Energy Levels of Light Nuclei
$A = 8$

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Abstract: An evaluation of $A = 5$–10 was published in *Nuclear Physics A*413 (1984), 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. Also, Reference key numbers have been changed to the NNDC/TUNL format.

(References closed June 1, 1983)

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^{8}n

(Not illustrated)

^{8}n has not been observed in the interaction of 700 MeV or of 400 GeV protons with uranium: the cross section is $< 2.3 \times 10^{-5}$ μb (1977TU02; 700 MeV), < 0.2 μb (1977TU03; 400 GeV). See also (1979AJ01).

^{8}He

(Figs. 11 and 14)

GENERAL: (See also (1979AJ01).)

Complex reactions involving ^{8}He (See (1979AJ01) for comments on the ^{18}O(α, ^{8}He) and ^{26}Mg(α, ^{8}He) reactions.): (1978VO10, 1978MA1D, 1979BE60, 1979BO22, 1980BO31, 1981BO1X, 1981SEZR, 1982BO35, 1982BO40, 1982GU1H, 1982OG02).

Hypernuclei: (1978PO1A, 1978SO1A, 1981WA1J).

Other topics: (1979BE1H, 1981AV02, 1982NG01).

Mass of ^{8}He: A study of the ^{64}Ni(α, ^{8}He)^{60}Ni reaction leads to an atomic mass excess of 31595 ± 9 keV for ^{8}He (1980TR1E) [(Using the new Wapstra masses for ^{64}Ni and ^{60}Ni.)] The value adopted by Wapstra, and by us, based on this and on some earlier measurements [see (1979AJ01)], is 31598 ± 9 keV. ^{8}He is then stable with respect to decay into ^{6}He + 2n by 2.137 MeV.

Table 8.1: Energy levels of ^{8}He

E_x (MeV)	$J^{\pi}; T$	$\tau_{1/2}$ (msec)	Decay	Reactions
g.s.	0^{+}; 2	119 ± 1.5	β^{-}	1, 2
2.6 ± 0.2	(2^{+}); 2			2

1. ^{8}He(β^{-})^{8}Li $\qquad Q_m = 10.648$

The half-life of ^{8}He is 122 ± 2 msec [see (1974AJ01)], 117.5 ± 1.5 msec (1981BJ03): the weighted mean is 119.0 ± 1.5 msec. The decay takes place $(84 \pm 1)\%$ to ^{8}Li*(0.98) [log ft = 4.20] and $(16 \pm 1)\%$ via the neutron unstable states ^{8}Li*(3.21, 5.4) [assignments to these states from an interpretation of the energy spectrum of the delayed neutrons]; $(32 \pm 3)\%$ of the emitted neutrons populate ^{7}Li*(0.48). Changed-particle emission (e.g. t, α) was not observed. The decay to ^{8}Li*(3.21, 5.4) suggest $\pi = +$ for ^{8}Li*(3.21) and 0^{+} or 1^{+} for ^{8}Li*(5.4) (1981BJ03). See also (1979DE15; theor.).

2. ^{9}Be(^{7}Li, ^{8}B)^{8}He $Q_{\rm m} = -28.264$

At $E(^{7}\rm Li) = 83$ MeV, $\theta = 10°$, the population of $^{8}\rm He_{g.s.}$ and of an excited state at 2.6 ± 0.2 MeV (presumably $J^{\pi} = 2^{+}$) are reported by (1982AL08): the differential cross section is 0.1 μb/sr.

^{8}Li

(Figs. 11 and 14)

GENERAL: (See also (1979AJ01).)

Special states: (1980OK01).

Complex reactions involving ^{8}*Li:* (1978BO1B, 1978DU1B, 1979BO22, 1979IV1A, 1980AN1T, 1980BO31, 1980GR10, 1980WI1L, 1981BO1X, 1981MO20, 1982BO35, 1982BO40, 1982GO1E, 1982GU1H, 1982MO1N).

Muon and neutrino interactions: (1978BA1G).

Reactions involving pions and other mesons: (1977VE1C, 1979BA16, 1980HA29, 1981JU1A, 1981NI03, 1982HA57).

Hypernuclei: (1978PO1A, 1979BU1C, 1980BE30, 1980DO1A, 1980IW1A, 1980MA1Z, 1982PI1J, 1982RA1L, 1981ST1G, 1981WA1J, 1982KO11).

Other topics: (1978SO1A, 1979BE1H, 1982NG01).

Ground state of ^{8}*Li:* (1981AV02, 1982NG01).

$J = 2$: see (1974AJ01)

$\mu = +1.65335 \pm 0.00035$ nm: see (1978LEZA)

$Q = 24 \pm 2$ mb: see also (1979AJ01)

1. ^{8}Li(β^{-})^{8}Be $Q_{\rm m} = 16.0037$

The β^{-} decay leads mainly to ^{8}Be*(2.9): see ^{8}Be, reaction 27. A recent measurement of the half-life is 836 ± 3 msec (1979MI1E). The value derived from a weighted means calculation using the earlier measurements ($\pm 4 - 8$ msec) quoted in (1974AJ01) and this recent value gives 840 ± 2 msec. We adopt 836 ± 6 msec, the value measured by (1971WI05). Log $ft = 5.60$ (M.J. Martin, private communication). See also (1981KO1D) and reaction 27 in ^{8}Be.

Table 8.2: Energy levels of ^{8}Li [a]

E_x (MeV ± keV)	$J^\pi; T$	τ or $\Gamma_{\rm c.m.}$ (keV)	Decay	Reactions
g.s.	$2^+; 1$	$\tau_{1/2} = 838 \pm 6$ msec	β^-	1, 2, 3, 7, 9, 10, 12, 13, 14, 15, 16, 18, 19, 20
0.9808 ± 0.1	$1^+; 1$	$\tau_{\rm m} = 12 \pm 4$ fsec	γ	2, 3, 7, 8, 10, 11, 12, 13, 14, 18, 19, 20
2.255 ± 3	$3^+; 1$	$\Gamma = 33 \pm 6$ keV	γ, n	2, 3, 4, 10, 12, 13, 14, 18, 20
3.21	$1^+; 1$	≈ 1000	n	5, 8
5.4	$(0, 1)^+; 1$	≈ 650	n	4, 5, 8
6.1 ± 100	(3); 1	≈ 1000	n	4, 5
6.53 ± 20	$4^+; 1$	35 ± 15	n	2, 4, 13, 14, 18
7.1 ± 100		≈ 400	n	4
(9)		≈ 6000		12
10.8222 ± 5.5	$0^+; 2$	< 12		17

[a] For additional states see reaction 5.

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

Angular distributions have been obtained at $E_{\rm t} = 23$ MeV for the proton groups to ^{8}Li*(0, 0.98, 2.26, 6.54 ± 0.03); $\Gamma_{\rm c.m.}$ for ^{8}Li*(2.26, 6.54) $= 35 \pm 10$ and 35 ± 15 keV, respectively; J for the latter is ≥ 4 (1978AJ02). See also (1983AB1A).

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

The cross section for capture radiation has been measured for $E_{\rm n} = 40$ to 1000 keV; it decreases from 50 μb to 5 μb over that interval. The cross section shows the resonance corresponding to ^{8}Li*(2.26): $E_{\rm res} = 254 \pm 3$ keV, $\Gamma_{\rm n} = 31 \pm 7$ keV, $\Gamma_\gamma = 0.07 \pm 0.03$ eV: see Table 8.3 and (1974AJ01). See also (1981MUZQ).

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

Table 8.3: Resonance parameters for ^{8}Li*(2.26) [a]

$E_{\rm res}$ (keV)	254 ± 3
$E_{\rm x}$ (MeV) [b]	2.261
Γ (keV)	35 ± 5
$\Gamma_{\rm n}$ ($E_{\rm r}$) (keV)	31 ± 7
Γ_γ (eV) [b]	0.07 ± 0.03
$\gamma_{\rm n}^2$ (keV)	594
θ^2	0.091
radius (fm)	3.30
$\sigma_{\rm max}$	12.0
J^π	3^+
$l_{\rm n}$	1

[a] Energies in lab system except for those labeled [b]. For references see (1974AJ01).

[b] Energies in c.m. system.

The thermal cross section is 0.97 ± 0.04 b, $\sigma_{\rm free} = 0.97 \pm 0.04$ b (1981MUZQ), 1.06 ± 0.03 b (1982AL16), the scattering amplitude (bound) $= -2.29 \pm 0.02$ fm (1981MUZQ). Total cross-section measurements have been reported for $E_{\rm n} = 5$ eV to 30 MeV [see (1974AJ01, 1979AJ01)] and at $E_{\rm n} = 2$ to 100 keV (1982AL16; $\pm 3\%$), and at $E_{\rm n} = 2.99$ to 49.64 MeV (1979KEZU, 1979LAZP) and 0.1 to 49.6 MeV [J.A. Harvey, private communication]. Elastic cross sections are also reported at $E_{\rm n} = 4.0$ to 7.5 MeV (1979KN01; also $\rm n_{0+1}$) and 7.47 to 13.94 MeV (1979HO11). See also (1977BI12, 1980BA2Q, 1980MI02, 1981KN03) and ^{7}Li. For polarization measurements see (1974AJ01) and (1982AL16).

A pronounced resonance is observed at $E_{\rm n} = 254$ keV with $J^\pi = 3^+$, formed by p-waves: see Table 8.3. 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. [However, the 2^- state is in contradiction with the work of (1982AL16).] Broad peaks are reported at $E_{\rm n} = 4.6$ and 5.8 MeV ($\pm$ 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: see (1974AJ01) and (1979KEZU). See also reaction 5.

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

(b) ^{7}Li(n, n′)^{3}H + ^{4}He $\qquad Q_{\rm m} = -2.4681$

The excitation 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 $E_n = 1.35$ MeV. A good fit is obtained with either $J^\pi = 1^-$ or 1^+ (2^+ not excluded), $\Gamma_{lab} = 1.14$ MeV. At higher energies a prominent peak is observed at $E_n = 3.8$ MeV ($\Gamma_{lab} = 0.75$ MeV) and there is some indication of a broad resonance ($\Gamma_{lab} = 1.30$ MeV) at $E_n = 5.0$ MeV: see (1974AJ01). [(1980OL06) do observe the onset of a resonance at 5 MeV.] The $E_n = 3.8$ and 5.0 MeV resonances are attributed to (2^+, 3^+) and (3^+, 3^-) states at ^{8}Li*(5.4, 6.4): see however reaction 1 here and (1978ST20). At higher energies there is some evidence for structures at $E_n = 6.8$ and 8 MeV followed by a decrease in the cross section to 20 MeV: see (1979AJ01). For other cross-section measurements see (1979AJ01), (1980OL06; $E_n = 0.48 \rightarrow 5.0$ MeV; 0.48 γ) and (1979HO11; $E_n = 8.0 \rightarrow 13.9$ MeV; n_{0+1}, n_2). See also (1977BI12, 1980MI02). The cross section for reaction (b) rises to 450 mb at $E_n \approx 8$ MeV and thereafter decreases slowly to 300 mb at $E_n = 15$ MeV (1976GAYV). In the range $E_n = 6.89$ to 8.96 MeV $\sigma_{ave} = 372$ mb ($\pm$ 4%) (1981SM04). Measurements are also reported for $E_n = 6.0$ to 9.97 MeV by (1981LI22). See also (1977BI12), (1980KA1R, 1982SH1K; applied) and (1979BE1K; theor.).

A multilevel multichannel R-matrix analysis of ^{7}Li + n, including all available elastic and inelastic scattering data, has recently been presented by (1981KN03). Six additional states of ^{8}Li are derived from the analysis at $E_x = 2.83$ [1^-], 3.91 [0^+], 4.20 [0^-], 4.57 [2^-], 4.73 [1^-] and 7.81 [2^-] MeV [J^π]. The states shown in Table 8.2 at 3.21, 5.4, 6.1, 7.1 and (9) MeV are located by (1981KN03) at 3.17 [1^+], 5.45 [3^-], 5.94 [4^-], 6.61 [1^-] and 8.63 [2^+, 3^+] MeV [J^π]. The sharp state ^{8}Li*(6.53) was not included in the analysis.

6. (a) ^{7}Li(n, 2n)^{6}Li	$Q_m = -7.2501$	$E_b = 2.033$
(b) ^{7}Li(n, p)^{7}He	$Q_m = -10.42$	
(c) ^{7}Li(n, d)^{6}He	$Q_m = -7.750$	

For reactions (a) and (c) see (1980MI02). See also ^{6}He and ^{6}Li and (1979AJ01).

7. ^{7}Li(d, p)^{8}Li $\qquad Q_m = -0.192$

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). Angular distributions have also been measured at several energies in the range of $E_d = 0.49 \rightarrow 3.44$ MeV (p_0) and 0.95 to 2.94 MeV (p_1). The lifetime of ^{8}Li*(0.98) is 10.1 ± 4.5 fsec: see (1979AJ01). See also (1981HU1G, 1982EL03, 1982WAZS) and ^{9}Be.

8. ^{8}He(β^-)^{8}Li $\qquad Q_m = 10.653$

See ^{8}He.

9. ^{9}Be(γ, p)^{8}Li $\qquad Q_m = -16.887$

See (1976MA34).

10. ^{9}Be(e, ep)^{8}Li $\qquad Q_m = -16.887$

At $E_e = 500$ MeV, ^{8}Li*(0, 0.98, 2.26) are populated (1977TU1C, 1979BA1U; prelim.): a large structure at $E_x \approx 25$ MeV, mostly of 1s strength, is also reported. See also (1979AJ01, 1979MO1G) and ^{9}Be.

11. ^{9}Be(π^+, π^+p)^{8}Li $\qquad Q_m = -16.887$

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

12. ^{9}Be(p, 2p)^{8}Li $\qquad Q_m = -16.887$

The summed proton spectrum at $E_p = 156$ 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 $E_x = 9$ and 16 MeV, with $\Gamma_{c.m.} \approx 6$ and 8 MeV; the latter may actually be due to continuum protons: see (1974AJ01). See also (1979JA1C) and (1980CA1A).

13. ^{9}Be(d, ^{3}He)^{8}Li $\qquad Q_m = -11.393$

Angular distributions have been reported for the ^{3}He ions to ^{8}Li*(0, 0.98, 2.26, 6.53) at E_d = 28 MeV [C^2S (abs) = 1.63, 0.61, 0.48, 0.092] and 52 MeV. The distributions to ^{8}Li*(6.53) [$\Gamma <$ 100 keV] are featureless: see (1979AJ01).

14. ^{9}Be(t, α)^{8}Li $\qquad Q_m = 2.927$

At $E_t = 12.98$ MeV, angular distributions of the α-particles to ^{8}Li*(0, 0.98, 2.26, 6.53 $\pm$ 0.02 [$\Gamma_{c.m.} < 40$ keV] have been measured: see (1974AJ01). At $E_{\vec{t}} = 17$ MeV, $\sigma(\theta)$ and A_y measurements, analyzed by CCBA, lead to $J^\pi = 4^+$ for ^{8}Li*(6.53) (1981AR19). For ^{8}Li*(0.98), $\tau_m = 14 \pm 5$ fsec, $E_x = 980.80 \pm 0.10$ keV: see (1974AJ01).

15. ^{9}Be(α, ^{5}Li)^{8}Li $\quad Q_m = -18.85$

See ^{5}Li (1981DA03).

16. ^{9}Be(^{7}Li, ^{8}Be)^{8}Li $\quad Q_m = 0.367$

The production of vector polarized ^{8}Li ions has been studied by (1981KO1D) in this reaction as well as in the ^{7}Li($^7\vec{\text{Li}}$, ^{6}Li)^{8}Li reaction. See also (1979AJ01).

17. ^{10}Be(p, ^{3}He)^{8}Li $\quad Q_m = -15.981$

At $E_p = 45$ MeV, ^{3}He ions are observed to a state at $E_x = 10.8222 \pm 0.0055$ 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: see (1979AJ01).

18. ^{10}B(^{6}Li, ^{8}B)^{8}Li $\quad Q_m = -17.730$

See (1979AJ01).

19. ^{11}B(n, α)^{8}Li $\quad Q_m = -6.632$

Angular distributions for the α_0 and α_1 groups have been measured at $E_n = 14.1$ MeV [see (1974AJ01)] and 14.4 MeV (1979AN18). See also ^{12}B in (1980AJ01).

20. ^{12}C(α, ^{8}B)^{8}Li $\quad Q_m = -41.440$

See (1974AJ01).

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

GENERAL: (See also (1979AJ01).)

Shell model: (1978RA1B, 1979EL04, 1981BO1Y, 1981RA06, 1981ST22, 1982FI13).

Collective, rotational and deformed models: (1978CA1D, 1979EL04, 1979MA1J, 1980FI09, 1981RA06, 1981ST22, 1982FI13).

Cluster and α-particle models: (1977WU1A, 1979GO24, 1979GR1F, 1979PA22, 1979ZH1C, 1980FU1G, 1980HA1M, 1980IK1B, 1981GA1J, 1981KA1P, 1981KN12, 1981KR1J, 1981ST22, 1982HA1M, 1982TS1A, 1982VA11, 1983KA1K, 1983RO1G).

Special states: (1978CA1D, 1978LA1D, 1978RA1B, 1979AR03, 1979GA1E, 1979HA1E, 1979IN07, 1979KA40, 1980KA28, 1980OK01, 1981BA2P, 1981BO1Y, 1981GA1G, 1981GA1J, 1981KU1H, 1981RA06, 1981SE06, 1981ST22, 1982BI09, 1982FI13, 1982HA1M, 1982OR03, 1983AR07, 1983JO03).

Electromagnetic transitions, giant resonances: (1979KA40, 1979PA22, 1981KN12, 1982HA1M).

Complex reactions involving ^{8}Be: (1978BE1G, 1978GU16, 1978VO1A, 1979BE1M, 1979BO22, 1979GE05, 1979HA1E, 1979SI09, 1981BL1G, 1981CH18, 1981GU1B, 1981GU1E, 1981WO1A, 1982GU1K, 1982GUZS, 1982KO17, 1982SH01).

Reactions involving pions and other mesons: (1978GI14).

Hypernuclei: (1978PO1A, 1978SO1A, 1981ST1G, 1981SU1D, 1981WA1J, 1982KO11).

Other topics: (1978FI1C, 1978LA1D, 1978RO17, 1978UL02, 1979AR03, 1979BE1H, 1979EL04, 1979GO24, 1979KA40, 1979KA43, 1979VA1A, 1980AM1B, 1980FI09, 1981BA2P, 1981CA1H, 1981KU1H, 1981SE06, 1981SU1D, 1982BE17, 1982BO01, 1982DE1N, 1982NG01, 1982VA1C, 1983AG1C, 1983AR07, 1983BA2F, 1983FI1J, 1983JO03).

Ground-state properties of ^{8}Be: (1978FI1C, 1978OV1A, 1978RO17, 1978SM02, 1978UL02, 1979IN07, 1979KA40, 1979PA22, 1981AV02, 1981CH18, 1981ST22, 1982BO01, 1982FI13, 1982HA1M, 1982NG01, 1982TS1A, 1982ZE1A, 1983AR07).

1. ^{8}Be → ^{4}He^{4}He $\qquad Q_{\rm m} = 0.09178$

$\Gamma_{\rm c.m.}$ for ^{8}Be$_{\rm g.s.}$ $= 6.8 \pm 1.7$ eV: see (1974AJ01). See, however, (1979FE1C). See also (1980PE1N, 1980RE1C; theor.).

2. ^{4}He(α, γ)^{8}Be $\qquad Q_{\rm m} = -0.09178$

Table 8.4: Energy levels of ^{8}Be [a]

E_x (MeV $\pm$ keV)	$J^\pi; T$	$\Gamma_{c.m.}$ (keV)	Decay	Reactions
g.s.	$0^+; 0$	6.8 ± 1.7 eV	α	1, 2, 4, 12, 13, 14, 15, 20, 21, 22, 23, 24, 26, 29, 30, 31, 32, 33, 34, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60
3.04 ± 30	$2^+; 0$	1500 ± 20	α	2, 4, 12, 13, 14, 15, 20, 22, 23, 24, 26, 27, 28, 29, 30, 31, 32, 33, 36, 37, 38, 39, 40, 41, 42, 43, 45, 46, 47, 48, 49, 50, 54
11.4 ± 300	$4^+; 0$	≈ 3500 [b]	α	4, 13, 14, 20, 23, 28, 30, 31, 32, 33, 39, 41, 48, 49, 50
16.626 ± 3	$2^+; 0 + 1$	108.1 ± 0.5	γ, α	2, 4, 12, 14, 15, 20, 22, 23, 28, 32, 33, 38, 39, 44, 45, 49
16.922 ± 3	$2^+; 0 + 1$	74.0 ± 0.4	γ, α	2, 4, 12, 14, 15, 20, 22, 23, 31, 32, 33, 38, 39, 44, 45, 49
17.640 ± 1.0	$1^+; 1$	10.7 ± 0.5	γ, p	5, 12, 15, 17, 20, 22, 31, 32, 33, 39, 44, 49
18.150 ± 4	$1^+; 0$	138 ± 6	γ, p	12, 15, 17, 20, 22, 31, 32, 33, 39
18.91	2^-	48 ± 20	γ, n, p	12, 15, 16, 17, 20
19.07 ± 30	3^+; (1)	270 ± 20	γ, p	12, 15, 17, 20, 32
19.24 ± 25	3^+; (0)	230 ± 30	n, p	16, 17, 20, 31, 32, 33, 39
19.4	1^-	≈ 650	n, p	12, 16, 17
19.86 ± 50	$4^+; 0$	700 ± 100	p, α	4, 12, 14, 19, 23, 32, 33, 39
20.1	$2^+; 0$	≈ 1100	n, p, α	3, 4, 16, 19, 32, 39
20.2	$0^+; 0$	< 1000	α	4

Table 8.4: Energy levels of ^{8}Be [a] (continued)

E_x (MeV ± keV)	$J^\pi; T$	$\Gamma_{c.m.}$ (keV)	Decay	Reactions
20.9	4^-	1600 ± 200	p	17
21.5	$3^{(+)}$	1000	γ, n, p	15, 16
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, 16, 17, 19, 33
22.63 ± 100		100 ± 50		14, 33
22.98 ± 100		230 ± 50		31, 33
24.0 [c]	$(1, 2)^-; 1$	≈ 7000	γ, p, α	15, 19
25.2	$2^+; 0$		p, d, α	4, 10, 19, 39
25.5	$4^+; 0$	broad	d, α	4, 10
27.4941 ± 1.8 [d]	$0^+; 2$	5.5 ± 2.0	γ, n, p, d, t, ^{3}He, α	3, 5, 7, 10, 35, 39
(28.6)		broad	γ, p	15, 39

[a] See also Table 8.8 and reaction 4.

[b] I am greatly indebted to Prof. F.C. Barker for enlightening discussions concerning the width of ^{8}Be*(11.4). See however reaction 31.

[c] Giant resonance: see reaction 15.

[d] See Table 8.5.

The yield of γ_1, has been measured for $E_\alpha = 32$ to 36 MeV. The yield of γ_0 for $E_\alpha = 33$ to 38 MeV is twenty times lower than for γ_1, consistent with E2 decay. An angular correlation measurement at the resonances corresponding to ^{8}Be*(16.6 + 16.9) [2^+; $T = 0 + 1$] gives $\delta = 0.19 \pm 0.03$, Γ_γ(M1) $= 6.4 \pm 0.5$ eV [weighted mean of the two published measurements listed in (1979AJ01)]. See also (1975NA12). On the basis of these results there is no evidence for violation of CVC or for the existence of SCC. The E_x of ^{8}Be*(3.0) is determined in this reaction to be 3.18 ± 0.05 MeV [see also Table 8.4 in (1974AJ01)]. For all references see (1979AJ01). See also (1979AL34).

3. (a) ^{4}He(α, n)^{7}Be $\quad Q_m = -18.9902 \quad E_b = -0.09178$

(b) ^{4}He(α, p)^{7}Li $\quad Q_m = -17.3459$

(c) ^{4}He(α, d)^{6}Li $\quad Q_m = -22.3714$

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): see (1979AJ01). The excitation functions for p_0, p_2,

Table 8.5: Parameters of the first $T = 2$ state in ^{8}Be [a]

E_x (MeV $\pm$ keV) [b]	27.4941 ± 1.8
$\Gamma_{c.m.}$ (keV) [c]	5.5 ± 2.0
Γ_{γ_5} (eV)	23 ± 4
Γ_{γ_0} (eV)	21.9 ± 3.9
$\Gamma_{n_{0+1}}$ (eV)	770 ± 470
Γ_{n_2} (eV)	880 ± 540
$\Gamma_{n_{3+4}}$ (eV)	1320 ± 805
Γ_{p_0} (eV)	33 ± 33
Γ_{p_1} (eV)	143 ± 33
Γ_{p_2} (eV)	165 ± 83
Γ_{p_3} (eV)	176 ± 110
Γ_{d_0} (eV)	1540 ± 220
Γ_{d_1} (eV)	495 ± 110
Γ_{t_0} (eV)	880 ± 220
$\Gamma_{^3He}$ (eV)	495 ± 110
Γ_{α} (eV)	11 ± 22
Γ_{α^*} (eV) [d]	583 ± 99

[a] (1979FR04). For the earlier references see Table 8.4 in (1979AJ01). For calculated widths for this state, and a calculated spectrum of $(1p)^4$ 0^+ states see (1983JO03).

[b] Weighted mean of values shown in (1979AJ01).

[c] (1976NO07). See also (1979AJ01). The partial particle widths shown below were obtained using this value.

[d] Transitions to ^{4}He*(20.1) [0^+].

d_0, d_1 for $E_\alpha = 54.96$ to 55.54 MeV have been measured in order to study the decay of the first $T = 2$ state in ^{8}Be: see Table 8.5. Cross sections for p_{0+1} are also reported at $E_\alpha = 60.2$, 92.4 and 140.0 MeV [see (1979AJ01)] and at $E_\alpha = 37.5$ to 43.0 MeV (1982SL01; p_0, p_1). The cross section for reaction (c) has been measured at three energies in the range $E_\alpha = 46.7$ to 49.5 MeV: see (1979AJ01).

The production of ^{6}Li, ^{7}Li and ^{7}Be [and ^{6}He] has been studied for $E_\alpha = 61.5$ to 158.2 MeV by (1982GL01). The production of ^{7}Li (via reactions (a) and (b)) in the interaction of cosmic rays with the interstellar medium is discussed: it appears that the cross section is too small to account for the observed ^{7}Li abundance and it is suggested that the "missing" ^{7}Li was produced in the Big Bang, thus supporting the theory of an open universe (1978GL03, 1982GL01). Inclusive proton and deuteron spectra have been measured at $E_\alpha = 110$, 130, 158 and 172 MeV (1981PA15). A study of the (α, αp) reaction at $E_\alpha = 119$ MeV is reported by (1981KA1V) [see for excited states of ^{4}He]. See also (1979AL34), (1979RA1C; astrophysics) and (1978SL02).

4. ^{4}He(α, α)^{4}He $\qquad E_b = -0.09178$

The $\alpha\alpha$ scattering reveals the ground state as a resonance with $Q_0 = 92.12 \pm 0.05$ keV, $\Gamma_{\rm c.m.} = 6.8 \pm 1.7$ eV, [$\tau = (0.97 \pm 0.24) \times 10^{-16}$ sec]. 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, $\Gamma < 1$ MeV, $\Gamma_\alpha/\Gamma < 0.5$. No evidence for other 0^+ states is seen above $E_\alpha = 43$ MeV.

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, $J^\pi = 2^+$): 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 Table 8.6], and states with $E_x = 20.2$, 22.2 and 25.2 MeV. The latter has a small Γ_α.

The $l = 4$ shift rises from $E_\alpha \approx 11$ MeV and indicates a broad 4^+ level at $E_x = 11.5 \pm 0.3$ MeV [$\Gamma = 4.0 \pm 0.4$ MeV]. 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).

Over the range $E_\alpha = 30$ to 70 MeV a gradual increase in δ_6 is observed. Some indications of a 6^+ state at $E_x \approx 28$ MeV and of an 8^+ state at ≈ 57 MeV have been reported; $\Gamma_{\rm c.m.} \approx 20$ and ≈ 73 MeV, respectively. A resonance is not observed at the first $T = 2$ state, ^{8}Be*(27.49): see Table 8.5. See (1979AJ01) for references.

The elastic scattering has also been studied at $E_\alpha = 650$ and 850 MeV [see (1979AJ01)] and at $E_\alpha = 158.2$ MeV (1978NA16), as well as at 4.32 and 5.07 GeV/c (1980BE14). Total cross sections are reported at 0.87 and 2.1 GeV/c (1978JA16). Inclusive inelastic cross sections have been measured at 4.32 and 5.07 GeV/c (1981BA1Q, 1981DU08). Elastic and quasielastic cross sections are reported at 17.9 GeV/c (1980AB1C). At 31, 44, 88 and 125 GeV elastic (at the two higher energies) and inelastic collisions have been studied by (1982BE1T, 1982BE1X). For a study of excited states of ^{4}He see (1980KA20). The bremstrahlung cross section has been measured for $E_\alpha = 9.35$ to 18.7 MeV: see (1974AJ01).

See also (1978BR1A, 1978CH1C, 1981SY1A, 1982FA1B, 1982FA1F, 1982YA1A) and (1978FI1D, 1978SA24, 1978SA2B, 1978SC1B, 1978TA1A, 1979BA18, 1979DY03, 1979FE1B, 1979GH01, 1979LU1A, 1979SA08, 1979SA1E, 1980CH1R, 1980DY1A, 1980KO1M, 1980LI1K, 1980MA30, 1980RA1D, 1980RE1C, 1980SH1M, 1980SI1M, 1980TO1E, 1980VI01, 1980ZH1B, 1981DY02, 1981ER11, 1981FR1N, 1981KI03, 1981KR15, 1981LI1V, 1981SH1A, 1981SU1D, 1982AO1A, 1982AO06, 1982BA29, 1982DR1C, 1982FI16, 1982HA1M, 1982LE1G, 1982LI1G, 1982OR03, 1982SC16, 1982SH08, 1982TI1A, 1983BA1T, 1983BR1F, 1983FI1K, 1983HO1F, 1983KO14, 1983VI1D; theor.).

5. ^{6}Li(d, γ)^{8}Be $\quad\quad$ $Q_m = 22.2796$

Table 8.6: Some ^{8}Be states with $16.6 < E_x < 23.0$ MeV [a]

E_x (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	Reaction
16.627 ± 5	113 ± 3	^{7}Li(^{3}He, d)
	90 ± 5	^{10}B(d, α)
16.623 ± 3	107.7 ± 0.5	^{4}He(α, α) [b]
16.630 ± 3	108.5 ± 0.5	^{4}He(α, α) [c]
16.626 ± 3	108.1 ± 0.5	"best" values
16.901 ± 5	77 ± 3	^{7}Li(^{3}He, d)
	70 ± 5	^{10}B(d, α)
16.925 ± 3	74.4 ± 0.4	^{4}He(α, α) [b]
16.918 ± 3	73.6 ± 0.4	^{4}He(α, α) [c]
16.922 ± 3	74.0 ± 0.4	"best" values
17.640 ± 1.0	10.7 ± 0.5	^{7}Li(p, γ)
18.155 ± 5	147	^{7}Li(p, γ)
18.150 ± 5	138 ± 6	^{10}B(d, α)
18.144 ± 5		^{9}Be(d, t)
18.150 ± 4	138 ± 6	"best" values
19.06 ± 20	270 ± 20	^{7}Li(p, γ)
19.071 ± 10	270 ± 30	^{9}Be(d, t)

Table 8.6: Some ^{8}Be states with $16.6 < E_x < 23.0$ MeV [a] (continued)

E_x (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	Reaction
19.07 ± 30	270 ± 20	"best" values [d]
19.21	208 ± 30	^{9}Be(p, d)
19.22 ± 30	265 ± 30	^{9}Be(^{3}He, α)
19.26 ± 30	220 ± 30	^{9}Be(d, t)
19.24 ± 25	230 ± 30	"best" values
19.86 ± 50	700 ± 100	^{9}Be(d, t)
22.05 ± 100	270 ± 70	^{9}Be(^{3}He, α)
22.63 ± 100	100 ± 50	^{9}Be(^{3}He, α)
22.98 ± 100	230 ± 50	^{9}Be(^{3}He, α)

[a] See Table 8.5 in (1979AJ01) for references. See also Tables 8.7, 8.9 and 8.10 here.
[b] R-matrix theory.
[c] Complex eigenvalue theory.
[d] I am grateful to Dr. F.C. Barker's comments on this state. See also (1978BA66).

The yield of γ-rays to ^{8}Be*(17.64) [1^+; $T = 1$] has been measured for $E_d = 6.85$ to 7.10 MeV. A resonance is observed at $E_d = 6962.8 \pm 3.0$ keV [$E_x = 27495.8 \pm 2.4$ keV, $\Gamma_{c.m.} = 5.5 \pm 2.0$ keV]; $\Gamma_\gamma = 23 \pm 4$ eV [1.14 ± 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: see Table 8.5. See also (1979AJ01). [The energy at resonance, E_d is ≈ 6965 keV, based on the new Q_m.]

6. ^{6}Li(d, n)^{7}Be $\qquad Q_m = 3.381 \qquad E_b = 22.2796$

Yield curves and cross sections have been measured for $E_d = 60$ keV to 5.5 MeV and 12 to 17 MeV [see (1979AJ01)], for 48 to 170 keV (1982CE02; $n_1\gamma$; deduced $S(E)$), for 0.4 to 1.0 MeV (1979RU07; activation) and 1.3 to 11.9 MeV (1980GU26). Polarization measurements are reported at $E_d = 0.27$ to 3.7 MeV. Comparisons of the populations of ^{7}Be*(0, 0.43) and of ^{7}Li*(0, 0.48) have been made at many energies, to $E_d = 7.2$ MeV. The n/p ratios are closely equal for analog states, as expected from charge symmetry. See (1979AJ01) for references. See also ^{7}Be, (1979EL03) in reaction 10, and (1981HO1E).

7. ^{6}Li(d, p)^{7}Li $\quad Q_m = 5.0255 \quad E_b = 22.2796$

Excitation functions have been measured for $E_d = 30$ keV to 5.4 MeV [see (1979AJ01)], for 36 to 170 keV (1981CE04; p_0, p_1 [from 47 keV]) and for 100 to 180 keV (1979BO33; σ_t). 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, $\Gamma = 10 \pm 3$ keV, $\Gamma_{p_0} << \Gamma_{p_1}$; $\Gamma_{p_0} < \Gamma_d$. Polarization measurements have been reported at $E_d = 0.6$ to 10.9 MeV: see (1979AJ01). See also ^{7}Li, (1974FI1D), (1979EL03, 1981HO1E), (1979SE04; theor.) and reaction 10.

8. ^{6}Li(d, d)^{6}Li $\quad E_b = 22.2796$

The yield of elastically scattered deuterons has been measured for $E_d = 2$ to 7.14 MeV; no resonances are observed: see (1974AJ01). See also (1974FI1D) and (1979SE04, 1982LE10; theor.).

9. (a) ^{6}Li(d, t)^{5}Li $\quad Q_m = 0.59 \quad E_b = 22.2796$

(b) ^{6}Li(d, ^{3}He)^{5}He $\quad Q_m = 0.90$

The cross section for tritium production rises rapidly to 190 mb at 1 MeV, then more slowly to 290 mb near 4 MeV: see (1974AJ01). See also ^{5}Li. For reaction (b) see ^{5}He.

10. (a) ^{6}Li(d, α)^{4}He $\quad Q_m = 22.3714 \quad E_b = 22.2796$

(b) ^{6}Li(d, αp)^{3}H $\quad Q_m = 2.5574$

(c) ^{6}Li(d, αn)^{3}He $\quad Q_m = 1.7936$

(d) ^{6}Li(d, 2d)^{4}He $\quad Q_m = -1.4753$

Cross sections and angular distributions (reaction (a)) have been measured at $E_d = 30$ keV to 13.6 MeV [see (1979AJ01)], at 47 to 147 keV (1981GO19; σ_t), at 100 to 180 keV (1979BO33; σ_t) and at $E(^6\text{Li}) = 10$ to 31 MeV (1979WA02: 30° yield of α_0 and α* to ^{4}He*(20.1)[0^+]). A critical analysis of the low-energy data has led to a calculation of the reaction rate parameters for thermonuclear reactions for plasma temperatures of 2 keV to 1 MeV (1978CL07). See also (1981GO19). Polarization measurements are reported at $E_d = 0.4$ to 11.8 MeV and at $E(^6\text{Li}) = 0.6$ MeV [see (1979AJ01)], at $E(^6\vec{\text{Li}}) = 0.4$ and 0.6 MeV (1981UL1A; TAP), at $E_{\vec{d}} = 5.0$ to 6.5 MeV and 8.0 to 10.0 MeV (1979RI03; VAP, TAP) and at $E_{\vec{d}} = 7.92$ MeV (1981KA21; analyzing powers at $\theta_{lab} = 65°$).

Pronounced variations are observed in the cross sections and in analyzing powers. 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. 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. The results are in agreement with those from 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. See also (1979EL03). A strong resonance is seen in the α* channel [to ^{4}He(20.1), $J^\pi = 0^+$] 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). $A_{yy} = 1$ points are reported at $E_d = 5.55 \pm 0.12$ ($\theta_{c.m.} = 29.7 \pm 1.0°$) and 8.80 ± 0.25 MeV ($\theta_{c.m.} = 90.0 \pm 1.0°$) [corresponds to $E_x = 26.44$ and 28.87 MeV] (1979RI03). 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$_{g.s.}$. See also (1979SOZZ).

An R-matrix analysis of the very accurate differential and cross-section measurements by (1977EL09) for ^{6}Li(d, n), (d, p) and (d, α) [$E_d = 0.1$ to 1.0 MeV] has been presented by (1979EL03): non-negligable direct and direct-compound interference are present in the (d, n) and (d, p) processes.

A kinematically complete study of reaction (b) has been reported at $E_d = 1.2$ to 8.0 MeV: the transition matrix element squared plotted as a function of $E_{\alpha\alpha*}$ (the relative energy in the channel ^{4}He$_{g.s.}$ + ^{4}He*(20.1)[0^+]) shows a broad maximum at $E_x \approx 25$ MeV. Analysis of these results, and of a study of ^{7}Li(p, α)α* [see reaction 19] which shows a peak of different shape at $E_x \approx 24$ MeV, indicate the formation and decay of overlapping states of high spatial symmetry, if the observed structures are interpreted in terms of ^{8}Be resonances (1978GE12, 1980CA13). Cross sections have been measured for reactions (b) [$E_d = 117$ to 772 keV] and (c) [$E_d = 204$ to 779 keV] (1979HO04). For reaction (d) see (1980LU1C). See also ^{6}Li, (1974AJ01, 1979AJ01) for earlier references, (1983KU1H; applied) and (1978FI1D, 1979SE04, 1980LE07, 1981KU1B; theor.).

11. ^{6}Li(t, n)^{8}Be $\qquad Q_m = 16.0223$

See (1966LA04, 1974AJ01).

12. (a) ^{6}Li(^{3}He, p)^{8}Be $\qquad Q_m = 16.7861$

(b) ^{6}Li(^{3}He, p)^{4}He^{4}He $\qquad Q_m = 16.8779$

Angular distributions have been reported at $E(^3\text{He}) = 1.4$ to 17 MeV [see (1974AJ01, 1979AJ01)] and in the range $E(^3\text{He}) = 0.46$ to 1.85 MeV (1980EL02; very accurate $\sigma(\theta)$; to ^{8}Be*(0, 3.0, 16.63, 16.92) and for the protons from reaction (b)) and $E(^6\vec{\text{Li}}) = 21$ MeV (1983KO04; p$_0$). The population of ^{8}Be*(17.64, 18.15, 19.0, 19.4, 19.9) has also been reported: see (1974AJ01).

Reaction (b) proceeds via ^{8}Be*(16.63, 16.92): $\Gamma = 117 \pm 10$ and 85 ± 10 keV, respectively. Interference effects are reported: see (1974AJ01). See also ^{9}B, (1978AL37, 1982LA20) and (1981DU1F; theor.).

13. (a) ^{6}Li(α, d)^{8}Be $\qquad Q_m = -1.5671$

(b) ^{6}Li(α, 2α)^{2}H $\qquad Q_m = -1.4753$

Deuteron groups have been observed to ^{8}Be*(0, 3.0, 11.3 ± 0.4). Angular distributions have been measured at $E_\alpha = 15.8$ to 48 MeV: see (1974AJ01, 1979AJ01).

A study of reaction (b) shows that the peak due to ^{8}Be*(3.0) is best fitted by using $\Gamma = 1.2 \pm 0.3$ MeV. At $E_\alpha = 42$ MeV the $\alpha - \alpha$ FSI is dominated by ^{8}Be*(0, 3.0). See also Table 8.4 in (1974AJ01), (1983GO07) and (1978ZE03, 1980ZE05, 1982BE1K, 1982BE17, 1983BE1P; theor.).

14. (a) ^{6}Li(^{6}Li, α)^{8}Be $\qquad Q_m = 20.804$

(b) ^{6}Li(^{6}Li, α)^{4}He^{4}He $\qquad Q_m = 20.896$

(c) ^{6}Li(^{6}Li, 2d)^{4}He^{4}He $\qquad Q_m = -2.951$

At E_{max}(^{6}Li) $= 13$ MeV reaction (a) proceeds via ^{8}Be*(0, 3.0, 16.6, 16.9, 22.5). The involvement of a state at $E_x = 19.9$ MeV ($\Gamma = 1.3$ MeV) is suggested. 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 8.6. 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: $I(16.6)/I(16.9) = 1.22 \pm 0.08$. Partial angular distributions for the α_0 group have been measured at fourteen energies for E(^{6}Li) $= 4$ to 24 MeV. See (1979AJ01) for the references.

At E(^{6}Li) $= 36$ to 46 MeV sequential decay (reaction (b)) via ^{8}Be states at $E_x = 11.4$, 16.9 and 19.65 MeV, with $\Gamma_{lab} = 7.8$, 2.4 and 3.7 MeV [(Primarily experimental widths. I am grateful to Prof. F.C. Barker for calling this to my attention.)], and ^{8}Be*(3.0), is reported by (1979WA13).

Reaction (c) has been studied at E(^{6}Li) $= 36$ to 47 MeV: enhancements in the yield have been observed in the yield of d-d and $\alpha - \alpha$ but not of α-d. These enhancements are due to double spectator poles. Their widths are smaller than predicted from the momentum distribution of $\alpha +$ d clusters in ^{6}Li. The enhancements are not due to phase space, FSI, or the involvement of states in ^{4}He, ^{6}Li or ^{8}Be. The strengths of the DSP peaks suggest qualitatively that quasi-free scattering is the basic mechanism producing the d-d or $\alpha - \alpha$ detected pairs (1980WA10, 1981WA15). See also (1982WA07, 1983LA1J; theor.).

15. ^{7}Li(p, γ)^{8}Be $\qquad Q_m = 17.2541$

Cross sections and angular distributions have been reporteed from $E_p = 30$ keV to 18 MeV. Gamma rays are observed to the ground (γ_0) and the the broad, 2^+, excited state at 3.0 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 $E_p = 0.44$ and 1.03 MeV,

Table 8.7: ^{8}Be levels from ^{7}Li(p, γ)^{8}Be [a]

$E_{\rm res}$ (keV)	$\Gamma_{\rm lab}$ (keV)	^{8}Be* (MeV)	$l_{\rm p}$	J^{π}	Res. [d]
441.4 ± 0.5 [b]	12.2 ± 0.5	17.640	1	1^{+}	$\gamma_0, \gamma_1, \gamma_3, \gamma_4$
1030 ± 5	168	18.155	1	1^{+}	$\gamma_0, \gamma_1, \gamma_3, \gamma_4$
1890	150 ± 50	18.91		(2^{-})	γ_3, γ_4
2060 ± 20	310 ± 20	19.06		$J = 1, 2, 3$	γ_1
				$\pi = (-)$ [c]	
(3100)		(20.0)			γ_1
4900		21.5			γ_1
5000	≈ 4500	21.6	0	$1^{-}; T = 1$	γ_0
6000		22.5			γ_1
7500	≈ 8000	23.8	(0)	$(1^{-}, 2^{-}); T = 1$	γ_1
(11100)		(27.0)			γ_1
13000	broad	28.6			

[a] See Table 8.6 in (1974AJ01, 1979AJ01) for the references.

[b] See (1959AJ76).

[c] See, however, reaction 17.

[d] $\gamma_0, \gamma_1, \gamma_3, \gamma_4$ respresent transitions to ^{8}Be*(0, 3.0, 16.6, 16.9), respectively.

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 8.7. 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*(3.0). The γ_0 and γ_1 giant resonance peaks each contain about 10% of the dipole sum strength. The main trend between $E_{\rm p} = 8$ and 17.5 MeV is a decreasing cross section.

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 $\sigma(J_{\rm c} = 2)/\sigma(J_{\rm c} = 1) = 3.2 \pm 0.5$. Radiative widths for the γ_0 and γ_1 decay are displayed in Table 8.8.

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. Squared $T = 1$ components calculated for ^{8}Be*(16.6, 16.9) are 40 and 60%, and 95 and 5% for ^{8}Be*(17.6, 18.2). The cross section for $(\gamma_3 + \gamma_4)$ has also been measured

Table 8.8: Electromagnetic transitions in ^{8}Be [a]

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

[a] See Table 8.7 in (1979AJ01) for the references. See also reaction 2 here.

[b] δ(E2/M1) $= 0.21 \pm 0.04$, averaged over the energy of the final state.

[c] Nearly pure M1: δ(E2/M1) $= -0.014 \pm 0.013$.

for $E_\mathrm{p} = 11.5$ to 30 MeV ($\theta = 90°$) by detecting the γ-rays and for $E_\mathrm{p} = 4$ to 13 MeV (at five energies) by detecting the two α-particles from the decay of ^{8}Be*(16.6, 16.9): a broad bump is observed at $E_\mathrm{p} = 8 \pm 2$ MeV (1981MA33). The angle and energy integrated yield only exhausts 8.6% of the classical dipole sum for $E_\mathrm{p} = 4$ to 30 MeV, suggesting that this structure does not represent the GDR built on ^{8}Be*(16.6, 16.9). A weak, very broad [$\Gamma \gtrsim 20$ MeV] peak may aslo be present at $E_\mathrm{x} = 20 - 30$ MeV. A direct-capture calculation adequately describes the observed cross section (1981MA33). For earlier references see (1979AJ01). See also (1982SC1H; applications) and (1979BA1V; theor.).

16. ^{7}Li(p, n)^{7}Be $\qquad Q_\mathrm{m} = -1.644 \qquad E_\mathrm{b} = 17.2541$

Measurements of cross sections have been reported for $E_\mathrm{p} = 1.9$ to 52 MeV [see (1974AJ01, 1979AJ01)] and at 60.1 to 199.1 MeV (1982WA02; activation σ). Polarization measurements have been reported at $E_\mathrm{p} = 2.05$ to 5.5 MeV, 30 and 50 MeV: see (1974AJ01).

The yield of ground-state neutrons (n_0) rises steeply from threshold and shows pronounced resonances at $E_\mathrm{p} = 2.25$ and 4.9 MeV. The yield of n_1 also rises steeply from threshold and exhibits a broad maximum near $E_\mathrm{p} = 3.2$ MeV and a broad dip at $E_\mathrm{p} \approx 5.5$ MeV, also observed in

Table 8.9: ^{8}Be levels from ^{7}Li(p, n)^{7}Be [a]

E_p (MeV)	Γ_{lab} (keV)	^{8}Be* (MeV)	J^π
1.88	55 ± 20	18.90	2^-
2.25	220	19.22	3^+
2.6 [b]	≈ 750	19.5	1^-
3.0	≈ 1250	19.9	(2^+)
4.9	1100	21.5	$3^{(+)}$
5.5	broad	22.1	[c]

[a] For references see Table 8.8 in (1979AJ01).
[b] $\gamma^2_{n_1}$ and $\gamma^2_{p_1} \approx 1\%$ of the Wigner limit.
[c] 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.

the p_1 yield. 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. The ratio of the cross section ^{7}Li(p, γ)^{8}Be*(18.9) $\xrightarrow{\gamma}$ ^{8}Be*(16.6 + 16.9) to the thermal-neutron-capture cross section ^{7}Be(n, γ)^{8}Be*(18.9) $\xrightarrow{\gamma}$ ^{8}Be*(16.6 + 16.9), provides a rough estimate 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. See, however, (1979AJ01) and (1977BA62) who finds a 10% impurity.

The structure at $E_p = 2.25$ MeV is ascribed to a 3^+, $T = (1)$, $l = 1$ resonance with $\Gamma_n \approx \Gamma_p$ and $\gamma^2_n/\gamma^2_p = 3$ to 10: see (1966LA04). At higher energies the broad peak in the n_0 yield at $E_p = 4.9$ MeV can be fitted by $J^\pi = 3^{(+)}$ with $\Gamma = 1.1$ MeV, $\gamma^2_n \approx \gamma^2_p$. The behavior of the n_1 cross section can be fitted by assuming a 1^- state at $E_x = 19.5$ MeV and a $J = 0, 1, 2$, postive-parity state at 19.9 MeV [presumably the 20.1–20.2 MeV states reported in reaction 4]. In addition the broad dip at $E_p \approx 5.5$ MeV may be accounted for by the interference of two 2^+ states. See Table 8.9. The total reaction cross section goes down exponentially from $E_p = 23$ to 199.1 MeV: see (1982WA02). See also ^{7}Be, (1977KO46, 1980AU02, 1982AB1D), (1979AJ01, 1982TA03), and (1979CH1C, 1979DU1A; applications).

17. (a) ^{7}Li(p, p)^{7}Li $E_b = 17.2541$

(b) ^{7}Li(p, p$'$)^{7}Li*

Absolute differential cross sections for elastic scattering have been reported for $E_p = 0.4$ 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 $E_p = 0.8$ to 12 MeV: see (1974AJ01). Polarization measurements have been reported at a number of energies in the range $E_p = 0.67$ to 155 MeV [see (1974AJ01, 1979AJ01)] and at 2.1 GeV/c (1979ZH1A).

Anomalies in the elastic scattering appear at $E_p = 0.44$, 1.03, 1.88, 2.1, 2.5, 4.2 and 5.6 MeV. Resonances at $E_p = 1.03$, 3 and 5.5 MeV and an anomaly at $E_p = 1.88$ MeV appear in the inelastic channel. A phase-shift analysis and a review of the exisitng cross-section data 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 a neutron threshold ($E_p = 1.88$ MeV) has a width of about 50 keV [see also reaction 16]; and that the $E_p = 2.05$ MeV resonance corresponds to a 3^+ state. The anomalous behavior of the $^5P_3$ phase around $E_p = 2.2$ MeV appears to result from the coupling of the two 3^+ states [resonances at $E_p = 2.05$ and 2.25 MeV]. The $^3S_1$ phase begins to turn postive after 2.2 MeV suggesting a 1^- state at $E_p = 2.5$ MeV: see Table 8.10. The polarization data show structures at $E_p = 1.9$ and 2.3 MeV. (1979AR10) have performed a phase-shift analysis of the (p, p) data: they find no indication of a possible 1^- state with $17.4 < E_x < 18.5$ MeV [see, however, reaction 15 in (1979AJ01)]. The absence of a 1^- state in this E_x region indicates that the shell-model residual interaction for negative-parity, $S = 0$, $T = 0$ states of ^{8}Be is deficient (1979AR10).

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 effects of the $T = 2$ state. Table 8.5 displays the upper limit for Γ_{p_0}/Γ. The inclusive cross section has been reported at $E_p = 640$ MeV (1981ER07). See also (1982AB1D), (1979AJ01) and (1979VE08, 1981BA36, 1983BA2H; theor.).

18. (a) ^{7}Li(p, d)^{6}Li $\quad Q_m = -5.026 \quad E_b = 17.2541$
(b) ^{7}Li(p, t)^{5}Li $\quad Q_m = -4.43$
(c) ^{7}Li(p, ^{3}He)^{5}He $\quad Q_m = -4.12$

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)]: see (1979AJ01). Poalrization measurements are reported at $E_p = 200$ and 400 MeV (1981LI1B) and 450 to 530 MeV (1981IR1A) [both prelim.]. See also (1979VE08; theor.).

19. ^{7}Li(p, α)^{4}He $\quad Q_m = 17.3459 \quad E_b = 17.2541$

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. Taking into account ^{8}Be $J^\pi = 2^+$ levels at 16.7, 16.9 and 20.6 MeV, an R-matrix fit for $E_p = 131$ to 561 keV leads to a quadratic energy dependence for the S-factor: $S = 0.065[1 + 1.82E - 2.51E^2]$ MeV · b, over the energy range $E_p = 0$ to 600 keV.

Table 8.10: ^{8}Be levels from ^{7}Li(p, p$_0$)^{7}Li and ^{7}Li(p, p$_1$)^{7}Li* [a]

E_p (MeV)	Γ_{lab} (keV)	^{8}Be* (MeV)	J^π	$\Gamma_{p'}$ (keV)
0.441	12.2 [c]	17.640 [h]	1^+	
1.030 ± 0.005	168	18.155	1^+	≈ 6
1.88 [b]	55 ± 20	18.90	2^-	
2.05	≈ 400	19.05	3^+	small
2.25		19.22	3^+	small
2.5 [d]	≈ 750	19.4	1^-	res
[e]				
4.2 ± 0.2 [f]	1800 ± 200	20.9	4^-	(res)
5.6	broad	22.2	[g]	res

[a] See references in Table 8.9 (1979AJ01).

[b] (p, n) threshold: see reaction 16.

[c] $\theta^2_p = 0.064$.

[d] See also Table 8.9, $\gamma^2_{n_1}$ and $\gamma^2_{p_1} \approx 1\%$ of the Wigner limit.

[e] A 2^+ state at $E_x \approx 20$ MeV appears to be necessary to account for the cross sections: see Table 8.4 and reaction 4.

[f] Reduced width is 70% of the Wigner limit.

[g] May be due to two 2^+ states. See also reaction 16.

[h] See also (1981BA36; theor.).

Excitation functions and angular distributions have been measured at many energies in the range $E_p = 23$ keV to 45.2 MeV [see (1979AJ01)] and at $E_p = 47.8$, 53.5, 58.5 and 62.5 MeV (1982BA1V). 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.

Broad resonances are reported to occur at $E_p = 3.0$ MeV [$\Gamma \approx 1$ MeV] and at ≈ 5.7 MeV [$\Gamma \approx 1$ MeV]. Structures are also reported at $E_p = 6.8$ MeV and at $E_p = 9.0$ MeV: see (1979AJ01). The 9.0 MeV resonance is also reflected in the behavior of the A_2 coefficient. The experimental data on the yields and on polarization 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. 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. 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. See (1979AJ01) for references.

A study of the ^{7}Li(p, α)^{4}He* reaction to ^{4}He*(20.1) [0^+] at $E_{\rm p} = 4.5$ to 12.0 MeV shows a broad maximum at $E_{\rm x} \approx 24$ MeV: see reaction 10 (1978GE12, 1980CA13). See also (1981BA1R), (1975ZI1A, 1980PE1N; astrophysics) and (1978FI1D, 1979DO19; theor.).

20. (a) ^{7}Li(d, n)^{8}Be $\qquad Q_{\rm m} = 15.0296$

(b) ^{7}Li(d, n)^{4}He^{4}He $\qquad Q_{\rm m} = 15.1213$

The population of ^{8}Be*(0, 3.0, 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*(3.0) 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 and at $E_{\rm d} = 15.25$ MeV. The angular distributions of the neutrons to ^{8}Be*(16.6, 17.6, 18.2) are fit by $l_{\rm p} = 1$: see (1974AJ01, 1979AJ01).

Reaction (b) appears to proceed primarily via ^{8}Be*(3.0, 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] as many state(s) at $E_{\rm x} \approx 20$ MeV: see (1979AJ01). See also (1980NE1B), (1978BA1F; applied) and ^{9}Be.

21. ^{7}Li(t, 2n)^{8}Be $\qquad Q_{\rm m} = 8.7723$

See (1979AJ01).

22. ^{7}Li(^{3}He, d)^{8}Be $\qquad Q_{\rm m} = 11.7606$

Deuteron groups are observed to ^{8}Be*(0, 3.0, 16.6, 16.9, 17.6, 18.2). For the parameters of ^{8}Be*(3.0) see Table 8.4 in (1974AJ01). For the $J^\pi = 1^+$ mixed isospin states see Table 8.6. Angular distributions have been measured for $E(^3{\rm He}) = 0.9$ to 24.3 MeV [see (1974AJ01, 1979AJ01)] and at $E(^3\vec{\rm He}) = 33.3$ MeV (1981BA1P; to ^{8}Be*(16.6, 17.6, 18.2)). See also ^{10}B and (1982AR08).

23. (a) ^{7}Li(α, t)^{8}Be $\qquad Q_{\rm m} = -2.5599$

(b) ^{7}Li(α, αt)^{4}He $\qquad Q_{\rm m} = -2.4681$

Angular distributions have been measured to $E_\alpha = 50$ MeV: see (1966LA04, 1974AJ01, 1979AJ01). The ground state of ^{8}Be decays isotropically in the c.m. system: $J^\pi = 0^+$. At $E_\alpha = 10$ MeV an anomaly ("ghost") is observed at $E_{\rm x} \approx 0.5$ MeV. Sequential decay (reaction (b)) is reported at $E_\alpha = 50$ MeV via ^{8}Be*(0, 3.0, 11.4, 16.6, 16.9, 19.9): see (1974AJ01). See also (1978ZE03, 1979ZE1B, 1980ZE05, 1982BE1K, 1983BE1P; theor.).

24. ^{7}Li(^{7}Li, ^{6}He)^{8}Be $\qquad Q_{\rm m} = 7.280$

See ^{6}He and (1979AJ01).

25. (a) ^{7}Be(n, p)^{7}Li $\qquad Q_{\rm m} = 1.644 \qquad E_{\rm b} = 18.8984$
(b) ^{7}Be(n, α)^{4}He $\qquad Q_{\rm m} = 18.9902$
(c) ^{7}Be(n, $\gamma\alpha$)^{4}He $\qquad Q_{\rm m} = 18.9902$

At thermal energies, the (n, p) cross section is $(4.8 \pm 0.9) \times 10^4$ b (1981MUZQ), the (n, α) cross section is ≤ 0.1 mb and the (n, $\gamma\alpha$) cross section is 155 mb. See also (1974AJ01) and (1983BA2H; theor.).

26. ^{7}Be(d, p)^{8}Be $\qquad Q_{\rm m} = 16.6738$

See (1974AJ01).

27. ^{8}Li(β^-)^{8}Be $\qquad Q_{\rm m} = 16.0037$

^{8}Li decays mainly to the broad 3.0 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: see (1955AJ61, 1966LA04). 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 (1980MC07).

Beta-α angular correlations have been measured for the decays of ^{8}Li and ^{8}B for the entire final-state distribution: see Table 8.10 in (1979AJ01). No evidence was seen for second-class currents. Recently (1980MC07) have measured the $\beta - \nu - \alpha$ correlations as a function of $E_{\rm x}$ in the decay of ^{8}Li and ^{8}B, detecting both α-particles involved in the ^{8}Be decay. They find that the decay is GT for $2 < E_{\rm x} < 8$ MeV. The absence of Fermi decay strength is expected because the isovector contributions from the tails of ^{8}Be*(16.6, 16.9) interfere destructively in this energy region: see (1980MC07). The results are consistent with the CVC predictions (1980MC07). See also (1978FO31), (1978BO30) and (1979DE15, 1980OK01, 1981HO06; theor.).

28. ^{8}B(β^+)^{8}Be $\qquad Q_{\rm m} = 17.979$

The decay [see reaction 1 in ^{8}B] proceeds mainly to ^{8}Be*(3.0) [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 $ft = 3.3$. The energy distribution of the α-particles has been measured. 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 $\Gamma = 14^{-3}_{+4}$ MeV ($a_2 = 6.0 \pm 0.5$ fm): see (1974AJ01). For $\beta^+ - \alpha$ angular correlation studies see reaction 27. See also (1978BO30).

29. (a) ^{9}Be(γ, n)^{8}Be $\quad Q_m = -1.6655$

(b) ^{9}Be(n, 2n)^{8}Be $\quad Q_m = -1.6655$

(c) ^{9}Be(p, pn)^{8}Be $\quad Q_m = -1.6655$

(d) ^{9}Be(t, tn)^{8}Be $\quad Q_m = -1.6655$

(e) ^{9}Be(α, αn)^{8}Be $\quad Q_m = -1.6655$

Neutron groups to ^{8}Be*(0, 3.0) have been studied for $E_\gamma = 18$ to 26 MeV: see (1974AJ01, 1979AJ01) and ^{9}Be. Reaction (b) appears to proceed largely via excited states of ^{9}Be with subsequent decay mainly to ^{8}Be*(3.0): 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, 3.0): see (1979AJ01), ^{9}Be and ^{9}B. See also (1978JE01). For reactions (d) and (e) see (1974AJ01) and ^{9}Be. For reaction (e) see (1979AJ01).

30. ^{9}Be(π^+, p)^{8}Be $\quad Q_m = 138.684$

Angular distributions are reported to ^{8}Be*(0, 3.0, 11.4) (unresolved) at $E_{\pi^+} = 50$ MeV (1980BA43).

31. (a) ^{9}Be(p, d)^{8}Be $\quad Q_m = 0.5591$

(b) ^{9}Be(p, d)^{4}He^{4}He $\quad Q_m = 0.6509$

Angular distributions of deuteron groups have been reported at $E_p = 0.11$ to 185 MeV [see (1974AJ01, 1979AJ01)], 14.3 and 26.2 MeV (1981BE53; d_0, d_1; and see below), 18.6 MeV (1983BEYY; d_0) and 50 and 72 MeV (1982ZA1B; d_0, d_1 and d) to ^{8}Be*(16.9 $\pm$ 17.6, 19.2). For spectroscopic factors see (1979AJ01). The angular distributions to ^{8}Be*(0, 3.0, 16.9, 17.6, 18.2, 19.1) are consistent with $l_n = 1$: see (1974AJ01) and (1982ZA1B). For spectroscopic factors see (1979AJ01).

An anomalous group is reported in the deuteron spectra between the d_0 and the d_1 groups. At $E_p = 26.2$ MeV, its (constant with θ) $E_x = 0.6 \pm 0.1$ MeV. Analyses of the spectral shape and transfer cross sections are consistent with this "ghost" feature being part of the Breit-Wigner tail of the $J^\pi = 0^+$ ^{8}Be$_{g.s.}$: it contains $< 10\%$ of the g.s. transfer strength (1981BE53). See also (1981OV02). An analysis of reported $\Gamma_{c.m.}$ for ^{8}Be*(3.0) in this reaction shows that there is no E_p dependence: (1981BE53) report that the average $\Gamma_{c.m.}$ at $E_p = 14.3$ and 26.2 MeV is 1.47 ± 0.04 MeV. $\Gamma_{c.m.} = 5.5 \pm 1.3$ eV for ^{8}Be$_{g.s.}$ and 5.2 ± 0.1 MeV for ^{8}Be*(11.4). Spectroscopic factors for ^{8}Be$_{g.s.}$ (including the "ghost" anomaly) and ^{8}Be*(3.0) are 1.23 and 0.22, respectively, at $E_p = 14.3$ MeV, and 1.53 and 1.02, respectively, at $E_p = 26.2$ MeV (1981BE53). Studies of the width of ^{8}Be*(3.0) in this reaction and in reactions 32, 42, 47 and 51 are reported by (1981OV02): the width is not appreciably ($< 10\%$) reaction dependent but the nearness of the decay threshold indicates that care must be taken in comparing decay widths from reaction and from scattering data. (1981OV02) find a mean $E_R = 3130 \pm 25$ keV (resonance energy in the $\alpha + \alpha$ c.m. system) [$E_x = 3038 \pm 25$ keV] and $\Gamma_{c.m.} = 1.50 \pm 0.02$ MeV for ^{8}Be*(3.0): the corresponding observed and formal reaction widths and channel radii are $\gamma_R^2 = 580 \pm 50$ keV, $\gamma_\lambda^2 = 680 \pm 100$ keV and $s = 4.8$ fm. See (1979AJ01) for the earlier work. For reaction (b) [FSI through ^{8}Be*(0, 3.0)] see (1974AJ01) and (1982LA11; $E_p = 30$ MeV).

32. (a) ^{9}Be(d, t)^{8}Be $\quad Q_m = 4.5918$

(b) ^{9}Be(d, t)^{4}He^{4}He $\quad Q_m = 4.6836$

Angular distributions have been measured for $E_d = 0.3$ to 28 MeV: see (1979AJ01). 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 8.6. 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 13] in ^{8}Li. For a study of the parameters of ^{8}Be*(3.0) see reaction 31 (1981OV02).

A kinematically complete study of reaction (b) at $E_d = 26.3$ MeV indicates the involvement of ^{8}Be*(0, 3.0, 11.4, 16.9, $19.9 + 20.1$): see (1974AJ01). See also (1982LA09).

33. (a) ^{9}Be(^{3}He, α)^{8}Be $\quad Q_m = 18.9123$

(b) ^{9}Be(^{3}He, α)^{4}He^{4}He $\quad Q_m = 19.0041$

Angular distributions have been measured in the range $E(^3\text{He}) = 3.0$ to 26.7 MeV and at $E(^3\vec{\text{He}}) = 33.3$ MeV (to ^{8}Be*(16.9, 17.6, 19.2)) [$S = 1.74, 0.72, 1.17$, assuming mixed isopsin for ^{8}Be*(16.9)]. The possibility of a broad state at $E_x \approx 25$ MeV is also suggested. See (1979AJ01) and Table 8.5 here.

Reaction (b) has been studied at $E(^3\text{He}) = 2.9$ to 10 MeV [see (1979AJ01)] and at 1.0 to 2.8 MeV (1978AR21, 1979BA27, 1981FA02, 1981FA07). The reaction has been reported to proceed via ^{8}Be*(0, 3.0, 11.4, 16.6, 16.9, 19.9, 22.5): see (1979AJ01) and (1978AR21, 1981FA07). In addition, observation of the quasi-free reaction process is reported by (1981FA07). See also ^{9}Be 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 $\quad Q_m = 0.367$
(c) ^{9}Be(^{12}C, ^{13}C)^{8}Be $\quad Q_m = 3.2809$
(d) ^{9}Be(^{13}C, ^{14}C)^{8}Be $\quad Q_m = 6.5110$
(e) ^{9}Be(^{16}O, ^{17}O)^{8}Be $\quad Q_m = 2.478$

Angular distributions (reactions (c) and (e)) have been studied at $E(^{12}\text{C}) = 12$ and 15 MeV and $E(^{16}\text{O}) = 11$, 15 and 18 MeV (1970BA49). See also (1982HU06) for reaction (c). See (1979AJ01) for earlier references.

35. ^{10}Be(p, t)^{8}Be $\quad Q_m = 0.0043$

Angular distributions for the transition to the first $T = 2$ state ^{8}Be*(27.49), 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: see (1979AJ01). The particle decay of this state has been studied by (1979FR04): see Table 8.5.

36. ^{10}B(π^-, 2n)^{8}Be $\quad Q_m = 130.533$

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: see (1979AJ01).

37. ^{10}B(n, t)^{8}Be $\quad Q_m = 0.2299$

See (1979AJ01) and ^{11}B in (1980AJ01).

38. ^{10}B(p, ^{3}He)^{8}Be $\quad Q_m = -0.5339$

At $E_p = 39.4$ MeV angular distribution measurements have been carried out for the ^{3}He groups to ^{8}Be*(0, 3.0, 16.6, 16.9): see (1974AJ01).

39. (a) ^{10}B(d, α)^{8}Be $\qquad$ $Q_{\mathrm{m}} = 17.8193$
(b) ^{10}B(d, α)^{4}He^{4}He $\qquad$ $Q_{\mathrm{m}} = 17.9111$

Angular distributions have been reported at $E_{\mathrm{d}} = 0.5$ to 7.5 MeV: see (1974AJ01, 1979AJ01). At $E_{\mathrm{d}} = 7.5$ MeV the population of ^{8}Be*(16.63, 16.92) is closely the same consistent with their mixed isospin character while ^{8}Be*(17.64) is relatively weak consistent with its nearly pure $T = 1$ character. ^{8}Be*(16.63, 16.92, 17.64, 18.15) have been studied for $E_{\mathrm{d}} = 4.0$ 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 very little isospin violation. At higher E_{x} only the 3^{+} state at $E_{\mathrm{x}} = 19.2$ MeV is observed, the neighboring 3^{+} state at $E_{\mathrm{x}} = 19.07$ MeV is not seen. $\Gamma_{16.6} = 90 \pm 5$ keV, $\Gamma_{16.9} = 70 \pm 5$ keV, $\Delta Q = 290 \pm 7$ keV: see Table 8.6.

In reaction (b) at $E_{\mathrm{d}} = 13.6$ MeV sequential decay is indicated via ^{8}Be*(0, 3.0, 11.4, $16.6 + 16.9$, $19.9 + 20.2$, 25.2, 27.4, 28.6) and possibly via a state with $E_{\mathrm{x}} = 15$ MeV, $\Gamma = 1.0 \pm 0.2$ MeV (1981NE08). See (1974AJ01, 1979AJ01) for the earlier work, ^{12}C in (1980AJ01) and (1981DU1F; theor.).

40. ^{10}B(α, ^{6}Li)^{8}Be $\qquad$ $Q_{\mathrm{m}} = -4.552$

At $E_{\alpha} = 27.2$ MeV (1982DO1F) and 150 MeV (1981DEZX) angular distributions are obtained involving ^{8}Be*(0, 3.0) + ^{6}Li$_{\mathrm{g.s.}}$. See also (1979AJ01) and ^{6}Li.

41. ^{10}B(^{7}Li, ^{9}Be)^{8}Be $\qquad$ $Q_{\mathrm{m}} = 10.668$

Angular distributions have been obtained at $E(^{7}\mathrm{Li}) = 24$ MeV to ^{8}Be*(0, 3.0, 11.4): see (1979AJ01).

42. (a) ^{11}B(p, α)^{8}Be $\qquad$ $Q_{\mathrm{m}} = 8.5896$
(b) ^{11}B(p, α)^{4}He^{4}He $\qquad$ $Q_{\mathrm{m}} = 8.6814$

Angular distributions have been measured at $E_{\mathrm{p}} = 0.78$ to 45 MeV [see (1974AJ01, 1979AJ01)] and at $E_{\mathrm{p}} = 125$ to 498 keV (1979DA03; α_0) and 6 to 18 MeV (1983BU06; α_0, α_1). For the parameters of ^{8}Be*(3.0) see reaction 31 (1981OV02). Reaction (b) has been studied for $E_{\mathrm{p}} = 0.15$ to 10.5 MeV [see (1974AJ01)] and at 20 MeV (1981LA07). The reaction proceeds predominantly by sequential two-body decay via ^{8}Be*(0, 3.0). See also ^{12}C in (1980AJ01), (1981HO13) and (1981DU1F; theor.).

43. ^{11}B(d, n)^{12}C → ^{8}Be + α $\qquad Q_m = 6.3650$

For the decay of excited states of ^{12}C to ^{8}Be*(0, 3.0), see (1983NEZZ) and ^{12}C in (1985AJ01).

44. ^{11}B(^{3}He, ^{6}Li)^{8}Be $\qquad Q_m = 4.5714$

At $E(^3\text{He}) = 25.6$ MeV angular distributions have been obtained for the ^{6}Li ions to ^{8}Be*(0, 16.6, 16.9, 17.6). In the range $E(^3\text{He}) = 25.2$ 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) [$J^\pi = 1^+$; $T = 1$]: see (1979AJ01).

45. ^{11}B(α, ^{7}Li)^{8}Be $\qquad Q_m = -8.756$

At $E_\alpha = 27.2$ MeV angular distributions involving ^{7}Li*(0, 0.48) and ^{8}Be$_{\text{g.s.}}$ as well as the "ghost" state [see e.g. reaction 31] have been studied by (1983DO1F, 1983DOZX): the cross section for formation of the "ghost" state is anomalously large. See (1979AJ01) and ^{7}Li.

46. (a) ^{12}C(γ, α)^{8}Be $\qquad Q_m = -7.3665$
(b) ^{12}C(e, eα)^{8}Be $\qquad Q_m = -7.3665$
(c) ^{12}C(π^+, $\pi^+\alpha$)^{8}Be $\qquad Q_m = -7.3665$

For reactions (a) and (b) see ^{12}C in (1975AJ02, 1980AJ01). For reaction (c) see (1979GI11).

47. (a) ^{12}C(n, nα)^{8}Be $\qquad Q_m = -7.3665$
(b) ^{12}C(p, pα)^{8}Be $\qquad Q_m = -7.3665$

These reactions involve ^{8}Be*(0, 3.0): see (1974AJ01, 1979AJ01), (1983AN02; reaction (a) at $E_n = 10 - 35$ MeV) (1981DE08; reaction (b) at $E_p = 45$ MeV) and ^{12}C in (1980AJ01). See also (1978GO14; theor.) and ^{13}C, ^{13}N in (1981AJ01, 1986AJ01).

48. (a) ^{12}C(d, ^{6}Li)^{8}Be $\qquad Q_m = -5.891$
(b) ^{12}C(d, dα)^{8}Be $\qquad Q_m = -7.3665$

Angular distributions have been obtained at $E_d = 12.7$ to 51.8 MeV [see (1974AJ01, 1979AJ01)] and at $E_d = 13.6$ MeV (1981DO15; to ^{8}Be*(0) and to "ghost" anomaly), 54.25 MeV (1980YA02: to ^{8}Be*(0, 3.0, 11.4)). $S_\alpha = 0.79$, 1.08, 1.27 for ^{8}Be*(0, 3.0, 11.4) [FRDWBA] (1980YA02). For the parameters of ^{8}Be*(3.0) see reaction 31 (1981OV02). For reaction (b) see (1979HE06). See also (1978BE1H) and (1983GA1J; theor.).

49. ^{12}C(^{3}He, ^{7}Be)^{8}Be $\qquad Q_m = -5.7789$

Angular distributions have been obtained at $E(^3\text{He}) = 25.5$ to 70 MeV [see (1979AJ01)] and at 41 MeV (1981LE01): ^{8}Be*(0, 3.0, 11.4, 16.6, 16.9, 17.6) have been populated. See also ^{7}Be.

50. (a) ^{12}C(α, 2α)^{8}Be $\qquad Q_m = -7.3665$
(b) ^{12}C(α, ^{8}Be)^{8}Be $\qquad Q_m = -7.4583$

This reaction has been studied up to $E_\alpha = 104$ MeV: see (1979AJ01). Angular correlations involving ^{8}Be*(0, 3.0) 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 $^8\text{Be}_{\text{g.s.}} = 2.4 \pm 0.4$. Angular distributions at $E_\alpha = 65$ MeV (reaction (b)) lead to $S_\alpha = 0.55$ and 0.75 (DWBA) for ^{8}Be*(0, 3.0). ^{8}Be*(11.4) was also observed. Reaction (a) has also been studied at $E_\alpha = 65$ MeV (1983YA01). See also (1981RU10), (1978BE1G), (1981BA20; theor.), ^{12}C in (1985AJ01) and ^{16}O in (1982AJ01).

51. ^{12}C(^{9}Be, ^{13}C)^{8}Be $\qquad Q_m = 3.2809$

Angular distributions involving $^8\text{Be}_{\text{g.s.}} + {}^{13}\text{C}_{\text{g.s.}}$ have been reported at $E(^9\text{Be}) = 20$ to 22.9 MeV (1979BO06) and at $E(^{12}\text{C}) = 10.5$, 12.0 and 13.5 MeV (1982TA21).

52. ^{12}C(^{12}C, ^{16}O)^{8}Be $\qquad Q_m = -0.2046$

Angular distributions involving $^8\text{Be}_{\text{g.s.}} + {}^{16}\text{O}_{\text{g.s.}}$ have been reported at $E(^{12}\text{C}) = 11.9$ to 22 MeV (1980WA16, 1982TA21) and at ≈ 37 MeV (see (1979AJ01)). See also ^{16}O in (1977AJ02, 1982AJ01). For ^{8}Be*(3.0) see (1981OV02). See also (1979GO1C).

53. ^{12}C(^{16}O, ^{20}Ne)^{8}Be $\qquad Q_m = -2.632$

See reaction 20 in ^{20}Ne (1983AJ01).

54. ^{13}C(p, ^{6}Li)^{8}Be $\qquad Q_{\rm m} = -8.613$

See ^{6}Li.

55. ^{13}C(d, ^{7}Li)^{8}Be $\qquad Q_{\rm m} = -3.587$

See ^{7}Li and (1981DO15).

56. ^{13}C(^{3}He, ^{8}Be)^{8}Be $\qquad Q_{\rm m} = 8.1731$

Angular distributions have been obtained at $E(^{3}\text{He}) = 3.3$, 5.0 and 5.8 MeV for the transition to $^{8}\text{Be}_{\text{g.s.}} + {}^{8}\text{Be}_{\text{g.s.}}$: see (1974AJ01). See also ^{16}O in (1982AJ01).

57. ^{13}C(α, ^{9}Be)^{8}Be $\qquad Q_{\rm m} = -10.7392$

See (1979BE1J).

58. ^{13}C(^{9}Be, ^{14}C)^{8}Be $\qquad Q_{\rm m} = 6.5110$

An angular distribution involving $^{8}\text{Be}_{\text{g.s.}}$ and $^{14}\text{C}_{\text{g.s.}}$ has been obtained at $E(^{9}\text{Be}) = 28.8$ MeV (1980BO21).

59. ^{16}O(α, ^{12}C)^{8}Be $\qquad Q_{\rm m} = -7.2537$

See (1980BE04, 1980BE15) and (1979AJ01).

60. ^{24}Mg(e, e$'^{16}$O)^{8}Be $\qquad Q_{\rm m} = -14.138$

See (1979SAZM).

^{8}B
(Figs. 13 and 14)

GENERAL: (See also (1979AJ01).)

Special states: (1980OK01).

Complex reactions involving ^{8}B (The reactions ^{6}Li(^{6}Li, ^{4}H)^{8}B, ^{12}C(^{6}Li, ^{10}Be)^{8}B, ^{9}Be(^{7}Li, ^{8}He)^{8}B and ^{12}C(^{7}Li, ^{11}Be)^{8}B have been studied at $E(^{6}Li) = 72$ MeV and $E(^{7}Li) = 83$ MeV (1982AL08): see ^{8}He, ^{10}Be, as well as ^{11}Be in (1985AJ01).): (1979BO22, 1980GR10, 1981MO20).

Astrophysical questions: (1981BA17, 1983LI01).

Reactions involving pions: (1981JU1A, 1981NI03, 1982HA57, 1983HU02).

Hypernuclei: (1981WA1J).

Other topics: (1979BE1H, 1982AW02, 1982NG01).

Ground state of ^{8}B: (1982NG01).

$\mu = 1.0355 \pm 0.0003$ nm: see (1978LEZA).

1. ^{8}B(β^{+})^{8}Be $\qquad Q_{\rm m} = 17.979$

The β^{+} decay leads mainly to ^{8}Be*(2.9). The mean half-lives listed in (1974AJ01) is 770 ± 3 msec; $\log ft = 5.64$. There is also a branch to a ^{8}Be* state at ≈ 16.6 MeV; $\log ft = 3.3$. See also (1979AJ01) and reaction 28 in ^{8}Be. See also (1978RA2A), (1979DA1D, 1980HA1V, 1980PE1N, 1981BA17, 1981BA2B, 1981BA2G, 1981IT1A, 1982BA80, 1982CO1D, 1982KL1C, 1983TR1F; astrophsyics) and (1979DE15, 1980OK01, 1981BA17, 1981HO06, 1982IT01; theor.).

2. ^{6}Li(d, π^{-})^{8}B $\qquad Q_{\rm m} = -135.266$

At $E_{\rm d} = 300$ and 600 MeV ^{8}B*(0, 0.78, 2.32) are populated: the cross sections are higher at the lower (subthreshold for pion production) energy (1982AS01). See also (1982LE1L).

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

Table 8.11: Energy levels of ^{8}B

E_x (MeV $\pm$ 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, 6, 7, 8, 9, 10
0.778 ± 7		$\Gamma = 40 \pm 10$	γ, p	2, 3, 4, 7, 8
2.32 ± 30	$3^+; 1$	350 ± 40		7, 8
10.619 ± 9	$0^+; 2$	< 60		8

Angular distributions for the n_0 group have been reported at $E(^3\text{He}) = 4.8$ to 5.7 MeV: $L = 0$. Two measurements for the E_x of ^{8}B*(0.78) are 767 ± 12 and 783 ± 10 keV [$\Gamma = 40 \pm 10$ keV]: see (1974AJ01) and ^{9}B.

4. ^{7}Be(p, γ)^{8}B $\qquad Q_m = 0.138$

Absolute cross sections have been measured for $E_p = 0.165$ to 10.0 MeV. A resonance at $E_p = 724$ keV [^{8}B*(0.771)] with $\Gamma_{lab} \approx 46$ keV [$\sigma_{peak} = 2.20 \pm 0.22$ μb, $\Gamma_\gamma = 50 \pm 25$ meV] is reported. The zero-energy cross-section factor $S_{17}(0) = 0.0216 \pm 0.0025$ keV $\cdot$ b (1983FI01), appreciably lower than earlier results: see (1979AJ01). Calulations by (1980BA35) had suggested that $S(0)$ was in the range 0.014 to 0.022 keV $\cdot$ b. The astrophysical implications of this reaction are discussed by (1975ZI1A, 1980BA1P, 1980BA35, 1980BA2M, 1981BA2F, 1982BA80, 1983FI01). The predicted ^{37}Cl ν-capture rate is decreased to 5.3 SNU, a reduction of about 25% in the previous value (1983FI01). See also (1980PE1N; astrophys.) and (1981WI04; theor.).

5. ^{7}Be(d, n)^{8}B $\qquad Q_m = -2.087$

See (1983HA1W).

6. ^{10}B(π^+, d)^{8}B $\qquad Q_m = 115.561$

See (1982DO01).

7. ^{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): $L = 2$ and $L = 0 + 2$ leading to $J^\pi = 2^+$ and 3^+, respectively. Measurements of E_x for ^{8}B*(2.32) yield 2.29 ± 0.05 MeV, 2.34 ± 0.04 MeV [$\Gamma_{lab} = 0.39 \pm 0.04$ MeV]. ^{8}B*(0.78) is also observed: see (1974AJ01).

8. ^{11}B(^{3}He, ^{6}He)^{8}B $\qquad Q_m = -16.914$

At $E(^3$He$) = 72$ MeV the first $T = 2$ state is observed at $E_x = 10.619 \pm 0.009$ MeV, $\Gamma < 60$ keV: dσ/dΩ(lab) $= 190$ nb/sr at $\theta_{lab} = 9°$. No other states are observed within 2.4 MeV of this state. ^{8}B*(0, 0.78, 2.32) have also been populated: see (1979AJ01).

9. ^{12}C(^{3}He, ^{7}Li)^{8}B $\qquad Q_m = -22.896$

See (1979AJ01).

10. ^{14}C(^{7}Li, ^{13}Be)^{8}B $\qquad Q_m = -40.0$

See (1983ALZM).

^{8}C

(Fig. 14)

Mass of ^{8}C: The atomic mass excess of ^{8}C is 35095 ± 23 keV (A.H. Wapstra, private communication). $\Gamma_{c.m.} = 230 \pm 50$ keV: see (1979AJ01). ^{8}C is stable with respect to ^{7}B + p ($Q = -0.13$ MeV) and unstable with respect to ^{6}Be+2p ($Q = 2.14$), ^{5}Li+3p ($Q = 1.55$), ^{4}He+4p ($Q = 3.51$). At $E(^3$He$) = 76$ MeV the differential cross section for formation of ^{8}C$_{g.s.}$ in the ^{14}N(^{3}He, ^{9}Li) reaction is ≈ 5 nb/sr at $\theta_{lab} = 10°$. 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 $\theta_{lab} = 20°$: see (1979AJ01). See also (1979BE1H, 1980TR1E) and (1979BO22, 1982NG01; theor.).

^{8}N

(Not illustrated)

Not observed: see (1982NG01; theor.).

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(Closed 1 June 1983)

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

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