Energy Levels of Light Nuclei
$A = 11$

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Abstract: An evaluation of $A = 11$–12 was published in *Nuclear Physics A*433 (1985), p. 1. This version of $A = 11$ 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 NNDC/TUNL format.

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Table of Contents for $A = 11$

Below is a list of links for items found within the PDF document. Figures from this evaluation have been scanned in and are available on this website or via the link below.

^{11}He

(Not illustrated)

^{11}He has not been observed: see (1980AJ01) and (1983ANZQ).

^{11}Li

(Figs. 1 and 4)

GENERAL

The mass excess of ^{11}Li is 40.94 ± 0.08 MeV (1975TH08). [(A.H. Wapstra, private communication) suggests 40.91 ± 0.11 MeV.] Using the value reported by (1975TH08) ^{11}Li is bound with respect to ^{9}Li$+$2n by 156 ± 80 keV and with respect to ^{10}Li$+$n by 966 ± 260 keV [see (1984AJ01) for the masses of ^{9}Li and ^{10}Li]. Systematics suggest $J^\pi = \frac{1}{2}^-$ for ^{11}Li$_{\text{g.s.}}$.

See also (1979AZ03, 1980AZ01, 1980BO31, 1981BO1X, 1982BO1Y, 1982OG02), (1981HA2C), (1979BO22, 1980MA1Z, 1981AV02, 1982KA1D, 1982NG01, 1983ANZQ, 1984VA06; theor.) and (1980AJ01).

1. ^{11}Li(β^-)^{11}Be $Q_{\text{m}} = 20.77$

The half-life of ^{11}Li is 8.5 ± 0.2 msec (1974RO31), 8.83 ± 0.12 msec (1981BJ01). (1981BJ01) recommend 8.7 ± 0.1 msec. The decay is complex: see Table 11.2. See also (1983RO1H).

Table 11.1: Energy Levels of ^{11}Li

E_{x} (MeV)	$J^\pi; T$	$\tau_{1/2}$ (msec)	Decay	Reaction
g.s.	$(\frac{1}{2}^-); \frac{5}{2}$	8.7 ± 0.1	β^-	1

^{11}Be

(Figs. 1 and 4)

GENERAL: (See also (1980AJ01).)

Model calculations: (1981RA06, 1981SE06, 1983MI1E, 1984VA06).

Electromagnetic transitions: (1980MI1G).

Complex reactions involving ^{11}Be: (1979BO22, 1980WI1L, 1983EN04, 1983WI1A, 1984GR08, 1984HI1A).

Hypernuclei: (1979BU1C, 1982IK1A, 1982KA1D, 1982KO11, 1983FE07, 1983KO1D, 1983MI1E).

Other topics: (1981SE06, 1982NG01).

Ground-state properties of ^{11}*Be:* (1981AV02, 1982NG01, 1983ANZQ).

Table 11.2: The β^- decay of ^{11}Li

Decay to ^{11}Be (MeV)	Branching ratio (%)	Log ft	β-delayed neutron decay to	Refs.
g.s.	≤ 2	≥ 6.3		(1981BJ01)
0.32 [a]	9.2 ± 0.7	5.59		(1981BJ01)
2.69 [b]			$^{10}Be_{g.s.} + n$	(1981JOZV)
3.89 [b]			^{10}Be*(3.37) + n	(1981JOZV)
3.96 [b]			^{10}Be*(3.37) + n	(1981JOZV)
10.59 [b,c]	2.9 ± 0.6		{ $^{8}Be_{g.s.} + 3n$; $^{6}He_{g.s.} + n + \alpha$ }	(1981LA11)
$\approx 18.5 \pm 0.5$ [b,d]	0.3 ± 0.05		^{8}Be*(3.0) + 3n	(1981LA11)

[a] The γ-ray from the decay of ^{11}B*(2.12) is observed (1980DE39).

[b] $P_{1n} = (85 \pm 1)$%, $P_{2n} = (4.1 \pm 0.4)$%, $P_{3n} = (1.9 \pm 0.2)$%. The fraction of 1n transitions to excited states of ^{10}Be is (41 ± 4)% (1981BJ01). (1980DE39) observe γ-rays from the decay of ^{10}Be*(3.37, 5.96, 6.18). [The work on the β^- decay of ^{11}Li does not exclude transitions to other states of ^{11}Be.]

[c] This state appears to decay by sequential 3n transitions via ^{10}Be*(9.4) and ^{9}Be*(2.43) to $^{8}Be_{g.s.}$ [(2.0 ± 0.6)%] and by n + α decay via ^{10}Be*(9.4) to $^{6}He_{g.s.}$ [(0.9 ± 0.3)%] (1981LA11).

[d] This state has not been reported in any other reaction. (1981LA11) report its decay by 3n emission to ^{8}Be*(3.0).

1. ^{11}Be(β^-)^{11}B $\qquad Q_m = 11.508$

The decay is complex: see reaction 28 in ^{11}B and Table 11.13. The half-life is 13.81 ± 0.08 sec (1970AL21). See also (1980AJ01).

2. ^{9}Be(t, p)^{11}Be $\qquad Q_m = -1.167$

Proton groups have been observed to the states displayed in Table 11.3. τ_m for the first excited state is 166±15 fsec (1983MI08), corresponding to a very large E1 transition strength of 0.36±0.03

W.u.; $E_\gamma = 320.04 \pm 0.10$ keV (see (1983MI08)). The J^π of ^{11}Be*(0.32) is $\frac{1}{2}^-$, as determined by a study of the yield of 320 keV γ-rays as a function of time in μ^- capture by ^{11}B. The strength of the E1 transition fixes J^π of ^{11}Be$_{\rm g.s.}$ to be $\frac{1}{2}^+$ or $\frac{3}{2}^+$, using the parity information obtained from the nature of the β^- decay of the ground state [see reaction 28 in ^{11}B]. ^{11}Be*(5.24, 6.71, 8.82) are strongly populated at $E_{\rm t} = 20$ MeV indicating that these states have a large overlap with ^{9}Be$_{\rm g.s.}$ + two neutrons. See (1980AJ01) for references.

Table 11.3: Energy Levels of ^{11}Be

$E_{\rm x}$ (MeV $\pm$ keV)	$J^\pi; T$	τ or $\Gamma_{\rm c.m.}$ (keV)	Decay	Reactions
0	$\frac{1}{2}^+; \frac{3}{2}$	$\tau_{1/2} = 13.81 \pm 0.08$ sec	β^-	1, 2, 4, 6
0.32004 ± 0.1	$\frac{1}{2}^-$	$\tau_{\rm m} = 166 \pm 15$ fsec	γ	2, 4, 5, 6, 7
1.778 ± 12	$(\frac{5}{2}, \frac{3}{2})^+$	$\Gamma = 100 \pm 20$	(n)	2, 4, 6
2.69 ± 20	$(\frac{1}{2}^\pm, \frac{3}{2}^\pm, \frac{5}{2}^+)$	200 ± 20	(n)	2, 7
3.41 ± 20	$(\frac{1}{2}^\pm, \frac{3}{2}^\pm, \frac{5}{2}^+)$	125 ± 20	(n)	2, 6
3.887 ± 15	$\geq \frac{7}{2}$	< 10	(n)	2
3.956 ± 15	$\frac{3}{2}^-$	15 ± 5	(n)	2, 7
5.240 ± 21		45 ± 10	(n)	2
(5.86)		≈ 300	(n)	2
6.51 ± 50		120 ± 50	(n)	2
6.705 ± 21		40 ± 20	(n)	2
7.03 ± 50		300 ± 100	(n)	2
8.816 ± 32		200 ± 50	(n)	2
10.59 ± 50		210 ± 40	(n)	2
[a]				

[a] See also Table 11.2.

3. ^{10}Be(n, γ)^{11}Be $\qquad Q_{\rm m} = 0.503$

See (1975AJ02).

4. ^{10}Be(d, p)^{11}Be $\qquad Q_{\rm m} = -1.722$

Angular distributions of the p_0 and p_1 groups have been measured at $E_d = 6$ MeV and 12 MeV: $l_n = 0$ [and therefore $J^\pi = \frac{1}{2}^+$ for ^{11}Be(0)] and 1, $S = 0.73 \pm 0.06$ and 0.63 ± 0.15, respectively. At $E_d = 25$ MeV ^{11}Be*(0, 0.32, 1.78) are strongly populated: $S = 0.77$, 0.96 and 0.50, respectively, $J^\pi = (\frac{5}{2}, \frac{3}{2})^+$ for ^{11}Be*(1.78) ($l_n = 2$)]. See (1980AJ01) for references.

5. ^{11}Li(β^-)^{11}Be † $\qquad Q_m = 20.76$

† Certain reactions on which no new work has been published will not be discussed in this review: see (1980AJ01).

See ^{11}Li.

6. ^{12}C(^{7}Li, ^{8}B)^{11}Be $\qquad Q_m = -28.189$

At $E(^7\text{Li}) = 82{-}83$ MeV groups corresponding to ^{11}Be*(0, 1.8, 3.4) are reported by (1982AL08, 1983AL20).

7. ^{13}C(^{6}Li, ^{8}B)^{11}Be $\qquad Q_m = -25.885$

At $E(^6\text{Li}) = 80$ MeV, ^{11}Be*(0.32) is strongly populated and the angular distribution to this state has been measured. ^{11}Be*(2.69, 4.0) are also observed: see (1980AJ01).

^{11}B

(Figs. 2 and 4)

GENERAL: (See also (1980AJ01).)

Shell and deformed models: (1981BO1Y, 1981RA06, 1982BO01, 1983VA31, 1984VA06).

Cluster model: (1979NI06, 1980FU1G, 1983SH38).

Special states: (1979NI06, 1980RI06, 1981BO1Y, 1981RA06, 1981SE06, 1983GO1R, 1983VA31, 1984GO1M, 1984VA06).

Electromagnetic transitions and giant resonances: (1978KR19, 1979DO17, 1979NI06, 1980FU1G, 1980KO1L, 1980RI06, 1981BO1Y, 1982AW02, 1982GO03, 1984KU07).

Astrophysical questions: (1978OR1A, 1979BJ1A, 1979RA1C, 1980CO1R, 1980DO1C, 1980FR1G, 1980RE1B, 1981AU1D, 1981AU1G, 1981GA1C, 1981GU1D, 1982SC1E, 1983HO15, 1983SI1B).

Applied work: (1980MU1D, 1981KU1C, 1983AM1A, 1983FI1C).

Complex reactions involving ^{11}B: (1978VO10, 1979AL22, 1979BO22, 1979GE1A, 1979SA27, 1979SA26, 1979SC1D, 1979ST1D, 1980GR10, 1980MI01, 1980MO28, 1980RI06, 1980WI1L, 1981BH02, 1981CI03, 1981ME13, 1981MO20, 1981TA16, 1981TA22, 1982BI1C, 1982FU04, 1982JA1C, 1982LU01, 1982LY1A, 1982MO1K, 1982WU1B, 1983CH23, 1983EN04, 1983FU04, 1983HA1C, 1983OL1A, 1983SA06, 1983SC1L, 1983SI1A, 1983SO08, 1983WA1F, 1983WI1A, 1984GO03, 1984GR08, 1984HI1A, 1984VO06).

Muon and neutrino capture and reactions (See also reaction 48.): (1980SC18, 1981MU1E, 1981OL01).

Pion and kaon capture and reactions (See also reactions 21, 32 and 50.): (1979AL1J, 1979AL21, 1979BA16, 1979BU1C, 1979KI1G, 1979PE1D, 1979PI1C, 1979ZI05, 1980DE11, 1980GR1G, 1980LE02, 1980SO05, 1980ZI1B, 1981BE63, 1981FE2A, 1981FR17, 1981GE1B, 1981RO1L, 1981RO1R, 1981TH1B, 1981ZI01, 1982DE1K, 1982ER04, 1983AN1F, 1983BA71, 1983FE07, 1983GE12, 1983GE13, 1983MO1F, 1983RO07, 1983ZE1C).

Hypernuclei: (1978SO1A, 1979BU1C, 1980IW1A, 1981ST1G, 1981WA1J, 1982DO1L, 1982ER1E, 1982GR1P, 1982KA1D, 1982KO11, 1982RA1L, 1983CH1T, 1983DO1B, 1983FE07, 1983SH38).

Other topics: (1979NI06, 1981CA1H, 1981SE06, 1982AW02, 1982BE17, 1982DE1N, 1982NG01, 1983GO1R).

Ground-state properties of ^{11}B (See also reactions 31 and 32.): (1979AL26, 1979NI06, 1979SA27, 1980BA45, 1980FU1G, 1980HO14, 1981AV02, 1981BO1Y, 1981OL01, 1981SE06, 1982BA37, 1982BO01, 1982LO13, 1982NG01, 1983ANZQ, 1983BU07, 1983MI08, 1983VA31, 1984KU07, 1984MI1B).

$$\mu = +2.688637(2) \text{ nm (1978LEZA)},$$

$$Q = 40.65(26)$$ mb [see (1980AJ01)],

$$B(\text{E2}; \tfrac{3}{2}^- \rightarrow \tfrac{1}{2}^-) = 2.1 \pm 0.4\ e^2 \cdot \text{fm}^4$$ (1980FE07).

Table 11.4: Energy Levels of ^{11}B

E_x (MeV ± keV)	$J^\pi; T$	τ_m (fsec) [a] or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
0	$\frac{3}{2}^-; \frac{1}{2}$	stable	—	1, 2, 6, 7, 8, 12, 13, 14, 15, 16, 17, 21, 22, 23, 24, 25, 28, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63
2.124693 ± 0.027	$\frac{1}{2}^-$	$\tau_m = 5.5 \pm 0.4$	γ	1, 6, 7, 8, 12, 13, 14, 15, 16, 17, 21, 22, 23, 28, 30, 31, 33, 34, 37, 38, 41, 46, 48, 49, 50, 51, 52, 53, 54, 55, 57, 58, 59, 60, 61, 62, 63
4.44489 ± 0.50	$\frac{5}{2}^-$	1.18 ± 0.04	γ	1, 2, 6, 7, 8, 12, 13, 14, 17, 21, 22, 23, 25, 27, 28, 30, 31, 33, 34, 37, 38, 41, 49, 51, 52, 53, 54, 58, 59, 60, 61, 62, 63
5.02031 ± 0.30	$\frac{3}{2}^-$	0.34 ± 0.01	γ	1, 6, 7, 8, 13, 14, 21, 22, 23, 25, 28, 30, 31, 33, 34, 37, 38, 49, 50, 52, 53, 54, 58, 59, 60, 61, 63
6.7429 ± 1.8	$\frac{7}{2}^-$	22 ± 5	γ	1, 2, 6, 13, 14, 17, 21, 22, 23, 25, 27, 30, 34, 37, 38, 49, 52, 53, 55, 58, 59, 60, 62, 63
6.79180 ± 0.30	$\frac{1}{2}^+$	1.7 ± 0.2	γ	1, 2, 6, 13, 14, 21, 22, 23, 28, 30, 34, 38, 41, 52, 53, 55, 63

Table 11.4: Energy Levels of ^{11}B (continued)

E_x (MeV ± keV)	$J^\pi; T$	τ_m (fsec) [a] or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
7.28551 ± 0.43	$\frac{5}{2}^+$	0.57 ± 0.04	γ	1, 2, 6, 12, 13, 14, 21, 22, 23, 28, 30, 34, 53, 63
7.97784 ± 0.42	$\frac{3}{2}^+$	0.57 ± 0.06	γ	1, 2, 13, 21, 22, 28, 30, 34
8.5603 ± 1.8	$\leq \frac{5}{2}^-$	0.70 ± 0.07	γ	1, 12, 13, 21, 22, 30, 31, 34, 59
8.9202 ± 2.0	$\frac{5}{2}^-$	$\Gamma = 4.37 \pm 0.02$ eV	γ, α	1, 2, 12, 13, 17, 21, 22, 25, 26, 30, 31, 34, 58, 59
9.1850 ± 2.0	$\frac{7}{2}^+$	$1.9^{+1.5}_{-1.1}$ eV	γ, α	1, 2, 13, 21, 22, 26, 34, 61
9.2744 ± 2	$\frac{5}{2}^+$	4	γ, α	1, 2, 13, 21, 22, 34, 61
9.876 ± 8	$\frac{3}{2}^+$	110 ± 15	α	5, 13, 28
10.26 ± 15	$\frac{3}{2}^-$	165 ± 25	γ, α	2, 5, 13
10.33 ± 11	$\frac{5}{2}^-$	110 ± 20	γ, α	2, 5, 13, 22, 34
10.597 ± 9	$\frac{7}{2}^+$	100 ± 20	γ, α	2, 5, 13, 18, 20, 34
10.96 ± 50	$\frac{5}{2}^-$	4500	α	5
11.265 ± 17	$\frac{9}{2}^+$	110 ± 20	α	5, 13
11.444 ± 19		103 ± 20	α	5, 13
11.589 ± 26	$\frac{5}{2}^+$	170 ± 30	n, α	3, 5, 13, 18, 20, 34
11.886 ± 17	$\frac{5}{2}^-$	200 ± 20	n, α	3, 5, 13, 18, 20
12.0 ± 200	$\frac{7}{2}^+$	≈ 1000	n, α	5, 18, 20
12.557 ± 16	$\frac{1}{2}^+(\frac{3}{2}^+); \frac{3}{2}$	210 ± 20	γ, p, α	5, 13, 16, 37
12.916 ± 12	$\frac{1}{2}^-; \frac{3}{2}$	155 ± 25	γ, p, α	5, 13, 16, 34, 37, 58
13.137 ± 40	$\frac{9}{2}^-$	426 ± 40	n, t, α	3, 13, 18, 19, 20
13.16	$\frac{5}{2}^+, \frac{7}{2}^+$	430	n, α	18, 20
14.04 ± 100	$\frac{11}{2}^+$	500 ± 200	n, α	3, 18, 20
14.34 ± 20	$\frac{5}{2}^+; \frac{3}{2}$	254 ± 18	γ, p	13, 16, 37
14.565 ± 15		≤ 30	n, t, α	3, 5, 13, 18, 19, 20, 37
15.32 ± 100	$(\frac{3}{2}, \frac{5}{2}, \frac{7}{2})^+; (\frac{3}{2})$	635 ± 180	γ, p, n, α	16, 18, 20, 34

Table 11.4: Energy Levels of ^{11}B (continued)

E_x (MeV $\pm$ keV)	$J^\pi; T$	τ_m (fsec) [a] or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
16.437 ± 20	$T = \frac{3}{2}$	≤ 30	p, d, α	10, 13, 31, 34
17.33		≈ 1000	n, d, t, α	10, 19, 20
17.43 ± 50	$T = \frac{3}{2}$	100 ± 30	γ, n, p, d, α	3, 8, 10, 13
18.0	$T = \frac{3}{2}$	870 ± 100		13
18.37 ± 50	$(\frac{1}{2}, \frac{3}{2}, \frac{5}{2})^+$	260 ± 80	γ, d	8
19.146 ± 30	$(\pi = +); \frac{3}{2}$	115 ± 25		13
19.7	$(\frac{1}{2}^+)$	broad	γ, d	8, 29
21.27 ± 50	$T = \frac{3}{2}$	300 ± 30		13
23.7	$(\frac{1}{2}, \frac{3}{2}, \frac{5}{2})^+$		γ, d	8
26.5		broad	γ, n	29

[a] From Table 11.5.

1. ^{6}Li(^{6}Li, p)^{11}B $Q_m = 12.215$

Angular distributions have been measured for proton groups to states with $E_x < 9.3$ MeV at $E(^6\text{Li}) = 2.4$ to 9.0 MeV: see (1980AJ01).

2. ^{7}Li(α, γ)^{11}B $Q_m = 8.665$

Resonances for capture radiation are displayed in Table 11.6.

3. ^{7}Li(α, n)^{10}B $Q_m = -2.7898$ $E_b = 8.665$

Table 11.7 displays the thresholds and resonances observed in this reaction. (1981SE04) have measured thick-target yields ($\pm 6\%$) for $E_\alpha = 4.385$ to 5.1 MeV at a number of angles: a broad resonance is observed near $E_\alpha = 4.7$ MeV. Thick-target yields have also been reported from threshold to 9.00 MeV (1979BA48).

Table 11.5: Electromagnetic transitions in ^{11}B [a]

Initial state	J^π	Γ_γ (total) (eV)	Branching ratios (%) to final state						
			g.s.	2.12	4.44	5.02	6.74	6.79	7.29
2.12	$\frac{1}{2}^-$	0.120 ± 0.009	100						
4.44 [b]	$\frac{5}{2}^-$	0.56 ± 0.02	100 [e]						
5.02 [b]	$\frac{3}{2}^-$	1.963 ± 0.067	85.6 ± 0.6 [f]	14.4 ± 0.6 [g]					
6.74 [b]	$\frac{7}{2}^-$	0.030 ± 0.007 [j]	70 ± 2 [h]	< 3	30 ± 2	< 1			
6.79 [b]	$\frac{1}{2}^+$	0.385 ± 0.044	67.5 ± 1.1	28.5 ± 1.1	< 0.04	4.0 ± 0.3			
7.29 [b]	$\frac{5}{2}^+$	1.149 ± 0.080	87.0 ± 2.0	< 1	5.5 ± 1	7.5 ± 1			
7.98 [b]	$\frac{3}{2}^+$	1.15 ± 0.15	46.2 ± 1.1	53.2 ± 1.2	< 0.06	< 0.09		< 0.10	0.85 ± 0.04
8.56 [b,l]	$\leq \frac{5}{2}^-$	0.946 ± 0.090	56 ± 2	30 ± 2	5 ± 1	9 ± 1			
8.92 [b]	$\frac{5}{2}^-$	4.368 ± 0.021	95 ± 1 [i]	< 1	4.5 ± 0.5	< 1	< 1	< 1	
9.19 [c,k]	$\frac{7}{2}^+$	$0.17^{+0.06}_{-0.03}$	0.9 ± 0.3		86.6 ± 2.3		12.5 ± 1.1	< 1.3	
9.27 [c,k]	$\frac{5}{2}^+$	1.15 ± 0.16	18.4 ± 0.9		69.7 ± 1.4		11.9 ± 0.6	< 0.6	
[d]									

[a] See discussion in (1982MI08). See also Table 11.4 in (1980AJ01) and Tables 11.6 and 11.14 here.

[b] See also (1965OL03).

[c] See also (1962GR07).

[d] See also Tables 11.6, 11.13 and 11.14.

[e] $\delta = -0.19 \pm 0.03$ (1968BE30).

[f] $\delta = 0.03 \pm 0.05$ (1968BE30).

[g] $\delta = -0.05 \pm 0.02$ (1968BE30).

[h] $\delta = -0.45 \pm 0.18$ (1968CO09). This value leads to too large a value of Γ_γ for an M3 transition (P.M. Endt, private communication).

[i] $\delta = -0.11 \pm 0.04$ (1968CO09).

[j] See also (1979AN16).

[k] Weighted mean of branching ratios and Γ_γ (1984HA13). Earlier work is also included: see (1984HA13).

[l] This is probably the ^{11}B analog of ^{11}C*(8.10). If so $J^\pi = \frac{3}{2}^-$.

Comments [mainly from (1962GR07, 1965OL03)]:

(1) *4.44 MeV.* $9.28 \rightarrow 4.44 \rightarrow 0$ angular distribution fixes $J = \frac{5}{2}$. Odd parity determined from direct interaction assignments.

(2) *5.02 MeV.* Internal pair correlation permit M1, E2 for the g.s. transition: $J^\pi \leq \frac{7}{2}^-$ (parity from l-assignments). $\tau_{\rm m}$ excludes $\frac{7}{2}$, branch to 2.12, $\frac{5}{2}$. Angular correlation fixes $\frac{3}{2}^-$.

(3) *6.74 MeV.* Internal pairs indicate practically pure E2 g.s. radiation. Angular distributions and branching ratios and (l-assignments) all lead to $\frac{7}{2}^-$.

(4) *6.79 MeV.* The allowed β-decay from ^{11}Be indicates $J^\pi \leq \frac{7}{2}^+$. The relatively strong γ-branch to ^{11}B*(2.12) favors $\frac{1}{2}^+$, $\frac{3}{2}^+$. All γ's from this level are isotropic, suggesting $J^\pi = \frac{1}{2}^+$, but not excluding $\frac{3}{2}^+$.

(5) *7.29 MeV.* The g.s. tansition is mainly E1, so $J^\pi \leq \frac{5}{2}^+$. The assignment $\frac{1}{2}^+$ is excluded by the strength of $(7.29 \rightarrow 4.44)$. $J^\pi = \frac{5}{2}^+$ is consistent with $\log ft > 8.04$ in the ^{11}Be β-decay.

(6) *7.98 MeV.* Transitions to ^{11}Be$_{\rm (g.s.)}$ and (2.12) are predominantly E1; thus ^{11}B*(7.98) has even parity, and the odd parity of ^{11}B*(2.12) is confirmed. The transition to ^{11}B*(2.12) is not isotropic, so $J^\pi = \frac{3}{2}^+$.

(7) *8.56 MeV.* Correlation of internal pairs indicate that the g.s. transition is M1 + E2 or E1 + M2, $J^\pi \leq \frac{5}{2}^+$ or $\leq \frac{7}{2}^-$; the lifetime to ^{11}B*(2.12) excludes $\frac{7}{2}^-$. If the level has even parity, the required M2 admixture is excessive. $J^\pi \leq \frac{5}{2}^-$ is favored.

(8) *8.92 MeV.* From ^{7}Li(α, γ)^{11}B, $J^\pi = \frac{3}{2}^+$, $\frac{5}{2}^+$, $\frac{5}{2}^-$. The internal pair correlation confirms $\frac{5}{2}^-$. For higher states see comments under individual reactions and (1968AJ02).

Table 11.6: Resonances in ^{7}Li(α, γ)^{11}B [a]

$E_{\rm res}$ (keV)	$\Gamma_{\rm c.m.}$ (keV)	^{11}B* (MeV)	J^π	$\omega\gamma$ (eV)	$\Gamma_{\gamma 0}$ (eV)	Percentage decay to ^{11}B*			
						0	4.44	6.74	6.79
401 ± 3 [b]	4.37 ± 0.02 eV	8.920	$\frac{5}{2}^-$	$(8.8 \pm 1.4) \times 10^{-3}$	4.15 ± 0.02 [c]	95 ± 1	4.5 ± 0.5		
814 ± 2 [b]	$1.8^{+1.5}_{-1.1}$ eV	9.183	$\frac{7}{2}^+$	0.310 ± 0.047	$0.17^{+0.05}_{-0.01}$ [d]	0.9 ± 0.3 [a]	90.8 ± 4.0	8.3 ± 1.0	< 1.3
953 ± 2 [b]	4	9.272	$\frac{5}{2}^+$	1.72 ± 0.24	0.20 ± 0.03 [c]	17.1 ± 1.0	71.7 ± 1.8	11.2 ± 0.6	< 0.6 [e]
2500 ± 20	433	10.26			17	[f]			
2620 ± 20	100	10.33			1.0	[f]			
2800 ± 50	≈ 140	10.45			$10/2J + 1$				
(3040)	90	(10.60)			< 0.2	[f]			

[a] See Table 11.6 in (1980AJ01) for comments and references.

[b] Γ_α(c.m.) $= (5.9 \pm 0.9) \times 10^{-3}$, $1.6^{+1.5}_{-1.1}$, and 4×10^3 eV for ^{11}B*(8.92, 9.19, 9.27) (1984HA13). See also Table 11.5.

[c] See Table 11.5.

[d] Γ_γ, not Γ_{γ_0}. See also Table 11.5.

[e] The decay to ^{11}B*(7.29, 7.98) [$J^\pi = \frac{5}{2}^+, \frac{3}{2}^+$] is also observed: $\approx 1\%$ and $\approx 0.03\%$ respectively.

[f] $< 10\%$ to ^{11}B*(2.12).

4. ^{7}Li(α, t)^{8}Be $\qquad Q_m = -2.5599 \qquad E_b = 8.665$

Excitation functions have been measured for $E_\alpha = 14$ to 25 MeV (t_0) and 18 to 25 MeV(t_1): see (1980AJ01). See also ^{8}Be in (1984AJ01).

5. ^{7}Li(α, α)^{7}Li $\qquad E_b = 8.665$

The elastic scattering and the scattering to ^{7}Li*(0.48) have been studied at many energies to $E_\alpha = 22.5$ MeV. Recent measurements are reported by (1979ST25; α_0; $E_\alpha = 1.36 - 3.20$ MeV) and (1981WA1P; α_0; $E_\alpha = 5.0$ and 6.0 MeV). Observed resonances are displayed in Table 11.8 here. Additional parameters are shown in Table 11.9 of (1975AJ02). See also (1982WA23) and (1980BA2K; theor.).

6. ^{7}Li(^{6}Li, d)^{11}B $\qquad Q_m = 7.189$

Angular distributions have been measured for $E(^7\text{Li}) = 3.3$ to 5.95 MeV: see (1975AJ02). See also ^{13}C in (1981AJ01).

7. ^{7}Li(^{7}Li, t)^{11}B $\qquad Q_m = 6.196$

Angular distributions have been measured at $E(^7\text{Li}) = 2.10$ to 5.75 MeV. At $E(^7\text{Li}) = 79.6$ MeV transitions are observed to several ^{11}B states. $^{11}\text{B}_{\text{g.s.}}$ is particularly strongly populated. See (1975AJ02) for references.

8. ^{9}Be(d, γ)^{11}B $\qquad Q_m = 15.816$

The $90°$ γ_0 differential cross section has been measured for $E_d = 0.5$ to 11.9 MeV: see (1975AJ02). The behavior of the γ_0, γ_1 and γ_{2+3} total cross sections and of the angular distributions of these γ-rays indicate two resonances at $E_d = 1.98 \pm 0.05$ and 3.12 ± 0.05 MeV with $\Gamma_{\text{lab}} = 225 \pm 50$ and 320 ± 100 keV, corresponding to ^{11}B*(17.43, 18.37). The higher resonance was not observable in the $\gamma_2 + \gamma_3$ cross section which was not measured beyond $E_d = 2.5$ MeV. The maximum γ_0 cross section observed is 10.1 ± 3.5 μb at $E_d \approx 0.96$ MeV. Resonant behavior is observed in the $90°$ γ_0 cross section at $E_d \approx 3.4$ and 9.65 MeV (^{11}B*(18.6, 23.7)) in addition to a wide structure at 4.7 MeV (^{11}B*(19.7)). The angular distributions of γ_0 from ^{11}B*(18.6, 23.7) are typical of E1 transitions. The (d, γ_0) reaction appears to proceed via excitation of the $T = \frac{1}{2}$ component of the giant dipole resonance in ^{11}B.

Table 11.7: Threshold and resonances in ^{7}Li(α, n)^{10}B [a]

E_α (MeV $\pm$ keV)	E_x (MeV $\pm$ keV)
4.380 ± 20	thresh.
$[4.72]$ [b]	11.67 ± 100
5.15 ± 70 [c,d]	11.99 ± 100
5.5	thresh.
7.10 [d,e]	13.15 ± 100
$[8.44]$	14.04 ± 100
$[9.21]$	14.53 ± 50
10.14	15.12 ± 100
$[11.33]$	(15.88 ± 200)
11.90	thresh.
12.56	(16.7 ± 300)
13.92	17.52 ± 30
14.53	thresh.

[a] For references see Table 11.7 in (1980AJ01).

[b] See also (1981SE04); broad structure.

[c] $J^\pi = \frac{3}{2}^-$ or $\frac{5}{2}^+$, $\Gamma_n \approx 300$ keV formed by $l_n = 0$ or 1 [comparison with ^{10}B(n, α)], $\Gamma_{lab} = 220$ keV.

[d] The n_0 yield shows the resonance at $E_\alpha \approx 5.2$ and 7.05 MeV: no others seen in the interval $4.5 < E_\alpha < 8$ MeV.

[e] The width of this resonance is large.

9. ^{9}Be(d, n)^{10}B $\qquad Q_m = 4.3620 \qquad E_b = 15.816$

The cross section follows the Gamow function for $E_d = 70$ to 110 keV. The fast-neutron and gamma yield rise smoothly to $E_d = 1.8$ MeV except for a possible "resonance" at $E_d \approx 0.94$ MeV. The fast neutron yield then remains approximately constant to 3 MeV: see (1968AJ02) for references. The excittion functions for $n_0 \rightarrow n_4$, and n to ^{10}B*(5.1, 6.57) have been measured for $E_d = 14$ to 16 MeV: no strong fluctuations are observed: see (1975AJ02). Thick-target yields for γ-rays have been measured at $E_d = 48$ to 170 keV (1982CE02; also deduced astrophysical S-factors). Thick-target yields are also reported at $E_d = 14.8$, 18.0 and 23.0 MeV: see (1980AJ01). Polarization measurements have been carried out at $E_d = 0.4$ to 5.5 MeV [see (1975AJ02, 1980AJ01)] and at $E_{\vec{d}} = 12.3$ MeV (1981BR1E, 1983LIZW; VAP; n_0, n_1, n_2). See also (1979GR2D; applied) and ^{10}B in (1984AJ01).

Table 11.8: Structure in ^{7}Li(α, α)^{7}Li and ^{7}Li(α, α')^{7}Li [a]

E_{α} [b] (keV)	E_{α} [c] (keV)	$\Gamma_{\text{c.m.}}$ (keV)	E_{x} (MeV $\pm$ keV)	J^{π}
1900 ± 10 [d]		130 ± 30	9.875 ± 10	$\frac{3}{2}^{+}$
2480 ± 50		150 ± 40	10.24 ± 50	$\frac{3}{2}^{(-)}$, $\frac{1}{2}$
	2630 ± 30	80 ± 30	10.34 ± 30	$\frac{5}{2}^{-}$, $\frac{7}{2}$
3040 ± 10 [d]	3040	70 ± 10	10.601 ± 10	$\frac{7}{2}^{+}$
3600 ± 50		4500	10.96 ± 50	$\frac{5}{2}^{-}$
	4120 ± 30	90 ± 50	11.29 ± 30	$\frac{9}{2}^{+}$
4430 ± 50	4430		11.49 ± 50	
4600 ± 50		150 ± 50	11.59 ± 50	
5050 ± 30		150 ± 50	11.88 ± 30	
	5300 ± 200	≈ 1000	12.0 ± 200	
	5500 ± 100	60 ± 50	(12.17 ± 100) [e]	
6100 ± 30		150 ± 50	12.55 ± 30	
6850 ± 60		270 ± 50	13.03 ± 60	
(7200 ± 50) [f]		50 ± 50	(13.25 ± 50) [e]	
	7800 ± 100	500 ± 200	(13.63 ± 100) [e]	
(8450 ± 200) [g]		500 ± 200	(14.0 ± 200)	
(9450 ± 200) [g]		≤ 250	(14.7 ± 200)	
	9950 ± 20	500 ± 200	(15.00 ± 20) [e]	
(11200 ± 200) [g]			(15.8 ± 200)	
[h]				

[a] (1966CU02), except where shown. See also Table 11.9 in (1975AJ02) and (1979ST25).

[b] ^{7}Li(α, $\alpha'\gamma$)^{7}Li: σ (total).

[c] ^{7}Li(α, α_0)^{7}Li.

[d] (1967PA19). Other values are listed in Table 11.8 of (1975AJ02).

[e] ^{7}Li(α, n)^{10}B threshold.

[f] Anomaly in angular distribution.

[g] Observed at $\theta = 60°$.

[h] For possible higher structures see (1971BI12, 1973KE13).

10. (a) ^{9}Be(d, p)^{10}Be $\quad Q_m = 4.5875 \quad E_b = 15.816$

(b) ^{9}Be(d, α)^{7}Li $\quad Q_m = 7.152$

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

Measurements of proton yields have been carried out at E_d up to 6.0 MeV for p_0 and p_1 [see (1975AJ02, 1980AJ01)] and at $E_{\vec{d}} = 29$ to 170 keV (1981CE04; thick target yield; $\sigma(\theta)$ at $150°$; deduction of astrophysical $S(\theta, E)$) and at $E_{\vec{d}} = 1.4$ to 2.5 MeV (1980DE45; p_0, p_1). The p_0 and p_1 yields show a resonance at $E_d = 750 \pm 15$ keV [^{11}B*(16.43), $\Gamma \approx 40$ keV] and the p_1 yield resonates at 1.85 MeV [^{11}B*(17.33), $\Gamma_{c.m.} \approx 1.0$ MeV] and 2.3 MeV [^{11}B*(17.70), sharp]. See also (1975AJ02) and (1980DE45) for other possible structures. Polarization of the protons have been measured at $E_d = 1$ to 21 MeV [see (1975AJ02, 1980AJ01)] and at $E_{\vec{d}} = 1.4$ to 2.5 MeV (1980DE45; VAP; p_0, p_1) and 2.0 to 2.8 MeV (1984AN1R; p_0, p_1). See also ^{10}Be in (1984AJ01) and (1984DE1W; theor.).

The yeild of α-particles (reaction (b)) has been measured for $E_d = 0.3$ to 14.43 MeV [see (1975AJ02, 1980AJ01)], at $E_{\vec{d}} = 1.4$ to 2.4 MeV (1980DE42, 1980DE43, 1980DE44; yields of α_0, α_1 and VAP) and 2.0 to 2.8 MeV (1984AN1R; α_0, α_1). The 0.75 MeV resonance, observed in reaction (a), is weakly populated in the α_0 yield. See also ^{7}Li in (1984AJ01).

The cross section for reaction (c) has been measured for $E_d = 0.15$ to 19 MeV: see (1968AJ02, 1975AJ02, 1980AJ01). Polarization measurements are reported at $E_{\vec{d}} = 12$ and 15 MeV [see (1980AJ01)] and at $E_{\vec{d}} = 2.0$ to 2.8 MeV (1984AN1R; t_0). There is no clear evidence of resonance structure. See also ^{8}Be in (1984AJ01).

11. ^{9}Be(d, d)^{9}Be $\quad E_b = 15.816$

Excitation functions for elastically scattered deuterons have been measured for $E_d = 0.4$ to 7.0 MeV and for 12.17 to 14.43 MeV (also d_1, d_2) [see (1975AJ02, 1980AJ01)] and at $E_{\vec{d}} = 2.0$ to 2.8 MeV (1982DE1P; also VAP). Polarization measurements have also been reported at $E_{\vec{d}} = 6.3$ to 15 MeV [see (1975AJ02, 1980AJ01)]. See also ^{9}Be in (1984AJ01).

12. ^{9}Be(t, n)^{11}B $\quad Q_m = 9.559$

Angular distributions have been measured at $E_t = 1.1$ to 1.7 MeV (n_0, n_1, n_2, n_6, n_8, n_9): see (1980AJ01).

13. ^{9}Be(^{3}He, p)^{11}B $\quad Q_m = 10.323$

Proton groups have been observed to a number of ^{11}B states: see Table 11.9. Angular distributions have been obtained at a number of energies in the range $E(^3\text{He}) = 1.0$ to 14 MeV [see (1980AJ01)], at $E(^3\text{He}) = 13.0$ to 14.2 MeV (1983PO13; p_0), at $E(^3\vec{\text{He}}) = 33$ MeV (1983LE17; $p_0 \rightarrow p_3$) and at $E(^3\text{He}) = 38$ MeV (1982ZW02). It is suggested that the $T = \frac{1}{2}$ strength is strongly fragmented (1982ZW02). See also (1983BI1P, 1983ZW1A).

At $E(^3\text{He}) = 13.6$ MeV (1982HA06) find equal values for the polarization in this reaction, and the analyzing power in the ^{11}B(p, ^{3}He) reaction, showing no violation of time-reversal invariance. This is confirmed by (1983RO22) at $E(^3\vec{\text{He}}) = 33$ MeV. See also (1981SL03, 1984PO02), (1968AJ02) and ^{12}C.

14. ^{9}Be(α, d)^{11}B $\qquad Q_m = -8.031$

Angular distributions have been measured at a number of energies in the range $E_\alpha = 23.4$ to 28.3 MeV [see (1980AJ01)] and at 30.1 MeV (1983VA1H; $d_0 \rightarrow d_3$). The predominant L-transfers are $L = 0$, 2; 0; 0 for ^{11}B*(0, 2.12, 5.02). The angular distribution to ^{11}B*(4.44) is flat at $E_\alpha = 27$ MeV. At $E_\alpha = 48$ MeV, ^{11}B*(16.44, 17.69, 18.0, 19.15) are not excited suggesting that these states are rather pure $T = \frac{3}{2}$ states (1982ZW02): see Table 11.9. See also (1983ZW1A).

15. ^{9}Be(^{6}Li, α)^{11}B $\qquad Q_m = 14.341$

Angualr distributions have been determined for seven α-groups at $E(^6\text{Li}) = 3$ to 4 MeV, and at 24 MeV to ^{11}B*(0, 2.12) and to a number of unresolved levels with $E_x \leq 13.2$ MeV: see (1968AJ02, 1975AJ02). For the breakup reactions see (1975AJ02). See also (1981OS1H).

16. ^{10}Be(p, γ)^{11}B $\qquad Q_m = 11.229$

The yield of γ_0 has been measured at $90°$ for $E_p = 0.6$ to 6.3 MeV. Observed resonances are displayed in Table 11.10. $T = \frac{3}{2}$ assignments are made for the states at $E_x = 12.56$, 12.91, 14.33 and 15.32 MeV whose energies match those of the first four states of ^{11}Be [compare with the $T = \frac{3}{2}$ states reported in ^{9}Be(^{3}He, p)^{11}B – Table 11.9]. See also Table 11.16. Several known $T = \frac{1}{2}$ states in ^{11}B are not observed in this reaction: see Table 11.4 (1970GO04, 1973GO09).

17. ^{10}B(n, γ)^{11}B $\qquad Q_m = 11.454$

The thermal capture cross section is 0.5 ± 0.2 b (1981MUZQ). For a listing of the observed capture γ-rays see Table 11.12 in (1975AJ02). See also (1980AJ01).

Table 11.9: Energy levels of ^{11}B from ^{9}Be(^{3}He, p)^{11}B

E_x (MeV ± keV) [a]	E_x (MeV ± keV) [b]	$\Gamma_{c.m.}$ (keV) [b]	L
0			0
2.1243 ± 0.9			0
4.4434 ± 1.8			0
5.0187 ± 2.3			0
6.7411 ± 3.0			
6.7909 ± 3.1			1
7.285 ± 10			
7.975 ± 10			
8.553 ± 10			0
8.909 ± 10	8.934 ± 15		$0 + 2$
9.175 ± 10	9.183 ± 15		$(1) + 3$
9.264 ± 10	9.265 ± 15	10 ± 10	$1 + 3$
9.86 ± 20	9.887 ± 15	104 ± 15	1
	10.265 ± 25	168 ± 25	2
	10.337 ± 20	123 ± 20	$0 + 2$
	10.580 ± 20	122 ± 20	$1 + 3$
	11.254 ± 20	110 ± 20	3
	11.437 ± 20	103 ± 20	$(0 + 2)$
	11.588 ± 30	180 ± 30	$1 + 3$
	11.889 ± 20	204 ± 20	$0 + 2$
	12.563 ± 20 [c]	202 ± 25	1
	12.920 ± 20 [c]	155 ± 25	2
	13.137 ± 40	426 ± 40	$1 + 3$
	$\equiv 14.40$ [d]	261 ± 25	$1 + 3$
	14.565 ± 15	≤ 30	(1)
	16.437 ± 20 [c,e]	≤ 30	
	$\equiv 17.69$ [c,e]	91 ± 25	$(0 + 2)$
	18.0 ± 100 [c,e]	870 ± 100	$(1 + 3)$
	19.146 ± 30 [c,e]	115 ± 25	3
	21.27 ± 50 [c]	300 ± 30	$(1 + 3)$

[a] See Table 11.9 in (1980AJ01) for references and Table 11.16 here.
[b] $E(^3\text{He}) = 38$ MeV (1982ZW02); DWBA analysis.
[c] $T = \frac{3}{2}$ state.
[d] This state may have mixed isospin ($T = \frac{1}{2} + T = \frac{3}{2}$).
[e] Not observed in ^{9}Be(α, d)^{11}B (1982ZW02).

Table 11.10: Levels of ^{11}B from the ^{10}Be(p, γ_0)^{11}B reaction (1970GO04)

E_p (MeV $\pm$ keV)	E_x (MeV)	$\Gamma_{c.m.}$ (keV)	$(J+\frac{1}{2})(\Gamma_p/\Gamma)\Gamma_{\gamma_0}$ [a] (eV)	Γ_{γ_0} [a] (eV)	$\Gamma_{\gamma_1}/\Gamma_{\gamma_0}$	J^π
(1.05 ± 40) [b]	(12.18)	230 ± 90	$3.1^{+2.9}_{-2.0}$			
1.46 ± 30	12.56	230 ± 65	10^{+7}_{-5}	10^{+7}_{-5}	0.25 ± 0.08	$\frac{1}{2}^+(\frac{3}{2}^+)$
1.85 ± 20	12.91	235 ± 27	29 ± 9	29 ± 9 [c]	≤ 0.06	$\frac{1}{2}^-$
3.41 ± 20	14.33	255 ± 36	29 ± 9	14.5 ± 4.3	≤ 0.1	$\frac{5}{2}^{(+)}(\frac{3}{2}^-)$
4.5 ± 100	15.32	635 ± 180	53^{+34}_{-26} [d]			

[a] Values reported in (1970GO04) are here shown multiplied by 1.7: see (1973GO09). See also Table 11.16.

[b] May be due to ^{10}B*(0.7) + n threshold: see also Table 11.10 in (1980AJ01).

[c] In the (e, e′) work of (1975KA02) a strong group is observed at $E_x = 13.0 \pm 0.1$ MeV. If it corresponds to the excitation of ^{11}B*(12.91) with $J^\pi = \frac{1}{2}^-$; $T = \frac{3}{2}$, $\Gamma_{\gamma_0} = 35 \pm 7$ eV (1975KA02).

[d] Assumes that $\sigma_{total} = 4\pi d\sigma/d\Omega(90°)$.

Table 11.11: Resonances in ^{10}B + n [a]

^{10}B(n, n′γ)^{10}B		^{10}B(n, α)^{7}Li		Yield of	^{11}B* (MeV)
E_{res} (MeV)	Γ (keV)	E_{res} (MeV)	Γ (keV)		
		0.23		σ_t, α	11.66
		0.53 [b]	140	α_0, α_1	11.94
1.93	260	1.86	570	σ_t, α_0, α_1, t, n′	13.2
(2.6)	broad	2.79	530	σ_t, α_0, α_1, n′	14.0
3.31	370	3.43	< 120	α_0, t, n′	14.57
4.1		4.1	800	σ_t, α_0, α_1, n′	15.2
4.73				n′	15.75
		5.7	broad	α_0, t	16.6
		6.4	broad	α_0, t	17.3

[a] See also Table 11.12. For references see Table 11.12 in (1980AJ01).

[b] See footnote [c] in Table 11.12.

18. (a) ^{10}B(n, n)^{10}B $E_b = 11.454$

(b) ^{10}B(n, n′)^{10}B*

The scattering amplitude (bound) $a = -0.2 \pm 0.4$ fm, σ(free) $= 2.23 \pm 0.06$ b (1983KO17). The total scattering cross section is constant at 2.23 ± 0.06 b for $E_n = 0.7$ to 10 keV and then rises to 2.97 b at $E_n = 127$ keV.

Total cross-section measurements in the range $E_n = 10$ to 500 keV show a broad maximum near $E_n = 0.23$ MeV, also observed in the (n, α) cross section. At higher energies the total cross section shows broad maxima at $E_n = 1.9$, 2.8 and 4.3 MeV: see Table 11.11. In the range $E_n = 5.5$ to 16 MeV σ_{tot} is constant at 1.5 b. See also (1983DA22).

Polarization measurements (0.075 to 2.2 MeV and 2.63 MeV) and measurements of differential cross sections (0.075 to 4.4 MeV) have been analyzed using R-matrix calculations: the results are shown in Table 11.12. They are consistent with results from ^{10}B(n, n′γ) and ^{7}Li(α, n). See (1980AJ01) for references.

Elastic and inelastic cross sections have also been reported at $E_n = 4$ to 14.1 MeV: see (1980AJ01). The yield of 0.7 MeV γ-rays has been studied from threshold to $E_n = 5.2$ MeV: observed resonances are displayed in Table 11.11. Inelastic scattering cross sections for formation of various ^{10}B states have been measured at a number of energies in the range $E_n = 1.45$ to 14.8 MeV: see (1975AJ02). See also ^{10}B in (1984AJ01), (1979CZ1A) and (1979GL1D; theor.).

19. (a) ^{10}B(n, p)^{10}Be $Q_m = 0.2255$ $E_b = 11.454$

(b) ^{10}B(n, d)^{9}Be $Q_m = -4.3620$

(c) ^{10}B(n, t)^{4}He^{4}He $Q_m = 0.3217$

The cross section for reaction (c) has been measured for $E_n = 1.4$ to 8.2 MeV: see (1968AJ02) and Table 11.11. See also (1980AJ01).

20. ^{10}B(n, α)^{7}Li $Q_m = 2.790$ $E_b = 11.454$

The “recommended” value of the thermal isotropic absorption cross section is 3837 ± 9 b (1981MUZQ). The α_0/α_1 branching for thermal neutrons is (6.733 ± 0.008)% (1967DE15), (6.699 ± 0.012)% (1979ST03). At $E_n = 2$ and 24 keV the values are (7.05 ± 0.16)% and (7.13 ± 0.15)%, respectively (1979ST03).

The cross section for this reaction has been measured for $E_n = 1.0$ to 14.8 MeV [see (1975AJ02, 1980AJ01)] and at 0.025 eV to 25 keV (1980BO1V), 0.5 eV to 10 keV (1979CA1C, 1980CA1R) and 98 to 2200 keV (1979VI04). Evaluations of the cross-section data are presented by (1978LI32, 1981IN1B, 1982HA1Y). For observed resonances see Tables 11.11 and 11.12.

Table 11.12: R-matrix analysis of resonant states in $^{10}B + n$ [a]

E_n (MeV)	E_x (MeV)	J^π	l_n	Γ_n (c.m., MeV)	$\Gamma_{\alpha 0}$ (c.m., MeV)	$\Gamma_{\alpha 1}$ (c.m., MeV)	$\Gamma_{c.m.}$ (keV)
	10.60 [b]	$\frac{7}{2}^+$	0	0.120 [b]	0.030	0.070	220
0.17	11.61	$\frac{5}{2}^+$	0	0.004	0.296	0.0	300
0.37	11.79 [b]	$\frac{7}{2}^+$	0	0.770	0.001	0.113	884
0.53 [c]	11.94	$\frac{5}{2}^-$	1	0.031	0.080	0.090	201
1.83	13.12	$\frac{9}{2}^-$	1	0.100	0.275	0.050	425
1.88	13.16	$\frac{5}{2}^+, \frac{7}{2}^+$	2	0.080	0.200	0.150	430
2.82	14.02	$\frac{11}{2}^+$	2	0.800	0.045	0.010	855
4.2	15.3	$(\frac{3}{2}, \frac{5}{2}, \frac{7}{2})^+$	2	0.500	0.100	0.100	700

[a] Analysis based on polarization and differential cross-section measurements of the elastic scattering, and on results from ^{10}B(n, α_0) and (n, α_1). The analysis used a two-level, four-channel R-matrix formalism with a non-diagonal background R-matrix: see (1973HA64). This analysis does not include ^{11}B*(14.53) because the resonance is weak, narrow and almost entirely in the α-channel (1973CO05). See also Table 11.11.

[b] See also (1979BE18).

[c] (1978SC31) report $E_{res} = 495 \pm 5$ keV, $\Gamma = 140 \pm 15$ keV, σ_{max} [in (n, $\alpha_1\gamma$)] $= 94 \pm 6$ mb.

Parity violation has been studied using polarized thermal neutrons: a small left-right asymmetry had been reported in the ($\vec{n}$, α_0) reaction (1979BO1E, 1981VE08). However, (1984VE1A) find $a_p < 8 \times 10^{-6}$ and $< 1.5 \times 10^{-6}$, respectively for the transitions to ^{7}Li*(0, 0.48). See also ^{7}Li in (1984AJ01), (1979BO1Q, 1980CZ1A) and (1977WA1B).

21. ^{10}B(p, π^+)^{11}B $\qquad Q_m = -128.895$

Angular distributions have been obtained at $E_p = 168$ to 186 MeV [see (1980AJ01)] and at 154.5 MeV (1981SJ02; to ^{11}B*(0, 2.12, 4.44; also A_y), 320, 410, 483 and 605 MeV (1980DI02, 1981CO1L; to ^{11}B*(0, 2.12)) and 800 MeV (1981NA1C, 1982NA1K; to ^{11}B*(0, 2.12, 4.44, 5.02, $6.74 + 6.79$, 7.29)). At $E_p = 200$ MeV the relative yields to ^{11}B*(0, 2.12, 4.44, 5.02, $6.74 + 6.79$, 7.29, 8.0, 8.56, 8.92, $9.19 + 9.28$) have been measured: they are similar to the relative yields in the (d, p) reaction except that ^{11}B*(8.93, $9.19 + 9.27$) are much less strongly excited in the (p, π^+) reaction (1980SO05). (1979MA38, 1979MA39) have measured the cross section for π^+ production near threshold. See also (1979ME2A, 1980AJ01, 1981AU1C, 1982CO1J, 1982HO1C, 1982LE1L, 1982WA1G).

22. ^{10}B(d, p)^{11}B $\qquad Q_{\rm m} = 9.230$

Reported proton groups are displayed in Table 11.14 of (1980AJ01). Angular distributions have been studied at many energies in the range $E_{\rm d} = 0.17$ to 28 MeV [see (1968AJ02, 1975AJ02, 1980AJ01)]. See also (1983HA1Q). The lowest five levels are formed by $l_{\rm n} = 1$ except for ^{11}B*(2.12) which appears to involve a spin-flip process. They are presumed to comprise the set $\frac{3}{2}^-, \frac{1}{2}^-, \frac{5}{2}^-, \frac{3}{2}^-, \frac{7}{2}^-$ expected as the lowest p^7 levels $(a/K \approx 4.0)$. ^{11}B*(9.19, 9.27) [$J^\pi = \frac{7}{2}^+, \frac{5}{2}^+$] show strong $l_{\rm n} = 0$ stripping and are ascribed to capture of a 2s neutron by ^{10}B: see (1968AJ02) for a listing of all the relevant references. Studies of pγ correlations are discussed in reaction 14 of (1968AJ02) and displayed in Table 11.5 of this paper. See also ^{12}C and (1978CO1D, 1980BO1T, 1981CE04) and (1982GO05; theor.).

23. ^{10}B(t, d)^{11}B $\qquad Q_{\rm m} = 5.197$

At $E_{\rm t} = 5.5$ MeV deuteron groups are observed to ^{11}B*(0, 2.12, 4.44, 5.02, 6.74, 6.79, 7.29). All the angular distributions appear to be characteristic of $l_{\rm n} = 1$: see (1968AJ02). See also (1980BO1T).

24. ^{10}B(α, ^{3}He)^{11}B $\qquad Q_{\rm m} = -9.124$

Angular distributions have been measured at $E_\alpha = 56$ MeV for the ground-state transitions in this, and in the analog (α, t) reactions: the average ratio of the (α, ^{3}He) to the (α, t) differential cross sections is 1.2 ± 0.1: see (1975AJ02).

25. ^{10}B(^{7}Li, ^{6}Li)^{11}B $\qquad Q_{\rm m} = 4.204$

At $E(^7{\rm Li}) = 24$ MeV angular distributions are reported to ^{11}B*(0, 6.74, 8.92). ^{11}B*(4.44, 5.02) are also populated. The (^{7}Li, ^{6}He) reaction [see reaction 15 in ^{11}C] has also been studied: see (1980AJ01).

26. ^{10}B(^{9}Be, ^{8}Be)^{11}B $\qquad Q_{\rm m} = 9.789$

The total reaction cross section for ^{9}Be + ^{10}B has been studied for $E(^{10}{\rm B}) = 2.2$ to 10.4 MeV: at low energies there is evidence for this neutron transfer reaction with the excitation of ^{11}B*(8.92, 9.19) (1979CH22).

Table 11.13: Beta decay of ^{11}Be (1982MI08) [a]

^{11}B (keV)	J^{π} [b]	Branching ratio [c] (%)	log ft	E_{γ} (keV)	I_{γ} [c] (%)	Transition to ^{11}B* (MeV)
g.s.	$\frac{3}{2}^-$	54.7 ± 2.0 [d]	6.830 ± 0.016			
2124.693 ± 0.027 [e]	$\frac{1}{2}^-$	31.4 ± 1.8	6.648 ± 0.025	2124.473 ± 0.027	100	g.s.
4444.89 ± 0.50	$\frac{5}{2}^-$	0.054 ± 0.004	10.93 ± 0.03 [f]	4443.90 ± 0.50	100	g.s.
5020.31 ± 0.30	$\frac{3}{2}^-$	0.282 ± 0.020	7.934 ± 0.031	5018.98 ± 0.40	85.6 ± 0.6	g.s.
				2895.30 ± 0.40	14.4 ± 0.6	2.12
6791.80 ± 0.30 [g]	$\frac{1}{2}^+$	6.47 ± 0.45	5.938 ± 0.030	6789.81 ± 0.50	67.5 ± 1.1	g.s.
				4665.90 ± 0.40	28.5 ± 1.1	2.12
				1171.31 ± 0.30	4.0 ± 0.3	5.02
7285.51 ± 0.43	$\frac{5}{2}^+$	< 0.03	> 8.04	7282.92	87.0 ± 2.0	g.s.
7977.84 ± 0.42 [h]	$\frac{3}{2}^+$	4.00 ± 0.30	5.576 ± 0.033	7974.73	46.2 ± 1.1	g.s.
				5851.47 ± 0.42	53.2 ± 1.2	2.12
				692.31 ± 0.10	0.85 ± 0.04	7.29
9.876	$\frac{3}{2}^+$	3.1 ± 0.4 [i]	4.04 ± 0.08			

[a] See also Table 11.15 in (1980AJ01).

[b] From Table 11.4.

[c] Adopted by (1982MI08); based on their work and on the earlier work.

[d] From the relative intensities of the γ-rays and $I_{2.13}/I_{\text{total}\beta} = 0.355 \pm 0.018$.

[e] See also (1980WA25, 1981AL03).

[f] Log $f_1 t$.

[g] Transition to ^{11}B*(4.44) is < 0.04%.

[h] Transitions to ^{11}B*(4.44, 5.02, 6.79) are < 0.06, < 0.09 and < 0.10%.

[i] From the relative intensities of the γ-rays and $I_{\alpha}/I_{2.13}$ of (1981AL03).

27. ^{10}B(^{13}C, ^{12}C)^{11}B $\qquad Q_{\rm m} = 6.508$

Total cross-section measurements involving ^{11}B*(4.44, 6.74) have been carried out for $E(^{13}{\rm C}) = 4.2$ to 13.3 MeV: see (1980AJ01) and (1983DA20).

28. ^{11}Be(β^-)^{11}B $\qquad Q_{\rm m} = 11.508$

^{11}Be decays to many states of ^{11}B: see Table 11.13 for the observed β^- and γ-transitions (1982MI08). ^{11}B*(9.88) decays via α-emission to ^{7}Li*(0, 0.48) with branching ratios (87.4 ± 1.2)% and (12.6 ± 1.2)%, respectively (1981AL03). A study of the $\beta\nu$ angular correlation in the first-forbidden decay of ^{11}Be to the $\frac{1}{2}^-$ state ^{11}B*(2.12) has been performed: the β-transition is dominated by rank-0 matrix elements and is of interest as a test of meson-exchange effects (1982WA18). See also (1980RI06; theor.).

29. (a) ^{11}B(γ, n)^{10}B $\qquad Q_{\rm m} = -11.454$
(b) ^{11}B(γ, p)^{10}Be $\qquad Q_{\rm m} = -11.229$
(c) ^{11}B(γ, d)^{9}Be $\qquad Q_{\rm m} = -15.816$
(d) ^{11}B(γ, t)^{8}Be $\qquad Q_{\rm m} = -11.224$

The giant dipole resonance is shown to consist mainly of $T = \frac{1}{2}$ states in the lower-energy region and of $T = \frac{3}{2}$ states in the higher energy region by observing the decay to states in ^{10}B and ^{10}Be (reactions (a) and (b)). Absolute measurements of the ^{11}B(γ, all n) cross section have been carried out from threshold to 35 MeV: the cross section exhibits a main peak at $E_\gamma = 25$ to 28 MeV and weak shoulders at 13 and 16 MeV. The integrated cross section to 35 MeV is 69.1 ± 0.8 MeV $\cdot$ mb: see (1980AJ01). (1979KA35) report the transition to ^{10}B*(1.74). For other structures reported in the (γ, n) and (γ, p) cross sections see (1975AJ02). The (γ, d_0) cross section peaks at ≈ 19 MeV, lower than it would if $T = \frac{3}{2}$ states were involved. The yield of 3.37 MeV γ-rays (from ^{10}Be*(3.37), reaction (b)) has been measured for $E_{\rm bs} = 100$ to 800 MeV.

For reaction (d) see (1983IS1D). See (1980AJ01) for references and for other photonuclear processes. See also (1980DU21, 1982DU1A, 1982GO03, 1983GO1T; theor.).

30. ^{11}B(γ, γ)^{11}B

Widths of excited states are shown in Table 11.14. See also (1980MO14) and (1980AJ01).

Table 11.14: Gamma widths from ^{11}B(γ, γ)^{11}B and ^{11}B(e, e)^{11}B [a]

E_x (MeV)	J^π	Γ_{γ_0} (eV)	Reaction	References
2.12	$\frac{1}{2}^-$	0.137 ± 0.020	γ, γ	(1965KE05)
		0.12 ± 0.02	γ, γ	(1968CR07)
		0.11 ± 0.02	γ, γ	(1978KU12)
		0.118 ± 0.013	γ, γ	(1980MO23)
		0.120 ± 0.009		mean
4.44 [b]	$\frac{5}{2}^-$	0.58 ± 0.04	γ, γ	(1978KU12)
		0.55 ± 0.02	γ, γ	(1980MO23)
		0.60 ± 0.09 (M1)	e, e	(1967SP02)
		$+0.016 \pm 0.002$ (E2)		
		0.56 ± 0.02		mean
5.02	$\frac{3}{2}^-$	1.80 ± 0.13	γ, γ	(1978KU12)
		1.64 ± 0.07	γ, γ	(1980MO23)
		1.73 ± 0.14 (M1)	e, e	(1967SP02)
		< 0.0034 (E2)		
		1.68 ± 0.06		mean
6.74 [b]	$\frac{7}{2}^-$	0.021 ± 0.005	γ, γ	(1980MO23)
6.79	$\frac{1}{2}^+$	0.26 ± 0.03	γ, γ	(1980MO23)
7.29	$\frac{5}{2}^+$	1.17 ± 0.26	γ, γ	(1978KU12)
		0.99 ± 0.07	γ, γ	(1980MO23)
		1.00 ± 0.07		mean
7.98	$\frac{3}{2}^+$	0.53 ± 0.07	γ, γ	(1980MO23)
8.56 [b]	$\leq \frac{5}{2}^-$	0.53 ± 0.05	γ, γ	(1980MO23)
8.92 [b]	$\frac{5}{2}^-$	4.20 ± 0.52	γ, γ	(1978KU12)
		4.16 ± 0.23	γ, γ	(1980MO23)
		4.0 ± 0.6 (M1)	e, e	(1966SP02)
		4.15 ± 0.20		mean

[a] See also Table 11.5 here, and Table 11.16 in (1980AJ01).

[b] See also (1979PO1B).

31. (a) ^{11}B(e, e$'$)^{11}B*

(b) ^{11}B(e, ep)^{10}Be $\qquad Q_{\rm m} = -11.229$

Magnetic elastic scattering at $\theta = 180°$ shows strong M3 effects: the derived ratio of static M3/M1, 2.9 ± 0.2 fm^2, suggests a jj-coupling scheme for ^{11}B$_{\rm g.s.}$. The quadrupole contribution to the elastic form factor is best accounted for by the undeformed shell model, $Q = 3.72$ (±20%) fm^2, r(rms) $= 2.42$ fm. [From muonic X-rays $\langle r^2\rangle^{1/2} = 2.47 \pm 0.04$ fm.] See (1980AJ01) for references. The excitation of ^{11}B*(2.1, 4.4, 5.0, 8.6, 8.9) has been studied by (1975KA02: $E_{\rm e} = 52$ to 90 MeV). The giant-resonance region, centered at ≈ 18 MeV, is characterized by a lack of prominent features except for a pronounced peak at $E_{\rm x} = 13.0 \pm 0.1$ MeV (mixed M1–E2) and a broad transverse group at $E_{\rm x} = 15.5$ MeV (1975KA02). At $E_{\rm e} = 121$, 186 and 250 MeV form factors (and $B({\rm E}\lambda)\uparrow$) are obtained for ^{11}B*(4.4, 6.7, 8.5, 8.9, 13.00 ± 0.15) and the excitation of ^{11}B*(14.50 ± 0.15, 16.7 ± 0.2) is also reported (1979PO1B).

For Γ_{γ_0} see Table 11.14. For reaction (b) see (1975AJ02). See also (1979RI1D), (1981RI1A) and (1981KE17, 1982BO1H, 1982KE1C, 1983AL04; theor.).

32. ^{11}B(π^+, π^+)^{11}B

The proton matter distribution in ^{11}B$_{\rm g.s.}$ has a radius of 2.368 ± 0.021 fm, assuming that for ^{12}C to be 2.44 fm. The result is not sensitive to the details of the optical-model calculations (1980BA45; $E_{\pi^+} = 38.6$ and 47.7 MeV). See also the "General" section here.

33. ^{11}B(n, n$'$)^{11}B*

Angular distributions have been reported for $E_{\rm n} = 4$ to 14.1 MeV [see (1980AJ01)] and at 2.6 to 8.0 MeV (1980WH01; n_0), 4.86 to 7.55 MeV (1983KO03; n_0, n_1 and, at the higher energies, n_2, n_3) and at 8 to 14 MeV (1983DA22). See also ^{12}B, and (1979GL1D, 1983KO1F; theor.).

34. ^{11}B(p, p$'$)^{11}B*

Observed proton groups are displayed in Table 11.15. Angular distributions have been measured for $E_{\rm p} = 6$ to 185 MeV [see (1980AJ01)] and at 1 GeV (1979AL26). See also (1980FA07). The analysis of the $\frac{3}{2}^- \rightarrow \frac{1}{2}^-$ transition [^{11}B*($0 \rightarrow 2.12$) at $E_{\vec{\rm p}} = 32$ MeV shows less spin-flip than predicted by DWBA (1981CO08). See also ^{12}C, (1981HO13) and (1979RO1B, 1980KO1V; theor.).

Table 11.15: States of ^{11}B from ^{11}B(p, p′)^{11}B* and ^{13}C(d, α)^{11}B [a]

E_x (keV) [b]	E_x (keV) [c]
0	0
2124.7 ± 0.5	2125.4 ± 1.4
4445.2 ± 0.5	4444.5 ± 1.6
5021.1 ± 0.6	5020.2 ± 1.9
6743.0 ± 0.7 [d]	6745.8 ± 3.4
6792.6 ± 1.6	6795 ± 3.0
7285.6 ± 1.5	
7978.0 ± 1.7	
8559.4 ± 1.9	8520 ± 70
8920.2 ± 2.0	8910 ± 60
9185.0 ± 2.0	
9274.4 ± 2.0	
10450 ± 150	
11650 ± 150	
12850 ± 100	
15200 ± 150	
16400 ± 150	

[a] For references see Table 11.17 in (1980AJ01).

[b] ^{11}B(p, p′)^{11}B.

[c] ^{13}C(d, α)^{11}B.

[d] Values below are normalized to $E_x = 4445.3$, 5020.0 and 6743.4 keV.

35. ^{11}B(d, d)^{11}B

The elastic scattering has been studied at $E_{\rm d} = 5.5$ MeV and 11.8 MeV: see (1980AJ01).

36. ^{11}B(t, t)^{11}B

The elastic scattering has been studied at $E_{\rm t} = 1.8$ and 2.1 MeV: see (1980AJ01).

37. ^{11}B(^{3}He, ^{3}He)^{11}B

The elastic scattering has been studied at $E(^3{\rm He}) = 8$ to 74 MeV: see (1975AJ02, 1980AJ01). At $E(^3{\rm He}) = 17.5$ and 40 MeV angular distributions have also been studied for the ^{3}He ions to ^{11}B*(2.12, 4.44, 5.02, 6.74) (1977SH09). $T = \frac{3}{2}$ states observed in this reaction are displayed in Table 11.16. There is a weak indication also of a state at $E_{\rm x} = 14.51$ MeV: see (1975AJ02).

38. ^{11}B(α, α')^{11}B

Angular distributions have been reported at $E_\alpha = 24$ to 29.0 MeV [see (1975AJ02, 1980AJ01)] and at 31.2 MeV (1981KO1U; α_0).

39. (a) ^{11}B(^{6}Li, ^{6}Li)^{11}B
(b) ^{11}B(^{7}Li, ^{7}Li)^{11}B

The elastic scattering has been studied at $E(^6{\rm Li}) = 28$ MeV: see (1975AJ02). For reaction (b) see (1983STZS).

40. (a) ^{11}B(^{9}Be, ^{9}Be)^{11}B
(b) ^{11}B(^{10}B, ^{10}B)^{11}B
(c) ^{11}B(^{11}B, ^{11}B)^{11}B

See (1975AJ02, 1980AJ01) and (1983DU13).

Table 11.16: $T = \frac{3}{2}$ states in ^{11}B [a]

Reaction	E_x (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	References
^{9}Be(^{3}He, p)^{11}B	12.563 ± 20	202 ± 25	(1982ZW02)
^{10}Be(p, γ)^{11}B	12.56 ± 30	230 ± 65	(1970GO04)
^{11}B(^{3}He, ^{3}He)^{11}B*	12.51 ± 50	260 ± 50	(1971WA21)
	12.557 ± 16	215 ± 21	mean
^{9}Be(^{3}He, p)^{11}B	12.920 ± 20	155 ± 25	(1982ZW02)
^{10}Be(p, γ)^{11}B	12.91 ± 20	235 ± 27	(1970GO04)
^{13}C(p, ^{3}He)^{11}B	12.94 ± 50	350 ± 50	(1968CO26)
^{13}C(p, ^{3}He)^{11}B	12.91 ± 30	260 ± 50	(1974BE20)
	12.916 ± 12	155 ± 25 [b]	mean
^{9}Be(^{3}He, p)^{11}B	14.40 [c]	261 ± 25	(1982ZW02)
^{10}Be(p, γ)^{11}B	14.33 ± 20	255 ± 30	(1970GO04)
^{11}B(^{3}He, ^{3}He)^{11}B*	14.40 ± 50	220 ± 50	(1971WA21)
	14.34 ± 20	254 ± 18	mean
^{10}Be(p, γ)^{11}B	15.32 ± 100 [d]	635 ± 180	(1970GO04)
^{9}Be(^{3}He, p)^{11}B	16.437 ± 20	≤ 30	(1982ZW02)
^{9}Be(^{3}He, p)^{11}B	17.69	91 ± 25	(1982ZW02)
^{9}Be(^{3}He, p)^{11}B	18.0 ± 100	870 ± 100	(1982ZW02)
^{9}Be(^{3}He, p)^{11}B	19.146 ± 30	115 ± 25	(1982ZW02)
^{9}Be(^{3}He, p)^{11}B	21.27 ± 50	300 ± 30	(1982ZW02)

[a] See also Table 11.18 in (1980AJ01).

[b] "Best" value.

[c] May have mixed isospin ($T = \frac{1}{2} + T = \frac{3}{2}$).

[d] Not reported in ^{9}Be(^{3}He, p)^{11}B: see Table 11.9.

41. (a) ^{11}B(^{12}C, ^{12}C)^{11}B
(b) ^{11}B(^{13}C, ^{13}C)^{11}B

The elastic scattering has been studied at $E(^{11}\text{B}) = 18.8$ to 34.1 MeV and at $E(^{12}\text{C}) = 15$ to 24 MeV and at 87 MeV [see (1980AJ01)] as well as at $E(^{11}\text{B}) = 25$, 40 and 50 MeV (1982MA20) and 28 MeV (1983SR01). The population of ^{11}B*(2.12, 4.44, 6.79) and of ^{12}C*(0, 4.43) are also reported. For yield and fusion studies see (1979FR05, 1981MA18, 1982MA20, 1983MA53, 1984MAZZ) for reaction (a) and (1983DA20) for reaction (b). See also (1982FR1T, 1983BI1A, 1983DU13) and (1978DZ1A, 1979IS07, 1979ZE1B, 1981YO05, 1982HA42; theor.).

42. ^{11}B(^{14}N, ^{14}N)^{11}B

The elastic scattering has been investigated at $E(^{14}\text{N}) = 41$, 77 and 133 MeV: see (1975AJ02). For fusion cross sections see (1983DA10).

43. (a) ^{11}B(^{16}O, ^{16}O)^{11}B
(b) ^{11}B(^{18}O, ^{18}O)^{11}B

The elastic scattering in reaction (a) has been studied at $E(^{16}\text{O}) = 14.5$ to 60 MeV and at $E(^{11}\text{B}) = 115$ MeV [see (1975AJ02, 1980AJ01)] as well as at $E(^{11}\text{B}) = 41.6$ and 49.5 MeV (1980PA01). A study of the elastic scattering in reaction (b) is reported at $E(^{11}\text{B}) = 115$ MeV (1980PR09). See also (1983GO13; theor.).

44. ^{11}B(^{20}Ne, ^{20}Ne)^{11}B

The elastic angular distribution has been obtained at $E(^{11}\text{B}) = 115$ MeV (1981GO11).

45. (a) ^{11}B(^{24}Mg, ^{24}Mg)^{11}B
(b) ^{11}B(^{25}Mg, ^{25}Mg)^{11}B
(c) ^{11}B(^{26}Mg, ^{26}Mg)^{11}B
(d) ^{11}B(^{27}Al, ^{27}Al)^{11}B

The elastic scattering angular distributions have been studied at $E(^{11}\text{B}) = 79.6$ MeV (1982FU09).

46. ^{11}B(^{40}Ca, ^{40}Ca)^{11}B

Angular distributions are reported at $E(^{11}\text{B}) = 51.5$ MeV to ^{11}B*(0, 2.12) (1980GL03, 1981HN01).

47. ^{11}C(β^+)^{11}B $Q_{\text{m}} = 1.982$

See ^{11}C.

48. ^{12}C(μ, nν)^{11}B $Q_{\text{m}} = 88.921$

The γ-decay of ^{11}B*(2.12) has been observed (1981GI08).

49. (a) ^{12}C(γ, p)^{11}B $Q_{\text{m}} = -15.956$
(b) ^{12}C(e, p)^{11}B $Q_{\text{m}} = -15.956$

The fraction of transitions to the ground and to excited states of ^{11}B (and to ^{11}C states reached in the (γ, n) reaction) has been measured at $E_{\text{bs}} = 21.7$ to 42 MeV: the ground state is predominantly populated [see (1980AJ01) and (1980IS1F)]. The population of analog states in the (γ, n) and (γ, p) reactions are similar: see ^{11}C. Differential cross sections for populating several states of ^{11}B have been measured at $E_\gamma = 21.7 \rightarrow 31$ MeV (1980IS1F) and at 60, 80 and 100 MeV: see (1980AJ01). The cross section for reaction (b) has been measured for $E_{\text{e}} = 21$, 25, 35, 45 and 55 MeV. The production of ^{11}B in astrophysical sites with large densities of high-energy electrons is discussed by (1983HO15). See also ^{12}C, (1979KI04), (1980GO13), (1982SC1E; astrophys.) and (1981BO14, 1982LO08, 1983OR03; theor.).

50. ^{12}C(e, ep)^{11}B $Q_{\text{m}} = -15.956$

At $E_{\text{e}} = 497$ MeV ^{11}B*(0, 2.1, 5.0) are populated: $l = 1$: see (1980AJ01). See also ^{12}C and (1979MO1G, 1980CA1L, 1982BE02, 1983MO1F) and (1983KL04; theor.).

51. ^{12}C(π^+, π^+p)^{11}B $Q_{\text{m}} = -15.956$

At $E_{\pi^+} = 100$ MeV [and 129.7 to 199.8 MeV (1981ZI01)] the reaction proceeds primarily to $^{11}B_{g.s.}$. At $E_\pi = 200$ MeV the ratios for σ_n/σ_p for the first excited states in ^{11}C/^{11}B are 1.4 ± 0.2 for π^- and $1/1.8 \pm 0.2$ for π^+. At $E_{\pi^+} = 60$ to 300 MeV ^{11}B*(4.44) [$J^\pi = \frac{5}{2}^-$] is strongly populated, as is the analog state in the mirror reaction. See (1980AJ01) for references. See also reaction 21 in ^{11}C, ^{12}C, (1983HUZZ, 1983MO1F) and (1982CH13; theor.). For the reaction ^{12}C(π^-, n)^{11}B see (1983CE04).

52. ^{12}C(p, 2p)^{11}B $\qquad Q_m = -15.956$

At $E_p = 98.7$ MeV well-resolved groups are observed to ^{11}B*(0, 2.12, 4.44, 5.02, 6.79). DWIA calculations lead to relative spectroscopic factors of 2.0, 0.37, 0.15, 1.08, 0.25 for these states [normalized to 2.0 for $^{11}B_{g.s.}$; overlap calculation]. No evidence is seen for the formation of giant resonances as the intermediate step in multistep reaction processes to ^{11}B*(4.44, 6.74) (1979DE35). For the earlier work see (1975AJ02, 1980AJ01). See also (1983CH1B) and (1981AM01, 1983IK03; theor.).

53. ^{12}C(d, ^{3}He)^{11}B $\qquad Q_m = -10.463$

Angular distributions of ^{3}He ions have been measured for $E_d = 20$ to 80 MeV: see (1975AJ02, 1980AJ01). reported C^2S for $^{11}B_{g.s.}$ are 3.22 or 4.42 depending on the choice of parameters (1978CO13; $E_d = 29$ MeV; see also (d, t) results – reaction 24 in ^{11}C) while (1975MA41; $E_d = 52$ MeV) find 2.98, 0.69, 0.31 for ^{11}B*(0, 2.12, 5.02). For a polarization study see (1981MA14). See also ^{14}N in (1986AJ01) and (1982ST1A; theor.).

54. ^{12}C(t, α)^{11}B $\qquad Q_m = 3.858$

Angular distributions have been measured for $E_t = 1$ to 3.4, 10.1 and 13 MeV: see (1975AJ02).

55. ^{12}C(α, ^{5}Li)^{11}B $\qquad Q_m = -17.92$

At $E_\alpha = 65$ MeV, ^{11}B*(0, 2.12, $6.74 + 6.79$) are strongly populated (1978SA26).

56. ^{12}C(^{12}C, ^{13}N)^{11}B $\qquad Q_m = -14.013$

Angular distributions involving the ground-state transitions have been measured at $E(^{12}\text{C}) = 93.8$ MeV (1979FU04) and 114 MeV (1974AN36). For yield measurements see (1980CO10). See also (1981CH1R) and (1981XU1A; theor.).

57. ^{12}C(^{19}F, ^{20}Ne)^{11}B $\quad Q_\text{m} = -3.108$

At $E(^{19}\text{F}) = 40$, 60 and 68.8 MeV angular distributions involving ^{11}B*(0, 2.12) and ^{20}Ne*(0, 1.63) have been measured: see (1980AJ01).

58. ^{13}C(p, ^{3}He)^{11}B $\quad Q_\text{m} = -13.184$

At $E_\text{p} = 50.5$ MeV, in addition to ^{11}B*(0, 2.12, 4.44, 5.02, 6.74, 8.92), a state is observed at $E_\text{x} = 12.94 \pm 0.05$ MeV, $\Gamma = 350 \pm 50$ keV. Comparison of the angular distributions of the ^{3}He and of the tritons [in the analog reaction] at $E_\text{p} = 43.7$ and 50.5 MeV lead to the assignments $J^\pi = \frac{1}{2}^-$, $T = \frac{3}{2}$ for this state and for ^{11}C*(12.50): the strong proton and the weak α-decay are consistent with this assignment: see Table 11.16. Angular distributions have been measured at $E_{|rmp} = 26.9$ to 49.6 MeV, involving the states above except for ^{11}B*(8.92) [see (1975AJ02, 1980AJ01)] and at $E_{\vec{\text{p}}} = 65$ MeV (1982KA01; to ^{11}B*(0, 2.12); also analyzing power). See also ^{14}N in (1986AJ01).

59. ^{13}C(d, α)^{11}B $\quad Q_\text{m} = 5.169$

Observed proton groups are displayed in Table 11.15. Angular distributions are reported at $E_\text{d} = 0.41$ to 14.1 MeV: see (1975AJ02).

60. ^{14}C(p, α)^{11}B $\quad Q_\text{m} = -0.783$

At $E_\text{p} = 41.9$ MeV angular distributions have been studied for the groups to ^{11}B*(0, 2.12, 4.44, 6.74) (1983AR1K). See also (1968AJ02).

61. (a) ^{14}N(n, α)^{11}B $\quad Q_\text{m} = -0.157$
(b) ^{14}N(n, 2α)^{7}Li $\quad Q_\text{m} = -8.822$

Angular distributions have been measured for $E_\text{n} = 4.9$ to 18.8 MeV [see (1975AJ02, 1980AJ01)] and at $E_\text{n} = 12.2$, 14.1 and 18 MeV (1978BU28; α_0). At $E_\text{n} = 14.1$ and 15.7 MeV various states of ^{11}B with $8.9 < E_\text{x} < 14.5$ MeV appear to be involved in the sequential decay to ^{7}Li. Angular correlation results are consistent with $J = \frac{7}{2}$ and $\frac{5}{2}$ for ^{11}B*(9.19, 9.27) respectively: see (1975AJ02).

62. ^{15}N(α, ^{8}Be)^{11}B $\qquad Q_{\rm m} = -11.082$

See (1980AJ01).

63. ^{16}O(d, ^{7}Be)^{11}B $\qquad Q_{\rm m} = -16.037$

At $E_{\rm d} = 80$ MeV angular distributions have been measured to ^{11}B*(0, 2.12, $4.44 + 5.02$, $6.74 + 6.79 + 7.29$) (1978OE1A). See also (1984NE1A).

64. ^{16}O(^{10}B, ^{11}B)^{15}O $\qquad Q_{\rm m} = -4.210$

See (1983OS08; theor.).

^{11}C
(Figs. 3 and 4)

GENERAL: (See also (1980AJ01).)

Model calculations: (1981RA06, 1983SH38).

Special states: (1981RA06).

Complex reactions involving ^{11}*C:* (1979BO22, 1980GR10, 1980WI1K, 1980WI1L, 1981MO20, 1982GE05, 1982LY1A, 1982RA31, 1983FR1A, 1983OL1A, 1983WI1A, 1984GR08, 1984HI1A).

Electromagnetic transitions: (1978KR19).

Applied work: (1979DE1H, 1982BO1N, 1982HI1H, 1982KA1R, 1982ME1C, 1982NE1D, 1982PI1H, 1982YA1C, 1983GO1P).

Pion and kaon capture and reactions (See also reactions 21, 22 and 29.): (1979AL1J, 1979AN1F, 1979BU1C, 1979DR09, 1981NI03, 1981RO1L, 1981RO1R, 1981ST14, 1982AS01, 1982GL04, 1984PO05).

Hypernuclei: (1981WA1J, 1982KA1D, 1982KO11, 1983SH38).

Other topics: (1981ST1G, 1982DE1N, 1982NG01).

Ground-state properties of ^{11}*C:* (1982BA37, 1982NG01, 1983ANZQ, 1983BU07).

$$\mu = -0.964 \pm 0.001 \text{ nm (1969WO03)},$$
$$Q = 34.26 \text{ mb (1978LEZA)}.$$

1. ^{11}C(β^+)^{11}B $\qquad Q_{\rm m} = 1.982$

The half-life of ^{11}C is 1223.1 ± 1.2 sec (This value may not be correct, see Erratum to this publication). Log $ft = 3.599 \pm 0.002$. The ratio of K-capture to positron emission is $(0.230^{+0.014}_{-0.011})$%. See (1980AJ01) for references. See also (1980RA16), (1984BO1C; astrophys.), (1982KA1C; applied) and (1980AF1A; theor.).

2. ^{6}Li(^{6}Li, n)^{11}C $\qquad Q_{\rm m} = 9.450$

At $E(^6\text{Li}) = 4.1$ MeV angular distributions have been obtained for the neutrons to ^{11}C*(2.00, 4.32, 4.80, $6.34 + 6.48$, 6.90, 7.50). In addition, nγ coincidences via ^{11}C*(8.42) [and an 8.42 MeV γ-ray] are reported. ^{11}C*(8.10) was not observed. The lifetimes, $\tau_{\rm m}$, for ^{11}C*(4.32, 6.90, 7.50) are < 140, < 69 and < 91 fsec, respectively. See (1980AJ01) for references.

Table 11.17: Energy Levels of ^{11}C [a]

E_x in ^{11}C (MeV $\pm$ keV)	$J^\pi; T$	τ or $\Gamma_{c.m.}$	Decay	Reactions
0	$\frac{3}{2}^-; \frac{1}{2}$	$\tau_{1/2} = 20.39 \pm 0.02$ min	β^+	1, 2, 3, 4, 5, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 33, 34, 35
2.0000 ± 0.5	$\frac{1}{2}^-$	$\tau_m = 10.3 \pm 0.7$ fsec	γ	2, 4, 5, 12, 13, 14, 15, 18, 19, 22, 23, 24, 25, 27, 30, 31
4.3188 ± 1.2	$\frac{5}{2}^-$	< 12 fsec	γ	2, 4, 5, 12, 13, 15, 18, 19, 21, 22, 23, 24, 25, 30
4.8042 ± 1.2	$\frac{3}{2}^-$	< 11 fsec	γ	2, 4, 12, 15, 18, 19, 22, 23, 25, 30
6.3392 ± 1.4	$\frac{1}{2}^+$	< 110 fsec	γ	2, 4, 13, 25
6.4782 ± 1.3	$\frac{7}{2}^-$	< 8 fsec	γ	2, 4, 5, 12, 13, 15, 18, 22, 23, 25, 29, 30
6.9048 ± 1.4	$\frac{5}{2}^+$	< 69 fsec	γ	2, 4, 12, 13, 23, 25, 30
7.4997 ± 1.5	$\frac{3}{2}^+$	< 91 fsec	γ	2, 4, 13, 23, 25, 30
8.1045 ± 1.7	$\frac{3}{2}^-$	0.06 ± 0.04 fsec [b]	γ	3, 13, 19, 23, 25
8.420 ± 2	$\frac{5}{2}^-$	0.043 ± 0.011 fsec [b]	γ	2, 3, 4, 12, 13, 15, 23, 25
8.655 ± 8	$\frac{7}{2}^+$	$\Gamma \leq 5$ keV	(γ)	12, 13, 15, 23
8.701 ± 20	$\frac{5}{2}^+$	15 ± 1	γ, p	5, 12, 13, 15
9.20 ± 50	$\frac{5}{2}^+$	500 ± 100	γ, p	5
9.65 ± 50	$(\frac{3}{2}^-)$	210 ± 50	γ, p, α	5, 7, 11, 23
9.78 ± 50	$(\frac{5}{2}^-)$	240 ± 60	γ, p	5, 7, 11, 23
9.97 ± 50	$(\frac{7}{2}^-)$	120 ± 20	γ, p	5
10.083 ± 5	$\frac{7}{2}^+$	≈ 230	γ, p, α	5, 7, 11, 13, 23
10.679 ± 5	$\frac{9}{2}^+$	200 ± 30	γ, p, α	5, 7, 11, 12, 23
11.03 ± 30	$T = \frac{1}{2}$	300 ± 60		23, 25, 30
11.44 ± 10		360	p, α	11, 23
(12.16 ± 40)		270 ± 50	p	4, 8, 19
12.4	$\pi = -$	1–2 MeV	γ, p	5, 25

Table 11.17: Energy Levels of ^{11}C [a] (continued)

E_x in ^{11}C (MeV $\pm$ keV)	$J^\pi; T$	τ or $\Gamma_{c.m.}$	Decay	Reactions
12.51 ± 30	$\frac{1}{2}^-; \frac{3}{2}$	490 ± 40 keV	p	4, 8, 19, 22, 30
12.65 ± 20	$(\frac{7}{2}^+)$	360	p, ^{3}He, α	5, 10, 11
(13.01)			γ, p	5
13.33 ± 60		270 ± 80		22, 30
13.4		1100 ± 100	p, α	11
13.90 ± 20	$(T = \frac{3}{2})$	200 ± 100	p	5, 7, 19, 30
14.07 ± 20		135 ± 50	n, p	6, 30
14.76 ± 40		≈ 450	n, p, ^{3}He	4, 6, 7, 10
15.35 ± 50	$\pi = -$	broad	γ, n, p	5, 6, 7, 25
15.59 ± 50		≈ 450	n, p	6, 7
16.7	$\pi = -$	800 ± 100	γ, p	5
(18.2)			γ, p	5
(23.0)				25
(28.0)				25

[a] See also Table 11.18.

[b] $\Gamma_{c.m.} = \Gamma_\alpha + \Gamma_\gamma = 11 \pm 7$ eV and 15.2 ± 3.8 eV for ^{11}C*(8.10, 8.42): see reaction 3.

3. ^{7}Be(α, γ)^{11}C $\qquad Q_m = 7.544$

At the resonances at $E_\alpha = 0.884 \pm 0.008$ and 1.376 ± 0.003 MeV [^{11}C*(8.107, 8.420)] $\omega\gamma = 0.331 \pm 0.041$ and 3.80 ± 0.57 eV, $\Gamma_\gamma = 0.350 \pm 0.056$ and 3.1 ± 1.3 eV for these two states and $\Gamma_\alpha = 6^{+12}_{-2}$ and 12.6 ± 3.8 eV, respectively (1984HA13).

4. ^{9}Be(^{3}He, n)^{11}C $\qquad Q_m = 7.558$

Reported neutron groups are listed in Table 11.16 of (1968AJ02). Angular distributions have been studied in the range $E(^3\text{He}) = 1.3$ to 13 MeV: see (1980AJ01). The dominant L-values are 0 for ^{11}C*(0, 8.10), 1 for ^{11}C*(6.34, 7.50), 2 for ^{11}C*(2.00, 4.32, 4.80, 6.48, 8.42) and 3 for ^{11}C*(6.90). Neutron groups to $T = \frac{3}{2}$ states have been reported at $E_x = 12.17 \pm 0.05$ [see, however, reaction 30], 12.55 ± 0.05 MeV and 14.7 ± 0.1 MeV: see Table 11.19.

Gamma branching ratios and multipolarities for ^{11}C levels up to $E_x = 7.5$ MeV have been studied by (1965OL03): see Table 11.18. Together with evidence from reactions 12 and 23 they lead to assignments of $J^\pi = \frac{1}{2}^-, \frac{5}{2}^-, \frac{3}{2}^-, \frac{1}{2}^+, \frac{7}{2}^-, \frac{5}{2}^+, \frac{3}{2}^+$ for ^{11}C*(2.00, 4.32, 4.80, 6.34, 6.48, 6.90, 7.50): see (1965OL03) and reaction 3 in (1968AJ02) for a summary of the evidence concerning these assignments. See (1980AJ01) for references. See also ^{12}C, (1981AN16, 1982MCZZ), (1979WA1F; applied) and (1981OS1H).

Table 11.18: Gamma decay of ^{11}C levels [a]

E_i (MeV)	J^π	τ_m (fsec)	E_f (MeV)	Branch
2.00	$\frac{1}{2}^-$	10.3 ± 0.7 fsec	0	100
4.32 [b]	$\frac{5}{2}^-$	< 12 [h]	0	100
4.80	$\frac{3}{2}^-$	< 11 [h]	0	85.2 ± 1.4
			2.00	14.8 ± 1.4
6.34 [c]	$\frac{1}{2}^+$	< 110	0	66.5 ± 2.1
			2.00	33.5 ± 2.1
6.48 [d]	$\frac{7}{2}^-$	< 8 [h]	0	88.5 ± 1.4
			4.32	11.5 ± 1.4
6.90 [e]	$\frac{5}{2}^+$	< 69	0	91 ± 2
			4.32	4.5 ± 1
			4.80	4.5 ± 1
7.50 [f]	$\frac{3}{2}^+$	< 91	0	36 ± 2
			2.00	64 ± 2
8.10 [i]	$\frac{3}{2}^-$	0.06 ± 0.04	0	74 ± 12
			2.00	26 ± 5
8.42 [i,l]	$\frac{5}{2}^-$	0.043 ± 0.011	0	100 [j]
8.70 [k,l]	$\frac{5}{2}^+$		0	42 ± 10
			4.32	42 ± 10
			4.80	2.4 ± 1.5
			6.48	13.6 ± 4.6
9.20 [k]	$\frac{5}{2}^+$		0	74 ± 18
			4.32	6 ± 5
			6.48	20 ± 10
9.65 [g,k]	$(\frac{3}{2}^-)$		0	60 ± 5
			4.32	32 ± 10
			4.80	8 ± 4

Table 11.18: Gamma decay of ^{11}C levels [a] (continued)

E_i (MeV)	J^π	τ_m (fsec)	E_f (MeV)	Branch
9.78 [g,k]	$(\frac{5}{2}^-)$		0	76 ± 16
			4.32	8 ± 2
			4.80	4 ± 2
			6.48	12 ± 4
9.97 [k]	$(\frac{7}{2}^-)$		4.32	90 ± 10
			6.48	10 ± 7
10.08 [k]	$\frac{7}{2}^+$		4.32	67 ± 8
			6.48	13 ± 6
10.68 [k]	$\frac{9}{2}^+$		6.48	100

[a] Mostly from (1965OL03) and (1968EA03): see Table 11.20 in (1980AJ01) for other references and additional information.
[b] Cascade via ^{11}C*(2.0) is $< 2\%$.
[c] Cascade via ^{11}C*(4.32) is $< 7\%$; that through ^{11}C*(4.80) is $< 3\%$.
[d] Cascades via ^{11}C*(2.00, 4.80) are $< 2\%$.
[e] Cascades via ^{11}C*(2.00, 6.34, 6.48) are < 1, < 5 and $< 5\%$, respectively. The cascade via ^{11}C*(4.80) is not reported by (1965OL03) [they suggest $< 3\%$].
[f] Cascades via ^{11}C*(4.32, 4.80, 6.34, 6.48, 6.90) are < 1, < 1, < 3, < 3 and $< 4\%$.
[g] See also (1979AN16).
[h] (1979AN16). See also (1981CA06) for τ_m of ^{11}C*(4.32, 4.80, 6.48).
[i] (1984HA13).
[j] Branching ratio to ^{11}C*(4.32) is $< 7\%$ (1984HA13).
[k] (1983WI09).
[l] $\Gamma_\gamma/\Gamma = 0.20 \pm 0.05$, < 0.06 and ≤ 0.1 for ^{11}C*(8.42, 8.66, 8.70), respectively: Γ_{total}(cm) ≤ 4.5, ≤ 4.5 and 15 ± 1 keV (1983WI09).
[m] (1981AL1C).

5. ^{10}B(p, γ)^{11}C $\qquad Q_m = 8.690$

This reaction has been investigated for $E_p = 0.07$ to 17.0 MeV. Reported resonances are displayed in Table 11.20. Observed capture γ-rays are displayed in Table 11.18 [see also for τ_m measurements]. Capture measurements for $E_p = 0.07$ to 2.20 MeV are consistent with five new

Table 11.19: $T = \frac{3}{2}$ states in ^{11}C [a]

Reaction	E_x (MeV)	$\Gamma_{c.m.}$ (keV)	Refs.
^{9}Be(^{3}He, n)^{11}C	12.55 ± 0.05	350 ± 100	(1971WA21)
^{10}B(p, p_2)^{10}B*	12.45 ± 0.10	400 ± 100	(1971WA21)
^{11}B(^{3}He, t)^{11}C	12.57 ± 0.07	370 ± 90	(1971WA21)
^{13}C(p, t)^{11}C	12.47 ± 0.06	550 ± 50	(1968CO26)
^{13}C(p, t)^{11}C	12.48 ± 0.04	540 ± 60	(1974BE20)
	12.51 ± 0.03	490 ± 40	mean
^{9}Be(^{3}He, n)^{11}C	13.7 ± 0.1		(1969BR30)
^{11}B(^{3}He, t)^{11}C	13.92 ± 0.05	260 ± 50	(1971WA21)

[a] See also Table 11.16 for $T = \frac{3}{2}$ states in ^{11}B, and Table 11.21 in (1980AJ01).

resonances (see Tables 11.20 and 11.18), the lowest two (at $E_p = 10$ and 560 keV) of which are s-wave resonances. Thermonuclear reaction rates for $T = (0.01 \rightarrow 5) \times 10^9$ °K are deduced from the results (1983WI09; see also for spectroscopic factors).

The 90° yield of γ_0 has been measured for $E_p = 2.6$ to 17 MeV and angular distributions have been obtained for $E_p = 2.8$ to 14 MeV. The excitation function is consistent with the giant resonance centered at $E_x \approx 16$ MeV. In addition to weak structures at $E_p = 4.75$ MeV and 10.5 MeV, there are three major peaks at $E_p = 4.1$, 7.0 and 8.8 MeV ($\Gamma = 1 - 2$ MeV) [$E_x = 12.4$, 15.0, 16.7 MeV]. At ^{11}C*(12.4), the γ_0 angular distribution is essentially isotropic: $\Gamma_p \Gamma_\gamma / \Gamma \approx 200$ eV, $\Gamma_\gamma \approx 5$ keV (assuming $\Gamma_p \approx 10$ keV). The $E_p = 4.1$ MeV resonance is probably part of the E1 giant resonance and is formed by s-wave capture. At the two higher resonances the angular distributions are characteristic of E1 giant resonances in light nuclei. The ^{10}B(p, γ_1) cross section is small for $E_p = 2.6$ to 17 MeV (1970KU09). See also (1979RO1C; applied).

6. ^{10}B(p, n)^{10}C $Q_m = -4.431$ $E_b = 8.690$

The total (p, n) cross section has been measured to $E_p = 10.6$ MeV: broad maxima are observed at $E_p = 5.92 \pm 0.02$, 6.68 ± 0.04, 7.33 ± 0.05 and 7.60 ± 0.05 MeV (see Table 11.20). The cross section for formation of $^{10}C_{g.s.}$ measured up to 12 MeV shows similar behavior to 8 MeV. At $E_p \approx 8$ MeV, a sharp maximum is observed. The cross section for production of 3.35 MeV γ-rays (from ^{10}C*) does not appear to show structure for $E_p = 8.5$ to 12 MeV. For references see (1980AJ01). See also ^{10}C in (1984AJ01) and (1979BA68).

Table 11.20: Resonances in ^{10}B + p [a]

$E_{\rm res}$ (MeV ± keV)	$E_{\rm x}$ (MeV)	J^π	$\Gamma_{\rm lab}$ (keV)	Decay
0.010 ± 2 [b]	8.699 ± 10	$\frac{5}{2}^+$	16 ± 1 [g]	γ
0.56 ± 60 [b]	9.20 ± 50	$\frac{5}{2}^+$	550 ± 100	γ
1.05 ± 60 [b]	9.64 ± 50	$(\frac{3}{2}^-)$	230 ± 50	γ, (p_0, α_0)
1.20 ± 50 [b]	9.78 ± 50	$(\frac{5}{2}^-)$	260 ± 60	γ, (p_0, α_0)
1.41 ± 50 [b]	9.97 ± 50	$(\frac{7}{2}^-)$	130 ± 20	γ
1.533 ± 5	10.083	$\frac{7}{2}^+$	≈ 250	p_0, α_0, α_1
2.189 ± 5 [c]	10.679	$\frac{9}{2}^+$	220 ± 30	p_0, α_0, α_1
3.03 ± 10 [d]	11.44		400	α_0, α_1
3.9 ± 100	12.20	$T = \frac{3}{2}$		p_2
4.1 ± 100	12.45	$T = \frac{3}{2}$	440 ± 100	p_2
4.1 [e,f]	12.4	$\pi = -$	1–2 MeV	γ_0
4.36 ± 20	12.65	$(\frac{7}{2}^+)$	400	γ_1, α_0, α_1, ^{3}He
(4.75)	(13.01)			γ_0
5.2	13.4		1200 ± 100	α_0, α_1
5.73 ± 20	13.90		≈ 500	γ_1, p
5.92 ± 20	14.07		broad	n
6.68 ± 40	14.76		≈ 500	n, p, ^{3}He
7.33 ± 50 [f]	15.35	$\pi = -$	broad	γ_0, n, p
7.60 ± 50	15.59		≈ 500	n, p
8.8 [f]	16.7	$\pi = -$	900 ± 100	γ_0
(10.5)	(18.2)			γ_0

[a] See also Table 11.18 here, and Tables 11.23 and 11.24 in (1975AJ02). Table 11.23 displays some other reported resonances; Table 11.24 gives detailed parameters for ^{11}C*(9.73, 10.08, 10.68, 12.65). For references see Table 11.22 in (1980AJ01). See also (1979AN16).

[b] (1983WI09).

[c] (1983ME1G; abstract) report resonances at $E_{\rm p} = 2.320$ and 2.575 MeV in the α_0 and α_1 yields, in addition to this resonance observed only in the α_0 yield. It is suggested that the two higher states have $J^\pi = \frac{7}{2}^+$ and $\frac{5}{2}^+$.

[d] See also (1979RI12).

[e] $\Gamma_{\rm p}\Gamma_\gamma/\Gamma \approx 20$ eV.

[f] Probably part of the E1 giant resonance.

[g] $\Gamma_\gamma/\Gamma_{\rm tot} = (2.6 \pm 0.15) \times 10^{-4}$: see (1983WI09). $\Gamma_\gamma/\Gamma_{\rm tot} = 0.20 \pm 0.05$ and < 0.06, respectively for ^{11}C*(8.42, 8.66): $\Gamma_{\rm tot} \leq 5$ keV for both states (1983WI09).

7. ^{10}B(p, p)^{10}B $E_b = 8.690$

Below $E_p = 0.7$ MeV the scattering can be explained in terms of pure s-wave potential scattering but the possibility of a state near $E_p = 0.27$ MeV ($E_x = 8.95$ MeV) cannot be excluded. The elastic scattering then shows two conspicuous anomalies at $E_p = 1.50 \pm 0.02$ MeV and at 2.18 MeV [$E_x = 10.05$ and 10.67 MeV] with $J^\pi = \frac{7}{2}^+$ and $\frac{9}{2}^+$: see Table 11.20. At higher energies (to $E_p = 10.5$ MeV) a single broad resonance is reported at $E_p \approx 5$ MeV. The yield of p_0 has also been measured at $\theta = 150°$ for $E_p = 5.4$ to 7.5 MeV (1981HO13). Polarization measurements are reported at 30.3 MeV (1976DE15, 1977PH02): optical-model parameters are derived. The depolarization parameter D has been measured for polarized protons with $E_p = 26$ and 50 MeV. For references see (1980AJ01).

8. ^{10}B(p, p′)^{10}B $E_b = 8.690$

The yield of γ_1 [from ^{10}B*(0.72)] rises monotonically from $E_p = 1.5$ to 4.1 MeV and then shows resonance behavior at $E_p = 4.36$ and 5.73 MeV: see Table 11.20. For $E_p = 6$ to 12 MeV, the cross section for γ_1 shows several sharp maxima superposed on a broad maximum ($\Gamma \approx 2.5$ MeV) at $E_p \approx 7.2$ MeV. See however (1975AJ02). Yields of five other γ-rays involved in the decay of ^{10}B*(1.74, 2.16, 3.59, 5.18) have also been measured in the range $E_p = 4$ to 12 MeV [see (1975AJ02)]. The yield of 0.72 MeV γ-rays has been studied for $E_p = 2.0$ to 4.1 MeV: no resonances are observed (1979RI12).

Excitation curves for the p_1, p_2 and p_3 groups have been measured for $E_p = 3.5$ to 5.0 MeV. Possible resonances are observed in the p_2 yield [to the $T = 1$ state ^{10}B*(1.74)] corresponding to the first $T = \frac{3}{2}$ states at $E_x = 12.16$ [see, however, reaction 30] and 12.50 MeV [see Table 11.19]: these do not occur in the yield of p_1 and p_3. Yield curves for inelastically scattered protons have also been measured at $E_p = 5.0$ to 16.4 MeV (p_1, p_2, p_3), 6.6 to 16.4 MeV (p_4), 8.9 to 16.4 MeV (p_5) and 10.9 to 16.4 MeV (p to ^{10}B*(6.03)): the principal feature for all groups, except that to ^{10}B*(6.03), is a structure at $E_p \approx 7.5$ MeV, $\Gamma \approx 4$ MeV. In addition narrower structures are observed, including three at $E_p = 5.75$, 6.90 and 7.80 MeV (± 0.2 MeV) and widths of ≈ 500 keV. For π^+ production see (1980DI02, 1981CO1L, 1982LO1K). See also (1979GL1D; theor.) and ^{10}B in (1984AJ01).

9. ^{10}B(p, d)^{9}B $Q_m = -6.212$ $E_b = 8.690$

Polarization measurements have been carried out at $E_p = 49.6$ MeV for the deuterons to ^{9}B*(0, 2.36): see (1975AJ02).

10. ^{10}B(p, ^{3}He)^{8}Be $Q_m = -0.5339$ $E_b = 8.690$

Two strong maxima are observed at $E_p \approx 4.5$ and 6.5 MeV: see Table 11.20. See also (1975AJ02).

11. ^{10}B(p, α)^{7}Be $\quad Q_m = 1.146 \quad E_b = 8.690$

The total cross section for this reaction has been measured for $E_p = 60$ to 180 keV: the extrapolated cross section at the Gamow energy, taken to be 19.1 keV, is $\approx 10^{-12}$ b. The thick-target yield for $E_p = 75$ keV to 3 MeV has been measured by (1975PE1A): the ^{7}Be yield constitutes a potential problem if natural boron is used as fuel in CTR devices.

The parameters of observed resonances are displayed in Table 11.20. The ground-state (α_0) α-particles exhibit broad resonances at $E_p = 1.17$, 1.53, 2.18, 3.0, 4.4, 5.1 and 6.3 MeV. Alpha particles to ^{7}Be*(0.43) [α_1] and 0.43 MeV γ-rays exhibit all but the 1.2 MeV resonance: see (1975AJ02). A broad maximum dominates the region from $E_p = 4$ MeV to about 7.5 MeV. A recent study of the yeild of 0.43 MeV γ-rays for $E_p = 2.0$ to 4.1 MeV suggests that the 3.0 MeV resonance, which is asymmetric, is due to two broad states. A weak structure at $E_p = 2.5$ MeV is also reported (1979RI12). See also ^{7}Be in (1984AJ01), (1979RA20) for the cross section at $E_p = 740$ MeV for ^{7}Be production, (1979RO1C; applied) and (1983LE28, 1983SZZY; astrophys.).

12. ^{10}B(d, n)^{11}C $\quad Q_m = 6.465$

Table 11.21 presents the results obtained in this reaction and in the (^{3}He, d) reaction. Information on τ_m and on the γ-decay of ^{11}C states is displayed in Table 11.18: see (1968AJ02, 1975AJ02) for references. See also (1981AN16), (1979LE1D; applied) and ^{12}C.

13. ^{10}B(^{3}He, d)^{11}C $\quad Q_m = 3.196$

Table 11.21 displays the information derived from this reaction and from the (d, n) reaction. The study of the angular distributions of the deuterons to ^{11}C*(8.66, 8.70) shows that these levels are the analogs, respectively, of ^{11}B*(9.19, 9.27) whose J^π are $\frac{7}{2}^+$ and $\frac{5}{2}^+$ [the ^{11}B states were studied in the (d, p) reaction]: $\Gamma_{c.m.}$ are $\ll 9$ keV and 15 ± 1 keV, respectively, for ^{11}C*(8.66, 8.70): see (1975AJ02) for references.

14. ^{10}B(α, t)^{11}C $\quad Q_m = -11.124$

Angular distributions have been measured at $E_\alpha = 25.1$ and 56 MeV [see (1980AJ01)] and at 29.5 MeV (1982VA1F; t_0, t_1). See also (1983BE1Q; theor.).

Table 11.21: Energy levels of ^{11}C from ^{10}B(d, n)^{11}C and ^{10}B(^{3}He, d)^{11}C [a]

E_x (MeV ± keV)	J^π	l [b]	l [c]	$S_{d,n}$ [c]	$S_{^3He,d}$ [c]	l [d]	$S_{^3He,d}$ [d]
0	$\frac{3}{2}^-$	1	1	1.12	0.88	1	1.09
2.0006 ± 0.9	$\frac{1}{2}^-$	(1)	(1)	(0.18)	(0.036)		
			(3)		≤ 0.09	(3)	< 0.40
4.322 ± 10	$\frac{5}{2}^-$	1	1	0.27	0.20	1	0.17, 0.19
4.808 ± 10	$\frac{3}{2}^-$	1	1	< 0.02		(1)	< 0.08
						(3)	< 0.35
6.345 ± 10	$\frac{1}{2}^+$		2		0.07	2	0.08
6.476 ± 10	$\frac{7}{2}^-$	1	1	0.86	0.56	1	0.73, 0.79
6.903 ± 10	$\frac{5}{2}^+$	(1)				2	0.06
						0	< 0.04
7.498 ± 10	$\frac{3}{2}^+$					2	0.08
8.107 ± 10	$\frac{3}{2}^-$					1	0.07
8.424 ± 8	$\frac{5}{2}^-$	1	1	0.65	0.46	1	0.73, 0.79
8.655 ± 8	$\frac{5}{2}^+$	0	0	$\underline{0.84}$	0.45		
			2	0.8	$\underline{0.32}$		
	$\frac{7}{2}^+$		0	$\underline{0.63}$	0.33	2	0.41
			2	0.6	$\underline{0.24}$	0	< 0.34
8.701 ± 20	$\frac{5}{2}^+$	(0)	0	$\underline{0.40}$	0.14	0	< 0.8
			2	≤ 0.2	0.13		
	$\frac{7}{2}^+$		0	$\underline{0.30}$	0.11		
			2	≤ 0.15	0.10		
10.08							
10.68 [e]			(0, 2)				

[a] See Table 11.23 in (1980AJ01) for references.
[b] From (d, n) work summarized in Table 11.20 of (1968AJ02).
[c] From (1970BO34): $S_{d,n}$ obtained at $E_d = 5.8$ MeV, $S_{^3He,d}$ obtained at $E(^3He) = 11.0$ MeV [both ±30%]. When $S_{d,n}$ and $S_{^3He,d}$ differ appreciably, the more reliable value is underlined.
[d] $E(^3He) = 21$ MeV; when two values are shown for $S_{^3He,d}$ they are in order of descending j.
[e] $\Gamma \approx 200$ keV.

15. ^{10}B(^{7}Li, ^{6}He)^{11}C $\qquad Q_{\rm m} = -1.285$

Angular distributions of ^{6}He ions have been measured at $E(^{7}\text{Li}) = 3.0$ to 3.8 MeV and at 24 MeV [to ^{11}C*(0, 4.32, 6.48)]. ^{11}C*(2.0, 4.80, 8.42, $8.66+8.70$) are also populated: see (1980AJ01) for references.

16. ^{10}B(^{14}N, ^{13}C)^{11}C $\qquad Q_{\rm m} = 1.139$

Elastic angular distributions have been obtianed at $E(^{14}\text{N}) = 73.9$ and 93.6 MeV (1979MO14).

17. ^{11}B(γ, π^-)^{11}C $\qquad Q_{\rm m} = -141.549$

See (1976MI15, 1981RO1L).

18. ^{11}B(p, n)^{11}C $\qquad Q_{\rm m} = -2.764$

Angular distributions have been measured at many energies up to 49.5 MeV [see (1980AJ01)] and at 5.49 to 7.29 MeV (1981HO13; n_0, n_1). ^{11}C*(4.32, 4.81, 6.33, 6.48) are also populated. See also (1981AN16, 1981MU1D), ^{12}C and (1980BA11; theor.).

19. ^{11}B(^{3}He, t)^{11}C $\qquad Q_{\rm m} = -2.001$

Angular distributions of t_0 and t_1 have been measured at $E(^{3}\text{He}) = 10$, 14 and 217 MeV [the latter also for the triton groups to ^{11}C*(4.3, 4.8, 6.48, 8.10) [see (1980AJ01)] and at $E(^{3}\vec{\rm He}) = 33$ MeV (1981BA1G). At $E(^{3}\text{He}) = 26$ MeV the known states of ^{11}C below $E_{\rm x} = 11$ MeV are populated and triton groups are also observed to the possibly $T = \frac{3}{2}$ states displayed in Table 11.19 as well as a state at 14.15 MeV. For references see (1980AJ01).

20. ^{12}C(γ, n)^{11}C $\qquad Q_{\rm m} = -18.721$

The fraction of transitions to the ground and to excited states of ^{11}C [and to ^{11}B states reached in the (γ, p) reaction] has been measured at $E_{\rm bs} = 24.5$, 27, 33 and 42 MeV: the ground state is predominantly populated. The population of analog states in the (γ, n) and (γ, p) reactions are similar. And a significant decay strength is found to the positive-parity states with $6 < E_{\rm x} < 8$ MeV.

In general the main contribution to the strength of the transitions to the various excited states of ^{11}B, ^{11}C lies in rather localized energy bands in ^{12}C which are a few MeV wide (1970ME17). See also reactions 24 and 25 in (1980AJ01), ^{12}C, (1979KI04, 1980GA29, 1980GO13) and (1982LO08; theor.).

21. (a) ^{12}C($\pi^{\pm}$, $\pi^{\pm}$n)^{11}C $\quad Q_{\rm m} = -18.721$

(b) ^{12}C(n, 2n)^{11}C $\quad Q_{\rm m} = -18.721$

(c) ^{12}C(p, pn)^{11}C $\quad Q_{\rm m} = -18.721$

(1978MO01) report the strong population of the $\frac{5}{2}^-$ state ^{11}C*(4.32) (and of the analog state in ^{11}B) for $E_{\pi^+} = 60$ to 300 MeV. See also (1982BU20) as well as (1982HO1C) and (1980KE13; theor.). For reactions (b) and (c) see (1980AJ01), and (1980MC1E) for reaction (c). See also ^{12}C.

22. ^{12}C(π^+, p)^{11}C $\quad Q_{\rm m} = 121.629$

Angular distributions have been obtained to ^{11}C*(0, 2.0, $4.3 + 4.8$, 6.5, 8.5) by (1978AM01; $E_{\pi^+} = 49.3$ MeV) and (1981AN10; $E_{\pi^+} = 90$ and 180 MeV). At the same momentum transfer this reaction and the (p, d) reaction give similar intensities to the low-lying states of ^{11}C. (1978AM01) have also reported population of a $T = \frac{3}{2}$ state at $E_{\rm x} = 12.5 \pm 0.3$ MeV. However (1981AN10) do not observe it: they suggest the possible excitation of ^{11}C*(13.3). See the discussion in (1982DO01). See also (1980GO16) and (1982LO1B; theor.).

23. ^{12}C(p, d)^{11}C $\quad Q_{\rm m} = -16.496$

Angular distributions have been measured for $E_{\rm p} = 19$ to 800 MeV [see (1968AJ02, 1975AJ02, 1980AJ01) for references] and at $E_{\rm p} = 52$ MeV (1980OH06; d to ^{11}C*(0, 4.30, 6.48)) and at $E_{\vec{\rm p}} = 65$ MeV (1980HO18; d$_0$, d$_1$). Observed states of ^{11}C are displayed in Table 11.24 of (1980AJ01). See also ^{13}N in (1986AJ01), (1981IR1A), (1980WH1A, 1982LO1B, 1982YA1A, 1983MO1F) and (1980CO06, 1980SA1K, 1980WI02, 1981JA1D, 1981LU1A, 1982SH06, 1983LU01; theor.).

24. ^{12}C(d, t)^{11}C $\quad Q_{\rm m} = -12.463$

At $E_{\rm d} = 28$ MeV the t$_0$ angular distribution has been measured and a detailed comparison has been made with the results for the mirror reaction ^{12}C(d, ^{3}He)^{11}B. At $E_{\rm d} = 29$ MeV the t$_0$ angular distribution leads to spectroscopic factors $C^2S = 2.82$ or 3.97 depending on different sets of parameters for ^{11}C$_{\rm g.s.}$. ^{11}C*(2.0, 4.32) are also populated. See also ^{14}N in (1986AJ01), and (1980AJ01) for references.

25. (a) $^{12}C(^{3}He, \alpha)^{11}C$ $\qquad Q_m = 1.857$

(b) $^{12}C(^{3}He, tp)^{11}C$ $\qquad Q_m = -17.957$

Table 11.22: Levels of ^{11}C from $^{12}C(^{3}He, \alpha)^{11}C$ [a]

E_x (MeV ± keV)	l	S_{rel}			
		$E(^3He) = 16$ MeV	24 MeV	28 MeV	35.6 MeV
0	1	1	1	1	1.00
1.999 ± 4	1	0.10	≤ 0.6	≤ 0.6	0.19
4.3188 ± 1.2	3	0.057	(0.04)	(0.06)	(0.031)
4.8042 ± 1.2	1	0.11	0.22	0.22	0.13
6.3392 ± 1.4	0	0.003 [b]	≤ 0.07	≤ 0.07	$\lesssim 0.2$
6.4782 ± 1.4	3	0.11 [b]	0.06	(0.06)	(0.21)
6.9048 ± 1.4	2	0.018	(0.15)	(0.17)	(0.054)
7.4997 ± 1.5	2	0.006 [b]	(0.07)	(0.09)	(0.046)
8.1045 ± 1.7	1	0.017 [b,c]			(0.035)
8.42	3	0.034 [b,d]			(0.041)

[a] See Table 11.18 for γ-decay work. Higher excited states are also reported: see text. See Table 11.25 in (1980AJ01) for references and for additional information.

[b] At $E(^3He) = 18$ MeV.

[c] Assuming $J^\pi = \frac{3}{2}^-$.

[d] Assuming $J^\pi = \frac{5}{2}^-$.

Angular distributions have been measured at many energies to $E(^3He) = 217$ MeV [see (1968AJ02, 1975AJ02, 1980AJ01) for references] as well as at 99.4, 119.1 and 139.6 MeV (1981TA25; $\alpha_0 \to \alpha_3, \alpha_5$). Observed states are displayed in Table 11.22. In addition the excitation of states at $E_x = 11.2$, 12.4, 15.3, 23 and (28) MeV has also been suggested: see (1980AJ01).

At $E(^3He) = 35.6$ MeV (1978FO13) find good fits by DWBA for strong $l = 1$ transitions, and reasonable agreement in the forward direction, as well as with $S_{theor.}$, for weak $l = 1$ transitions. Transitions involving $l = 0$ or 2 (and 3) are weak and the agreement with theory is poor. It is suggested that $^{11}C^*(8.10)$ $[\frac{3}{2}^-]$ is predominantly a $p_{3/2}$ hole state coupled to $^{12}C^*(7.65)$ $[0^+]$ (1978FO13).

Alpha-gamma correlations have been studied for $E(^3He) = 4.7$ to 12 MeV: see, in particular, (1968EA03). Their results are summarized in Table 11.20 and are discussed in detail in reaction 22 of (1968AJ02). A measurement of the linear polarization of the 2.00 MeV γ-ray (together with knowledge of the τ_m) fixes $J^\pi = \frac{1}{2}^-$ for $^{11}C^*(2.00)$ (1968BL09). $\tau_m = 10.3 \pm 0.7$

fsec for ^{11}C*(2.00) (1981AL1C). See also ^{12}N, ^{15}O in (1981AJ01, 1986AJ01), (1983MO1F) and (1982KU17; theor.).

Reaction (b) has been studied at $E(^3\text{He}) = 75$ MeV: transitions to ^{11}C*(0, 2.0, 4.3, 4.8, 6.3) are observed by looking at p, t angular correlations (1983ST10).

26. ^{12}C(^{6}Li, ^{7}Li)^{11}C $\qquad Q_\text{m} = -11.471$

The angular distributions involving $^7\text{Li}_\text{g.s.} + {}^{11}\text{C}_\text{g.s.}$ and $^7\text{Li}^*_{0.48} + {}^{11}\text{C}^*_{2.00}$ have been studied at $E(^6\text{Li}) = 36$ MeV: see (1980AJ01).

27. ^{12}C(^{10}B, ^{11}B)^{11}C † $\qquad Q_\text{m} = -7.266$

† I am indebted to Dr. F.C. Barker for his comments on this reaction.

At $E(^{10}\text{B}) = 100$ MeV, angular distributions have been measured involving $^{11}\text{B}_\text{g.s.} + {}^{11}\text{C}_\text{g.s.}$, $^{11}\text{B}_\text{g.s.} + {}^{11}\text{C}_{2.00}$ and $^{11}\text{C}_\text{g.s.} + {}^{11}\text{B}_{2.12}$. Both ^{12}C(^{10}B, ^{11}B)^{11}C (with ^{11}B detected in the forward direction) and ^{12}C(^{10}B, ^{11}C)^{11}B (with ^{11}C detected in the forward direction) were measured. In each case, $^{11}\text{B}_\text{g.s.} + {}^{11}\text{C}_{2.00}$ and $^{11}\text{C}_\text{g.s.} + {}^{11}\text{B}_{2.12}$ were not resolved, but the authors (1975NA15) argue that the (^{10}B, ^{11}B) case would have little contribution from $^{11}\text{C}_\text{g.s.} + {}^{11}\text{B}_{2.12}$ (because of the spins of ^{10}B and $^{11}\text{B}_{2.12}$), so that it essentially gives the $^{11}\text{B}_\text{g.s.} + {}^{11}\text{C}_{2.00}$ angular distribution, and similarly for the other case.

28. ^{12}C(^{12}C, ^{13}C)^{11}C $\qquad Q_\text{m} = -13.774$

Angular distributions involving $^{11}\text{C}_\text{g.s.}$ have been studied at $E(^{12}\text{C}) = 114$ MeV [see (1980AJ01)] and at 93.8 MeV (1979FU04). Cross sections for production of ^{11}C at $E(^{12}\text{C}) = 0.40$, 1.05 and 2.1 GeV/nucleon are reported by (1983SM03). See also (1981CH1R).

29. ^{13}C(π^+, d)^{11}C $\qquad Q_\text{m} = 118.907$

At $E_{\pi^+} = 32$ MeV angular distributions have been obtained for the deuterons to ^{11}C*(0, 6.48) (1982DO01).

30. ^{13}C(p, t)^{11}C $\qquad Q_\text{m} = -15.185$

At $E_p = 43.7$ to 50.5 MeV angular distributions of the tritons have been studied to ^{11}C*(0, 2.00, 4.32, 4.80, 6.48, 6.90, 7.50) and to a $T = \frac{3}{2}$ state at $E_x = 12.47$ MeV [see Table 11.19] whose J^π is determined to be $\frac{1}{2}^-$ [it is thus the analog of ^{11}Be*(0.32)]. The state decays primarily by p $\rightarrow$ ^{10}B*(1.74). Alpha decay to ^{7}Be$^*_{\rm g.s.+0.4}$ is also observed. Angular distributions have also been measured for $E_p = 26.9$ to 43.1 MeV [see (1980AJ01)] and at $E_p = 65$ MeV (1982KA01; t_0, t_1). At $E_p = 46.7$ MeV the $T = \frac{3}{2}$ state is also observed by (1974BE20) who, in addition, report the population of states with $E_x = 11.03 \pm 0.03$, 13.33 ± 0.06, 13.90 ± 0.04 and 14.07 ± 0.04 MeV [$\Gamma = 300 \pm 60$, 270 ± 80, 150 ± 50 and 135 ± 50 keV, respectively]. However, the $T = \frac{3}{2}$ state at $E_x = 12.16$ MeV reported by (1971WA21) in reactions 4, 8 and 19 is not observed by (1974BE20).

31. ^{14}N(p, α)^{11}C $\qquad Q_m = -2.922$

Angular distributions have been reported at a number of energies in the range $E_p = 5.00$ to 44.3 MeV for the α_0 and α_1 groups: see (1975AJ02, 1980AJ01). See also (1981AU1D; astrophys.).

32. ^{14}N(p, pt)^{11}C $\qquad Q_m = -22.736$

See (1978GO14, 1983GO10; theor.).

33. ^{14}N(^{10}B, ^{13}C)^{11}C $\qquad Q_m = 1.139$

This reaction has been studied at $E(^{10}\rm B) = 100$ MeV: see (1980AJ01).

34. ^{16}O(p, ^{6}Li)^{11}C $\qquad Q_m = -22.183$

See (1975AJ02) and (1980HO14; theor.).

35. ^{16}O(d, ^{7}Li)^{11}C $\qquad Q_m = -17.157$

See (1984NE1A).

^{11}N

(Fig. 4)

The ^{14}N(^{3}He, ^{6}He)^{11}N reaction has been studied at E(^{3}He) $= 70$ MeV. A ^{6}He group is observed which corresponds to a state in ^{11}N with an atomic mass excess of 25.23 ± 0.10 MeV and $\Gamma = 740 \pm 100$ keV. The cross section for forming this state is 0.5 μb/sr at $10°$. The observed state is interpreted as being the $J^\pi = \frac{1}{2}^-$ mirror of ^{11}Be*(0.32) because of its width; the $\frac{1}{2}^+$ mirror of ^{11}Be$_{\rm g.s.}$ would be expected to be much broader (1974BE20). The ^{11}N state is unbound with respect to decay into ^{10}C$+$p by 2.24 MeV. See also (1980AJ01) and (1981WA1J, 1982AW02, 1982KA1D, 1982NG01, 1983ANZQ; theor.).

^{11}O, ^{11}F, ^{11}Ne

(Not illustrated)

These nuclei have not been observed: see (1980AJ01) and (1982NG01, 1983ANZQ; theor.).

References

(Closed 01 June 1984)

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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