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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.

(References closed June 1, 1984)

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^{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, 1982BO40, 1982OG02), (1981HA2C), (1979BO22, 1980MA1Z, 1981AV02, 1982KA1D, 1982NG01, 1983ANZQ, 1984VA06; theor.) and (1980AJ01).

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

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 $(41 \pm 4)\%$ (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 $^{8}Be_{g.s.}$ $[(2.0 \pm 0.6)\%]$ and by n + α decay via ^{10}Be*(9.4) to $^{6}He_{g.s.}$ $[(0.9 \pm 0.3)\%]$ (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 $E_t = 20$ 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_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	$\frac{1}{2}^-$	$\tau_m = 166 \pm 15$ 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 $\qquad Q_m = 0.503$

See (1975AJ02).

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

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 † $Q_m = 20.76$

† 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 $Q_m = -28.189$

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 $Q_m = -25.885$

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, 1981ROZU, 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, 1984MIZM).

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

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

B(E2; $\frac{3}{2}^- \rightarrow \frac{1}{2}^-) = 2.1 \pm 0.4\ e^2 \cdot$ 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 $\qquad Q_m = 12.215$

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 $\qquad Q_m = 8.665$

Resonances for capture radiation are displayed in Table 11.6.

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

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 $^{11}{\rm Be}_{\rm (g.s.)}$ 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_{res} (keV)	$\Gamma_{c.m.}$ (keV)	^{11}B* (MeV)	J^{π}	$\omega\gamma$ (eV)	Γ_{γ_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)	$\Gamma_{\rm c.m.}$ (keV)	$E_{\rm x}$ (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 $Q_m = 4.5875$ $E_b = 15.816$

(b) ^{9}Be(d, α)^{7}Li $Q_m = 7.152$

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

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 $E_b = 15.816$

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 $Q_m = 9.559$

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 $Q_m = 10.323$

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; $p_0 \to p_3$) 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; $d_0 \to d_3$). 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 $\pm$ keV) [a]	E_x (MeV $\pm$ 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 $\qquad E_b = 11.454$

(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 (1979GLZV; theor.).

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

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

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

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 $\qquad Q_m = 2.790 \qquad E_b = 11.454$

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 $(6.733 \pm 0.008)\%$ (1967DE15), $(6.699 \pm 0.012)\%$ (1979ST03). At $E_n = 2$ and 24 keV the values are $(7.05 \pm 0.16)\%$ and $(7.13 \pm 0.15)\%$, 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)	$\Gamma_{\alpha 0}$	$\Gamma_{\alpha 1}$	$\Gamma_{c.m.}$ (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, (1984VEZW) 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 (1981NAZY, 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 $\qquad Q_m = 9.230$

Reported proton groups are displayed in Table 11.14 of (1980AJ01). Angular distributions have been studied at many energies in the range $E_d = 0.17$ to 28 MeV [see (1968AJ02, 1975AJ02, 1980AJ01)]. See also (1983HA1Q). The lowest five levels are formed by $l_n = 1$ 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 $l_n = 0$ 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 $\qquad Q_m = 5.197$

At $E_t = 5.5$ 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 $l_n = 1$: see (1968AJ02). See also (1980BO1T).

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

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 $\qquad Q_m = 4.204$

At $E(^7\text{Li}) = 24$ 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 $\qquad Q_m = 9.789$

The total reaction cross section for ^{9}Be + ^{10}B has been studied for $E(^{10}\text{B}) = 2.2$ 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 $Q_m = 6.508$

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

28. ^{11}Be(β^-)^{11}B $Q_m = 11.508$

^{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 $(87.4 \pm 1.2)\%$ and $(12.6 \pm 1.2)\%$, 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 $Q_m = -11.454$
(b) ^{11}B(γ, p)^{10}Be $Q_m = -11.229$
(c) ^{11}B(γ, d)^{9}Be $Q_m = -15.816$
(d) ^{11}B(γ, t)^{8}Be $Q_m = -11.224$

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 · 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 $E_{bs} = 100$ 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, $Q = 3.72$ ($\pm 20\%$) 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(Eλ)↑) 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 (1979GLZV, 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 $E(^{3}\text{He}) = 8$ to 74 MeV: see (1975AJ02, 1980AJ01). At $E(^{3}\text{He}) = 17.5$ 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 $E(^{6}\text{Li}) = 28$ 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 $E(^{11}B) = 18.8$ to 34.1 MeV and at $E(^{12}C) = 15$ to 24 MeV and at 87 MeV [see (1980AJ01)] as well as at $E(^{11}B) = 25$, 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, 1983BI13, 1983DU13) and (1978DZ1A, 1979IS07, 1979ZE1B, 1981YO05, 1982HA42; theor.).

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

The elastic scattering has been investigated at $E(^{14}N) = 41$, 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 $E(^{16}O) = 14.5$ to 60 MeV and at $E(^{11}B) = 115$ MeV [see (1975AJ02, 1980AJ01)] as well as at $E(^{11}B) = 41.6$ and 49.5 MeV (1980PA01). A study of the elastic scattering in reaction (b) is reported at $E(^{11}B) = 115$ MeV (1980PR09). See also (1983GO13; theor.).

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

The elastic angular distribution has been obtained at $E(^{11}B) = 115$ 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 $E(^{11}B) = 79.6$ MeV (1982FU09).

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

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

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

See ^{11}C.

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

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

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

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 $E_\mathrm{bs} = 21.7$ 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 $E_\mathrm{e} = 21$, 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 $\qquad Q_\mathrm{m} = -15.956$

At $E_\mathrm{e} = 497$ 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 $\qquad Q_\mathrm{m} = -15.956$

At $E_{\pi^+} = 100$ MeV [and 129.7 to 199.8 MeV (1981ZI01)] the reaction proceeds primarily to ^{11}B$_{\rm g.s.}$. At $E_\pi = 200$ MeV the ratios for $\sigma_{\rm n}/\sigma_{\rm p}$ 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 $\qquad Q_{\rm m} = -15.956$

At $E_{\rm p} = 98.7$ 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$_{\rm g.s.}$; 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 $\qquad Q_{\rm m} = -10.463$

Angular distributions of ^{3}He ions have been measured for $E_{\rm d} = 20$ to 80 MeV: see (1975AJ02, 1980AJ01). reported C^2S for ^{11}B$_{\rm g.s.}$ are 3.22 or 4.42 depending on the choice of parameters (1978CO13; $E_{\rm d} = 29$ MeV; see also (d, t) results – reaction 24 in ^{11}C) while (1975MA41; $E_{\rm d} = 52$ 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 $\qquad Q_{\rm m} = 3.858$

Angular distributions have been measured for $E_{\rm t} = 1$ to 3.4, 10.1 and 13 MeV: see (1975AJ02).

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

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 $\qquad Q_{\rm m} = -14.013$

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 $\qquad Q_{\text{m}} = -3.108$

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 $\qquad Q_{\text{m}} = -13.184$

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 $\qquad Q_{\text{m}} = 5.169$

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 $\qquad Q_{\text{m}} = -0.783$

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 $\qquad Q_{\text{m}} = -0.157$
(b) ^{14}N(n, 2α)^{7}Li $\qquad Q_{\text{m}} = -8.822$

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 $Q_{\rm m} = -11.082$

See (1980AJ01).

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

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 $Q_{\rm m} = -4.210$

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, 1979ANZM, 1979BU1C, 1979DR09, 1981NI03, 1981RO1L, 1981ROZU, 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 $\qquad Q_{\mathrm{m}} = 1.982$

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 $\qquad Q_{\mathrm{m}} = 9.450$

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, τ_{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 ± 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 $E(^3\mathrm{He}) = 1.3$ 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: $\Gamma_{\rm total}$(cm) ≤ 4.5, ≤ 4.5 and 15 ± 1 keV (1983WI09).
[m] (1981AL1C).

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

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 (1979RO12; 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_{res} (MeV ± keV)	E_x (MeV)	J^π	Γ_{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 $E_p = 2.320$ 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] $\Gamma_p\Gamma_\gamma/\Gamma \approx 20$ eV.

[f] Probably part of the E1 giant resonance.

[g] $\Gamma_\gamma/\Gamma_{tot} = (2.6 \pm 0.15) \times 10^{-4}$: see (1983WI09). $\Gamma_\gamma/\Gamma_{tot} = 0.20 \pm 0.05$ and < 0.06, respectively for ^{11}C*(8.42, 8.66): $\Gamma_{tot} \leq 5$ 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 (1979GLZV; 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 $\qquad Q_m = 1.146 \qquad E_b = 8.690$

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 ussed 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) $[\alpha_1]$ 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, (1979RO12; applied) and (1983LE28, 1983SZZY; astrophys.).

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

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 $\qquad Q_m = 3.196$

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 $\qquad Q_m = -11.124$

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 $\quad Q_{\rm m} = -1.285$

Angular distributions of ^{6}He ions have been measured at $E(^{7}{\rm Li}) = 3.0$ 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 $\quad Q_{\rm m} = 1.139$

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

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

See (1976MI15, 1981RO1L).

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

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 $\quad Q_{\rm m} = -2.001$

Angular distributions of t_0 and t_1 have been measured at $E(^{3}{\rm He}) = 10$, 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 $E(^{3}{\rm He}) = 26$ 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 $\quad Q_{\rm m} = -18.721$

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, α)^{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, α)^{11}C [a]

E_x (MeV ± keV)	l	S_{rel}			
		$E(^3$He$) = 16$ 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 $E(^3$He$) = 18$ MeV.

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

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

Angular distributions have been measured at many energies to $E(^3$He$) = 217$ MeV [see (1968AJ02, 1975AJ02, 1980AJ01) for references] as well as at 99.4, 119.1 and 139.6 MeV (1981TA25; $\alpha_0 \rightarrow \alpha_3$, α_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 $E(^3$He$) = 35.6$ 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 $E(^3$He$) = 4.7$ 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 $\quad Q_\text{m} = -11.471$

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 † $\quad Q_\text{m} = -7.266$

† 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 $\quad Q_\text{m} = -13.774$

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 $\quad Q_\text{m} = 118.907$

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 $\quad Q_\text{m} = -15.185$

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 → ^{10}B*(1.74). Alpha decay to $^7\text{Be}^*_{\text{g.s.}+0.4}$ 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 $E(^{10}\text{B}) = 100$ 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 $E(^3\text{He}) = 70$ 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 $^{11}\text{Be}_{\text{g.s.}}$ 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.

1962GR07 L.L. Green, G.A. Stephens and J.C. Willmott, Proc. Phys. Soc. (London) 79 (1962) 1017

1965KE05 E.F. Kennedy and W.C. Miller, Nucl. Phys. 63 (1965) 634

1965OL03 J.W. Olness, E.K. Warburton, D.E. Alburger and J.A. Becker, Phys. Rev. 139 (1965) B512

1966CU02 R.Y. Cusson, Nucl. Phys. 86 (1966) 481

1966SP02 E. Spamer, Z. Phys. 191 (1966) 24

1967DE15 A.J. Deruytter and P. Pelfer, J. Nucl. Energy 21 (1967) 833

1967PA19 P. Paul, N.G. Puttaswamy and D. Kohler, Phys. Rev. 164 (1967) 1332

1967SP02 E. Spamer and H. Artus, Z. Phys. 198 (1967) 445

1968AJ02 F. Ajzenberg-Selove and T. Lauritsen, Nucl. Phys. A114 (1968) 1

1968BE30 R.A.I. Bell, R.D. Gill, B.C. Robertson, J.S. Lopes and H.J. Rose, Nucl. Phys. A118 (1968) 481

1968BL09 R.S. Blake, G. Johnson, H. Laurent, J.P. Schapira and F. Picard, Nucl. Phys. A117 (1968) 561

1968CO09 M.N.H. Comsan, M.A. Farouk, A.A. El-Kamhawy, M.S.M. El-Tahawy and A.N. Lvov, Z. Phys. 212 (1968) 71

1968CO26 S.W. Cosper, R.L. McGrath, J. Cerny, C.C. Maples, G.W. Goth and D.G. Fleming, Phys. Rev. 176 (1968) 1113

1968CR07 W.L. Creten, R.J. Jacobs and H.M. Ferdinande, Nucl. Phys. A120 (1968) 126

1968EA03 L.G. Earwaker and J.H. Montague, Nucl. Phys. A109 (1968) 507

1969BR30 O.D. Brill, A.D. Vongai and A.A. Ogloblin, Izv. Akad. Nauk SSSR Ser. Fiz. 33 (1969) 615; Bull. Acad. Sci. USSR Phys. Ser. 33 (1970) 567

1969WO03 G. Wolber, H. Figger, R.A. Haberstroh and S. Penselin, Phys. Lett. A29 (1969) 461

1970AL21 D.E. Alburger and G.A.P. Engelbertink, Phys. Rev. C2 (1970) 1594

1970BO34 W. Bohne, J. Bommer, H. Fuchs, K. Grabisch, M. Hagen, H. Homeyer, U. Janetzki, H. Lettau, H. Morgenstern, G. Roschert et al., Nucl. Phys. A157 (1970) 593

1970GO04 D.R. Goosman, E.G. Adelberger and K.A. Snover, Phys. Rev. C1 (1970) 123

1970KU09 H.M. Kuan, M. Hasinoff, W.J. O'Connell and S.S. Hanna, Nucl. Phys. A151 (1970) 129

1970ME17 H.A. Medicus, E.M. Bowey, D.B. Gayther, B.H. Patrick and E.J. Winhold, Nucl. Phys. A156 (1970) 257

1971BI12 H.G. Bingham, K.W. Kemper and N.R. Fletcher, Nucl. Phys. A175 (1971) 374

1971WA21 B.A. Watson, C.C. Chang and M. Hasinoff, Nucl. Phys. A173 (1971) 634

1973CO05 J.M. Cox, H.D. Knox, R.O. Lane and R.W. Finlay, Nucl. Phys. A203 (1973) 89

1973GO09 D.R. Goosman and R.W. Kavanagh, Phys. Rev. C7 (1973) 1717

1973HA64 S.L. Hausladen, C.E. Nelson and R.O. Lane, Nucl. Phys. A217 (1973) 563

1973KE13 H. Kelleter, G. Hrehuss and C. Mayer-Boricke, Nucl. Phys. A210 (1973) 502

1974AN36 N. Anyas-Weiss, J.C. Cornell, P.S. Fisher, P.N. Hudson, A. Menchaca-Rocha, D.J. Millener, A.D. Panagiotou, D.K. Scott, D. Strottman, D.M. Brink et al., Phys. Rept. 12 (1974) 201

1974BE20 W. Benenson, E. Kashy, D.H. Kong-A-Siou, A. Moalem and H. Nann, Phys. Rev. C9 (1974) 2130

1974RO31 E. Roeckl, P.F. Dittner, C. Detraz, R. Klapisch, C. Thibault and C. Rigaud, Phys. Rev. C10 (1974) 1181

1975AJ02 F. Ajzenberg-Selove, Nucl. Phys. A248 (1975) 1

1975KA02 P.T. Kan, G.A. Peterson, D.V. Webb, S.P. Fivozinsky, J.W. Lightbody, Jr. and S. Penner, Phys. Rev. C11 (1975) 323

1975MA41 G. Mairle and G.J. Wagner, Nucl. Phys. A253 (1975) 253

1975NA15 K.G. Nair, H. Voit, C.W. Towsley, M. Hamm, J.D. Bronson and K. Nagatani, Phys. Rev. C12 (1975) 1575

1975PE1A R.J. Peterson, C.S. Zaidins, M.J. Fritts, N.A. Roughton and C.J. Hansen, Ann. Nucl. Energy 2 (1975) 503

1975TH08 C. Thibault, R. Klapisch, C. Rigaud, A.M. Poskanzer, R. Prieels, L. Lessard and W. Reisdorf, Phys. Rev. C12 (1975) 644

1976DE15 R. de Swiniarski, F.G. Resmini, C. Glashausser and A.D. Bacher, Helv. Phys. Acta 49 (1976) 227

1976MI15 K. Min, P. Stoler, S. Trentalange, E.J. Winhold, P.F. Yergin, A.M. Bernstein, W. Turchinetz and K.S.R. Sastry, Phys. Rev. C14 (1976) 807

1977PH02 D.-L. Pham and R. de Swiniarski, Nuovo Cim. A41 (1977) 543

1977SH09 M.A.M. Shahabuddin, C.J. Webb and V.R.W. Edwards, Nucl. Phys. A284 (1977) 83

1977WA1B Wattecamps, Proc. Int. Specialists Symp. on Neutron Standard Appl., 1977 (1977) 67

1978AM01 J.F. Amann, P.D. Barnes, K.G.R. Doss, S.A. Dytman, R.A. Eisenstein, J.D. Sherman and W.R. Wharton, Phys. Rev. Lett. 40 (1978) 758

1978BU28 S. Buzhynski, P. Zupranski, K. Rusek, I.M. Turkevich and Y. Turkevich, Izv. Akad. Nauk SSSR Ser. Fiz. 42 (1978) 2383; Bull. Acad. Sci. USSR Phys. Ser. 42 (1978) 143

1978CO13 J.D. Cossairt, S.B. Talley, D.P. May, R.E. Tribble and R.L. Spross, Phys. Rev. C18 (1978) 23

1978CO1D Cosman, Elkamhawy, Farouk and Oraby, Atomkernenergie 32 (1978) 189

1978DZ1A Dzhamalov, Dolinskii and Mukhamedzhanov, Izv. Akad. Nauk SSSR Ser. Fiz. 42 (1978) 2365

1978FO13 H.T. Fortune, D.J. Crozier, B. Zeidman and M.E. Cobern, Nucl. Phys. A303 (1978) 14

1978GO14 N.F. Golovanova and I.M. Ilin, Izv. Akad. Nauk SSSR Ser. Fiz. 42 (1978) 1528; Bull. Acad. Sci. USSR Phys. Ser. 42 (1978) 154

1978KR19 K.S. Krane, At. Data Nucl. Data Tables 22 (1978) 269

1978KU12 N. Kumagai, G. Isoyama, E. Tanaka, K. Kageyama and T. Ishimatsu, Nucl. Instrum. Meth. Phys. Res. 157 (1978) 423

1978LEZA C.M. Lederer, V.S. Shirley, E. Browne, J.M. Dairiki, R.E. Doebler, A.A. Shihab-Eldin, L.J. Jardine, J.K. Tuli and A.B. Buyrn, Table of Isotopes 7th Ed. (1978)

1978LI32 H. Liskien and E. Wattecamps, Nucl. Sci. Eng. 68 (1978) 132

1978MO01 C.L. Morris, R.L. Boudrie, J.J. Kraushaar, R.J. Peterson, R.A. Ristinen, G.R. Smith, J.E. Bolger, W.J. Braithwaite, C.F. Moore and L.E. Smith, Phys. Rev. C17 (1978) 227

1978OE1A W. Oelert, A. Djaloeis, C. Mayer-Boricke, P. Turek and S. Wiktor, AIP Conf. Proc. 47 (1978) 730

1978OR1A Orth, Buffington, Smoot and Mast, Astrophys. J. 226 (1978) 1147

1978SA26 A. Saha, R. Kamermans, J. van Driel and H.P. Morsch, Phys. Lett. B79 (1978) 363

1978SC31 R.A. Schrack, G.P. Lamaze and O.A. Wasson, Nucl. Sci. Eng. 68 (1978) 189

1978SO1A Sokol, Izv. Akad. Nauk SSSR Ser. Fiz. 42 (1978) 1829

1978VO10 V.V. Volkov, A.G. Artyukh, G.F. Gridnev, A.N. Mezentsev, V.L. Mikheev, A. Popescu, D.G. Popescu, A.M. Sukhov and L.P. Chelnokov, Izv. Akad. Nauk. SSSR Ser. Fiz. 42 (1978) 2234; Bull. Acad. Sci. USSR Phys. Ser. 42 (1978) 14

1979AL1J Alster and Warszawski, Phys. Rept. 52 (1979) 87

1979AL21 V.V. Alizade, A.V. Kuptsov, V.P. Kurochkin, L.L. Nemenov, G.I. Smirnov and D.M. Khazins, Yad. Fiz. 30 (1979) 363; Sov. J. Nucl. Phys. 30 (1979) 187

1979AL22 Y. Alhassid, R.D. Levine, J.S. Karp and S.G. Steadman, Phys. Rev. C20 (1979) 1789

1979AL26 G.D. Alkhazov, S.L. Belostotskii, A.A. Vorobev, O.A. Domchenkov, Y.V. Dotsenko, N.P. Kuropatkin, V.N. Nikulin and M.A. Shuvaev, Pisma Zh. Eksp. Teor. Fiz. 29 (1979) 88; JETP Lett. 29 (1979) 80

1979AN16 A. Anttila, J. Keinonen and R. Hentela, Phys. Rev. C20 (1979) 920

1979ANZM K. Aniol, D. Chiang, I. Halpern, D. Drake and G. Haouat, Bull. Amer. Phys. Soc. 24 (1979) 821, AD19

1979AZ03 R.E. Azuma, L.C. Carraz, P.G. Hansen, B. Jonson, K.-L. Kratz, S. Mattsson, G. Nyman, H. Ohm, H.L. Ravn, A. Schroder et al., Phys. Rev. Lett. 43 (1979) 1652

1979BA16 B. Bassalleck, H.-D. Engelhardt, W.D. Klotz, F. Takeutchi, H. Ullrich and M. Furic, Nucl. Phys. A319 (1979) 397

1979BA48 J.K. Bair and J. Gomez del Campo, Nucl. Sci. Eng. 71 (1979) 18

1979BA68 V.N. Baturin, V.P. Koptev, E.M. Maev, M.M. Makarov, V.V. Nelyubin, V.V. Sulimov, A.V. Khanzadeev and G.V. Shcherbakov, Pisma Zh. Eksp. Teor. Fiz. 30 (1979) 86; JETP Lett. 30 (1979) 78

1979BE18 H. Beer and R.R. Spencer, Nucl. Sci. Eng. 70 (1979) 98

1979BJ1A Bjarle, Herrstrom, Jonnsson and Kristiansson, Z. Phys. A291 (1979) 383

1979BO1E Borovikova et al., Pisma V Zh. Eksp. Teor. Fiz. 30 (1979) 527

1979BO1Q Bowman and Behrens, Bull. Amer. Phys. Soc. 24 (1979) 864

1979BO22 V.I. Bogatin, O.V. Lozhkin and Y.P. Yakovlev, Nucl. Phys. A326 (1979) 508

1979BU1C Bunyatov et al., Yad. Fiz. 30 (1979) 1054

1979CA1C Carlson, Bowman, Behrens and Todd, Bull. Amer. Phys. Soc. 24 (1979) 864

1979CH22 M.L. Chatterjee, H.C. Cheung and B. Cujec, Nucl. Phys. A323 (1979) 461

1979CZ1A Czirr and Carlson, Bull. Amer. Phys. Soc. 24 (1979) 864

1979DE1H Del Fiore et al., Int. J. Appl. Radiat. Isotp. 30 (1979) 543

1979DE35 D.W. Devins, D.L. Friesel, W.P. Jones, A.C. Attard, I.D. Svalbe, V.C. Officer, R.S. Henderson, B.M. Spicer and G.G. Shute, Aust. J. Phys. 32 (1979) 323

1979DO17 G.E. Dogotar, R.A. Eramzhyan, M. Gmitro, H.R. Kissener and E. Tinkova, J. Phys. (London) G5 (1979) L221

1979DR09 B.J. Dropesky, G.W. Butler, C.J. Orth, R.A. Williams, M.A. Yates-Williams, G. Friedlander and S.B. Kaufman, Phys. Rev. C20 (1979) 1844

1979FR05 A.D. Frawley, J.F. Mateja, A. Roy and N.R. Fletcher, Phys. Rev. C19 (1979) 2215

1979FU04 C.B. Fulmer, R.M. Wieland, D.C. Hensley, S. Raman, G.R. Satchler, A.H. Snell, P.H. Stelson and R.G. Stokstad, Phys. Rev. C20 (1979) 670

1979GE1A Gelbke, BNL-51115 (1979) 1

1979GLZV S.G. Glendinning, F.O. Purser and C.R. Gould, Bull. Amer. Phys. Soc. 24 (1979) 830, BE1

1979GR2D Greenwood, Bull. Amer. Phys. Soc. 24 (1979) 886

1979IS07 M. Ismail and M.A. Sharaf, Atomkernernerg. Kerntech. (Germany) 33 (1979) 219

1979KA35 I.M. Kapitonov, E.V. Lazutin, V.I. Mokeev, E.S. Omarov and I.M. Piskarev, Yad. Fiz. 30 (1979) 1175; Sov. J. Nucl. Phys. 30 (1979) 609

1979KI04 V.V. Kirichenko, A.F. Khodyachikh, P.I. Vatset, I.V. Dogyust and V.A. Zolenko, Yad. Fiz. 29 (1979) 572; Sov. J. Nucl. Phys. 29 (1979) 292

1979KI1G Kim and Primakoff, Mesons in Nucl., Eds. Rho and Wilkenson (1979) 69

1979LE1D Len and Cecil, Bull. Amer. Phys. Soc. 24 (179) 886

1979MA38 R.E. Marrs, R.E. Pollock and W.W. Jacobs, Phys. Rev. C20 (1979) 2308

1979MA39 R.E. Marrs and R.E. Pollock, Phys. Rev. C20 (1979) 2446

1979ME2A D.F. Measday and G.A. Miller, Ann. Rev. Nucl. Part. Sci. 29 (1979) 121

1979MO14 T. Motobayashi, I. Kohno, T. Ooi and S. Nakajima, Nucl. Phys. A331 (1979) 193

1979MO1G Mougey, Proc. Mainz, 1979, Springer Lect. Notes 108 (1979) 124

1979NI06 H. Nishioka, S. Saito and M. Yasuno, Prog. Theor. Phys. 62 (1979) 424

1979PE1D Petrov and Shabelskii, Sov. J. Nucl. Phys. 30 (1979) 66

1979PI1C Pickar et al., Bull. Amer. Phys. Soc. 24 (1979) 819

1979PO1B Polischuk et al., Sov. J. Nucl. Phys. 29 (1979) 297

1979RA1C Ramaty, Kozlovsky and Lingenfelter, Astrophys. J. Suppl. Series 40 (1979) 487

1979RA20 J.R. Radin, E. Gradsztajn and A.R. Smith, Phys. Rev. C20 (1979) 787

1979RI12 Y. Rihet, G. Costa, C. Gerardin and R. Seltz, Phys. Rev. C20 (1979) 1583

1979RI1D Richter, Proc. Mainz, 1979, Springer Lec. Notes 108 (1979) 19

1979RO12 N.A. Roughton, M.R. Fritts, R.J. Peterson, C.S. Zaidins and C.J. Hansen, At. Data Nucl. data Tables 23 (1979) 177

1979RO1B Rotter, J. Phys. (London) G5 (1979) 1575

1979SA26 F. Saint-Laurent, M. Conjeaud, S. Harar, J.M. Loiseaux, J. Menet and J.B. Viano, Nucl. Phys. A327 (1979) 517

1979SA27 G.R. Satchler, Nucl. Phys. A329 (1979) 233

1979SC1D Scott, Prog. Nucl. Phys. 4 (1979) 5

1979ST03 M.L. Stelts, R.E. Chrien, M. Goldhaber, M.J. Kenny and C.M. McCullagh, Phys. Rev. C19 (1979) 1159

1979ST1D Stanley, Glover and Petrovich, Bull. Amer. Phys. Soc. 24 (1979) 816

1979ST25 J.P. Stoquert, N. Bendjaballah, H. Beaumevieille, C. Gerardin and R. Seltz, J. Phys. (Paris) 40 (1979) 813

1979VI04 G. Viesti and H. Liskien, Ann. Nucl. Energy 6 (1979) 13

1979WA1F Watermann et al., Med. Phys. (USA) 6 (1979) 432

1979ZE1B Zelenskaya and Teplov, Izv. Akad. Nauk SSSR Ser. Fiz. 43 (1979) 2375

1979ZI05 H.J. Ziock, R.J. Ellis, K.O.H. Ziock, J. Bolger, E. Boschitz, J. Arvieux, R. Corfu and J. Piffaretti, Phys. Rev. Lett. 43 (1979) 1919

1980AF1A Afzal, Ansari and Sergal, Lett. Nuovo Cim. 29 (1980) 350

1980AJ01 F. Ajzenberg-Selove and C.L. Busch, Nucl. Phys. A336 (1980) 1

1980AZ01 R.E. Azuma, T. Bjornstad, H.A. Gustafsson, P.G. Hansen, B. Jonson, S. Mattsson, G. Nyman, A.M. Poskanzer, H.L. Ravn, the ISOLDE Collaboration, Phys. Lett. B96 (1980) 31

1980BA11 V.V. Balashov, H.W. Barz and H.U. Jager, J. Phys. (London) G6 (1980) L77

1980BA2K Barashencov and Musulmanbecov, Z. Phys. A296 (1980) 371

1980BA45 B.M. Barnett, W. Gyles, R.R. Johnson, K.L. Erdman, J. Johnstone, J.J. Kraushaar, S. Lepp, T.G. Masterson, E. Rost, D.R. Gill et al., Phys. Lett. B97 (1980) 45

1980BO1T Bondouk and Omar, Atomkernernerg. Kerntech. 35 (1980) 216, 219

1980BO1V Bowman, Behrans, Gwin and Todd, Proc. Int. Conf. on Nucl. Cross Sect. for Tech., Knoxville, TN, 1979 (1980) 97

1980BO31 V.I. Bogatin, E.A. Ganza, O.V. Lozhkin, Yu.A. Murin and V.S. Oplavin, Yad. Fiz. 32 (1980) 27; Sov. J. Nucl. Phys. 32 (1980) 14

1980CA1L Calarco et al., Proc. Int. Conf. on Nucl. Phys., Berkeley (1980) 228

1980CA1R Carlson et al., Proc. Int. Conf. on Nucl. Cross Sect. for Tech., Knoxville, TN, 1979 (1980) 89

1980CO06 J.R. Comfort and B.C. Karp, Phys. Rev. C21 (1980) 2162; Erratum Phys. Rev. C22 (1980) 1809

1980CO10 T.M. Cormier and B.R. Fulton, Phys. Rev. C22 (1980) 565

1980CO1R Cook, Stone and Vogl, Astrophys. J. 238 (1980) L97

1980CZ1A Czirr and Carlson, Proc. Int. Conf. on Nucl. Cross Sect. for Tech., Knoxville, TN, 1979 (1980) 84

1980DE11 A. Deloff, Phys. Rev. C21 (1980) 1516

1980DE39 C. Detraz, D. Guillemaud, M. Langevin, F. Naulin, M. Epherre, R. Klapisch, M. de Saint-Simon, C. Thibault and F. Touchard, J. Phys. Lett. (Paris) 41 (1980) L-459.

1980DE42 A.S. Deineko, I.I. Zalyubovsky, I.Ya. Malakhov, V.D. Sarana and N.A. Shlyakhov, Izv. Akad. Nauk SSSR Ser. Fiz. 44 (1980) 957; Bull. Acad. Sci. USSR Phys. Ser. 44 (1980) 51

1980DE43 A.S. Deineko, Yu.V. Lyashko, I.Ya. Malakhov, V.D. Sarana, V.E. Storizhko and N.A. Shlyakhov, Izv. Akad. Nauk. SSSR Ser. Fiz. 44 (1980) 2375

1980DE44 A.S. Deineko, I.I. Zalyubovsky, I.Ya. Malakhov, V.D. Sarana and N.A. Shlyakhov, Izv. Akad. Nauk SSSR Ser. Fiz. 44 (1980) 2382

1980DE45 A.S. Deineko, I.I. Zalyubovsky, I.Ya. Malakhov, V.D. Sarana, V.E. Storizhko and N.A. Shlyakhov, Izv. Akad. Nauk SSSR Ser. Fiz. 44 (1980) 2652; Bull. Acad. Sci. USSR Phys. Ser. 44 (1980) 163

1980DI02 M. Dillig, P. Couvert, T.S. Bauer, R. Beurtey, A. Boudard, G. Bruge, H. Catz, A. Chaumeaux, H.H. Duhm, J.L. Escudie et al., Nucl. Phys. A333 (1980) 477

1980DO1C Domogatsky and Nadyozhin, Astrophys. Space Sci. 70 (1980) 33, 77

1980DU21 E.I. Dubovoi, Izv. Akad. Nauk SSSR Ser. Fiz. 44 (1980) 2434; Bull. Acad. Sci. USSR Phys. Ser. 44 (1980) 2341

1980FA07 E. Fabrici, S. Micheletti, M. Pignanelli, F.G. Resmini, R. De Leo, G. D'Erasmo and A. Pantaleo, Phys. Rev. C21 (11980) 844

1980FE07 M.P. Fewell, R.H. Spear, T.H. Zabel and A.M. Baxter, Aust. J. Phys. 33 (1980) 505; Erratum Aust. J. Phys. 37 (1984) 239

1980FR1G P.H. Frampton and S.L. Glashow, Phys. Rev. Lett. 44 (1980) 1481

1980FU1G Furutani et al., Suppl. Prog. Theor. Phys. 68 (1980) 193

1980GA29 A.V. Gann, V.I. Noga, Yu.N. Ranyuk, Yu.N. Telegin and G.G. Jonsson, Yad. Fiz. 32 (1980) 1161

1980GL03 C.W. Glover, K.W. Kemper, L.A. Parks, F. Petrovich and D.P. Stanley, Nucl. Phys. A337 (1980) 520

1980GO13 H. Goringer and B. Schoch, Phys. Lett. B97 (1980) 41

1980GO16 F. Goetz, J.-P. Egger, P. Gretillat, C. Lunke, E. Schwarz and C. Perrin, Helve. Phys. Acta 53 (1980) 31

1980GR10 R.E.L. Green and R.G. Korteling, Phys. Rev. C22 (1980) 1594

1980GR1G Gram et al., Proc. Int. Conf. on Nucl. Phys., Berkeley (1980) 732

1980HO14 T. Honda, Y. Kudo and H. Horie, Prog. Theor. Phys. (Kyoto) 63 (1980) 872

1980HO18 K. Hosono, M. Kondo, T. Saito, N. Matsuoka, S. Nagamachi, T. Noro and H. Shimizu, Nucl. Phys. A343 (1980) 234

1980IS1F Ishkanov, Kapitonov, Shvednunov and Chumakov, Yad. Fiz. 32 (1980) 305

1980IW1A Iwao, Lett. Nuovo Cim. 29 (1980) 40

1980KE13 B.D. Keister, Nucl. Phys. A350 (1980) 365

1980KO1L Kostin, Koval, Kopanets and Tsytko, Ukr. Fiz. Zh. 25 (1980) 881

1980KO1V Koptev, Maev, Makarov and Khanzadeev, Yad. Fiz. 31 (1980) 1501

1980LE02 T.-S.H. Lee and D. Kurath, Phys. Rev. C21 (1980) 293

1980MA1Z Mandal and Saha, Can. J. Phys. 58 (1980) 300

1980MC1E McCullagh, Hill, Wohn and Mercier, Bull. Amer. Phys. Soc. 25 (1980) 560

1980MI01 T. Mikumo, M. Sasagase, M. Sato, T. Ooi, Y. Higashi, Y. Nagashima and M. Yamanouchi, Phys. Rev. C21 (1980) 620

1980MI1G D.J. Millener, Phys. Rev. C22 (1980) 1355

1980MO14 R. Moreh, W.C. Sellyey and R. Vodhanel, Phys. Lett. B92 (1980) 286

1980MO23 R. Moreh, W.C. Sellyey and R. Vodhanel, Phys. Rev. C22 (1980) 1820; Erratum Phys. Rev. C23 (1981) 2799

1980MO28 G.C. Morrison, R.K. Bhowmik, E.C. Pollacco, J.B.A. England and N.E. Sanderson, J. Phys. (Paris) Colloq. 41 (1980) C10-243

1980MU1D Muller et al., Nucl. Instrum. Meth. Phys. Res. 170 (1980) 151

1980OH06 H. Ohnuma, J. Kasagi, F. Kakimoto, S. Kubono and K. Koyama, J. Phys. Soc. Jpn. 48 (1980) 1812

1980PA01 L.A. Parks, D.P. Stanley, L.H. Courtney and K.W. Kemper, Phys. Rev. C21 (1980) 217

1980PR09 G. Proudfoot, H.S. Bradlow, P.S. Fisher, N.S. Godwin, J. King, D. Sinclair and W.D.M. Rae, Nucl. Phys. A345 (1980) 278

1980RA16 K. Ramavataram, R. Larue, V. Turcotte, C. St-Pierre and S. Ramavataram, Nuovo Cim. A58 (1980) 342

1980RE1B Read et al., Bull. Amer. Phys. Soc. 25 (1980) 592

1980RI06 W.A. Richter and P.R. de Kock, Z. Phys. A297 (1980) 343

1980SA1K Saini and Jain, Proc. Int. Conf. on Nucl. Phys., Berkeley (1980) 893

1980SC18 L.A. Schaller, L. Schellenberg, A. Ruetschi and H. Schneuwly, Nucl. Phys. A343 (1980) 333

1980SO05 F. Soga, R.D. Bent, P.H. Pile, T.P. Sjoreen and M.C. Green, Phys. Rev. C22 (1980) 1348

1980WA25 E.K. Warburton and D.E. Alburger, Nucl. Instrum. Meth. 178 (1980) 443

1980WH01 R.M. White, R.O. Lane, H.D. Knox and J.M. Cox, Nucl. Phys. A340 (1980) 13

1980WH1A C.A., Jr. Whitten, Nucl. Phys. A335 (1980) 419

1980WI02 C. Wilkin, J. Phys. (London) G6 (1980) 69

1980WI1K L. Winsberg, E.P. Steinberg, D. Henderson and A. Chrapkowski, Phys. Rev. C22 (1980) 2108

1980WI1L L. Winsberg, Phys. Rev. C22 (1980) 2123

1980ZI1B H.J. Ziock, R.C. Minehart, E.A. Wadlinger, H.J. Weber, K.O. Ziock and K.P. Ziock, Phys. Rev. C22 (1980) 907

1981AJ01 F. Ajzenberg-Selove, Nucl. Phys. A360 (1981) 1

1981AL03 D.E. Alburger, D.J. Millener and D.H. Wilkinson, Phys. Rev. C23 (1981) 473

1981AL1C Alexander, Ball, Davies and Mitchell. J. Nucl. Materials 96 (1981) 51

1981AM01 K. Amos, I. Morrison and R. Smith, Phys. Rev. C23 (1981) 1

1981AN10 R.E. Anderson, B. Hoistad, R.L. Boudrie, E.W. Hoffman, R.J. Macek, C.L. Morris, H.A. Thiessen, G.R. Smith and J. Kallne, Phys. Rev. C23 (1981) 2616

1981AN16 B. Anders, P. Herges and W. Scobel, Z. Phys. A301 (1981) 353

1981AU1C Auld, Santa Fe 1980, AIP Conf. Proc. 69 (1981) 93

1981AU1D Audouze, Prog. Part. Nucl. Phys. 6 (1981) 125

1981AU1G Austin, Prog. Part. Nucl. Phys. 7 (1981) 1

1981AV02 I.K. Averyanov, A.I. Golubev and A.A. Sadovoy, Yad. Fiz. 33 (1981) 66

1981BA1G Basak et al., Santa Fe 1980, AIP Conf. Proc. 69 (1981) 593

1981BE63 V.B. Belyaev and O.P. Solovtsova, Yad. Fiz. 33 (1981) 699; Sov. J. Nucl. Phys. 33 (1981) 363

1981BH02 R.K. Bhowmik, E.C. Pollacco, J.B.A. England, G.C. Morrison and N.E. Sanderson, Nucl. Phys. A363 (1981) 516

1981BJ01 T. Bjornstad, H.A. Gustafsson, P.G. Hansen, B. Jonson, V. Lindfors, S. Mattsson, A.M. Poskanzer, H.L. Ravn, the ISOLDE Collaboration, Nucl. Phys. A359 (1981) 1

1981BO14 S. Boffi, C. Giusti and F.D. Pacati, Nucl. Phys. A359 (1981) 91

1981BO1X Bogatin et al., Yad. Fiz. 34 (1981) 104

1981BO1Y Bouten and Bouten, Prog. Part. Nucl. Phys. 5 (1981) 55

1981BR1E Brooks, Lister, Nelson and Dhuga, Santa Fe 1980, AIP Conf. Proc. 69 (1981) 656

1981CA06 Sl. Cavallaro, S. Incardona, M.L. Sperduto and M. Romeo, Nuovo Cim. A62 (1981) 1

1981CA1H Cahn and Glashow, Science 213 (1981) 607

1981CE04 F.E. Cecil and R.F. Fahlsing, Phys. Rev. C24 (1981) 1769; Erratum Phys. Rev. C25 (1982) 2137

1981CH1R Chu et al., Chin. Phys. 1 (1981) 421

1981CI03 M.A. Cirit and F. Yazici, Phys. Rev. C23 (1981) 2627

1981CO08 W.D. Cornelius, J.M. Moss and T. Yamaya, Phys. Rev. C23 (1981) 1364

1981CO1L Couvert and Dillig, Proc. Versailles Conf. (1981) 192

1981FE2A H.W. Fearing, Prog. Part. Nucl. Phys. 7 (1981) 113

1981FR17 E. Friedman, Phys. Lett. B104 (1981) 357

1981GA1C Garcia-Munoz, Guzik, Simpson and Wefel, Bull. Amer. Phys. Soc. 26 (1981) 557

1981GE1B Geesaman et al., Proc. Versailles Conf. (1981) 302

1981GI08 M. Giffon, A. Goncalves, P.A.M. Guichon, J. Julien, L. Roussel and C. Samour, Phys. Rev. C24 (1981) 241

1981GO11 N.S. Godwin, W.D.M. Rae, B. Cooke, A. Etchegoyen, N.J. Eyre, P.S. Fisher, G. Proudfoot and D. Sinclair, Nucl. Phys. A363 (1981) 493

1981GU1D Guzik, Astrophys. J. 244 (1981) 695

1981HA2C Hansen, Nucl. Struct., NATO B67 (1981) 289

1981HN01 V. Hnizdo, C.W. Glover and K.W. Kemper, Phys. Rev. C23 (1981) 236

1981HO13 J. Hohn, J. Kayser, W. Pilz, D. Schmidt and D. Seeliger, J. Phys. (London) G7 (1981) 803

1981IN1B Int. Nucl. Data Comm. INDC-36/LN (1981)

1981IR1A Irom et al., Proc. Versailles Conf. (1981) 546

1981JA1D Jain, Proc. Versailles Conf. (1981) 548

1981JOZV B. Jonson, H.A. Gustafsson, P.G. Hansen, P. Hoff, P.O. Larsson, S. Mattsson, G. Nyman, H.L. Ravn and D. Schardt, Proc. Int. Conf. Nuclei Far from Stability, Helsingor, Denmark, 1 (1981) 265; CERN 81-09 (1981)

1981KE17 B.K. Kerimov, A.I. Elgavkhari and A.G. Ganiev, Izv. Akad. Nauk SSSR Ser. Fiz. 45 (1981) 2197; Bull. Acad. Sci. USSR Phys. Ser. 45 (1981) 152

1981KO1U Kong et al., Phys. Energ. Fortis Phys. Nucl. 5 (1981) 600

1981KU1C Kuzmin, Solin and Nemilov, Proc. Samarkand Conf. (1981) 603

1981LA11 M. Langevin, C. Detraz, D. Guillemaud, F. Naulin, M. Epherre, R. Klapisch, S.K.T. Mark, M. De Saint Simon, C. Thibault and F. Touchard, Nucl. Phys. A366 (1981) 449

1981LU1A Ludeking and Vary, Bull. Amer. Phys. Soc. 26 (1981) 622

1981MA14 G. Mairle, G.J. Wagner, K.T. Knopfle, Ken Pao Liu, H. Riedesel, V. Bechtold and L. Friedrich, Nucl. Phys. A363 (1981) 413

1981MA18 J.F. Mateja, A.D. Frawley, L.C. Dennis, K. Abdo and K.W. Kemper, Phys. Rev. Lett. 47 (1981) 311

1981ME13 M.C. Mermaz, J. Barrette and H.E. Wegner, Phys. Rev. C24 (1981) 2148

1981MO20 J. Mougey, R. Ost, M. Buenerd, A.J. Cole, C. Guet, D. Lebrun, J.M. Loiseaux, P. Martin, M. Maurel, E. Monnand et al., Phys. Lett. B105 (1981) 25

1981MU1D Murphy et al., Santa Fe 1980, AIP Conf. Proc. 69 (1981) 1478

1981MU1E Mukhopadhyay and Hintermann, Santa Fe 1980, AIP Conf. Proc. 69 (1981) 1068

1981MUZQ S.F. Mughabghab, M. Divadeenam and N.E. Holden, Neutron Cross Sections Part A, Z=1-60 (1981)

1981NAZY H. Nann, K.K. Seth, S. Iversen and B. Hoistad, Bull. Amer. Phys. Soc. 26 (1981) 581, EH5

1981NI03 T. Nishi, I. Fujiwara, N. Imanishi, H. Moriyama, K. Otozai, R. Arakawa, S. Saito, T. Tsuneyoshi, N. Takahashi, S. Iwata et al., Nucl. Phys. A352 (1981) 461

1981OL01 A. Olin, P.R. Poffenberger, G.A. Beer, J.A. Macdonald, G.R. Mason, R.M. Pearce and W.C. Sperry, Nucl. Phys. A360 (1981) 426

1981OS1H Osman, Atomkernernerg. Kerntech. 38 (1981) 212

1981RA06 I. Ragnarsson, S. Aberg, H.-B. Hakansson and R.K. Sheline, Nucl. Phys. A361 (1981) 1

1981RI1A Richter, Nucl. Struct., NATO B67 (1981) 241

1981RO1L Rowley et al., Proc. Versailles Conf. (1981) 107

1981ROZU D. Rowley, J. Lerose, K. Min, B.O. Sapp, P. Stoler, E.J. Winhold, P.F. Yergin, I. Blomqvist, A.M. Bernstein, H.S. Caplan, et al., Bull. Amer. Phys. Soc. 26 (1981) 1123, BC1

1981SE04 R.M. Sealock, H.-Y. Wu and J.C. Overley, Nucl. Phys. A357 (1981) 279

1981SE06 M. Seya, M. Kohno and S. Nagata, Prog. Theor. Phys. 65 (1981) 204

1981SJ02 T.P. Sjoreen, P.H. Pile, R.E. Pollock, W.W. Jacobs, H.O. Meyer, R.D. Bent, M.C. Green and F. Soga, Phys. Rev. C24 (1981) 1135

1981SL03 R.J. Slobodrian, C. Rioux, R. Roy, H.E. Conzett, P. von Rossen and F. Hinterberger, Phys. Rev. Lett. 47 (1981) 1803

1981ST14 M.M. Sternheim and R.R. Silbar, Phys. Rev. C24 (1981) 574

1981ST1G W. Stepien-Rudzka and S. Wycech, Nucl. Phys. A362 (1981) 349

1981TA16 S.L. Tabor, L.C. Dennis, K.W. Kemper, J.D. Fox, K. Abdo, G. Neuschaefer, D.G. Kovar and H. Ernst, Phys. Rev. C24 (1981) 960

1981TA22 S.L. Tabor, L.C. Dennis and K. Abdo, Phys. Rev. C24 (1981) 2552

1981TA25 M. Tanaka, K. Iwamoto, T. Yamagata, S. Kishimoto, B. Saeki, K. Yuasa, T. Fukuda, K. Okada, I. Miura, M. Inoue et al., Nucl. Phys. A372 (1981) 173

1981TH1B A.W. Thomas, Nucl. Phys. A354 (1981) 51

1981VE08 V.A. Vesna, A.I. Egorov, E.A. Kolomensky, V.M. Lobashev, A.N. Pirozhkov, L.M. Smotritsky and N.A. Titov, Pisma Zh. Eksp. Teor. Fiz. 33 (1981) 429; JETP Lett. (USSR) 33 (1981) 411

1981WA1J Wang, Zhang, Li and Ruan, Proc. Versailles Conf. (1981) 374

1981WA1P Wang et al., Ann. Rept. Inst. Phys. Acad. Sin. 11 (1981) 1

1981XU1A Xu et al., Phys. Energ. Fortis Phys. Nucl. 5 (1981) 607

1981YO05 M.I. Yousef and R. Reif, Yad. Fiz. 33 (1981) 1006; Sov. J. Nucl. Phys. 33 (1981) 531

1981ZI01 H.J. Ziock, R.J. Ellis, K.O.H. Ziock, J. Bolger, E. Boschitz, J. Arvieux, R. Corfu and J. Piffaretti, Phys. Rev. C24 (1981) 2674

1982AL08 D.V. Aleksandrov, Yu.A. Glukhov, A.S. Demyanova, V.I. Dukhanov, I.B. Mazurov, B.G. Novatsky, A.A. Ogloblin, S.B. Sakuta and D.N. Stepanov, Yad. Fiz. 35 (1982) 277; Sov. J. Nucl. Phys. 35 (1982) 158

1982AS01 E. Aslanides, A.M. Bergdolt, O. Bing, P. Fassnacht, F. Hibou, N. Willis, P. Kitching, Y. Le Bornec, B. Tatischeff, K. Baba et al., Phys. Lett. B108 (1982) 91

1982AW02 A.M. Awin and P.E. Shanley, Nucl. Phys. A386 (1982) 101

1982BA37 BR.H. Bassel, B.A. Brown, R. Lindsay and N. Rowley, J. Phys. (London) G8 (1982) 1215

1982BE02 M. Bernheim, A. Bussiere, J. Mougey, D. Royer, D. Tarnowski, S. Turck-Chieze, S. Frullani, S. Boffi, C. Giusti, F.D. Pacati et al., Nucl. Phys. A375 (1982) 381

1982BE17 T.L. Belyaeva and N.S. Zelenskaya, Izv. Akad. Nauk SSSR Ser. Fiz. 46 (1982) 154

1982BI1C Bikov et al., in Kiev (1982) 559

1982BO01 M. Bouten and M.C. Bouten, J. Phys. (London) G8 (1982) 61

1982BO1H Bogdanov, Kerimov and Safin, in Kiev (1982) 399

1982BO1N Boyd, Bull. Amer. Phys. Soc. 27 (1982) 761

1982BO40 V.I. Bogatin, E.A. Ganza, O.V. Loshkin, Yu.A. Murin, V.S. Oplavin, N.A. Perfilov, Yu.P. Yakovlev, Yad. Fiz. 36 (1982) 33; Phys. At. Nucl. 36 (1980) 19

1982BU20 G.W. Butler, B.J. Dropesky, C.J. Orth, R.E.L. Green, R.G. Korteling and G.K.Y. Lam, Phys. Rev. C26 (1982) 1737

1982CE02 F.E. Cecil, R.F. Fahlsing and R.A. Nelson, Nucl. Phys. A376 (1982) 379

1982CH13 N.S. Chant, L. Rees and P.G. Roos, Phys. Rev. Lett. 48 (1982) 1784

1982CO1J Couvert, AIP Conf Proc. 79 (1982) 187

1982DE1K D. Dehnhard, Nucl. Phys. A374 (1982) 377

1982DE1N de Wet, Found. Phys. 12 (1982) 285

1982DE1P Deineko et al., in Kiev (1982) 320

1982DO01 K.G.R. Doss, P.D. Barnes, N. Colella, S.A. Dytman, R.A. Eisenstein, C. Ellegaard, F. Takeutchi, W.R. Wharton, J.F. Amann, R.H. Pehl et al., Phys. Rev. C25 (1982) 962

1982DO1L Dover, Conf. on Hypernucl. Kaon Phys., Heidelberg, June 1982 (1982) 351

1982DU1A Dubovoi and Chitanava, in Kiev (1982) 421

1982ER04 T.E.O. Ericson and L. Tauscher, Phys. Lett. B112 (1982) 425

1982ER1E Eramzhyan, Fetisovm Majling and Zofka, Conf. on Hypernucl. Kaon Phys., Heidelberg, June 1982 (1982) 91

1982FR1T Frohlich, Duck, Treu and Voit, Bad Honnef Symp, 1981 (1982) 79

1982FU04 T. Fukuda, M. Ishihara, M. Tanaka, I. Miura, H. Ogata and H. Kamitsubo, Phys. Rev. C25 (1982) 2464

1982FU09 C.B. Fulmer, S. Mukhopadhyay, G.R. Satchler, R.L. Auble, J.B. Ball, F.E. Bertrand, E.E. Gross and D.C. Hensley, Nucl. Phys. A385 (1982) 83

1982GE05 J.V. Geaga, M.M. Gazzaly, G.J. Igo, J.B. McClelland, M.A. Nasser, A.L. Sagle, H. Spinka, J.B. Carroll, J.B. McCaslin, V. Perez-Mendez et al., Nucl. Phys. A386 (1982) 589

1982GL04 I.V. Glavanakov, Yad. Fiz. 35 (1982) 875

1982GO03 N.G. Goncharova, B.S. Ishkhanov and V.I. Mokeev, Yad. Fiz. 35 (1982) 43; Sov. J. Nucl. Phys. 35 (1982) 26

1982GO05 S.A. Goncharov, Ya. Dobesh, E.I. Dolinsky, A.M. Mukhamedzhanov and Ya. Tseipek, Yad. Fiz. 35 (1982) 662

1982GR1P Grypeos and Koutroulos, Conf. on Hypernucl. Kaon Phys., Heidelberg, June 1982 (1982) 167

1982HA06 R.A. Hardekopf, P.W. Keaton, P.W. Lisowski and L.R. Veeser, Phys. Rev. C25 (1982) 1090

1982HA1Y Hale, Stewart and Young, ENDF-301, BNL-NCS-51619 (1982) 31

1982HA42 Q. Haider and F.B. Malik, Phys. Rev. C26 (1982) 989

1982HI1H R.R. Highfill, Bull. Amer. Phys. Soc. 27 (1982) 777

1982HO1C Hoistad, AIP Conf. Proc. 79 (1982) 105

1982IK1A Ikeda, Miyahara and Bando, Conf. on Hypernucl. Kaon Phys., Heidelberg, June 1982 (1982) 149

1982JA1C Jacak et al., MSU (1982) 32; Bull. Amer. Phys. Soc. 27 (1982) 715

1982KA01 S. Kato, K. Okada, M. Kondo, K. Hosono, T. Saito, N. Matsuoka, T. Noro, S. Nagamachi, H. Shimizu, K. Ogino et al., Phys. Rev. C25 (1982) 97

1982KA1C K. Kakihara, Y. Kasida and T. Ido, Radioisotopes 31 (1982) 357

1982KA1D K. Kar and J.C. Parikh, Pramana 19 (1982) 555

1982KA1R Kauppila, Bull. Amer. Phys. Soc. 27 (1982) 785

1982KE1C Kerimov, Agalarov, Ishankuliev and Safin, in Kiev (1982) 397

1982KO11 N.N. Kolesnikov, D. Amarasingam and V.I. Tarasov, Yad. Fiz. 35 (1982) 32; Sov. J. Nucl. Phys. 35 (1982) 20

1982KU17 Y. Kudo, Phys. Rev. C26 (1982) 2323

1982LE1L Le Bornec and Willis, AIP Conf. Proc. 79 (1982) 155

1982LO08 J.T. Londergan and L.D. Ludeking, Phys. Rev. C25 (1982) 1722

1982LO13 M. Lozano, J.I. Escudero and G. Madurga, J. Phys. (London) G8 (1982) 1259

1982LO1B Londergain, AIP Conf. Proc. 79 (1982) 339

1982LO1K Lolos, AIP Conf. Proc. 79 (1982) 201

1982LU01 B. Ludewigt, G. Gaul, R. Glasow, H. Lohner and R. Santo, Phys. Lett. B108 (1982) 15

1982LY1A U. Lynen, H. Ho, W. Kuhn, D. Pelte, U. WinklerW. F.J. Muller, Y. -T. Chu, P. Doll, A. Gobbi, K. Hildenbrand et al., Nucl. Phys. A387 (1982) 129

1982MA20 J.F. Mateja, A.D. Frawley, L.C. Dennis, K. Abdo and K.W. Kemper, Phys. Rev. C25 (1982) 2963

1982MCZZ J. McKamy, R.N. Boyd, H.J. Hausman, J. Kerns, P. Koncz, E. Sugarbaker, H.R. Suiter and M. Wiescher, Bull. Amer. Phys. Soc. 27 (1982) 561, HXa11

1982ME1C Mercier, Hill, Wohn and Smith, Bull. Amer. Phys. Soc. 27 (1982) 540

1982MI08 D.J. Millener, D.E. Alburger, E.K. Warburton and D.H. Wilkinson, Phys. Rev. C26 (1982) 1167

1982MO1K C.B.O. Mohr, Aust. J. Phys. 35 (1982) 1

1982NA1K Nann, AIP Conf. Proc. 79 (1982) 219

1982NE1D Nelson, Bull. Amer. Phys. Soc. 27 (1982) 792

1982NG01 Nguyen Tien Nguyen and I. Ulehla, Czech. J. Phys. B32 (1982) 1040

1982OG02 Yu.Ts. Oganesyan, Yu.E. Penionzhkevich, E. Gierlik, R. Kalpakchieva, T. Pawlat, C. Borcea, A.V. Belozerov, Yu.P. Kharitonov, S.P. Tretyakova, V.G. Subbotin et al., Pisma Zh. Eksp. Teor. Fiz. 36 (1982) 104; JETP Lett. 36 (1982) 129

1982PI1H G. Pinto, Bull. Amer. Phys. Soc. 27 (1982) 792

1982RA1L Rahman Khan, Conf. on Hypernucl. Kaon Phys., Heidelberg, June 1982 (1982) 115

1982RA31 J.R. Radin, H. Quechon, G.M. Raisbeck and F. Yiou, Phys. Rev. C26 (1982) 2565

1982SC1E Schaeffer, Reeves and Orland, Astrophys. J. 254 (1982) 688

1982SH06 J.R. Shepard and E. Rost, Phys. Rev. C25 (1982) 2660

1982ST1A Strobel, Bull. Amer. Phys. Soc. 27 (1982) 487

1982VA1F Vasilieva et al., in Kiev (1982) 324

1982WA18 E.K. Warburton, D.E. Alburger and D.H. Wilkinson, Phys. Rev. C26 (1982) 1186

1982WA1G P.L. Walden, Nucl. Phys. A374 (1982) 277

1982WA23 C.W. Wang, G.C. Kiang, L.L. Kiang, G.C. Jon and E.K. Lin, J. Phys. Soc. Jpn. 51 (1982) 3093

1982WU1B Wu et al., Chin. Phys. 2 (1982) 726

1982YA1A A.I. Yavin, Nucl. Phys. A374 (1982) 297

1982YA1C T. Yamada, Bull. Amer. Phys. Soc. 27 (1982) 813

1982ZW02 B. Zwieglinski, W. Benenson, G.M. Crawley, S. Gales and D. Weber, Nucl. Phys. A389 (1982) 301

1983AL04 G.D. Alkhazov and O.A. Domchenkov, Yad. Fiz. 37 (1983) 84; Sov. J. Nucl. Phys. 37 (1983) 46

1983AL20 D.V. Aleksandrov, E.A. Ganza, Yu.A. Glukhov, V.I. Dukhanov, I.B. Mazurov, B.G. Novatsky, A.A. Ogloblin, D.N. Stepanov, V.V. Paramonov and A.G. Trunov, Yad. Fiz. 37 (1983) 797; Sov. J. Nucl. Phys. 37 (1983) 474

1983AM1A G. Amsel and J.A. Davies, Nucl. Instrum. Meth. Phys. Res. 218 (1983) 177

1983AN1F L. Antonuk, G. Blanpied, D. Bovet, E. Bovet, Y. de Coulon, J.P. Egger, F. Goetz, P. Gretillat, C. Lunke, C. Perrin et al., Sin Newsl. 15 (1983) 40

1983ANZQ Y. Ando, M. Uno and M. Yamada, JAERI-M-83-025 (1983)

1983AR1K Aryaeinejad et al., Bull. Amer. Phys. Soc. 28 (1983) 968

1983BA71 C.J. Batty, Nucl. Phys. A411 (1983) 399

1983BE1Q Belyaeva, in Moscow (1983) 478

1983BI13 J.R. Birkelund and J.R. Juizenga, Ann. Rev. Nucl. Part. Sci. 33 (1983) 265

1983BI1P Bilwes et al., An. Fis. Ser. A79 (1983) 190

1983BU07 B. Buck and S.M. Perez, Phys. Rev. Lett. 50 (1983) 1975; Erratum Phys. Rev. Lett. 51 (1983) 1395

1983CE04 C. Cernigoi, N. Grion, G. Pauli, R. Rui, R. Cherubini and D.R. Gill, Nucl. Phys. A411 (1983) 382

1983CH1B Chant, AIP Conf. Proc. 97 (1983) 205

1983CH1T Chen, Zhuang, Jin and King, in Florence (1983) 44, 45

1983CH23 B. Chambon, D. Drain, C. Pastor, A. Dauchy, A. Giorni and C. Morand, Z. Phys. A312 (1983) 125

1983DA10 B. Dasmahapatra, B. Cujec and F. Lahlou, Can. J. Phys. 61 (1983) 657

1983DA20 B. Dasmahapatra, B. Cujec and F. Lahlou, Nucl. Phys. A408 (1983) 192

1983DA22 J.H. Dave and C.R. Gould, Phys. Rev. C28 (1983) 2212

1983DO1B C.B. Dover and A. Gal, Ann. Phys. 146 (1983) 309

1983DU13 G.G. Dussel, A.O. Gattone and E.E. Maqueda, Phys. Rev. Lett. 51 (1983) 2366

1983EN04 Y.M. Engel and R.D. Levine, Phys. Rev. C28 (1983) 2321

1983FE07 V.N. Fetisov, L. Majling, J. Zofka and R.A. Eramzhyan, Z. Phys. A314 (1983) 239

1983FI1C D. Fink, Nucl. Instrum. Meth. Phys. Res. 218 (1983) 456

1983FR1A W.A. Friedman and W.G. Lynch, Phys. Rev. C28 (1983) 950

1983FU04 T. Fukuda, M. Ishihara, M. Tanaka, H. Ogata, I. Miura, M. Inoue, T. Shimoda, K. Katori and S. Nakayama, Phys. Rev. C27 (1983) 2029

1983GE12 P.M. Gensini, Lett. Nuovo Cim. 38 (1983) 469

1983GE13 P.M. Gensini, Lett. Nuovo Cim. 38 (1983) 620

1983GO10 N.F. Golovanova, E.T. Ibraeva and V.G. Neudachin, Yad. Fiz. 37 (1983) 883; Sov. J. Nucl. Phys. 37 (1983) 526

1983GO13 J. Gomez del Campo and G.R. Satchler, Phys. Rev. C28 (1983) 952

1983GO1P Goeschl, Bull. Amer. Phys. Soc. 28 (1983) 44

1983GO1R Gontcharova, Kissener and Eramzhian, in Moscow (1983) 188

1983GO1T Goltsov, Goncharova and Matveev, in Moscow (1983) 211

1983HA1C Harvey et al., in Florence (1983) 511

1983HA1Q Hannachi et al., in Florence (1983) 237

1983HO15 D.H.H. Hoffmann, A. Richter, G. Schrieder and K. Seegebarth, Astrophys. J. 271 (1983) 398

1983HUZZ J. Hurd, J. Boswell, R.C. Minehart, Y. Tzeng, H.J. Ziock and K.O.H. Ziock, Bull. Amer. Phys. Soc. 28 (1983) 671

1983IK03 Y. Ikebata and Y. Kudo, Prog. Theor. Phys. 70 (1983) 1457

1983IS1D Ishkanov et al., in Moscow (1983) 337

1983KL04 W.E. Kleppinger and J.D. Walecka, Ann. Phys. 146 (1983) 349; Erratum Ann. Phys. 151 (1983) 497

1983KO03 P.E. Koehler, H.D. Knox, D.A. Resler, R.O. Lane and D.J. Millener, Nucl. Phys. A394 (1983) 221

1983KO17 L. Koester, K. Knopf and W. Waschkowski, Z. Phys. A312 (1983) 81

1983KO1D Koutroulos, in Florence (1983) 689

1983KO1F S. Komoda and T. Sekiya, Atomkernenerg. Kerntech. 42 (1983) 101

1983LE17 P.M. Lewis, O. Karban, J.M. Barnwell, J.D. Brown, P.V. Drumm, J.M. Nelson and S. Roman, Nucl. Phys. A404 (1983) 205

1983LE28 J.R. Letaw, R. Silberberg and C.H. Tsao, Astrophys. J. Suppl. 51 (1983) 271

1983LIZW P.M. Lister, F.D. Brooks and J.M. Nelson, Bull. Amer. Phys. Soc. 28 (1983) 658, AX5

1983LU01 L.D. Ludeking and J.P. Vary, Phys. Rev. C27 (1983) 1967

1983MA53 J.F. Mateja, J. Garman and A.D. Frawley, Phys. Rev. C28 (1983) 1579

1983ME1G Medili, Abzouzi, Beaumevieille and Bendjaballah, in Florence (1983) 236

1983MI08 D.J. Millener, J.W. Olness, E.K. Warburton and S.S. Hanna, Phys. Rev. C28 (1983) 497

1983MI1E K. Miyahara, K. Ikeda and H. Bando, Prog. Theor. Phys. 69 (1983) 1717

1983MO1F J. Mougey, Nucl. Phys. A396 (1983) 39

1983OL1A D.L. Olson, B.L. Berman, D.E. Greiner, H.H. Heckman, P.J. Lindstrom and H.J. Crawford, Phys. Rev. C28 (1983) 1602

1983OR03 V.N. Orlin, Nucl. Phys. A405 (1983) 263

1983OS08 A. Osman and S.A. Saleh, Acta Phys. Acad. Sci. Hung. 54 (1983) 25

1983PO13 J. Pouliot, R. Roy, P. Bricault, L. Potvin and R.J. Slobodrian, Can. J. Phys. 61 (1983) 1609

1983RO07 R.M. Rockmore, Phys. Rev. C27 (1983) 2150

1983RO1H E. Roeckl, Nucl. Phys. A400 (1983) 131

1983RO22 S. Roman, O. Karban, M. Barnwell, J.D. Brown, P.V. Drumm, P.M. Lewis and J.M. Nelson, Phys. Rev. C28 (1983) 2515

1983SA06 M. Sato, M. Sasagase, Y. Nagashima, J. Schimizu, T. Nakagawa, Y. Fukuchi and T. Mikumo, Phys. Rev. C27 (1983) 2621

1983SC1L D.K. Scott, Nucl. Phys. A409 (1983) 291

1983SH38 Y.-J. Shi, Phys. Rev. C28 (1983) 2452

1983SI1A R.H. Siemssen, Nucl. Phys. A400 (1983) 245

1983SI1B J.A. Simpson, Ann. Rev. Nucl. Part. Sci. 33 (1983) 323

1983SM03 A.R. Smith, J.B. McCaslin, J.V. Geaga, J.C. Hill and J.P. Vary, Phys. Rev. C28 (1983) 1614

1983SO08 L.G. Sobotka, M.L. Padgett, G.J. Wozniak, G. Guarino, A.J. Pacheco, L.G. Moretto, Y. Chan, R.G. Stokstad, I. Tserruya and S. Wald, Phys. Rev. Lett. 51 (1983) 2187

1983SR01 J. Sromicki, M. Hugi, J. Lang, R. Muller, E. Ungricht, L. Jarczyk, B. Kamys, A. Magiera, Z. Rudy, A. Strzalkowski et al., Nucl. Phys. A406 (1983) 390

1983ST10 W.A. Sterrenburg, M.N. Harakeh, S.Y. Van Der Werf and A. Van Der Woude, Nucl. Phys. A405 (1983) 109

1983STZS M.N. Stephens and K.W. Kemper, Bull. Amer. Phys. Soc. 28 (1983) 994, EB1

1983SZZY J. Szabo, M. Varnagy, Z.T. Body and J. Csikai, Proc. Int. Conf. Nucl. Data for Sci. and Tech., Geel, Belium, 1982; Ed., K.H. Bockhoff (1983) 956

1983VA1H Vasilieva et al., in Moscow (1983) 331

1983VA31 A.G.M. van Hees and P.W.M. Glaudemans, Z. Phys. A314 (1983) 323

1983WA1F Wang et al., in Florence (1983) 591

1983WI09 M. Wiescher, R.N. Boyd, S.L. Blatt, L.J. Rybarcyk, J.A. Spizuoco, R.E. Azuma, E.T.H. Clifford, J.D. King, J. Gorres, C. Rolfs et al., Phys. Rev. C28 (1983) 1431

1983WI1A Wilczynski, Proc. Int. Conf. on Nucl. Phys., Florence, August-Sept. 1983; Eds., P. Blasi and R.A. Ricci; Vol. 2 (1983) 305

1983ZE1C B. Zeidman and D.F. Geesaman, Nucl. Phys. A396 (1983) 419

1983ZW1A Zwieglinski, Benenson, Crawley and Gales, in Orsay (1983) 29

1984AJ01 F. Ajzenberg-Selove, Nucl. Phys. A413 (1984) 1

1984AN1R Antufev et al., in Alma Ata (1984) 338

1984BO1C Boyd, Turner, Rybarcyk and Joseph, Private Communication (1984)

1984DE1W Deineko et al., in Alma Ata (1984) 339

1984GO03 A. Gokmen, H. Breuer, A.C. Mignerey, B.G. Glagola, K. Kwiatkowski and V.E. Viola, Jr., Phys. Rev. C29 (1984) 1595

1984GO1M Goncharova, Kissener and Eramzhain, in Alma Ata (1984) 152

1984GR08 R.E.L. Green, R.G. Korteling and K.P. Jackson, Phys. Rev. C29 (1984) 1806

1984HA13 G. Hardie, B.W. Filippone, A.J. Elwyn, M. Wiescher and R.E. Segel, Phys. Rev. C29 (1984) 1199

1984HI1A A.S. Hirsch, A. Bujak, J.E. Finn, L.J. Gutay, R.W. Minich, N.T. Porile, R.P. Scharenberg and B.C. Stringfellow, Phys. Rev. C29 (1984) 508

1984KU07 D. Kurath and R.D. Lawson, Phys. Rev. C29 (1984) 2303

1984MAZZ J.F. Mateja, A.D. Frawley, D.G. Kovar, D. Henderson, H. Ikezoe, R. Janssens, G. Rosner, GT. Stephens and B. Wilkins, Bull. Amer. Phys. Soc. 29 (1984) 624, AE4

1984MIZM I.A. Mitropolsky and E.F. Khefter, in Alma Ata (1984) 241

1984NE1A Nemets, Rudchik and Chuvilski, in Alma Ata (1984) 334

1984PO02 J. Pouliot, P. Bricault, J.G. Dufour, L. Potvin, C. Rioux, R. Roy and R.J. Slobodrian, J. Phys. (Paris) 45 (1984) 71

1984PO05 N.T. Porile, A.A. Caretto, B.J. Dropesky, C.J. Orth, L.C. Liu and G.C. Giesler, Phys. Rev. C29 (1984) 2239

1984VA06 A.G.M. van Hees and P.W.M. Glaudemans, Z. Phys. A315 (1984) 223

1984VEZW V.A. Vesna, A.I. Egorov, E.A. Kolomensky, A.F. Kornyushkin, V.M. Lobashev, I.S. Okunev, B.G. Peskov, A.N. Pirozhkov, L.M. Smotritsky, N.A. Titov, et al., in Alma Ata (1984) 310

1984VO06 W. von Oertzen, H. Lettau, H.G. Bohlen and D. Fick, Z. Phys. A315 (1984) 81

1986AJ01 F. Ajzenberg-Selove, Nucl. Phys. A449 (1986) 1