Energy Levels of Light Nuclei
$A = 7$

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Abstract: An evaluation of A = 5–10 was published in *Nuclear Physics A*490 (1995), 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. Also, reference key numbers have been changed to the NNDC/TUNL format — see introduction to references for more information.

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^{7}H

(Not illustrated)

^{7}H has not been observed. Attempts have been made to detect it in the spontaneous fission of ^{252}Cf (82AL1C) and in the ^{7}Li(π^-, π^+) reaction [see (84AJ01)]. The ground state is calculated to have $J^\pi = \frac{1}{2}^+$ and to be unstable with respect to 1n, 2n, 3n and 4n emission. Excited states are predicted at 4.84, 5.00 and 6.96 MeV, with $J^\pi = \frac{3}{2}^+$, $\frac{5}{2}^+$ and $\frac{5}{2}^-$ [$(0+1)\ \hbar\omega$ model space] and at 3.88, 3.94 and 5.99 MeV with $J^\pi = \frac{3}{2}^+$, $\frac{5}{2}^+$ and $\frac{1}{2}^+$ [$(0+2)\ \hbar\omega$ model space] (85PO10). See also (84BE1C, 87FL1A, 87GO1Z, 87PE1C) and (85GA1C, 86GA1J; theor.).

^{7}He

(Fig. 10)

GENERAL: See also (84AJ01).

Hypernuclei: (82KA1D, 83FE07, 84AS1D, 85KO1G, 86DA1B, 86DO01, 86ME1F).

Other topics: (83ANZQ, 84FR13, 84VA06, 86GI10, 86SH1L, 87BO40, 87GO1Z, 87PE1C).

Mass of ^{7}He: The atomic mass excess of ^{7}He is 26.11 ± 0.03 MeV: ^{7}He is then unbound with respect to decay into $^{6}\text{He} + \text{n}$ by 0.44 MeV: see (84AJ01). The ground state is calculated to have $J^\pi = \frac{3}{2}^-$ and to be unstable with respect to decay into $^{6}\text{He}+\text{n}$ by about 1 MeV (85PO10). [I am indebted to F.C. Barker for his comments.] See also (87BEYI).

1. ^{7}Li(π^-, γ)^{7}He $\qquad Q_m = 128.37$

Capture γ-rays from the transition to $^{7}\text{He}_{\text{g.s.}}$ are reported by (86PE05).

2. ^{7}Li(n, p)^{7}He $\qquad Q_m = -10.42$

The proton group corresponding to $^{7}\text{He}_{\text{g.s.}}$ has $\Gamma < 0.2$ MeV: see (79AJ01). At $E_n =$ 60 MeV broad bumps in the spectra are ascribed to states at $E_x \sim 20 \pm 1$ MeV [$\Gamma = 9 \pm 2$ MeV] and, possibly, at ≈ 6 MeV (84BR03, 83BR1C) [see for discussion of the GDR]. See also (87HE24) and (87BR32).

Table 7.1
Energy levels of ^{7}He [a])

E_x (MeV) [b])	$J^\pi; T$	$\Gamma_{c.m.}$ (keV)	Decay	Reactions
g.s.	$(\frac{3}{2})^-; \frac{3}{2}$	160 ± 30	n	1, 2, 3, 4

[a]) Excited states are calculated at 4.27, 4.55 and 5.38 MeV with $J^\pi = \frac{1}{2}^-, \frac{1}{2}^+$ and $\frac{5}{2}^-$ [$(0+1)\ \hbar\omega$ model space]. In the $(0+2)\ \hbar\omega$ model space the excited states are at 3.43, 5.03 and 7.47 MeV with $J^\pi = \frac{1}{2}^-, \frac{5}{2}^-$ and $\frac{3}{2}^-$ (85PO10).
[b]) See also reactions 2 and 4, and the preliminary reports in (87BEYI, 87BO40).

3. ^{7}Li(t, ^{3}He)^{7}He $\qquad Q_m = -11.18$

The ^{3}He particles to the ground state of ^{7}He have been observed at $E_t = 22$ MeV. The width of the ground state is 160 ± 30 keV; for a radius of 2.2 fm and $l_n = 1$, 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 $E_x < 2.4$ MeV: see (79AJ01).

4. (a) ^{7}Li(^{7}Li, ^{7}Be)^{7}He $\qquad Q_m = -12.07$
(b) ^{7}Li(^{11}B, ^{11}C)^{7}He $\qquad Q_m = -13.19$
(c) ^{9}Be(^{6}Li, ^{8}B)^{7}He $\qquad Q_m = -23.60$
(d) ^{9}Be(^{9}Be, ^{11}C)^{7}He $\qquad Q_m = -14.07$
(e) ^{9}Be(^{11}B, ^{13}N)^{7}He $\qquad Q_m = -11.44$
(f) ^{9}Be(^{14}C, ^{16}O)^{7}He $\qquad Q_m = -7.01$

At $E(^6\text{Li}) = 72$ MeV and at $E(^7\text{Li}) = 70$ MeV (reactions (a) and (c)) there is no evidence for excited states with $\Gamma \leq 2$ MeV for $E_x < 10$ MeV (85AL1G, 85AL1B, 85AL1H). The ground state of ^{7}He is strongly populated. Reactions (b), (d), (e) and (f) have been investigated at $E(^{11}\text{B}) = 88$, $E(^9\text{Be}) = 106.7$ and $E(^{14}\text{C}) = 152.6$ MeV. The ground state of ^{7}He is populated. There is some evidence for a second state in reaction (f) at $E_x = 2.9 \pm 0.5$, $\Gamma = 1.5 \pm 0.5$ MeV (87BEYI). See also (79AJ01) and (88BEYJ).

^{7}Li

(Figs. 8 and 10)

GENERAL: See also (84AJ01).

Shell model: (83BU1B, 83KU17, 83SH1D, 83VA31, 84CH24, 84RE1B, 84VA06, 84ZW1A, 85FI1E, 85GO11, 86AV1F, 87KA09, 87KI1C, 88WO04).

Cluster and α-particle models: (81PL1A, 83FU1D, 83HO22, 83PA06, 83SH1D, 83SR1C, 84BA53, 84DA07, 84DU1B, 84DU17, 84JO1A, 84KA06, 84KA04, 84LO09, 84MI1F, 84SH26, 85FI1E, 85FU01, 85FU11, 85KW02, 85WA17, 86AV1F, 86FA11, 86FI1F, 86KR12, 86SA15, SA86KK, 86VA13, 87BA1I, 87IM04, 87KA09, 87LE1D, 87TA06, 87ZH1E, 88US1A).

Special states: (81PL1A, 82PO12, 83BU1B, 83FI1D, 83HO22, 83KU17, 83VA31, 84DU1B, 84DU17, 84FI1G, 84OH01, 84RE1B, 84VA06, 84VA1C, 84ZW1A, 85BA68, 85FI1E, 85GO11, 85GO1A, 86BA2J, 86FI1F, 86SA15, 86VA13, 87KI1C, 87SV1A, 87WA1J, 87ZH1E, 88KW1A, 88US1A, 88ZH1B).

Electromagnetic transitions, giant resonances: (83FI1D, 83GM1A, 83KU17, 84CH24, 84DU17, 84KA06, 84KA04, 84MO1D, 84SH26, 85FI1E, 85GO23, 85GO1A, 85WA17, 86ER1A, 86FI1F, 86ME13, 86VA13, 87AR1E, 87KI1C, 87LE1D, 87ZH1E).

Astrophysical questions: (82AU1A, 82CA1A, 82GR1A, 82WA1B, 83SI1B, 83WA1H, 84RA1E, 84TR1C, 84YA1A, 85BO1E, 85BO1K, 85DE1E, 85DE1K, 85GI1C, 85HO1A, 85MI1E, 85SC1C, 85SC1D, 85WA1K, 86BO1H, 86MA1U, 86ME13, 86PA1H, 86RE1C, 86RO1P, 86SA1G, 86SH1G, 86SP1A, 86WI1D, 87AR1J, 87AR1C, 87AU1E, 87CO1X, 87DO1H, 87DU1C, 87FO1B, 87HO1M, 87KA1R, 87KA1V, 87MA1T, 87MA2C, 87PA1F, 87RA1D, 87RE1F, 87RO1D, 87SP1C, 87SP1D, 88BA1H, 88KAZY, 88KA07, 88KA1H, 88ME1B, 88RE1B).

Complex reactions involving ^{7}Li: (82GU1B, 83CH23, 83EF1A, 83GU1A, 83GU1B, 83KH04, 83KU1B, 83LE1F, 83MA53, 83MU08, 83NA08, 83OL1A, 83SI1A, 83SO08, 83ST1A, 83UT01, 84AI1A, 84BE1E, 84DA07, 84EC01, 84GR08, 84HI1A, 84IS02, 84MO29, 84RE1A, 84SH17, 84SI15, 84ST1B, 84XI1B, 85AG1A, 85BH1A, 85FA02, 85GL1C, 85GO20, 85KI1C, 85MA02, 85MA13, 85MC03, 85MO17, 85SH1G, 85WA1F, 85WA22, 85WO11, 86AV1A, 86BL12, 86DA1C, 86GL1E, 86GO1F, 86HA1B, 86JO1A, 86KA1C, 86KA1G, 86KO1L, 86ME06, 86MO1C, 86MO1E, 86NA1D, 86RE13, 86SAZJ, 86SA30, 86SA1N, 86SHZO, 86SH1F, 86SI1B, 86SO10, 86TA1F, 86TA1G, 86TA1M, 86TU1A, 86TU01, 86WA1H, 86WE1C, 86YA1L, 87AK1A, 87AU1C, 87BA39, 87BE1F, 87BL13, 87CH26, 87CO1R, 87DE37, 87DO02, 87FA02, 87FE1A, 87GL1G, 87GO17, 87GR11, 87HE1H, 87JA06, 87KI05, 87KI1M, 87MU03, 87MU1D, 87NA01, 87NI04, 87PO1I, 87SA04, 87SH23, 87SI1C, 87SO13, 87SO15, 87ST01, 87TA1F, 87TE1D, 87TR05, 87WA09, 87YA16, 88BL09, 88CA06, 88CEZZ, 88GO1H, 88KA1L, 88KI05, 88KW1A, 88RU01, 88SA19, 88SH1E, 88SH20, 88ST06, 88TA1A, 88VA1E).

Polarization of ^{7}Li: (83HA1H, 84JO1A, 84NI01, 85TU1A, 85WE08, 86CH1Q, 86FR03, 86ME13, 86NO1C, 86SA15, 86ST1E, 86TA1G, 86TU01, 87AR1E, 87FI1D, KA87C, 87KA1I, 87KA1V, 87MU04, 87SA04, 88GR07, 88KA02).

Table 7.2
Energy levels of ^{7}Li

E_x (MeV ± keV)	J^π; T	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
g.s.	$\frac{3}{2}^-$; $\frac{1}{2}$		stable	1, 2, 4, 5, 6, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49
0.477612 ± 0.003	$\frac{1}{2}^-$; $\frac{1}{2}$	$\tau_m = 105 \pm 3$ fsec [a]	γ	4, 5, 6, 10, 11, 14, 15, 16, 17, 18, 19, 20, 21, 24, 25, 30, 31, 32, 33, 34, 35, 36, 37, 39, 40, 41, 42, 43, 44, 46, 47, 48, 49
4.630 ± 9	$\frac{7}{2}^-$; $\frac{1}{2}$	$\Gamma = 93 \pm 8$ keV	t, α	3, 4, 10, 11, 15, 16, 17, 18, 19, 20, 21, 25, 34, 35, 37, 42, 45
6.68 ± 50	$\frac{5}{2}^-$; $\frac{1}{2}$	875^{+200}_{-100}	t, α	3, 11, 15, 16, 17, 21, 35, 42, 48
7.4595 ± 1.0	$\frac{5}{2}^-$; $\frac{1}{2}$	89 ± 7	n, t, α	2, 3, 7, 8, 9, 11, 15, 16, 17, 18, 21, 32, 34, 35, 42
9.67 ± 100	$\frac{7}{2}^-$; $\frac{1}{2}$	~ 400	n, t, α	2, 3, 11, 16, 18, 21, 35
9.85	$\frac{3}{2}^-$; $\frac{1}{2}$	~ 1200	n, α	7, 32
11.24 ± 30	$\frac{3}{2}^-$; $\frac{3}{2}$	260 ± 35	n, p	7, 8, 34
13.7		~ 500	n	13
14.7 [b]		~ 700	n	13

[a]) See table 7.2 in (79AJ01), table 7.5 here and reaction 35.
[b]) See also reactions 7, 9, 13, 20 and 33 for possible additional states.

Applications: (83AM1A, 83AS03, 83FI1C, 83KU1C, 84CA1D, 84SA1E, 84XI1A, 85AD1B, 85PA1A, 86AU1A, 86BE1J, 86EN1A, 86FI1D, 86KL1B, 86KR1C, 86LI1J, 86MA1S, 86RA1D, 86SA1M, 86SC1G, 86ST1E, 86ZA1C).

Muon and neutrino capture and reactions: (83GM1A, 84RO1B, 85MA1D, 85RU01, 86MA16, 87KU23, 87SU06, 88AL1H).

Pion capture and reactions involving pions: (82BA1H, 83AB1B, 83AS1B, 83AS1C, 83BA26, 83BA1A, 83BA1G, 83GE12, 83GM1A, 83HE17, 83KA19, 83PE14, 83RA1D, 83SE16, 83SP06, 84AB1B, 84BA1T, 84BA1U, 84BO1H, 84BU1D, 84HU1C, 84JI03, 84ZA1A, 85LA20, 85IR01, 85MO1F, 86AN1J, 86AV1F, 86BA1C, 86CE04, 86CH1P, 86DO01, 86ER1A, 86KA1J, 86MO1J, 86PA12, 86PE05, 86PR01, 86RO03, 86YO06, 86ZO1A, 87BA2F, 87CH1D, 87MA1I, 87ROZY, 88GIZT, 88PO1E).

Reactions involving kaons and other mesons: (83BA71, 83FE07, 83GE13, 83GE1C, 84BA1M, 84BO1H, 84CH1H, 84MO09, 85GA1C, 85KN1A, 85MO1F, 86BA1W, 86CH1P, 86DO01, 86GA1J, 86GA1H, 86HU1B, 86KA1J, 86MA1C, 86MO1J, 86ZO1A, 87CH1D, 87KN09, 87PO1H, 88HA1I).

Reactions involving antiprotons: (84GU06, 85DU05, 86DU10, 86KO1E, 86MO1J, 87GR1I, 87PO05).

Hypernuclei: (82KA1D, 82MO1B, 83BA1M, 83FE07, 83MA64, 83MO1C, 83SH38, 83SH1E, 84AS1D, 84BA1M, 84BO1H, 84CH1G, 84CH1H, 84HA1D, 84MI1C, 84MI1E, 84MO09, 84MO1H, 84SH1J, 84ZH1B, 85AH1A, 85KN1A, 85KO1G, 85MO1F, 86AN1R, 86BA1W, 86CH1P, 86DA1B, 86ER1A, 86GA1H, 86HU1B, 86MA1C, 86ME1F, 86YA1F, 87KN09, 87MI1A, 87PO1H, 87WA1J, 87YA1M, 88TA1B).

Other topics: (83FU1D, 83PA06, 83SH1D, 84LO09, 84OH01, 85AN28, 85GO23, 85KA01, 85TU1A, 86DE1J, 86GL1A, 86GR1A, 87AJ1A, 87LE1D, 87SV1A, 88BA1R, 88FIZT, 88GU1C, 88KW1A).

Coulomb excitation of ^{7}*Li*: (84SH17, 84VE03, 84VE08, 86FA11).

Ground-state properties of ^{7}*Li*: (83ANZQ, 83SR1C, 83VA31, 84AN1B, 84CH24, 84DU17, 84GE05, 84KA06, 84MI1B, 84NI01, 84OH01, 84PE12, 84SH26, 84VE03, 85AN28, 85BU02, 85CL1A, 85FI1E, 85FU11, 85GO1A, 85HA18, 85KL1B, 85SA32, 85WA17, 86KO1V, 86RO03, 86SY1A, 87AR1E, 87HA30, 87KA1U, 87KA22, 87KI1C, 87SV1A, 87TR1D, 88JO1C, 88KA02, 88KA07, 88PO1E, 88TA1D, 88VA03, 88WO04).

$$\mu = +3.256424\ (2)\ \text{n.m.: see (78LEZA).}$$

$Q = -40.6 \pm 0.8$ mb (88DI1B). See (88DI1B) for a review of earlier determinations, particularly those of (84SU09, 84VE03, 84VE08, 85WE08).

B(E2): $\frac{3}{2}^- \rightarrow \frac{1}{2}^- = 8.3 \pm 0.5\ e^2 \cdot \text{fm}^4$ (85WE08). See also (84VE08), (88TA1D) and (84AJ01).

Isotopic abundance: $(92.5 \pm 0.2)\%$ (84DE1A). See also (87LA1J, 88LA1C).

Table 7.3

^{7}Li levels from ^{3}H + ^{4}He [a])

E_x (MeV ± keV)	J^π	l_α	LS term	R (fm)	θ^2_α [b])	θ^2_{no}
4.65 ± 20	$\frac{7}{2}^-$	3	$^2F_{7/2}$	4.0	0.57 ± 0.04	
{ 6.64 ± 100	$\frac{5}{2}^-$	3	$^2F_{5/2}$	4.0	1.36 ± 0.13	0.000 ± 0.002
{ 6.79 ± 90	$\frac{5}{2}^-$	3	$^2F_{5/2}$	4.4	0.52	
7.47 ± 30	$\frac{5}{2}^-$	3	$^4P_{5/2}$	4.0	0.011 ± 0.001	0.26 ± 0.02
9.67 ± 100	$\frac{7}{2}^-$	3	$^4D_{7/2}$	4.0	0.53 ± 0.22	2.3 ± 0.7 [c])

[a]) For references see table 7.3 in (79AJ01).

[b]) $\gamma^2/(\frac{3}{2}\hbar^2/\mu a^2)$.

[c]) θ^2_{n1} to ^{6}Li*(2.19).

The interaction nuclear radius of ^{7}Li is 2.23 ± 0.02 fm (85TA18). [See also for derived nuclear matter, charge and neutron matter r.m.s. radii].

1. ^{3}H(α, γ)^{7}Li $Q_m = 2.4678$

Excitation functions and angular distributions have been studied for $E_\alpha = 0.5$ to 2.0 MeV. The cross section rises smoothly as expected for a direct capture process: see (66LA04) and (87BU18; γ_0, γ_1). $S(E)$ and the branching ratio DC $\rightarrow$ 478/DC $\rightarrow$ 0 have been measured by (SC87D): $S(0) = 0.14 \pm 0.02$ keV · b, including earlier measurements. Using $S(0) = 0.100$ keV · b, (87KA1R) predict Big-Bang production of ^{7}Li at all relevant densities and calculate the bounds on the mass density of the Universe from the observed ^{7}Li abundance. For other astrophysical calculations see (84WA11, 84YA1A, 85CA41, 85DE1K, 85KA1H, 85KA1K, 86KA45, 86LA22, 86ME13, 88KA02, 88KAZY, 88KA07, 88KA1H). See also (84NE1B; applied) and (84KA01; theor.).

2. ^{3}H(α, n)^{6}Li $Q_m = -4.7823$ $E_b = 2.4678$

The cross section for this reaction has been measured for $E_\alpha = 11$ to 18 MeV: the data show the effect of ^{7}Li*(7.46) 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 are displayed in table 7.3. The yield of ^{6}Li ions at 0° (lab) has also been measured for $E_\alpha = 11.310$ to 11.930 MeV with 2–3% accuracy: the data were then reduced to obtain the c.m. differential cross sections at 0° and 180° for the inverse reaction in the energy region corresponding to formation of ^{7}Li*(7.46): see (79AJ01). See also (85CA41; astrophys.).

3. ^{3}H(α, α)^{3}H $E_b = 2.4678$

The excitation curves for the elastic scattering show the effects of ^{7}Li*(4.63, 6.68, 7.46, 9.67). The derived level parameters are displayed in table 7.3. Angular distributions have been studied for $E_\alpha = 2.13$ to 2.98 MeV and $E_{\vec{t}} = 6.0$ to 17 MeV [see (79AJ01, 84AJ01)] and at $E_\alpha = 56.3$ to 95.5 MeV (86YA1M; prelim.; also A_y]. A polarization extremum ($A_y = -1$) occurs near $E_t = 11.1$ MeV, $\theta = 95°$: see (84AJ01). For the breakup of ^{7}Li into α + t in various processes see (84AJ01) and (84SH17, 87FO08, 87PO03) as well as "Complex reactions" on p. 54. For cross section calculations from an R-matrix calculation see (87KN04).

For muon catalysis see (84KR1B). See also (81PL1A, 83FI1B, 83FU11, 83FU19, 83HA1K, 83LO09, 84DU1B, 84FI1G, 84FU04, 84HO1C, 84KA01, 84KR10, 84LO1C, 85FU01, 85FU11, 85SH22, 86BA2J, 86BO01, 86KA30, SA86KK, 88FIZT; theor.).

4. ^{4}He(^{3}He, π^{+})^{7}Li $Q_m = -137.119$

^{7}Li*(0 + 0.48, 4.63) have been populated at $E(^{3}\mathrm{He}) = 266.5$ and 280.5 MeV: see (84AJ01). See also (84GE05, 87KA09; theor.).

5. ^{4}He(α, p)^{7}Li $Q_m = -17.3462$

Angular distributions have been reported at $E_\alpha = 39.9$ to 140 MeV [see (79AJ01, 84AJ01)] and at 61.5 to 158.2 MeV (82GL01) and 198.4 MeV (85WO11) for the transitions to ^{7}Li*(0, 0.48). See (82GL01, 85WO11) for a discussion of ^{7}Li production in the Big Bang. See also ^{8}Be and (86KA26; theor.).

6. ^{6}Li(n, γ)^{7}Li $Q_m = 7.2501$

$Q_0 = 7251.02 \pm 0.09$ keV (85KO47)

The thermal capture cross section is 38.5±3.0 mb (81MUZQ). Gamma rays are observed corresponding to transitions to ^{7}Li*(0, 0.48) with branching ratios (62 ± 2) and (38 ± 2)% (85KO47). ^{7}Li*(4.63, 6.68) are not populated [$\leq$ 5%] (85KO47). See (79AJ01) for the earlier work. See also (AB85F). The decay of ^{7}Li*(7.46)$\rightarrow$^{6}Li$_{\mathrm{g.s.}}$ + n in the interaction of 35 MeV/A ^{14}N ions on Ag is reported by (87BL13).

Table 7.4
Resonance parameters for 7.5–7.2 MeV levels in ^{7}Li and ^{7}Be [a])

Reaction	^{6}Li + n	^{6}Li + p
E_r (keV, lab)	262 [b])	1840
$\Gamma(E_r)$ (keV, cm)	154	836
E_λ (keV above g.s.)	7700	7580
$\Gamma_{n,p}(E_r)$ (keV, cm)	118	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, cm)	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]) These states are believed to have a $^4P_{5/2}$ character, consistent with their large θ^2_n and θ^2_p. For references see table 7.4 in (79AJ01).
[b]) 244.5 ± 1.0 keV (82SM02).

7. ^{6}Li(n, n)^{6}Li $\qquad E_b = 7.2501$

The real coherent scattering length is 2.0 ± 0.1 fm; the complex scattering lengths are $b_+ = (0.67 \pm 0.14) - i(0.08 \pm 0.01)$ fm, $b_- = (4.67 \pm 0.17) - i(0.62 \pm 0.02)$ fm; $\sigma_{\rm free} = 0.70 \pm 0.01$ b (83KO17). See also (79GL12). (83AL1E) report σ_s (below 10 keV) $= 0.72 \pm 0.02$ b. See also (81MUZQ). The total cross section has been measured from $E_n = 4$ eV to 49.6 MeV [see (76GA1A, 84AJ01)], at 0.6 to 80 keV (82AL1B) and at 0.08 to 3.0 MeV (83KN1D; prelim.).

A pronounced resonance occurs at $E_n = 244.5 \pm 1.0$ keV [$E_x = 7459.5 \pm 1.0$ keV] with a peak cross section of 11.2 ± 0.2 b (SM82): see table 7.4. No other clearly defined resonance is observed to $E_n = 49.6$ MeV although the total cross section exhibits a broad maximum at $E_n \simeq 4.5$ MeV: see (84AJ01). The analyzing power has been measured for $E_{\vec{n}} = 1.48$ to 5 MeV [see (84AJ01)] and 5 to 17 MeV (86PF1A; prelim.). Recent multi-level, multi-channel R-matrix analyses (87KN04, 83KN06) for $E_n \leq 8$ MeV [using also data from other channels] include 13 normal and 14 non-normal parity states with $E_x \leq 17$ MeV. [Only ten states have been seen directly in reaction or compound nucleus cross-section work.] Two positive-parity states provide an explanation for the anisotropy of the ^{6}Li(n, α) work at low energies (83KN06). For the results of an earlier R-matrix analysis see (84AJ01). Cross sections for n_0 and n_1 have also been measured at $E_n = 7.75$ and 8.90 MeV (87SC08).

The excitation function for 3.56 MeV γ-rays exhibits an anomaly, also seen in the (n, p) reaction (reaction 8). The data are well fitted assuming $E_{\rm res} = 3.50$ and 4.60 MeV [$E_x = 10.25 \pm 0.10$ and 11.19 ± 0.05 MeV], $T = \frac{1}{2}$ and $\frac{3}{2}$, $\Gamma_{\rm c.m.} = 1.40 \pm 0.10$ and 0.27 ± 0.05 MeV, respectively; both $J^\pi = \frac{3}{2}^-$: see (79AJ01) for a discussion of these and other (unpublished) data.

See also ^{6}Li, (84FE1A, 85CH37, 86DR1D), (83DA22, 83GO1H, 84SH1C, 88MA1H), (86BO1J; applications) and (81PL1A, 83FA17, 83FU11, 83FU19, 84FU04, 84WA1H, 85FU01, 85LI1F; theor.).

8. (a) ^{6}Li(n, 2n)^{5}Li $\quad Q_m = -5.67 \quad E_b = 7.2501$
(b) ^{6}Li(n, p)^{6}He $\quad Q_m = -2.725$
(c) ^{6}Li(n, d)^{5}He $\quad Q_m = -2.37$

For reaction (a) see (85CH37, 86CH1R). The excitation function for reaction (b), measured from threshold to $E_n = 8.9$ MeV, exhibits an anomaly at $E_n = 4.6$ MeV. The excitation function, at forward angles, of p_0 is approximately constant for $E_n = 4.4$ to 7.25 MeV: see (79AJ01). The excitation function, at forward angles, of deuterons (reaction (c)) increases monotonically for $E_n = 5.4$ to 6.8 MeV: see (79AJ01). See also ^{5}He, ^{6}He, (86WA1F), (84SH1C, 86AU1D, 88MA1H), (86BO1J; applications) and (87KN04; theor.).

9. ^{6}Li(n, α)^{3}H $\quad Q_m = 4.7821 \quad E_b = 7.2501$

The isotopic thermal cross section is 940 ± 4 b: see (81MUZQ). See also (85SW01). A resonance occurs at $E_n = 241 \pm 3$ keV with $\sigma_{max} = 3.3$ b: see (86CA1G, 84AJ01). 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 7.4. Above the resonance the cross section decreases monotonically to $E_n = 18.2$ MeV, except for a small bump near $E_n \approx 1.8$ MeV and an inflection near $E_n = 3.5$ MeV. For a description of R-matrix analyses which suggest the location of higher states of ^{7}Li, see reaction 7 and (84AJ01), as well as (87KN04).

Angular distributions have been measured at many energies in the range $E_n = 0.1$ to 14.1 MeV [see (79AJ01, 84AJ01)] as well as at 35 eV to 325 keV (83KN03) and 2.16 to 4.20, 7.1 and 13.7 MeV (86BA32, 86BA2A). Polarization measurements have been reported for $E_{\vec{n}} = 0.2$ to 2.4 MeV: the data suggest interference between s-waves and the p-wave resonance at 0.25 MeV. Interference between this $\frac{5}{2}^-$ state and a broad $\frac{3}{2}^-$ state 2 MeV higher also appears to contribute. At the higher energies A_y is close to +0.9 near 90° and varies slowly with E_n: see (79AJ01). See also (83VE10, 84VE1A).

For a study of coincidences in the ^{6}Li(n, αd)n reaction see (86MI11). The triton production cross section at $E_n = 14.92$ MeV is 32 ± 3 mb (85GO18). The total α production cross section [which includes the (n, nd) process] at $E_n = 14.95$ MeV is 512 ± 26 mb (86KN06).

See also (83AS1D, 83CO1E, 86CA1H), (84SH1C, 85BO1D, 86MI1G), (84YA1A; astrophysics), (84XI1A, 85GO18, 86BA2N, 86BO1J, 86BR1L, 86CH1S, 86CO1H, 86FA1B, 86GO1K, 86GR1F, 86MA1R, 86PE1K, 86SA1R, 86SA1H, 86SE1D, 86SU1J, 86TA1H, 86VE1A, 86WI1B; applications) and (86HA1W; theor.).

10. ^{6}Li(p, π^+)^{7}Li $\qquad$ $Q_m = -133.101$

At $E_p = 600$ MeV, the reaction preferentially excites ^{7}Li*(4.63). Angular distributions have been obtained for the pions to ^{7}Li*(0, 0.48, 4.63) at $E_p = 600$ and 800 MeV. ^{7}Li*(11.24) [$T = \frac{3}{2}$] is not observed: see (84AJ01). Recently $\sigma(\theta)$ and A_y measurements were reported at $E_{\vec{p}} = 800$ MeV (87SO1C; prelim.). See also (85LE19).

11. ^{6}Li(d, p)^{7}Li $\qquad$ $Q_m = 5.0255$

Angular distributions of proton groups have been studied for $E_d = 0.12$ to 15 MeV and at 698 MeV: see (66LA04, 74AJ01, 79AJ01, 84AJ01). J^π of ^{7}Li*(0.48) is $\frac{1}{2}^-$. The two higher states have $E_x = 4630 \pm 9$ and 7464 ± 10 keV, $\Gamma_{c.m.} = 93 \pm 8$ and 91 ± 8 keV. The breakup reactions involve ^{7}Li*(4.63, 7.46) and possibly ^{7}Li*(9.6) [$\Gamma = 0.5 \pm 0.1$ MeV]: see (79AJ01). See also ^{8}Be and (88KO1C).

12. ^{6}Li(^{6}Li, ^{5}Li)^{7}Li $\qquad$ $Q_m = 1.58$

See (87MI34) and ^{5}Li.

13. (a) ^{7}Li(γ, n)^{6}Li $\qquad$ $Q_m = -7.2501$
(b) ^{7}Li(γ, 2n)^{5}Li $\qquad$ $Q_m = -12.92$
(c) ^{7}Li(γ, p)^{6}He $\qquad$ $Q_m = -9.975$
(d) ^{7}Li(γ, pn)^{5}He $\qquad$ $Q_m = -11.84$
(e) ^{7}Li(γ, d)^{5}He $\qquad$ $Q_m = -9.62$
(f) ^{7}Li(γ, t)^{4}He $\qquad$ $Q_m = -2.4678$

The total photoneutron cross section rises sharply from 10 MeV to reach a broad plateau at about 15 mb from 14 to 20 MeV, decreases more slowly to about 0.5 mb at 25 MeV and then decreases further to about 0.3 mb at $E_\gamma = 30$ MeV (monoenergetic photons): there are indications of weak structure through the entire region: see (79AJ01) and (88DI02). [I am indebted to Prof. B.L. Berman for his comments.] A recent study by (86SI18; $E_{b.s.}$) reports evidence for the excitation of ^{7}Li*(7.46), as well as of states at $E_x = 13.75 \pm 0.03$ and 14.65 ± 0.03 MeV with $\Gamma \simeq 500$ and 700 keV [and integrated cross sections of $\simeq$0.14 and 0.17 MeV · mb], in addition to a major broad structure at 17 MeV. The integrated cross section to 23 MeV is 39 ± 4 MeV · mb for the n_0 transition and 17 ± 4 MeV · mb for the n_1 transition: together these account for 0.4 of the exchange augmented dipole sum of ^{7}Li: see (79AJ01). The integrated cross section for formation of ^{6}Li*(3.56) is 4 ± 1 MeV · mb to 30 MeV and 11 ± 3 MeV · mb to 55 MeV: see (84AJ01).

The total absorption cross section for *natural* Li in the range 10 to 340 MeV shows a broad peak at ∼30 MeV ($\sigma_{\rm max} \sim 3$ mb), a minimum centered at ∼150 MeV at ∼0.3 mb and a fairly smooth increase in cross section to ∼3 mb at ∼320 MeV: see (84AJ01).

The cross section for the (γ, p) reaction (reaction (c)) shows a maximum at ∼15.6 MeV with a width of ∼4 MeV. It then decreases fairly smoothly to 27 MeV. The integrated cross section for 11 → 28 MeV is 13.2 ± 2.0 MeV · mb: see (74AJ01, 79AJ01, 84AJ01). Differential cross sections for the (γ, n_0+n_2) and (γ, p_0) processes are reported by (83SE07, 85SE17; $E_\gamma = 48$ to 141 MeV). Reaction (e) has been studied in the giant resonance region with $E_{\rm bs} \leq 30$ MeV. Deuteron groups to ^{5}He$_{\rm g.s.}$ and possibly to the first excited state are reported. States of ^{7}Li with $E_{\rm x} = 25$–30 MeV may be involved when $E_{\rm bs} = 37$ to 50 MeV is used: see (79AJ01). At $E_\gamma = 0.9$ GeV, (85RE1A) have studied π^- emission with the population of ^{6}Li*(2.19).

The cross section for reaction (f) at 90° displays a broad resonance at $E \sim 7.7$ MeV ($\Gamma = 7.2$ MeV) with an integrated cross section of 6.2 MeV · mb, a plateau for 12 → 22 MeV (at ∼0.6 the cross section at 7.7 MeV) and a gradual decrease to 48 MeV. The (γ, t) cross section integrated from threshold to 50 MeV is 8.1 MeV · mb: see (84AJ01), and (86VO1E). See also (85HA1H, 86GO1M) and (83BE45, 83BO1B, 83BU1A, 83SR1B, 84KR10, 85GO1A, 85ST1A, 86AH03, 86BA2G, 87BU04, 87KA1V, 87KI1C, 87KO43, 87LU1B, 87VA05, 88SH20; theor.).

14. ^{7}Li(γ, γ)^{7}Li

See table 7.4 in (66LA04) [summary of early measurements] for $\tau_{\rm m}$ of ^{7}Li*(0.48) = 107 ± 5 fsec. See also (84AJ01), (87BE1K) and (86DU1F; theor.).

15. (a) ^{7}Li(e, e)^{7}Li
(b) ^{7}Li(e, ep)^{6}He $\quad Q_{\rm m} = -9.975$
(c) ^{7}Li(e, en)^{6}Li $\quad Q_{\rm m} = -7.2501$

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: $r_{\rm r.m.s.} = 2.39 \pm 0.03$ fm, $|Q| = 42 \pm 2.5$ mb. From results obtained for $E_{\rm e} = 24.14$ to 97.19 MeV, $r_{\rm r.m.s.} = 2.35 \pm 0.10$ fm (model independent), 2.29 ± 0.04 fm (shell model). 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. See (79AJ01) for references.

Inelastic scattering studies show peaks corresponding to ^{7}Li*(0.48, 4.63, 6.68, 7.46): see (74AJ01) and table 7.5. Form factors for ^{7}Li*(0, 0.48) have recently been studied at $E_{\rm e} = 80$ to 680 MeV (87LI1J; prelim.).

Table 7.5
Levels of ^{7}Li from ^{7}Li(e, e′) [a]

E_x (MeV)	$J^\pi; T$	Γ_{γ_0} (eV)	Type
0.48	$\frac{1}{2}^-; \frac{1}{2}$	$(2.8 \pm 1.6) \times 10^{-7}$	C2
		$(6.30 \pm 0.31) \times 10^{-3}$	M1
4.63 ± 0.05 [b]	$\frac{7}{2}^-; \frac{1}{2}$		C2 [d]
6.6 ± 0.1 [c]	$\frac{5}{2}^-; \frac{1}{2}$		C2
7.5 ± 0.08	$\frac{5}{2}^-; \frac{1}{2}$	0.6 ± 0.3	C2
		0.9 ± 0.4 [e]	

[a] For a summary of B(E2↑) measurements, see table 7.6 in (66LA04) and ^{7}Li, general. For references see (79AJ01, 84AJ01).
[b] $B(\text{E2}\uparrow)\ [\frac{3}{2}^- \rightarrow \frac{7}{2}^-] = 17.5\ e^2 \cdot \text{fm}^4$.
[c] $\Gamma_{\text{c.m.}} = 875^{+200}_{-100}$ keV.
[d] Purely longitudinal.
[e] From ^{7}Li(γ, n). See also fit by (80BA34).

For quasi-elastic processes see (84AJ01) and (85SE17). See also (83BE1A, 87DE1A) and (84DO1A, 84DU1B, 84KA06, 84KA04, 84PE12, 84SH26, 85WA17, 86BA1V, 86DO11, SA86KK, 87KA22, SA87C, 88BO05; theor.).

16. ^{7}Li(π, π)^{7}Li

^{7}Li*(0, 0.48, 4.63, 6.68, 7.46, 9.67) have been populated in this reaction. Angular distributions have been measured at $E_{\pi^+} = 49.7$ MeV and $E_{\pi^\pm} = 143$ and 164.4 MeV: see (84AJ01). Total and partial cross sections have been obtained for $E_{\pi^\pm}$ in the range $85 \rightarrow 315$ MeV [see (84AJ01)] and at $E_{\pi^+} = 50$ MeV (83NA18). For the (π^+, 2p) reaction see ^{5}He (86RI01). For studies of (π^+, pd) and ($\pi^\pm$, pn) see (86WH01) and (86YO06), respectively. For π^+ induced fission of ^{7}Li see (83BA26). See also “General”, p. 54.

17. (a) ^{7}Li(n, n)^{7}Li
(b) ^{7}Li(n, nt)^{4}He $\qquad Q_m = -2.4678$

Angular distributions have been measured at $E_n = 1.5$ to 18 MeV [see (79AJ01, 84AJ01)] and at $E_n = 5.4$, 6.0, 14.2 MeV (85CH37; n_{0+1}, n_2), 7 to 14 MeV (83DA22; n_0), 8.0 and 24.0 MeV (86HA1S; n_0 and n_2 at 24 MeV; prelim.), at 8.9 MeV (84FE1A; n_{0+1}, n_2; prelim.) and at 14.7 MeV (84SH01; n_{0+1}). Reaction (b) at $E_n = 14.4$ MeV proceeds primarily via ^{7}Li*(4.63) although some involvement of ^{7}Li*(6.68) may also occur: see (79AJ01). See also ^{8}Li, (86LI1H, 87DE14, 87SC08) and (85CO18; applications).

18. (a) ^{7}Li(p, p)^{7}Li

(b) ^{7}Li(p, 2p)^{6}He $\qquad Q_m = -9.975$

(c) ^{7}Li(p, pd)^{5}He $\qquad Q_m = -9.62$

(d) ^{7}Li(p, pn)^{6}Li $\qquad Q_m = -7.2501$

(e) ^{7}Li(p, pα)^{3}H $\qquad Q_m = -2.4678$

Angular distributions of protons have been measured for $E_p = 1.0$ to 185 MeV [see (74AJ01, 84AJ01)] and at $E_{\vec{p}} = 1.89$ to 2.59 MeV (86SA1P; p$_0$; prelim.). Inelastic proton groups have been observed to ^{7}Li*(0.48, 4.63, 7.46, 9.6): see (52AJ38, 74AJ01). Double differential cross sections for the continuum are reported at $E_{\vec{p}} = 65$ MeV (87TO06; prelim.).

For reaction (b) see (84PA1B, 85PA1B; 50–100 MeV; prelim.) and (85BE1J, 85DO1B; 1 GeV). See also ^{6}He and (84AJ01). For reaction (c) see (86WA11). For reaction (d) see (85BE1J) and ^{6}Li. Reaction (d) has been studied at $E_p = 200$ MeV: the deuteron spectroscopic factor is close to unity and the results indicate that the deuteron cluster momentum distribution is characterized, at small momentum, by a FWHM of 140 MeV/c. Cross sections for the (p, pt) reaction (reaction (e)) are very small but are consistent with a spectroscopic factor of unity for t + ^{4}He in ^{7}Li (86WA11). For reaction (e) see also (83GO06, 85PA1C, 85PA04). See also ^{5}He and (84AJ01).

See also ^{8}Be, (83AN18, 83GL1A, 86SH1P, 87GAZM, 87PA1G), (83CH1B, 87LE1D), (86HA1T; applications) and (84GU14, 85KA1D, 85PA03, 86IM1A, 87IM1F, 87IM04, 87VD01; theor.).

19. ^{7}Li(d, d)^{7}Li

Angular distributions have been reported for $E_d = 1.0$ to 28 MeV [see (74AJ01, 79AJ01)] and at 50 MeV (88KO1C; prelim.). See also ^{9}Be and (87GO1O) for a breakup study.

20. (a) ^{7}Li(^{3}He, ^{3}He)^{7}Li

(b) ^{7}Li(^{3}He, pd)^{7}Li $\qquad Q_m = -5.49353$

Angular distributions have been reported at $E(^3\text{He}) = 11$ MeV to 44.0 MeV and at $E(^3\vec{\text{He}}) = 33.3$ MeV: see (74AJ01, 84AJ01). The missing mass spectrum in reaction (b) at $E(^3\text{He}) = 120$ MeV indicate, in addition to the unresolved group to ^{7}Li*(0, 0.48), a small peak at $E_x = 17.8 \pm 0.5$ MeV, possibly some structure between 30 and 40 MeV, a peak at 40.5 ± 0.5 MeV ($\Gamma \sim 2$–3 MeV) and possibly some structure at higher energies (85FR01). For pion production see (84BR22).

21. (a) ^{7}Li(α, α)^{7}Li

(b) ^{7}Li(α, 2α)^{3}H $\qquad Q_m = -2.4678$

Angular distributions (reaction (a)) have been reported for $E_\alpha = 3.6$ to 29.4 MeV [see (74AJ01, 84AJ01)] and at $E_\alpha = 35.3$ MeV (85DI08; α to ^{7}Li*(0, 0.48, 4.63, 6.68, 7.46, 9.67); collective coupled channel analysis). See also (87BU1E).

Reaction (b) has been studied at $E_\alpha = 18$ to 64.3 MeV [see (74AJ01, 84AJ01] and at 27.2 MeV (85KO29). ^{7}Li*(4.63) is strongly involved in the sequential decay, as are possibly ^{7}Li*(6.68, 7.46). See also (87DM1C, 87VA29, 88DM1A), (88BO1D) and (86ZE01, 87KO1L; theor.).

22. (a) ^{7}Li(^{6}Li, ^{6}Li)^{7}Li

(b) ^{7}Li(^{7}Li, ^{7}Li)^{7}Li

For reaction (a) see ^{6}Li. The elastic angular distribution (reaction (b)) has been studied for $E(^7\text{Li}) = 4.0$ to 6.5 MeV [see (74AJ01)] and 2.0 to 5.5 MeV (83NO08).

23. ^{7}Li(^{9}Be, ^{9}Be)^{7}Li

Elastic angular distributions have been measured at $E(^7\text{Li}) = 34$ MeV [see (79AJ01)] and at 78 MeV (86GL1C, 86GL1D; also to ^{7}Li*(4.63)). For the interaction cross section at 790 MeV/A see (85TA18).

24. (a) ^{7}Li(^{10}B, ^{10}B)^{7}Li

(b) ^{7}Li(^{11}B, ^{11}B)^{7}Li

For reaction (a) see ^{10}B. Angular distributions have been studied for reaction (b) to ^{7}Li*(0, 0.48) and at $E(^7\text{Li}) = 34$ MeV (87CO02, 87CO16). See also (87HN1A; theor.).

25. (a) ^{7}Li(^{12}C, ^{12}C)^{7}Li

(b) ^{7}Li(^{13}C, ^{13}C)^{7}Li

Angular distributions (reaction (a)) involving ^{7}Li*(0, 0.48) have been studied at $E(^7\text{Li}) =$ 4.5 to 89 MeV [see (75AJ02, 79AJ01, 84AJ01)] and at $E(^7\text{Li}) = 53.8$ MeV and $E(^{12}\text{C}) =$ 92.3 MeV (84VI02, 86CO02; also to ^{7}Li*(4.63)) and at $E(^7\text{Li}) = 131.8$ MeV (88KA09; ^{7}Li*(0 + 0.48); and various states in ^{12}C) as well as at $E(^7\vec{\text{Li}}) = 21.1$ MeV (84MO06; elastic). See also (86GL1D) and ^{12}C in (85AJ01, 90AJ01). Breakup studies involving

^{7}Li*(4.63) are reported at $E(^{7}\text{Li})$ = 70 MeV (86DA1C, 86YO1C; prelim.) and 132 MeV (86SH1Q; prelim.). The interaction cross section on carbon at 790 MeV/A has been measured by (85TA18).

The elastic scattering in reaction (b) has been studied for $E(^{7}\text{Li})$ = 4.5 to 34 MeV [see ^{13}C in (85AJ01)] and recently by (87CO02, 87CO16; 34 MeV; also to ^{7}Li*(0.48)). See also (83ST1B), (83BI1A, 84HA53, 86KA1C, 86MO1E, 87PA12) and (80KH09, 82GU1B, 83KH1A, 84BE35, 84GR05, 84UH1A, 85HE25, 85KH08, 85SA13, 86KA1B, 86SA15, 86SAZJ, SA86KK, 86YO1A, 87AR13, 87KA1I, SA87C, 88OT01, 88SA10; theor.).

26. (a) ^{7}Li(^{14}N, ^{14}N)^{7}Li
(b) ^{7}Li(^{15}N, ^{15}N)^{7}Li

Elastic angular distributions (reaction (a)) are reported at $E(^{7}\text{Li})$ = 36 MeV [see (81AJ01)] and $E(^{14}\text{N})$ = 150 MeV (86GO1H) while those for reaction (b) have been studied at $E(^{7}\text{Li})$ = 28.8 MeV [see ^{15}N in (86AJ01)].

27. ^{7}Li(^{16}O, ^{16}O)^{7}Li

The elastic scattering has been studied at $E(^{7}\text{Li})$ = 9.0 to 20 and at 68 MeV [see ^{16}O in (86AJ04)] as well as at $E(^{7}\text{Li})$ = 50 MeV (84CO20). For fusion cross section and breakup studies see (84MA28, 86MA19, 86SC28, 88MA07). See also (82GU1B, 88PR02; theor.).

28. ^{7}Li(^{20}Ne, ^{20}Ne)^{7}Li

Angular distributions have been studied at $E(^{7}\text{Li})$ = 36, 68 and 89 MeV: see ^{20}Ne in (83AJ01).

29. (a) ^{7}Li(^{24}Mg, ^{24}Mg)^{7}Li
(b) ^{7}Li(^{25}Mg, ^{25}Mg)^{7}Li
(c) ^{7}Li(^{26}Mg, ^{26}Mg)^{7}Li
(d) ^{7}Li(^{27}Al, ^{27}Al)^{7}Li

The elastic scattering has been studied at $E(^{7}\text{Li})$ = 89 MeV and at 27 MeV (reaction (b)): see (84AJ01). A study of the breakup on ^{27}Al is reported by (86NA1D) and the interaction cross section at 790 MeV/A has been measured by (85TA18). See also (88OT01, 88SA10; theor.).

Table 7.6
The branching ratio of $^7Be(\varepsilon)^7Li$ to $^7Li^*(0.48)$

Branching ratio (%)	Reference
10.32 ± 0.16	(62TA11)
10.42 ± 0.18	(73PO10)
10.35 ± 0.08	(74GO26)
10.10 ± 0.45	(83BA15)
10.61 ± 0.23	(83DA14)
10.6 ± 0.5	(83DO07)
10.61 ± 0.17	(84FI10)
10.7 ± 0.2	(83MA34)
9.8 ± 0.5	(83NO03)
10.9 ± 1.1	(83KN10)
11.4 ± 0.7	(84EV01)
10.49 ± 0.07	(84SK01)
10.52 ± 0.06	weighted mean [a])

[a]) Weighted mean of "modern" experiments. The weighted mean of all values shown above is (10.45 ± 0.04)%.

30. (a) $^7Li(^{28}Si, ^{28}Si)^7Li$
(b) $^7Li(^{40}Ca, ^{40}Ca)^7Li$
(c) $^7Li(^{48}Ca, ^{48}Ca)^7Li$

Angular distributions involving $^7Li^*(0, 0.48)$ and various states of ^{28}Si and ^{40}Ca have been studied at $E(^7Li) = 45$ MeV. The elastic scattering on ^{40}Ca and ^{48}Ca has been studied at $E(^7Li) = 28$, 34 and 89 MeV [the latter also to $^7Li^*(0.48)$]: see (84AJ01). Angular distributions (reaction (b)) involving $^7Li^*(0, 0.48)$ have also been reported at $E(^7Li) = 34$ MeV (85SA25). See also (85GO11, SA86KK, SA87C; theor.).

31. $^7Be(\varepsilon)^7Li$ $\qquad Q_m = 0.862$

The decay proceeds to the ground and 0.48 MeV states. The branching ratio to $^7Li^*(0.48)$ is (10.52 ± 0.06)%: see table 7.6 and (84AJ01). The adopted half-life is 53.29 ± 0.07 d. Both transitions are superallowed: $\log ft = 3.32$ and 3.55 for the decays to $^7Li^*(0, 0.48)$. See also (79AJ01). The first-excited state has E_x [from E_γ] $= 477.612 \pm 0.002$ keV: see (84AJ01). See also (83TA1A), (82BA1J, 83FO1A, 83VO1C, 84BO1C, 84DA1H, 84HA1M, 84SU1A, 85BA1N, 85BA1M, 85CA41, 85DE1H, 85KR1B, 86GR04, 86HA1I, 86RO1N, 87AR1J, 87BA1U, 87FR1C, 87KR10, 87RI1E, 87RO1D, 87WE1C, 88BA1H, 88FO1A; astrophysics) and (83WA13, 83WA1J, 86DU1E, 86HA1Q, 87DR1A; theor.).

32. ^{9}Be(π^-, 2n)^{7}Li $Q_m = 119.866$

The capture of stopped pions has been studied in a kinematically complete experiment: ^{7}Li*(0, 0.48) are weakly populated. Two large peaks are attributed to the excitation of ^{7}Li*(7.46, 10.25). The recoil momentum distributions corresponding to these peaks are rather similar and both indicate a strong $L = 0$ component: see (79AJ01).

33. ^{9}Be(n, t)^{7}Li $Q_m = -10.4378$

An angular distribution is reported at $E_n = 14.6$ MeV (87ZA01; t_{0+1}). See also (79A-J01) and ^{10}Be.

34. (a) ^{9}Be(p, ^{3}He)^{7}Li $Q_m = -11.2016$
(b) ^{9}Be(p, pd)^{7}Li $Q_m = -16.6951$

At $E_p = 43.7$ MeV angular distributions have been obtained for the ^{3}He particles corresponding to ^{7}Li*(0, 0.48, 4.63, 7.46). The 7.46 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*(7.46) involves both $L = 0$ and 2, with a somewhat dominant $L = 0$ character. The $J^\pi = \frac{3}{2}^-$, $T = \frac{3}{2}$ state is located at $E_x = 11.28 \pm 0.04$ MeV, $\Gamma = 260 \pm 50$ keV: see (79AJ01). Reaction (b) at $E_p = 58$ MeV involved ^{7}Li*(0, 0.48, 7.47) (85DE17). See also (87KA25).

35. (a) ^{9}Be(d, α)^{7}Li $Q_m = 7.1516$
(b) ^{9}Be(d, t)2 ^{4}He $Q_m = 4.6838$

Angular distributions have been measured for $E_d = 0.4$ to 27.5 MeV [see (66LA04, 74AJ01, 79AJ01)] and at $E_{\vec{d}} = 2.0$ to 2.8 MeV (84AN1D; α_0, α_1). A study at 11 MeV finds $\Gamma_{c.m.} = 93 \pm 25$ and 80 ± 20 keV, respectively for ^{7}Li*(4.63, 7.46). No evidence is found for the $T = \frac{3}{2}$ state ^{7}Li*(11.25). 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*(9.7) are $E_x = 9.36 \pm 0.05$ MeV, $\Gamma = 0.8 \pm 0.2$ MeV: see (79AJ01). [$E_x = 6.75 \pm 0.20$ MeV, $\Gamma = 0.87 \pm 0.20$ MeV (86PA1E; prelim.)]. A study of inclusive α-spectra at $E_d = 50$ MeV has been reported by (87KA17) who suggest the involvement of a ^{7}Li state at $E_x = 18 \pm 1$ MeV, $\Gamma = 5 \pm 1$ MeV. For reaction (b) see also (87VA29). See also ^{11}B in (85AJ01) and (88NE1A; theor.).

36. (a) ^{9}Be(^{6}Li, ^{8}Be)^{7}Li $\quad Q_m = 5.585$
(b) ^{9}Be(^{9}Be, ^{11}B)^{7}Li $\quad Q_m = -0.8798$

Angular distributions involving ^{7}Li*(0, 0.48) have been reported at $E(^{6}\text{Li}) = 32$ MeV (85CO09) and $E(^{9}\text{Be}) = 14$ MeV (85JA09).

37. ^{10}B(n, α)^{7}Li $\quad Q_m = 2.7905$

Angular distributions of α_0, α_1 and of α_2 at the higher energies have been measured at $E_n = 2$ keV to 14.4 MeV: see (79AJ01, 84AJ01). τ_m (0.48) $= 102 \pm 5$ fsec (85KO47). A search for an asymmetry of α-particles emitted forward and backward with respect to the neutron spin (due to parity non-conserving effects) gives upper limits of 3.7×10^{-6} and 6.1×10^{-7} for the α_0 and α_1 groups, respectively (86ER1C). For other polarization studies (involving both n and ^{10}B) see (86KO19) and ^{11}B in (90AJ01). See also (86CO1M; applications).

38. ^{10}B(d, ^{5}Li)^{7}Li $\quad Q_m = -1.40$

See ^{5}Li.

39. ^{10}B(α, ^{7}Be)^{7}Li $\quad Q_m = -16.200$

Angular distributions involving $^{7}\text{Li}_{\text{g.s.}}$ and $^{7}\text{Be}_{\text{g.s.}}$ and ^{7}Li*(0.48) + ^{7}Be*(0.43) have been studied at $E_\alpha = 91.8$ MeV (85JA12, 86JA03). See also (88SH1E; theor.).

40. ^{11}Be(β^-)^{11}B*$\rightarrow$^{7}Li + α $\quad Q_m = 1.216$

Delayed α-particles have been observed in the β^- decay of ^{11}Be: they are due to the decay of ^{11}B*(9.88) [$J^\pi = \frac{3}{2}^+$]. This state decays by α-emission $(87.4 \pm 1.2)\%$ to the ground state of ^{7}Li and $(12.6 \pm 1.2)\%$ to ^{7}Li*(0.48) (81AL03). See also ^{11}Be, ^{11}B in (85AJ01).

41. ^{11}B(^{3}He, ^{7}Be)^{7}Li $\quad Q_m = -7.076$

Angular distributions involving $^{7}\text{Li}_{\text{g.s.}}$ and $^{7}\text{Be}_{\text{g.s.}}$ and ^{7}Li*(0.48) + ^{7}Be*(0.43) have been studied at $E(^{3}\text{He}) = 71.8$ MeV (86JA02, 86JA03). See also (87KW01, 87KW03; theor.).

42. ^{11}B(α, ^{8}Be)^{7}Li $\quad Q_m = -8.7556$

Angular distributions have been measured at $E_\alpha = 27.2$ to 29.0 MeV and at 65 MeV. At $E_\alpha = 65$ and 72.5 MeV, ^{7}Li*(0, 4.63) are very strongly populated while ^{7}Li*(0.48, 6.68, 7.46) are weakly excited: see (79AJ01, 84AJ01).

43. ^{12}C(d, ^{7}Be)^{7}Li $\quad Q_m = -17.540$

Angular distributions involving ^{7}Li$_{g.s.}$ and ^{7}Be$_{g.s.}$ and ^{7}Li*(0.48) + ^{7}Be*(0.43) have been studied at $E_d = 39.8$ MeV [see (79AJ01)] and at 78.0 MeV (86JA03, 86JA15). See also (84NE1A) and (87KW01, 87KW03; theor.).

44. ^{12}C(t, ^{8}Be)^{7}Li $\quad Q_m = -4.8988$

Angular distributions have been studied at $E_t = 38$ MeV to ^{8}Be$_{g.s.}$ and ^{7}Li*(0, 0.48) (86SI1B; prelim.).

45. ^{12}C(α, ^{9}B)^{7}Li $\quad Q_m = -24.898$

Angular distributions are reported at $E_\alpha = 49.0$ and 80.1 MeV (84GO03). See also (84AJ01).

46. ^{12}C(^{6}Li, ^{11}C)^{7}Li $\quad Q_m = -11.472$

Angular distributions have been obtained at $E(^6\text{Li}) = 36$ MeV for the transitions to ^{7}Li*(0, 0.48): see (79AJ01). See also (86GL1E).

47. ^{13}C(d, ^{8}Be)^{7}Li $\quad Q_m = -3.5879$

At $E_d = 14.6$ MeV angular distributions are reported for the transitions to ^{7}Li*(0, 0.48) and ^{8}Be$_{g.s.}$: see (79AJ01). See also (84NE1A, 84SH1D).

48. ^{14}N(n, 2α)^{7}Li $\qquad Q_{\rm m} = -8.8220$

At $E_{\rm n} = 14.1$ MeV, ^{7}Li*(0, 0.48) are approximately equally populated: see (79AJ01). Differential cross sections have been measured at $E_{\rm n} = 14.4$ and 18.2 MeV involving $^{8}{\rm Be}_{\rm g.s.}$ and ^{7}Li*(0 + 0.48, 4.63) (86TU02).

49. (a) ^{17}O(d, ^{12}C)^{7}Li $\qquad Q_{\rm m} = -2.5803$
(b) ^{18}O(d, ^{13}C)^{7}Li $\qquad Q_{\rm m} = -5.678$
(c) ^{19}F(d, ^{14}N)^{7}Li $\qquad Q_{\rm m} = -6.1220$

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)]: see (79AJ01). See also (84AJ01).

^{7}Be

(Figs. 9 and 10)

GENERAL: See also (84AJ01).

Nuclear models: (83BU1B, 83FU1D, 83HO22, 83PA06, 84BA53, 84KA06, 84WA02, 85FI1E, 86FI1F, 86KR12, 86VA13).

Special states: (82PO12, 83BU1B, 83HO22, 84FI1G, 84WA02, 85FI1E, 86FI1F, 86VA13, 86XU02, 88KW1A).

Electromagnetic transitions, giant resonances: (84KA06, 85FI1E, 86FI1F, 86ME13).

Astrophysical questions: (84EN1A, 84HA1B, 84RA1E, 85BO1E, 85GI1C, 85DE1K, 85KL1A, 86BA50, 86HU1D, 86MA1U, 86ME13, 87FI1C, 87KA1U, 87MA1X, 87MA2C, 87RA1D, 88KA07).

Complex reactions involving ^{7}*Be*: (81AS04, 83AS05, 83EN04, 83GU1A, 83MA53, 83OL1A, 83SO08, 83ST1A, 83WA19, 84BE1E, 84GL1E, 84GO03, 84GR08, 84HI1A, 84MO29, 84NE1A, 84ST1B, 85BA1L, 85JA1B, 85MO08, 85MO17, 85ST1B, 85TA18, 85TR1B, 85WO11, 86AV1B, 86AV1D, 86BL12, 86CA30, 86CS1A, 86GL1E, 86GO1B, 86ME06, 86MO1C, 86MO34, 86WE1C, 86XU02, 86XU1B, 87AU1C, 87BA39, 87BL13, 87CH26, 87DE37, 87DU07, 87FE1A, 87GE1B, 87GL1G, 87GR11, 87HA1M, 87JA06, 87KO15, 87LY04, 87NA01, 87NI04, 87PO1I, 87ST01, 87TA1F, 87TR05, 87VI1B, 87WA09, 87YA16, 88BE09, 88BL09, 88BUZI, 88BU1Q, 88CA06, 88CEZZ, 88GO1F, 88KI05, 88KW1A, 88LI1A, 88PO1F, 88RU01, 88SA19, 88VA1E, 88VUZZ).

Applications: (83AS03, 84EN1A, 85TA1D, 86FI1C, 87FI1C, 88IV1A).

Table 7.7
Energy levels of ^{7}Be

E_x (MeV ± keV)	$J^\pi; T$	τ or $\Gamma_{c.m.}$	Decay	Reactions
g.s.	$\frac{3}{2}^-; \frac{1}{2}$	$\tau_{1/2} = 53.29 \pm 0.07$ d	ε	1, 2, 4, 5, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 20, 21, 22, 23, 24, 25, 27, 28
0.42908 ± 0.10	$\frac{1}{2}^-; \frac{1}{2}$	$\tau_m = 192 \pm 25$ fs	γ	2, 4, 5, 9, 10, 13, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 27, 28
4.57 ± 50	$\frac{7}{2}^-; \frac{1}{2}$	$\Gamma = 175 \pm 7$ keV	^{3}He, α	3, 5, 10, 13, 15, 16, 17, 18
6.73 ± 100	$\frac{5}{2}^-; \frac{1}{2}$	1.2 MeV	^{3}He, α	3, 8, 9, 13, 17
7.21 ± 60	$\frac{5}{2}^-; \frac{1}{2}$	≤ 0.5 MeV	p, ^{3}He, α	3, 6, 8, 9, 13, 16
9.27 ± 100	$\frac{7}{2}^-; \frac{1}{2}$		p, ^{3}He, α	3
9.9	$\frac{3}{2}^-; \frac{1}{2}$	~ 1.8 MeV	p, ^{3}He, α	3, 6
11.01 ± 30	$\frac{3}{2}^-; \frac{3}{2}$	320 ± 30	p, ^{3}He, α	3, 6, 13, 17
17 [a])	$\frac{1}{2}^-; \frac{1}{2}$	~ 6.5 MeV	^{3}He	3

[a]) For possible states at higher E_x see reactions 3 and 6.

Reactions involving pions and kaons: (83KA19, 84HU1C, 85LA20, 85MO1F, 87KA09, 88GIZT).

Hypernuclei: (82KA1D, 83SH38, 83SH1E, 84MI1C, 84MI1E, 84ZH1B, 85AH1A, 86DA1B, 87MI1A, 87PO1H, 88TA1B).

Other topics: (83FU1D, 83PA06, 85AN28, 87AJ1A, 88FIZT, 88KW1A).

Ground state of ^{7}Be: (83ANZQ, 84KA06, 85AN28, 85FI1E, 85HA18, 85TA18, 86KO1V, 87KA1U, 87KA22, 88KA07).

The interaction nuclear radius of ^{7}Be is 2.22 ± 0.02 fm (85TA18). [See also for derived nuclear matter, charge and neutron matter r.m.s. radii].

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

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

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

The capture cross sections have been measured for $E_\alpha = 0.250$ to 5.80 MeV and at $E(^{3}\text{He}) = 19$ to 26 MeV [see (74AJ01, 84AJ01)], at $E_{c.m.} = 195$ to 686 keV (88HI06), and at

$E_\alpha = 385$ to 2728 keV (84OS03) and 1225 keV (84AL24). One of the main reasons for doing these measurements is to determine the astrophysical $S(0)$ factor. The values of $S(0)$ appear, on the average, to be higher if the experiment involves measurement of the 0.48 MeV γ following ε-capture rather than if it involves a direct measurement of the capture γ-rays. It is not entirely clear why this should be so. Contaminant production of ^{7}Be may be involved: see (88HI06) and e.g. (84AL24, 85FI1D, 86LA22). Earlier measurements, sometimes recalculated, are discussed by (86LA22, 87KA1R, 88HI06). The latter adopt best values of $S(0) = 0.51 \pm 0.02$ keV · b [prompt γ-rays] and 0.58 ± 0.02 keV · b [^{7}Be activity] (88HI06). See also (84AL24, 85FI1D, 87KA1R, 88BA1H). Theoretical calculations are in general agreement with the experimental values. For instance (85BU02) from a cluster-model calculation obtain $S(0) = 0.47 \pm 0.02$ keV·b while (83WA13, 84WA06) obtain $S(0) = 0.60$ keV·b. The solar model calculations of (82BA1F) used $S_{34}[S(0)] = 0.52 \pm 0.02$ keV · b. It appears clear that the uncertainty in S_{34} is not of severe consequence to the solar neutrino problem [see, e.g. (85FI1D)]. For astrophysical considerations see (84AJ01) and (82BA1J, 82KA1E, 83FO1A, 83HA1B, 84DA1H, 84HA1M, 84IW01, 84WA11, 84YA1A, 85BA1Q, 85BO1K, 85CA41, 85DE1K, 85KA1H, 85KA1K, 86BA50, 86FI1B, 86KA45, 86ME13, 87AR1J, 87AS05, 87RO1D, 87WE1C, 88FO1A, 88KAZY, 88KA07, 88KA1H). See also (86LI04; theor.).

3. (a) ^{4}He(^{3}He, ^{3}He)^{4}He $\qquad E_b = 1.587$
   (b) ^{4}He(^{3}He, p)^{6}Li $\qquad Q_m = -4.0185$

Elastic-scattering studies have been reported for $E = 0.25$ to 198.4 MeV [see (74AJ01, 79AJ01, 84AJ01)] and at $E_\alpha = 56.3$ to 95.5 MeV (85NE08, 86YA14). Polarization measurements have been carried out at $E = 4.3$ to 98 MeV [see (79AJ01)] and at $E(^3\vec{\text{He}}) = 55$ to 95 MeV (86YA14).

For $l \leq 4$, only f-wave phase shifts show resonance structure for $E(^3\text{He}) < 18$ MeV, corresponding to ^{7}Be*(4.57, 6.73, 9.27): see table 7.7. 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 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 $\gamma^2(\text{p}_0)/\gamma^2(\text{p}_1) = (16^{+5}_{-10})\%$. A phase-shift analysis (single-level R-matrix) has been carried out for $E(^3\text{He}) = 18$ to 32 MeV: the p-wave phase shifts indicate a $\frac{1}{2}^-$ state at $E_x \sim 16.7$ MeV ($E_r = 26.4$ MeV), with $\Gamma = 6.5$ MeV. There is the suggestion also of broad $l = 4$ and 5 states at $E(^3\text{He}) > 30$ MeV [$E_x > 19$ MeV]: see (84AJ01).

The differential cross section for reaction (b) has been determined for $E(^3\text{He}) = 8$ to 28 MeV [see (79AJ01)] and at $E_\alpha = 22.2$ to 26.5 MeV. Resonances are observed corresponding to ^{7}Be*(7.21, 9.27) in the p_0 yield, to ^{7}Be*(9.27) in the p_1 yield and to states at $E_x \sim 10$ MeV ($T = \frac{1}{2}$) and 11.0 MeV ($T = \frac{3}{2}$) in the yield of 3.56 MeV γ-rays. The evidence for the latter derives mainly from interference arguments. There is also some evidence for an extremely broad $J^\pi = \frac{1}{2}^-$ structure at $E_x \geq 10$ MeV [see also ^{6}Li(p, p)]:

Table 7.8
^{7}Be levels [a]) from ^{3}He + ^{4}He

E_x (MeV ± keV)	J^π	l_α	LS term	θ^2_α [b])	θ^2_p
4.57 ± 50	$\frac{7}{2}^-$	3	$^2F_{7/2}$	0.70 ± 0.04	
6.73 ± 100	$\frac{5}{2}^-$	3	$^2F_{5/2}$	1.36 ± 0.13	0.000 ± 0.002
7.21 ± 60	$\frac{5}{2}^-$	3	$^4P_{5/2}$	0.010 ± 0.001	0.26 ± 0.02
9.27 ± 100	$\frac{7}{2}^-$	3	$^4D_{7/2}$	0.70 ± 0.26	$0.29^{+0.09}_{-0.18}$ [f])
10.0 [c])	$\frac{3}{2}^-$	1	($^4P_{3/2}$)		
∼ 10.0 [d])	$\frac{1}{2}^-$		($^4P_{1/2}$)		
11.00 ± 50 [e])	$\frac{3}{2}^-$	1	($^2P_{3/2}$, $^2D_{3/2}$)		0.13 ± 0.02 [g])

[a]) See also table 7.10 (66LA04). For references see table 7.7 in (79AJ01).
[b]) $\gamma^2/(\frac{3}{2}\hbar^2/\mu a^2)$. $R = 4.0$ fm.
[c]) $\Gamma = 1.8$ MeV.
[d]) Broad.
[e]) $\Gamma = 0.4 \pm 0.05$ MeV; $T = \frac{3}{2}$.
[f]) $\theta^2_{p1} = 1.8 \pm 0.5$.
[g]) θ^2_{p2}.

see table 7.8 and (74AJ01, 84AJ01). For α + ^{3}He correlations see (87PO03). See also "Complex Reactions" on p. 68. For elastic and inelastic inclusive scattering cross sections at $p_\alpha = 7.0$ GeV/c see (84SA1C, 87BA13). See also (84IW01; astrophysics) and (81PL1A, 83HO22, 83LO09, 84BL21, 84FI1G, 84HO1C, 84HU1C, 84KA01, 85FR1F, 86FR12, 87KA09, 87OSZZ, 87TA06, 88FIZT; theor.).

4. ^{4}He(α, n)^{7}Be $\qquad Q_m = -18.990$

Angular distributions have been reported at $E_\alpha = 61.5$ to 158.2 MeV (82GL01) and 198.4 MeV (85WO11) for the transitions to ^{7}Be*(0 + 0.43). See also ^{8}Be.

5. ^{6}Li(p, γ)^{7}Be $\qquad Q_m = 5.606$

At low energies ($E_p = 0.2$ to 1.2 MeV) gamma transitions are observed to the ground (γ_0) and to the 0.43 MeV (γ_1) states. The yield shows no resonance and the branching ratio remains approximately constant at (61 ± 5)% to the ground state and (39 ± 2)% to ^{7}Be*(0.43): see (74AJ01, 84AJ01). Angular distributions of γ_0 and γ_1 have been studied at $E_p = 0.50$, 0.80 and 1.00 MeV (87TI05). At $E_p = 44.4$ MeV, ^{7}Li*(4.57) is strongly populated (85HA05). See also (83OS04), (83HA1B, 84BO1C, 85CA41; astrophysics) and (85BL1B).

6. (a) ^{6}Li(p, p)^{6}Li $E_b = 5.606$

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

(c) ^{6}Li(p, pα)^{2}H $Q_m = -1.4750$

Measurements of elastic angular distributions have been reported for $E_p = 0.5$ to 600 MeV: see (66LA04, 74AJ01) and ^{6}Li. 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 7.4. The 5 MeV resonance has $\Gamma \simeq 1.8$ MeV and appears to also be formed by p-waves: γ_p^2 is then 3 ± 2 MeV $\cdot$ fm. A weak rise near $E_p = 8$ to 9 MeV may indicate a further level, ^{7}Be* $\simeq 13$ MeV. A broad resonance at $E_p = 14$ MeV has also been suggested. Polarization measurements have been carried out for $E_p = 1.2$ to 800 MeV [see (74AJ01, 79AJ01, 84AJ01)] and at $E_{\vec{p}} = 4$ to 10 MeV (86BE1H; p$_0$) and 25 and 35 MeV (82RO1B, 83PO1B, 83PO1C; p$_0$, p$_1$). A phase-shift analysis for $E_p = 0.5$ to 5.6 MeV shows that only ^{2}S, ^{4}S and ^{4}P are involved. The ^{4}P$_{5/2}$ phase resonates at $E_p = 1.8$ MeV, and the broad resonance at 5 MeV can be reproduced equally well by either ^{4}P$_{3/2}$ or ^{4}P$_{1/2}$: tensor polarization measurements are necessary to distinguish between the two: see (74AJ01).

The reaction cross section for formation of ^{6}Li*(2.19) has been measured for $E_p = 3.6$ to 9.40 MeV: a broad resonance indicates the presence of a state with $E_x \sim 10$ MeV, $\Gamma = 1.8$ MeV, $J^\pi = (\frac{3}{2}, \frac{5}{2})^-$, $T = \frac{1}{2}$. The cross-section and angular distributions of p$_2$ (^{6}Li*(3.56)) for $E_p = 4.26$ to 9.40 MeV are analyzed in terms of two $J^\pi = \frac{3}{2}^-$ states at $E_x \sim 10$ and 11 MeV: see reaction 3. The total cross section for formation of ^{6}Li*(3.56) decreases slowly with energy for $E_p = 24.3$ to 46.4 MeV. The total reaction cross section has been measured for $E_p = 25.0$ to 48 MeV (85CA36). K_y^y spectra at $E_{\vec{p}} = 50$, 65 and 80 MeV, $\theta = 3°$–$20°$, are reported by (87SA46).

For the inclusive cross section at $E_p = 200$ MeV [back angles] see (84AV07). For reaction (b) see ^{5}He. For reaction (c) see ^{6}Li. See also ^{7}Be, (83GL1A, 84BA1U, 87TO06), (86PO1F, 86SA1Q; applications), (86BA1N, 86PF1A) and (81NE1B, 81PL1A, 83HO22, 83KA37, 86SA30, 87KN04; theor.).

7. ^{6}Li(p, n)^{6}Be $Q_m = -5.071$ $E_b = 5.606$

The yield of neutrons increases approximately monotonically from threshold to $E_p =$ 14.3 MeV: see (74AJ01). The transverse polarization transfer, D_{NN} (0°), for the g.s. transition has been measured for $E_{\vec{p}} = 30$ to 160 MeV: see (86TA1E, 84TA07) and ^{6}Be. Polarization measurements are reported at $E_{\vec{p}} = 50$ and 80 MeV (87SA46) and at 52.8 MeV (88HE08) [$K_y^{y'}$ (0°) $= -0.33 \pm 0.04$; also $K_z^{z'}$)]. See also (86MC09; $E_{\vec{p}} = 800$ MeV), ^{6}Be, (84BA1U, 86SA1Q) and (86RA1F).

8. ^{6}Li(p, α)^{3}He $Q_m = 4.0185$ $E_b = 5.606$

Thermonuclear reaction rates and the astrophysical S-factor have been derived from the low-energy ($E_p < 0.7$ MeV) cross section measurements: $S(0) \simeq 3.1$ MeV $\cdot$ b: see (74AJ01, 79AJ01, 84AJ01). At higher energies the cross section exhibits a broad, low maximum near $E_p = 1$ MeV and a pronounced resonance at $E_p = 1.85$ MeV ($\Gamma < 0.5$ MeV). No other structure is reported up to $E_p = 5.6$ MeV. Measurements between $E_p = 0.4$ and 3.4 MeV show that the polarizations are generally large and positive: see (74AJ01).

Angular distributions have been reported for $E_p = 0.15$ to 45 MeV [see (74AJ01, 79AJ01, 84AJ01)] and at 47.8, 53.5, 58.5 and 62.5 MeV (84NE05). See also (83SZ1A, 86KI1G), (85CA41; astrophys.), (86MC1D; applications) and (84KR1B; theor.).

9. ^{6}Li(d, n)^{7}Be $\qquad Q_m = 3.381$

Angular distributions of the n_0 and n_1 groups have been measured at $E_d = 0.20$ to 15.25 MeV: see (74AJ01, 79AJ01). The n_1–γ correlations are isotropic, indicating $J^\pi = \frac{1}{2}^-$ for ^{7}Be* (0.43). 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), $\Gamma_{c.m.} = 1.2$ and 0.5 MeV, respectively]: see (66LA04). See also ^{8}Be and (88KO1C).

10. ^{6}Li(^{3}He, d)^{7}Be $\qquad Q_m = 0.112$

Angular distributions of the d_0 and d_1 groups to ^{7}Be*(0, 0.43) have been measured at $E(^3\text{He}) = 8$, 10, 14 and 18 MeV and at $E(^3\vec{\text{He}}) = 33.3$ MeV [^{7}Be*(4.57) is also populated]: see (74AJ01, 84AJ01).

11. ^{6}Li(^{6}Li, ^{5}He)^{7}Be $\qquad Q_m = 1.01$

See (87MI34) and ^{5}He.

12. ^{7}Li(π^+, π^0)^{7}Be $\qquad Q_m = 3.742$

Forward-angle differential cross sections have been measured at $E_{\pi^+} = 20$ MeV (87IR01; also at 155° and 166°), at 33.5, 41.1, 48.7 and 58.8 MeV (85IR01, 85IR02), 70 to 180 MeV [see (84AJ01)] and from 300 to 550 MeV (88RO03).

13. ^{7}Li(p, n)^{7}Be $\qquad Q_m = -1.644$

$E_{\text{thresh.}} = 1880.443 \pm 0.020$ keV (85WH1A)

The excitation energy of ^{7}Be*(0.43) is 429.20 ± 0.10 keV, $\tau_m = 192 \pm 25$ fsec: see (79AJ01). Angular distributions of n_0 and n_1 have been reported at $E_p = 1.9$ to 119.8 MeV [see (74AJ01, 79AJ01, 84AJ01)] and at 200, 300 and 400 MeV (87WA1K; prelim.; n_{0+1}). ^{7}Be*(4.55, 6.51, 7.19, 10.79) have also been populated: see (74AJ01, 79AJ01). The ratios of σ_1/σ_0 (^{7}Be*(0.43)/^{7}Be$_{\text{g.s.}}$) have been measured at 24.8, 35 and 45 MeV and yield the ratio of spin-flip to spin-nonflip strength $|V_{0\tau}/V_\tau|^2$ (80AU02). See also ^{8}Be, (83KI1B, 84BR32, 84JE1A, 84TA07, 85JE1A, 85TA1C, 87HE24, 88HE08), (84KE1B, 85BA66, 85KE1D, 86CO1L; applications), (83RA1C, 84TA1F, 85GO1F, 87GO1V, 87RA32) and (83KR10, 84PE12; theor.).

14. (a) ^{7}Li(d, 2n)^{7}Be $\qquad Q_m = -3.869$

(b) ^{7}Li(t, 3n)^{7}Be $\qquad Q_m = -10.126$

See (87AL1K; $E(^7\text{Li}) = 65$ MeV).

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

Angular distributions of t_0 and t_1 have been measured at $E(^3\text{He}) = 3.0$ to 4.0 MeV and at $E(^3\vec{\text{He}}) = 33.3$ MeV: see (74AJ01, 84AJ01). The width of ^{7}Be*(4.57), $\Gamma_{\text{c.m.}} = 175 \pm 7$ keV: see (74AJ01). See also ^{10}B.

16. ^{7}Li(^{6}Li, ^{6}He)^{7}Be $\qquad Q_m = -4.369$

This reaction has been studied at $E(^6\text{Li}) = 14$, 25 and 35 MeV/A. ^{7}Be*(0, 0.43) are strongly populated and ^{7}Be*(4.57, 7.21) are also evident. At the highest energy the reaction mechanism is predominantly one-step (87WI09, 86AN29). See also ^{6}He, (88AL1G, 88BUZH, 88BU1Q), (86AU1C, 87AU04, 88AN1B) and (84BA53; theor.).

17. ^{9}Be(p, t)^{7}Be $\qquad Q_m = -12.082$

Angular distributions of tritons have been measured at $E_p = 43.7$ and 46 MeV [see (79AJ01)] and at 50 and 72 MeV (84ZA07; t_{0+1}, t_2). The 11 MeV state has $E_x = 11.01 \pm 0.04$ MeV, $\Gamma = 298 \pm 25$ 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)]: see (79AJ01).

18. ^{10}B(p, α)^{7}Be $\qquad Q_m = 1.146$

Angular distributions have been studied for $E_p = 2.8$ to 7.0 MeV [see (74AJ01)] and for 18 to 45 MeV (86HA27; α_0, α_1, α_2; see for spectroscopic factors). E_x of ^{7}Be*(0.43) = 428.89 ± 0.13 keV (79RI12). See also ^{11}C in (85AJ01), (83DO07) and (88KOZL; applied).

19. ^{10}B(d, ^{5}He)^{7}Be $\qquad Q_m = -1.97$

See ^{5}He.

20. ^{10}B(α, ^{7}Li)^{7}Be $\qquad Q_m = -16.200$

See ^{7}Li.

21. ^{11}B(^{3}He, ^{7}Li)^{7}Be $\qquad Q_m = -7.076$

See ^{7}Li.

22. ^{12}C(p, ^{6}Li)^{7}Be $\qquad Q_m = -22.566$

See ^{6}Li and (87KW03; theor.).

23. ^{12}C(d, ^{7}Li)^{7}Be $\qquad Q_m = -17.540$

See ^{7}Li.

24. ^{12}C(^{3}He, ^{8}Be)^{7}Be $\qquad Q_m = -5.779$

Angular distributions involving ^{7}Be*(0, 0.43) have been reported at $E(^{3}\mathrm{He}) = 25.5$ to 70 MeV [see (79AJ01, 84AJ01)] and at $E(^{3}\vec{\mathrm{He}}) = 33.4$ MeV (86CL1B; also A_y; prelim.). See also (86RA15; theor.).

25. ^{12}C(α, ^{9}Be)^{7}Be $\qquad Q_{\rm m} = -24.692$

At $E_\alpha = 42$ MeV, angular distributions have been measured involving ^{7}Be*(0, 0.43) and ^{9}Be$_{\rm g.s.}$: see (74AJ01). Angular distributions have also been measured at $E_\alpha = 49.0$ and 80.1 MeV (84GO03).

26. ^{12}C(^{7}Li, ^{12}B)^{7}Be $\qquad Q_{\rm m} = -14.231$

See (84BA53; theor.).

27. ^{16}O(^{3}He, ^{12}C)^{7}Be $\qquad Q_{\rm m} = -5.5746$

Angular distributions have been reported at $E(^{3}\text{He}) = 25.5$ to 70 MeV to ^{7}Be*(0, 0.43) and to various states of ^{12}C: see ^{12}C in (85AJ01). See also (86BA1F; theor.).

28. ^{16}O(^{7}Li, ^{16}N)^{7}Be $\qquad Q_{\rm m} = -11.281$

Angular distributions have been studied at $E(^{7}\text{Li}) = 50$ MeV involving ^{7}Be*(0, 0.43) and various states of ^{16}N (84CO20, 86CL03). See also ^{16}N in (86AJ04) and (84BA53; theor.).

29. ^{24}Mg(^{3}He, ^{20}Ne)^{7}Be $\qquad Q_{\rm m} = -7.723$

See (86RA15; theor.).

^{7}B

(Fig. 10)

The mass excess of ^{7}B from a study of the ^{10}B(^{3}He, ^{6}He)^{7}B reaction is 27.94 ± 0.10 MeV and the width of the ground state is $\Gamma = 1.4 \pm 0.2$ MeV: see (74AJ01). ^{7}B is unbound with respect to ^{6}Be + p, ^{5}Li + 2p and ^{4}He + 3p by 2.28, 1.68 and 3.65 MeV, respectively. The other work described in (84AJ01) has not been published. See also (85AN28), (86HU1D; astrophysics) and (82KA1D, 83ANZQ, 83AU1B; theor.).

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