Energy Levels of Light Nuclei
$A = 8$

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Abstract: An evaluation of $A = 5$–10 was published in *Nuclear Physics A*320 (1979), p. 1. This version of $A = 8$ 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.

(References closed 1978)

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^{8}n

(Not illustrated)

^{8}n has not been observed in the interaction of 0.7 and 400 GeV protons with uranium: the cross section is $< 2.3 \times 10^{-5}$ μb (1977TU02) at 0.7 GeV and < 0.2 μb at 400 GeV (1977TU1B). See also (1977DE08) and (1978SA1E).

^{8}He

(Figs. 11 and 14)

GENERAL: (See also (1974AJ01).)

See (1973AL1B, 1973TO16, 1974IR04, 1974MA1E, 1975AB1D, 1975BE31, 1976BE1G, 1976IR1B, 1976VA29, 1978KO1H, 1978NA07).

Mass of ^{8}He: The atomic mass excess of ^{8}He is 31596 ± 7 keV (1977TR07). See also (1974CE05, 1975JA10, 1975KO18, 1978RO01). ^{8}He is then stable with respect to decay into ^{6}He + 2n by 2.141 MeV. See also (1974AJ01, 1976TR1B) and (1975JE02; theor.). The IMME coefficients based on the latest masses of the $T = 2$ states in $A = 8$ are calculated by (1977TR07).

1. ^{8}He(β^{-})^{8}Li $\qquad Q_{\mathrm{m}} = 10.649$

The half-life is 122 ± 2 msec. The decay takes place 88% to ^{8}Li*(0.98) [$\log ft = 4.19$ †] [consistent with $J^{\pi} = 1^{+}$ for ^{8}Li*(0.98)] and (12 ± 1)% via ^{8}Li states which decay by neutron emission (1965PO06). See also (1973AN11, 1976DE31).

2. ^{18}O(α, ^{14}O)^{8}He $\qquad Q_{\mathrm{m}} = -37.962$

At $E_{\alpha} = 58$ MeV, $\theta_{\mathrm{lab}} = 8°$, the differential cross for formation of ^{8}He$_{\mathrm{g.s.}}$ is 40 ± 15 nb/sr (1975JA10).

3. ^{26}Mg(α, ^{22}Mg)^{8}He $\qquad Q_{\mathrm{m}} = -44.989$

This reaction has been studied at $E_{\alpha} = 80$ MeV (1966CE01) and 110.6 MeV (1974CE05).

† M.J. Martin, Nucl. Data Project, private communication.

^{8}Li

(Figs. 11 and 14)

GENERAL: (See also (1974AJ01).)

Nuclear models: (1975KH1A, 1977ST24).

Special states: (1974IR04, 1976IR1B, 1978KH03).

Electromagnetic interactions: (1974KU06, 1976KU07).

Special reactions: (1973SI38, 1974BA70, 1974BA1N, 1974BO08, 1975FE1A, 1975ZE01, 1976BE67, 1976BO08, 1976BU16, 1977FE1B, 1977PR05, 1977ST1J, 1977YA1B, 1978DI04).

Muon and neutrino interactions: (1977BA1P).

Pion and kaon reactions (See also reaction 16.): (1968ZE1A, 1973AG05, 1973AG06, 1973CA1C, 1974BO1F, 1974ZI1A, 1975CO06, 1975KU1J, 1977JU1B, 1977MA1K, 1978MO01, 1978VE1B).

Astrophysical questions: (1977SC1D, 1977ST1J).

Other topics: (1974IR04, 1974SE1B, 1975KH1A, 1976IR1B, 1977TR07, 1978GA1C, 1978RO01).

Ground state properties: (1974KU06, 1974SHYR, 1975BE31, 1976FU06, 1977TR07, 1978RO01, 1978ZA1D).

$J = 2$ (1973NE10);

$\mu = +1.65335 \pm 0.00035$ nm (1973HA12). See also (1974AJ01);

$Q = 24 \pm 2$ mb (1975MI04);

$= 32 \pm 6$ mb (1974AC03);

$= 32$ mb (1977DU06).

1. ^{8}Li(β^{-})^{8}Be $\qquad Q_{\rm m} = 16.005$

The β-decay leads mainly to ^{8}Be*(2.9): see ^{8}Be. The adopted half-life [see (1974AJ01)] $=$ 842 ± 6 msec, $\log ft = 5.61$ (B. Zimmerman, private communication). The distribution of recoil momenta indicates $J^{\pi} = 2^{+}$ for ^{8}Li$_{\rm g.s.}$. The coefficient for the angular correlation between β^{-}, $\overline{\nu_{\rm e}}$ and α-particles, $b = -0.88 \pm 0.08$ (1965GR25), -1.01 ± 0.07 (1966EI02), in substantial agreement with $b = -1$, expected from axial vector coupling. (1975MI04) have looked at the symmetry of the β-decay in polarized ^{8}Li nuclei and have determined the quadrupole moment for ^{8}Li$_{\rm g.s.}$: see the "GENERAL" section here. See also reaction 28 in ^{8}Be.

Table 8.1: Energy levels of ^{8}Li

E_x (MeV $\pm$ keV)	$J^{\pi}; T$	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
g.s.	$2^+; 1$	$\tau_{1/2} = 842 \pm 6$ msec	β^+	1, 2, 3, 10, 11, 13, 14, 15, 17, 18, 19, 20, 22, 23, 24, 25, 26, 27, 28, 29, 31
0.9808 ± 0.1	$1^+; 1$	$\tau_m = 12 \pm 4$ fsec	γ	2, 10, 12, 16, 17, 18, 19, 23, 25, 26, 27, 28, 29
2.255 ± 3	$3^+; 1$	$\Gamma = 33 \pm 6$ keV	γ, n	2, 3, 4, 17, 18, 19, 23, 26
3.21	1; 1	≈ 1000	n	5
5.4		≈ 650	n	4, 5
6.1 ± 100	(3); 1	≈ 1000	n	4, 5
6.53 ± 20	≥ 4	35 ± 15	n	2, 4, 18, 19, 23
7.1 ± 100		≈ 400	n	4
(9)		≈ 6000		17, 18
10.8222 ± 5.5	$0^+; 2$	< 12		21

2. ^{6}Li(t, p)^{8}Li $\qquad Q_m = 0.801$

Angular distributions have been obtained at $E_t = 23$ MeV for the proton groups to ^{8}Li*(0, 0.98, 2.26, 6.54 ± 0.03); $\Gamma_{c.m.}$ for ^{8}Li*(2.26, 6.54) $= 35 \pm 10$ and 35 ± 15 keV, respectively; J for the latter is ≥ 4 (1978AJ02).

3. ^{7}Li(n, γ)^{8}Li $\qquad Q_m = 2.033$

The cross section for capture radiation has been measured for $E_n = 40$ to 1000 keV: it decreases from 50 μb to 5 μb over the interval. The cross section shows the resonance corresponding to ^{8}Li*(2.26): $\Gamma_{\gamma} = 0.07 \pm 0.03$ eV (1959IM04); $E_{res} = 254 \pm 3$ keV, $\Gamma_n = 31 \pm 7$ keV (1971AL09): see Table 8.2. For unpublished data see (1974AJ01). See also (1976GAYV).

4. ^{7}Li(n, n)^{7}Li $\qquad E_b = 2.033$

The thermal cross section is 1.07 ± 0.04 b (1960HU1A); the coherent scattering length (thermal, bound) is -2.1 ± 0.1 fm (see (1973MU14)). See also (1974RO20). Total cross-section measurements have been reported for $E_n = 5$ eV to 30 MeV [see (1974AJ01, 1976GAYV)] and

Table 8.2: Resonance parameters for ^{8}Li*(2.26) (1970ME1C) [a]

$E_{\rm res}$ (keV) [b]	261.2
$E_{\rm x}$ (MeV) [c]	2.261
Γ (keV)	35 ± 5 [d]
$\Gamma_{\rm n}(E_{\rm r})$ (keV)	36.5
Γ_{γ} (eV) [c]	0.07 ± 0.03 [e]
$\gamma_{\rm n}^2$ (keV)	594
θ^2	0.091
radius (fm)	3.30
$\sigma_{\rm max}$ [b]	12.0
J^{π}	3^{+}
$l_{\rm n}$	1

[a] Energies in lab system except for those labeled [c].
[b] $E_{\rm res} = 254 \pm 3$ keV, $\Gamma_{\rm n} = 31 \pm 7$ keV (1971AL09).
[c] Energies in c.m. system.
[d] (1960HU1A).
[e] (1959IM04).

by (1976KN1D, 1976LA1C; $E_{\rm n} = 4$ to 7.5 MeV), (1974HY01; 14.1 MeV) and (1976MI1C; 14.6 MeV). For polarization measurements see (1966LA04, 1974AJ01). For angular distribution measurements see ^{7}Li.

A pronounced resonance is observed at $E_{\rm n} = 261$ keV with $J^{\pi} = 3^{+}$, formed by p-waves (Table 8.2) (1970ME1C). A good account of the polarization is given by the assumption of levels at $E_{\rm n} = 0.25$ and 3.4 MeV, with $J^{\pi} = 3^{+}$ and 2^{-}, together with a broad $J^{\pi} = 3^{-}$ level at higher energy (1964LA19). Broad peaks are reported at $E_{\rm n} = 4.6$ and 5.8 MeV (± 0.1 MeV) [^{8}Li*(6.1, 7.1)] with $\Gamma \approx 1.0$ and 0.4 MeV, respectively, and there is indication of a narrow peak at $E_{\rm n} = 5.1$ MeV [^{8}Li*(6.5)] with $\Gamma << 80$ keV and of a weak, broad peak at $E_{\rm n} = 3.7$ MeV (1971FO1A) [and see (1974AJ01)]. See also (1977ST24, 1978ST20; theor.).

5. ^{7}Li(n, n$'$)^{7}Li* $\qquad E_{\rm b} = 2.033$

The exciation function for 0.48 MeV γ-rays shows an abrupt rise from threshold (indicating s-wave formation and emission) and a broad maximum ($\Gamma \approx 1$ MeV) at $E_{\rm n} = 1.35$ MeV. A good fit is obtained with either $J^\pi = 1^-$ or 1^+ (2^+ not excluded), $\Gamma_{\rm lab} = 1.14$ MeV (1955FR10). At higher energies a prominent peak is observed at $E_{\rm n} = 3.8$ MeV ($\Gamma_{\rm lab} = 0.75$ MeV) and there is some indication of a broad resonance ($\Gamma_{\rm lab} = 1.30$ MeV) at $E_{\rm n} = 5.0$ MeV. The two resonances are interpreted as being due to states with $J^\pi = 2^+$ or 3^+ [^{8}Li*(5.4)] [see, however, (1978ST20)] and $J^\pi = 3^+$ or 3^- [^{8}Li*(6.4)] [(1972PR03): Γ_λ, γ_λ^2 and θ_λ^2 are listed for these two states under various assumptions]. (1977BA62) predicts a 2^- state at $E_{\rm x} = 2.74$ MeV and 1^- states at 3.52 and 5.4 MeV with $\Gamma \approx 1.8$, 2.5 and 3.8 MeV. The excitation function for 0.48 MeV γ-rays has been measured at $125°$ for $E_{\rm n} = 0.4$ to 20 MeV: it shows the structures described above followed by a decrease in the cross section from $E_{\rm n} = 6$ to 20 MeV with some evidence of structures at $E_{\rm n} = 6.8$ and 8 MeV (1977DI1A).

Cross-section measurements have also been reported for $E_{\rm n} = 0.57$ to 4.0 MeV (1976SM1B), 4.0 to 7.5 MeV (1977KN1B) and 7 to 13 MeV (1976BI1B; $\rm n_{0+1}$, $\rm n_2$). See also (1976MI1C, 1978LI1C) and the review in (1976GAYV). For applications see (1974ST1D).

6. ^{7}Li(n, 2n)^{6}Li $\quad Q_{\rm m} = -7.251 \quad E_{\rm b} = 2.033$

See (1974KO35, 1976GAYV).

7. ^{7}Li(n, p)^{7}He $\quad Q_{\rm m} = -10.40 \quad E_{\rm b} = 2.033$

See (1977RI07) and ^{7}He. See also (1976SL2A).

8. ^{7}Li(n, d)^{6}He $\quad Q_{\rm m} = -7.751 \quad E_{\rm b} = 2.033$

See ^{6}He. See also (1976SL2A).

9. ^{7}Li(n, t)^{4}He + n $\quad Q_{\rm m} = -2.467 \quad E_{\rm b} = 2.033$

The cross section rises to 450 mb at $E_{\rm n} \approx 8$ MeV and thereafter decreases slowly to 300 mb at $E_{\rm n} = 15$ MeV (1976GAYV). See also (1975VO1C, 1978QA01), (1974ST1D; applied) and (1976SL2A).

10. ^{7}Li(d, p)^{8}Li $\quad Q_{\rm m} = -0.192$

Angular distributions of the p_0 and p_1 groups [$l_n = 1$] at $E_d = 12$ MeV have been analyzed by DWBA: $S_{exp} = 0.87$ and 0.48 respectively for ^{8}Li*(0, 0.98) [$S_{exp}/S_{theor} = 0.84$, 1.09] (1967SC29). Angular distributions have also been measured at several energies in the range $E_d = 0.49 \rightarrow 3.44$ MeV (p_0) and 0.95 to 2.94 MeV (p_1) by (1975MC02). The first excited state decays by emitting a 980 ± 10 keV γ-ray. The transition is M1 (1962CH14). The lifetime of ^{8}Li*(0.98) is 10.1 ± 4.5 fsec (1971TH02). See also (1975MI04, 1978HA1K), (1974AJ01, 1976HA1J) and (1974LO10, 1975KU27, 1976KU07; theor.).

11. ^{7}Li(t, d)^{8}Li $\qquad Q_m = -4.225$

See ^{10}Be in (1974AJ01).

12. ^{8}He(β^-)^{8}Li $\qquad Q_m = 10.649$

See ^{8}He.

13. ^{9}Be(γ, p)^{8}Li $\qquad Q_m = -16.888$

See ^{9}Be.

14. ^{9}Be(e, ep)^{8}Li $\qquad Q_m = -16.888$

At $E_e = 801$ MeV two groups are observed at $Q = -28.7 \pm 0.1$ and -16.9 ± 0.1 MeV corresponding to the ejection of 1s and 1p protons (1974GO35). See also ^{9}Be and (1977BE1Q, 1977MO1F).

15. ^{9}Be(n, d)^{8}Li $\qquad Q_m = -14.663$

See ^{10}Be.

16. ^{9}Be(π^+, π^+p)^{8}Li $\qquad Q_m = -16.888$

The population of ^{8}Li*(0.98) and its subsequent γ-decay are reported by (1978MO01).

17. ^{9}Be(p, 2p)^{8}Li $\qquad Q_{\rm m} = -16.888$

The summed proton spectrum at $E_{\rm p} = 156$ MeV shows peaks corresponding to ^{8}Li(0) and ^{8}Li*$(0.98 + 2.26)$ [unresolved]. In addition s-states [$J^{\pi} = 1^{-}, 2^{-}$] are suggested at $E_{\rm x} = 9$ and 16 MeV, with $\Gamma_{\rm c.m.} \approx 6$ and 8 MeV: the latter may actually be due to continuum protons (1967RO06). See also ^{9}Be.

18. ^{9}Be(d, ^{3}He)^{8}Li $\qquad Q_{\rm m} = -11.394$

Angular distributions have been reported for the ^{3}He ions to ^{8}Li*(0, 0.98, 2.26, 6.53) at $E_{\rm d} = 27.97$ MeV (1977OO01; $C^{2}S$(abs.) $= 1.63$, 0.61, 0.48, 0.092) and 52 MeV (1975SC41; $S_{{\rm p}_{3/2}} = 1.50$, 0.63, 0.50 for the first three states, with the ground state value normalized to the predicted theoretical value). The distributions to ^{8}Li*(6.53) [$\Gamma < 100$ keV (1974DI1A, 1975DI1B)] are featureless (1975DI1B, 1975SC41, 1977OO01). See reaction 32 [^{9}Be(d, t)] in ^{8}Be (1977OO01). At $E_{\rm d} = 80$ MeV, (1974DI1A, 1975DI1B; abstracts) report a broad peak at $E_{\rm x} \approx 9$ MeV corresponding to s-shell pickup. See also (1975RO1E).

19. ^{9}Be(t, α)^{8}Li $\qquad Q_{\rm m} = 2.926$

At $E_{\rm t} = 12.98$ MeV, α-particle groups are observed to ^{8}Li*(0, 0.98, 2.26) and to a state at $E_{\rm x} = 6.530 \pm 0.020$ MeV with $\Gamma_{\rm c.m.} < 40$ keV (1965WA12). For angular distributions to these four states, see (1968AJ01): the distribution of the α-particles to ^{8}Li*(6.53) is rather featureless and does not involve a forward maximum, suggesting $l > 1$. A large l-transfer is consistent with the narrow width of this unbound state (1968AJ01). See also (1974AJ01) for unpublished measurements and earlier work.

The mean lifetime, $\tau_{\rm m} = 14 \pm 5$ fsec for ^{8}Li*(0.98): $E_{\rm x} = 980.80 \pm 0.10$ keV (1972CO09). See also ^{12}B in (1975AJ02).

20. ^{9}Be(^{7}Li, ^{8}Be)^{8}Li $\qquad Q_{\rm m} = 0.368$

See (1974KE1C) and (1974AJ01).

21. ^{10}Be(p, ^{3}He)^{8}Li $\qquad Q_{\rm m} = -15.982$

At $E_p = 45$ MeV ^{3}He ions are observed to a state of $E_x = 10.8222 \pm 0.0055$ MeV ($\Gamma_{c.m.} < 12$ keV): the angular distributions for the transition to this state, and to its analog (^{8}Be*(27.49)), measured in the mirror reaction [^{10}Be(p, t)^{8}Be] are very similar. They are both consistent with $L = 0$ using a DWBA (LZR) analysis (1975RO01). The particle decay of the $T = 2$ state has been studied by (1975ADZV; abstract).

22. ^{10}Be(d, α)^{8}Li $\quad Q_m = 2.372$

See ^{12}B in (1975AJ02).

23. ^{10}B(^{6}Li, ^{8}B)^{8}Li $\quad Q_m = -17.730$

At $E(^6\text{Li}) = 80$ MeV, ^{8}Li*(0, 0.98, 2.26, 6.53) are populated (1976WE09, 1977WE1B).

24. ^{11}B(γ, ^{3}He)^{8}Li $\quad Q_m = -27.210$

See (1963NE07).

25. ^{11}B(n, α)^{8}Li $\quad Q_m = -6.633$

Angular distributions for the α_0 and α_1 groups have been measured at $E_n = 14.1$ MeV (1973BO26). See also ^{12}B in (1975AJ02) and (1977AN1C).

26. ^{12}C(α, ^{8}B)^{8}Li $\quad Q_m = -41.444$

At $E_\alpha = 129$ MeV, ^{8}B groups are observed to ^{8}Li*(0, 0.98, 2.26) (1968MC02).

27. ^{13}C(^{3}He, ^{8}B)^{8}Li $\quad Q_m = -25.812$

See (1976BE1L).

28. ^{13}C(^{7}Li, ^{12}C)^{8}Li $\quad Q_m = -2.914$

At $E(^7\text{Li}) = 34$ MeV angular distributions have been measured for the transitions to $^8\text{Li}_{\text{g.s.}} + {}^{12}\text{C}_{\text{g.s.}}$, $^8\text{Li}^*_{0.98} + {}^{12}\text{C}_{\text{g.s.}}$, $^8\text{Li}_{\text{g.s.}} + {}^{12}\text{C}^*_{4.4}$ and $^8\text{Li}^*_{0.98} + {}^{12}\text{C}^*_{4.4}$ (1973SC26).

29. ^{14}N(^{3}He, ^{9}C)^{8}Li $\qquad Q_{\text{m}} = -32.064$

At $E(^3\text{He}) = 76$ MeV ^{8}Li*(0, 0.98) are populated (1976RO04).

30. ^{18}O(^{7}Li, ^{17}O)^{8}Li $\qquad Q_{\text{m}} = -6.012$

See (1974AJ01).

31. ^{24}Mg(^{3}He, ^{19}Na)^{8}Li $\qquad Q_{\text{m}} = -32.876$

See (1975BE38).

^{8}Be
(Figs. 12 and 14)

GENERAL: (See also (1974AJ01).)

Shell model: (1973AR1C, 1974KA11, 1975GO07, 1975SC1K, 1976AR07, 1976JI1A, 1976ST04).

Collective, rotational and deformed models: (1974BO25, 1974LE04, 1975AR28, 1975KH1A).

Cluster and α-particle models: (1970YU02, 1973AB1A, 1973AR1C, 1974CH01, 1974DR05, 1974KA11, 1975AB1E, 1975SC1K, 1976BA1N, 1976ST04, 1977AR08, 1977BE50, 1977FU1D, 1977FU1F, 1977HE10, 1977HE1C, 1977KA1K, 1977KI10, 1977SE1D, 1977SM1A, 1977ZA04, 1978AR1M, 1978ST10, 1978TO09).

Special levels: (1973DO1B, 1974HA1G, 1974IR04, 1974KA11, 1974KU06, 1974MC04, 1974NE1B, 1975SH01, 1976IR1B, 1976JI1A, 1977BA62, 1977FU1F, 1977KA1K, 1978AR1M, 1978BA31, 1978BA66, 1978SE1C, 1978SH04, 1978ST10).

Electromagnetic transitions: (1974HA1C, 1974KU06, 1976KU07, 1977HE1C, 1977KU20, 1978TO09).

Special reactions: (1974GA1E, 1974KO16, 1975FE1A, 1975UN1A, 1976AR02, 1976VA29, 1976WO11, 1977GA1F, 1978ZO1A).

Pion and kaon reactions: (1973AR1B, 1973CA1C, 1974AM01, 1974BO1F, 1974ZI1A, 1977BA51).

Other topics: (1973DO1B, 1973KR1B, 1973PE05, 1974BE1K, 1974BE1L, 1974CH01, 1974DZ03, 1974IR04, 1974KU06, 1974MC04, 1975AR10, 1975AR28, 1975ER09, 1975GO07, 1975KH1A, 1975KO1C, 1975SH01, 1976AR07, 1976IR1B, 1976KH04, 1976KU07, 1976SA16, 1977AR08, 1977BE1U, 1977HE10, 1977TR07, 1978BA31, 1978JE1B, 1978KA1G, 1978MC04, 1978RO01, 1978RO17, 1978SH04).

Ground state of ^{8}Be: (1973AB1A, 1973DO1B, 1973FA1C, 1973PA20, 1973PE05, 1974DR05, 1974DZ03, 1975BE31, 1976BE1G, 1976IR1B, 1976OV1B, 1978RO17).

1. ^{8}Be $\rightarrow$ ^{4}He^{4}He $\qquad Q_{\rm m} = 0.09188$

$\Gamma_{\rm c.m.}$ for the ^{8}Be$_{\rm g.s.}$ $= 6.8 \pm 1.7$ eV (1968BE02). See also (1974FE1B, 1976FE1A) and (1974LI16; theor.).

2. ^{4}He(α, γ)^{8}Be $\qquad Q_{\rm m} = -0.09188$

The yield of γ_1 has been measured for $E_\alpha = 32$ to 36 MeV: see (1975NA12, GA77F, 1977PA26). An angular correlation measurement at the resonances corresponding to ^{8}Be*(16.6 + 16.9) [2^+; $T = 0 + 1$] gives $\delta = 0.19 \pm 0.03$ (1978BO30); Γ_γ(M1) $= 6.1 \pm 0.53$ eV (1978BO30), 7.4 ± 1.0 eV (1977PA26), 5.50 ± 0.60 eV (1977LO1D, 1977LO1E). On the basis of these results there is no evidence for violation of CVC or for the existence of second-class currents: see (1978BO30). (1977PA26) find $E_x = 3.18 \pm 0.05$ MeV for the energy of the first excited state (see also Table 8.4 in (1974AJ01)). The yield of γ_0 for $E_\alpha = 33$ to 38 MeV is twenty times lower than that for γ_1, consistent with E2 decay (1977GAZZ). See also (1975NA1C) and (1977GA1E).

Table 8.3: Energy Levels of ^{8}Be [a]

E_x (MeV ± keV)	$J^\pi; T$	$\Gamma_{c.m.}$ (keV)	Deacy	Reactions
g.s.	0^+; 0	6.8 ± 1.7 eV	α	1, 2, 4, 11, 12, 13, 14, 15, 21, 22, 23, 24, 25, 27, 30, 31, 32, 33, 34, 36, 38, 39, 40, 41, 42, 43, 45, 47, 48, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 64, 66, 68, 69
2.94 ± 30	2^+; 0	1560 ± 30	α	2, 4, 12, 13, 14, 15, 21, 23, 24, 25, 27, 28, 29, 30, 31, 32, 33, 37, 38, 39, 40, 41, 42, 43, 45, 47, 48, 50, 51, 52, 53, 54, 57, 61
11.4 ± 300	4^+; 0	≈ 3500 [b]	α	4, 13, 21, 24, 31, 33, 40, 43, 45, 52, 53, 54
16.626 ± 3	$2^+; 0 + 1$	108.1 ± 0.5	γ, α	2, 4, 12, 14, 15, 21, 23, 24, 29, 31, 32, 33, 38, 40, 45, 47, 48, 52, 53
16.922 ± 3	$2^+; 0 + 1$	74.0 ± 0.4	γ, α	2, 4, 12, 14, 15, 21, 23, 24, 31, 32, 33, 38, 40, 45, 47, 48, 52, 53
17.641 ± 1.5	1^+; 1	10.7 ± 0.5	γ, p	5, 12, 15, 17, 21, 23, 31, 32, 33, 40, 45, 47, 53
18.150 ± 4	1^+; 0	138 ± 6	γ, p	12, 15, 17, 21, 31, 32, 33, 40, 45

Table 8.3: Energy Levels of ^{8}Be [a] (continued)

E_x (MeV ± keV)	$J^\pi; T$	$\Gamma_{c.m.}$ (keV)	Deacy	Reactions
18.91	2^-	48 ± 20	γ, n, p	12, 15, 16, 17, 21, 31, 45
19.069 ± 10	3^+; (1)	270 ± 20	γ, p	12, 15, 17, 21, 32, 45
19.24 ± 25	3^+; (0)	230 ± 30	n, p	16, 17, 21, 31, 32, 33, 40
19.4	1^-	≈ 650	n, p	12, 16, 17
19.86 ± 50	4^+; 0	700 ± 100	p, α	4, 12, 14, 20, 24, 32, 48
20.1	2^+; 0	≈ 1100	n, p, α	3, 4, 16, 20, 24, 32, 48
20.2	0^+; 0	< 1000	α	4
20.9	4^-	1600 ± 200	p	17
21.5	$3^{(+)}$	1000	n, p	16, 31
22.0 [c]	1^-; 1	≈ 4000	γ, p	15
22.05 ± 100		270 ± 70		33
22.2	2^+; 0	≈ 800	n, p, d, α	3, 4, 10, 17, 20
22.63 ± 100		100 ± 50		14, 33
22.98 ± 100		230 ± 50		31, 33
24.0 [c]	$(1, 2)^-$; 1	≈ 7000	γ, p	15
25.2	2^+; 0		p, d, α	4, 10, 20, 33
25.5	4^+; 0	broad	d, α	4, 10
27.494 ± 2 [d]	0^+; 2	5.5 ± 2.0	γ, p, d, α	3, 5, 7, 8, 10, 35
(28.6)		broad	γ, p	15

[a] See also Table 8.7.

[b] I am greatly indebted to Prof. F.C. Barker for enlightening discussions concerning the width of ^{8}Be*(11.4).

[c] Giant resonance: see reaction 15.

[d] See Table 8.4.

3. (a) ^{4}He(α, n)^{7}Be $\quad Q_m = -18.992 \quad E_b = -0.09188$

   (b) ^{4}He(α, p)^{7}Li $\quad Q_m = -17.347$

   (c) ^{4}He(α, d)^{6}Li $\quad Q_m = -22.3733$

Table 8.4: Parameters of the first $T = 2$ state in ^{8}Be

E_x (MeV)	27.4922 ± 0.0026	(1975RO01)
	27.4958 ± 0.0024	(1976NO07)
Γ (keV)	10 ± 3	(1969BL14)
	14.7 ± 4.0	(1976HI04)
	12 ± 3	(1975RO01)
	5.5 ± 2.0	(1976NO07)
Γ_{γ_5} [b]	23 ± 4 eV	(1976NO07)
Γ_{p_0}/Γ	$0.012 < \Gamma_{p_0}/\Gamma < 0.023$ [a]	(1976HI04)
Γ_{p_2}/Γ	> 0.005	(1976HI04)
Γ_{d_0}/Γ	> 0.0014	(1976HI04)
Γ_{d_1}/Γ	> 0.0018	(1976HI04)
Γ_{α_0}/Γ	< 0.003	(1976HI04)
[c]		

[a] Lower limit from ^{4}He(α, p_0); upper limit from ^{7}Li(p, p_0) (1976HI04).
[b] $\Gamma_{\gamma_1} < 0.01$ eV (1977LO1F; prelim.).
[c] $\Gamma_d \Gamma_\gamma / \Gamma < 2.5$ eV (1975GE1F; prelim.).

The cross sections for formation of ^{7}Li*(0, 0.48) [$E_\alpha = 39$ to 49.5 MeV] and ^{7}Be*(0, 0.43) [39.4 to 47.4 MeV] both show structures at $E_\alpha \approx 40.0$ and ≈ 44.5 MeV: they are due predominantly to the 2^+ states ^{8}Be*(20.1, 22.2). The cross sections for (a) and (b) are of interest in accounting for the abundance of ^{7}Li in the galaxy (1977KI12). Cross sections for p_{0+1} are also reported at $E_\alpha = 60.2$, 92.4 and 140.0 MeV (1975KI14). See also (1977RA1B). The cross section for reaction (c) has been measured at three energies in the range $E_\alpha = 46.7$ to 49.5 MeV (1977KI12). See also (1977KI05). (1976HI04) have measured the excitation functions for p_0, p_2, d_0, d_1 for $E_\alpha = 54.96$ to 55.54 MeV to study the decay of the first $T = 2$ state in ^{8}Be: see Table 8.4. See also (1975MA1G), (1977AU1B, 1977KO1J; astrophys.) and ^{6}Li, ^{7}Li and ^{7}Be.

4. ^{4}He(α, α)^{4}He $\qquad E_b = -0.09188$

The $\alpha\alpha$ scattering reveals the ground state as a resonance with $Q_0 = 92.12 \pm 0.05$ keV, $\Gamma_{\text{c.m.}} = 6.8 \pm 1.7$ eV, [$\tau = (0.97 \pm 0.24) \times 10^{-16}$ sec] (1968BE02). For $E_\alpha = 30$ to 70 MeV the $l = 0$ phase shift shows resonant behavior at $E_\alpha = 40.7$ MeV, corresponding to a 0^+ state at $E_x = 20.2$ MeV,

Table 8.5: Some ^{8}Be states with $16.6 < E_x < 23.0$ MeV [a]

E_x (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	Reaction	Refs.
16.627 ± 5	113 ± 3	^{7}Li(^{3}He, d)	(1967MA12) [b]
	90 ± 5	^{10}B(d, α)	(1971NO04)
16.623 ± 3	107.7 ± 0.5	^{4}He(α, α)	(1978HI04) [c]
16.630 ± 3	108.5 ± 0.5	^{4}He(α, α)	(1978HI04) [d]
16.626 ± 3	108.1 ± 0.5	best value	
16.901 ± 5	77 ± 3	^{7}Li(^{3}He, d)	(1967MA12) [b]
	70 ± 5	^{10}B(d, α)	(1971NO04)
16.925 ± 3	74.4 ± 0.4	^{4}He(α, α)	(1978HI04) [c]
16.918 ± 3	73.6 ± 0.4	^{4}He(α, α)	(1978HI04) [d]
16.922 ± 3	74.0 ± 0.4	best value	
17.641 ± 1.5	10.7 ± 0.5	^{7}Li(p, γ)	Table 8.6 [a]
18.156 ± 5	147	^{7}Li(p, γ)	Table 8.6
18.150 ± 5	138 ± 6	^{10}B(d, α)	(1970CA12)
18.144 ± 5		^{9}Be(d, t)	(1977OO01)
18.150 ± 4	138 ± 6	best value	
19.06 ± 20	270 ± 20	^{7}Li(p, γ)	Table 8.6
19.071 ± 10	270 ± 30	^{9}Be(d, t)	(1977OO01)
19.069 ± 10	270 ± 20	best value	[h]
19.21	208 ± 30	^{9}Be(p, d)	(1967KU10)
19.22 ± 30	265 ± 30	^{9}Be(^{3}He, α)	(1976AJ01) [g]
19.26 ± 30	220 ± 30	^{9}Be(d, t)	(1977OO01)
19.24 ± 25 [e]	230 ± 30	best value	
19.86 ± 50	700 ± 100	^{9}Be(d, t)	(1977OO01)

Table 8.5: Some ^{8}Be states with $16.6 < E_x < 23.0$ MeV [a] (continued)

E_x (MeV $\pm$ keV)	$\Gamma_{c.m.}$ (keV)	Reaction	Refs.
22.05 ± 100 [f]	270 ± 70	^{9}Be(^{3}He, α)	(1976AJ01)
22.63 ± 100	100 ± 50	^{9}Be(^{3}He, α)	(1976AJ01)
22.98 ± 100 [f]	230 ± 50	^{9}Be(^{3}He, α)	(1976AJ01)

[a] See also Table 8.5 in (1974AJ01) and Tables 8.6, 8.8, 8.9 here.

[b] See also (1970CA12, 1971PI06, 1977OO01, 1978HI04).

[c] R-matrix theory.

[d] Complex eigenvalue theory.

[e] See also (1969SU02): 19.16 ± 0.07 MeV.

[f] The states at 22.0 ± 0.15 and 22.9 ± 0.15 reported by (1969SU02) in the ^{9}Be(p, d) reaction have $\Gamma_{c.m.} \geq 1$ MeV.

[g] And private communication.

[h] See, however, (1978BA66).

$\Gamma < 1$ MeV, $\Gamma_\alpha/\Gamma < 0.5$. No evidence for other 0^+ states is seen above $E_\alpha = 43$ MeV (1972BA83): see also (1974AJ01).

The d-wave phase shift becomes appreciable for $E_\alpha > 2.5$ MeV and passes through resonance at $E_\alpha = 6$ MeV ($E_x = 3.18$ MeV, $\Gamma = 1.5$ MeV, $J^\pi = 2^+$) (1963TO02): see Table 8.4 in (1974AJ01). Five 2^+ levels are observed from $l = 2$ phase shifts measured from $E_\alpha = 30$ to 70 MeV: ^{8}Be*(16.6, 16.9) with $\Gamma_\alpha = \Gamma$ [see (1978HI04) and Table 8.5], and states with $E_x = 20.2$, 22.2 and 25.2 MeV. The latter has a small Γ_α (1972BA83).

The $l = 4$ shift rises from $E_\alpha \approx 11$ MeV and indicates a broad 4^+ level at $E_x = 11.4 \pm 0.3$ MeV (1959BR71), 11.7 ± 0.4 MeV [$\Gamma = 4.0 \pm 0.4$ MeV] (1974CH45). A rapid rise of δ_4 at $E_\alpha = 40$ MeV corresponds to a 4^+ state at 19.9 MeV with $\Gamma_\alpha/\Gamma \approx 0.96$; $\Gamma < 1$ MeV and therefore $\Gamma_\alpha < 1$ MeV, which is < 5% of the Wigner limit. A broad 4^+ state is also observed near $E_\alpha = 51.3$ MeV ($E_x = 25.5$ MeV) (1972BA83, 1978LE13).

Over the range $E_\alpha = 30$ to 70 MeV a gradual increase in δ_6 is observed (1972BA83). Some indications of a 6^+ state at $E_x \approx 28$ MeV and of an 8^+ state at ≈ 57 MeV have been reported by (1965DA1A) with $\Gamma_{c.m.} \approx 20$ and ≈ 73 MeV, respectively. A resonance is not observed at the first $T = 2$ state, ^{8}Be*(27.49): see Table 8.4 (1976HI04). The elastic scattering has also been studied at $E_\alpha = 160$ MeV (1978RO1G), at 650 and 850 MeV (1976FO03), 850 and 1370 MeV (1977TE1A) and at 4.30 and 5.05 GeV/c (1977BE1R, 1977BE1T). The total cross section has been measured at 0.87 and 2.1 GeV/A (1975JA1A).

The bremsstrahlung cross section has been measured for $E_\alpha = 9.35$ to 18.7 MeV: see (1974AJ01). See also (1975GR1C; theor.).

See also (1975IG1A, 1975TO1A, 1976SL02, 1977KI05, 1978BR1E, 1978CH1G, 1978FI1E) and (1973CO1C, 1973FA1C, 1973HA1F, 1973TA1B, 1974AT1A, 1974BA1P, 1974FR1B, 1974FR06, 1974LU05, 1974RA16, 1974TH04, 1974WA02, 1974WA1D, 1975AN1F, 1975BA76, 1975BE1M, 1975BE16, 1975CL1C, 1975DU09, 1975GR05, 1975GR41, 1975GR1C, 1975HE07, 1975HO1E, 1975KU09, 1975MA27, 1975TA1D, 1976AL1E, 1976BA1E, 1976BR32, 1976CO18, 1976CU07, 1976GO12, 1976HA18, 1976HA1L, 1976HO1A, 1976JA1F, 1976LE1J, 1976LI1E, 1976ME1C, 1976MI17, 1976MO31, 1976RA1E, 1977AL1G, 1977AN1B, 1977BA17, 1977BE50, 1977BU01, 1977CA06, 1977CH1C, 1977DA20, 1977FL13, 1977FR12, 1977FR18, 1977FU1E, 1977HO1D, 1977HO1E, 1977HU1A, 1977IK1A, 1977KO1K, 1977LA1D, 1977MA1J, 1977SA1C, 1977ST1G, 1977TH09, 1977ZA04, 1977ZI01, 1978AR1M, 1978FO1G, 1978FR1F, 1978FR1H, 1978LE13, 1978MA20, 1978NO1B, 1978SA24, 1978ST10, 1978TO09, 1978VA03, 1978YA1A; theor.).

5. ^{6}Li(d, γ)^{8}Be $\qquad$ $Q_{\rm m} = 22.2814$

The yield of γ-rays to ^{8}Be*(17.64) $[1^{+}; T = 1]$ has been measured for $E_{\rm d} = 6.85$ to 7.10 MeV: a resonance is observed at $E_{\rm d} = 6962.8 \pm 3.0$ keV $[E_{\rm x} = 27495.8 \pm 2.4$ keV, $\Gamma_{\rm c.m.} = 5.5 \pm 2.0$ keV]; $\Gamma_{\gamma} = 23 \pm 4$ eV $[1.14 \pm 0.20$ W.u.] for this M1 transition from the first $0^{+}; T = 2$ state in ^{8}Be, in good agreement with the intermediate coupling model (1976NO07). The γ_1 transition from ^{8}Be*(27.49) to ^{8}Be*(2.9) is not observed: assuming $\Gamma_{\rm d_0}/\Gamma = 0.78$, $\Gamma_{\gamma}^{\Delta T=2}/\Gamma < 2 \times 10^{-6}$. If $\Gamma_{\rm c.m.} = 5.5$ keV, $\Gamma_{\gamma}^{\Delta T=2} < 0.01$ eV $[< 1.5 \times 10^{-3}$ W.u.] for this E2, $\Delta T = 2$ transition (1977LO1F).

6. (a) ^{6}Li(d, n)^{7}Be $\qquad$ $Q_{\rm m} = 3.382$ $\qquad$ $E_{\rm b} = 22.2814$
(b) ^{6}Li(d, n)^{4}He + ^{3}He $\qquad$ $Q_{\rm m} = 1.7955$

The yield curve has been measured for $E_{\rm d} = 0.06$ to 5.5 MeV and 12 to 17 MeV: see (1974AJ01) and (1977SZ05: 0.10 to 0.18 MeV; activation cross section), (1977EL09: 0.20 to 0.90 MeV; cross sections for $\rm n_0$ and $\rm n_1$) and (1974MCZS, 1975MC02: 0.5 to 3.0 MeV; $\rm n_1\gamma$). Polarization measurements have been reported at $E_{\rm d} = 0.27$ to 0.60 MeV (1966MI06: $\rm n_1$) and $E_{\vec{\rm d}} = 0.6$, 0.8 and 1.0 MeV (1977GL05; $\rm n_1$) and at $E_{\rm d} = 2.5$ to 3.7 MeV (1970TH08; $\rm n_0$, $\rm n_1$). See also ^{7}Be.

Comparisons of the populations of ^{7}Be*(0, 0.43) and of ^{7}Li*(0, 0.48) have been made at many energies, up to $E_{\rm d} = 7.2$ MeV. The n/p ratios are closely equal for analog states, as expected from charge symmetry: see (1974AJ01) and (1977EL09). See also (1973GL1A, 1974AU1B) and (1976MO23, 1977EL11, 1977MC1C; applications).

7. (a) ^{6}Li(d, p)^{7}Li $\qquad$ $Q_{\rm m} = 5.026$ $\qquad$ $E_{\rm b} = 22.2814$
(b) ^{6}Li(d, p)^{4}He + ^{3}H $\qquad$ $Q_{\rm m} = 2.5592$

Excitation functions have been measured for $E_d = 30$ keV to 5.4 MeV: see (1974AJ01). Recent cross-section measurements are reported at $E_d = 0.1$ to 1.0 MeV (1977EL09; p_0, p_1) and 0.5 to 3.4 MeV (1974MCZS, 1975MC02; p_0, p_1, $p_1\gamma$). There is no resonance at $E_d = 0.4$ MeV: see (1976MO23). An anomaly is observed in the p_1/p_0 intensity ratio at $E_d = 6.945$ MeV, corresponding to the first 0^+; $T = 2$ state: $E_x = 27.483 \pm 0.010$ MeV, $\Gamma = 10 \pm 3$ keV, $\Gamma_{p_0} << \Gamma_{p_1}$, $\Gamma_{p_0} < \Gamma_d$ (1969BL14). See also (1975GE1F).

Polarization measurements for p_0 and p_1 have been reported at $E_{\overline{d}} = 0.6$ and 0.96 MeV (1977GL05) and $E_d = 2.1$ to 10.9 MeV (1968DU09, 1968FI07, 1970FI07). The latter report pronounced differences in the angular distributions of the vector analyzing power of the two $l_n = 1$ transitions to ^{7}Li*(0, 0.48). See also ^{7}Li, (1974AU1B, 1978VA1D), (1974AJ01, 1975SE07, 1976MO23) and (1977EL11; applications).

8. ^{6}Li(d, d)^{6}Li $E_b = 22.2814$

The yield of elastically scattered deuterons has been measured for $E_d = 2$ to 7.14 MeV [see (1974AJ01)]: no resonances are observed, except, possibly, for a very weak anomaly at $E_d = 6.96$ MeV (1975GE1F; abstract). See also ^{6}Li and (1974CH58; theor.).

9. (a) ^{6}Li(d, t)^{5}Li $Q_m = 0.59$ $E_b = 22.2814$
(b) ^{6}Li(d, ^{3}He)^{5}He $Q_m = 0.90$

The cross section for tritium production rises rapidly to 190 mb at 1 MeV, then more slowly to 290 mb near 4 MeV. There is evidence of deviation from isotropy near 0.4 MeV (1955MA20). See also ^{5}Li. For reaction (b) see ^{5}He.

10. (a) ^{6}Li(d, α)^{4}He $Q_m = 22.3733$ $E_b = 22.2814$
(b) ^{6}Li(d, αp)^{3}H $Q_m = 2.5592$
(c) ^{6}Li(d, αn)^{3}He $Q_m = 1.7954$
(d) ^{6}Li(d, 2d)^{4}He $Q_m = -1.4735$

Cross sections and angular distributions (reaction (a)) have been measured at $E_d = 0.03$ to 12 MeV [see (1974AJ01)] and at $E_d = 0.118$ to 0.975 MeV (1977EL09: very accurate total reaction cross sections), 0.50 to 3.4 MeV (1974MCZS, 1975MC02; σ_R), 1.0 to 11.5 MeV (1977RI09; $\sigma(\theta)$: see below) and 13.6 MeV (1978FU03; ang. distrib. to ^{4}He*(20.1, 21.1, 25.5)) and $E(^6\text{Li}) = 10$ to 31 MeV (1979WA02: 30° yield of α_0 and α* to ^{4}He*(20.08) [0^+]). A critical analysis of the low energy data has led to a calculation of the reaction rate parameter for thermonuclear reactions for plasma temperatures of 2 keV to 1 MeV (1978CL07). Polarization measurements are reported at

$E_d = 0.40$ to 11.8 MeV and at $E(^6Li) = 0.6$ MeV [see (1974AJ01)] and at $E_{\vec{d}} = 1.5$ to 11.5 MeV (1977RI09: vector and tensor analyzing powers). At $E_{\vec{d}} = 5$, 6, 8 and 9 MeV, $A_{yy} = 1$ is observed at certain angles: see (1978SE01).

Pronounced variations are observed in the cross sections and in the analyzing powers (1977RI09). Maxima are seen at $E_d = 0.8$ MeV, $\Gamma_{lab} \approx 0.8$ MeV and $E_d = 3.75$ MeV, $\Gamma_{lab} \approx 1.4$ MeV (1963ME09, 1964PA06). The 4 MeV peak is also observed in the tensor component coefficients with $L = 0$, 4 and 8 and in the vector component coefficients: two overlapping resonances are suggested. At higher energies all coefficients show a fairly smooth behavior which suggests that only broad resonances can exist (1977RI09). The results of this and other experiments are in good agreement with the results of (1972BA83) [^{4}He(α, α): reaction 4], that is with two 2^+ states at $E_x = 22.2$ and 25.2 MeV and a 4^+ state at 25.5 MeV (1977RI10). A strong resonance is seen in the α* channel [to ^{4}He*(20.08), $J^\pi = 0^+$] presumably due to ^{8}Be*(25.2, 25.5). In addition the ratio of the α^*/α differential cross sections at 30° show a broad peak centered at $E_x \approx 26.5$ MeV (which may be due to interference effects) and suggest a resonance-like anomaly at $E_x \approx 28$ MeV (1979WA02). See also the discussion in (1974AJ01). At $E_d = 6.945$ MeV, the α_0 yield shows an anomaly corresponding to ^{8}Be*(27.49), the 0^+; $T = 2$ analog of ^{8}He$_{g.s.}$ (1969BL14) [(1975GE1F); prelim.) find $E_d = 6962 \pm 7$ keV, $\Gamma \approx 10$ keV.]

For reaction (b) see (1977RO18: $E_d = 0.465$; evidence for QSI) and (1977MI13: $E_d = 7.5$, 9, 10, 10.5 MeV; see ^{5}Li, ^{7}Li). For reaction (c) see (1974AJ01). For reaction (d) see (1977MI13, 1978FU03). See also ^{6}Li.

See also (1975GL08, 1975WI25, 1976UL1C, 1978VA1D), (1975SE07, 1977SE1C, 1977SE09, 1978FI1E), (1976MO23, 1977EL11, 1978MO1J; applications) and (1974LI1E; theor.).

11. (a) ^{6}Li(t, n)^{8}Be $Q_m = 16.0240$
(b) ^{6}Li(t, n)^{4}He^{4}He $Q_m = 16.1159$

See (1966LA04, 1974AJ01).

12. (a) ^{6}Li(^{3}He, p)^{8}Be $Q_m = 16.7878$
(b) ^{6}Li(^{3}He, p)^{4}He^{4}He $Q_m = 16.8797$

Proton groups are observed to ^{8}Be*(0, 2.9, 16.63, 16.92, 17.64): see Tables 8.4 and 8.5 in (1974AJ01). The excitation of ^{8}Be*(18.15, 19.0, 19.4, 19.9) is also reported by (1971GL07). Angular distributions have been measured at $E(^3He) = 1.4$ to 17 MeV [see (1974AJ01)] and at 3, 4.5 and 6 MeV (1976GO1F; p_0, p_1) and 14 MeV (1977IR01; p_0, p_1).

Reaction (b) proceeds via ^{8}Be*(16.63, 16.92): $\Gamma = 117 \pm 10$ and 85 ± 10 keV, respectively. Interference effects are reported (1969VI05): see also Table 8.5. See also (1976GO1F, 1977AR09), (1977AS04; theor.) and ^{9}B.

13. (a) ^{6}Li(α, d)^{8}Be $\quad Q_{\rm m} = -1.5654$

(b) ^{6}Li(α, 2α)^{2}H $\quad Q_{\rm m} = -1.4735$

Deuteron groups have been observed to ^{8}Be*(0, 2.9, 11.3 ± 0.4). Angular distributions have been measured at $E_\alpha = 20$ to 48 MeV [see (1974AJ01)] and at $E_\alpha = 15.8$ to 25.1 MeV (1974KO24; d_0, d_1), 17.3, 23.3, 25.1 MeV (1974LE14; d_0, d_1), 20 and 24 MeV (1974GR21; d_0) and 29.4 MeV (1974MA49; d_0, d_1). Large differential cross sections at back angles are analyzed by (1974GR21) using both direct and exchange amplitudes.

A study of reaction (b) shows that the peak due to ^{8}Be*(2.9) is best fitted by using $\Gamma = 1.2 \pm 0.3$ MeV (1969BA18): see also Table 8.4 in (1974AJ01). At $E_\alpha = 42$ MeV the $\alpha - \alpha$ FSI is dominated by ^{8}Be*(0, 2.9) (1977BO22). See also (1974MA49, 1976LE1K).

14. (a) ^{6}Li(^{6}Li, α)^{8}Be $\quad Q_{\rm m} = 20.808$

(b) ^{6}Li(^{6}Li, α)^{4}He^{4}He $\quad Q_{\rm m} = 20.900$

This reaction proceeds via ^{8}Be*(0, 2.9, 16.6, 16.9, 22.5), and there is indication also that the direct three-body break-up (reaction (b)) is possible (1971GA21, 1972GA32: $E_{\rm max}$(^{6}Li) $= 13.0$ MeV). The involvement of a state at $E_{\rm x} = 19.9$ MeV ($\Gamma = 1.3$ MeV) is suggested by (1966MA40). Good agreement with the shapes of the peaks corresponding to ^{8}Be*(16.6, 16.9) is obtained by using a simple two-level formula with interference, corrected for the effect of final state Coulomb interaction, assuming $\Gamma(16.6) = 90$ keV and $\Gamma(16.9) = 70$ keV: see also Table 8.5 (1971NO04). The ratio of the intensities of the groups corresponding to ^{8}Be*(16.6, 16.9) remains constant for E(^{6}Li) $= 4.3$ to 5.5 MeV: $I(16.6)/I(16.9) = 1.22 \pm 0.08$ (1966MA40, 1966KI09). Partial angular distributions for the α_0 group have been measured at fourteen energies for E(^{6}Li) $= 4$ to 24 MeV (1970FR06). See also (1975NO1C; theor.) and (1974AJ01).

15. ^{7}Li(p, γ)^{8}Be $\quad Q_{\rm m} = 17.255$

Cross sections and angular distributions have been reported from $E_{\rm p} = 30$ keV to 18 MeV. Gamma rays are observed to the ground (γ_0) and to the broad, 2^+, excited state at 2.9 MeV (γ_1) and to ^{8}Be*(16.6, 16.9) (γ_3, γ_4). Resonances for both γ_0 and γ_1 occur at $E_{\rm p} = 0.44$ and 1.03 MeV, and for γ_1 alone at 2, 4.9, 6.0, 7.3, and possibly at 3.1 and 11.1 MeV. In addition broad resonances are reported at $E_{\rm p} \approx 5$ MeV (γ_0), $\Gamma \approx 4 - 5$ MeV, and at $E_{\rm p} \approx 7.3$ MeV (γ_1), $\Gamma \approx 8$ MeV: see Table 8.6. The $E_{\rm p} \approx 5$ MeV resonance ($E_{\rm x} \approx 22$ MeV) represents the giant dipole resonance based on ^{8}Be(0) while the γ_1 resonance, ≈ 2.2 MeV higher, is based on ^{8}Be*(2.9). The γ_0 and γ_1 giant resonance peaks each contain about 10% of the dipole sum strength (1976FI1C). The main trend between $E_{\rm p} = 8$ and 17.5 MeV is a decreasing cross section (1976FI1C). (1977UL02) have studied the analyzing power for $E_{\overline{\rm p}} = 0.38$ to 0.96 MeV: the data indicate some possibility of a 1^- state at 17.70 MeV.

Table 8.6: ^{8}Be levels from ^{7}Li(p, γ)^{8}Be

$E_{\rm res}$ (keV)	$\Gamma_{\rm lab}$ (keV)	^{8}Be* (MeV)	$l_{\rm p}$	J^π	Res. [c]	Refs.
441.4 ± 0.5 [a]	12.2 ± 0.5	17.641	1	1^+	$\gamma_0, \gamma_1, \gamma_3, \gamma_4$	A
1030 ± 5	168	18.156	1	1^+	$\gamma_0, \gamma_1, \gamma_3, \gamma_4$	A, (1976FI1C) [d]
1890	150 ± 50	18.91		(2^-)	γ_3, γ_4	(1969SW01)
2060 ± 20	310 ± 20	19.06		$J = 1, 2, 3, \pi = (-)$ [b]	γ_1	A, (1976FI1C)
(3100)		(20.0)			γ_1	(1976FI1C)
4900		21.5			γ_1	(1976FI1C)
5000	≈ 4500	21.6	0	$1^-; T = 1$	γ_0	A, (1976FI1C)
6000		22.5			γ_1	(1976FI1C)
7500	≈ 8000	23.8	(0)	$(1^-, 2^-); T = 1$	γ_1	A, (1976FI1C)
(11100)		(27.0)			γ_1	(1976FI1C)
13000	broad	28.6				(1967FE04)

A: see references listed for this resonance in Table 8.6 of (1974AJ01).

[a] See (1959AJ76).

[b] (1964SC19). See, however, reaction 17.

[c] $\gamma_0, \gamma_1, \gamma_3, \gamma_4$ represent transitions to ^{8}Be*(0, 2.9, 16.6, 16.9), respectively.

[d] See also (1970FI1B).

At the $E_{\rm p} = 0.44$ MeV resonance ($E_{\rm x} = 17.64$ MeV) the radiation is nearly isotropic consistent with p-wave formation, $J^\pi = 1^+$, with channel spin ratio $\sigma(J_{\rm c} = 2)/\sigma(J_{\rm c} = 1) = 3.2 \pm 0.5$ (1961ME10). Radiative widths for the γ_0 and γ_1 decay are displayed in Table 8.7. A careful study of the α-breakup of ^{8}Be*(16.63, 16.92) [both $J^\pi = 2^+$] for $E_{\rm p} = 0.44$ to 2.45 MeV shows that the non-resonant part of the cross section for production of ^{8}Be*(16.63) is accounted for by an extranuclear direct-capture process. Resonances for production of ^{8}Be*(16.63, 16.92) are observed at $E_{\rm p} = 0.44$, 1.03 and 1.89 MeV [^{8}Be*(17.64, 18.15, 18.9)]. The results are consistent with the hypothesis of nearly maximal isospin mixing for ^{8}Be*(16.63, 16.92): decay to these states is not observed from the 3^+ states at $E_{\rm x} = 19$ MeV, but rather from the 2^- state at 18.9 MeV excitation (1969SW01). (1968PA09) find squared $T = 1$ components of 40% and 60% in ^{8}Be*(16.6, 16.9) and of 95% and 5% in ^{8}Be*(17.6, 18.2). See also (1974SO1D, 1978GO1F, 1978ZI1A; applied work), (1974VA1C; astrophys.) and (1977BA62, 1978BA66; theor.).

16. ^{7}Li(p, n)^{7}Be $\qquad Q_{\rm m} = -1.644 \qquad E_{\rm b} = 17.255$

Measurements of cross sections have been reported for $E_{\rm p} = 1.9$ to 52 MeV: see (1974AJ01) and the review article by (1975LI1E). Recent measurements have been carried out at $E_{\rm p} = 1.9$ to

Table 8.7: Electromagnetic transitions in ^{8}Be[a]

Transition	Γ_γ (eV)	$\|M\|^2$ (W.u.)	Refs.
$17.6 \to 0$	16.7	0.15	see (1974AJ01)
$17.6 \to 2.9$	8.15 ± 0.07 (M1) [b]	0.12	(1961ME10)
	0.15 ± 0.07 (E2)		(1961ME10)
$17.6 \to 16.6$	0.032 ± 0.003 [c]	1.48 ± 0.15 (M1)	(1969SW01)
$17.6 \to 16.9$	0.0013 ± 0.0003	0.15 ± 0.04 (M1)	(1969SW01)
$18.15 \to 0$	3.0		(1976FI1C)
$18.15 \to 2.9$	3.8		(1976FI1C)
$18.15 \to 16.6$	0.077 ± 0.019	1.04 ± 0.26 (M1)	(1969SW01)
$18.15 \to 16.9$	0.062 ± 0.007	1.51 ± 0.17 (M1)	(1969SW01)
$18.9 \to 16.6$	0.168	0.053 (E1)	(1969SW01)
$18.9 \to 16.9$	0.099	0.045 (E1)	(1969SW01)
$19.07 \to 2.9$	10.5		(1976FI1C)

[a] See also Table 8.7 in (1974AJ01) and reaction 2 here.
[b] (1967CO19) report δ(E2/M1) $= 0.21 \pm 0.04$, averaged over the energy of the final state.
[c] Nearly pure M1: δ(E2/M1) $= -0.014 \pm 0.013$ (1969SW02).

3.8 MeV (1974BU16: n_0; $d\sigma/d\Omega(0°)$), 4.2 to 25.9 MeV (1976PO06: n_0, n_1; $3.5°$), and for neutron production at $0°$ at 14.3, 19.4 and 29.6 MeV (1975MC18), 29.4, 39.2 and 50.6 MeV (1976RO10), and 24.7 to 44.7 MeV (1977SC37). Polarization measurements have been reported at $E_p = 2.05$ to 5.5 MeV and 30 and 50 MeV: see (1974AJ01). See also (1976DO1F, 1978LE10). For angular distributions see ^{7}Be.

The yield of ground state neutrons (n_0) rises steeply from threshold and shows pronounced resonances at $E_p = 2.25$ and 4.9 MeV (1963BO06). The yield of n_1 also rises steeply from threshold (1964BU08) and exhibits a broad maximum near $E_p = 3.2$ MeV (1961BE05, 1972PR03) and a broad dip at $E_p \approx 5.5$ MeV, also observed in the p_1 yield (1972PR03).

Multi-channel scattering length approximation analysis of the 2^- partial wave near the n_0 threshold indicates that the 2^- state at $E_x = 18.9$ MeV is virtual relative to the threshold and that its width $\Gamma = 50 \pm 20$ keV (1974AR10). The ratio of the cross section for ^{7}Li(p, γ)^{8}Be*(18.9) $\xrightarrow{\gamma}$ ^{8}Be*($16.6 + 16.9$) [obtained by (1969SW01)] to the thermal neutron capture cross section ^{7}Be(n, γ)^{8}Be*(18.9) $\xrightarrow{\gamma}$ ^{8}Be*($16.6 + 16.9$) [obtained by (1973BA1J)], provides a rough etsimate of the isospin impurity of ^{8}Be*(18.9): $\sigma_{p,\gamma}/\sigma_{n,\gamma} \approx 1.5 \times 10^{-5}$ and therefore the $T = 1$ isospin impurity is < 4% in intensity (1974AR10). See, however, (1977BA62; theor.) who estimates ≈ 10% isospin mixing.

The structure at $E_\mathrm{p} = 2.25$ MeV is ascribed to a 3^+, $T = (1)$, $l = 1$ resonance with $\Gamma_\mathrm{n} \approx \Gamma_\mathrm{p}$ and $\gamma^2_\mathrm{n}/\gamma^2_\mathrm{p} = 3$ to 10: see (1966LA04). At higher energies the broad peak in the n_0 yield at $E_\mathrm{p} = 4.9$ MeV can be fitted by $J^\pi = 3^{(+)}$ with $\Gamma = 1.1$ MeV, $\gamma^2_\mathrm{n} \approx \gamma^2_\mathrm{p}$ (1963BO06). The behavior of the n_1 cross section can be fitted by assuming a 1^- state at $E_\mathrm{x} = 19.5$ MeV and a $J = 0, 1, 2$, positive-parity state at 19.9 MeV [presumably the 20.1–20.2 MeV states reported in reaction 4]. In addition the broad dip at $E_\mathrm{p} \approx 5.5$ MeV may be accounted for by the interference of two 2^+ states (1972PR03). See Table 8.8.

The ratio of the cross sections of the (p, n_1) reaction to ^{7}Be*(0.43) to that for the (p, p_1) reaction to the analog state ^{7}Li*(0.48) has been measured for $E_\mathrm{p} = 2.4$ to 10 MeV and 23 to 52 MeV [see (1974AJ01)] and at $E_\mathrm{p} = 3$ to 25.9 MeV (1976PO06): at the lower energies the ratio varies very strongly with energy. [An average value for the ratio over the range 5 to 26 MeV is ≈ 0.3.] See also (1973AT01, 1974AR05, 1976CY1A), (1974LE1E, 1974LO1B, 1975SO1C, 1976RI1B, 1976SL02), (1976BR1E, 1976CA1F, 1977LO10, 1977ME1C; applications) and (1974CO1B, 1976AR1F, 1977ST18, 1978BA66, 1978DE37; theor.).

17. (a) ^{7}Li(p, p)^{7}Li $\qquad E_\mathrm{b} = 17.255$

(b) ^{7}Li(p, p′)^{7}Li*

Absolute differential cross sections for elastic scattering have been reported for $E_\mathrm{p} = 0.4$ to 12 MeV and at 14.5, 20.0 and 31.5 MeV. The yields of inelastically scattered protons (to ^{7}Li*(0.48)) and of 0.48 MeV γ-rays have been measured for $E_\mathrm{p} = 0.8$ to 12 MeV: see (1974AJ01). (1976SO1B; prelim.) reports total cross-section meeasurements at $E_\mathrm{p} = 25$, 30, 35, 40, 45 and 48 MeV. Polarization measurements have been reported at $E_\mathrm{p} = 0.67$ to 10.6 MeV and at 14.5, 49.8, 152 and 155 MeV: see (1974AJ01). The polarization has also been studied by (1974DE45; p_0) for $E_\mathrm{p} = 1.8$ to 3.0 MeV. For angular distribution see ^{7}Li.

Anomalies in the elastic scattering appear at $E_\mathrm{p} = 0.44$, 1.03, 1.88, 2.1, 2.5, 4.2 and 5.6 MeV. Resonances at $E_\mathrm{p} = 1.03$, 3 and 5.5 MeV and an anomaly at $E_\mathrm{p} = 1.88$ MeV appear in the inelastic channel. A phase-shift analysis and a review of the existing cross-section data by (1973BR13) show that the 0.44 and 1.03 MeV resonances are due to 1^+ states which are a mixture of $^5P_1$ and $^3P_1$ with a mixing parameter of $+25°$; that the 2^- state at the neutron threshold ($E_\mathrm{p} = 1.88$ MeV) has a width of about 50 keV [see also reaction 16]; and that the $E_\mathrm{p} = 2.05$ MeV reosnance corresponds to a 3^+ state. The anomalous behavior of the $^5P_3$ phase around $E_\mathrm{p} = 2.2$ MeV appears to result from the coupling of the two 3^+ states [resonances at $E_\mathrm{p} = 2.05$ and 2.25 MeV]. The $^3S_1$ phase begins to turn positive after 2.2 MeV suggesting a 1^- state at $E_\mathrm{p} = 2.5$ MeV (1973BR13): see Table 8.9, (1972PR03) and (1977BA62, 1978BA66; theor.). The polarization data of (1974DE45) show structures at $E_\mathrm{p} = 1.9$ and 2.3 MeV. See also (1974AR10, 1976MA64).

An attempt has been made to observe the $T = 2$ state [^{8}Be*(27.47)] in the p_0, p_1 and p_2 yields. None of these shows the effect of the $T = 2$ state. Table 8.4 displays the upper limit for $\Gamma_{\mathrm{p}_0}/\Gamma$ (1976HI04). See (1973GO41, 1978FR12), (1976IK01) and (1975MA1H, 1977ST18, 1978DE37; theor.).

18. ^{7}Li(p, d)^{6}Li $\quad Q_m = -5.026 \quad E_b = 17.255$

The excitation function for d_0 measured for $E_p = 11.64$ to 11.76 MeV does not show any effect from the $T = 2$ state [^{8}Be*(27.47)] (1976HI04). See also ^{6}Li.

19. (a) ^{7}Li(p, t)^{5}Li $\quad Q_m = -4.43 \quad E_b = 17.255$
(b) ^{7}Li(p, ^{3}He)^{5}He $\quad Q_m = -4.12$

See ^{5}Li and ^{5}He.

20. ^{7}Li(p, α)^{4}He $\quad Q_m = 17.347 \quad E_b = 17.255$

The cross section follows the expression $E^{-1}e^{-B/\sqrt{E}}$, with $B = 91.5 \pm 4.5$ keV$^{1/2}$, in the range $E_p = 23$ to 50 keV. The cross section in that interval rises from 0.013 to 2.4 μb (1967FI05). Taking into account ^{8}Be $J^\pi = 2^+$ levels at 16.7, 16.9 and 20.6 MeV, (1972BA41) has made an R-matrix fit to the revised data of (1971SP05) for $E_p = 131$ to 561 keV and has obtained a quadratic energy dependence for the S-factor: $S = 0.065[1 + 1.82E - 2.51E^2]$ MeV $\cdot$ b, over the energy range $E_p = 0$ to 600 keV.

Excitation functions and angular distributions have been measured at many energies in the range $E_p = 23$ keV to 45.2 MeV: see (1966LA04, 1974AJ01). Recent measurements include those of (1976SA1C: 1.6 to 12.0 MeV) and (1976HI04: 11.64 to 11.76 MeV). Polarization measurements have been carried out for $E_p = 0.8$ to 10.6 MeV: see (1974AJ01). In the range $E_p = 3$ to 10 MeV the asymmetry has one broad peak in the angular distribution at all energies except near 5 MeV; the peak value is 0.98 ± 0.04 at 6 MeV and is essentially 1.0 for $E_p = 8.5$ to 10 MeV (1968PL01, 1969KI04) [see Fig. 12 in (1969KI04) and Fig. 6 (1968PL01) for contour maps of the asymmetry].

Broad resonances are reported to occur at $E_p = 3.0$ MeV [$\Gamma \approx 1$ MeV] and at ≈ 5.7 MeV [≈ 1 MeV]. Structures are also reported at $E_p = 6.8$ MeV and at $E_p = 9.0$ MeV: see (1974AJ01) and (1976SA1C). The 9.0 MeV resonance is also reflected in the behavior of the A_2 coefficient (1968PL01). The experimental data on yields and on polarization have been analyzed by (1971KU10): the data appear to require including two 0^+ states [at $E_x \approx 19.7$ and 21.8 MeV] with very small α-particle widths, and four 2^+ states [at $E_x \approx 15.9$, 20.1, 22.2 and 25 MeV]. See however reaction 4 and (1972BA83). A 4^+ state near 20 MeV was also introduced in the calculation but its contribution was negligible. The observed discrepancies are said to be probably due to the assumption of pure $T = 0$ for these states (1971KU10). At $E_p = 11.64$ to 11.76 MeV the excitation function does not show any effect due to the $T = 2$ state at $E_x = 27.47$ MeV (1976HI04).

For a study of spallation see (1976KO03) and (1978FI1E). See also (1974VA1B), (1978PR1B; applied) and (1974LO1B, 1975CI1A; theor.).

Table 8.8: ^{8}Be levels from ^{7}Li(p, n)^{7}Be

E_p (MeV)	Γ_{lab} (keV)	^{8}Be* (MeV)	J^π	Refs.
1.88	55 ± 20	18.90	2^-	(1974AR10)
2.25	220	19.22	3^+	(1957NE1A, 1961BE05)
2.6 [a]	≈ 750	19.5	1^-	(1972PR03)
3.0	≈ 1250	19.9	(2^+)	(1972PR03)
4.9	1100	21.5	$3^{(+)}$	(1959GI47, 1963BO06)
5.5	broad	22.1	[b]	(1972PR03)

[a] $\gamma^2_{n_1}$ and $\gamma^2_{p_1} \approx 1\%$ of the Wigner limit (1972PR03).
[b] The broad dip in the n_1 yield at the same energy as the broad bump in the p_1 yield may be due to interference of two 2^+ states (1972PR03).

Table 8.9: ^{8}Be levels from ^{7}Li(p, p_0)^{7}Li and ^{7}Li(p, p_1)^{7}Li*

E_p (MeV)	Γ_{lab} (keV)	^{8}Be* (MeV)	J^π	$\Gamma_{p'}$ (keV)	Refs.
0.441	12.2 [b]	17.641	1^+		A, (1973BR13)
1.030 ± 0.005	168	18.156	1^+	≈ 6	A, (1973BR13)
1.88 [a]	55 ± 20	18.90	2^-		(1973BR13, 1974AR10, 1974DE45)
2.05	≈ 400	19.05	3^+ [g]	small	A, (1973BR13)
2.25		19.22	3^+ [g]	small	A, (1973BR13, 1974DE45)
2.5 [c]	≈ 750	19.4	1^-	res	(1972PR03, 1973BR13)
[d]					
4.2 ± 0.2	1800 ± 200	20.9 [e]	4^-	(res)	(1965GL03)
5.6	broad	22.2	[f]	res	(1965GL03, 1972PR03)

A: See references listed in (1974AJ01).
[a] (p, n) threshold: see reaction 16.
[b] $\theta^2_p = 0.064$.
[c] See also Table 8.8, $\gamma^2_{n_1}$ and $\gamma^2_{p_1} \approx 1\%$ of the Wigner limit (1972PR03).
[d] A 2^+ state at $E_x \approx 20$ MeV appears to be necessary to account for the cross sections: see Table 8.3 and reaction 4 (1972PR03).
[e] Reduced width is 70% of the Wigner limit (1965GL03).
[f] May be due to two 2^+ states (1972PR03). See also reaction 16.
[g] See also (1978BA66; theor.).

21. (a) ^{7}Li(d, n)^{8}Be $\quad Q_{\rm m} = 15.031$

(b) ^{7}Li(d, n)^{4}He^{4}He $\quad Q_{\rm m} = 15.123$

The population of ^{8}Be*(0, 2.9, 16.6, 16.9, 17.6, 18.2, 18.9, 19.1, 19.2) has been reported in reaction (a): for the parameters of ^{8}Be*(2.9) see Table 8.4 in (1974AJ01). Angular distributions of n_0 and n_1 have been reported at $E_{\rm d} = 0.7$ to 3.0 MeV [see (1974AJ01)] and at $E_{\rm d} = 15.25$ MeV (1975AZ02; also n to ^{8}Be*($16.6 + 16.9$); spectroscopic factors). The angular distributions of the neutrons to ^{8}Be*(16.6, 17.6, 18.2) are fit by $l_{\rm p} = 1$: see (1974AJ01). See also (1978BA66; theor.).

Reaction (b) appears to proceed primarily via ^{8}Be*(2.9, 16.6, 16.9) and ^{5}He$_{\rm g.s.}$: see (1974AJ01). However, ^{8}Be*(11.4) may also be involved [$E_{\rm x} = 11.4 \pm 0.05$ MeV, $\Gamma_{\rm c.m.} = 2.8 \pm 0.2$ MeV (1969HO11), 3.4 ± 0.1 MeV (1976FO21)] as may state(s) at $E_{\rm x} \approx 20$ MeV (1978AR10). Attempts to observe n-α rescattering ("proximity scattering") proceeding via ^{8}Be*(16.6, 16.9) have been unsuccessful: see (1974AJ01). See, however, (1975GR43). See also (1973HU12, 1974DA28, 1974GR44, 1975DA15, 1977LO10), (1976EA1A, 1976NE1B; applications) and ^{5}He and ^{9}Be.

22. ^{7}Li(t, 2n)^{8}Be $\quad Q_{\rm m} = 8.774$

See (1975JE04).

23. (a) ^{7}Li(^{3}He, d)^{8}Be $\quad Q_{\rm m} = 11.762$

(b) ^{7}Li(^{3}He, pn)^{8}Be $\quad Q_{\rm m} = 9.537$

Deuteron groups are observed to ^{8}Be*(0, 2.9, 16.6, 16.9, 17.6). For the parameters of ^{8}Be*(2.9) see Table 8.4 in (1974AJ01). The $J^\pi = 1^+$ mixed isospin states have been studied by (1967MA12): see Table 8.5. Angular distributions have been measured at a number of energies in the range E(^{3}He) $= 0.9$ to 24.3 MeV [see (1974AJ01)] and at 1.2 to 2.5 MeV (1975BO56, 1977BO29). For reaction (b) see (1976DA24). See also (1977SL1B), (1974AL07), (1975KU27, 1975TR02, 1976KU07, 1977BA62; theor.) and ^{9}Be.

24. (a) ^{7}Li(α, t)^{8}Be $\quad Q_{\rm m} = -2.559$

(b) ^{7}Li(α, αt)^{4}He $\quad Q_{\rm m} = -2.467$

Angular distributions have been measured up to $E_\alpha = 50$ MeV [see (1966LA04, 1974AJ01)] and at 23.2 and 25.0 MeV (1974DM01; t_0, and t_1 at higher energy) and 29.4 MeV (1974MA49; t_0, t_1). The ground state of ^{8}Be does decay isotropically in the cm system: $J^\pi = 0^+$ (1970LA14). At $E_\alpha = 10$ MeV an anomaly ("ghost") is observed at $E_{\rm x} \approx 0.5$ MeV: see (1971BE52) and reaction 31. Sequential decay (reaction (b)) is reported at $E_\alpha = 50$ MeV via ^{8}Be*(0, 2.9, 11.4, 16.6, 16.9, 19.9) (1970LA14). See also (1974MA49). See also (1976LE1K) and (1977BE51; theor.).

25. ^{7}Li(^{7}Li, ^{6}He)^{8}Be $\qquad Q_m = 7.281$

At $E(^7\text{Li}) = 1.4$, 1.7 and 1.8 MeV, the angular distributions of ^{6}He ions leaving ^{8}Be in its ground and 2.9 MeV states are essentially isotropic (1968ST12).

26. (a) ^{7}Be(n, p)^{7}Li $\qquad Q_m = 1.6443 \qquad E_b = 18.900$
(b) ^{7}Be(n, α)^{4}He $\qquad Q_m = 18.992$
(c) ^{7}Be(n, $\gamma\alpha$)^{4}He $\qquad Q_m = 18.992$

At thermal energies, the (n, p) cross section is $(4.8 \pm 0.9) \times 10^4$ b (1973MU14), the (n, α) cross section is ≤ 0.1 mb and the (n, $\gamma\alpha$) cross section is 155 mb (1963BA34). These values, and comparison of the (p, n) cross section with that of reaction (a), support the $J^\pi = \frac{3}{2}^-$ assignment for ^{7}Be(0) (1957NE1A, 1963BA34). See also (1974AJ01) and (1977BA62; theor.).

27. ^{7}Be(d, p)^{8}Be $\qquad Q_m = 16.675$

^{8}Be*(0, 2.9) is populated in this reaction at $E_d = 0.8$ to 1.7 MeV. See also Table 8.4 in (1974AJ01).

28. ^{8}Li(β^-)^{8}Be $\qquad Q_m = 16.005$

^{8}Li decays mainly to the broad 2.9 MeV, 2^+ level of ^{8}Be, which decays into two α particles. Both the β-spectrum and the resulting α-spectrum have been extensively studied. There appears to be an increasing excess of α-particles with E_α which may reflect transitions into the tail of the $J^\pi = 2^+$ level at $E_x = 16.63$ MeV. See (1955AJ61, 1966LA04) for earlier references. See also ^{8}B(β^+).

Studies of the distribution of recoil momenta and neutrino recoil correlation indicate that the decay is overwhelmingly GT, axial vector [see reaction 1 in ^{8}Li] and that the ground state of ^{8}Li has $J^\pi = 2^+$: see (1966LA04).

Angular correlations have been measured for the decays of ^{8}Li and ^{8}B as a test of the conserved vector current theory of β-decay. The values of the coefficients are displayed in Table 8.10 (1962NO02, 1963GR11, 1966EI02, 1975TR06). The experimental value of δ [$\delta \equiv B(^8\text{Li}) - B(^8\text{B})$] is $(5.4 \pm 0.4)\ W_\beta$, consistent with CVC theory (1966EI02). There is no evidence for second class currents in this decay: see, e.g., (1975TR06). See also (1973AN11, 1974TR01, 1978FO1H, 1978HA1K, 1978MC1E), (1973BR1C, 1975CA1F, 1976CA1E, 1977GA1E, 1978BO30) and (1973KU1D, 1973TA30, 1974HO1D, 1974KU06, 1975KR14, 1975WI1E, 1976KU1B, 1977KU1E, 1977KU20, 1977OK1A, 1977SA23, 1977TE1B, 1977WI02, 1978KH03; theor.).

Table 8.10: $\alpha - \beta$ angular correlation coefficients in ^{8}Li, ^{8}B [a]

Nuclide	A/W_β	B/W_β	W_β (MeV)	δ/W_β [b]	Refs.
^{8}Li	$(-8.7 \pm 0.7) \times 10^{-3}$	$(+3.2 \pm 0.6) \times 10^{-3}$	11	$(7.0 \pm 1.2) \times 10^{-3}$	(1962NO02)
^{8}Li	$(-8.3 \pm 1.1) \times 10^{-3}$	$(+3.7 \pm 1.0) \times 10^{-3}$	7.5		(1963GR11)
^{8}Li	$(-9.7 \pm 0.7) \times 10^{-3}$	$(+3.1 \pm 0.3) \times 10^{-3}$	6.6	$(5.4 \pm 0.4) \times 10^{-3}$	(1966EI02)
^{8}Li	$(-8.09 \pm 0.13) \times 10^{-3}$	$(+3.25 \pm 0.58) \times 10^{-3}$	6.9		(1975TR06)
^{8}Li	$(-9.34 \pm 0.14) \times 10^{-3}$	$(+3.18 \pm 0.62) \times 10^{-3}$	10.9		(1975TR06)
^{8}Li	$(-9.78 \pm 0.26) \times 10^{-3}$	$(+4.29 \pm 1.16) \times 10^{-3}$	12.9		(1975TR06)
^{8}B	$(-8.7 \pm 0.9) \times 10^{-3}$	$(-3.9 \pm 1.0) \times 10^{-3}$	11		(1962NO02)
^{8}B	$(-11.1 \pm 1.3) \times 10^{-3}$	$(-2.3 \pm 0.3) \times 10^{-3}$	7.0		(1966EI02)
^{8}B	$(-7.09 \pm 0.18) \times 10^{-3}$	$(-4.75 \pm 0.55) \times 10^{-3}$	6.9		(1975TR06)
^{8}B	$(-8.66 \pm 0.16) \times 10^{-3}$	$(-4.66 \pm 0.54) \times 10^{-3}$	10.9		(1975TR06)
^{8}B	$(-9.34 \pm 0.22) \times 10^{-3}$	$(-4.96 \pm 0.82) \times 10^{-3}$	12.9		(1975TR06)

[a] $W(\theta) = 1 + A\ \cos\theta + B\ \cos^2\theta$.
[b] $\delta \equiv B(^{8}\text{Li}) - B(^{8}\text{B})$.

29. ^{8}B(β^+)^{8}Be $\qquad Q_m = 17.980$

The decay proceeds mainly to ^{8}Be*(2.9) [see Table 8.4 in (1974AJ01) for its parameters]. Detailed study of the high energy portion of the α-spectrum reveals a maximum near $E_\alpha = 8.3$ MeV, corresponding to transitions to ^{8}Be*(16.63), for which parameters $E_x = 16.67$ MeV, $\Gamma = 150$ to 190 keV or $E_x = 16.62$ MeV, $\Gamma = 95$ keV are derived. $\log ft = 2.9$ (1964MA35), 3.33 (1969BA43). The $\log ft$ value is consisatent with the identification $J^\pi = 2^+$, $T = 1$ for ^{8}Be*(16.63) (1964MA35) [actually this state is of mixed $T = 0$ and 1 isospin]. The energy distribution of α-particles has also been measured by (1969CL10). Analysis of this data and of data from $\alpha{-}\alpha$ scattering in a three level R-matrix formalism indicate a 2^+ state of ^{8}Be at $E_x = 12.0^{-3.0}_{+3.5}$ MeV and of $\Gamma = 14^{-3}_{+4}$ MeV ($a_2 = 6.0 \pm 0.5$ fm) (1969CL10).

For angular correlation measurements see reaction 28 and Table 8.10 (1962NO02, 1966EI02, 1975TR06). See also (1974TR01). There is no evidence for second-class currents in this decay: see, e.g., (1975TR06). See also (1973BR1C, 1975CA1F, 1976CA1E, 1977GA1E, 1978BO30) and (1974HO1D, 1974KU06, 1975KR14, 1975WI1E, 1976KU1B, 1976KU07, 1977KU1E, 1977OK1A, 1977TE1B, 1977WI02, 1978KH03; theor.).

30. (a) ^{9}Be(γ, n)^{8}Be $\qquad Q_m = -1.6652$
(b) ^{9}Be(n, 2n)^{8}Be $\qquad Q_m = -1.6652$
(c) ^{9}Be(p, pn)^{8}Be $\qquad Q_m = -1.6652$
(d) ^{9}Be(t, tn)^{8}Be $\qquad Q_m = -1.6652$

(e) ^{9}Be(α, αn)^{8}Be $\qquad Q_m = -1.6652$

Neutron groups to ^{8}Be*(0, 2.94) have been studied for $E_\gamma = 18$ to 26 MeV (1977BU02). See also (1974AJ01) and ^{9}Be. Reaction (b) appears to proceed largely via excited states of ^{9}Be with subsequent decay mainly to ^{8}Be*(2.9): see (1966LA04, 1974AJ01), ^{9}Be and ^{10}Be. Reaction (c) has been studied at $E_p = 45$ and 47 MeV: the reaction primarily populates ^{8}Be*(0, 2.9) (1977WA05). See also (1977JE01, 1978CH07), ^{9}Be and ^{9}B. For reactions (d) and (e) see (1974AJ01) and ^{9}Be. For reaction (e) see (1974GR42).

31. (a) ^{9}Be(p, d)^{8}Be $\qquad Q_m = 0.5594$

(b) ^{9}Be(p, d)^{4}He^{4}He $\qquad Q_m = 0.6513$

Angular distributions of deuteron groups have been reported at $E_p = 0.11$ to 185 MeV [see (1974AJ01)] and at $E_p = 4.6$ MeV (1974YA1C; d$_0$), 17.7 MeV (1977GU14; d$_0$, d$_1$) and $E_{\overline{p}} = 15$ MeV (1976DA15; d$_0$, d$_1$). In the latter work S for ^{8}Be*(0, 2.9) are 0.80 and 1.05 (see also reaction 32) (1976DA15). For other work on spectroscopic factors see (1974AJ01).

Besides ^{8}Be*(2.9) [see Table 8.4 in (1974AJ01)] ^{8}Be*(11.4, 16.6, 16.9, 17.6, 18.2, 18.9, 19.2, (20.0), 21.5, 22.0, 23.0, (24.5), 26.0) are populated. See also Table 8.5. (1969SU02) report $E_x = 11.3 \pm 0.3$ MeV for the 4^+ state. At $E_p = 46$ and 100 MeV the angular distributions to ^{8}Be*(16.9, 17.6, 18.2, 19.1) are consistent with $l = 1$ (1967VE01, 1968LE01, 1971SC26).

An anomaly has been reported in deuteron spectra between the d$_0$ and d$_1$ groups. At $E_p = 39.9$ MeV it is seen at $E_x \approx 0.6$ MeV. An R-matrix analysis using a three-level approximation for both the 0^+ and the 2^+ contributions shows that the anomaly is due to a "ghost" of the 0^+ state which produces the ground state group (1976BA67). See (1974AJ01) for the earlier work. Reaction (b) at $E_p = 9$ MeV is dominated by strong FSI through ^{8}Be*(0, 2.9) and ^{6}Li*(2.19) with little or no yield from a direct three-body decay (1971EM01). See also (1974AD1B, 1974LO1B), (1978PR1A; applied) (1976BO15, 1978BA66; theor.) and ^{10}B.

32. (a) ^{9}Be(d, t)^{8}Be $\qquad Q_m = 4.5921$

(b) ^{9}Be(d, t)^{4}He^{4}He $\qquad Q_m = 4.6840$

Angular distributions have been measured for $E_d = 0.3$ to 20 MeV [see (1966LA04, 1974AJ01)] and at 0.15 to 2.5 MeV (1974CH1L; t$_0$), 0.6 to 2.2 MeV (1974FR02; t$_0$), 0.9 to 2.5 MeV (1974BO42, 1975BO1C; t$_0$), 0.9 to 3.1 MeV (1975ZW01; t$_0$), 12.35 and 14.06 MeV (1978TA04; t$_0$, t$_1$), 13.6 MeV (1973ZA06; t$_0$), 28.0 MeV (1977OO01: see below) and at $E_{\overline{d}} = 15$ MeV (1976DA15; t$_0$, t$_1$; $S = 0.37$, 0.55: see also reaction 31).

At $E_d = 27.97$ MeV angular distributions of triton groups to ^{8}Be*(16.6, 16.9, 17.6, 18.2, 19.1, 19.2, 19.8) have been analyzed using DWUCK: absolute C^2S are 0.074, 1.56, 0.22, 0.17, 0.41, 0.48, 0.40, respectively. See also Table 8.5. An isospin amplitude impurity of 0.21 ± 0.03 is found for ^{8}Be*(17.6, 18.2) (1977OO01). See also ^{9}Be(d, ^{3}He) [reaction 18] in ^{8}Li and (1978BA66; theor.).

A kinematically complete study of reaction (b) at $E_d = 26.3$ MeV indicates the involvement of ^{8}Be*(0, 2.9, 11.4, 16.9, $19.9 + 20.1$) (1973SO08). See also (1974SO1C, 1975DO04, 1975ZA06, 1976HE1F), (1974AJ01) and ^{11}B in (1980AJ01).

33. (a) ^{9}Be(^{3}He, α)^{8}Be $\quad Q_m = 18.9126$

(b) ^{9}Be(^{3}He, α)^{4}He^{4}He $\quad Q_m = 19.0045$

Angular distributions have been measured in the range $E(^3\text{He}) = 3.0$ to 26.7 MeV [see (1974AJ01)] and at $E(^3\text{He}) = 1.75$, 2.12, 2.43 and 2.95 MeV (1974SA1K; α_0), 4, 5 and 7 MeV (1975BI14: to ^{8}Be*(17.6, 18.2)), 4 to 7 MeV (1978BI15; α_0), 9 and 10 MeV (1975RO09; α_0) and at $E(\overline{^3\text{He}}) = 33.3$ MeV (1976KA23: to ^{8}Be*(16.9, 17.6, 19.2)) [$S = 1.74$, 0.72, 1.17, assuming mixed isospin for ^{8}Be*(16.9)]. The parameters of observed states are displayed in Table 8.4 of (1974AJ01) and Table 8.5 here. In a recent experiment (1974CA32) suggest $E_x = 2.80 \pm 0.05$ and 11.8 ± 0.5 MeV for the first two excited states of ^{8}Be. In addition to three relatively sharp states reported in the range $22 < E_x < 23$ MeV [see Table 8.5] (1976AJ01) suggest the possibility of a broad state at $E_x \approx 25$ MeV. See also (1978BA66; theor.).

Reaction (b) has been studied at $E(^3\text{He}) = 3.0$ and 4.0 MeV (1966SU04, 1968MO05, 1972TA04, 1975KA05) and at 2.9 to 10 MeV (1975RO09). See also (1976AR11). The reaction proceeds via ^{8}Be*(0, 2.9, 11.4, 16.6, 16.9, 19.9, 22.5) (1972TA04). See, however, (1975RO09): $\Gamma_{\text{c.m.}}$ for ^{8}Be*(2.9) is reported to be 0.94 ± 0.04 MeV. $J^\pi = 2^+$ is indicated for ^{8}Be*(16.6, 16.9) (1966SU04, 1968MO05). See also (1976ST1B), (1976RO1L) and ^{12}C in (1980AJ01).

34. (a) ^{9}Be(^{6}Li, ^{7}Li)^{8}Be $\quad Q_m = 5.585$

(b) ^{9}Be(^{7}Li, ^{8}Li)^{8}Be $\quad Q_m = 0.368$

(c) ^{9}Be(^{12}C, ^{13}C)^{8}Be $\quad Q_m = 3.2812$

(d) ^{9}Be(^{13}C, ^{14}C)^{8}Be $\quad Q_m = 6.5114$

(e) ^{9}Be(^{16}O, ^{17}O)^{8}Be $\quad Q_m = 2.479$

(f) ^{9}Be(^{18}O, ^{19}O)^{8}Be $\quad Q_m = 2.292$

(g) ^{9}Be(^{19}F, ^{20}F)^{8}Be $\quad Q_m = 4.9360$

At $E(^6\text{Li}) = 5.5$ and 6.5 MeV angular distributions involving ^{8}Be$_{\text{g.s.}}$ and ^{7}Li*(0, 0.48) have been measured (1974VO06). For reaction (b) see (1974KE1C). For reaction (c) see (1977UH1A, 1978CH02). For reaction (d) see (1975SE03, 1975SE04). Reaction (e) has been studied at $E(^{18}\text{O}) = 16$ and 20 MeV (1971KN05). See also (1974AJ01) for the earlier work.

35. ^{10}Be(p, t)^{8}Be $Q_{\rm m} = 0.0049$

At $E_{\rm p} = 34$ MeV tritons are observed to the first $T = 2$ state, $E_{\rm x} = 27.4922 \pm 0.0026$ MeV, $\Gamma_{\rm c.m.} = 12 \pm 3$ keV: the angular distributions for the transitions to this state and to ^{8}Li*(10.82), reached in the (p, ^{3}He) reaction, are very similar. They are both consistent with $L = 0$ using a DWBA (LZR) analysis (1975RO01). The particle decay of the $T = 2$ state has been studied by (1975ADZV; abstract).

36. ^{10}B(γ, d)^{8}Be $Q_{\rm m} = -6.0259$

See ^{10}B.

37. ^{10}B(π^{-}, 2n)^{8}Be $Q_{\rm m} = 130.534$

Using stopped pions, ^{8}Be states at ≈ 3 and ≈ 19 MeV are populated. The 19 MeV structure may be due to a superposition of three peaks at 17, 19 and 22 MeV (1977BA51).

38. (a) ^{10}B(n, t)^{8}Be $Q_{\rm m} = 0.2314$
(b) ^{10}B(n, t)^{4}He^{4}He $Q_{\rm m} = 0.3233$

Angular distributions have been measured at $E_{\rm n} = 14.4$ MeV (1964VA14; t_0, t_1). See also (1974TU1A). For reaction (b) see (1967VA12). See also ^{11}B in (1980AJ01).

39. ^{10}B(p, ^{3}He)^{8}Be $Q_{\rm m} = -0.5323$

At $E_{\rm p} = 39.4$ MeV angular distribution measurements have been carried out for the ^{3}He groups to ^{8}Be*(0, 2.9, 16.6, 16.9): the ratio d$\sigma(16.63)$/d$\sigma(16.91)$ has a mean value of 0.65 ± 0.05 for $\theta = 15°$ to $30°$, suggesting possibly a preferential excitation of the $T = 1$ components of these two states. The ratio of the differential cross sections dσ(p, t) [to ^{8}B$_{\rm g.s.}$] to dσ(p, ^{3}He) [to ^{8}Be*(16.63, 16.92)] ($15°$ to $30°$) seems to also suggest this (1971SQ01).

40. (a) ^{10}B(d, α)^{8}Be $Q_{\rm m} = 17.8208$
(b) ^{10}B(d, α)^{4}He^{4}He $Q_{\rm m} = 17.9127$

Angular distributions have been reported at $E_d = 0.5$ to 7.5 MeV [see (1974AJ01)] and at $E_d = 0.8$ to 9.0 MeV (1978BU04), 1.83 MeV (1974LA29; α_0, α_1) and 5 MeV (1975RO09; α_0). At $E_d = 7.5$ MeV the total cross section for formation of ^{8}Be*(16.63), $\sigma_t(16.63)$, is about $1.15\sigma_t(16.92)$, consistent with the mixed isospin character of these two states. $\sigma_t(18.15)$ is $\approx 0.85\sigma_t(16.92)$, but the other nearby 1^+ state ^{8}Be*(17.64) has $\sigma_t(17.64) \approx 0.07\sigma_t(16.92)$, consistent with the nearly pure $T = 1$ nature of ^{8}Be*(17.64) (1966BR08). These four states [^{8}Be*(16.63, 16.92, 17.64, 18.15)] have been studied for $E_d = 4.0$ to 12.0 MeV. Interference between the 2^+ states [^{8}Be*(16.63, 16.92)] varies as a function of energy. The cross-section ratios for formation of ^{8}Be*(17.64, 18.15) vary in a way consistent with a change in the population of the $T = 1$ part of the wave function over the energy range: at the higher energies, there is little isospin violation. At higher E_x only the 3^+ state at $E_x = 19.2$ MeV is observed, the neighboring 3^+ state at $E_x = 19.07$ MeV is not seen (1970CA12). There is some question as to whether a two-level fit can be made for the α groups to ^{8}Be*(16.63, 16.92). ((1970CA12) and W.D. Callender, private communication) are dubious about this, feeling that other 2^+ states have to be brought into the calculation. Based onn a two-level fit they find the following average values: $\Gamma_{16.6} = 113$ keV, $\Gamma_{16.9} = 80$ keV, $\Delta Q = 302$ keV. However, (1971NO04) state that the two-level fit is appropriate of the spectra are properly corrected for effects of final state Coulomb interactions: $\Gamma_{16.6} = 90 \pm 5$ keV, $\Gamma_{16.9} = 70 \pm 5$ keV, $\Delta Q = 290 \pm 7$ keV: see (1978HI04) and Table 8.5. See also Table 8.4 in (1974AJ01) and (1977BA62, 1978BA66; theor.).

Reaction (b) [$E_d < 5$ MeV] takes place mainly by a sequential process involving ^{8}Be*(0, 2.9, 11.4, 16.6, 16.9): see (1975RO09, 1975VA04) and the earlier work in (1974AJ01). See also (1970HU1B, 1976GR22, 1977LA13, 1977NO10), (1974AD1B), and ^{12}C in (1980AJ01).

41. ^{10}B(^{3}He, pα)^{8}Be $\qquad Q_m = 12.3273$

At $E(^3\text{He}) = 2.45$ and 6.00 MeV this reaction proceeds primarily by sequential decay via ^{8}Be*(0, 2.9) and via ^{5}Li, ^{9}B and ^{12}C states (1966WA16).

42. ^{10}B(α, ^{6}Li)^{8}Be $\qquad Q_m = -4.552$

Angular distributions have been obtained at $E_\alpha = 46$ MeV for the transitions to ^{8}Be*(0, 2.9) (1970ZE03). See also ^{6}Li (1974WO1C, 1976WO11).

43. ^{10}B(^{7}Li, ^{9}Be)^{8}Be $\qquad Q_m = 10.670$

Angular distributions have been obtained at $E(^7\text{Li}) = 24$ MeV to ^{8}Be*(0, 2.9, 11.4) (1977KO27).

44. (a) ^{11}B(γ, t)^{8}Be $\quad Q_{\rm m} = -11.2238$

(b) ^{11}B(γ, t)^{4}He^{4}He $\quad Q_{\rm m} = -11.1319$

See ^{11}B in (1980AJ01).

45. (a) ^{11}B(p, α)^{8}Be $\quad Q_{\rm m} = 8.5902$

(b) ^{11}B(p, α)^{4}He^{4}He $\quad Q_{\rm m} = 8.6821$

Angular distributions have been measured at $E_{\rm p} = 0.78$ to 45 MeV [see (1974AJ01)] and at $E_{\rm p} = 5.08$ to 38 MeV (1975BU1B, 1978BU1D; α_0) and 7.3 MeV (1974KA1J; α_0, α_1). Observed parameters for ^{8}Be*(2.9) are shown in Table 8.4 of (1974AJ01). (1977FU09) find that the width of this state varies with $E_{\rm p}$. ^{8}Be$_{\rm g.s.}$ decays isotropically, as expected from its 0^+ character (1976KO18).

Reaction (b) has been studied for $E_{\rm p} = 0.15$ to 10.5 MeV. The reaction proceeds predominantly by sequential two-body decay via ^{8}Be*(0, 2.9): see (1974AJ01), ^{12}C in (1975AJ02, 1980AJ01) and (1974KA1J, 1975VA04, 1976GR22, 1977LA13, 1977OH1A). See also (1972TH1C, 1977GR10) and (1978BI1E; applied).

46. ^{11}B(d, nα)^{8}Be $\quad Q_{\rm m} = 6.3656$

See ^{9}Be and (1978GR07).

47. ^{11}B(^{3}He, ^{6}Li)^{8}Be $\quad Q_{\rm m} = 4.5702$

At E(^{3}He) $= 25.6$ MeV angular distributions have been obtained for the ^{6}Li ions to ^{8}Be*(0, 16.6, 16.9, 17.6). In the range E(^{3}He) $= 25.2$ to 26.3 MeV, the group to ^{8}Be*(18.2) [$J^\pi = 1^+$; $T = 0$] is not observed: its intensity is < 0.15 of the intensity to ^{8}Be*(17.6) [$J^\pi = 1^+$; $T = 1$] (1974DE25). For the earlier work see (1974AJ01), (1972YO02) and ^{6}Li.

48. ^{11}B(α, ^{7}Li)^{8}Be $\quad Q_{\rm m} = -8.757$

Angular distributions have been reported at $E_\alpha = 28.4$ and 29.0 MeV for ^{8}Be$_{\rm g.s.}$ + ^{7}Li$_{\rm g.s.}$, ^{8}Be$_{\rm g.s.}$ + ^{7}Li$^*_{0.48}$ and ^{8}Be$^*_{2.9}$ + ^{7}Li (29 MeV only) by (1968KA24) and at 42 MeV for ^{8}Be$_{\rm g.s.}$ + ^{7}Li$_{\rm g.s.}$ and ^{8}Be$_{\rm g.s.}$ + ^{7}Li$^*_{0.48}$ by (1968MI05). At $E_\alpha = 65$ MeV ^{8}Be*($16.6 + 16.9$, 20.0) are apparently also excited (1973WO06). See also (1974WO1C, 1974WO1D), (1973SC1B) and ^{7}Li.

49. (a) ^{12}C(γ, α)^{8}Be $\quad Q_m = -7.3667$

(b) ^{12}C(e, eα)^{8}Be $\quad Q_m = -7.3667$

See ^{12}C in (1975AJ02, 1980AJ01).

50. ^{12}C(n, nα)^{8}Be $\quad Q_m = -7.3667$

This reaction proceeds via ^{8}Be*(0, 2.9) at $E_n = 13$ to 18 MeV and via states in ^{5}He, ^{9}Be and ^{12}C (1966MO05, 1975AN01). See also (1975AN1G, 1976AN1A) and ^{12}C in (1975AJ02, 1980AJ01).

51. (a) ^{12}C(p, pα)^{8}Be $\quad Q_m = -7.3667$

(b) ^{12}C(p, d^{3}He)^{8}Be $\quad Q_m = -25.720$

Reaction (a) has been studied for $13 < E_p < 160$ MeV. At low energies it involves ^{8}Be$_{\rm g.s.}$; at higher energies ^{8}Be*(0, 2.9): see (1974AJ01) and (1969EP01, 1977IO1A, 1977RO02). See also ^{12}C in (1975AJ02, 1980AJ01), (1978CH1G, 1978DE1J) and (1977CH02; theor.). For reaction (b) see (1977CO07; 100 MeV; ^{8}Be(0)) [$S_\alpha = 0.56 \pm 0.12$].

52. ^{12}C(d, ^{6}Li)^{8}Be $\quad Q_m = -5.893$

Angular distributions have been obtained at $E_d = 19.5$, 28 and 51.8 MeV [see (1974AJ01)] and at $E_d = 12.7$ and 13.2 MeV (1975GO36; ^{8}Be$_{\rm g.s.}$), 13.6 and 14.6 MeV (1974GA30; ^{8}Be$_{\rm g.s.}$), at $E_{\vec{d}} = 16$ MeV (1976JA1G; ^{8}Be$_{\rm g.s.}$), at $E_d = 35$ MeV (1975BE01; ^{8}Be$_{\rm g.s.}$) and at 54.3 MeV (1977TA1D: to ^{8}Be*(0, 2.9, 11.4, $16.6 + 16.9$)). See also (1973FO1A) and (1974DO03, 1976NA05, 1978TA1F; theor.).

53. ^{12}C(^{3}He, ^{7}Be)^{8}Be $\quad Q_m = -5.781$

Angular distributions have been measured involving ^{8}Be$_{\rm g.s.}$ + ^{7}Be$_{\rm g.s.}$ and ^{8}Be$_{\rm g.s.}$ + ^{7}Be*(0.43) at $E(^3{\rm He}) = 25.5$, 27.0 and 29.0 MeV (1976PI10) and at 28 MeV (1970DE12). In addition at $E(^3{\rm He}) = 70$ MeV the distributions involving ^{8}Be*(2.9, 11.4, 16.6) and ^{7}Be$_{0+1}$, ^{8}Be*(16.9) and ^{7}Be*(0.43), and ^{8}Be*(17.6) and ^{7}Be*(0, 0.43) have been studied by (1976ST11). See also (1975AU01), (1974DO03; theor.) and ^{7}Be.

54. (a) ^{12}C(α, 2α)^{8}Be $\qquad Q_{\rm m} = -7.3667$

(b) ^{12}C(α, ^{8}Be)^{8}Be $\qquad Q_{\rm m} = -7.4586$

This reaction has been studied up to $E_\alpha = 104$ MeV: see (1974AJ01). Angular correlations involving ^{8}Be*(0, 2.9) have been studied at $E_\alpha = 90$ MeV: S_α(PWIA) $= 2.9 \pm 0.4$ and 2.8 ± 0.3, respectively; S_α(DWIA) for ^{8}Be$_{\rm g.s.}$ $= 2.4 \pm 0.4$ (1976SH02).

Angular distributions at $E_\alpha = 65$ MeV (reaction (b)) lead to $S_\alpha = 0.55$ and 0.75 (DWBA) for ^{8}Be*(0, 2.9). ^{8}Be*(11.4) was also observed (1974WO1C, 1976WO11). See also (1977KA1J).

See also ^{12}C in (1975AJ02, 1980AJ01), ^{16}O in (1977AJ02), (1973RU09, 1974RU06, 1975CO1C, 1977MC07, 1977YA1A) and (1976ME20; theor.).

55. (a) ^{12}C(^{11}B, ^{15}N)^{8}Be $\qquad Q_{\rm m} = 3.6246$

(b) ^{12}C(^{12}C, ^{16}O)^{8}Be $\qquad Q_{\rm m} = -0.2047$

At $E(^{12}$C$) \approx 37$ MeV angular distributions (reaction (b)) are reported involving ^{8}Be$_{\rm g.s.} + {}^{16}$O$_{\rm g.s.}$ (1975EB03, 1976EB01). See also ^{16}O in (1977AJ02), ^{24}Mg in (1978EN06), (1974AJ01) and (1974HO30, 1976AR02, 1977WA04). For reaction (a) see (1978FR20) and ^{15}N in (1981AJ01).

56. ^{12}C(^{16}O, ^{20}Ne)^{8}Be $\qquad Q_{\rm m} = -2.6358$

See (1974ME09) and ^{20}Ne in (1978AJ03).

57. ^{13}C(p, ^{6}Li)^{8}Be $\qquad Q_{\rm m} = -8.615$

Angular distributions have been measured at $E_{\rm p} = 45$ MeV for the transitions to ^{8}Be*(0, 2.9) (1971BR07). See also ^{6}Li.

58. ^{13}C(d, ^{7}Li)^{8}Be $\qquad Q_{\rm m} = -3.589$

See ^{7}Li.

59. ^{13}C(^{3}He, ^{8}Be)^{8}Be $\qquad Q_{\rm m} = 8.1728$

Angular distributions have been obtained at $E(^3\text{He}) = 3.3$, 5.0 and 5.8 MeV for the transition to $^8\text{Be}_{\text{g.s.}} + {}^8\text{Be}_{\text{g.s.}}$ (1968JA07). See also ^{12}C in (1975AJ02), ^{16}O in (1977AJ02), (1974BA42) and (1973OG1A).

60. (a) $^{14}\text{N(n, }^7\text{Li)}^4\text{He}^4\text{He}$ $\quad Q_\text{m} = -8.823$

(b) $^{14}\text{N(n, t)}^4\text{He}^4\text{He}^4\text{He}$ $\quad Q_\text{m} = -11.2899$

See (1976TU04, 1977TU1D). See also ^{7}Li.

61. $^{14}\text{N(d, }2\alpha)^8\text{Be}$ $\quad Q_\text{m} = 6.2076$

See (1972FA07).

62. $^{14}\text{N}(\alpha, {}^{10}\text{B})^8\text{Be}$ $\quad Q_\text{m} = -11.7051$

See (1974WO1C, 1976WO11).

63. $^{14}\text{N}(^{10}\text{B}, 6\alpha)$ $\quad Q_\text{m} = 0.3655$

See (1974AJ01).

64. $^{15}\text{N}(\alpha, {}^{11}\text{B})^8\text{Be}$ $\quad Q_\text{m} = -11.0832$

See (1974WO1C, 1974WO1D, 1976WO11).

65. $^{16}\text{O(p, p)}^4\text{He}^4\text{He}^4\text{He}^4\text{He}$ $\quad Q_\text{m} = -14.4368$

See ^{16}O in (1977AJ02).

66. $^{16}\text{O}(\alpha, {}^{12}\text{C})^8\text{Be}$ $\quad Q_\text{m} = -7.2538$

See (1974WO1C, 1974WO1D, 1976WO11), (1973SC1B) and ^{12}C in (1980AJ01).

67. $^{16}O(^{6}Li, 2\alpha)^{14}N$ $Q_{\mathrm{m}} = 1.6370$

See (1975MI1A).

68. $^{16}O(^{16}O, ^{24}Mg)^{8}Be$ $Q_{\mathrm{m}} = -0.4852$

See (1976AR02), ^{20}Ne in (1978AJ03) and ^{24}Mg in (1978EN06).

69. $^{19}F(p, ^{12}C)^{8}Be$ $Q_{\mathrm{m}} = 0.8599$

See ^{20}Ne in (1978AJ03).

^{8}B

(Figs. 13 and 14)

GENERAL: (See also (1974AJ01).)

Nuclear models: (1975KH1A).

Special states: (1974IR04, 1976IR1B, 1978KH03).

Electromagnetic interactions: (1974KU06, 1976KU07).

Special reactions: (1974BA70, 1976BE1K, 1976WE09, 1977WE1B, 1977YA1B).

Pion and kaon reactions: (1973CA1C, 1977JU1B).

Astrophysical questions: (1973BA1H, 1973DE1D, 1973TR1C, 1974DA18, 1976BA1J, 1977BA1V, 1977SC1D).

Other topics: (1974IR04, 1975KH1A, 1976IR1B, 1977TR07, 1978RO01).

Ground state properties: (1974SHYR, 1975BE31, 1976FU06).

$$\mu = 1.0355 \pm 0.003 \text{ nm (1973MIYZ).}$$

1. ^{8}B(β^+)^{8}Be $\qquad Q_{\rm m} = 17.980$

The β^+ decay leads mainly to ^{8}Be*(2.9). The mean of half-lives listed in (1974AJ01) is 770 ± 3 msec; $\log ft = 5.64$ (1966BA1A). There is also a branch to a ^{8}Be state at ≈ 16.6 MeV; $\log ft = 2.9$ (1964MA35), 3.33 (1969BA43). See reaction 29 in ^{8}Be. See (1973TR1B, 1974BA1Q, 1974CL1E, 1974UL1B, 1974VA1C, 1975UL1A, 1977HA1M) for astrophysical considerations.

2. ^{6}Li(^{3}He, n)^{8}B $\qquad Q_{\rm m} = -1.975$

Angular distributions for the n_0 group have been reported at $E(^{3}\text{He}) = 4.8$ to 5.7 MeV. The appearance of a forward peak indicates an $L = 0$ transfer and hence a knockout mechanism ($L = 0$ is forbidden for simple diproton stripping) (1967VA24). The first excited state is at 767 ± 12 (1965FA03), 783 ± 10 keV (1965MC06: $\Gamma = 40 \pm 10$ keV). See also (1966LA04) and ^{9}B.

Table 8.11: Energy levels of ^{8}B

E_x (MeV ± keV)	$J^\pi; T$	$\tau_{1/2}$ or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
g.s.	$2^+; 1$	$\tau_{1/2} = 770 \pm 3$ msec	β^+	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11
0.778 ± 7		$\Gamma = 40 \pm 10$	γ, p	2, 6, 8
2.32 ± 30	$3^+; 1$	350 ± 40		6, 8
10.619 ± 9	$0^+; 2$	< 60		8

3. ^{7}Be(p, γ)^{8}B $\qquad Q_m = 0.137$

Absolute cross sections have been measured for $E_p = 0.165$ to 10.0 MeV [see (1974AJ01)] and at $E_p = 0.36$ MeV (1977WI05). A resonance at $E_p = 724$ keV [^{9}B*(0.77)] with $\Gamma_{lab} \approx 46$ keV [$\sigma_{peak} = 2.20 \pm 0.22\ \mu$b, $\Gamma_\gamma = 50 \pm 25$ meV] is reported by (1966PA16, 1972KA1B).

The zero-energy cross-section factor $S(0) = 0.032 \pm 0.003$ keV · b, dS/d$E = -3 \times 10^{-5}$ b ((1972KA1B) and P.D. Parker, private communication). The change in the S-value is due to a remeasurement of the ^{7}Li(d, p) cross section: see ^{9}Be. See also (1974AJ01, 1977WI05). The relevance of this reaction to astrophysics is discussed by (1971BA1A, 1973BA1H, 1974VA1C, 1974HO11). See also (1974AJ01, 1974LO1B).

4. ^{9}Be(p, 2n)^{8}B $\qquad Q_m = -20.428$

See (1974DA18) and ^{10}B.

5. ^{10}B(π^+, d)^{8}B $\qquad Q_m = 115.563$

The ground state tranisition has been studied at $E_{\pi^+} = 50$ MeV (1977AM1B).

6. ^{10}B(p, t)^{8}B $\qquad Q_m = -18.531$

At $E_p = 49.5$ MeV angular distributions have been measured for the tritons to ^{8}B*(0, 2.32) (1970SQ01): $L = 2$ and $L = 0 + 2$, leading to $J^\pi = 2^+$ and 3^+, respectively. See also ^{10}B(p, ^{3}He)^{8}Be. The energy of the excited state is 2.29 ± 0.05 MeV (1970SQ01), 2.34 ± 0.04 MeV (1968BR23): $\Gamma_{lab} = 390 \pm 40$ keV (1967MC14). ^{8}B*(0.78) is also observed.

7. ^{10}B(^{6}Li, ^{8}Li)^{8}B $Q_{\rm m} = -17.730$

See (1976WE09, 1977WE1B) and ^{8}Li.

8. ^{11}B(^{3}He, ^{6}He)^{8}B $Q_{\rm m} = -16.917$

At $E(^{3}{\rm He}) = 50$ MeV, ^{6}He groups are observed to the first three states of ^{8}B (1967MC14). At $E(^{3}{\rm He}) = 72$ MeV the first $T = 2$ state is observed at $E_{\rm x} = 10.619 \pm 0.009$ MeV, $\Gamma < 60$ keV: dσ/dΩ(lab) $= 190$ nb/sr at $\theta_{\rm lab} = 9°$. No other states are observed within 2.4 MeV of this state (1975RO01).

9. ^{12}C(^{3}He, ^{7}Li)^{8}B $Q_{\rm m} = -22.899$

This reaction has been studied at $E(^{3}{\rm He}) = 40.7$ MeV (1971DE37). See also (1975PA11).

10. ^{12}C(α, ^{8}Li)^{8}B $Q_{\rm m} = -41.444$

See (1968MC02).

11. ^{13}C(^{3}He, ^{8}Li)^{8}B $Q_{\rm m} = -25.812$

See (1976BE1L).

^{8}C
(Fig. 14)

Mass of ^{8}C: The atomic mass excess of ^{8}C is 35096 ± 26 keV, $\Gamma_{\rm c.m.} = 230 \pm 50$ keV: see (1977TR07). See also (1974AJ01, 1974RO17, 1976TR1B, 1978RO01). ^{8}C is stable with respect to ^{7}B + p ($Q = -0.13$ MeV) and unstable with respect to ^{6}Be + 2p ($Q = 2.143$), ^{5}Li + 3p ($Q = 1.55$), ^{4}He + 4p ($Q = 3.514$). At $E(^{3}{\rm He}) = 76$ MeV the differential cross section for formation of ^{8}C$_{\rm g.s.}$ in the ^{14}N(^{3}He, ^{9}Li) reaction is ≈ 5 nb/sr at $\theta_{\rm lab} = 10°$ (1976RO04). The ^{12}C(α, ^{8}He)^{8}C reaction has been studied at $E_{\alpha} = 156$ MeV: dσ/d$\Omega \approx 20$ nb/sr at $\theta_{\rm lab} = 20°$ (1974RO17). See also (1976RO1M) and (1974IR04, 1975BE31, 1976IR1B; theor.).

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