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Energy Levels of Light Nuclei
$A = 10$

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Abstract: An evaluation of $A = 5$–10 was published in *Nuclear Physics A*227 (1974), p. 1. This version of $A = 10$ differs from the published version in that we have corrected some errors discovered after the article went to press. Figures and introductory tables have been omitted from this manuscript. Reference key numbers have been changed to the TUNL/NNDC format.

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^{10}He

(Not illustrated)

^{10}He has not been observed when ^{232}Th has been bombarded with 145 MeV ^{15}N ions (1971AR21), nor in the spontaneous fission of ^{252}Cf (1967CO1K). See also (1966PO09). It is particle unstable: the calculated $(M - A) = 52.75$ MeV. The breakup energies into ^{9}He + n and ^{8}He + 2n are calculated to be -1.1 and -4.9 MeV, respectively (1972TH13). See also (1966GA25, 1972GA1F).

See also (1968CE1A, 1973KO1D) and (1969BA55, 1970RY04, 1971LO13, 1971RY1A; theor.).

^{10}Li

(Not illustrated)

^{10}Li is not observed in the 5.3 GeV bombardment of uranium (1966PO09). Based on the tentative locations of the $T = 2$ analogs, ^{10}Be*(21.3) [reaction 2 in ^{10}Be: see (1970CH1Q, 1973AB10)] and ^{10}B*(23.0) [reaction 9 in ^{10}B: see (1968HA1K)], the mass excess of ^{10}Li, $(M - A) = 33.10 \pm 0.06$ MeV (1973AB10). The breakup energy into ^{9}Li + n is then -0.06 ± 0.06 MeV. Using the calculated values suggested by (1969GA1G, 1972TH13), $E_{\rm b} = -1.1 \pm 0.3$ MeV. See also (1966GA25) and (1968CE1A).

^{10}Be

(Figs. 19 and 22)

GENERAL: (See also (1966LA04).)

Shell model: (1961KO1A, 1968FA1B, 1969SA1A, 1970BO35, 1970KA32, 1973KU03, 1973SA30).

Cluster and alpha-particle model: (1973KU03).

Special levels: (1970BO35, 1970FR1C, 1970PE18, 1973SA30).

Electromagnetic transitions: (1965ST22, 1973SA30).

Astrophysical questions: (1967KO1F, 1967SH1B, 1971LE33, 1971RA1K, 1972SI1G, 1973LA19, 1973RA37, 1974SI1H).

Special reactions: (1967KO1F, 1967SH1B, 1968YI01, 1969AR13, 1969GA18, 1969GO1H, 1969YI1A, 1971AR02, 1971LE33, 1971RA1K, 1972AM04, 1972PN1A, 1972SI1G, 1972VO06, 1973KO1D, 1973KU03, 1973LA19, 1973VO1G, 1973WI15).

Pion capture and reactions (See also reaction 12.): (1971DA10, 1972FA14, 1972FU1C, 1972KA1F, 1973KA1D).

Other topics: (1968FA02, 1968FA1B, 1968JO1E, 1968NE1C, 1969SA1A, 1970FO1B, 1970PE18, 1971BA2Y, 1972AN05, 1972CA37, 1972PN1A, 1972ST1C, 1973BU20, 1973JU2A, 1973KU03, 1973MA48, 1973MU11).

Table 10.1: Energy levels of ^{10}Be

E_x (MeV $\pm$ keV)	$J^\pi; T$	τ or $\Gamma_{c.m.}$	Deacy	Reactions
g.s.	$0^+; 1$	$\tau_{1/2} = (1.6 \pm 0.2) \times 10^6$ y	β^-	1, 3, 4, 5, 12, 13, 14, 17, 18, 19, 21, 22, 24, 25, 26, 27, 28, 30
3.3680 ± 0.2	$2^+; 1$	$\tau_m = 180 \pm 17$ fsec	γ	3, 4, 5, 12, 13, 18, 19, 21, 24, 26, 28
5.9583 ± 0.3	$2^+; 1$	$\tau_m < 80$ fsec	γ	4, 5, 12, 13, 28
5.9599 ± 0.6	$1^-; 1$		γ	4, 12, 13, (28)
6.1793 ± 0.7	$0^+; 1$	$\tau_m = 1.1^{+0.4}_{-0.3}$ psec	π, γ	4, 12, 13
6.2633 ± 5	$2^-; 1$		γ	4, 12, 13
7.371 ± 1	$3^-; 1$	$\Gamma = 15.7 \pm 0.5$ keV	n	4, 6, 12, 13
7.542 ± 1	$2^+; 1$	6.3 ± 0.8 keV	n	6, 12, 13
9.27	$(4^-); 1$	≈ 100 keV	n	4, 6, 12, 28
(9.4)	$(2^+); 1$	≈ 400 keV	n	6, 12
10.7	$\geq 1; 1$		n	4, 6
(11.75 ± 110)				4, 12
(17.4)			n, t	2
17.79		110 ± 35 keV	n, t	2, 4
18.55		≈ 350 keV	γ, n, t	2, 4
(18.6)		≈ 1.1 MeV	γ, t	2
(21.3)	$(T = 2)$	400 keV	p, t	2
(24.0)		broad		24

Ground-state properties: (1968FA02, 1968FA1B, 1972ST1C, 1973SA30).

1. ^{10}Be(β^-)^{10}B $\qquad Q_m = 0.5559$

The half-life is $(1.6 \pm 0.2) \times 10^6$ y (1972EM01), $(1.7 \pm 0.4) \times 10^6$ y (1972MC26) and $(1.5 \pm 0.3) \times 10^6$ y (1972YI01): we adopt $\tau_{1/2} = (1.6 \pm 0.2) \times 10^6$ y: $\log ft = 13.42$ (B. Zimmerman and G. Fox, private communication). The spectrum is of the D_2 type (1950WU1A). For a discussion of astrophysical and nuclear chronology considerations see (1972YI01). See also (1969VA1C, 1970WA11; theor.) and (1966BR1N).

2. (a) ^{7}Li(t, γ)^{10}Be $\quad Q_{\rm m} = 17.251$

(b) ^{7}Li(t, n)^{9}Be $\quad Q_{\rm m} = 10.4389 \quad E_{\rm b} = 17.251$

(c) ^{7}Li(t, p)^{9}Li $\quad Q_{\rm m} = -2.397$

(d) ^{7}Li(t, d)^{8}Li $\quad Q_{\rm m} = -4.2249$

(e) ^{7}Li(t, α)^{6}He $\quad Q_{\rm m} = 9.837$

The yield of γ_0 and γ_1 (to ^{10}Be*(0, 3.4)) has been studied at $90°$ for $E_{\rm t} = 0.5$ to 3.0 MeV. The γ_1 yield shows a peak at $E_{\rm t} = 1.85$ MeV, $\Gamma_{\rm lab} \approx 0.5$ MeV. The γ_0 yield peaks near the same energy but with a width $\Gamma_{\rm lab} \approx 1.5$ MeV (1973BL1B).

The neutron yield exhibits a weak structure at $E_{\rm t} = 0.24$ MeV and broad resonances at $E_{\rm t} \approx 0.77$ MeV [$\Gamma = 160 \pm 50$ keV] and 1.74 MeV (1960SE12, 1961VA43, 1962SE1A).

The yields of ^{9}Li and ^{8}Li (reactions (c) and (d)) have been studied from threshold to $E(^{7}{\rm Li}) = 21$ MeV (1970CH1Q) and $E_{\rm t} = 6.5$ MeV (1973AB10). A sharp minimum is observed in the ^{9}Li yield at $E(^{7}{\rm Li}) \approx 13.6$ MeV (1970CH1Q) and $E_{\rm t} = 5.62$ MeV (1973AB10). It may correspond to a $T = 2$ state in ^{10}Be at $E_{\rm x} = 21.2$ MeV, $\Gamma_{\rm c.m.} = 0.4$ MeV (1970CH1Q, 1973AB10).

For reaction (e) see (1966LA04). See also ^{6}He, ^{8}Li, ^{9}Li and ^{9}Be.

3. ^{7}Li(α, p)^{10}Be $\quad Q_{\rm m} = -2.5638$

Angular distributions of the p_0 and p_1 groups have been measured at $E_\alpha = 30$ MeV (1960KL03, 1972ME07). See also (1966LA04).

4. ^{7}Li(^{7}Li, α)^{10}Be $\quad Q_{\rm m} = 14.784$

Angular distributions are reported for $E(^{7}{\rm Li}) = 2.1$ to 5.75 MeV (1969CA1A; α_1, $\alpha_{2+3+4+5}$), 3.5 to 5.75 MeV (1969CA1A; α_0) and 30.3 MeV (1971GL07; α-groups to ^{10}Be*(0, 3.4, 6.0, 7.4, 9.4, 10.7, 11.9, 17.9)). (1971GL07) also report an α-group corresponding to ^{10}Be*(18.8). See also (1970OG1A), (1966RO1E; theor.) and ^{14}C in (1976AJ04).

5. ^{9}Be(n, γ)^{10}Be $\quad Q_{\rm m} = 6.8120$

$Q_0 = 6811.9 \pm 0.4$ keV (1966GR18);

$Q_0 = 6812.5 \pm 1.0$ keV (1967RA24).

The thermal capture cross section is 9.2 ± 1.0 mb (1973MU14). Reported γ transitions are displayed in Table 10.2 (1960BA01, 1961JA19, 1963DR02, 1966GR18, 1969WE10). See (1968FO1A) for astrophysical considerations. See also (1968RO1H).

Table 10.2: Neutron capture γ-rays in ^{10}Be

E_γ [b] (keV)	Transition	Intensities [a]			E_x [b] (keV)
		A	B	C	
6809.4 ± 0.4	capt. $\rightarrow$ g.s.	62	70	65	
5955.9 ± 0.5	5.96 [d] $\rightarrow$ g.s.	1.4	2	$\lesssim 2$	5958.3 ± 0.3
3443.3 ± 0.3	capt. $\rightarrow 3.37$	11	15	11	
3367.4 ± 0.2 [c]	$3.37 \rightarrow$ g.s.	37	28	28	3368.0 ± 0.2
2589.9 ± 0.25	5.96 [d] $\rightarrow 3.37$	28	17	21	
853.5 ± 0.3	capt. $\rightarrow 5.96$ [d]	29.4	16	24	

A: (1960BA01: see (1963DR02)).
B: (1961JA19).
C: (1963DR02).
[a] Gamma rays per 100 captures.
[b] (1966GR18).
[c] Not Doppler broadened (1969WE10).
[d] This is the 2^+ member of the doublet at $E_x = 5.96$ MeV: see reaction 13.

6. ^{9}Be(n, n)^{9}Be $E_b = 6.8120$

The older cross section data is summarized in (1964ST25). More recent measurements of the total cross section are reported for $E_n = 0.5$ to 20 MeV ((1971SC1P), and R.B. Schwartz, private communication), 1.9 to 4.6 MeV (1968JO1F), 2.5 to 15 MeV (1971FO1A), 13.70 to 14.60 MeV (1968HU1E, 1969AN1E, 1970AN1F), 23 to 45 MeV (1972BU1T), 36.3 to 58.9 MeV (1972AU01: at five energies in this range) and at a neutron momentum of 10 GeV/c (1968EN1A). Angular distributions are summarized in (1970GA1A). See also ^{9}Be. The coherent scattering length (thermal, bound) is 7.74 ± 0.10 fm (1973MU14).

Five resonances are reported in the total cross section, at $E_n = 0.63$, 0.82, 2.73, (2.85) and 4.3 MeV; see Table 10.3. Polarization and differential cross sections are reported for $E_n = 0.2$ to 2 MeV by (1961LA1A, 1962EL01, 1964LA04). Analysis of these data leads to the 3^-, 2^+ assignments for ^{10}Be*(7.37, 7.55) (1964LA04). Below $E_n = 0.5$ MeV the scattering cross section reflects the effect of bound 1^- and 2^- states, presumably ^{10}Be*(5.960, 6.26). There is also indication of interference with s-wave background and with a broad $l = 1$, $J^\pi = 3^+$ state (1964LA04). The structure at $E_n = 2.73$ MeV is ascribed to two levels: a broad state at about 2.85 MeV with $J^\pi = 2^+$, and a narrow one, $\Gamma \approx 100$ keV, at $E_n = 2.73$ MeV with a probable assignment of $J^\pi = 4^-$ (1951BO45, 1966SC16). The 4^- assignment results from a study of the polarization of the n_0 group at $E_n = 2.60$ to 2.77 MeV. A rapid variation of the polarization over this interval is observed, and the data are consistent with 4^- ($l = 2$) for ^{10}Be*(9.27) (1966SC16). The polariza-

Table 10.3: Resonances in ^{9}Be(n, n)^{9}Be

E_{res} [a] (MeV ± keV)	^{10}Be* (MeV)	$\Gamma_{c.m.}$ (keV)	J^π	l	R (fm)	θ^2 (%)	Refs.
0.6220 ± 0.8 [b]	7.371	15.7 ± 0.5 [b]	3^-	2	5.6	7.5	(1951BO45, 1964LA04)
0.8118 ± 0.7 [b]	7.542	6.3 ± 0.8 [b]	2^+	1	5.6	0.28	(1951BO45, 1955WI25, 1964LA04)
2.73	9.27	≈ 100	(4^-)	(2)			(1951BO45, 1966SC16) [b]
(2.85)	9.4	≈ 400	(2^+)	(1)			(1951BO45)
4.3	10.7		≥ 1				(1961FO07)

[a] (1962PE10) report an additional anomaly in the cross section at $E_n = 207$ keV.
[b] (1971SC1P) and R.B. Schwartz, private communication.

tion of the n_0 group has also been studied at $E_n = 4$ MeV (1967GO1G). See also (1966DA1B). A weak dip at $E_n \approx 4.3$ MeV is ascribed to a level with $J \geq 1$ (1961FO07).

See also (1966LA04), (1969MA39), (1966CH1C) and (1966AG1A, 1966JA08, 1966SE1E, 1967BE1F, 1967HO1F, 1972FR09; theor.).

7. (a) ^{9}Be(n, n′)^{9}Be* $E_b = 6.8120$

(b) ^{9}Be(n, 2n)^{8}Be $Q_m = -1.6651$

Data on non-elastic cross sections are summarized by (1964ST25). The processes involved include (n, 2n) and (n, n′)^{9}Be* $\rightarrow$ n + ^{8}Be; the (n, α) process is relatively weak. The total non-elastic cross section rises rapidly from threshold to 730 ± 100 mb at $E_n = 5.2$ MeV (1968EA1B). The cross section is ≈ 600 mb at $E_n = 6$ MeV and then falls slowly to 500 mb at 14 MeV. In the range 3.5 to 6.0 MeV, ^{9}Be(n, n′)^{9}Be*(2.4) accounts for about half of the non-elastic cross section (1959MA34: see (1964ST25)). The (n, 2n) cross section increases slowly from $E_n = 2.00$ to 2.70 (the threshold for the process ^{9}Be(n, n′)^{9}Be*(2.4) $\rightarrow$ n + ^{8}Be) and then sharply, reaching a plateau with a value ≈ 580 mb at 6.40 MeV (1969HO45, 1972BL1H). See also (1968EA1B).

See also (1966LA04), (1966JE1B) and (1966FE04, 1967RO1E, 1967SA1F, 1968GR1F, 1969MA39, 1969PR17, 1971AL1E).

8. ^{9}Be(n, p)^{9}Li $Q_m = -12.836$ $E_b = 6.8120$

See (1966LA04, 1972ED01) and (1970BA1L).

9. ^{9}Be(n, d)^{8}Li $Q_m = -14.664$ $E_b = 6.8120$

Table 10.4: Radiative transitions in ^{9}Be(d, p)^{10}Be [a]

E_x (keV)	Transition	ΔJ^π	Mult.	Branch (%)	τ_m (psec)	Γ_γ (meV)
3368.0 ± 0.2 [b]	$3.37 \to$ g.s.	$2^+ \to 0^+$	E2	100	0.189 ± 0.020 [g]	3.48 ± 0.37
					0.160 ± 0.030 [h]	4.11 ± 0.78
5958.3 ± 0.3 [b,e]	$5.96 \to 3.37$	$2^+ \to 2^+$	M1	> 90	< 0.08 [h]	
	$5.96 \to$ g.s.	$2^+ \to 0^+$	E2	< 10		
5959.9 ± 0.6 [c,e]	$5.96 \to$ g.s.	$1^- \to 0^+$	E1	83^{+10}_{-6}		
	$5.96 \to 3.37$	$1^- \to 2^+$	E1	17^{+6}_{-10}		
6179.3 ± 0.7 [d]	$6.18 \to 5.96$	$0^+ \to 1^-$	E1	4.6 ± 1.5 [d]	$1.1^{+0.4}_{-0.3}$ [d]	0.028 ± 0.012
	$6.18 \to 3.37$	$0^+ \to 2^+$	E2	95 ± 2 [d]		0.57 ± 0.17
	$6.18 \to$ g.s.	$0^+ \to 0^+$	E0	0.24 ± 0.08 [d]		$(1.4 \pm 0.6) \times 10^{-3}$
6263.3 ± 5 [d]	$6.26 \to 5.96$	$2^- \to 1^-$ $2^- \to 2^+$	M1 E1	≤ 1 [f]		
	$6.26 \to 3.37$	$2^- \to 2^+$	E1	99^{+1}_{-2} [f]		
	$6.26 \to$ g.s.	$2^- \to 0^+$	M2	1 ± 1 [f]		

[a] See also Tables 10.2 and 10.5 in (1966LA04).
[b] From (1966GR18): ^{9}Be(n, γ)^{10}Be.
[c] From (1966GR18, 1969RO12): see (1969AL17).
[d] See (1969AL17).
[e] (1966WA1C) and F.C. Young, private communication.
[f] (1969RO12).
[g] (1968FI09).
[h] (1966WA10).

The cross section for the (n, d) reaction has been measured for $E_{\rm n} = 16.3$ to 18.7 MeV (1969SC05).

10. ^{9}Be(n, t)^{7}Li $Q_{\rm m} = -10.4389$ $E_{\rm b} = 6.8120$

See (1966JE1B, 1966LA04) and (1972BI1E).

11. ^{9}Be(n, α)^{6}He $Q_{\rm m} = -0.602$ $E_{\rm b} = 6.8120$

The cross section for production of ^{6}He shows a smooth rise to a broad maximum of 104 ± 7 mb at 3.0 MeV, followed by a gradual decrease to 70 mb at 4.4 MeV. No indication of resonance is found at $E_{\rm n} = 2.7$ MeV (1957ST95). From $E_{\rm n} = 3.9$ to 8.6 MeV, the cross section decreases smoothly from 100 mb to 32 mb (1961BA53). At $E_{\rm n} = 14.4$ MeV, the total cross section for the α_0 transition is 11.7 ± 1.8 mb (1967PA03). See also (1966JE1B, 1966LA04) and (1970BA1L).

12. ^{9}Be(p, π^+)^{10}Be $Q_{\rm m} = -133.539$

At $E_{\rm p} = 185$ MeV the π^+ spectrum shows groups corresponding to ^{10}Be*(0, 3.37 ± 0.12, 6.07 ± 0.13, 7.39 ± 0.13, 9.31 ± 0.24, 11.75 ± 0.11). Angular distributions have been obtained for the π^+ corresponding to these six states (1973DA09). See also reaction 3 in ^{10}C and (1971DA10).

13. ^{9}Be(d, p)^{10}Be $Q_{\rm m} = 4.5873$
$Q_0 = 4.590 \pm 0.008$ (1967SP09).

Angular distributions of proton groups have been studied at many energies. Except at the lowest energies the stripping process appears to dominate: see (1966LA04) for the earlier references and (1968BE1E: 0.30 to 1.0 MeV; p_0), (1973SA1Q: 0.9 to 3.1 MeV; p_0, p_1), (1969RO12: 2.8 MeV; p_0, p_1 and p to ^{10}Be*(5.958, 5.960)), (1970PO03: 4.50 to 6.0 MeV; p_0, p_1), (1964SC12, 1967SC29: 11.8 MeV; p_0, p_1) and (1969AR1B: 15 MeV; p_0). The angular distributions show $l_{\rm n} = 1$ transfer for ^{10}Be*(0, 3.37, 5.958), $l_{\rm n} = 0$ transfer for ^{10}Be*(5.960, 6.26) and $l_{\rm n} = 2$ transfer for ^{10}Be*(7.37). ^{10}Be*(6.18, 7.54) are also populated. See (1954JU23, 1969RO12) and Table 10.4 in (1966LA04).

Attempts to understand the γ-decay of ^{10}Be*(5.96) and its population in ^{9}Be(n, γ)^{10}Be led to the discovery that it consisted of two states separated by 1.6 ± 0.5 keV. The lower of the two has $J^\pi = 2^+$ and decays primarily by a cascade transition via ^{10}Be*(3.37) [it is the state fed in the

^{9}Be(n, γ) decay]; the higher state has $J^{\pi} = 1^{-}$ and goes mainly by a crossover to ^{10}Be$_{\rm g.s.}$. Angular correlations measured with the γ-ray detector located normal to the reaction plane ($\equiv$ angular distributions) lead to $l_{\rm n}$ values consistent with the assignments of 2^{+} and 1^{-} for ^{10}Be*(5.9658, 5.9660) obtained from the character of the γ-decay (1969RO12). ^{10}Be*(6.18) decays primarily to ^{10}Be*(5.9660): $E_{\gamma} = 219.4 \pm 0.3$ keV (1969AL17). See Table 10.4 for a listing of the information on radiative transitions obtained in this reaction (1969AL17, 1969RO12), and lifetime measurements (1966WA10, 1968FI09, 1969AL17). For (p, γ) correlations through ^{10}Be*(3.37) see (1966LA04) and (1967FA03, 1969CA1F).

The probabilities $p_{3/2}$ for transfer of a neutron with angular momentum $\frac{3}{2}$ have been determined for the p_0 and p_1 groups using vector polarized deuterons with $E_{\rm d} = 10$ and 12 MeV, and compared with the shell model calculations of (1965CO25, 1967CO32) [(1970FI07); and see also (1967SC29)]. For polarization measurements see ^{11}B in (1975AJ02) and (1966LA04).

See also (1968LA1F), (1966WA1C, 1967LE1F, 1967WA1C, 1967YO1C, 1968SC1E, 1969CO1H) and (1971JO22, 1972DZ06, 1973DO02; theor.).

14. ^{9}Be(t, d)^{10}Be $\qquad Q_{\rm m} = 0.5544$

The d_0 group has been observed at $E_{\rm t} = 1.6$ to 3.5 MeV (1967BI1E). See also (1969NA04) and ^{12}B in (1975AJ02).

15. ^{9}Be(α, ^{3}He)^{10}Be $\qquad Q_{\rm m} = -13.7665$

Not reported.

16. ^{9}Be(^{14}N, ^{13}N)^{10}Be $\qquad Q_{\rm m} = -3.742$

See (1973TO05; theor.).

17. ^{9}Be(^{18}O, ^{17}O)^{10}Be $\qquad Q_{\rm m} = -0.679$

The angular distribution has been measured at $E(^{18}{\rm O}) = 16$ and 20 MeV (1971KN05).

18. (a) ^{10}Be(p, p)^{10}Be
(b) ^{10}Be(d, d)^{10}Be

Angular distributions of the p_0 and p_1 groups have been measured at $E_p = 12.0$ to 16.0 MeV. The elastically scattered deuterons have been studied at $E_d = 12.0$ and 15.0 MeV. B(E2) for the ^{10}Be*(3.4) $\xrightarrow{\gamma}$ ^{10}Be(0) transition is $23.8\ e^2 \cdot$ fm^4 (from a comparison of the angular distributions with DWBA predictions) (1970AU02).

19. ^{10}B(n, p)^{10}Be $\qquad Q_m = 0.2266$

See (1966GO1D, 1970NE03).

20. ^{10}B(t, ^{3}He)^{10}Be $\qquad Q_m = -0.5372$

Not reported.

21. ^{11}B(γ, p)^{10}Be $\qquad Q_m = -11.2294$

Transitions to ^{10}Be*(3.4) from the upper region of the giant resonance in ^{11}B are reported to be about twice as intense as those from the lower region (1971PA10): see ^{11}B in (1975AJ02). Angular distributions of the p_0 and p_1 groups have been measured with $E_{bs} = 18.5$ MeV (1970SO03). See also (1969MU10).

22. ^{11}B(n, d)^{10}Be $\qquad Q_m = -9.0047$

The angular distribution of the d_0 group has been measured at $E_n = 14.4$ MeV (1968MI10, 1971MI12).

23. ^{11}B(e, ep)^{10}Be $\qquad Q_m = -11.2294$

See (1969BA1F; theor.).

24. ^{11}B(p, 2p)^{10}Be $\qquad Q_m = -11.2294$

Structure is observed in the summed proton spectrum corresponding to $Q = -10.9 \pm 0.35$, -14.7 ± 0.4, -21.1 ± 0.4, -35 ± 1 MeV: see (1966LA04, 1966TY01). See also (1971RA26), (1966JA09, 1967KO1B, 1968JA1D; theor.) and ^{11}B in (1975AJ02).

25. ^{11}B(d, ^{3}He)^{10}Be $Q_{\rm m} = -5.7356$

Angular distributions have been obtained for the ^{3}He group to ^{10}Be(0) at $E_{\rm d} = 11.8$ MeV (1967FI07) and at 22 MeV (1971ST05: also ^{3}He to ^{10}Be*(3.4)).

26. ^{11}B(t, α)^{10}Be $Q_{\rm m} = 8.585$

Angular distributions of α_0 and α_1 have been measured for $E_{\rm t} = 1.0$ to 2.1 MeV (1969SI12).

27. ^{11}B(^{14}N, ^{15}O)^{10}Be $Q_{\rm m} = -3.937$

Angular distributions of the ground-state transitions have been measured at E(^{14}N) $= 41$, 77 and 113 MeV (1971LI11). See also (1973SC1J) and (1973DE1U; theor.).

28. ^{12}C(^{6}Li, ^{8}B)^{10}Be $Q_{\rm m} = -21.443$

At E(^{6}Li) $= 80$ MeV, ^{10}Be*(0, 3.37, 5.95 ± 0.05) are strongly populated. There is also some evidence for the excitation of ^{10}Be*(9.27 ± 0.1). Angular distributions have been measured to the first three of these states (1973CE1B).

29. ^{12}C(^{11}B, ^{13}N)^{10}Be $Q_{\rm m} = -9.286$

See (1969BR1D).

30. ^{13}C(n, α)^{10}Be $Q_{\rm m} = -3.836$

See ^{14}C in (1976AJ04).

31. (a) ^{13}C(^{11}B, ^{14}N)^{10}Be $Q_{\rm m} = -3.679$
(b) ^{15}N(^{11}B, ^{16}O)^{10}Be $Q_{\rm m} = 0.898$
(c) ^{16}O(^{11}B, ^{17}F)^{10}Be $Q_{\rm m} = -10.629$

See (1969BR1D).

^{10}B

(Figs. 20 and 22)

GENERAL: (See also (1966LA04).)

Shell model: (1961KO1A, 1965CO25, 1966HA18, 1966MA1P, 1966WI1E, 1967CO32, 1967EV1C, 1967HS1A, 1967PI1B, 1968GO01, 1969VA1C, 1970CO1H, 1971NO02, 1972LE1L, 1973HA49, 1973JO1K, 1973KU03, 1973SA30).

Cluster and α-particle model: (1965NE1B, 1967TA1C, 1969BA1J, 1969HU1F, 1969NA1M, 1970NA06, 1971NO02, 1972LE1L, 1973KU03).

Special levels: (1967CO32, 1967HS1A, 1968GO01, 1968HE1G, 1969CO1H, 1969HA1F, 1971NO02, 1972VA36, 1973SA30).

Electromagnetic transitions: (1962MO1A, 1965CO25, 1967HS1A, 1967KU1E, 1968BI1C, 1968HE1G, 1968KU1D, 1969HA1F, 1969VA1C, 1972BE1E, 1972EV03, 1972LO1D, 1972TA21, 1972NA05, 1973HA49, 1973SA30).

Astrophysical questions: (1968HA1C, 1970BA1M, 1972CL1A, 1972KO1E, 1973AU1H, 1973LA19, 1973RE1G, 1974AU1A).

Special reactions: (1968YI01, 1969DA1D, 1969GA18, 1969YI1A, 1971AR02, 1971BA16, 1972OB1B, 1972PN1A, 1973KU03, 1973LA19, 1973VO1G).

Muon capture: (1967BA78, 1967BU1D, 1968BA2G, 1969WU1A, 1970FA15, 1971DE2D, 1972BU29, 1973BU20, 1973MU11, 1974MU1J).

Pion capture and reactions: (1965CH12, 1968BA2G, 1968BO32, 1968NO1A, 1968RI1H, 1968WI1B, 1968TA1C, 1969BU1C, 1969CH1C, 1969CH19, 1969GO1C, 1969KA1L, 1969MO1E, 1970CH1F, 1970BA1E, 1971CA01, 1971CA1J, 1972FU1C [†], 1972HU1A, 1972KA1F, 1972SW1A, 1973KA1D, 1973NY04, 1973UL1D).

Kaon capture and reactions: (1972BA09, 1973CH1M).

Other topics: (1965CO25, 1966HA18, 1966WI1E, 1967CA17, 1967EV1C, 1967MI1A, 1968GO01, 1968JO1C, 1968RI1H, 1969HO1M, 1970CO1H, 1970FO1B, 1972AN05, 1972CA37, 1972LE1L, 1972PN1A, 1973CL09, 1973CO16, 1973JO1K, 1973JU2A, 1973KU03, 1973MA48, 1973RO1R).

Ground-state properties: (1965CO25, 1966MA1P, 1966WI1E, 1967BA78, 1967SH05, 1967SH14, 1969LE1B, 1969PE1D, 1969VA1C, 1969WU1A, 1970HI08, 1971TA1A, 1972LE1L, 1972VA36, 1973CO1P, 1973MA1K, 1973SA30, 1973SU1B).

$$J = 3 \text{ (1967BE1T)};$$

[†] (1972FU1C) observe the γ-de-excitation of ^{10}B*(0.7, 1.7, 2.2) formed in ratio 2:1:1 when π^- are stopped in a carbon target.

Table 10.5: Energy Levels of ^{10}B [a]

E_x (MeV ± keV)	$J^\pi; T$	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
g.s.	$3^+; 0$	stable		1, 4, 5, 6, 7, 12, 13, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 41, 42, 43, 44, 45, 47, 48, 49, 50, 51, 53, 54, 55, 56, 57, 58, 59
0.71832 ± 0.09	$1^+; 0$	$\tau_m = 1.013 \pm 0.015$ nsec	γ	1, 4, 5, 7, 12, 13, 18, 19, 20, 26, 27, 29, 31, 32, 39, 41, 42, 43, 47, 48, 49, 56
1.74016 ± 0.17	$0^+; 1$	< 30 fsec	γ	1, 4, 12, 13, 18, 19, 20, 26, 27, 29, 31, 39, 41, 42, 43, 47, 48, 52
2.1550 ± 1.0	$1^+; 0$	2.13 ± 0.18 psec	γ	1, 4, 12, 13, 18, 19, 26, 27, 29, 31, 32, 41, 42, 43, 47, 48, 49, 56
3.5897 ± 2.2	$2^+; 0$	147 ± 14 fsec	γ	1, 4, 5, 7, 13, 18, 19, 26, 27, 29, 31, 32, 40, 41, 42, 43, 47, 48, 49, 56
4.773 ± 3	$3^+; 0$	$\Gamma = 0.014$ keV	γ, α	1, 4, 7, 12, 18, 19, 26, 27, 29, 31, 32, 41, 42, 43, 47, 48
5.112 ± 4	$2^-; 0$	1.2	γ, α	1, 18, 19, 27, 29, 31, 32, 41, 42, 43, 48
5.166 ± 4	$2^+; 1$	0.003	γ, α	1, 18, 19, 27, 31, 40, 41, 42, 43
5.180 ± 10	$1^+; 0$	200 ± 30	γ, α	1, 3, 13, 29, 31, 32, 41, 42
5.924 ± 4	$2^+; 0$	6 ± 1	γ, α	1, 3, 18, 19, 27, 32, 41, 43, 47, 48, 56
6.025 ± 2	4^+	0.05 ± 0.03	γ, α	1, 3, 18, 19, 25, 27, 29, 31, 32, 41, 43, 47, 48, 52, 56
6.133 ± 2	3^-	2.36 ± 0.03	α	1, 3, 18, 19, 27, 29, 32, 41, 43, 47, 48, 56

Table 10.5: Energy Levels of ^{10}B [a] (continued)

E_x (MeV ± keV)	$J^\pi; T$	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
6.561 ± 2	(2^+)	25.1 ± 1.1	d, α	3, 17, 18, 19, 27, 29, 31, 32, 41, 43, 48
6.881 ± 5	$1^-; 0+1$	120 ± 10	γ, p, d, α	1, 13, 15, 17, 18
7.002 ± 6	$(1, 2)^+; (0)$	100 ± 10	p, d, α	3, 17, 18, 27, 29, 43, 48
7.431 ± 7	$(1)^-; 0+1$	100 ± 10	γ, p, d, α	1, 13, 17, 47
7.467 ± 10	1^+	65 ± 10	(γ), p	13, 15
7.477 ± 2	$2^-; 1$	74 ± 4	γ, p	13, 15, 18, 25, 27, 43
7.5595 ± 1.0	$0^+; 1$	2.65 ± 0.18	γ, p	13, 15, 18, 43
(7.67 ± 30)	$(1^+; 0)$	250 ± 20	p, d	15, 17
7.84 ± 30	1^-	260 ± 30	γ, p, α	3, 13, 15, 18, 43
8.07 ± 50	$(2^-; 0)$	800 ± 200	p, d, α	17, 18
(8.65)	$(1^+, 2^+)$	≈ 300	p	15
8.889 ± 6	$3^{(-)}; (1)$	84 ± 7	n, p	14, 15
8.894 ± 2	$2^+; 1$	36 ± 2	γ, p, α	13, 15, 17, 23
9.7	$T = 1$	≈ 600	n, p, α	14, 17
10.84 [b]		≈ 500	γ, n, p	13, 14, 15, 23
11.53 ± 40		270 ± 50		41, 43
12.57 ± 30	$(0^+, 1^+, 2^+)$	90 ± 30	γ, p	13, 15, 43
(13.3)	$(0^+, 1^+, 2^+)$	≈ 300	γ, p	13
14.1 ± 0.2		1100 ± 200	α	3, 41
(14.1)	$(0^+, 1^+, 2^+)$	≈ 250	γ, p	13
(14.6)	$(0^+, 1^+, 2^+)$	≈ 150	γ, p	13
(15.6)	$(2^+, 3^+, 4^+)$	≈ 400	γ, p	13
18.43	$2^-; 1$	340	γ, ^{3}He	7
18.8	$2^+; (1)$	< 600	γ, ^{3}He, α	7, 11
19.3	$2^-; 1$	190 ± 20	γ, n, p, ^{3}He, α	7, 8, 9, 11, 13
20.1 ± 100	$1^-; 1$	350 ± 70	γ, n, p, t, ^{3}He, α	7, 8, 9, 10, 11, 23
(21.1)			γ, ^{3}He	7
(23.0)	$T = 2$	≈ 500	p, ^{3}He	9
23.1 ± 100			γ, n	23

[a] See also Tables 10.6 and 10.9.

[b] For J^π for these and many higher states see Table 10.11.

Table 10.6: Electromagnetic transitions in ^{10}B [a]

Initial state	$J^\pi; T$	Γ_γ (total) (eV)	Branching ratios (%) to final states at: g.s. $3^+;0$	0.72 $1^+;0$	1.74 $0^+;1$	2.16 $1^+;0$	3.59 $2^+;0$	4.77 $3^+;0$	Γ_γ/Γ	Refs.
0.72	$1^+;0$	6.5×10^{-7}	100							Table 10.9
1.74	$0^+;1$	> 0.02	< 0.2	100						Table 10.9, (1966SE03, 1969YO01)
2.16	$1^+;0$	3.1×10^{-4}	21.1 ± 1.6	27.3 ± 0.9	51.6 ± 1.6					Table 10.9, (1969YO01)
3.59	$2^+;0$	4.4×10^{-3}	19 ± 3	67 ± 3	< 0.3	14 ± 2				Table 10.9, (1966SE03, 1968WA15, 1969GA06, 1969YO01)
4.77	$3^+;0$	0.033 ± 0.006	0.5 ± 0.1	> 99					$(2.3 \pm 0.3) \times 10^{-3}$ [b]	Table 10.7, (1966AL06)
5.11	$2^-;0$	0.1	64 ± 7	31 ± 7	5 ± 5					Table 10.7, (1966FO05)
5.17	$2^+;1$	2.9 ± 1.1	5 ± 1	24 ± 3	< 0.5	69 ± 5	7 ± 3		0.88 ± 0.04 [c]	Table 10.7, (1966AL06, 1966FO05, 1967PA01)
5.18	$1^+;0$	0.06 ± 0.03			≈ 100					Table 10.7
5.92	$2^+;0$	≤ 54	82 ± 5	18 ± 5					≤ 0.009	Table 10.7, (1966FO05, 1969YO01)
6.03	4^+	≤ 0.5	≈ 100	[d]					≤ 0.009	Table 10.7, (1969YO01)
6.13 [e]	3^-	≤ 21							≤ 0.009	(1969YO01)

[a] See also Table 10.7 in (1966LA04).
[b] $\Gamma_\alpha = 14 \pm 3$ eV.
[c] $\Gamma_\alpha = 0.44 \pm 0.09$ eV.
[d] Other branches $< 3\%$.
[e] For γ-decay of higher ^{10}B states [see Table 10.5], refer to Tables 10.10, 10.11 and 10.12.

$\mu = +1.8007$ nm (1969FU11, 1971SH26);
$Q = +0.08$ b (1969FU11); [$+0.0847 \pm 0.0006$ b (1970NE05); theor.]; see also (1968SC18).

1. ^{6}Li(α, γ)^{10}B $\qquad Q_m = 4.460$

Six resonances are observed in the range $E_\alpha = 0.5$ to 3.8 MeV, corresponding to ^{10}B*(4.77, 5.11, 5.17, 5.18, 5.92, 6.03): see Table 10.7 (1957ME27, 1961SP02, 1966AL06, 1966FO05, 1966SE02, 1971AU1H). Some weak effects corresponding to ^{10}B*(6.13) may also be present (1966FO05). Angular distribution and branching ratio measurements are consistent with 3^+ for ^{10}B*(4.77) and 2^-, 2^+, 1^+, 2^+ and 4^+ for the five higher states: see (1966LA04) and (1966AL06, 1966FO05, 1966SE02). The results are in good agreement with the I.P.M. calculations of (1965CO25). See also (1967WA1C).

2. (a) ^{6}Li(α, n)^{9}B $\qquad Q_m = -3.975 \qquad E_b = 4.460$
(b) ^{6}Li(α, p)^{9}Be $\qquad Q_m = -2.1251$
(c) ^{6}Li(α, d)^{8}Be $\qquad Q_m = -1.5656$

The excitation functions for neutrons (1963ME08: from threshold to $E_\alpha = 15.5$ MeV) and for d_0 particles (1963BL20: $E_\alpha = 9.5$ to 11.4 MeV) do not show resonance structure. See also ^{8}Be, ^{9}Be and ^{9}B.

3. ^{6}Li(α, α)^{6}Li $\qquad E_b = 4.460$

Reported anomalies in the elastic scattering are listed in Table 10.8 (1962DE10, 1967ME08, 1971BA41). See also (1965SI1B). The 1^+ assignment for ^{10}B*(5.18) supports the proposal by (1961TR1B) that it is a member of the doublet formed by two-nucleon excitation into the 2s shell, whose other member is the $J^\pi = 0^+$; $T = 1$ state at 7.56 MeV.

Excitation functions of α_0 have been reported since (1966LA04) at $E_\alpha = 2.0$ to 3.7 MeV (1967ME08), 2.5 to 4.5 MeV (1972BO07), 3.3 to 5.0 MeV (1971BA41) and 13.3 to 18.0 MeV (1970BI1B, 1971BI12). In the high-energy work, the yield curves are generally monotonically decreasing functions of energy except in the region $E_\alpha = 15.7$ to 17 MeV, where a broad resonance structure is observed which may correspond to weak excitation of ^{10}B*(14.0) (1970BI1B, 1971BI12). Excitation functions for α_0 and α_1 [to ^{6}Li*(2.19)] at $E_\alpha = 9.5$ to 12.5 MeV do not show resonance structure (1963BL20). See also (1969TR1B, 1972RI10; theor.).

4. ^{6}Li(^{6}Li, d)^{10}B $\qquad Q_m = 2.987$

Table 10.7: Levels of ^{10}B from ^{6}Li(α, γ)^{10}B [a]

E_{res} (keV)	E_x (MeV)	$J^\pi; T$	Γ_{lab} (keV)	Decay to E_f	Branch (%)	$\omega\gamma$ (eV)	Γ_γ (eV)	$\lvert M \rvert^2$ [g]
500 ± 25	4.760	$3^+; 0$		0	0.5 ± 0.1			
				0.72	> 99		0.033 ± 0.006 [c]	
1085	5.112	$2^-; 0$	2 [b]	0	64 ± 7	0.059 ± 0.012 [d]		1.5 [e]
								9×10^{-4} [k]
				0.72	31 ± 7	0.028 ± 0.008		1.5 [e]
								6×10^{-4} [k]
				1.74	5 ± 5	0.005 ± 0.005		100 ± 100 [e]
1175 [i]	5.166	$2^+; 1$	< 0.5 [b]	0	5 ± 1	0.035 ± 0.007	0.15 [g]	0.8 [f]
								0.06 [h]
				0.72	24 ± 3	0.17 ± 0.04	0.56 [g]	4 [f]
								0.4 [h]
				1.74	2 ± 1	0.017 ± 0.008		160 ± 80 [f]
				2.15	69 ± 5	0.47 ± 0.09	1.20 [g]	80 [f]
								3.8 [h]
				3.58	9 ± 2 [g]		0.19 [g]	
1210 ± 35	5.187	$1^+; 0$	340 ± 50	1.74	≈ 100		0.06 ± 0.03	
2435	5.922	2^+	10 ± 1	0	82 ± 5	0.31 ± 0.06		$0.27 \to 25$ [f,j]
				0.72	18 ± 5	0.07 ± 0.02		$0.1 \to 9$ [f,j]
				1.74		< 0.02		
2605	6.024	4^+	< 1.5 [b]	0	≈ 100	0.57 ± 0.08		20 [f]
								4×10^{-3} [h]
				0.72		< 0.02		
4032 ± 5	6.881 [l,m]	$T = 0 + 1$		0	6 ± 2			
				0.72	19 ± 3			

Table 10.7: Levels of ^{10}B from ^{6}Li(α, γ)^{10}B [a] (continued)

$E_{\rm res}$ (keV)	$E_{\rm x}$ (MeV)	$J^{\pi}; T$	$\Gamma_{\rm lab}$ (keV)	Decay to $E_{\rm f}$	Branch (%)	$\omega\gamma$ (eV)	Γ_{γ} (eV)	$\lvert M\rvert^{2}$ [g]
				1.74	52 ± 3			
				2.15	13 ± 4			
4950 ± 10	7.432 [l]			[n]				

[a] (1957ME27, 1961SP02, 1966AL06, 1966FO05, 1966SE02, 1971AU1H). See also (1966LA04).

[b] See (1958ME81) and ^{9}Be(d, n)^{10}B.

[c] $\Gamma_{\gamma}/\Gamma = (2.3 \pm 0.3) \times 10^{-3}$, $\Gamma_{\alpha} = 14 \pm 3$ eV (1966AL06).

[d] Absolute errors only.

[e] M2.

[f] E2.

[g] (1966FO05).

[h] M1.

[i] $\Gamma_{\gamma} = 2.9 \pm 1.1$ eV, $\Gamma_{\alpha} = 0.44 \pm 0.09$ eV, $\omega\gamma = 0.63 \pm 0.13$ eV; α branch is 13 ± 4% (1966AL06).

[j] E2/M1 $= 0.01$ or 10 (1957ME27).

[k] E1.

[l] (1971AU1H) and V. Meyer, private communication.

[m] $\Gamma_{\rm c.m.} = 110 \pm 10$ keV.

[n] $\Gamma_{\rm c.m.} = 90 \pm 10$ keV. At $0°$ the branches to ^{10}B*(0, 0.72) are equally strong. $J^{\pi} = 2^{-}; T = 0 + 1$ is suggested (V. Meyer, private communication).

Table 10.8: ^{10}B levels from ^{6}Li(α, α)^{6}Li

E_α (keV)	E_x (MeV)	Γ_{lab} (keV)	$J^\pi; T$	Refs.
1210 ± 30	5.19	175	1^+; 0	(1962DE10)
2440	5.93	≈ 30	2^+; 0	(1962DE10)
2606.0 ± 1.5	6.025	0.09 ± 0.04	4^+	(1967ME08)
2785.5 ± 1.5	6.133	3.93 ± 0.05	3^-	(1967ME08)
3498.5 ± 1.6 [a]	6.561	41.8 ± 1.9	4^-, 2^- [d]	(1967ME08) [b]
4250 ± 15 [a]	7.012	183 ± 25	$(2)^+$; (0) [d]	(1971BA41)
(5500)	(7.76)			(1965SI1B) [c]
16000	14.0	broad		(1970BI1B, 1971BI12)

[a] There is evidence of broad structure near these states (1971BA41).

[b] See also (1971BA41).

[c] This result was published in an abstract.

[d] See, however, (1973SI27) in reaction 17.

Angular distributions of deuteron groups have been determined at $E(^{6}\text{Li}) = 2.4$ to 9.0 MeV (d_0, d_1, d_3) and 7.35 and 9.0 MeV (d_4, d_5) (1966KI09). The d_2 group is also observed but its intensity is weak: see (1960MO17, 1961MO02, 1966KI09). For τ_m measurements see Table 10.9 (1969TH01). See also (1971PO1D), (1966BR1G), (1966RO1E; theor.) and ^{12}C in (1975AJ02).

5. ^{6}Li(^{7}Li, t)^{10}B $\quad Q_m = 1.993$

Angular distributions of the t_0 and t_1 groups have been measured at $E(^{6}\text{Li}) = 3.3$ MeV (1967GA06) and $E(^{7}\text{Li}) = 3.78$ to 5.95 MeV (1967KI03). For τ_m measurements see Table 10.9 (1969TH01). See also (1968DA20), (1972GA1E), (1966LA04) and ^{13}C in (1976AJ04).

6. ^{6}Li(^{9}Be, ^{5}He)^{10}B $\quad Q_m = 1.99$

See (1962MC12, 1963NO02).

7. ^{7}Li(^{3}He, γ)^{10}B $\quad Q_m = 17.788$

Table 10.9: Lifetimes of ^{10}B states [a]

^{10}B state	τ_m	Reactions	Refs.
0.72	1.013 ± 0.015 nsec	mean of values quoted in Table 10.20	(1966LA04)
1.74	< 40 fsec	^{11}B(^{3}He, α)	(1968DO01)
	< 30 fsec	^{9}Be(^{3}He, d)	(1966FI01, 1968FI09)
	< 22 fsec	^{11}B(^{3}He, α)	(1969JA1N)
	< 30 fsec	"best" value	
2.16 [b]	$2.1^{+0.8}_{-0.5}$ psec	^{11}B(^{3}He, α)	(1968DO01)
	$2.7^{+0.5}_{-0.4}$ psec	^{9}Be(d, n), ^{9}Be(^{3}He, d), ^{10}B(p, p$'$)	(1968FI09)
	2.0 ± 0.6 psec	^{9}Be(d, n)	(1969AL17)
	2.0 ± 0.25 psec	^{11}B(^{3}He, α)	(1969JA1N)
	2.15 ± 0.45 psec	^{7}Li(α, n)	(1970GA01)
	2.13 ± 0.18 psec	mean of above values	
3.59	152 ± 21 fsec	^{11}B(^{3}He, α)	(1969JA1N)
	100 ± 30 fsec	^{6}Li(^{6}Li, d), ^{6}Li(^{7}Li, t)	(1969TH01)
	115 ± 40 fsec [d]	^{9}Be(d, n)	(1966WA10)
	150 ± 15 fsec	^{9}Be(d, n), ^{10}B(p, p$'$)	(1968FI09)
	170 ± 70 fsec	^{11}B(^{3}He, α)	(1968DO01)
	147 ± 14 fsec	mean of last three values	
5.17 [c]	< 80 fsec	^{9}Be(d, n)	(1966WA10)

[a] See also (1966LA04).

[b] See also (1966FI01, 1969TH01).

[c] See also (1967PA01).

[d] Based on τ_m of ^{10}Be*(3.37) $= 180$ fsec.

Capture γ-rays have been observed for $E(^3He) = 0.8$ to 3.0 MeV (1965PA02, 1971LI20) and 3.0 to 6.0 MeV (1968LI03). The γ_0 and γ_5 yields [to ^{10}B*(0, 4.77)] show resonances at $E(^3He) = 1.1$ and 2.2 MeV [$E_{res} = 0.92$ and 2.1 MeV: see (1971LI20)], the γ_1 and γ_4 yields [to ^{10}B*(0.72, 3.59)] at 1.4 MeV and the γ_4 yield at 3.4 MeV: see Table 10.10 (1965PA02, 1968LI03, 1971LI20). Both the 1.1 and 2.2 MeV resonances [^{10}B*(18.4, 19.3)] appear to result from s-wave capture; the subsequent decay is to two 3^+ states [^{10}B*(0, 4.77)]. Therefore the most likely assignment is $J^\pi = 2^-$; $T = 1$ for both [there appears to be no decay of these states via α_2 to ^{6}Li*(3.56) which has $J^\pi = 0^+$; $T = 1$: see reaction 11] (1965PA02, 1971LI20). The assignment for ^{10}B*(18.8) [1.4 MeV resonance] is 1^+ or 2^+ but there appears to be α_2 decay and therefore $J^\pi = 2^+$. ^{10}B*(20.2) [3.4 MeV resonance] has an isotropic angular distribution of γ_4 and therefore $J^\pi = 0^+, 1^-, 2^-$. The γ_2 group resonates at this energy which eliminates 2^-, and 0^+ is eliminated on the basis of the strength of the transition which is too large for E2 (1971LI20).

8. ^{7}Li(^{3}He, n)^{9}B $\quad Q_m = 9.353 \quad E_b = 17.788$

The excitation curve is smooth up to $E(^3He) = 1.8$ MeV (1962SE1A, 1963DU12, 1966DI04) and the n_0 yield shows resonance behavior at $E(^3He) = 2.2$ and 3.25 MeV, $\Gamma_{lab} = 270 \pm 30$ and 500 ± 100 keV. No other resonances are observed up to $E(^3He) = 5.5$ MeV (1966DI04). See also Table 10.10.

9. ^{7}Li(^{3}He, p)^{9}Be $\quad Q_m = 11.2027 \quad E_b = 17.788$

The yield of p_0 and p_2 has been measured for $E(^3He) = 0.60$ to 1.25 MeV (1971ST35): it is suggested that ^{10}B*(18.4) is formed. The yield of protons is relatively flat for $E(^3He) = 1.8$ to 4.8 MeV with some indication of weak maxima at ≈ 2.3 and 3.3 MeV (1961WO05, 1972LI31). See also (1969SA04, 1970DI1F). The yield of γ-rays from the decay of the $T = \frac{3}{2}$ state of ^{9}Be at 14.39 MeV to ^{9}Be*(0, 2.4) has been studied at $E(^3He) = 5.0$ to 10.0 MeV: some suggestion is reported of a $T = 2$ state at $E_x \approx 23$ MeV, $\Gamma \approx 0.5$ MeV (1968HA1K: unpublished results; W.D. Harrison, private communication).

10. (a) ^{7}Li(^{3}He, d)^{8}Be $\quad Q_m = 11.762 \quad E_b = 17.788$
(b) ^{7}Li(^{3}He, t)^{7}Be $\quad Q_m = -0.8804$

Yields of tritons have been measured for $E(^3He) = 0.65$ to 1.25 MeV (1971ST35; d_0), 2.0 to 4.2 MeV (1969OR01; t_0), 8.0 to 10.0 MeV (1968MA1W; t_0, t_1) and 10 to 16 MeV (1969NU1A; t_0, t_1). A broad peak is reported at $E(^3He) \approx 3.5$ MeV (1969OR01). For reaction (a) see ^{8}Be.

11. ^{7}Li(^{3}He, α)^{6}Li $\quad Q_m = 13.3279 \quad E_b = 17.788$

Table 10.10: Resonances in ^{7}Li + ^{3}He

$E_{\rm res}$ (MeV)	$\Gamma_{\rm c.m.}$ (keV)	$E_{\rm x}$ (MeV)	$J^{\pi}; T$	Γ_{γ} (eV) for transition to g.s.	0.72	3.59	4.77	Γ_{α} (keV)	$\Gamma_{\rm n}$	$\Gamma_{\rm p}$	$\Gamma_{\rm t}$	Refs.
0.92	340	18.43	$2^-; 1$	≥ 3			≥ 17					(1965PA02, 1971LI20)
1.4	< 600	18.8	$2^+, 1^+$		≥ 20	≥ 20 [b]		res. < 80				(1965PA02, 1965PA03, 1971LI20)
2.1	280 [a]	19.3	$2^-; 1$	≥ 12			≥ 49	res. < 20	res. n_0	(p)		(1963DU12, 1965PA03, 1966DI04, 1968LI03, 1971LI20, 1972LI31)
3.4	910 [a]	20.2	$1^-; 1$			≥ 350		res. α_2	res. n_0	(p)	res. t_0	(1961WO05, 1966DI04, 1968LI03, 1971LI20)
(4.7)		(21.1)			res.							(1968LI03)

[a] (1966DI04) report $\Gamma_{\rm c.m.} = 190 \pm 20$ and 350 ± 70 keV, respectively, from the n_0 yield.
[b] Assumes isotropy of angular distribution (1971LI20).

Excitation functions have been measured at $E(^3\mathrm{He}) = 1.3$ to 5.4 MeV (1965FO07; α_0, α_1, α_2), 2.0 to 4.2 MeV (1969OR01; α_0), 2.5 to 4.2 MeV (1969OR01; α_2), 5.0 to 8.0 MeV (1970OR03; α_0, α_1, α_2) and 16.0 to 18.0 MeV (1971ZA07; α_0). The α_0 group (at $8°$) shows a broad maximum at ≈ 2 MeV, a minimum at 3 MeV, followed by a steep rise which flattens off between $E(^3\mathrm{He}) = 4.5$ and 5.5 MeV. Integrated α_0 and α_1 yields rise monotonically to 4 MeV and then tend to decrease (1965FO07). Angular distributions give evidence of the resonances at $E(^3\mathrm{He}) = 1.4$ and 2.1 MeV seen in ^{7}Li(^{3}He, γ)^{10}B: $J^\pi = 2^+$ or 1^-; $T = (1)$ for both [see, however, reaction 7]: Γ_α is small (1965PA03). The α_2 yield [to ^{6}Li*(3.56), $J^\pi = 0^+$; $T = 1$] shows some structure at $E(^3\mathrm{He}) = 1.4$ MeV and a broad maximum at ≈ 3.3 MeV (1965FO07, 1969OR01): see Table 10.10.

12. ^{7}Li(α, n)^{10}B $\qquad Q_\mathrm{m} = -2.790$

Angular distributions have been measured for the n_0 group at $E_\alpha = 4.78$ to 7.85 MeV (1972VA02) and 13.5 and 13.9 MeV (1962KJ05), and for the n_1 group [to ^{10}B*(0.7)] at $E_\alpha = 6.71$ to 7.85 MeV (1972VA02). The n_2 group has also been seen in this reaction (1972VA02). Slow-neutron threshold measurements have been reported corresponding to the formation of ^{10}B*(0, 0.72, (4.77), (6.42)): see (1957BI84, 1963ME08) and (1966LA04). The lifetime of ^{10}B*(2.16), $\tau_\mathrm{m} = 2.16 \pm 0.43$ psec: the “best” value for τ_m based on this and on other measurements [see Table 10.9] is 2.4 ± 0.3 psec corresponding to $\Gamma_\gamma = 275 \pm 35$ μeV. The γ-decay of ^{10}B*(2.15) involves $E_\gamma = 415.1 \pm 0.5$ keV $(2.15 \to 1.74)$, 1435.6 ± 1.0 keV $(2.15 \to 0.72)$ and 719.1 ± 0.6 keV $(0.72 \to 0)$. The excitation energies for the first three excited states are then 719.1 ± 0.6, 1739.7 ± 1.5 and 2154.8 ± 1.2 keV (1970GA01). See also (1972DA32).

13. ^{9}Be(p, γ)^{10}B $\qquad Q_\mathrm{m} = 6.5853$

Parameters of observed resonances are listed in Tables 10.11 and 10.12. Table 10.6 summarizes the γ-transitions from this and other reactions.

The $E_\mathrm{p} = 0.33$ MeV resonance (^{10}B* $= 6.88$ MeV) is ascribed to s-wave protons because of its comparatively large proton width [see ^{9}Be(p, p)] and because of the isotropy of the γ-radiation. The strong transition to ^{10}B*(1.74) requires E1 and hence $J^\pi = 1^-$; $T = 0$. $T = 0$ is also indicated by the large deuteron width. On the other hand, the strength of E1 transitions to ^{10}B*(0.7, 2.1) indicates $T = 1$. The amplitudes for the $T = 0$ and $T = 1$ parts of the wave function for ^{10}B*(6.88) are 0.92 and 0.39, respectively (1972RE07). See also (1969CO1G, 1969RO12, 1971AU1H).

The proton capture data near $E_\mathrm{p} = 1$ MeV appears to require at least five resonant states, at $E_\mathrm{p} = 938$, (980), 992, 1083 and 1290 keV. The narrow $E_\mathrm{p} = 1083$ keV level (^{10}B* $= 7.56$ MeV) is formed by p-wave protons, $J^\pi = 0^+$ [see ^{9}Be(p, p), ^{9}Be(p, α)]. The isotropy of the gamma rays supports this assignment (1961TA02). The strong M1 transitions to $J^\pi = 1^+$; $T = 0$ levels at 0.7, 2.16 and 5.18 MeV (Table 10.12) indicate $T = 1$ (1959WA16). See also (1970BO1Y).

The excitation function for ground-state radiation shows resonance at $E_\mathrm{p} = 992$ ($\Gamma = 80$ keV) and 1290 keV ($\Gamma = 230$ keV) (1962EL06, 1964HO02). Elastic scattering studies indicate

Table 10.11: Resonances in ^{9}Be(p, γ)^{10}B [a]

E_p (MeV $\pm$ keV)	E_x (MeV)	$\Gamma_{c.m.}$ (keV)	$J^\pi; T$	Γ_p/Γ	Γ_γ (eV)	Refs.
0.330	6.88	130 ± 5 [f]	$1^-; 0+1$ [b]	0.30	4.8	(1956CL69, 1969CO1G)
0.938 ± 10	7.429	140 ± 30	$(1)^-; 0+1$ [b]	0.7	2.4	(1962EL06, 1964HO02, 1969CO1G)
(0.98)	(7.47)		(2^+)			(1962EL06)
0.992 ± 2	7.477	72 ± 4	$2^-; 1$	≈ 0.65	25.8	(1964HO02)
1.0832 ± 0.4	7.5595	2.65 ± 0.18	$0^+; 1$	1.0	8.5	(1964BO13, 1964HO02, 1972HA63)
1.29	7.75	210 ± 60	$2^-; (1)$ [c]	≈ 0.65	8.5	(1964HO02)
2.567 ± 2	8.894	36 ± 2	$2^+; 1$			(1953MA1A, 1956MA55)
4.72	10.83	≈ 500	$2^+, 3^+, 4^+$			(1952HA10, 1970FI1B) [d,e]
6.7	12.6	< 200	$0^+, 1^+, 2^+$			(1970FI1B) [e]
(7.0)	(12.9)	(≈ 100)	$(\pi = +)$			(1970FI1B) [e]
7.5	13.3	≈ 300	$0^+, 1^+, 2^+$			(1970FI1B) [e]
8.4	14.1	≈ 250	$0^+, 1^+, 2^+$			(1970FI1B) [e]
8.9	14.6	≈ 150	$2^+, 3^+, 4^+$			(1970FI1B) [e]
10.0	15.6	≈ 400	$2^+, 3^+, 4^+$			(1970FI1B) [e]
14.6	19.7	≈ 500	$2^-, 3^-, 4^-$			(1970FI1B) [e]

[a] See Table 10.12 for decay schemes.
[b] See also (1969RO12).
[c] See, however, (1973RO24) in reaction 15.
[d] See also (1969FI1C).
[e] G.A. Fisher, private communication.
[f] V. Meyer, private communication.

s-wave formation and $J^\pi = 2^-$ for both (1956MO90). For the lower level ($E_x = 7.48$ MeV) the intensity of the g.s. capture radiation, $\Gamma_\gamma = 25$ eV (1964HO02) indicates E1 and $T = 1$. The angular distribution of γ-rays, $1 + 0.1 \sin^2\theta$, is consistent with s-wave formation with some d-wave admixture (1953PA22) or with some contribution from a nearby p-wave resonance (1956MO90); possibly a $J^\pi = 2^+$ level at $E_p = 980$ keV (1956MO90, 1962EL06: see, however, (1964HO02)).

The angular distribution of ground-state radiation at $E_p = 1330$ keV is isotropic and $\Gamma_\gamma = 8.5$ eV (1964HO02), supporting E1, $T = 1$ for this level ($E_x = 7.75$ MeV). See, however, (1973RO24): reaction 15.

Transitions to ^{10}B*(0.7) [γ_1] show resonance at $E_p = 992$, 1290 and 938 keV, $\Gamma = 155$ keV (1962EL06, 1964HO02). The latter is presumably also a resonance for (p, d) and (p, α). An assignment of $J^\pi = 2^-$; $T = 0$ is consistent with the data, although the E1 radiation then seems somewhat too strong for a $\Delta T = 0$ transition (1964HO02). See also (1973RO24) in reaction 15.

A resonance for capture radiation at $E_p = 2.567 \pm 0.003$ ($E_x = 8.894$ MeV) has a width of 40 ± 2 keV and decays mainly via ^{10}B*(0.7) (1953MA1A). It appears from the width that this resonance corresponds to that observed in ^{9}Be(p, α), $J^\pi = 2^+$; $T = 1$ and not to the ^{9}Be(p, n)

Table 10.12: Radiative transitions in ^{9}Be(p, γ)^{10}B

Initial state (MeV)	Γ_γ(tot) (eV)	Relative intensities to final states									Refs.
		ground $3^+;0$	0.72 $1^+;0$	1.74 $0^+;1$	2.16 $1^+;0$	3.59 $2^+;0$	5.11 $2^-;0$	5.17 $2^+;1$	5.18 $1^+;0$	5.92 $2^+;0$	
6.88			0.35 ± 0.04	0.48 ± 0.04	0.11 ± 0.04						(1972RE07)
$E_p = 0.33$		0.05	0.20 ± 0.02	0.53 ± 0.02	0.13 ± 0.01	< 0.01	0.04 ± 0.01	0.02 ± 0.01	< 0.01	0.035 ± 0.005	A
	4.8		1.0	2.6	0.5				0.65		(1956CL69)
		< 0.7	6.4	15	4.5	≈ 1			< 2.9		(1959ME1A)
$1^-;0$			0.039 ± 0.005	0.103 ± 0.008	0.032 ± 0.010					W.u.	(1972RE07)
7.43											
$E_p = 0.94$	[2.4]	< 2	1.3	$[< 0.14]$	0.62	0.5			$[< 1]$		(1964HO02)
$(1)^-;0$			0.013		0.013	0.03				$\|M\|^2$E1	(1964HO02)
7.48		400	< 10	19	22	< 7			< 13		(1959ME1A)
$E_p = 0.99$	[25.8]	25	0.3	$[< 0.14]$	0.49	0			$[< 1]$		(1964HO02)
$2^-;1$		0.19	0.003		0.10					$\|M\|^2$E1	(1964HO02)
7.56											
$E_p = 1.08$		< 3	100	< 8	< 8	< 4			23		(1959ME1A)
	6.6		100	< 2	10				40		(1962ME1A)
	[8.5]	< 0.2	6.7	< 0.3	0.8	< 0.2			1.0		(1964HO02)
$0^+;1$			1.0		0.24				3.5	$\|M\|^2$M1	(1964HO02)
7.75 [a]	14.6	83%									(1963FU11)
$E_p = 1.29$	[8.5]	6.6	0.9	< 0.08	0.3	0.3			0.4		(1964HO02)
$2^-;1$		0.044	0.008		0.006	0.013			0.08	$\|M\|^2$E1	(1964HO02)

A: V. Meyer, private communication.

[a] See, however, Table 10.14.

resonance at the same energy (1956MA55). A further resonance is reported at $E_\mathrm{p} = 4.72 \pm 0.01$ MeV, $\Gamma \approx 0.5$ MeV (1952HA10).

In the range $E_\mathrm{p} = 4$ to 18 MeV, the γ_0 yield at 90° shows the resonance at $E_\mathrm{p} = 4.7$ MeV ($E_\mathrm{x} = 10.7$ MeV) and shows fluctuations suggesting states at $E_\mathrm{x} \approx 14.6$, 15.6 and 19.7 MeV. It is suggested that ^{10}B*(19.7) decays via E1 and therefore $J^\pi = 2^-, 3^-, 4^-$. The other three states presumably decay by M1 and therefore $J^\pi = 2^+, 3^+, 4^+$. These fluctuations appear on a nearly constant γ_0 yield with a 90° differential cross section ≈ 1.5 μb/sr. The average yield of γ_1 is $\approx \frac{2}{3}$ of the γ_0 yield. The broad giant resonance peak is centered at $E_\mathrm{x} \approx 14.5$ MeV. Fluctuations in the γ_1 yield are reported at $E_\mathrm{x} \approx 12.6$, 13.3 and 14.1 MeV. These states presumably decay by M1 to ^{10}B*(0.7) [$J^\pi_\mathrm{f} = 1^+$] and therefore $J^\pi_\mathrm{i} = 0^+, 1^+, 2^+$. The weak γ_2 yield (to ^{10}B*(1.74) [$J^\pi = 0^+$; $T = 1$]) seems to exhibit a broad peak centered near $E_\mathrm{x} = 15$ MeV (maximum 90° differential cross section ≈ 0.5 μb/sr) and possibly some structure near $E_\mathrm{x} = 20$ MeV. The γ_3 yield (to ^{10}B*(2.16) [$J^\pi = 1^+$]) increases to ≈ 0.4 μb/sr at $E_\mathrm{x} \approx 16$ MeV and seems to remain constant beyond that energy, with some suggestion of a fluctuation corresponding to $E_\mathrm{x} \approx 12.9$ MeV. ^{10}B*(12.9) appears to have positive parity. Angular distributions of γ_0, γ_1, γ_2 and γ_3 are also reported (1970FI1B; G.A. Fisher, private communication). See also (1969FI1C).

The magnetic moment of ^{10}B*(0.72) has been studied via γ-γ correlations from ^{10}B*(7.56): g $= +0.63 \pm 0.12$ (1972AV01). For measurements of the mean life of ^{10}B*(0.72), see Table 10.20. See also (1965ZO1A, 1966ED1A) and (1966LA04, 1973SU1E).

14. ^{9}Be(p, n)^{9}B $\qquad Q_\mathrm{m} = -1.8498 \qquad E_\mathrm{b} = 6.5853$

Resonances in neutron yield occur at $E_\mathrm{p} = 2.56$ and 4.7 MeV: see Table 10.13. There is some indication of a broad maximum near $E_\mathrm{p} = 3.5$ MeV; a peak reported at $E_\mathrm{p} = 4.9$ MeV for n_1 neutrons may reflect the effect of this level (1959MA20). A sharp break at $E_\mathrm{p} = 6.55 \pm 0.03$ MeV is ascribed to a level in ^{9}B at 4.04 MeV (1964BA16). See also (1972VO17).

The $E_\mathrm{p} = 2.56$ MeV resonance is considerably broader than that observed at the same energy in ^{9}Be(p, α) and ^{9}Be(p, γ) and the two resonances are believed to be distinct (1956MA55). The shape of the resonance and the magnitude of the cross section can be accounted for with $J^\pi = 3^-$ or 3^+: the former assignment is in better accord with ^{10}Be*(7.37). For $J^\pi = 3^-$, $\theta^2_\mathrm{n} = 0.135$, $\theta^2_\mathrm{p} = 0.115$ ($R = 4.47$ fm). The $J^\pi = 2^+$ level should contribute about 10% to the cross section at $E_\mathrm{p} = 2.56$ MeV (1962AL1A).

There are no resonances at threshold as had been reported by (1970SI1F, 1971SI1K): see (1970CO06). See also reaction 15.

For angular distributions see ^{9}B. For polarization measurements see (1966LA04) and (1972SH1K). See also (1969VE02, 1970DA26, 1971JU05, 1973NE1G). For astrophysical considerations see (1969BA1N).

15. (a) ^{9}Be(p, p)^{9}Be $\qquad E_\mathrm{b} = 6.5853$

(b) ^{9}Be(p, pn)^{8}Be $\qquad Q_\mathrm{m} = -1.6651$

Table 10.13: Resonances in ^{9}Be(p, n)^{9}B

$E_{\rm res}$ (MeV $\pm$ keV)	$\Gamma_{\rm lab}$ (keV)	$E_{\rm x}$ (MeV)	$J^{\pi}; T$	$\sigma_{\rm max}$ (mb)	Refs.
2.562 ± 6	85 ± 10	8.889	$3^{(-)}$; (1)		(1956MA55, 1962AL1A)
	100 ± 10			160	(1959GI47)
3.5	≈ 700	9.7			(1956MA55, 1959MA20)
				240	(1959GI47)
4.72 ± 10	500	10.84			(1952HA10)
4.68 ± 30				470	(1955MA84, 1959GI47)
4.62 ± 30					(1959MA20)
4.94 ± 30	≈ 100			510	(1955MA84, 1959GI47)
4.82 ± 60				[a]	(1959MA20)

[a] Resonance for n_1 only; possibly due to 3.5 MeV resonance.

Elastic scattering has been studied for $E_{\rm p} = 0.2$ to 2.7 MeV by (1956DE33, 1956MO90, 1969MO29, 1973RO24). Below $E_{\rm p} = 0.7$ MeV only s-waves are present exhibiting resonance at $E_{\rm p} = 330$ keV [^{10}B*(6.88)], $J^{\pi} = 1^{-}$. Between $E_{\rm p} = 0.8$ to 1.6 MeV polarization and cross-section measurements are well fitted by a phase-shift analysis, using only the $^{3}S_{1}$, $^{5}S_{2}$, $^{5}P_{1}$ and $^{5}P_{2}$ phases. Four levels satisfy the data, 1^{+} and 2^{-} states at $E_{\rm x} = 7.48$ MeV, a sharp 0^{+} state at $E_{\rm x} = 7.56$ MeV, and a 1^{-} state at 7.82 MeV: see Table 10.14 (1956MO90, 1973RO24).

Pronounced minima at $E_{\rm p} = 2.48$ and 2.55 are observed in the polarization (p_0): these are ascribed to $T = 1$ analogs of the 3^{-} and 2^{+} states ^{10}Be*(7.37, 7.52) (1970AN1B). A resonance corresponding to ^{10}B*(8.89) is also reported by (1956DE33). The yield of p_0, p_1 and p_2 has been measured for $E_{\rm p} = 4.2$ to 6.0 MeV by (1972YA06): structures are reported at $E_{\rm p} \approx 4.7$ MeV ($\Gamma \approx 0.3$ MeV) in the p_2 yield and at $E_{\rm p} \approx 5.1$ MeV in the p_1 yield (1972YA06). Excitation curves for the p_0 group have been measured for $E_{\rm p} = 6.0$ to 15.0 MeV (1972VO17, 1973VO02): a strong anomaly is observed at $E_{\rm p} = 6.7$ MeV: see Table 10.14. (1973VO02) find that the p_0 differential cross sections and polarization analyzing power are adequately described by a spherical optical model potential for $E_{\rm p} = 13$ to 30 MeV: only the volume real potential depth $V_{\rm R}$ and the surface imaginary potential depth $W_{\rm S}$ need vary with energy. When coupled-channels analyses were made (1973VO02) found that a quadrupole-deformed optical model potential with a deformation $\beta = 1.1$ gives an improved description of the (p, p_0) data and good fits to data obtained for (p, p_2). See also (1971WE07).

The reports of anomalies in the yield of protons near the threshold for the (p, n) reaction, by (1968SI07, 1970SI1F, 1971SI1K), are in error: see (1970CO06, 1972GO1Q). See also (1965HU10, 1967CA1K, 1967MC1E, 1970BO1Y).

Cross section measurements have also been reported at $E_{\rm p} = 6.36$ to 6.48 MeV (1971VA34; yield of p_1), 16.2 to 29.1 MeV (1973MO02; $\sigma_{\rm R}$, and also σ for p_2 and p_3), 24.4 to 45.9 MeV

Table 10.14: Resonances in ^{9}Be(p, p)^{9}Be

E_{res} (keV)	E_x (MeV)	$\Gamma_{c.m.}$ (keV)	J^π	Γ_p/Γ	Refs.
330	6.88	145	1^-	0.30	(1956MO90, 1969MO29)
980 ± 10	7.467	65 ± 10	$1^{+\ a}$	1.0	(1956MO90, 1969MO29, 1973RO24)
980 ± 10 [a]	7.467	80 ± 8	2^-	0.90 ± 0.05	(1956DE33, 1956MO90, 1969MO29, 1973RO24)
1084 ± 2	7.560	2.7	0^+	1.0	(1956MO90, 1969MO29)
(1200 ± 30)	(7.67)	250 ± 20	(1^+)	0.30 ± 0.10	(1969MO29)
1370 ± 20	7.817	265 ± 30	$1^{-\ a}$	0.90 ± 0.05	(1956MO90, 1969MO29, 1973RO24)
(2300)	(8.65)	≈ 300	$(1^+, 2^+)$		(1973RO24)
(2480)	(8.82)		$(3^-; 1)$		(1970AN1B)
2560	8.89		≥ 2; (1)	large	(1956DE33, 1970AN1B)
(4700)	(10.8)	≈ 300			(1972YA06)
(5100)	(11.2)				(1972YA06)
6700	12.6	broad			(1972VO17, 1973VO02)

[a] See, however, (1969MO29). (1969MO29) also suggest states at $E_x = 7.44$ and 8.1 MeV with $J^\pi = 1^-$ and 2^+, respectively and $\Gamma_{c.m.} = 130 \pm 10$ and ≈ 80 keV, respectively: see discussion in (1973RO24).

(1969MC1A; σ_R), and 232 to 553 MeV (1972RE06; σ_R). See also (1966LA04) for the earlier work.

Polarization measurements involving the elastic group have been carried out at $E_p = 0.9$ to 2.7 MeV (1973RO24), 0.9 to 3.0 MeV (1970AN1B), 2.2 to 3.8 MeV (1968BL1F), 3.0 to 12.0 MeV (1970LO03), 7.0, 8.5 and 10.0 MeV (1967KO1E; also p_2 at $E_p = 11.0$ MeV), 14.5 MeV (1965RO22), 17.8 MeV (1966BA2B), 25 MeV (1973BI1H, 1973BI1N), 30.3 MeV (1967WA1G), 42.0 MeV (1966CA01; p), 49.3 MeV (1970CL10; also p_2), 49.8 MeV (1971MA13, 1971MA44; also p_2), 138.2 and 145 MeV (1966JA08, 1966JA1F) and 990 MeV (1973VO1L). Polarization measurements on the proton group to ^{9}Be*(2.4) [p_2] have also been carried out at $E_p = 8$ to 10 MeV (1969BE1Q). See also (1966LA04).

For reaction (b) see (1967WA1H, 1972WA30). For spallation see (1970KO25). For astrophysical considerations see (1971EL1B). See also (1966RO1B, 1969CO1J, 1970SL1B) and (1967SA1C, 1969GU1K, 1969WA11, 1971BA87, 1971IN05, 1973GU08, 1973HU05; theor.).

16. ^{9}Be(p, t)^{7}Be $Q_m = -12.0831$ $E_b = 6.5853$

See ^{7}Be.

17. (a) ^{9}Be(p, d)^{8}Be $Q_m = 0.5595$ $E_b = 6.5853$

(b) ^{9}Be(p, α)^{6}Li $Q_m = 2.1251$

Knowledge of the cross sections of these two reactions at low energies is of importance for power generation and astrophysical considerations: see (1973SI27). Absolute cross sections for the d_0 and α_0 groups have been measured for $E_p = 28$ to 697 keV with $\pm 5 - 6$% uncertainty. The value of $S_{\rm c.m.}$ $(E = 0)$ for the combined cross sections is estimated to be (35^{+45}_{-15}) MeV · b. At the 0.33 MeV resonance ($J^\pi = 1^-$), $\sigma_{\alpha_0} = 360 \pm 20$ mb and $\sigma_{d_0} = 470 \pm 30$ mb. The data (including angular distributions), analyzed by an R-matrix compound nucleus model, were fitted by assuming three states at E_p(c.m.) $= -20$ keV ($J^\pi = 2^+$; 3^+ possible) [$E_x = 6.57$ MeV], 310 keV (1^-) and 410 keV (1^+; 2^+ or 3^+ possible) (1973SI27). Measurements of the yields of d_0, α_0 and α_1 for $E_p = 0.2$ to 2.0 MeV have been reported by (1969TU1A): the total cross section is reported to show definite peaks at $E_p = 0.330$, 0.450, 0.935 and 1.80 MeV. The yields of α_0 and d_0 have also been measured for $E_p = 0.3$ to 0.9 MeV by (1968BE1N), and the yield of d_0 has been obtained at several angles for $E_p = 6$ to 15 MeV (1972VO1H). The total cross sections for d_0 and d_1 have been measured for $E_p = 17.0$, 21.0, 25.0 and 29.1 MeV (1973MO02). See also (1970BO1Y, 1971GU23). Polarization measurements have been made at $E_p = 0.30$ to 1.25 MeV (1971KE1D; d_0, α_0), 0.33 MeV (1967RO07; d_0), 1.6 to 3.8 MeV (1965DA05, 1968FR10; d_0), 3, 4 and 5 MeV (1966VE03; d_0), 4.91, 6.90, 8.27, 9.80 MeV (1967IV01; d_0), 5 to 12 MeV (1969LO1E; d_0), 13.0 and 15.0 MeV (1972VO1H; d_0) and 185 MeV (1968IN02, 1969IN1C; d to ^{8}Be*(16.9, 19.2)). Previous studies are described in (1966LA04). Observed resonances are exhibited in Table 10.15. Deuteron production has been studied for $E_p = 1$ to 3 GeV by (1969ED02). See also (1966MI1E, 1969CO1J), and (1969KO1P, 1971MC1H, 1971SA1J).

18. ^{9}Be(d, n)^{10}B $\qquad Q_m = 4.3607$

Neutron groups are observed corresponding to the ^{10}B states listed in Table 10.16. Thresholds for slow-neutron production corresponding to ^{10}B states from 4.77 to 6.56 MeV are reported in Table 10.17. Angular distributions have been measured at many energies: see (1959AJ76, 1966LA04) for earlier references and (1965BU10: $E_d = 2.6$ to 3.2, and 7 MeV; see Table 10.16), (1967FI01: $E_d = 3.0$, 3.5 and 5.5 MeV; see Table 10.16), (1967FU04: $E_d = 5.5$ MeV; n_0, n_2, n_3) and (1973PA14: $E_d = 7.0$, 12.0, 15.0, 16.0 MeV; $E_x < 6.6$ MeV). See also (1969RO14, 1971DE2C). The values of l_p and spectroscopic factors obtained in the analyses by (1965BU10, 1967FI01, 1973PA14) are shown in Table 10.16. The spectroscopic factors measured for ^{10}B*(1.74) ($J^\pi = 0^+$; $T = 1$) are brought into accord with shell model predictions when the $\bar{t} \cdot \bar{T}$ interaction is considered (1967TA1A): see also (1966SI02, 1967FU04, 1973PA14).

There have been many reports of additional neutron groups [see (1959AJ76, 1966LA04)], in particular a state at 2.86 MeV. (1967GL03: $E_d = 1.7$ and 1.8 MeV) have shown that such a state does not exist: the intensity of a neutron group to such a state ≤ 0.4% relative to ^{10}B*(3.59) and ≤ 0.3% relative to ^{10}B*(2.16). See also (1965MA50).

Observed γ-transitions are listed in Tables 10.6 and 10.18 (1949RA02, 1963WA17, 1964WA05, 1969GA06). Reported values of τ_m for a number of ^{10}B states are displayed in Table 10.9 (1966WA10, 1968FI09, 1969AL17).

Table 10.15: Resonances in ^{9}Be(p, d)^{8}Be and ^{9}Be(p, α)^{6}Li

E_p (MeV)	E_x (MeV)	$\Gamma_{c.m.}$ (keV)	$J^\pi; T$	Γ_p/Γ	θ^2_p	θ^2_d	θ^2_α	Refs.
0.34	6.89		$1^-; 0$	0.30	0.34	0.15	0.055	(1956MO90, 1969TU1A, 1973SI27)
0.46	7.00		$1^+(2^+, 3^+)$ [b]		0.3	0.3	0.1	(1949TH05, 1951NE03, 1969TU1A, 1973SI27)
(0.68)	(7.20)							(1949TH05, 1951NE03)
0.94	7.43	140	$(2^-; 0)$	0.7	0.04	0.02		(1956WE37, 1964HO02, 1969TU1A)
1.15	7.62	225 ± 50	$(1^+; 0)$	≈ 0.4	≈ 0.1			(1956WE37, 1964HO02)
1.65	8.07	800 ± 200	$(2^-; 0)$	≈ 0.07	0.18	0.21		(1956WE37, 1964HO02)
(1.80)	(8.20)							(1969TU1A)
(2.3)	(8.7)	(≈ 220)						(1956WE37, 1965MO1K)
2.56	8.89	36 ± 2	$2^+; 1$				[a]	(1956WE37)
3.5	9.7		$; 1$				[a]	(1959MA20)
4.49	10.62		$; 1$				[a]	(1959MA20)

[a] Resonance for α_2 to ^{6}Li*(3.56), $J^\pi = 0^+; T = 1$.
[b] See, however, (1971BA41) in reaction 3.

From all the various experiments the following picture emerges: the first five states of ^{10}B have even parity [from l_p]. The ground state is known to have $J = 3$, by direct measurement, and ^{10}B*(1.74) has $J^\pi = 0^+$ and is the $T = 1$ analogue of the ^{10}C$_{\rm g.s.}$ [from the β^+ decay of ^{10}C]. Then looking at the branching ratios and lifetimes of the other states, the sequence for ^{10}B*(0, 0.72, 1.74, 2.16, 3.59) is $J^\pi = 3^+, 1^+, 0^+, 1^+, 2^+$, respectively [see discussion in (1966LA04, 1966WA10)].

See also ^{11}B and (1965FO1C, 1966FI01, 1970SR01, 1970WI1C, 1972SR04, 1972SR02, 1973WE1T, 1973WE19), (1966WA1C, 1967LE1F) and (1970FO1B, 1970MI1G, 1973CO16; theor.).

19. ^{9}Be(^{3}He, d)^{10}B $\quad\quad$ $Q_{\rm m} = 1.0916$

Deuteron groups have been seen corresponding to a number of states of ^{10}B: see Table 10.19 (1960HI08, 1966FO08, 1966SI02, 1967CR04). See also (1970CA28). No evidence is seen for previously reported states at $E_{\rm x} = 5.58$ and 6.40 MeV (1966FO08). Angular distributions obtained at $E_{\rm d} = 10$ MeV (1967CR04), 10.2 MeV (1960HI08), 17 MeV (1966SI02) [see also (1973PA14)], 22 MeV (1969MA1R) and 25 MeV (1960WE04, 1967SI1A) have been analyzed by DWBA and lead to the l_p and the spectroscopic factors shown in Table 10.19. See also (1971BI1D), (1967LE1F) and (1968TA1A, 1972DZ1A, 1973CO16; theor.). For $\tau_{\rm m}$ measurements see Table 10.9 (1966FI01, 1968FI09).

20. ^{9}Be(α, t)^{10}B $\quad\quad$ $Q_{\rm m} = -13.229$

Angular distributions have been obtained at $E_\alpha = 27$ MeV (1973KE1E; t_0, t_1, t_3), 28.3 MeV (1965KA14; t_0, t_1) and $E_\alpha = 43$ MeV (1967DE1K, 1967SI1A; t_0, t_2). At $E_\alpha = 27$ MeV, ^{10}B*(1.7) is not observed (1973KE1E). See also (1966LA04).

21. ^{9}Be(^{14}N, ^{13}C)^{10}B $\quad\quad$ $Q_{\rm m} = -0.9654$

See ^{13}C in (1970AJ04, 1976AJ04)

22. ^{10}Be(β^-)^{10}B $\quad\quad$ $Q_{\rm m} = 0.5559$

See ^{10}Be.

23. (a) ^{10}B(γ, n)^{9}B $\quad\quad$ $Q_{\rm m} = -8.435$
(b) ^{10}B(γ, p)^{9}Be $\quad\quad$ $Q_{\rm m} = -6.5853$
(c) ^{10}B(γ, d)^{8}Be $\quad\quad$ $Q_{\rm m} = -6.0258$
(d) ^{10}B(γ, α)^{6}Li $\quad\quad$ $Q_{\rm m} = -4.460$

Table 10.16: Levels of ^{10}B from ^{9}Be(d, n)^{10}B [a]

(1965BU10)			(1973PA14)		(1967FI01)	
^{10}B* (MeV ± keV)	l_p [d]	S_{rel} [e]	S_{rel} [k]	^{10}B* (MeV ± keV)	l_p [g]	S_{rel} [h]
0	1	1.0	1.0	0	1	1.0
0.72 [b]	1	2.3	1.97	0.72 ± 10	1	2.8
1.74 [b]	1	1.0 [f]	1.42	1.74 ± 10	1	1.4 [f]
2.16 [b]	1	0.41	0.41	2.15 ± 10	1	0.5
3.59 [b]	1	0.45	0.10	3.58 ± 10	(1)	0.3
4.77 [b]	(≥ 2)	0.43		4.77 ± 10	undetermined	0.07 if $l = 1$ 0.4 if $l = 2$
5.11 ± 20	0	1.3	0.14	5.11 ± 12	0	1.7 [i]
5.16 ± 20	1		0.43	5.17 ± 14	1	0.6
5.90 ± 80	(1)	1.3	0.49	5.93 ± 10	1	0.7
6.10 ± 80	(2)			{ 6.03 ± 12 { 6.14 ± 10	(2)	0.3 [i,j]
6.35 ± 50	(0)	(0.86), 0.51				
6.50 ± 50	1			6.57 ± 10	(3)	
6.95 ± 30 [c]	0	1.8		{ 6.89 ± 15 { 7.00 ± 12	(1) (1)	
7.50 ± 50				7.48 ± 15		
7.60 ± 50				7.56 ± 25		
(7.85 ± 50)						
(8.07 ± 50)						
(8.12 ± 50)						

[a] See also Table 10.17 in (1966LA04).
[b] E_x not determined for the first five excited states.
[c] $\Gamma \approx 200$ keV.
[d] $E_d = 2.6 - 3.2$ MeV and 7 MeV.
[e] $E_d = 7$ MeV.
[f] See, however, discussion in text and (1967TA1A).
[g] $E_d = 3.0, 3.5, 5.5$ MeV.
[h] Average of values shown by (1967FI01).
[i] PWBA.
[j] If $J = 3$.
[k] Average of values shown by (1973PA14) at $E_d = 12.0, 15.0$ and 16.0 MeV.

Table 10.17: Slow-neutron thresholds in ^{9}Be(d, n)^{10}B (1954BO79)

E_d (MeV)	E_x (MeV)	Γ (keV)
0.52	4.79	< 10
0.92 [a]	5.11	< 10
0.99 [a]	5.17	< 10
1.92	5.93	< 10
2.08	6.06	< 10
2.20	6.16	< 20
2.53	6.43	
2.70	6.57	≈ 30

[a] 0.921 ± 0.009 and 0.989 ± 0.009 MeV (1962WA21): $E_x = 5.113$ and 5.169 MeV.

Absolute measurements have been made of the ^{10}B(γ, all n) cross section from threshold to 28 MeV: the giant resonance is broad with the major structure contained in two peaks at $E_x = 20.1 \pm 0.1$ and 23.1 ± 0.1 MeV ($\sigma \approx 6.5$ mb) (1973HU09, 1973HU1D). The integrated cross section to 29 MeV is 66.7 MeV · mb (1965HA19). See also (1964GR1A) and (1973AR1L). Using 12.5 MeV bremsstrahlung (1968SH21) report peaks in the (γ, p) cross section corresponding to ^{10}B states at 8.8 ± 0.1 [$J^\pi = 2^+$], 9.2 ± 0.1 [3^+] and (≈ 10.5) [$\pi = +$] MeV, with $T = 1$. See (1959AJ76, 1966LA04) for reactions (c) and (d).

24. ^{10}B(γ, γ)^{10}B

See (1967LO1B).

25. ^{10}B(e, e)^{10}B

The quadrupole contribution to the elastic form factor is best accounted for by the undeformed shell model, $Q = 7.45$ ($\pm$20%) fm^2, $\langle r^2 \rangle^{1/2} = 2.45$ fm (1966ST12). The magnetic form factors for $E_e = 70$ to 200 MeV have been determined for the elastic group (+ a small contribution due to ^{10}B*(0.7)): there is no evidence of an M3 contribution – the magnetic octupole moment $\lesssim 1.6$ fm^2, $a_0 = 1.4 \pm 0.2$ fm (1966RA29). At $E_e = 29.2$ to 57.8 MeV (1966SP02) has studied the inelastic groups corresponding to $E_x = 6.014 \pm 0.020$ ($J^\pi = 4^+$, E2) and 7.477 ± 0.020 MeV

Table 10.18: Gamma rays observed in ^{9}Be(d, n)^{10}B

Transition	E_γ (keV)	Branching ratio [d] (%)
$0.7 \to$ g.s.	716.6 ± 1 [a]	100
$1.7 \to$ g.s.		< 2
$1.7 \to 0.7$	1022 ± 2 [a]	100
$2.16 \to$ g.s.	2152 ± 15 [a]	22
$2.16 \to 0.7$	1433 ± 5 [a]	27
$2.16 \to 1.7$	413.5 ± 1 [a]	51
$3.59 \to$ g.s.	3583 ± 13 [b,c]	19 ± 4 [e]
$3.59 \to 0.7$	2872 ± 15 [b,c]	70 ± 7 [e]
$3.59 \to 1.74$		< 1 [e]
$3.59 \to 2.16$		11 ± 2 [e]
$5.17 \to$ g.s.	5159 ± 16 [b]	5.5 ± 0.7 [b]
$5.17 \to 0.7$	4461 ± 13 [b,c]	29.5 ± 2 [b]
$5.17 \to 2.16$	3028 ± 15 [b]	65 ± 2 [b]

[a] (1949RA02).
[b] (1963WA17): Doppler corrected.
[c] M1 + E2 (1964WA05).
[d] See Table 10.6.
[e] (1969GA06).

($J^\pi = 2^+$, M1) [‡]: $\Gamma_{\gamma_0} = 0.122 \pm 0.020$ eV and 12.0 ± 2.2 eV [§], and $\Gamma_{\gamma_0}/\Gamma_{\rm w} = 14$ and 1.4, respectively. $\Gamma_{\rm tot} \approx 40$ keV for ^{10}B*(7.48) (1966SP02). A number of other inelastically scattered electron groups are reported by (1966KO08) at $E_{\rm e} = 50$ MeV: Γ_{γ_0} values are given (± 50%). See also (1965FR07, 1965VA1G).

See also (1966PE1E), (1966IS1A, 1967LE1E, 1968GO1J) and (1967KA1A, 1969UB1B, 1969VI02, 1970LA13; theor.).

26. ^{10}B(n, n)^{10}B

Elastic angular distributions have been measured for $E_{\rm n} = 1.5$ to 5.0 MeV by (1970PO1E, 1973NE1H). At higher energies in addition to the elastic group (not resolved from the group

[‡] See, however, Table 10.11.
[§] Reanalysis of the data, including Coulomb distortion effects, leads to $\Gamma_{\gamma_0} = 11.0 \pm 2.2$ eV (1969CH1A) for ^{10}B*(7.48). See also (1972THZF).

Table 10.19: Levels of ^{9}Be(^{3}He, d)^{10}B

E_x (MeV ± keV)	J^π	l_p [e]	S_{rel} [f]	S_{rel} [i]
0	3^+	1	1.0	1.0
0.717 ± 10 [a]	1^+	1	1.8	1.8
1.744 ± 10 [a]	0^+	1	2.6 [g]	2.6 [g]
2.156 ± 10 [a]	1^+	1	0.71	0.55
3.59 [b]	2^+	1	0.30	
4.77 [c]			0.15	
5.11 [d]				
			0.66 [h]	
5.17 [c,d]				
5.92 [c,d]	2^+	1	1.2	
6.03 [d]				
6.13 [c,d]			0.90 [h]	
6.56 [c,d]			0.86 [h]	

[a] (1960HI08). See also (1970CA28).

[b] The E_x of this state and of the states listed below have not been determined.

[c] (1967CR04).

[d] (1966FO08).

[e] See text.

[f] $E_d = 10$ MeV (1967CR04).

[g] The $\bar{t} \cdot \bar{T}$ term significantly changes S_{rel} (1968TA1A).

[h] $(2J + 1)S_{rel}$.

[i] $E_d = 17$ MeV (1966SI02); see also (1973PA14).

to ^{10}B*(0.7)), angular distributions have been obtained for the neutrons to ^{10}B*(1.74 ± 2.16, 3.59, 4.77, unresolved states near 5.0, 6.0, 6.6): see (1969HO1G: $E_{\rm n} = 7.02$ and 7.55 MeV), (1970CO12: $E_{\rm n} = 9.72$ MeV) and (1968AL1E, 1970VA19: $E_{\rm n} = 14.1$ MeV). The gamma decay of ^{10}B states with $E_{\rm n} < 6.1$ MeV has been studied by (1970NE03). See also (1969HA1R), (1966LA04) and ^{11}B in (1975AJ02).

27. ^{10}B(p, p′)^{10}B

Angular distributions of elastically scattered protons have been measured at $E_{\rm p} = 3.0$ to 10.5 MeV (1970BO17), 5.1 to 16.5 MeV (1968WA1H, 1969WA23), 33.6 MeV (1970KU1D) and 49.5 MeV (1970SQ01). Observed inelastic groups are displayed in Table 10.20 (1953BO70, 1962AR02, 1964AR04). Angular distributions for the proton groups to the first five excited states and to ^{10}B*(6.04) have been measured in the range $E_{\rm p} = 5.1$ to 16.5 MeV (1968WA1H, 1969WA23). See also (1966LA04). The 4^+ state at 6.03 MeV is the most strongly excited of the ^{10}B states: see (1962SC12, 1965HA17, 1969DE1N, 1969WA23): B(E2↑) $= 26 \pm 5$ fm^4 and Γ(E2↓) $= 0.14$ eV (1965JA1A). For optical model parameters see (1969WA11, 1970SQ01).

Gamma rays have been observed with $E_\gamma = 718.5 \pm 0.2$ keV and 1021.5 ± 0.5 keV (1966FR09: from decay of $E_{\rm x} = 718.5 \pm 0.2$ and 1740.0 ± 0.6 keV) and $E_\gamma = 720.1 \pm 2.0$, 1022.0 ± 2.0, 1435.1, 2155.6 ± 2.0 and 2868.5 ± 2.0 keV (1969PA09: from decay of $E_{\rm x} = 720.4 \pm 1.9$, 1742.3 ± 2.3, 2155.4 ± 1.9 and 3589.7 ± 2.2 keV). See also reaction 39. (1968MA18) report δ(E2/M1) $= -(0.23^{+0.06}_{-0.05})$ or $-(4.1^{+1.0}_{-0.7})$ for the $2.15 \rightarrow 0.72$ transition. The $1.74 \rightarrow$ g.s. and $3.59 \rightarrow 1.74$ transitions have not been observed: < 0.2% and < 0.3%, respectively (1966SE03). The branching ratio for $5.17 \rightarrow 1.74$ is < 0.5% and $5.17 \rightarrow 3.59$ is (4.5 ± 1)% [see Table 10.6] (1967PA01). See Table 10.9 for other $\tau_{\rm m}$ measurements (1966FI01, 1968FI09). See also (1971SC1N) and (1969TI02, 1973HU05, 1973KA04, 1973ZW1A; theor.). See also ^{11}C in (1975AJ02).

28. (a) ^{10}B(p, 2p)^{9}Be $\quad Q_{\rm m} = -6.5853$
(b) ^{10}B(p, pn)^{9}B $\quad Q_{\rm m} = -8.435$
(c) ^{10}B(p, pα)^{6}Li $\quad Q_{\rm m} = -4.460$

The summed proton spectrum (reaction (a)), observed at $E_{\rm p} = 460$ MeV, shows peaks corresponding to the removal of an $l \neq 0$ proton at $Q = -6.7 \pm 0.5$, -11.9 ± 0.5 and -17.1 ± 0.6 MeV; for removal of an $l = 0$ proton, $Q = -30.5 \pm 0.6$ MeV (1966TY01). See also (1966JA1A, 1967JA1E, 1968JA1G, 1969KO1J; theor.) and (1966LA04). For reaction (b) see (1970TH1F) and for reaction (c) see (1971GA1J).

29. ^{10}B(d, d′)^{10}B*

Table 10.20: ^{10}B levels from ^{10}B(p, p′), ^{10}B(d, d′) and ^{10}B(^{3}He, ^{3}He′)

E_x (MeV ± keV)			$\Gamma_{c.m.}$ (keV)	L	β_L
(1953BO70) [a]	(1962AR02) [a]	(1964AR04) [a]	(1964AR04)	(1968SQ01) [h]	(1968SQ01) [h]
0	0				
0.717 ± 5 [b]	0.72 ± 10			2	0.37 ± 0.04
1.739 ± 5 [c]	1.74 ± 10 [c]			(3)	(0.69 ± 0.09)
2.152 ± 5	2.15 ± 10			2	0.36 ± 0.04
3.583 ± 5	3.58 ± 10			2	0.36 ± 0.04
4.771 ± 5	4.77 ± 10				
	5.11 ± 10				
	5.16 ± 10 [d]				
	5.18 ± 10 [e]		110 ± 10 [g]		
		5.92 ± 10	< 5		
		6.03 ± 10	< 5		
		6.13 ± 10	< 5	2	0.62 ± 0.03
		6.55 ± 10	25 ± 5		
		7.00 ± 10	95 ± 10		
		7.48 ± 10 [f]	90 ± 15		

[a] (p, p′) and (d, d′).

[b] 719 ± 1.6 keV (1952CR30), 718 ± 5 keV (1954DA20).

[c] This state not observed at $E_d = 7.6$ MeV (1953BO70) nor at $E_d = 10.0$ MeV (1962AR02). Intensity of this d_2 group $\lesssim$ 1% of d_3 group for $E_d = 6$ to 9 MeV (1972ST1M).

[d] Not observed in (d, d′) at $E_d = 10$ MeV (1962AR02).

[e] Not reported in (p, p′) at $E_p = 10$ MeV (1962AR02).

[f] Relative intensity in (d, d′) at $E_d = 11.4$ MeV $< 2\%$.

[g] (1962AR01).

[h] (^{3}He, ^{3}He′): $E(^{3}\mathrm{He}) = 32.5$ MeV.

Deuteron groups have been observed corresponding to twelve states of ^{10}B: see Table 10.20 (1953BO70, 1962AR02, 1964AR04, 1972ST1M). The very low intensity of the group to ^{10}B*(1.74) (1972ST1M) and the absence of the group to ^{10}B*(5.17) (1962AR02) is good evidence of their $T = 1$ character. Angular distributions have been reported at $E_{\rm d} = 4$, 6 and 8 MeV (1965LE1B, 1967DI01; d_0), 7.0 and 9.0 MeV (1972ST1M; d_2 and d_3), 11.8 MeV (1967FI07; d_0, d_1. d_3, d_4, d_5, d_6 and d to unresolved 6 MeV states) and 28 MeV (1968GA13, 1968ME1E; d_0; see for optical parameters). See also (1966BR1G), (1968NE1A, 1969NE08; theor.) and ^{12}C in (1975AJ02).

30. ^{10}B(t, t)^{10}B

Angular distributions of elastically scattered tritons have been measured at $E_{\rm t} = 1.5$ MeV (1963HO19, 1969HE08) and 2.5, 2.7, 3.1 and 3.3 MeV (1971GE09).

31. ^{10}B(^{3}He, ^{3}He)^{10}B

Angular distributions of elastically scattered ^{3}He have been measured at $E(^3{\rm He}) = 4$, 8, 10, 12, 15 and 18 MeV (1970DU07), 9.8 MeV (1967PA1H), 13.2, 17.2 and 24.3 MeV (1972BU30), 14 MeV (1970NU02) and 32.5 MeV (1968SQ01). See also (1970BA1P). For derived optical model parameters see (1968SQ01, 1970DU07, 1970NU02, 1972BU30). Angular distributions have also been measured at $E(^3{\rm He}) = 32.5$ MeV to ^{10}B*(0.72, 1.74, 2.16, 3.59, 4.77, $5.11 + 5.17 + 5.18$, 6.03, 6.56). $L = 2$ gives a good fit to the distributions of ^{3}He ions to ^{10}B*(0.72, 2.16, 3.59, 6.03): derived $\beta_{\rm L}$ are shown in Table 10.20 (1968SQ01). See also (1967CO1J, 1970BA1P) and (1968HO1C).

32. (a) ^{10}B(α, α')^{10}B*
(b) ^{10}B(α, 2α)^{6}Li $\qquad Q_{\rm m} = -4.460$

Angular distributions of elastically scatted α-particles have been measured at $E_\alpha = 5$ to 30 MeV (1972DA04) and at 56 MeV (1969GA11). For optical model parameters see (1970ZE03, 1972DA04). Inelastic α-groups are also reported to ^{10}B*(0.72, 2.16, 3.59, 4.77, $5.11+5.17+5.18$, $5.92 + 6.03$, 6.13, 6.56) (1972DA04). ^{10}B*(1.74) is not seen (1967CO1P, 1972DA04).

At $E_\alpha = 24$ MeV, analysis of the angular distributions of the α-particles emitted in the decay of ^{10}B*(4.77, 5.92) suggests 4^+ for the former (see, however, Table 10.5) and 2^+ for the latter (1973EI03). See also (1966GE12, 1971GA1J, 1974DO1G) and (1969GA01) in ^{14}N in (1970AJ04).

33. (a) ^{10}B(^{6}Li, ^{6}Li)^{10}B
(b) ^{10}B(^{7}Li, ^{7}Li)^{10}B

For reaction (a) see (1970BO1W). The elastic scattering in reaction (b) has been studied at $E(^{7}\text{Li}) = 24$ MeV (1972WE08). See also (1969RO1G; theor.).

34. ^{10}B(^{10}B, ^{10}B)^{10}B

See (1967BE1T).

35. ^{10}B(^{12}C, ^{12}C)^{10}B

The elastic scattering angular distribution has been measured at $E(^{10}\text{B}) = 18$ MeV (1968VO1A, 1969VO10).

36. ^{10}B(^{14}N, ^{14}N)^{10}B

See (1970IS1A).

37. (a) ^{10}B(^{16}O, ^{16}O)^{10}B
(b) ^{10}B(^{18}O, ^{18}O)^{10}B

The elastic scattering in reaction (a) has been studied with $E(^{16}\text{O}) = 15.0$ to 32.5 MeV: see (1968OK06, 1968OK1B, 1969KR03); that in reaction (b) has been studied for $E(^{18}\text{O}) = 20$, 24 and 30.5 MeV (1971KN05). See also (1970BL1E).

38. ^{10}B(^{19}F, ^{19}F)^{10}B

The elastic scattering has been studied for $E(^{19}\text{F}) = 20$ and 24 MeV (1971KN05).

39. ^{10}C(β^{+})^{10}B $\qquad$ $Q_{\text{m}} = 3.650$

Table 10.21: The beta decay of ^{10}C

Decay to ^{10}B* (MeV)	Branching ratio (%)	$\log ft$	Refs.
0.72	98.53 ± 0.02	3.047 [d]	(1972RO03) [a]
1.74	1.465 ± 0.014	$3.499^{+0.005}_{-0.006}$ [b]	(1972RO03) [a]
	1.52 ± 0.08		(1969BR13)
2.15	$\leq 8 \times 10^{-4}$ [c]	≥ 5.67	(1972GO1A)

[a] See also (1966FR09, 1969FR02, 1969FR09).
[b] Includes radiative corrections (1972RO03). (1973TO04) using the same input data find $3.497^{+0.005}_{-0.006}$, including both radiative and charge dependent corrections.
[c] See also (1969BR13).
[d] B. Zimmerman and G. Fox, private communication.

The half-life is 19.48 ± 0.05 sec (1962EA02), 19.27 ± 0.08 sec (1963BA52): the weighted mean is 19.42 ± 0.06 sec [¶] . The decay is to ^{10}B*(0.7, 1.7): see Table 10.21 for branching ratios and $\log ft$ (1969BR13, 1972GO1A, 1972RO03). The vector coupling constant determined from the decay to the analog state ^{10}B*(1.7) is $G^{\rm V}_{\beta} = (1.396 \pm 0.009) \times 10^{-49}$ erg · cm^3 (1972RO03). See also (1972FR1L). The excitation energies of ^{10}B*(0.7, 1.7) are $E_{\rm x} = 718.32 \pm 0.09$ and 1740.16 ± 0.17 keV [$E_{\gamma} = 718.29 \pm 0.09$ and 1021.78 ± 0.14 keV] (1969FR02). See also (1966FR09). See also (1967MU1A, 1969FR09) and (1965CO25, 1966BA1A, 1968BO1U, 1968MO1F, 1969BL1E, 1969BL1D, 1969KA1B, 1970DA21, 1972BE04, 1972WI1C, 1973HA49, 1973TO04, 1973WI11; theor.).

40. ^{11}B(γ, n)^{10}B $\qquad Q_{\rm m} = -11.4560$

The intensities of the transitions to ^{10}B*(3.59, 5.17) [$T = 0$ and 1, respectively] depend on the region of the giant dipole resonance in ^{11}B from which the decay takes place: it is suggested that the lower energy region consists mainly of $T = \frac{1}{2}$ states and the higher energy region of $T = \frac{3}{2}$ states (1971PA10). See also reaction 22 in ^{10}Be, and ^{11}B in (1975AJ02). See also (1969MU10).

41. ^{11}B(p, d)^{10}B $\qquad Q_{\rm m} = -9.2314$

Angular distributions of deuteron groups have been measured at $E_{\rm p} = 19$ MeV (1963LE03; d_0, d_1, d_2, d_3, d_4), 33.6 MeV (1968KU04, 1970KU1D; d_0, d_1, d_2, d_3, d_4, d_5 and deuterons to states

[¶] See also Table 10.24.

at 5.18 (unres.), 6.04 (unres.)) and 154.8 MeV (1969BA05, 1969TO1A; d_0, d_1, d_2, d_3, d_4 and d to 5.1 ± 0.1, 11.4 ± 0.2 and 14.1 ± 0.2 MeV). The weak excitation of states at 6.56 and 7.5 MeV is also reported (1968KU04), and $\Gamma_{\text{c.m.}}$ of ^{10}B*(11.4) $= 1.1 \pm 0.2$ MeV (1969BA05). Spectroscopic factors have been extracted by [(1963LE03): PWBA; (1968KU04): DWBA; (1969BA05) and (1969TO1A): DWBA].

42. ^{11}B(d, t)^{10}B $\qquad Q_{\text{m}} = -5.1984$

Angular distributions have been measured at $E_{\text{d}} = 11.8$ MeV (1967FI07; t_0, t_1, t_2, t_3; $l = 1$; $S = 1.88$, 0.94, 1.35, 1.35, respectively) and at $E_{\text{d}} = 21.6$ MeV (1967DE1M; $t_0 \rightarrow t_5$ and t to ^{10}B*(5.1); S_{rel} extracted). A dependence of the angular distribution on the isospin of the final state is discussed by (1967FU04).

43. (a) ^{11}B(^{3}He, α)^{10}B $\qquad Q_{\text{m}} = 9.1225$
(b) ^{11}B(^{3}He, 2α)^{6}Li $\qquad Q_{\text{m}} = 4.662$

Reported levels are listed in Table 10.22 (1965GO05, 1967PU04). See also (1966LA04). Angular distributions have been measured at $E(^3\text{He}) = 1.0$, 1.8, 2.15 MeV (1966LO15; $\alpha_0 \rightarrow \alpha_3$), 8, 10, 12 MeV (1973CO19; α_0) and 33 MeV (1969DE10: see Table 10.22). See also the earlier work of (1960TA12, 1965FO06). The decays of many of the states have been studied by (1966AL06, 1968WA15, 1969YO01): see Table 10.6. Lifetime measurements are summarized in Table 10.9 (1968DO01, 1969JA1N).

Alpha-α angular correlations (reaction (b)) have been measured for the transitions via ^{10}B*(5.92, 6.03, 6.13, 6.56, 7.00). The results are consistent with $J^\pi = 2^+$ and 4^+ for ^{10}B*(5.92, 6.03) and require $J^\pi = 3^-$ for ^{10}B*(6.13). There is substantial interference between levels of opposite parity for the α-particles due to ^{10}B*(6.56, 7.00): the data are fitted by $J^\pi = 3^+$ for ^{10}B*(7.00) and $(3, 4)^-$ for ^{10}B*(6.56) [the ^{6}Li(α, α) results then require $J^\pi = 4^-$] (1971YO05). See, however, (1973SI27) in reaction 17. See also (1970LI1K).

44. ^{11}B(^{16}O, ^{17}O)^{10}B $\qquad Q_{\text{m}} = -7.314$

See (1968OK06) and (1969BR1D).

45. ^{12}C(γ, d)^{10}B $\qquad Q_{\text{m}} = -25.1885$

See (1972SK08).

Table 10.22: ^{10}B levels from ^{11}B(^{3}He, α)^{10}B

E_x [a] (MeV $\pm$ keV)	E_x [b] (MeV $\pm$ keV)	$\Gamma_{c.m.}$ [b] (keV)	l [c]	S_{rel} [c]
0			1	1.0
0.718 ± 7			1	0.22
1.744 ± 7			1	0.73
2.157 ± 6			1	0.44
3.587 ± 6			1	0.09
4.777 ± 5			1	0.09
5.114 ± 5				
5.166 ± 5			1	1.81
5.923 ± 5				
6.028 ± 5				
6.131 ± 5				
6.573 ± 8	6.566 ± 10	30 ± 10		
	7.002 ± 10	95 ± 10		
7.475 ± 10				
7.567 ± 10				
	7.87 ± 40	240 ± 50		
	11.53 ± 40	270 ± 50		
	12.57 ± 30	90 ± 30		

[a] (1965GO05).
[b] (1967PU04).
[c] (1969DE10): 33 MeV; JULIE code.

46. ^{12}C(n, t)^{10}B $\quad Q_m = -18.9309$

Not reported.

47. (a) ^{12}C(p, ^{3}He)^{10}B $\quad Q_m = -19.6948$

(b) ^{12}C(p, pd)^{10}B $\quad Q_m = -25.1885$

Angular distributions of ^{3}He ions have been measured at $E_p = 39.8$ MeV (1973HO10: to ^{10}B*(0, 0.72, 1.74, 2.16, 3.59)) and 185 MeV (1968TI1A, 1972DA26: to ^{10}B*(0, 1.0, 1.7, 2.5, 3.5, 4.8, 6.0, 7.3)). See also (1966KI07) and (1968SA1H, 1971BA61; theor.). For reaction (b) see (1972BO17), (1968PA1J) and (1966LH1A, 1971BA16; theor.).

48. ^{12}C(d, α)^{10}B $\quad Q_m = -1.3409$

Alpha groups have been observed to the known states of ^{10}B below $E_x = 7.1$ MeV: see Table 10.23 (1962AR02, 1965PE17, 1970AN1J). Angular distributions have been determined for α_0, α_1, α_3 and α_4 at 9.2 to 13.9 MeV (1965BA06, 1966BA32, 1968KL06), 11.4 and 12.4 MeV (1965DO08), 12 MeV (1970AN1J), 13 MeV (1965ME13), 14.7 to 19.7 MeV (1961YA08, 1963YA1B) and 24 MeV (1965PE17). Angular distributions have also been measured at $E_d = 5.00$ to 8.40 MeV (1969CO02; α_0, α_1), 6.2 to 6.8 MeV (1965NE10; α_0, α_1), 12 MeV (1970AN1J; α to ^{10}B*(4.77, 5.11, 5.17, 5.92, 6.03, 6.13, 6.56), 24 MeV (1965PE17; α to ^{10}B*(4.77, 5.17, 6.03)). See also (1969CU08).

The population of the isospin-forbidden group to ^{10}B*(1.74) [α_2] has been studied with E_d up to 30 MeV. For $E_d \lesssim 15$ MeV the reaction appears to proceed via compound nucleus formation [see ^{14}N]; at the higher energies direct interaction mechanism may be involved: see (1966LA04) and (1966ME09, 1968JA09, 1969SM03, 1971JA04, 1971RI15, 1971VO04). See also (1966HA09). Angular distributions of the α_2 group have been reported at $E_d = 7.0$ to 14.0 MeV (1969SM03, 1971RI15), 9.0 to 12.5 MeV (1966ME09), 14.0 to 17.0 MeV (1971VO04), 14.8, 18.0, 21.0, 29.1 MeV (1968JA09, 1971JA04).

See also (1966PA1J, 1967BR1B, 1969DE29), (1966BR1G, 1969SC1F) and (1966DR1C, 1966GR1G, 1966HO1D, 1966ME1E, 1966WA1G, 1967NO1A, 1968NO1C, 1968ZE1B, 1969NO1B, 1969NO1C, 1971BA61; theor.).

49. ^{12}C(α, ^{6}Li)^{10}B $\quad Q_m = -23.715$

At $E_\alpha = 42$ MeV angular distributions have been measured for the transitions to $^{6}\mathrm{Li}_{\mathrm{g.s.}} + {}^{10}\mathrm{B}_{\mathrm{g.s.}}$, $^{6}\mathrm{Li}_{\mathrm{g.s.}} + {}^{10}\mathrm{B}^*_{0.72}$, $(^{6}\mathrm{Li}^*_{2.19} + {}^{10}\mathrm{B}_{\mathrm{g.s.}}) + (^{6}\mathrm{Li}_{\mathrm{g.s.}} + {}^{10}\mathrm{B}^*_{2.15})$, $^{6}\mathrm{Li}_{\mathrm{g.s.}} + {}^{10}\mathrm{B}^*_{2.15}$, $^{6}\mathrm{Li}^*_{2.19} + {}^{10}\mathrm{B}^*_{0.72}$ (1972RU03). See also ^{16}O in (1977AJ02).

Table 10.23: ^{10}B levels from ^{12}C(d, α)^{10}B

E_x [a] (MeV ± keV)	E_x [c] (MeV ± keV)
	0
0.72 ± 10	0.72 ± 20
[b]	[d]
2.15 ± 10	2.15 ± 20
3.58 ± 10	3.59 ± 20
4.77 ± 10	4.77 ± 30
5.11 ± 10	
[b]	5.17 ± 50
	[e]
	6.04 ± 50
	[e]
	6.67 ± 110
	7.05 ± 100

[a] (1962AR02).
[b] Absent: intensity of $E_x = 5.17$ MeV group < 1% relative to average of $T = 0$ levels.
[c] (1965PE17).
[d] See discussion in text.
[e] The excitation of ^{10}B*(5.92, 6.13, 6.56) is also reported by (1970AN1J).

50. ^{12}C(^{10}B, 3α)^{10}B $Q_m = -7.2748$

See (1965SH1A, 1967BI1F).

51. (a) ^{12}C(^{11}B, ^{13}C)^{10}B $Q_m = -6.5096$
(b) ^{12}C(^{14}N, ^{16}O)^{10}B $Q_m = -4.4518$

See (1969BR1D, 1972MO1E, 1973SC1J).

52. ^{13}C(p, α)^{10}B $Q_{\rm m} = -4.0627$

Angular distributions have been measured at $E_{\rm p} = 43.7$ and 50.5 MeV for the α-particle groups to ^{10}B*(1.74) [$L = 1$] and ^{10}B*(6.03) [$L = 3$] (1972MA21).

53. ^{13}C(^{11}B, ^{14}C)^{10}B $Q_{\rm m} = -3.2790$

See (1969BR1D, 1972MO1E, 1973SC1J).

54. (a) ^{14}N(γ, α)^{10}B $Q_{\rm m} = -11.6134$
(b) ^{14}N(p, αp)^{10}B $Q_{\rm m} = -11.6134$

For reaction (a) see (1959AJ76); for reaction (b) see (1961CL09).

55. ^{14}N(d, ^{6}Li)^{10}B $Q_{\rm m} = -10.140$

See (1970MC1G).

56. ^{14}N(^{3}He, ^{7}Be)^{10}B $Q_{\rm m} = -10.027$

At $E(^{3}\text{He}) = 41$ MeV, the population of ^{10}B*(0, 0.72, 2.16, 3.59, 6.1) has been observed. The transition to ^{10}B*(1.74) [$T = 1$] is very weak (1971DE37).

57. ^{15}N(^{11}B, ^{16}N)^{10}B $Q_{\rm m} = -8.966$

See (1969BR1D).

58. ^{16}O(p, ^{7}Be)^{10}B $Q_{\rm m} = -20.533$

See (1969HO1H).

59. ^{20}Ne(^{11}B, ^{21}Ne)^{10}B $Q_{\rm m} = -4.695$

See (1969BR1D).

^{10}C

(Figs. 21 and 22)

GENERAL: (See also (1966LA04).)

Model calculations: (1968FA1B, 1969SA1A, 1969SO08, 1973SA30).

Special reactions: (1967AU1B, 1969YI1A, 1971AR02).

Pion reactions (See also reaction 3.): (1973AL1E, 1973CH20).

Other topics: (1968FA02, 1968FA1B, 1969SO08, 1969SO1E, 1970FO1B, 1972AN05, 1972CA37).

Ground-state properties: (1966KE16, 1968FA02, 1968FA1B, 1969GA1G, 1973SA30).

1. ^{10}C(β^+)^{10}B $\quad Q_{\rm m} = 3.650$

^{10}C decays with a half-life of 19.42 ± 0.06 sec to ^{10}B*(0.7, 1.7): the branching ratios are 98.53 ± 0.02% and 1.465 ± 0.014%, respectively (1972RO03): see reaction 39 in ^{10}B and Tables 10.21 and 10.24.

2. ^{7}Be(^{3}He, 2p)^{4}He^{4}He $\quad Q_{\rm m} = 11.274 \quad E_{\rm b} = 14.999$

See (1972PA1C; astrophys.).

3. ^{9}Be(p, π^-)^{10}C $\quad Q_{\rm m} = -136.634$

At $E_{\rm p} = 185$ MeV the π^- spectrum shows groups corresponding to ^{10}C*(0, 3.36 ± 0.07, 5.28 ± 0.06, 6.63 ± 0.15). Angular distributions have been obtained for the π^- corresponding to these four states. The π^+/π^- intensity ratio is usually $\gg 1$ for analog states in ^{10}Be and ^{10}C (1973DA09). See also (1971DA10, 1972RO22, 1973DI1J).

4. ^{9}Be(^{3}He, 2n)^{10}C $\quad Q_{\rm m} = -5.566$

See (1973MO1N).

5. ^{10}B(p, n)^{10}C $\quad Q_{\rm m} = -4.433$

Table 10.24: Energy levels of ^{10}C

E_x (MeV ± keV)	$J^\pi; T$	τ or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
g.s.	$0^+; 1$	$\tau_{1/2} = 19.42 \pm 0.06$ sec [b]	β^+	1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
3.3527 ± 1.5	$2^+; 1$	$\tau_m = 155 \pm 25$ fsec	γ	3, 5, 6, 7, 9, 11
5.28 ± 40	$(2^+); 1$	$\Gamma = 300 \pm 50$		3, 5, 6, 9
6.60 ± 40		$\Gamma = 300 \pm 50$		3, 5, 6, 9
(10.2 ± 200)		$\Gamma \approx 1500$		9
10.72 [a]				11

[a] Three states with $E_x \approx 10$ MeV are reported in reaction 11 (preliminary results).
[b] (1974AZ01) report $\tau_{\frac{1}{2}} = 19.28 \pm 0.02$ sec.

$$E_{thresh.} = 4880.0 \pm 2.0 \text{ keV};$$

$$Q_0 = -4432.8 \pm 1.8 \text{ keV (1966FR09)}.$$

The first excited state of ^{10}C is located at $E_x = 3.3527 \pm 0.0015$ MeV (1969PA09: from γ-decay), 3.38 ± 0.03 MeV (1963EA01: neutron threshold), 3.35 ± 0.01 MeV (1966SE03: from γ-decay). τ_m for ^{10}C*(3.35) $= 155 \pm 25$ fsec; $\Gamma_\gamma = 4.25 \pm 0.69$ meV (1968FI09). Angular distributions have been measured for the n_0 and n_1 groups and for the neutrons corresponding to ^{10}C*(5.2±0.3) at $E_p = 30$ and 50 MeV. The excitation of ^{10}C*(6.5±0.3, 8.3±0.3, 8.9±0.3) is also reported (1970CL01). See also (1969BR13, 1973GO1V), (1966LA04) and ^{11}C in (1975AJ02).

6. ^{10}B(^{3}He, t)^{10}C $\qquad Q_m = -3.669$

At $E(^3\text{He}) = 14$ MeV the angular distribution of the t_0 group has been measured (1970NU02). At $E(^3\text{He}) = 30.6$ and 40 MeV triton groups have been observed to ^{10}C*(0, 3.37 ± 0.03, (5.03 ± 0.06), 5.28 ± 0.06, (5.60 ± 0.06), 6.58 ± 0.06) (1966MA36). At $E(^3\text{He}) = 30.3$ MeV, the energy of the first excited state is determined to be 3.344 ± 0.008 MeV, and the triton groups corresponding to the two states at $E_x = 5.03$ and 5.60 MeV suggested by (1966MA36) are assigned to ^{11}C (1968BR23). See also ^{13}N in (1976AJ04).

7. ^{10}B(^{6}Li, ^{6}He)^{10}C $\qquad Q_m = -7.160$

Both ^{10}C*(0, 3.35) are strongly populated at $E(^6\text{Li}) = 30$ MeV, $\theta = 16°$ (1972LE1P).

8. ^{12}C(γ, 2n)^{10}C $\qquad Q_m = -31.846$

See (1959OC07).

9. ^{12}C(p, t)^{10}C $\qquad Q_m = -23.364$

Angular distributions have been reported at $E_p = 30.0$ to 54.1 MeV (1967CO23; t_0), 43 MeV (1967BE27; t_0, t_1, and to ^{10}C*(5.3)), 43.7 MeV (1966CE05; t_0, t_1) and 49.5 MeV (1970NE17; t_0, t_1; polarized protons). $L = 0$, 2 and 2, respectively for ^{10}C*(0, 3.35, 5.3), and therefore $J^\pi = 0^+$, 2^+ and 2^+: see (1967BE27). [^{10}C*(5.3) may correspond to several unresolved states: see ^{10}Be.] At $E_p = 43$ and 52 MeV (1967BE27) report the excitation of ^{10}C*(5.29 ± 0.06, 6.61 ± 0.06) [$\Gamma_{c.m.} = 300 \pm 50$ keV for both these states]. The states at $E_x = 7.2 \pm 0.2$ and 10.2 ± 0.2 MeV reported by (1965BA17) are not observed. See also (1965CA1C, 1968TA1P) and (1971KA04; theor.).

10. ^{12}C(^{12}C, ^{10}C)^{14}C $\qquad Q_m = -18.723$

See (1972MO1E, 1973SC1J).

11. ^{13}C(^{3}He, ^{6}He)^{10}C $\qquad Q_m = -15.243$

At $E(^3\text{He}) = 70.3$ MeV the angular distributions of the ^{6}He ions corresponding to the population of ^{10}C*(0, 3.35) have been measured. The group to ^{10}C*(3.35) is much more intense than the ground state group: multi-step processes may be important (1973KA16). Three states of ^{10}C are observed with $E_x \approx 10$ MeV. One of these [$E_x = 10.72$ MeV] is very strongly populated. A search for a $T = 2$ state with $E_x \approx 22$ MeV was unsuccessful (1973BE2J).

12. ^{14}N(^{3}He, ^{7}Li)^{10}C $\qquad Q_m = -12.816$

See (1971DE37).

References

(Closed December 31, 1973)

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

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