrsim 10.0$	$\frac{1}{2}^-; \frac{1}{2}$	broad	p, ^{3}He, α	3
11.01 ± 30	$\frac{3}{2}^-; \frac{3}{2}$	320 ± 30	p, ^{3}He, α	3, 6, 13, 16

$E_\alpha = 1$ MeV (1963TO06). The branching ratio γ_1/γ_0 [^{7}Be*(0.43)/^{7}Be(0)] is approximately constant at 37% for $E_\alpha = 0.57$ to 3.2 MeV (1963PA12, 1969NA24). The zero-energy intercept of the cross-section factor $S = 0.61 \pm 0.07$ keV · b and (dS/dE)$_0$ $= -(5.8 \pm 0.3) \times 10^{-4}$ b using all of the data. If the low-energy data ($E_{cm} \leq 0.7$ MeV) is fitted using a direct capture calculation (1963TO06) the zero-energy intercept of the cross-section factor is $S = 0.51 \pm 0.05$ keV · b and (dS/dE)$_0$ $= -(2.8 \pm 0.4) \times 10^{-4}$ b (1969NA24). A second-order (in energy) polynominal fit to the low-energy data ($E_{cm} \leq 0.8$ MeV) determines $S = 0.61 \pm 0.07$ keV · b and (dS/dE)$_0$ $= -(5.8 \pm 0.3)$ b (1969NA24). Recent papers discussing the astrophysical implications of this reaction are (1967TO1B, 1968BA2E, 1971CA1B, 1972KA1B, 1973BA2C, 1973TR1E). See also (1966LA04).

3. (a) ^{4}He(^{3}He, ^{3}He)^{4}He $\quad E_b = 1.5864$

(b) ^{4}He(^{3}He, p)^{6}Li $\quad Q_m = -4.0200$

Elastic scattering studies have previously been reported for $E(^{3}\text{He}) = 2.5$ to 30 MeV and for $E_\alpha = 11$ to 41 MeV: See (1966LA04). More recent measurements have been made at $E(^{3}\text{He}) =$ 1.72, 2.46, 2.98 MeV (1971CH42), 5 to 18 MeV (1967SP10), 12.0 to 19.0 MeV (1967DU1B), 17.8

to 30.0 MeV (1970JA04), 18 to 70 MeV (1969BA2B), 19.5 to 51.1 MeV (1970BR42), 27.2 to 42.8 MeV (1969SC16) and at $E_\alpha = 5.94$ to 7.90 MeV (1968IV01), 42 MeV (1970VI01), 43.4 to 58.2 MeV (1969CA1E), 66 to 104 MeV (1971FE02, 1971FE03, 1973FE11) and 140 MeV (1972FR1J, 1972PU1C, 1972FR1K). Differential cross sections have been calculated by (1973KO1Q) for $E_{\rm cm} < 44.5$ MeV using the one-channel resonating=group method, and including exchange terms and odd-even absorption. Polarization measurements have been carried out at $E(^3{\rm He}) = 7.8$ to 13.0 MeV (1969AR07, 1971AR1K) and at 11.5 to 13.0 MeV (1970MC07), and at $E_\alpha = 4.33$ to 9.83 MeV (1972BO42), 7.5 to 18.5 MeV (1970HA1M, 1970HA1P, 1972HA64), 13.0 MeV (1971AR1K) and 98 MeV (1973FE11). The ratios of γ^2 to the Wigner limit are, respectively, $0.31^{-0.09}_{+0.04}$ and $0.29^{-0.16}_{+0.07}$ for ^{7}Be*(0, 0.43) (1972BO42).

For $l \leq 4$, only f-wave phase shifts show resonance structure for $E(^3{\rm He}) < 18$ MeV, corresponding to ^{7}Be*(4.57, 6.73, 9.27): see Table 7.6 (1967SP10, 1968IV01). No structure corresponding to ^{7}Be*(7.21) ($J^\pi = \frac{5}{2}^-$) is seen in the elastic data. The s-wave phase shift is somewhat greater than hard-sphere; the p-wave splitting agrees with (1964BA09, 1967SP10). The decay of ^{7}Be*(9.27) ($J^\pi = \frac{7}{2}^-$) to ^{6}Li(0) requires f-shell configuration admixture. An estimate of the yield of ground state protons relative to those corresponding to ^{6}Li*(2.19) yields $\gamma^2({\rm p}_0)/\gamma^2({\rm p}_1) = 16^{+5}_{-10}$% (1967SP10). At higher energies [$E(^3{\rm He}) = 27.2$ to 42.8 MeV] (1969SC16) report that the s- and f-wave phase shifts fall appreciably below the predictions of resonating group calculations, while (1970BR42) see some indication of broad resonant structure at $E(^3{\rm He}) \approx 34$ MeV, in rough qualitative agreement with such calculations. For inelastic scattering in reaction (a) see (1971HA21) and (1973FI04). The bremsstrahlung cross section at $E(^3{\rm He}) = 7.4$ MeV is 12.6 ± 3.4 μb/sr^2 (1973FR17).

The differential reaction cross section for reaction (b) has been determined for $E(^3{\rm He}) = 8$ to 18 MeV: resonances are observed corresponding to ^{7}Be*(7.21, 9.27) in the p_0 yield and to ^{7}Be*(9.27) in the p_1 yield: see Table 7.6 (1967SP10). A study of the gamma rays from ^{6}Li*(3.56) (p_2) carried out at $E(^3{\rm He}) = 13.8$ to 18.5 MeV shows the excitation of two $J^\pi = \frac{3}{2}^-$ states at $E_{\rm x} \approx 10.0$ MeV ($T = \frac{1}{2}$) and 11.00 ± 0.05 MeV ($\Gamma = 400 \pm 50$ keV, $\theta^2_{\rm p_2} = 0.13 \pm 0.02$, $T = \frac{3}{2}$). The $T = \frac{3}{2}$ resonance is evidenced mainly through interference. There is also evidence for an extremely broad $J^\pi = \frac{1}{2}^-$ structure at $E_{\rm x} \gtrsim 10$ MeV (1967HA07, 1967HA08: see also ^{6}Li(p, p)^{6}Li).

See also (1970LI06, 1972BI1G, 1973KO1R), (1966PH1A) and (1966BA26, 1966RA1B, 1966TH1C, 1967OK1A, 1968BR1H, 1968LE1K, 1969TA1G, 1970NE1F, 1971FU09, 1971KU22, 1971PL06, 1971TA23, 1972BR1Q, 1972CL1C, 1972NE17; theor.).

4. ^{4}He(α, n)^{7}Be $\qquad Q_{\rm m} = -18.9921$

See ^{8}Be.

5. ^{6}Li(p, γ)^{7}Be $\qquad Q_{\rm m} = 5.6064$

Table 7.6: ^{7}Be levels from ^{3}He + ^{4}He [a]

E_x (MeV $\pm$ keV)	J^π	l_α	LS term	R (fm)	θ^2_α [b]	θ^2_p	$\theta^2_{p'}$	Refs.
4.57 ± 50 [c]	$\frac{7}{2}^-$	3	$^2F_{7/2}$	4.0	0.70 ± 0.04			(1967SP10)
4.566				4.4	0.34			(1968IV01)
6.73 ± 100 [c]	$\frac{5}{2}^-$	3	$^2F_{5/2}$	4.0	1.36 ± 0.13	0.000 ± 0.002		(1967SP10)
7.21 ± 60 [c]	$\frac{5}{2}^-$	3	$^4P_{5/2}$	4.0	0.010 ± 0.001	0.26 ± 0.02		(1967SP10)
9.27 ± 100	$\frac{7}{2}^-$	3	$^4D_{7/2}$	4.0	0.70 ± 0.26	$0.29^{+0.09}_{-0.18}$	1.8 ± 0.5	(1967SP10)
10.0 [d]	$\frac{3}{2}^-$	1	$(^4P_{3/2})$					(1967HA07, 1967HA08)
≈ 10.0 [e]	$\frac{1}{2}^-$		$(^4P_{1/2})$					(1967HA07, 1967HA08)
11.00 ± 50 [f]	$\frac{3}{2}^-$	1	$(^2P_{3/2}, {}^2D_{3/2})$			0.13 ± 0.02 [g]		(1967HA07, 1967HA08)

[a] Compare to Table 7.10 in (1966LA04).
[b] $\gamma^2/(\frac{3}{2}\hbar^2/\mu a^2)$.
[c] See also (1968LE1K).
[d] $\Gamma = 1.8$ MeV.
[e] Broad.
[f] $\Gamma = 0.4 \pm 0.05$ MeV; $T = \frac{3}{2}$.
[g] $\theta^{2''}_p$.

Gamma transitions are observed to the ground (γ_0) and to the 0.43 MeV (γ_1) states. The yield shows no evidence of resonance for $E_p = 0.2$ to 1.0 MeV and the branching ratio remains approximately constant at (62 ± 5)% to the ground state, 38% to ^{7}Be*(0.43), < 4% to ^{7}Be*(4.57) (1955BA59, 1956WA03, 1969JO1K, 1969SW1C). At $E_p = 1.06$ MeV a resonance in the yield of 0.43 MeV γ-rays is reported by (1968WO1E), corresponding to ^{7}Be*(6.52). See, however, (1963MC09). See also (1966LA1D) and (1966LA04).

6. (a) ^{6}Li(p, p)^{6}Li $\qquad E_b = 5.6064$

(b) ^{6}Li(p, 2p)^{5}He $\qquad Q_m = -4.59$

Measurements of elastic angular distributions have recently been reported by (1968ME25: $E_p = 14$ to 15.8 MeV). Earlier measurements are listed in (1966LA04). Two resonances are reported at $E_p = 1.84$ and 5 MeV in the elastic yield [^{7}Be*(7.21, 9.9)]. The parameters of the lower resonance are shown in Table 7.3 (1963MC09). The 5 MeV resonance has $\Gamma \approx 1.8$ MeV and appears to also be formed by p-waves: γ^2_p is then 3 ± 2 MeV $\cdot$ fm. A weak rise near $E_p = 8$ to 9 MeV may indicate a further level, ^{7}Be* ≈ 13 MeV (1963HA53). Differential cross sections are reported by (1971BI11: 6.868 MeV) and by (1969LE08: 1.36 MeV). See also ^{6}Li. Polarization measurements (elastic scattering) have been carried out at $E_p = 1.21$ to 3.22 MeV (1969PE22), 14.5 MeV (1965RO22), 49.8 MeV (1971MA13), 152 MeV (1966RO1C), and 155 MeV (1968GE04). A phase-shify analysis for $E_p = 0.5$ to 5.6 MeV shows that only ^2S, ^4S and

^4P are involved. The $^4P_{5/2}$ phase resonantes at $E_\mathrm{p} = 1.8$ MeV, and the broad resonance at 5 MeV can be reproduced equally well by either $^4P_{3/2}$ or $^4P_{1/2}$: tensor polarization measurements are necessary to distinguish between the two (1969PE22). See (1966LA04) for earlier results. An S-matrix analysis of the cross section of this reaction and of reactions 3 and 9 has been reported by (1966HU1C, 1968LE1K).

The reaction cross section for formation of ^{6}Li*(2.19) has been measured for $E_\mathrm{p} = 3.6$ to 9.40 MeV: a broad resonance indicates the presence of a state with $E_\mathrm{x} \approx 10$ MeV, $\Gamma = 1.8$ MeV, $J^\pi = (\frac{3}{2}, \frac{5}{2})^-$; $T = \frac{1}{2}$ (1967HA07, 1967HA08). The cross section and terms of two $J^\pi = \frac{3}{2}^-$ states at $E_\mathrm{x} \approx 10$ and 11 MeV: see reaction 3 (1967HA07, 1967HA08). The total cross section for formation of ^{6}Li*(3.56) decreases slowly with energy for $E_\mathrm{p} = 24.3$ to 46.4 MeV (1968AU06). Polarization measurements involving the p_1 and p_2 groups have been carried out $E_\mathrm{p} = 49.8$ MeV (1971MA44). For the total scattering cross section at 1 GeV, see (1967IG1A).

See also (1967CA1G, 1968OL1B), (1971PL1C), (1966LE1E, 1969WA11, 1970LE02, 1972BR20, 1973LA26; theor.). For reaction (b) see ^{6}Li, ^{5}He and (1973NA1M).

7. ^{6}Li(p, n)^{6}Be $\quad Q_\mathrm{m} = -5.070 \quad E_\mathrm{b} = 5.6064$

The yield of neutrons increases approximately monotonically from threshold to $E_\mathrm{p} = 14.3$ MeV (1964BA16). See also (1971BU1D). For polarization measurements at $E_\mathrm{p} = 30$ and 50 MeV, see (1969RO20). See also (1969CL06, 1971JU05), (1970RA33; theor.) and ^{6}Be.

8. ^{6}Li(p, d)^{5}Li $\quad Q_\mathrm{m} = -3.44 \quad E_\mathrm{b} = 5.6064$

See ^{5}Li.

9. ^{6}Li(p, α)^{3}He $\quad Q_\mathrm{m} = 4.0200 \quad E_\mathrm{b} = 5.6064$

Over the range $E_\mathrm{p} = 25$ to 50 keV, the cross section rises from 0.8 to 72 μb: in the formula $\sigma \approx E^{-1}\mathrm{e}^{-B/\sqrt{E}}$, $B = 90 \pm 6$ keV$^{1/2}$ (1967FI05). Cross section measurements for $E_\mathrm{p} = 62$ to 188 keV show deviation from an s-wave Gamow plot above ≈ 130 keV (1966GE11). Using cross-section measurements at $E_\mathrm{p} = 151$ and 317 keV, as well as the (1966GE11) data, (1971SP05) calculate $S(0) = 3.0$ MeV $\cdot$ b. See also (1969AU1C).

At higher energies the cross section exhibits a broad, low maximum near $E_\mathrm{p} = 1$ MeV and a pronounced resonance at $E_\mathrm{p} = 1.85$ MeV (1951BA79, 1956MA91). No other structure is reported up to $E_\mathrm{p} = 5.6$ MeV (1963JE03, 1964FA03). Measurements between $E_\mathrm{p} = 0.4$ and 3.4 MeV show that the polarizations are generally large and positive. The $E_\mathrm{p} = 1.9$ MeV resonance appears in A_1 and A_2 (1968BR18). S-matrix analysis of the cross section of this reaction and of reactions 3 and 6 are reported by (1966HU1C, 1968LE1K). Angular distributions are reported at $E_\mathrm{p} = 151$

and 317 keV (1971SP05), at $E_p = 0.5$ to 1.82 MeV (1969JO1J), 3 to 45 MeV (1973SC1V) and 12, 14 and 16 MeV (1973WE07). Angular distributions at $E_p = 8$ to 18.5 MeV have been analyzed using a finite-range multi-interaction DWBA formalism. The analysis leads to reduced widths of 0.69 for $\alpha + $d in a relative s-state, 0.04 for $\alpha + $d in a relative d-state and 0.44 for ^{3}He + t in a relative s-state (1973WE07). Yield and cross section measurements are reported by (1968BE1P: 0.3 to 1.0 MeV) and (1969LE08: $E_p = 1.36$ MeV). See also (1974GO1V) and see (1966LA04) for earlier measurements.

Searches for excited states of ^{3}He have been unsuccessful: see (1968OL1B: $E_p = 20$ MeV), (1971BR12, 1972BU16: $E_p = 45$ MeV). See also (1970KO25, 1972BE1Y). See (1971BR12, 1973FI04) for discussions of the excited states of ^{4}He.

See also (1967SP09, 1967VA1F) and (1969BE1M, 1969BO1G, 1972CL1C, 1972HU09: theor.).

10. ^{6}Li(d, n)^{7}Be $\qquad Q_m = 3.3818$

Two neutron groups are observed, corresponding to ^{7}Be*(0, 0.43). Angular distributions of the n_0 and n_1 groups have been measured at $E_d = 0.24$ to 3.5 MeV [see (1966LA04) and (1966SC26)]: $l_p = 1$, $J^\pi \leq \frac{5}{2}^-$ for both states. At $E_d = 12$, 15 and 17 MeV differential cross sections for the population of ^{7}Be(g.s. $+ 0.43$) have been measured by (1970GA07).

The n-γ correlations are isotropic, indicating $J^\pi = \frac{1}{2}^-$ for ^{7}Be*(0.43) (1956NE13): $E_\gamma = 428.9 \pm 2$ keV (1952TH24). Broad maxima are observed in the ratio of low-energy to high-energy neutrons at $E_d = 4.2$ and 5.1 MeV [^{7}Be*(6.5, 7.2), $\Gamma_{cm} = 1.2$ and 0.5 MeV, respectively] (1957SL01).

11. ^{6}Li(^{3}He, d)^{7}Be $\qquad Q_m = 0.1126$

Angular distributions of the d_0 and d_1 groups to ^{7}Be*(0, 0.43) have been measured at $E_d = 8$, 10, 14 and 18 MeV: all the distributions show an $l = 1$ maximum at small angles. The DWBA analysis leads to a ratio of spectroscopic factors S^*/S [for ^{7}Be*(0.43)/^{7}Be(0)] $= 1.55$, in fair agreement with other measurements (1968LU02). See also (1964MA57) and (1970JA1J: theor.).

12. ^{6}Li(α, t)^{7}Be $\qquad Q_m = -14.2082$

Angular distributions of triton groups have been reported at $E_\alpha = 40$ MeV (1965OG03: ^{7}Be*($0 + 0.43, 4.57 + (5.0 \pm 0.3)$)), 43 MeV (1967DE1K: ^{7}Be*(0, 0.43)) and 46 MeV (1969FO1C: ^{7}Be*(0, 0.43, 4.57)). See also (1967OG1A).

13. ^{6}Li(p, n)^{7}Be $\qquad Q_m = -1.64422$

$E_{\text{thresh.}} = 1880.612 \pm 0.090$ keV (1970RO07); the recommended value for $E_{\text{thresh.}}$ based on this and on other experiments is 1880.59 ± 0.08 keV (1970RO07). See also (1966MA60, 1966RO09, 1967MA1D, 1973MA1V). The excitation energy of the first excited state is 429.20 ± 0.10 keV (1972BO02). The lifetime of ^{7}Be*(0.43), $\tau_{\text{m}} = 1.92 \pm 0.2$ msec. The ratio of this lifetime to that of ^{7}Li*(0.48) is 1.82 ± 0.20. This value, and the values of τ_{m} are in agreement with intermediate coupling calculations assuming LS coupling predominates $(a/K < 3.6)$ (1966PA11).

Angular distributions are reported at $E_{\text{p}} = 1.9$ to 2.36 MeV (1967BE61; n_0), 2.1 to 3.8 MeV (1971BU1D; n_0), 2.6 to 5.4 MeV (1972EL19; n_0), 3.2 to 5.4 MeV (1972EL19; n_1), at 17.5 MeV (1972AZ01; n_0, n_1, n_2) and at 30 and 50 MeV (1969CL06; $n_0 + n_1$). Above $E_{\text{p}} \approx 7$ MeV, neutrons corresponding to ^{7}Be*(4.57) are seen (1959AJ81, 1960HI04, 1963BO06). At $E_{\text{p}} = 30$ to 50 MeV, neutron groups are observed to states at $E_{\text{x}} = 4.61 \pm 0.07$, 7.21 ± 0.06, 9.6 ± 0.3, 11.3 ± 0.2, 12.3 ± 0.2, 13.24 ± 0.15, 14.39 ± 0.15, 15.3 ± 0.2, 16.3 ± 0.2, 18.3 ± 0.2, 19.7 ± 0.3 ande 20.5 ± 0.2 MeV (1965BA39). See also (1967LO07, 1969JU1A, 1970BO1U, 1971DA24, 1971WA1J), (1966PA04, 1969MA1P, 1969MA1G, 1968TH1H, 1971TH1K; theor.), (1966LA04) and ^{8}Be.

14. ^{7}Li(^{3}He, t)^{7}Be $\qquad\qquad Q_{\text{m}} = -0.8804$

Angular distributions have been measured at $E(^3\text{He}) = 3.0$ to 4.0 MeV (1969OR01; t_0, t_1), 8.7 and 9.7 MeV (1968MA1W; t_0, t_1), 14 MeV (1969NU1A; t_0, t_1) and 25.2 MeV (1968BR1G; t_0, t_1, t_2). The width of ^{7}Be*(4.57), $\Gamma_{\text{cm}} = 175 \pm 7$ keV (1971PI06). See also (1967BL1E) and (1971WE1L, 1971WE1M; theor.).

15. ^{7}Li(^{6}Li, ^{6}He)^{7}Be $\qquad\qquad Q_{\text{m}} = -4.372$

At $E(^6\text{Li}) = 31.8$ MeV, the reaction is observed to ^{7}Be*($(0 + 0.43)$, 4.57) (1971CH1B).

16. ^{9}Be(p, t)^{7}Be $\qquad\qquad Q_{\text{m}} = -12.0831$

Angular distributions of tritons have been measured at $E_{\text{p}} = 43.7$ MeV (1965DE08, 1966CE05, 1968BR23: ^{7}Be*(0, 0.43, 4.57, 6.51, 11.01)) and 46 MeV (1967VE01: ^{7}Be($0 + 0.43$, 4.57, 6.51, 10.79)). The 11 MeV state has $E_{\text{x}} = 11.01 \pm 0.04$ MeV (1968BR23), $\Gamma = 298 \pm 25$ keV, $J^\pi = \frac{3}{2}^-$; $T = \frac{3}{2}$ [the J^π; T assignments are based on the similarity of the angular distribution to that in the (p, ^{3}He) reaction to ^{7}Li*(11.13)] (1965DE08). See also (1967MC14), (1969BA1Z, 1969IN1A) and (1967BA1E; theor.).

17. ^{10}B(p, α)^{7}Be $\qquad\qquad Q_{\text{m}} = 1.1462$

Alpha groups corresponding to ^{7}Be*(0, 0.43) have been studied by many observers: see (1952AJ38, 1959AJ76). Some reported values for the energy of the first excited state are: 431 ± 5 keV (1950VA01), 434.4 ± 4 keV (1951BR10), 429 ± 3 keV (1952CR30), 428.5 ± 1.8 keV (1952TH24). In addition the excitation of ^{7}Li*(4.72 ± 0.08, 6.27 ± 0.10, 7.21 ± 0.10, (14.6 ± 0.3)) is reported by (1955RE16). At $E_{\rm p} = 18.6$ MeV ($\theta = 30°$) (1968PA15) find that the intensity of a group to ^{7}Be*(14.6) is $<$ 2% that reported by (1955RE16). Angular distributions have been measured at $E_{\rm p} = 2.8$ to 7.0 MeV (1964JE01). See also ^{11}C and (1966LA04).

18. ^{10}B(^{3}He, ^{6}Li)^{7}Be $\qquad Q_{\rm m} = -2.874$

At $E(^3{\rm He}) = 30.0$ MeV angular distributions have been obtained for the transitions to ^{7}Be*(0, 0.43) + ^{6}Li*(0, 2.19): see (1970DE12, 1972OH01).

19. ^{10}B(α, ^{7}Li)^{7}Be $\qquad Q_{\rm m} = -16.202$

At $E_\alpha = 45.6$ MeV (1969FO06) have measured the angular distributions of the ^{7}Li and of the ^{7}Be ions, corresponding to the ground-state transitions. At a given angle the intensities of the two ions are the same, implying that the wave functions of the ground states of ^{7}Li and ^{7}Be are very similar (1969FO06). See also (1971RO1A, 1971SI28, 1973NA1N; theor.).

20. ^{11}B(d, ^{6}He)^{7}Be $\qquad Q_{\rm m} = -11.563$

At $E_{\rm d} = 40$ MeV the cross section of the ground-state reaction is twice (to ± 10%) that for the reaction to ^{6}Li*(3.56) + ^{7}Li(0), in agreement with isospin conservation (1972GO1P).

21. ^{11}B(^{3}He, ^{7}Li)^{7}Be $\qquad Q_{\rm m} = -7.079$

See (1971RO1A).

22. ^{12}C(p, ^{6}Li)^{7}Be $\qquad Q_{\rm m} = -22.569$

At $E_{\rm p} = 36.0$, 40.7, 45.0, 50.0 and 56.8 MeV angular distributions have been obtained for the transitions to ^{7}Be*($0 + 0.43$) (1971BR07, 1971HO25, 1971HO1K).

23. ^{12}C(d, ^{7}Li)^{7}Be $\qquad Q_m = -17.543$

At $E_d = 39.8$ MeV angular distributions have been measured for the transitions ^{7}Li(0)+^{7}Be(0), ^{7}Li*(0.43) + ^{7}Be(0), ^{7}Li(0) + ^{7}Be*(0.43) and ^{7}Li*(0.43) + ^{7}Be*(0.43). The ratios of the ^{7}Li(0) and ^{7}Be(0) cross sections show asymmetries exceeding 20% (1971HO1K, 1971YO06). See also (1971SI28; theor.).

24. ^{12}C(^{3}He, ^{8}Be)^{7}Be $\qquad Q_m = -5.780$

Angular distributions have been obtained at $E(^{3}\text{He}) = 25.5$ to 29 MeV (1972PI1A, 1973PI1D: ^{7}Be*(0, 0.43)), 28 and 30 MeV (1970DE12, 1973KL1B: ^{7}Be*(0, 0.43) + ^{8}Be*(0, 2.9)), 35.6 MeV (1969NE1D, 1969ZE1A, 1970FO1D: ^{7}Be*(0, 0.43)) and 37 and 41 MeV (1967ZA1B: ^{7}Be*$(0 + 0.43)$). See also (1965EN01).

25. ^{12}C(α, ^{9}Be)^{7}Be $\qquad Q_m = -24.694$

At $E_\alpha = 42$ MeV, angular distributions have been measured to ^{7}Be*(0, 0.43)+^{9}Be(0) (1972RU03).

26. ^{13}C(p, ^{7}Li)^{7}Be $\qquad Q_m = -20.264$

At $E_p = 45.0$ MeV the angular distribution has been measured for the transition to ^{7}Li(0) + ^{7}Be(0) (1971BR07).

27. ^{16}O(p, ^{10}B)^{7}Be $\qquad Q_m = -25.270$

See (1969HO1H).

28. ^{16}O(^{3}He, ^{12}C)^{7}Be $\qquad Q_m = -5.575$

Angular distributions are reported at $E(^{3}\text{He}) = 25.5$ to 29 MeV (1972PI1A: to ^{7}Be*(0, 0.43)), 30 MeV (1970DE12, 1973KL1B: to ^{12}C*(0, 4.4, 7.7, 9.6) + ^{7}Be*(0, 0.43)) and 41 MeV (1967ZA1B).

29. ^{16}O(α, ^{13}C)^{7}Be $\qquad Q_{\rm m} = -21.207$

At $E_\alpha = 42$ MeV, angular distributions have been obtained for the transitions to ^{7}Be*(0, 0.43)+ ^{13}C(0) (1972RU03).

30. ^{19}F(d, ^{14}C)^{7}Be $\qquad Q_{\rm m} = -7.140$

The angular distribution to ^{7}Be*$(0 + 0.43)$ + ^{14}C(0) has been measured at $E_{\rm d} = 14.9$ MeV (1967DE03).

31. (a) ^{19}F(^{3}He, ^{15}N)^{7}Be $\qquad Q_{\rm m} = -2.426$

(b) ^{20}Ne(^{3}He, ^{16}O)^{7}Be $\qquad Q_{\rm m} = -3.144$

(1970DE12, 1973KL1B) have studied, at $E(^{3}$He$) = 30$ MeV, the angular distributions to ^{15}N(0) + ^{7}Be*(0, 0.43) and to ^{16}O*(0, $6.06 + 6.13$) + ^{7}Be*(0, 0.43).

^{7}B

(Fig. 10)

1. ^{10}B(^{3}He, ^{6}He)^{7}B $\qquad Q_{\rm m} = -18.55$

A ^{6}He group corresponding to the unbound ground state of ^{7}B has been identified at $E(^{3}$He$) =$ 50 MeV: $M - A$ (^{7}B) $= 27.94 \pm 0.10$, $\Gamma = 1.4 \pm 0.2$ MeV. The isobaric quartet mass law would predict $M - A = 27.76 \pm 0.17$ MeV. ^{7}B is unbound with respect to ^{6}Be + p $(Q = 2.27)$, ^{5}Li + 2p $(Q = 1.68)$, ^{4}He + 3p $(Q = 3.65)$. The expected single-particle width is $\Gamma = 0.64$ MeV: it is suggested that the two-proton and three-proton decays make an appreciable contribution to the width (1967MC14). See also (1960GO1B, 1968CE1A, 1968ST1J, 1969GA1P, 1972CA37, 1972CE1A).

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(Closed December 31, 1973)

References are arranged and designated by the year of publication followed by the first two letters of the first-mentioned author's name and then by two additional characters. Most of the references appear in the National Nuclear Data Center files (Nuclear Science References Database) and have NNDC key numbers. Otherwise, TUNL key numbers were assigned with the last two characters of the form 1A, 1B, etc. In response to many requests for more informative citations, we have, when possible, included up to ten authors per paper and added the authors' initials.

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