Energy Levels of Light Nuclei
$A = 11$

F. Ajzenberg-Selove

University of Pennsylvania, Philadelphia, Pennsylvania 19104-6396

Abstract: An evaluation of $A = 11$–12 was published in *Nuclear Physics A*248 (1975), 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 January 31, 1975)

The original work of Fay Ajzenberg-Selove was supported by the US Department of Energy [DE-AC02-76-ER02785]. Later modification by the TUNL Data Evaluation group was supported by the US Department of Energy, Office of High Energy and Nuclear Physics, under: Contract No. DEFG05-88-ER40441 (North Carolina State University); Contract No. DEFG05-91-ER40619 (Duke University).

Table of Contents for $A = 11$

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

^{11}He

(Not illustrated)

This nucleus has not been observed: see (1974IR04).

^{11}Li

(Figs. 1 and 4)

^{11}Li has been observed in the bombardment of heavy nuclei by GeV protons. Its mass excess is 40.9 ± 0.1 MeV (1973KLZN). ^{11}Li is bound: E_b for breakup into ^{9}Li + 2n and ^{10}Li + n are 0.2 and 0.3 MeV, respectively [see (1974AJ01) for a discussion of the mass of ^{10}Li]. ^{11}Li has a half-life of 8.5 ± 1 msec (1969KL08), 8.5 ± 0.2 msec (1974RO31): it decays to neutron unstable states of ^{11}Be with $P_n = (61 \pm 7)\%$ (1974RO31) [based on $P_n(^9\text{Li}) = 35\%$]. See also (1968TH04, 1970AR27, 1971AR1P), (1968AJ02, 1969GA1G, 1969GA32, 1972CE1A, 1972GA1F, 1972KL1A, 1972TH13, 1972WA07, 1973BR1C, 1973KO1D, 1973VO1D, 1974TH01) and (1971DO1F, 1974IR04, 1974MA1E; theor.).

^{11}Be

(Figs. 1 and 4)

GENERAL: (See also (1968AJ02).)

Model calculations: (1970TA1J, 1973SA30, 1973SP02, 1974IR04).

Special reactions: (1969AR13, 1971AR02, 1972VO06, 1973BA81, 1973KO1D, 1973WI15).

Muon capture (See also reaction 2.): (1967DE1E, 1968DE20, 1969BE41, 1970VA24, 1971BE57, 1973MU1B).

Pion reactions: (1962DY1A, 1971BE85).

Mass of ^{11}Be: The mass excess of ^{11}Be is given as 20.181 ± 0.015 MeV (1965MA54) [based on (1962PU01, 1965RY01)] and as 20.174 ± 0.007 MeV (1970GO11). (1971WA37) adopt 20.177 ± 0.006 MeV, and so do we. See also (1974TH01).

1. ^{11}Be(β^-)^{11}B $\qquad Q_m = 11.509$

The decay proceeds to ^{11}B*(0, 2.12, 5.02, 6.79, 7.98, 9.87) with $J^\pi = \frac{3}{2}^-, \frac{1}{2}^-, \frac{3}{2}^-, \frac{1}{2}^+, \frac{3}{2}^+$ and $\frac{3}{2}^+$, respectively: see Table 11.16 (1971AL07). The half-life is 13.81 ± 0.08 sec (1970AL21). See also (1967FL16, 1968AJ02). The nature of the decay indicates $J = \frac{1}{2}$ or $\frac{3}{2}$, even parity for the ground state of ^{11}Be: see (1971AL07).

Table 11.1: Energy levels of ^{11}Be

E_x (MeV $\pm$ keV)	$J^\pi; T$	τ or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
0	$\frac{1}{2}^+; \frac{3}{2}$	$\tau_{1/2} = 13.81 \pm 0.08$ sec	β^-	1, 2, 3, 5, 7, 8
0.3198 ± 0.2	$\frac{1}{2}^-$	$\tau_m = 0.18 \pm 0.06$ psec	γ	2, 5
1.785 ± 14	$(\frac{1}{2}, \frac{3}{2}, \frac{5}{2})^+$	$\Gamma = 100 \pm 20$	(n)	2
2.69 ± 20	$(\frac{1}{2}, \frac{3}{2}, \frac{5}{2})^+$	200 ± 20	(n)	2
3.41 ± 20	$(\frac{1}{2}, \frac{3}{2}, \frac{5}{2})^+$	125 ± 20	(n)	2
3.89 ± 20		< 10	(n)	2
3.96 ± 20		15 ± 5	(n)	2
5.25 ± 30		45 ± 10	(n)	2
(5.86)		≈ 300	(n)	2
6.51 ± 50		120 ± 50	(n)	2
6.72 ± 30		40 ± 20	(n)	2
7.03 ± 50		300 ± 100	(n)	2
8.84 ± 50		200 ± 50	(n)	2

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

Proton groups have been observed to many states of ^{11}Be by (1962PU01: $E_t = 14$ MeV) and (1972AJ01: $E_t = 20$ MeV): see Table 11.2. The first excited state has an excitation energy of 319.8 ± 0.2 keV and $\tau_m = 0.18 \pm 0.06$ psec, corresponding to a very strong E1 transition of 0.33 W.u. (1971HA25). 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 (1968DE20). The strength of the E1 transition fixes J^π of ^{11}Be$_{g.s.}$ 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 1]. J^π limits for ^{11}Be*(1.79, 2.69, 3.41) are derived from angular distribution studies (1962PU01, 1964HI08). ^{11}Be*(5.25, 6.72, 8.84) are strongly populated at $E_t = 20$ MeV indicating that these states have a large overlap with ^{9}Be$_{g.s.}$ + two neutrons (1972AJ01). See also (1968AJ02) and (1970AL21, 1971AL07).

3. ^{9}Be(^{6}He, α)^{11}Be $\qquad Q_m = 6.344$

See ^{15}C in (1970AJ04).

4. ^{10}Be(n, γ)^{11}Be $\qquad Q_m = 0.503$

Table 11.2: Levels of ^{11}Be from ^{9}Be(t, p)^{11}Be

E_x (keV) [a]	E_x (keV) [b]	Γ_{lab} (keV) [a]	$\Gamma_{c.m.}$ (keV) [b]	J^π
0	0			$\frac{1}{2}^+$
319.8 ± 0.2 [c]	322 ± 10			$\frac{1}{2}^-$
1780 ± 20	1790 ± 20	110 ± 15	130 ± 25	$(\frac{1}{2}, \frac{3}{2}, \frac{5}{2})^+$
2700 ± 25	2680 ± 30	250 ± 20	250 ± 50	$(\frac{1}{2}, \frac{3}{2}, \frac{5}{2})^+$
3410 ± 25	3410 ± 30	150 ± 20	145 ± 30	$(\frac{1}{2}, \frac{3}{2}, \frac{5}{2})^+$
3890 ± 20	3890 ± 30	< 10	≤ 10	
3960 ± 20	3960 ± 30	< 10	15 ± 5	
	5250 ± 30		45 ± 10	
	(5860)		≈ 300	
	6510 ± 50		120 ± 50	
	6720 ± 30		40 ± 20	
	7030 ± 50		300 ± 100	
	8840 ± 50		200 ± 50	

[a] (1962PU01).
[b] (1972AJ01).
[c] (1971HA25).

The capture cross section is < 1 mb (E.T. Jurney, private communication).

5. ^{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 (1970GO11: p_1 only) and 12 MeV (1970AU02): $l_n = 0$ [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 (1970AU02). $E_x = 318 \pm 7$ keV for ^{11}Be*(0.32) (1970GO11). See also (1973GO09) and ^{12}B.

6. ^{11}Li(β^-)^{11}Be $\qquad Q_m = 20.7$

See ^{11}Li.

7. ^{11}B(n, p)^{11}Be $\qquad Q_m = -10.726$

See (1967FL16) and ^{12}B.

8. ^{14}C(^{18}O, ^{21}Ne)^{11}Be $\qquad Q_{\rm m} = -12.208$

See (1974BA15).

^{11}B

(Figs. 2 and 4)

GENERAL: (See also (1968AJ02).)

Shell model: (1968GO01, 1970CO1H, 1971BA2Y, 1971NO02, 1972LE1L, 1973HA49, 1973KU03, 1973SA30, 1974ME19).

Cluster and collective models: (1969BA1J, 1970BA1Q, 1971NO02, 1972LE1L, 1973KU03).

Special levels: (1968GO01, 1969HA1G, 1969HA1F, 1970FR1C, 1971NO02, 1972MS01, 1973MA1K, 1973SA30, 1974IR04).

Electromagnetic transitions: (1967WA1C, 1969HA1G, 1969HA1F, 1969WA1C, 1970AL1E, 1972KE36, 1972MU1B, 1972TA21, 1972NA05, 1973HA49, 1973SA30, 1974ME19, 1974MU13).

Astrophysical questions: (1967MI1A, 1972CL1A, 1972KO1E, 1973AU1H, 1973CA1B, 1973CO1B, 1973LA19, 1973RE1G, 1973TI1A, 1973TR1B, 1973WE1D, 1974AU1A, 1974BO1K, 1974JA11, 1974MO1G, 1974RE1A, 1974WO1G).

Special reactions: (1968HA1C, 1968YI01, 1969DA1D, 1969GA18, 1969YI1A, 1971AR02, 1971BA16, 1973KO1D, 1973KU03, 1973LA19, 1973WI15, 1974BA70, 1974BE58, 1974FO22, 1974JA11, 1974LA18, 1975CR01, 1975KU01, 1975PO02).

Muon capture and muon reactions: (1968DE20, 1969BE41, 1969WU1A, 1970FA15, 1970VA24, 1971BE57, 1971BU11, 1971DE2D, 1972BE71, 1972MI15 †).

Pion capture and pion reactions: (1968BO32, 1968GR1C, 1968LO1A, 1968NO1A, 1968NY1A, 1968RI1H, 1968TA1C, 1968WI1B, 1969AG1A, 1969BU1C, 1969MO1E, 1970BA1E, 1970LI1H, 1971BA16, 1971BE85, 1971FA09, 1971NO08, 1971KA62, 1972HU1A, 1973AL1D, 1973CH20, 1973JA1J, 1973NY04, 1974HU14, 1974KA07, 1974LE12, 1974TA18).

Kaon reactions: (1972BA09, 1973CH1M).

Other topics: (1968BU1B, 1968GO01, 1968ME13, 1970CO1H, 1971BA2Y, 1972AN05, 1972CA37, 1972LE1L, 1972MU1B, 1972PN1A, 1973CL09, 1973JU2A, 1973KU03, 1973MA48, 1973RO1R, 1974IR04, 1974MO1H, 1974MU13, 1975KU01).

Ground state properties: (1967CO1D, 1967SH14, 1968PE16, 1968RO1E, 1969LE1B, 1969WU1A, 1971TA1A, 1971ZO03, 1972GL06, 1972LE1L, 1972VA36, 1973CO1P, 1973KU1L, 1973MA1K, 1973SA30, 1973SU1B, 1973SU1C, 1974HA27, 1974ME19, 1974MU13).

$$\mu = +2.68864 \pm 0.00007 \text{ nm (1969FU11, 1971SH26);}$$

$$Q = 0.0386 \text{ b (1968SC18);}$$

$$[Q = 0.04065 \pm 0.00026 \text{ b (1970NE05; theor.)}].$$

† (1972MI15) have observed the γ-decay of ^{11}B*(2.12).

Table 11.3: Energy levels of ^{11}B [a]

E_x in ^{11}B (MeV ± keV)	$J^\pi; T$	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
g.s.	$\frac{3}{2}^-; \frac{1}{2}$	stable		1, 2, 7, 8, 9, 13, 14, 15, 16, 17, 18, 19, 26, 27, 28, 29, 30, 31, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 64, 65, 66, 67, 68, 69, 70
2.1247 ± 0.4	$\frac{1}{2}^-$	$\Gamma = 0.136 \pm 0.010$ eV	γ	1, 7, 8, 9, 14, 15, 16, 26, 27, 28, 36, 37, 39, 40, 41, 45, 49, 53, 54, 55, 56, 57, 58, 59, 61, 62, 64, 65, 67, 68, 69
4.4451 ± 0.5	$\frac{5}{2}^-$	0.610 ± 0.030 eV	γ	1, 2, 7, 8, 9, 14, 15, 16, 19, 26, 27, 28, 37, 39, 40, 41, 44, 45, 49, 54, 55, 56, 57, 58, 64, 65, 67, 68, 69
5.0207 ± 0.6	$\frac{3}{2}^-$	2.6 ± 0.3 eV	γ	1, 7, 8, 9, 14, 15, 16, 26, 27, 28, 36, 37, 39, 40, 41, 45, 55, 56, 57, 58, 64, 65, 67, 68, 69
6.7429 ± 0.6	$\frac{7}{2}^-$	$\tau_m < 10$ fsec	γ	1, 2, 7, 14, 15, 19, 27, 28, 40, 41, 45, 57, 64, 65, 68, 69
6.7929 ± 1.0	$\frac{1}{2}^+$	< 35 fsec	γ	1, 2, 7, 14, 15, 16, 27, 28, 36, 40, 41, 45, 49, 56, 57, 65, 68
7.2856 ± 1.5	$(\frac{3}{2}, \frac{5}{2})^+$	$\Gamma = 1.1 \pm 0.6$ eV	γ	1, 7, 14, 15, 16, 27, 28, 39, 40, 41, 45, 57
7.9780 ± 1.3	$\frac{3}{2}^+$	$\tau_m < 30$ fsec	γ	1, 14, 16, 27, 36, 41, 57
8.5594 ± 1.9	$\leq \frac{5}{2}^-$	$\Gamma = 1.7 \pm 0.2$ eV	γ	1, 14, 27, 39, 41, 45
8.9202 ± 2.0	$\frac{5}{2}^-$	5.2 ± 0.6 eV	γ, α	1, 2, 14, 19, 27, 39, 41, 64
9.1860 ± 2.0	$\frac{7}{2}^+$	3 eV	γ, α	1, 2, 14, 27, 41, 68
9.2750 ± 2.0	$\frac{5}{2}^+$	7 keV	γ, α	1, 2, 14, 27, 39, 41, 68
9.870 ± 10	$\frac{3}{2}^+$	130 ± 30	α	6, 14, 36
10.26 ± 20	$\frac{3}{2}^-, \frac{1}{2}$	150 ± 40	γ, α	2, 6
10.33 ± 20	$(\frac{5}{2}, \frac{7}{2})^-$	70 ± 20	γ, α	2, 6, 16, 27
(10.45 ± 50)		≈ 140	γ, α	2, 41
10.601 ± 10	$\frac{7}{2}^+$	70 ± 10	γ, n, α	2, 6, 25
10.96 ± 50	$\frac{5}{2}^-$	4500	α	6
11.29 ± 30	$\frac{9}{2}^+$	90 ± 50	α	6

Table 11.3: Energy levels of ^{11}B [a] (continued)

E_x in ^{11}B (MeV $\pm$ keV)	$J^\pi; T$	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
11.49 ± 50			α	6
11.61 ± 50	$\frac{5}{2}^+$	150 ± 50	n, α	3, 6, 20, 25, 41
11.8	$\frac{7}{2}^+$	880	n, α	6, 25
11.88 ± 30		150 ± 50	α	6
11.99 ± 100	$\frac{5}{2}^-$	170	n, α	3, 25
(12.18 ± 40)		230 ± 90	γ, p	18
12.56 ± 30	$\frac{1}{2}^+(\frac{3}{2}^+); T = \frac{3}{2}$	240 ± 50	γ, p, α	6, 16, 18, 38, 44
12.91 ± 20	$\frac{1}{2}^-; T = \frac{3}{2}$	240 ± 30	γ, p, α	18, 39, 41, 44, 64
13.03 ± 60		270 ± 50	α	6, 39
13.12	$\frac{9}{2}^-$	425	n, α	3, 20, 25
13.16	$\frac{5}{2}^+, \frac{7}{2}^+$	430	n, α	3, 20, 25
14.04 ± 100	$\frac{11}{2}^+$	500 ± 200	n, α	3, 6, 20, 21, 25
14.33 ± 20	$\frac{5}{2}^{(+)}, (\frac{3}{2}^-); T = \frac{3}{2}$	250 ± 40	γ, p	18, 44
14.53 ± 50		< 120	n, t, α	3, 6, 20, 21, 24, 25, 44
15.32 ± 100	$(\frac{3}{2}, \frac{5}{2}, \frac{7}{2})^+; T = \frac{3}{2}$	635 ± 180	γ, n, p, α	3, 6, 18, 20, 21, 25, 38, 41
15.8 ± 200			n, α	3, 6, 21
16.4 ± 150		broad	n, t, α	3, 24, 25, 41
(16.43 ± 15)		≈ 40	p, d, α	11
17.33		≈ 1000	n, p, d, t, α	11, 24, 25
17.50 ± 50		185 ± 40	γ, n, p, d, α	3, 9, 11, 38
18.37 ± 50	$(\frac{1}{2}, \frac{3}{2}, \frac{5}{2})^+$	260 ± 80	γ, d	9
(19.7)	$(\frac{1}{2})^+$	broad	γ, d	9, 56
21.6			γ, p	38
23.5	$(\frac{1}{2}, \frac{3}{2}, \frac{5}{2})^+$		γ, p	9, 38
25.2 ± 100		broad	γ, n, p	38
27.7			γ, p	38
29.2			γ, p	38

[a] See also Tables 11.4, 11.5 and 11.19.

Table 11.4: Electromagnetic transitions in ^{11}B [a]

Initial state	J^π; T	Γ_γ (total) [c] (eV)	Branching ratios (%) to final states						Refs.
			g.s. $\frac{3}{2}^-$; $\frac{1}{2}$	2.12 $\frac{1}{2}^-$; $\frac{1}{2}$	4.45 $\frac{5}{2}^-$; $\frac{1}{2}$	5.02 $\frac{3}{2}^-$; $\frac{1}{2}$	6.74 $\frac{7}{2}^-$; $\frac{1}{2}$	6.70 $(\frac{1}{2},\frac{3}{2})^+$; $\frac{1}{2}$	
2.12	$\frac{1}{2}^-$; $\frac{1}{2}$	0.136 ± 0.010	100						
4.45	$\frac{5}{2}^-$; $\frac{1}{2}$	0.610 ± 0.030	100 [e]	< 0.5					
			> 97	< 3					(1968BE30)
5.02 [b]	$\frac{3}{2}^-$; $\frac{1}{2}$	2.6 ± 0.3	85 ± 2	15 ± 2	0.3				
			88 ± 2	12 ± 2					(1968EA03)
			88 ± 2.5 [f]	12 ± 2.5 [g]					(1968BE30)
			83 ± 5	17 ± 5					(1971AL07)
6.74 [b,h]	$\frac{7}{2}^-$; $\frac{1}{2}$		70 ± 2	< 3	30 ± 2	< 1			
6.79 [b]	$\frac{1}{2}^+$; $\frac{1}{2}$		71 ± 5	29 ± 5	< 8	< 8			
			66.0 ± 1.5	30.0 ± 1.5	< 0.5	4.1 ± 0.9			(1971AL07)
			67 ± 3	33 ± 3					(1968EA03)
7.29 [c]	$(\frac{3}{2},\frac{5}{2})^+$; $\frac{1}{2}$	1.1 ± 0.6	87 ± 2	< 1	5.5 ± 1	7.5 ± 1			
7.98 [b]	$\frac{3}{2}^+$; $\frac{1}{2}$		47 ± 2	53 ± 2	< 1	< 1			
			45 ± 2	55 ± 2	< 1.6	< 1.6	< 1.5	< 1.4	(1971AL07)
8.56	$\leq \frac{5}{2}^-$; $\frac{1}{2}$	1.7 ± 0.1	56 ± 2	30 ± 2	5 ± 1	9 ± 1			
			50	30	10	10			(1972NI05)
8.92 [i]	$\frac{5}{2}^-$; $\frac{1}{2}$	5.2 ± 0.6	96		4				(1972NI05)
			93 ± 5		2.3 ± 1				(1962GR07)
			95 ± 1	< 1	4.5 ± 0.5	< 1	< 1	< 1	
9.19	$\frac{7}{2}^+$; $\frac{1}{2}$	≈ 3	0.9 ± 0.3		82.8 ± 2.0		12.8 ± 0.4	< 1.3	(1962GR07)
9.28	$\frac{5}{2}^+$; $\frac{1}{2}$		19.7 ± 1.0		67.5 ± 2.0		12.8 ± 0.7	< 0.6	(1962GR07)
d									

[a] (1965OL03) except where shown.

[b] See also (1972NI05).

[c] From Table 11.7, corrected for branching to other states.

[d] See Tables 11.6, 11.11, and 11.17 for higher states.

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

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

[g] $\delta = -0.05 \pm 0.2$ (1968BE30).

[h] $\delta = -0.45 \pm 0.18$ (1968CO09).

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

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

1) *4.45 MeV*. $9.28 \to 4.45 \to 0$ 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). τ_m excludes $\frac{7}{2}$, branch to 2.12, $\frac{5}{2}$. Angular correlation (1968BE30) fixes $\frac{5}{2}^-$.

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*(21.2) favors $\frac{1}{2}^+$, $\frac{3}{2}^+$. (1968EA03) finds that 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. transition is mainly E1, so $J^\pi \leq \frac{5}{2}^+$. The assignment $\frac{1}{2}^+$ is excluded by the strength of $(7.29 \to 4.45)$.

6) *7.98 MeV*. Transitons to ^{11}B(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 transiton 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 11.5: Lifetimes of some ^{11}B states

^{11}B state	τ_m (fsec)	Refs.
2.12	4.8 ± 0.4	Table 11.17
4.45	1.12 ± 0.06	Table 11.17
5.02	0.33 ± 0.03	Table 11.17
6.74	< 300	(1966WA10)
	< 210	(1969TH01)
	< 10	(1969BEYX)
6.79	< 50	(1969BEYX)
	< 35	(1969TH01)
7.29	< 23	(1969TH01)
	0.6 ± 0.3	Table 11.17
7.98	< 66	(1969TH01)
	< 30	(1969BEYX)
8.56	< 60	(1969TH01)
	0.33 ± 0.20	Table 11.17
8.92	0.16 ± 0.03	Table 11.17

1. ^{6}Li(^{6}Li, p)^{11}B $\qquad Q_m = 12.218$

Angular distributions of the protons have been reported at $E(^{6}\text{Li}) = 2.0$ MeV (1971PO1D; unpublished: $E_x \leq 8.0$ MeV) and 2.4 to 9.0 MeV (1966KI09: $E_x < 9.3$ MeV). For γ-spectra see (1962BE24, 1969TH01) and Table 11.4. τ_m, measured in this reaction and in reactions 7, 8 and 29 are shown in Table 11.5 (1969TH01).

2. ^{7}Li(α, γ)^{11}B $\qquad Q_m = 8.666$

Resonances for capture radiation are displayed in Table 11.6 (1951BE13, 1954HE22, 1967PA19). Angular distributions, branching ratios and correlations have been studied by (1959JO25, 1962GR07): they determine $J^\pi = \frac{5}{2}^-, \frac{7}{2}^-, \frac{5}{2}^-$ or $(\frac{3}{2}^+)$, $\frac{7}{2}^+$ and $\frac{5}{2}^+$, respectively for ^{11}B*(4.45, 6.74, 8.92, 9.19, 9.28): see (1968AJ02) for a more complete discussion and Tables 11.4 and 11.6. See also (1969OM1A).

3. ^{7}Li(α, n)^{10}B $\qquad Q_m = -2.790 \qquad E_b = 8.666$

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

E_r (keV)	$\Gamma_{c.m.}$ (keV)	^{11}B* (MeV)	J^π	$\omega\Gamma_s$ [d] (eV)	$\Gamma_{\gamma 0}$ [e] (eV)	Percentage decay to ^{11}B* [f]			
						0	4.44	6.74	6.79
401 [b]	< 1 [b]	8.921	$(\frac{5}{2})^-$	0.04	[j]	93 ± 5	2.3 ± 1		
819 ± 1 [b]	≈ 3 [g] eV	9.187	$\frac{7}{2}^+$	0.55		0.9 ± 0.3	82.8 ± 2.0	12.8 ± 0.4	< 1.3
958 ± 1 [b]	7 [b]	9.276	$\frac{5}{2}^+$	3.5		19.7 ± 1.0	67.5 ± 2.0	12.8 ± 0.7	< 0.6
2500 ± 20 [c]	433	10.26			17	[h]			
2620 ± 20 [c]	100	10.33			1.0	[h]			
2800 ± 50 [c]	≈ 140 [i]	10.45			$10/2J + 1$				
(3040) [c]	90	(10.60)			< 0.2	[h]			

[a] See also Tables 11.4, 11.8, 11.9 and 11.17 and Table 11.4 in (1968AJ02).
[b] (1951BE13). See also (1954HE22).
[c] (1967PA19).
[d] $\omega\Gamma_\gamma\Gamma_\alpha/\Gamma$, in c.m. (1951BE13, 1959JO25). See also (1965OL03).
[e] (1967PA19); based on analysis using $R = 4.9$ fm, $\gamma_W^2 = 1.0$ MeV.
[f] (1962GR07). See also Table 11.4.
[g] (1965OL03).
[h] $< 10\%$ to ^{11}B*(2.12) (1967PA19).
[i] Observed width (1967PA19).
[j] See Table 11.17.

Cross section measurements have recently been carried out by (1968MA07) for $E_\alpha = 4.43$ to 5.12 MeV (n_0) and by (1972VA02) for $E_\alpha = 4.5$ to 8.0 MeV (n_0) and 5.7 to 8.0 MeV (n_1). Results from these and previous measurements are displayed in Table 11.7 (1957BI84, 1959GI47, 1963ME08). See also (1968DA1H).

4. ^{7}Li(α, p)^{10}Be $\qquad Q_m = -2.5638 \qquad E_b = 8.666$

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

5. ^{7}Li(α, t)^{8}Be $\qquad Q_m = -2.5586 \qquad E_b = 8.666$

Excitation functions have been measured for $E_\alpha = 14$ to 25 MeV (t_0) and 18 to 25 MeV (t_1): they are essentially smooth (1972VA34). See also ^{8}Be in (1974AJ01) and (1974KA32; theor.).

Table 11.7: Thresholds and resonances in ^{7}Li(α, n)^{10}B

(1957BI84)		(1959GI47)	(1963ME08)	
E_{α} (MeV $\pm$ keV)	Γ_{lab} (keV)	E_{α} (MeV $\pm$ keV)	E_{α} (MeV $\pm$ keV)	E_{x} (MeV $\pm$ keV)
4.379 ± 6 (thresh.)			4.380 ± 20	thresh.
4.7			[4.72]	11.67 ± 100
5.15 ± 80	220	5.15 ± 70 [a]	[5.22] [c]	11.99 ± 100
		(5.64)	5.5	thresh.
		7.15 [b]	7.05 [c]	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	17.53 ± 30
			14.53	thresh.

[a] $J^{\pi} = \frac{3}{2}^{-}$ or $\frac{5}{2}^{+}$, $\Gamma_{\text{n}} \approx 20$ keV, $\Gamma_{\alpha} \approx 300$ keV, formed by $l_{\text{n}} = 0$ or 1 (1959GI47) [comparison with ^{10}B(n, α)].

[b] The width of this resonance is large.

[c] The n_0 yield shows the resonances at $E_{\alpha} \approx 5.2$ and 7.05 MeV: no others are seen in the interval $4.5 < E_{\alpha} < 8$ MeV (1972VA02).

6. ^{7}Li(α, α)^{7}Li $\qquad E_{\text{b}} = 8.666$

The elastic scattering has been studied for $E_{\alpha} = 1.6$ to 12 MeV (1966CU02), 2.5 to 4.5 MeV (1972BO07), 8.6 to 12.5 MeV and 17.0 to 22.5 MeV (1973KE13) and 12.0 to 18.0 MeV (1970BI1B, 1971BI12). The inelastic scattering, leading to ^{7}Li*(0.48), has been studied at $E_{\alpha} =$ 1.6 to 12 MeV (1966CU02), 1.6 to 3.2 MeV (1967PA19), 2.5 to 4.5 MeV (1972BO07), 5.8 to 6.7 MeV (1975BA06) and 17.0 to 22.5 MeV (1973KE13). See also (1968AJ02) for earlier references.

Observed resonances are displayed in Tables 11.8 and 11.9 (1966CU02, 1967PA19). A weak structure at $E_{\alpha} \approx 12.7$ MeV and broad structures at $E_{\alpha} \approx 12$ to 15 MeV are reported by (1970BI1B, 1971BI12): it is not clear whether these correspond to states in ^{11}B. (1973KE13) suggest that the deviations from smooth behavior in the excitation functions are due to the exchange of a triton cluster between two α-particles. See also ^{7}Li in (1974AJ01).

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

E_α [b] (keV)	E_α [c] (keV)	$\Gamma_{\text{c.m.}}$ (keV)	E_x (MeV $\pm$ keV)
1900 ± 10 [d]		130 ± 30	9.875 ± 10
2480 ± 50		150 ± 40	10.24 ± 50
	2630 ± 30	80 ± 30	10.34 ± 30
3040 ± 10 [d]	3040	70 ± 10	10.601 ± 10
3600 ± 50		≥ 900	10.96 ± 50
	4120 ± 30	90 ± 50	11.29 ± 30
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)

[a] (1966CU02), except where shown. See also Table 11.9.
[b] ^{7}Li(α, $\alpha'\gamma$)^{7}Li: σ(total).
[c] ^{7}Li(α, α_0)^{7}Li.
[d] (1967PA19). Other values are 1889 ± 10 (1954LI48), 1910 ± 20 (1957BI84), 1920 ± 30 keV (1966CU02); and 3060 ± 30 (1957BI84), 3032 ± 10 keV (1966CU02).
[e] ^{7}Li(α, n)^{10}B threshold.
[f] Anomaly in angular distribution.
[g] Observed at $\theta = 60°$.

Table 11.9: Resonance parameters in ^{7}Li(α, α)^{7}Li

E_r (MeV)	E_x (MeV)	J^π	$\Gamma_{c.m.}$ [a] (keV)	$\Gamma_{c.m.}$ [b] (keV)	Γ_i/Γ_e [a,e]	Γ_i/Γ_e [b,c]
1.90	9.88	$\frac{3}{2}^+$	250	290	4.0	0.18 [e]
2.50	10.26	$\frac{3}{2}^{(-)}, \frac{1}{2}$	200	433	0.04	0.13
2.62	10.33	$\frac{5}{2}^-, \frac{7}{2}^-$	100	100	0	0
2.80	10.45			≈ 140		$\ll 1$
3.04	10.60	$\frac{7}{2}^+$	90	90	1.0	0.49
3.54	10.92	$\frac{5}{2}^-$	4500		1.5	
[d]		$\frac{1}{2}^+$	4000		4.6	
4.12	11.29	$\frac{9}{2}^+$	100		0	

[a] (1966CU02): used $R = 6$ fm.
[b] (1967PA19): used $R = 4.9$ fm, $\gamma^2_W = 1.0$ MeV.
[c] Width ratio: inelastic/elastic.
[d] Broad level in background: E_λ(c.m.) = 1.71. See, however, (1967PA19).
[e] $\Gamma_{\gamma_0} < 0.5$ eV (1967PA19).

7. ^{7}Li(^{6}Li, d)^{11}B $\qquad Q_m = 7.192$

Angular distributions of deuterons have been measured at $E(^7\text{Li}) = 3.3$ MeV (1967GA06: $d_0 \rightarrow d_3$) and 3.78 to 5.95 MeV (1967KI03: $d_0 \rightarrow d_3$, d_{4+5}, d_6). For γ-spectra see (1962BE24, 1969TH01) and Table 11.4. For τ_m see Table 11.5 (1969TH01). See also ^{13}C in (1976AJ04).

8. ^{7}Li(^{7}Li, t)^{11}B $\qquad Q_m = 6.199$

Angular distributions have been measured at $E(^7\text{Li}) = 2.10$ to 5.75 MeV (1969CA1A: $t_0 \rightarrow t_3$). For τ_m see Table 11.5 (1969TH01). At $E(^7\text{Li}) = 79.6$ MeV transitions are observed to several ^{11}B states. ^{11}B$_{g.s.}$ is particularly strongly populated: 23 μb/sr, at 7.4° (1974CE06). See also (1974CE1A).

9. ^{9}Be(d, γ)^{11}B $\qquad Q_m = 15.8167$

Radiative transitions have been observed to ^{11}B*(0, 2.12, 4.45 + 5.02) at $E_d = 0.5$ to 1.4 MeV (1966ZI01) and 0.56 to 3.56 MeV (1970BA1R, 1971BA72). The 90° γ_0 differential cross section has been measured for $E_d = 0.5$ to 5.5 MeV (1963SU09, 1966SU05, 1966SU1C) and 2.9 to 11.9 MeV (1974DE01, 1974DE39). 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 $\Gamma_{lab} = 225 \pm 50$ 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 (1971BA72). (1974DE39) observe resonant behavior 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.

10. ^{9}Be(d, n)^{10}B $\qquad Q_m = 4.3607 \qquad E_b = 15.8167$

The cross section follows the Gamow function for $E_d = 70$ to 110 keV (1955RA14). The fast neutron and γ-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 excitation 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 (1973PA14). Polarization measurements have been reported at $E_d = 0.9$ to 2.5 MeV (1970MI04: $n_0 \rightarrow n_4$), 3.0 to 5.5 MeV (1974TH02: $n_0 \rightarrow n_5$ and n to ^{10}B*(5.1, 6.6)) and 3.0 and 3.5 MeV (1970SP1A, 1971SP1C: $n_0 \rightarrow n_4$). For papers dealing with applications see (1971DA21, 1971EL1B, 1972LU1B, 1973AU1G, 1973WE1T, 1973WE19). See also (1972DA34, 1973SZ07), (1970MI1G; theor.) and ^{10}B in (1974AJ01).

11. (a) ^{9}Be(d, p)^{10}Be $\qquad Q_m = 4.5873 \qquad E_b = 15.8167$
(b) ^{9}Be(d, α)^{7}Li $\qquad Q_m = 7.1511$
(c) ^{9}Be(d, t)^{8}Be $\qquad Q_m = 4.5925$

Recently measurements of proton yields have been carried out by (1974AN01: 0.3 to 0.9 MeV; p_0, p_1), (1974FR02: 0.6 to 2.7 MeV (p_0), 1.0 to 2.7 MeV (p_1)), (1972AR31: 0.75 to 2.25 MeV; p_0), (1974BO42: 0.9 to 2.5 MeV; p_0, p_1), (1973SA1Q: 0.9 to 3.1 MeV; p_0, p_1) and (1970PO03: 4.5 to 6.0 MeV; p_0, p_1). From these and previous measurements it appears that 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 (1974AN01) and the p_1 yield a resonance at 1.85 MeV [^{11}B*(17.33)], $\Gamma_{c.m.} \approx 1.0$ MeV (1973SA1Q). [The latter is also reported in the yield of 3.37 MeV γ-rays by (1957MC35).] Broad maxima have also been reported at $E_d \approx 0.9$ MeV, (1.3) and 2.1 MeV by (1952CA19: p_0) [see also (1972AR31)] and at 1.3 MeV by (1957MC35: 3.37 MeV γ-ray). (1974FR02) report a broad resonance at $E_d = 1.8$ MeV and a sharp resonance at 2.3 MeV, in the p_1 yield. See also (1968BE1E). Polarization of the protons has been studied at many energies in the range $E_d = 1$ to 21 MeV: see (1968AJ02) for the earlier work and (1968YU01: 7.0 MeV; p_0), (1969CU10: 10.0 MeV; p_0), (1970FI07: 10 and 12 MeV;

p_0, p_1), (1971GR20: 11.8 MeV; p_0), (1971BR44: 12 MeV; p_0), (1972BU26: 12.0 MeV; p_0, p_1), (1968BA19, 1973JO10: 12.3 MeV; p_0, p_1). See also (1967SA06, 1972FI1E, 1973FI1C). See also ^{10}Be in (1974AJ01).

The yields of α-particles, both α_0 and α_1, (reaction (b)) have been measured at $E_d = 0.3$ to 0.9 MeV (1974AN01), 0.5 to 2.3 MeV (1962BI11), 0.6 to 2.0 MeV (1974FR02), 0.9 to 2.2 MeV (1971SA27) and 8 to 12.4 MeV (1966DO1A; also α_2 for $E_d = 9$ to 12.4 MeV). (1974AN01) report a weak indication of the 0.75 MeV resonance, observed in the proton yield, in the α_0 yield. (1962BI11) find no clear indication of resonance structure. See also (1968BE1E, 1973SZ07) and ^{7}Li in (1974AJ01).

The cross section for reaction (c) has been measured for $E_d = 0.15$ to 19 MeV: see (1968AJ02) for the earlier references and (1974AN01: 0.3 to 0.9 MeV; t_0), (1974FR02: 0.6 to 2.0 MeV; t_0), (1974BO42: 0.9 to 2.5 MeV; t_0) and (1973SA1Q: 0.9 to 3.1 MeV; t_0). There is no clear evidence of resonance structure: see, however, (1955JU10, 1955JU1B, 1958JU38). See also ^{8}Be in (1974AJ01).

See also (1973BI1G), (1971EL1B: applied) and (1971KO41; theor.).

12. ^{9}Be(d, d)^{9}Be $\quad E_b = 15.8167$

Excitation functions for elastically scattered deuterons have been measured for $E_d = 0.4$ to 1.8 MeV (1963RE16), 1.0 to 2.2 MeV (1972LO05), 1.0 to 2.5 MeV (1968MA1H), 4.5 to 6.0 MeV (1970PO03) and 5.0 to 7.0 MeV (1971DJ02). Polarization measurements involving the d_0 group have been reported at $E_d = 6.3$ MeV (1971DJ02), 11.8 MeV (1971GR20) and 12.6 MeV (1971ZA04). See also (1970VE06, 1971SP1C) and ^{9}Be in (1974AJ01).

13. ^{9}Be(t, n)^{11}B $\quad Q_m = 9.5591$

Angular distributions are reported at $E_t = 1.1$ MeV (1970MAZE; unpublished).

14. ^{9}Be(^{3}He, p)^{11}B $\quad Q_m = 10.3229$

Proton groups have been observed to a number of ^{11}B states: see Table 11.10 (1959HI69, 1966BR18). See also (1970CA28). Angular distributions of many of these proton groups have been studied at $E(^3\text{He}) = 1.0$ to 10.2 MeV: see (1968AJ02) for references and (1973SU07: $E(^3\text{He}) = 0.82$ and 1.10 MeV). L assignments derived from the higher energy work (1960HI08) are also shown in Table 11.10. Gamma ray branching ratios and multipolarities for ^{11}B levels up to $E_x = 9.19$ MeV have been extensively studied by (1958FE70, 1961DO03, 1964AL22, 1965OL03): see Table 11.4 and the discussion in (1968AJ02). Lifetime measurements are shown in Table 11.5 (1969BEYX; abstract). See also (1970OG1A) and (1970LK1A; theor.).

Table 11.10: Energy levels of ^{11}B from ^{9}Be(^{3}He, p)^{11}B [a]

(1959HI69) [b]	(1966BR18)	(1960HI08)
E_x (MeV $\pm$ keV)		L
0	0	0
2.130 ± 10	2.1243 ± 0.9	0
4.445 [c]	4.4434 ± 1.8	0
5.023 ± 10	5.0187 ± 2.3	0
6.739 ± 10	6.7411 ± 3.0	
6.791 ± 10	6.7909 ± 3.1	1
7.285 ± 10		
7.975 ± 10		
8.553 ± 10		0
8.909 ± 10		0
9.175 ± 10		
9.264 ± 10		
9.86 ± 20 [d]		

[a] The previously quoted results of (1963GR20, 1965MA1E) are not displayed here because they have not subsequently been published.

[b] The original results were normalized to the second excited state taken to be at 4.459 MeV. Here they are shown normalized to 4.445 MeV.

[c] (1966BR18).

[d] $\Gamma \approx 150$ keV.

15. ^{9}Be(α, d)^{11}B $\qquad Q_m = -8.031$

Angular distributions have been measured at $E_\alpha = 27.0$ (1975PU01: $d_0 \rightarrow d_6$) and 28.3 MeV (1965KA14: $d_0 \rightarrow d_3$). The predominant L-transfer are $L = 0$, 2; 0 and 0, respectively for ^{11}B*(0, 2.12, 5.02). The angular distribution for ^{11}B*(4.45) is flat (1975PU01). See also (1970OG1A) and (1971BU1K; theor.).

16. (a) ^{9}Be(^{6}Li, α)^{11}B $\qquad Q_m = 14.343$

(b) ^{9}Be(^{6}Li, 2α)^{7}Li $\qquad Q_m = 5.677$

(c) ^{9}Be(^{6}Li, αp)^{10}Be $\qquad Q_m = 3.114$

(d) ^{9}Be(^{6}Li, αt)^{8}Be $\qquad Q_m = 3.119$

Angular distributions have been determined for seven α-groups at $E(^6\text{Li}) = 3$ to 4 MeV: see (1968AJ02). Angular distributions have also been obtained at $E(^6\text{Li}) = 24$ MeV to ^{11}B*(0, 2.12) and to a number of unresolved levels with $E_x \leq 13.2$ MeV (1967CH34, 1968DA20). See also (1970OG1A).

The breakup reactions (reactions (b), (c) and (d)) have been studied at $E(^6\text{Li}) = 3.5$ MeV by (1968JA08): reaction (b) goes mainly via a sequential process involving ^{11}B*(10.3, 11.4, 12.6, 13.16, 13.5). The results for reaction (c) are not conclusive. ^{11}B*(12.6, 13.16) may possibly contribute to reaction (d) (1968JA08).

17. (a) ^{9}Be(^{7}Li, αn)^{11}B $\quad Q_m = 7.092$
(b) ^{9}Be(^{9}Be, ^{7}Li)^{11}B $\quad Q_m = -0.880$

For reaction (a) see (1964CA18). For reaction (b) see (1970LK1A; theor.).

18. ^{10}Be(p, γ)^{11}B $\quad Q_m = 11.229$

The yield of ground state γ-rays has been measured at $90°$ for $E_p = 0.6$ to 6.3 MeV. Observed resonances are displayed in Table 11.11. The anomaly observed at $E_p = 1.05$ MeV may not correspond to a state in ^{11}B: it occurs at the threshold for ^{10}B*(0.72) + n. The other four resonances correspond to states in ^{11}B whose energies match well with those of the first four states in ^{11}Be: $T = \frac{3}{2}$. Several known $T = \frac{1}{2}$ states in ^{11}B are not observed in this reaction: see Table 11.3 (1970GO04, 1973GO09).

19. ^{10}B(n, γ)^{11}B $\quad Q_m = 11.4560$
$Q_0 = 11454.7 \pm 1$ keV (1967RA24);
$Q_0 = 11453 \pm 2$ keV (1967TH05).

The thermal capture cross section is 0.5 ± 0.2 b (1973MU14). For a listing of the observed capture γ-rays see Table 11.12 (1967TH05). The τ_m for ^{11}B*(6.74) is 10^{+12}_{-8} fsec (1969WE07). See also (1973AR1M, 1974AR1K, 1974ST1C) and (1968FOZY; astrophys.).

20. ^{10}B(n, n)^{10}B $\quad E_b = 11.4560$

The "free" neutron scattering cross section, $\bar{\sigma}_s = 2.23 \pm 0.06$ b. The coherent scattering amplitude (bound) is $a = +1.4 \pm 0.5$ fm (1973MU14). See also (1969BA1P). The total scattering

Table 11.11: Levels of ^{11}B from the ^{10}Be(p, γ_0))^{11}B reaction (1970GO04)

E_p (MeV ± keV)	E_x (MeV)	$\Gamma_{c.m.}$ (keV)	$(J+\frac{1}{2})(\Gamma_p/\Gamma)\Gamma_{\gamma_0}$ [e] (eV)	Γ_{γ_0} [a,e] (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 [f]	≤ 0.06	$\frac{1}{2}^-$ [c]
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] These values assume that $J \neq \frac{3}{2}$: see (1970GO04).

[b] See discussion in text.

[c] See Table 11.3.

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

[e] Values reported in (1970GO04) are here shown multiplied by 1.7: see (1973GO09).

[f] 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 $J^\pi = \frac{1}{2}^-$; $T = \frac{3}{2}$, $\Gamma_{\gamma_0} = 36 \pm 7$ eV (1975KA02).

Table 11.12: Neutron capture γ-rays from ^{10}B + n [a]

E_γ (keV)	ΔE_x (keV)	I_γ [b]	Assignment
11447 ± 2 [c]	11453 ± 2	6 ± 1	capt. → g.s.
8916 ± 2	8920 ± 2	15 ± 2	8.92 → g.s.
7006 ± 2	7008 ± 2	54 ± 3	capt. → 4.45
6739 ± 2	6741 ± 2	19 ± 1	6.74 → g.s.
	5020	< 2	5.02 → g.s.
4711 ± 2	4712 ± 2	25 ± 1	capt. → 6.74
4444 ± 2	4445 ± 2	65 ± 3	4.45 → g.s.
2534 ± 2	2534 ± 2	15 ± 2	capt. → 8.92
2295 ± 2	2296 ± 2	10 ± 3	6.74 → 4.45
	2120	< 3	2.12 → g.s.

[a] (1967TH05).

[b] Photons/100 captures.

[c] $\Gamma_\gamma = 0.01$ eV (1957BA18).

Table 11.13: Resonances in ^{10}B + n [a]

^{10}B(n, n′γ)^{10}B (1960DA08)		^{10}B(n, α)^{7}Li (1961DA16)		Yield of	^{11}B* (MeV)
E_{res} (MeV)	Γ (keV)	E_{res} (MeV)	Γ (keV)		
		0.23 [b]		σ_t, α	11.66
		0.53	140	α_0, α_1	11.94
1.93	260	1.86 [e]	570	σ_t [c], α_0, α_1, t	13.2
(2.6)	broad	2.79	530	σ_t [c], α_0, α_1	14.0
3.31	370	3.43	< 120	α_0, t	14.57
4.1		4.1	800	σ_t [c], α_0, α_1	15.2
4.73		[d]			15.75
		5.7	broad	α_0, t	16.6
		6.4	broad	α_0, t	17.3

[a] See also Table 11.14.
[b] (1951BO45, 1966MO09, 1970NE03).
[c] (1951BO45).
[d] (1961FO07).
[e] $J^\pi \geq \frac{11}{2}^+$ (1961DA16). See, however, Table 11.14.

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 (1970AS10).

Total cross section measurements in the range $E_n = 10$ to 500 keV confirm the broad maximum near $E_n = 0.23$ MeV, originally suggested by (1951BO45) and also observed in the (n, α) cross section (1966MO09). At higher energies the total cross section shows broad maxima at $E_n = 1.9$ and 2.8 MeV (1951BO45) and at 4.3 MeV (1961FO07): see Table 11.13. In the range $E_n = 5.5$ to 16 MeV σ_{tot} is constant at 1.5 b (1961FO07).

Polarization measurements (0.075 to 2.2 MeV and 2.63 MeV) and measurements of differential cross sections (0.075 to 4.4 MeV) by (1971LA10, 1973CO05, 1973HA2G, 1973HA64) have been analyzed using R-matrix calculations: the results are shown in Table 11.14. They are consistent with results from ^{10}B(n, n′γ) and ^{7}Li(α, n).

Elastic scattering differential cross sections are also reported at $E_n = 7.02$ and 7.55 MeV (1969HO1G) and at 9.72 MeV (1970CO12). See also (1969MA39, 1970PO1E), (1967IR1A, 1972LA1F) and (1966AG1A, 1967BE1F; theor.).

21. ^{10}B(n, n′)^{10}B* $\qquad E_b = 11.4560$

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 11.13 (1960DA08). See also (1970NE03). Inelastic scattering cross sections for formation of various ^{10}B states have been measured by (1970NE03: $E_n = 1.45$ to 4.90 MeV, and 14.8 MeV), (1969HO1G: $E_n = 7.02$ and 7.55 MeV) and (1970CO12: $E_n = 9.72$ MeV). See also ^{10}B in (1974AJ01) and (1969RO1F).

22. $^{10}B(n, p)^{10}Be$ $\qquad Q_m = 0.2226$ $\qquad E_b = 11.4560$

The thermal cross section is < 0.2 b (1973MU14). See also ^{9}Be in (1974AJ01) and (1970NE03).

23. $^{10}B(n, d)^{9}Be$ $\qquad Q_m = -4.3607$ $\qquad E_b = 11.4560$

See ^{9}Be in (1974AJ01).

24. (a) $^{10}B(n, t)^{8}Be$ $\qquad Q_m = 0.2318$ $\qquad E_b = 11.4560$
(b) $^{10}B(n, t)^{4}He^{4}He$ $\qquad Q_m = 0.3237$

The cross section for reaction (b) has been measured for $E_n = 1.4$ to 8.2 MeV by (1961DA16). Fluctuations are observed at some of the resonant energies in the $^{10}B(n, \alpha)$ reaction: see Table 11.13. See also (1968ST1D) and (1969AN25, 1971AN1M).

25. $^{10}B(n, \alpha)^{7}Li$ $\qquad Q_m = 2.790$ $\qquad E_b = 11.4560$

The "recommended" value of the thermal isotropic absorption cross section is 3837 ± 9 b (1973MU14). See also (1970ME1F). The ground state branching for thermal neutrons is $6.308 \pm 0.006\%$ (1967DE15). See also (1968MA07), and (1968AJ02) for earlier references. The cross section for $E_n = 10$ eV to 200 keV is given by the expression

$$13.837/\sqrt{E} - 0.312 - 1.014 \times 10^{-2}\sqrt{E} + \frac{2.809\times10^5}{\sqrt{E}[(170.3-E)^2+2.243\times10^4]} \text{ b (1970SO1A).}$$

The cross section for the (n, α_0) reaction has been calculated by (1968MA07) from that for the $^{7}Li(\alpha, n)$ reaction: $E_n = 30$ to 516 keV.

The α_1 cross section has been measured for $E_n = 47$ keV to 4.9 MeV and at 14.8 MeV (1970NE03): the cross section is substantially higher than that reported by (1961DA16). Observed resonances are displayed in Tables 11.13 and 11.14 (1961DA16).

Table 11.14: 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	$\frac{7}{2}^+$	0		0.030	0.070	100
0.17	11.61	$\frac{5}{2}^+$	0	0.004	0.296	0.0	300
0.37	11.79	$\frac{7}{2}^+$	0	0.770	0.001	0.113	884
0.53	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] (1971LA10, 1972HA04, 1973CO05, 1973HA64): 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^0 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 11.13.

Other recent measurements include those by (1969BO03) at $E_n = 30$ to 800 keV (relative cross sections for α_0 and α_1) and by (1969AN25) at 14.4 MeV (cross section for formation of $\alpha_0 + \alpha_1$, α_2). (1972HA04) have calculated differential cross sections for α_0 and α_1 based on R-matrix parameters derived from neutron elastic scattering, polarization measurements and (n, α) data. See also (1974HA1W, 1975HA1G; theor.). See also ^{7}Li in (1974AJ01), (1968GI1D, 1968GU1B, 1968ST1D, 1970DE1H, 1972LA1F, 1975FR1B), (1964FO1A; astrophys.) and (1968MO1D, 1968PA1E, 1973FA1M, 1973LI1E; applied).

26. ^{10}B(p, π^+)^{11}B $\qquad Q_m = -128.895$

Angular distributions for proton capture to ^{11}B*(0, 2.15 ± 0.10) have been measured at $E_p = 185$ MeV. The population of ^{11}B*($4.45 + 5.02$) and of unresolved higher states is also observed but an attempt to observe $T = \frac{3}{2}$ analogue states in ^{11}B and ^{11}N (the latter populated via (p, π^-)) was unsuccessful (1974DA27).

27. ^{10}B(d, p)^{11}B $\qquad Q_m = 9.2314$

Proton groups reported by (1951VA1A, 1953EL12, 1961JA23, 1966BR18) are listed in Table 11.15. Angular distributions have been studied at many energies in the range $E_d = 0.17$ to 28 MeV [see (1968AJ02) for a listing of the earlier references] and (1970HU1B: 0.35 MeV; $p_0 \rightarrow p_3$, p_{4+5}, p_6, p_7), (1973CO18: 0.67 to 2.32 MeV; p_{4+5}), (1970PO03: 4.5 to 5.5 MeV; $p_0 \rightarrow p_3$) and (1967GO27: 13.6 MeV; p_0). 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, 9.28) [$J^\pi = \frac{7}{2}^+$ and $\frac{5}{2}^+$, respectively] show strong $l = 0$ stripping and are ascribed to capture of a 2s neutron by ^{10}B: see (1968AJ02) for a listing of all the relevant references. The probability $p_{3/2}$ for transfer of a neutron with angular momentum $\frac{3}{2}$ has been determined for the p_0 group using vector polarized deuterons with $E_d = 10$ and 12 MeV, and compared with shell model calculations of (1965CO25, 1967CO32), (1970FI07; and see also (1967SC29)).

Studies of pγ correlations are discussed in reaction 14 of (1968AJ02) and displayed in Table 11.4 of this paper.

See also ^{12}C, (1967CO30, 1967SP09, 1973BR24), (1973FO02) and (1969BO1F, 1969DO08, 1970DE35, 1970DO07, 1970DO13; theor.).

28. ^{10}B(t, d)^{11}B $\qquad Q_m = 5.1984$

At $E_d = 5.5$ MeV, deuteron groups are observed to the ground state of ^{11}B and to states at $E_x = 2.126$, 4.449, 5.027, 6.769, 6.806 and 7.301 MeV (± 10 keV). All the angular distributions appear to be characteristic of $l_n = 1$ (1961BA10). See also ^{13}C in (1976AJ04).

29. ^{10}B(α, ^{3}He)^{11}B $\qquad Q_m = -9.1225$

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 (1968GA1C, 1969GA11).

30. (a) ^{10}B(^{6}Li, ^{5}Li)^{11}B $\qquad Q_m = 5.79$
(b) ^{10}B(^{7}Li, ^{6}Li)^{11}B $\qquad Q_m = 4.205$

See (1969TH01) for reaction (a) and (1974KO1G) for reaction (b).

31. ^{10}B(^{14}N, ^{13}N)^{11}B $\qquad Q_m = 0.902$

Table 11.15: ^{11}B levels from ^{10}B(d, p)^{11}B

(1951VA1A, 1953EL12)	(1961JA23)	(1966BR18)	l_n	(1962HI07)	l_n	(1960BI08)
E_x (MeV ± keV)		E_x (MeV ± keV)		$(2J+1)\theta^2$		$(2J+1)\theta^2$
0	0	0	1	0.120	1	1.00
2.140 ± 14 [a]	2.128 ± 10	2.1246 ± 1.1				0.09
4.464 ± 14 [a]	4.449 ± 8	4.4458 ± 2.1	1	0.048		0.46
5.039 ± 14 [a]	5.023 ± 8	5.0192 ± 2.4	(1)	(0.010)		0.11
6.765 ± 13 [a,b]		6.7439 ± 2.2	1	0.210	1	1.72
6.815 ± 13 [a,b]		6.7938 ± 2.2				
7.298 ± 6			(2?)	(0.022)		
7.987 ± 9					isotropic	
8.568 ± 5	8.565 ± 10		(2?)		2	
8.927 ± 5	8.926 ± 10		1	0.186	0, 2	
9.191 ± 5	9.190 ± 10		0	0.242	0	
9.276 ± 5	9.278 ± 10		0	0.175	0	
10.32 ± 20 [c]						

[a] Corrected by (1966BR18).
[b] 6.752 ± 6, 6.804 ± 6: see (1964AL22).
[c] $\Gamma = 54 \pm 17$ keV (1953EL12).

See (1968GA03) and (1968GO1K, 1970GO1B, 1970SC1G, 1973MC17, 1973OS03; theor.) and (1968AJ02).

32. ^{10}B(^{15}N, ^{14}N)^{11}B $\quad Q_m = 0.622$

Not reported.

33. ^{10}B(^{16}O, ^{15}O)^{11}B $\quad Q_m = -4.213$

See (1968OK06).

34. ^{10}B(^{18}O, ^{17}O)^{11}B $\quad Q_m = 3.409$

The angular distribution has been measured at $E(^{18}\mathrm{O}) = 20$ and 24 MeV (1971KN05). See also (1974SW04).

35. ^{10}B(^{19}F, ^{18}F)^{11}B $\qquad Q_\mathrm{m} = 1.025$

The angular distribution has been measured at $E(^{19}\mathrm{F}) = 20$ and 24 MeV (1971KN05). See also (1968GA03) and (1970GO1B; theor.).

36. ^{11}Be(β^-)^{11}B $\qquad Q_\mathrm{m} = 11.509$

^{11}Be decays to ^{11}B*(0, 2.12, 5.02, 6.79, 7.98, 9.87): see Table 11.16 for the parameters of the observed β and γ transitions (1971AL07). Delayed α-particles are also observed with a total I_α of 3.0%/decay. These α-particles are not observed to be in coincidence with 478 keV γ-rays [upper limit $= 5\%$ for $E_\alpha > 0.3$ MeV], suggesting that they result from the decay of ^{11}B*(9.87) to $^{7}\mathrm{Li}_{\mathrm{g.s.}}$ (1971AL07). The half-life of ^{11}Be is 13.81 ± 0.08 sec (1970AL21). See also (1968AJ02) and (1974AL11).

37. ^{11}B(γ, γ)^{11}B

Mean gamma widths of low-lying states obtained by resonance scattering and transmission studies are listed in Table 11.17 (1958ME79, 1958RA14, 1959CO95, 1964BO22, 1965KE05, 1968CR07, 1973SA21, 1974LE1K). See also (1974WE1R) and (1968AJ02).

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

(b) ^{11}B(γ, p)^{10}Be $\qquad Q_\mathrm{m} = -11.2294$

(c) ^{11}B(γ, d)^{9}Be $\qquad Q_\mathrm{m} = -15.8167$

(d) ^{11}B(γ, t)^{4}He + ^{4}He $\qquad Q_\mathrm{m} = -11.1323$

(e) ^{11}B(γ, α)^{7}Li $\qquad Q_\mathrm{m} = -8.666$

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)) (1971PA10). Absolute measurements of the ^{11}B(γ, all n) cross section from threshold to 28 MeV have been carried out by (1973HU09, 1973HU1D): the cross section exhibits a maximum at $E_\gamma = 25.2 \pm 0.1$ MeV ($\sigma \approx 8$ mb) in addition to some weaker structure. The integrated cross section from threshold to 27.6 MeV is 0.37 ± 0.04 in units of 60 NZ/A.

Table 11.16: Beta decay of ^{11}Be (1971AL07) [a]

^{11}B* [b] (keV)	J^{π} [c]	I_{β} (%)	log ft	E_{γ} (keV)	I_{γ} [d] (%)	Transition to ^{11}B*
g.s.	$\frac{3}{2}^{-}$	57 ± 3	6.81 ± 0.02			
2125.0 ± 0.7	$\frac{1}{2}^{-}$	29 ± 3	6.68 ± 0.04	2124.8 ± 0.7	33 ± 3	g.s.
4445	$\frac{5}{2}^{-}$	< 0.06	> 10.9 [e]			
5020.1 ± 1.7	$\frac{3}{2}^{-}$	0.28 ± 0.11	7.94 ± 0.14	5019.3 ± 1.7	0.47 ± 0.09	g.s.
				2893.1 ± 0.8	0.093 ± 0.028	2125
6742.7 ± 1.8 [g]	$\frac{7}{2}^{-}$	< 0.08				
6792.6 ± 1.8	$\frac{1}{2}^{+}$	6.8 ± 0.8	5.91 ± 0.05	6790.5 ± 1.8	4.51 ± 0.69	g.s.
				4666.3 ± 1.8	2.00 ± 0.28	2125
				1772.2 ± 0.7	0.28 ± 0.06	5020
7286	$(\frac{3}{2}, \frac{5}{2})^{+}$	< 0.16				
7978.1 ± 1.9	$\frac{3}{2}^{+}$	3.9 ± 0.5	5.58 ± 0.05	7974.7 ± 1.9	1.74 ± 0.30	g.s.
				5851.8 ± 1.9	2.13 ± 0.34	2125
8559	$\leq \frac{5}{2}^{-}$	< 0.06	> 7.0			
8920	$\frac{5}{2}^{-}$	< 0.02	> 8.5 [e]			
9870	$\frac{3}{2}^{+}$	3.0 ± 0.7 [f]	4.03 ± 0.15 [f]			

[a] See also Table 11.12 in (1968AJ02).

[b] When errors are indicated the excitation energies are determined in this experiment from the measured E_{γ}.

[c] From Table 11.3.

[d] Intensity in % per β-decay, normalized to $33 \pm 3\%$ for the 2.13 MeV γ-intensity.

[e] log $f_1 t$. Q_0 assumed to be 11.506 ± 0.007 MeV.

[f] Assuming that the breakup of ^{11}B*(9.87) is solely to ^{7}Li$_{g.s.}$. If the inelasticity for the breakup of ^{11}B*(9.87) is that suggested by (1966CU02), then the β-branch is $15 \pm 3.5\%$, log $ft = 3.33 \pm 0.15$, and the β branches to the other ^{11}B states have to be recalculated: see (1971AL07).

[g] Energy derived from E_x of ^{11}B*(6.79) and known ΔE of 4th and 5th states (1970BR23) [49.9 keV].

Table 11.17: Gamma widths from $^{11}B(\gamma, \gamma)^{11}B$ and $^{11}B(e, e)^{11}B$ [a]

E_x (MeV)	J^π	$\Gamma_{\gamma 0}$ (eV)	Reaction	Refs.
2.12 [b]	$\frac{1}{2}^-$	0.14 ± 0.018	$\gamma\gamma$	(1958ME79)
		0.11 ± 0.04	$\gamma\gamma$	(1964BO22)
		0.137 ± 0.020	$\gamma\gamma$	(1965KE05)
		0.12 ± 0.02	$\gamma\gamma$	(1968CR07)
		0.23 ± 0.09	$\gamma\gamma$	(1973SA21)
		0.14 ± 0.04	ee	(1975KA02)
		0.17 ± 0.034	ee	(1962ED02)
		0.136 ± 0.010		mean
4.45	$\frac{5}{2}^-$	0.56 ± 0.08	$\gamma\gamma$	(1958RA14)
		0.43 ± 0.095	$\gamma\gamma$	(1959CO95)
		0.53 ± 0.21	$\gamma\gamma$	(1973SA21)
		0.615 ± 0.037	$\gamma\gamma$	(1974LE1K)
		0.73 ± 0.07 (M1)+ 0.020 ± 0.002 (E2)	ee	(1975KA02)
		0.60 ± 0.09 (M1)+ 0.016 ± 0.002 (E2)	ee	(1967SP02)
		0.610 ± 0.030		mean
5.02 [e]	$\frac{3}{2}^-$	1.1 ± 0.2 [d]	$\gamma\gamma$	(1959CO95)
		2.4 ± 0.8	ee	(1966KO08)
		3.7 ± 1.5	ee	(1962ED02)
		1.73 ± 0.14 (M1) < 0.0034 (E2)	ee	(1967SP02)
		2.12 ± 0.21	ee	(1975KA02)
7.29	$(\frac{3}{2}, \frac{5}{2})^+$	1.0 ± 0.5	ee	(1962ED02)
8.56	$\leq \frac{5}{2}^-$	0.73 ± 0.07 (M1) 0.23 ± 0.03 (E2)	ee	(1975KA02) [f]
8.92	$\frac{5}{2}^-$	4.0 ± 0.6 (M1)	ee	(1966SP02)
		4.93 ± 0.50	ee	(1975KA02)

[a] See also Tables 11.4 and 11.5.
[b] See also (1963VA10, 1966KO08, 1974LE1K).
[c] See also (1962ED02, 1966KO08). (This footnote is not labeled in the table.)
[d] See (1967SP02).
[e] See also (1974LE1K).
[f] See also (1966SP02).

The results are consistent with the photoabsorption cross section proceeding via $T = \frac{1}{2}$ at lower energies (1973HU09). This is also the picture derived from the (γ, d_0) cross section (reaction (c)): it peaks at $\approx$ 19 MeV, lower than it would if $T = \frac{3}{2}$ states were involved (1974DE01). See also (1968KA38, 1969MU10, 1971KA70, 1972SL1B) and (1970HA28).

The cross section for (γ, n) shows many peaks in the range $E_\gamma = 12$ to 28 MeV (1965HA19). (1969SO06, 1970SO03) report resonances at $E_\gamma = 12.4$, 13.1, 13.65, 14.75, 15.1, 15.5, 15.85, 16.2, 16.5, 16.9, 17.5, (20.2), 21.6, 23.2, (24.5), 25.5, 27.7 and 29.2 MeV in the (γ, p) cross section. [See (1970SO03) also for Γ_γ and J^π for the states below 18 MeV (mainly $\frac{5}{2}^+$), and for an evaluation of the structure reported by (1965HA19).] See also (1972BU1J, 1973SP02) and (1971DU11; theor.). For reactions (d) and (e) see (1959AJ76).

39. (a) ^{11}B(e, e)^{11}B
(b) ^{11}B(e, ep)^{10}Be $\qquad Q_m = -11.229$

The charge-scattering radius is 1.55 fm (1959ME24). Magnetic elastic scattering at $\theta = 180°$ shows strong M3 effects: the derived ratio of static M3/M1, 2.9 ± 0.2 fm^2, suggesting a j-j coupling scheme for ^{11}B$_{\text{g.s.}}$ (1966RA29). 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(r.m.s.) $= 2.42$ fm (1966IS1A, 1966ST12). The excitation of ^{11}B*(2.1, 4.4, 5.0, 8.6, 8.9) has been studied by (1975KA02: $E_e = 52$ to 90 MeV). (1973FL1A) report the excitation of ^{11}B*(7.30, 9.27) at the same E_e. The giant resonance region, centered at $\approx$ 18 MeV, is characterized by a lack of prominent features except for a pronounced peak at $E_x = 13.0 \pm 0.1$ MeV (mixed M1-E2) and a broad transverse group at $E_x = 15.5$ MeV (1975KA02).

Ground state transition widths for various excited states are listed in Table 11.17 (1962ED02, 1966KO08, 1966SP02, 1967SP02, 1975KA02). For reaction (b) see (1971VL01, 1972VL1A) and ^{10}Be in (1974AJ01). See also (1968AJ02), (1971RI1E), (1968GO1J, 1972THZF), (1968JA1D, 1969VI02, 1973DO01, 1973GA19, 1973RO11, 1973SP02; theor.).

40. ^{11}B(n, n$'$)^{11}B*

Angular distributions of neutrons have been measured at $E_n = 7.55$ MeV (1969HO1G: $n_0 \to n_2$), 9.72 MeV (1970CO12: $n_0 \to n_3$, n_{4+5}) and 14.1 MeV (1970AL08: $n_0 \to n_3$, n_{4+5}, n_6). For branching ratios see Table 11.4 (1972NI05). See also ^{12}B, (1968AL1E, 1970PO1E) and (1968CA1A, 1969WA11, 1971MI12, 1971OT03, 1974BI07; theor.).

41. (a) ^{11}B(p, p$'$)^{11}B*
(b) ^{11}B(p, 2p)^{10}Be $\qquad Q_m = -11.229$

Observed proton groups are displayed in Table 11.18 (1969SU03, 1971BR41, 1974KA15). Angular distributions have been measured at E_p = 12 to 21.5 MeV (1972TH1C), 30.3 MeV (1969KA15: $p_0 \to p_2$), 100 MeV (1970HO07: $p_0 \to p_3$), 155 MeV (1968GE04: $p_0 \to p_3$, p_{4+5}) and 185 MeV (1969SU03: $p_0 \to p_2$ and p to ^{11}B*(8.56, 8.92)). For an angular correlation experiment see (1970HU01). See also (1968AJ02), (1970TH1F, 1973CA1H), (1969WA11, 1971LO05, 1973KA04; theor.) and ^{12}C. For reaction (b) see ^{10}Be in (1974AJ01). The spectroscopic factors for the (t + ^{8}Be) and (α + ^{7}Li) cluster structures in ^{11}B [as determined from a study of the ^{11}B(p, α)^{6}Li reaction] are ≈ 0.77 and ≈ 0.02, respectively (1972DE01, 1972DE02).

42. ^{11}B(d, d)^{11}B

The elastic scattering has been studied at $E_d = 5.5$ MeV (1971HIZF) and 11.8 MeV (1967FI07). See also (1968VE11, 1968VE1C, 1970VE06, 1971TAZN) and (1969VE09, 1970EL16; theor.).

43. ^{11}B(t, t)^{11}B

The elastic scattering has been studied at $E_t = 1.8$ and 2.1 MeV (1969HE08, 1969SI12).

44. (a) ^{11}B(^{3}He, ^{3}He)^{11}B
(b) ^{11}B(^{3}He, ^{6}He)^{8}Be $\qquad Q_m = 4.570$

The elastic scattering has been studied at $E(^3\text{He})$ = 8, 10, 12, 15 and 18 MeV (1969MI15, 1969PA11), 14 MeV (1970NU02) and 18.3, 20.6 and 27.2 MeV (1972BU30), and 74 MeV (1974AS06: also ^{11}B*(4.45)). A coupled channel analysis of the 74 MeV results suggests a quadrupole deformation $\beta_2 = +0.43$ or -0.50 for ^{11}B (1974AS06). At $E(^3\text{He}) = 29.8$ MeV a number of ^{11}B states are populated, including suggested $T = \frac{3}{2}$ states [see Table 11.19] with $E_x = 12.51 \pm 0.05$, 12.98 ± 0.09 and 14.40 ± 0.05 MeV, with $\Gamma_{\text{c.m.}} = 260 \pm 50$, 390 ± 120 and 220 ± 50 keV, respectively. There is a weak indication also of a state at $E_x = 14.51$ MeV (1971WA21). See also (1969AD1C, 1970BA1P, 1970DU07). For reaction (b) see (1972YO02).

45. (a) ^{11}B(α, α)^{11}B
(b) ^{11}B(α, 2α)^{7}Li $\qquad Q_m = -8.666$

Angular distributions have been reported at $E_\alpha = 28.3$ MeV (1965KO1A: $\alpha_0 \to \alpha_3$, α_{4+5}, α_6), 28.4 and 29.0 MeV (1968KA24: α_0) and 28.5 MeV (1967NA06: $\alpha_0 \to \alpha_3$, α_{4+5}, α_6, α_8). For reaction (b) see (1969FU09).

Table 11.18: States of ^{11}B from ^{11}B(p, p′)^{11}B* and ^{13}C(d, α)^{11}B

(1969SU03) [a,d]	(1971BR41) [a]	(1974KA15) [a]	(1970BR23) [b]	(1969SU03)	
	E_x (keV)			B(M1)↑ [e]	B(E2)↑ [f]
0		0	0		
2130 ± 30		2124.7 ± 0.5	2125.4 ± 1.4	0.55 [c]	3.4 ± 0.8
4450 ± 30	4445.3 [c]	4445.2 ± 0.5	4444.5 ± 1.6	0.71 ± 0.12	16.9 [c]
5030 ± 50	5020.0 [c]	5021.1 ± 0.6	5020.2 ± 1.9	0.67 ± 0.12	1.4 ± 0.7
6700 ± 60	6743.4 [c]	6743.0 ± 0.7	6745.82 ± 3.4		10.0 ± 1.5
	6792.6 ± 1.6		6795 ± 3.0		
	7285.6 ± 1.5				
	7978.0 ± 1.7				
8520 ± 70	8559.4 ± 1.9			0.27 ± 0.06	4.1 ± 0.8
8910 ± 60	8920.2 ± 2.0			0.86 ± 0.14	1.0 ± 0.5
	9185.0 ± 2.0				
	9274.4 ± 2.0				
10450 ± 150					
11650 ± 150					
12850 ± 100					
15200 ± 150					
16400 ± 150					

[a] ^{11}B(p, p′)^{11}B*.

[b] ^{13}C(d, α)^{11}B.

[c] Values in this column normalized to this value.

[d] See also (1965HA17).

[e] See discussion of validity of these numbers in (1969SU03).

[f] Other experiments show that the 2.12 $\rightarrow$ 0 transition is 100 % M1.

46. ^{11}B(^{6}Li, ^{6}Li)^{11}B

The elastic scattering has been measured at $E(^{6}\text{Li}) = 28$ MeV (1972BA52) and analyzed by the optical model.

47. ^{11}B(^{9}Be, ^{9}Be)^{11}B

See (1970LK1A; theor.).

48. (a) ^{11}B(^{10}B, ^{10}B)^{11}B
(b) ^{11}B(^{11}B, ^{11}B)^{11}B

See (1975HI1D), and (1967GU1A) for reaction (b).

49. ^{11}B(^{12}C, ^{12}C)^{11}B

The elastic scattering has been studied at $E(^{11}\text{B}) = 28$ MeV (1969VO07, 1969VO10), at $E(^{12}\text{C}) = 15$, 17, 20 and 24 MeV (1974BO15), and at $E(^{12}\text{C}) = 87$ MeV (1971LI11). The population of ^{11}B*(2.12, 4.45, 6.79) and of ^{12}C*(0, 4.43) has also been reported: see (1969VO07). See also (1974DA1P) and (DE63Y, 1970AN1D; theor.).

50. ^{11}B(^{14}N, ^{14}N)^{11}B

The elastic scattering has been investigated at $E(^{14}\text{N}) = 41$, 77 and 113 MeV (1971LI11).

51. ^{11}B(^{16}O, ^{16}O)^{11}B

The elastic scattering has been studied at $E(^{16}\text{O}) = 14.5$ to 27.5 MeV (1968OK1B) and 27, 30, 32.5, 35 and 60 MeV (1969VO10, 1972SC03, 1974KO1P). See also (1969BR1D, 1971BO1V) and (1970SC1G, 1974DE17; theor.).

52. ^{11}C(β^{+})^{11}B $\qquad Q_{\text{m}} = 1.982$

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

Reaction	E_x (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	Refs.
^{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)
	12.56 ± 30	240 ± 50	"best"
^{10}Be(p, γ)^{11}B	12.91 ± 20	235 ± 27	(1970GO04)
^{11}B(^{3}He, ^{3}He)^{11}B*	12.98 ± 90	390 ± 120	(1971WA21)
^{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)
	12.91 ± 20	240 ± 30	"best"
^{10}Be(p, γ)^{11}B	14.33 ± 20	255 ± 36	(1970GO04)
^{11}B(^{3}He, ^{3}He)^{11}B*	14.40 ± 50	220 ± 50	(1971WA21)
	14.33 ± 20	250 ± 40	"best"
^{10}Be(p, γ)^{11}B	15.32 ± 100	635 ± 180	(1970GO04)

[a] These states have also been seen in other reactions: see Table 11.3. The parameters shown in that table reflect all the pertinent data. See also Table 11.22 for $T = \frac{3}{2}$ states in ^{11}C.

See ^{11}C.

53. ^{12}C(γ, p)^{11}B $\qquad Q_m = -15.9572$

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 $E_{bs} = 24.5, 27, 33$ and 42 MeV: the ground state is predominantly populated. The population of analog states in the (γ, n) and (γ, p) reactions are similar: see ^{11}C (1970ME17). See also the discussions in (1973DI1C, 1973SP03, 1974DI17) and in ^{12}C. Angular distributions of the p_{0+1} and the $p_{2+3+4+5}$ groups have been measured by (1974FI17: $E_\gamma =$ 60, 80, 100 MeV). See also (1968FR12) and (1970MU1D, 1971BI01, 1973MS01, 1973MS02; theor.).

54. ^{12}C(e, ep)^{11}B $\qquad Q_m = -15.9572$

At $E_e = 497$ MeV the excitation of ^{11}B*(0, 2.1, 5.) has been observed by Auriol *et al.* (see (1972RA1E)). See also (1967AM1A), ^{12}C and (1968BO1D, 1968CI1B, 1968WA1D, 1969BA1F, 1972BE59, 1974HA14; theor.).

55. ^{12}C(n, d)^{11}B $\qquad Q_m = -13.7325$

Angular distributions have been measured at $E_n = 56$ MeV for the deuterons to ^{11}B*(0, 2.12, $4.45 + 5.02$) (1974KI1A).

56. ^{12}C(p, 2p)^{11}B $\qquad Q_m = -15.9572$

Gross structure is seen in the summed proton spectrum with $Q = -15.6 \pm 0.6$ and -34.3 ± 0.8 MeV (1965RI1A, 1966TY01), -15.0 ± 0.5 and -35.5 ± 1.0 MeV (1971LA16), corresponding to ^{11}B$_{\rm g.s.}$ and an excited state with $J^\pi = \frac{1}{2}^+$ at $E_x \approx 19.5$ MeV (ejection of p- and s-protons, respectively). High resolution experiments show groups corresponding to ^{11}B*(0, 2.12, 4.45, 5.02, 6.79) (1965PU02, 1967PU01, 1974ST1R). See also (1969EP01, 1971HA61, 1971HO03, 1972PU1A), (1968AJ02, 1969RU1A, 1973JA01), (1967KO1B, 1969MC13, 1970KA01, 1971YO1E, 1972KO13, 1972LI1J, 1972ST33, 1973GU18, 1973GU1D; theor.) and ^{12}C.

57. ^{12}C(d, ^{3}He)^{11}B $\qquad Q_m = -10.4634$

Angular distributions of ^{3}He ions have been measured at $E_d = 20$, 24, 28 MeV (1971IN1C; unpublished: to ^{11}B*(0, 2.12, 4.45, 5.02, $6.74 + 6.79$, 7.29, 7.98)), 28 MeV (1968GA13: to g.s.), 28 and 50 MeV (1968DU01: ^{11}B*(0, 6.74)), 28.5 MeV (1966DE1C: to g.s.), 52 MeV (1968HI01: to ^{11}B*(0, 2.12, 4.45, 5.02, $6.74 + 6.79$, 7.29)) and 80 MeV (1974AS04: to ^{11}B*(0, 4.45)). A coupled channels Born approximation analysis gives good agreement with the angular distributions: a positive β_2 is suggested by the results (1974AS04): see, however, (1974KU17). See also (1969KA1A, 1973WA1E, 1974DI1A) and (1969TA1D, 1973ST16, 1974ST18; theor.).

58. ^{12}C(t, α)^{11}B $\qquad Q_m = 3.8574$

Angular distributions of the α-particles to ^{11}B*(0, 2.12) have been measured at $E_t = 1$ to 2 MeV (1962GU01), 1.11 to 3.40 MeV (1969ET01 and private communication), 10.1 MeV (1962PU01) and 13 MeV (1965AJ01; also α_2, α_3). Electromagnetic transitions have been studied by (1968BE30): see Table 11.4 (1968BE30) confirm $J = \frac{3}{2}$ for ^{11}B*(5.02). See also (1969AR1B) and (1969NA1C; theor.).

59. ^{12}C(^{10}B, ^{11}C)^{11}B $\qquad Q_m = -7.266$

This reaction has been studied at $E(^{10}\mathrm{B}) = 100$ MeV: $^{11}\mathrm{B}_{\mathrm{g.s.}}$ is much more strongly excited than ^{11}B*(2.12) (1973YO1C, 1973YO1D). The ratios of the yields $^{11}\mathrm{B}_{\mathrm{g.s.}}$/$^{11}\mathrm{C}_{\mathrm{g.s.}}$ and ^{11}B*(2.12)/^{11}C*(2.00) have been studied at 100 MeV. They differ from 1 by a few percent at certain angles: the deviations are more pronounced for the first excited states (1974HA1V).

60. ^{12}C(^{12}C, ^{13}N)^{11}B $\qquad Q_{\mathrm{m}} = -14.014$

The angular distribution involving the ground state transitions has been measured at $E(^{12}\mathrm{C}) = 114$ MeV (1974AN36). See also (1967WI04, 1969BR1G).

61. ^{12}C(^{14}N, ^{15}O)^{11}B $\qquad Q_{\mathrm{m}} = -8.665$

See (1966PO1B, 1967BI06, 1967VO1A, 1974AN36). See also (1969BR1D, 1973SC1J) and ^{15}O in (1976AJ04).

62. ^{12}C(^{19}F, ^{20}Ne)^{11}B $\qquad Q_{\mathrm{m}} = -3.112$

At $E(^{19}\mathrm{F}) = 40$, 60 and 68.8 MeV angular distributions involving $^{20}\mathrm{Ne}_{\mathrm{g.s.}} + {}^{11}\mathrm{B}_{\mathrm{g.s.}}$, $^{20}\mathrm{Ne}^*_{1.63} + {}^{11}\mathrm{B}_{\mathrm{g.s.}}$ and $^{20}\mathrm{Ne}_{\mathrm{g.s.}} + {}^{11}\mathrm{B}^*_{2.12}$ ($E = 68.8$ MeV only) have been measured by (1972SC03). See also (1969VO1D, 1970VO1F) and (1972BO21; theor.).

63. ^{13}C(n, t)^{11}B $\qquad Q_{\mathrm{m}} = -12.4214$

Not reported.

64. ^{13}C(p, ^{3}He)^{11}B $\qquad Q_{\mathrm{m}} = -13.1852$

At $E_{\mathrm{p}} = 50.5$ MeV, in addition to ^{11}B*(0, 2.12, 4.45, 5.02, 6.74, 8.92), a state is observed at $E_{\mathrm{x}} = 12.94 \pm 0.05$ MeV, $\Gamma = 350 \pm 50$ keV. Comparison of the angular distributions of the ^{3}He and of the tritons [in the analog reaction] at $E_{\mathrm{p}} = 43.7$ 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 (1968CO26). The $T = \frac{3}{2}$ state is also observed at $E_{\mathrm{p}} = 40$ MeV by (1974BE20): $E_{\mathrm{x}} = 12.91 \pm 0.03$ MeV, $\Gamma = 260 \pm 50$ keV. ^{11}B*(12.55, 14.33) reported by (1970GO04) in the ^{10}Be(p, γ)^{11}B reaction are not observed by (1974BE20): see Table 11.19. Angular distributions have been measured to ^{11}B*(0, 2.12, 4.45, 5.02) at $E_{\mathrm{p}} = 26.9$ to 43.1 MeV (1975MI01) and at 43.7 and 49.6 MeV (1968FL02). See also (1969SC1F).

65. ^{13}C(d, α)^{11}B $\qquad Q_m = 5.1686$

Observed proton groups are displayed in Table 11.18 (1970BR23). Angular distributions are reported at $E_d = 0.41$ to 0.81 MeV (1971PU01: α_0, α_1), 1.0 to 2.7 MeV (1970LI1E: α_0, α_1), 1.4 MeV (1966KL1A: α_0), 3.3 to 4.2 MeV (1963MA24: α_0), 6.8 MeV (1968DE26: $\alpha_0 \rightarrow \alpha_3$), 11.7 MeV (1969CU08: $\alpha_0 \rightarrow \alpha_3$) and 12.1, 13.3 and 14.1 MeV (1970KL04: $\alpha_0 \rightarrow \alpha_3$). See also (1968AJ02), (1967SP09, 1968CO04, 1971LI1K) and ^{15}N.

66. ^{13}C(^{17}O, ^{19}F)^{11}B $\qquad Q_m = -4.864$

See (1974CH1Q).

67. ^{14}C(p, α)^{11}B $\qquad Q_m = -0.7837$

Angular distributions of the $\alpha_0 \rightarrow \alpha_3$ groups have been measured at $E_p = 18$ MeV (1962BR34).

68. (a) ^{14}N(n, α)^{11}B $\qquad Q_m = -0.1574$
(b) ^{14}N(n, 2α)^{7}Li $\qquad Q_m = -8.823$

Angular distributions for the α_0 and α_1 groups have been measured at $E_n = 4.9$ MeV (1972KI12), 14.1 MeV (1968BA30 [also α_{2+3}], 1968HS03 [also α_2, α_3, α_{4+5}], 1968MA11, 1973BO26), 14.8 to 18.8 MeV (1971SA31) and 14.9 MeV (1968LE11). See also (1969DI1B, 1970DI1A, 1974TU1A). The angular distribution of the 2.12 MeV γ-ray ($E_\gamma = 2118 \pm 5$ keV) is isotropic; that for the 4.4 MeV γ-ray shows a weak anisotropy. Both γ-rays are Doppler broadened: $\tau_m < 100$ fsec [see Table 11.5] (1972NY02). See also (1971NY03) and ^{15}N in (1976AJ04).

At $E_n = 14.1$ and 15.7 MeV various states of ^{11}B with $8.9 < E_x < 14.5$ MeV appear to be involved in the sequential decay to ^{7}Li. Angular correlation results are consistent with $J^\pi = \frac{7}{2}$ and $\frac{5}{2}$ for ^{11}B*(9.19, 9.28), respectively (1971SC16).

69. ^{15}N(α, ^{8}Be)^{11}B $\qquad Q_m = -11.083$

At $E_\alpha = 72.5$ MeV, the excitation of ^{11}B*(0, 2.12, 4.45, 5.02, 6.74) is reported (1974WO1D).

70. ^{19}F(^{12}C, ^{20}Ne)^{11}B $\qquad Q_m = -3.112$

See (1971BO1V).

^{11}C

(Figs. 3 and 4)

GENERAL: (See also (1968AJ02).)

Shell model: (1972LE1L, 1973HA49, 1973SA30, 1974ME19).

Cluster and collective model: (1972LE1L).

Special levels: (1969HA1G, 1969HA1F, 1972MS01, 1973SA30, 1974IR04).

Electromagnetic transitions: (1967WA1C, 1969HA1F, 1969HA1G, 1969WA1C, 1973HA49, 1973SA30, 1974ME19).

Astrophysical questions: (1970BA1M, 1972KO1E, 1973LA19).

Special reactions: (1968BE1F, 1968HA1C, 1968MO1C, 1968NO07, 1969GA18, 1969HI1A, 1969YI1A, 1970KR1C, 1970MO38, 1971AR02, 1971BA16, 1971BI22, 1971EP02, 1973CO1V, 1973JO07, 1973LA19, 1973PH1B, 1973SK01, 1973VA12, 1973WE1N, 1974DI16, 1974HA61).

Applied topics: (1974PE04).

Pion capture and pion reactions: (1968DA1G, 1968NY1A, 1970LI1H, 1971BL02, 1971KA62, 1971NO08, 1972SE13, 1973AL1D, 1973AL1E, 1973AR1B, 1973CH20, 1973HO43, 1973JA1J (and a correlation (1974JA29)), 1974AM01, 1974MI11).

Other topics: (1968BU1B, 1970SH1C, 1972AB14, 1972AN05, 1972CA37, 1972LE1L, 1973RO1R, 1974IR04).

Ground state properties: (1967CO1D, 1967SH14, 1968PE16, 1968RO1E, 1969FU11, 1971TA1A, 1971ZO03, 1972LE1L, 1972VA36, 1973CO1P, 1973MA1K, 1973SA30, 1974ME19).

$$\mu = -0.964 \pm 0.001 \text{ nm (1969WO03);}$$

$$\mu = \pm 0.997 \text{ nm (1968SC18);}$$

$$\mu = -0.964 \pm 0.001 \text{ nm (1973CO1P); see also (1971SH26);}$$

$$Q = \pm 0.0322 \text{ b (1968SC18).}$$

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

The half-life of ^{11}C is 20.40 ± 0.04 min (1969AW02). [The weighted mean value of previously reported half-lives is 20.34 ± 0.04 min: see Table 11.15 in (1968AJ02).] $\log ft = 3.591 \pm 0.002$ (B. Zimmerman, private communication). Relativistic corrections to the $\log ft$ value are considered by (1970ST04). The ratio of K-capture to positron emission is $(0.230^{+0.014}_{-0.011})\%$ (1967CA09). See also (1957SC29, 1969BE09, 1970BE66, 1972CH1G, 1973HO43), (1968FI02) and (1969LE1D, 1969SU15, 1970DA21, 1970KO41, 1971VA1C, 1973EM1B, 1973MU1D, 1973WI04, 1973WI11, 1974LE1G, 1974ME19, 1974WI1M; theor.).

Table 11.20: Energy levels of ^{11}C [a]

E_x in ^{11}C (MeV ± keV)	$J^\pi; T$	τ or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
g.s.	$\frac{3}{2}^-; \frac{1}{2}$	$\tau_{1/2} = 20.40 \pm 0.04$ min	β^+	1, 2, 4, 5, 12, 14, 15, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 35, 36
2.0000 ± 0.5	$\frac{1}{2}^-$	$\tau_m < 0.5$ psec	γ	2, 4, 5, 12, 14, 17, 21, 22, 23, 26, 28, 29, 30, 31, 32, 33
4.3188 ± 1.2	$\frac{5}{2}^-$	< 0.14 psec	γ	2, 4, 5, 12, 14, 17, 21, 23, 26, 28, 32
4.8042 ± 1.2	$\frac{3}{2}^-$	< 0.5 psec	γ	2, 4, 12, 14, 17, 21, 23, 26, 28, 32
6.3392 ± 1.4	$\frac{1}{2}^+$	< 0.11 psec	γ	2, 4, 12, 14, 17, 21, 28
6.4782 ± 1.3	$\frac{7}{2}^-$	< 0.25 psec	γ	2, 4, 5, 12, 14, 17, 21, 23, 26, 28, 32
6.9048 ± 1.4	$\frac{5}{2}^+$	< 69 fsec	γ	2, 4, 12, 14, 17, 23, 26, 28, 32
7.4997 ± 1.5	$\frac{3}{2}^+$	< 91 fsec	γ	2, 4, 12, 14, 17, 26, 28, 32
8.1045 ± 1.7	$\frac{3}{2}^-$		(γ)	4, 12, 14, 17, 26, 28
8.425 ± 8	$\frac{5}{2}^-$		γ	2, 4, 12, 14, 17, 26, 28
8.655 ± 8	$\frac{7}{2}^+$	$\Gamma \ll 9$ keV	(γ)	12, 14, 17, 26
8.701 ± 20	$\frac{5}{2}^+$	15 ± 1		12, 14, 26
9.732 ± 5	$(\frac{5}{2}^+)$	450 ± 50	γ, p, α	5, 7, 11, 26
10.084 ± 5	$\frac{7}{2}^+$	≈ 230	p, α	7, 11, 14, 26
10.680 ± 5	$\frac{9}{2}^+$	200 ± 30	p, α	7, 11, 12, 26
(10.799 ± 5)			p, α	7, 11
11.030 ± 5	$T = \frac{1}{2}$	300 ± 60	p, α	7, 11, 26, 32
11.44 ± 10		360	p, α	7, 11, 26
11.954 ± 7			p, α	7, 11
(12.16 ± 40)	$(T = \frac{3}{2})$	270 ± 50	p	4, 8, 22
12.4	$\pi = -$	$1 - 2$ MeV	γ, p	5
12.50 ± 30	$\frac{1}{2}^-; \frac{3}{2}$	490 ± 40	p, α	4, 8, 22, 32
12.65 ± 20	$(\frac{7}{2}^+)$	360	p, ^{3}He, α	7, 8, 10, 11
(13.01)			γ, p	5

Table 11.20: Energy levels of ^{11}C [a] (continued)

E_x in ^{11}C (MeV ± keV)	$J^\pi; T$	τ or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
13.33 ± 60		270 ± 80		32
13.4		1100 ± 100	p, α	7, 11
13.90 ± 20	$(T = \frac{3}{2})$	200 ± 100	p	4, 8, 22, 32
14.07 ± 20		135 ± 50	n, p	6, 7, 32
14.76 ± 40		≈ 450	n, p, ^{3}He	6, 8, 10
15.35 ± 50	$\pi = -$	broad	γ, n, p	5, 6, 8
15.59 ± 50		≈ 450	n, p	6, 8
16.7	$\pi = -$	800 ± 100	γ, p	5
(18.2)			γ, p	5

[a] See also Table 11.21.

2. (a) ^{6}Li(^{6}Li, n)^{11}C $\quad Q_m = 9.453$
   (b) ^{7}Li(^{6}Li, 2n)^{11}C $\quad Q_m = 2.203$
   (c) ^{7}Li(^{7}Li, 3n)^{11}C $\quad Q_m = -5.048$

At $E(^6\text{Li}) = 4.1$ MeV (reaction (a)) 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, n-γ coincidences via ^{11}C*(8.43) [and a 8.43 MeV γ-ray] are reported. ^{11}C*(8.10) was not observed (1967BA53). See also (1969GU1D). The lifetimes, τ_m, for ^{11}C*(4.32, 6.90, 7.50) are < 140, < 69 and < 91 fsec, respectively. The upper limits for τ_m of ^{11}C*(6.34, 6.48) [which were unresolved] are 0.5 psec. The ground state transition from ^{11}C*(7.50) has $E_\gamma = 7505 \pm 8$ keV (1969TH01). For reaction (b) see (1968AJ02). For reaction (c) see (1974CE06).

3. ^{7}Be(α, γ)^{11}C $\quad Q_m = 7.545$

See (1972PA1C, 1975FO19).

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

Reported neutron groups are listed in Table 11.16 of (1968AJ02). Angular distributions have

Table 11.21: Gamma decay of ^{11}C levels

E_i (MeV)	J_i^π	τ_m [b] (psec)	E_f (MeV)	Branch [a] (%)	Mult. [a]	Branch [c] (%)	X [c]
2.00	$\frac{1}{2}^-$	< 0.5	0	100			
4.32	$\frac{5}{2}^-$	< 0.5	0	100	M1	100	$+0.17 \pm 0.03$ [g]
		< 0.14 [h]	2.00	< 2		< 2	
4.80	$\frac{3}{2}^-$	< 0.5	0	83 ± 4	M1	86 ± 2 [f]	[e]
			2.00	17 ± 4		14 ± 2 [f]	[e]
6.34	$\frac{1}{2}^+$	< 0.11	0	65 ± 3	E1	68 ± 3	
			2.00	35 ± 3		32 ± 3 [d]	
			4.32			< 7	
			4.80	< 4		< 3	
6.48	$\frac{7}{2}^-$	< 0.25	0	89 ± 2	E2	88 ± 2	-0.01 ± 0.06
			2.00	< 2		< 4	
			4.32	11 ± 2		12 ± 2	
			4.80			< 2	
6.90	$\frac{5}{2}^+$	< 0.16	0	89 ± 3	E1	91 ± 2	0.02 ± 0.03
		< 0.07 [h]	2.00	< 2		< 1	
			4.32	11 ± 3		4.5 ± 1	
			4.80	< 3		4.5 ± 1	
			6.34	< 5			
			6.48	< 5			
7.50	$\frac{3}{2}^+$	< 0.5	0	36 ± 2	E1	37 ± 3	-0.04 ± 0.04
		< 0.09 [h]	2.00	64 ± 2	E1	63 ± 8	0 ± 0.03
			4.32	< 3		< 1	
			4.80	< 3		< 1	
			6.34	< 3			
			6.48	< 3			
			6.90	< 4			
9.73 [i]	$(\frac{5}{2}^+)$		0	65 ± 15			
			2.00	3			
			4.32	12 ± 2			
			6.48	20			

[a] From ^{9}Be(^{3}He, n)^{11}C and ^{10}B(d, n)^{11}C (1965OL03): includes earlier measurements, except for ^{11}C*(9.73): see footnote [i].

[b] (1966WA10).

[c] (1968EA03): ^{12}C(^{3}He, α)^{11}C: $X \equiv$ amplitude ratio of $(L+1)/L$.

[d] The cascade is through ^{11}C*(2.0) and not ^{11}C*(4.3) (1968EA03).

[e] See ^{12}C(^{3}He, α)^{11}C.

[f] 86 ± 3, $14 \pm 3\%$ (1966GA19); 84 ± 3, $16 \pm 3\%$ (1967BL22).

[g] $+0.16$ (-0.02, $+0.06$) (1966GA19); 0.13 ± 0.04 (1967BL22).

[h] (1969TH01).

[i] (1961JA11): ^{10}B(p, γ)^{11}C.

been studied in the range $E(^{3}\text{He}) = 1.3$ to 10 MeV: see (1968AJ02) for the earlier references and (1969DE1F, 1971DE2C: $E(^{3}\text{He}) = 4.0$ MeV), (1969HO1F: 4.25 and 6.2 MeV), (1974FU11: 10.5 and 13.0 MeV). The dominant L-values from the angular distributions reported by (1974FU11) 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, 8.43) and 3 for ^{11}C*(6.90). Neutron groups to $T = \frac{3}{2}$ states have been reported by (1971WA21) [$E_x = 12.17 \pm 0.05$ and 12.55 ± 0.05 MeV] and by (1969BR30) [$E_x = 12.5 \pm 0.1$, 13.7 ± 0.1 and 14.7 ± 0.1 MeV]: see Table 11.22.

Gamma branching ratios and multipolarities for ^{11}C levels up to $E_x = 7.5$ MeV have been studied by (1965OL03, 1965RO07): see Table 11.21. Together with evidence from reactions 12 and 27 they lead to assignments of $J^\pi = \frac{1}{2}^-, \frac{5}{2}^-, \frac{3}{2}^-, \frac{1}{2}^+, \frac{7}{2}^-, \frac{5}{2}^+$ and $\frac{3}{2}^+$, respectively for ^{11}C*(2.00, 4.32, 4.80, 6.34, 6.48, 6.90, 7.50): see (1965OL03, 1965RO07) and reaction 3 in (1968AJ02) for a summary of the evidence concerning these assignments.

See also (1973SU07), (1968NE1A, 1970EL17, 1970MA38) and ^{12}C.

5. ^{10}B(p, γ)^{11}C $\qquad Q_m = 8.691$

A broad resonance is reported at $E_p = 1.15$ MeV: see Table 11.23 (1956CH20, 1957HU79, 1967PA19). Capture γ-rays are observed corresponding to the ground state transition and to cascades via ^{11}C*(2.00, 4.32, 6.48): see Table 11.21 (1961JA11). See also (1961DO03).

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 (1973SU1E) and (1973HA1X, 1973SP02; theor.). The lifetimes of ^{11}C*(4.32, 6.49), $\tau_m < 20$ fsec (1969ROZT; abstract).

Table 11.22: Possible $T = \frac{3}{2}$ states in ^{11}C [a]

Reaction	E_x (MeV)	$\Gamma_{c.m.}$ (keV)	Refs.
^{9}Be(^{3}He, n)^{11}C	12.17 ± 0.05	200 ± 100	(1971WA21)
^{10}B(p, p_2)^{10}B**	12.20 ± 0.10		(1971WA21)
^{11}B(^{3}He, t)^{11}C	12.15 ± 0.05	290 ± 50	(1971WA21)
	12.16 ± 0.04 [b]	270 ± 50	mean
^{9}Be(^{3}He, n)^{11}C	12.55 ± 0.05	350 ± 100	(1971WA21)
^{9}Be(^{3}He, n)^{11}C	12.5 ± 0.1		(1969BR30)
^{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)
	12.50 ± 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]

[a] See also Table 11.19 for $T = \frac{3}{2}$ states in ^{11}B.
[b] See, however, reaction 32 (1974BE20).

6. ^{10}B(p, n)^{10}C $\qquad Q_m = -4.433 \qquad E_b = 8.691$

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 11.23) (1963EA01). 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 (1966SE03). See also (1973ZW1A; theor.) and ^{10}C in (1974AJ01).

7. ^{10}B(p, p)^{10}B $\qquad E_b = 8.691$

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 Tables 11.23 and 11.24 (1960OV1A, 1962OV02: $E_p = 0.15$ to 3.0 MeV). The elastic scattering has also been studied recently by (1970BO17: $E_p = 3$ to 10.5 MeV), and (1969WA11: $E_p = 5.0$ to 13.4 MeV; optical model analyses). (1969WA11) report a single broad resonance at $E_p \approx 5$ MeV, while (1970BO17) report seven resonances in the corresponding energy interval, in addition to resonances at $E_p = 3.6$ and 4.4 MeV. See also (1962AN11). The depolarization parameter D has been measured for polarized protons with $E_p = 25$ MeV (1974BI1F) and 50 MeV (1970BA05). See also (1970BE1B) and (1973ZW1A, 1974GU13; theor.).

8. ^{10}B(p, p′)^{10}B* $E_b = 8.691$

The yield of γ_1 [from ^{10}B*(0.72)] rises monotonically from $E_p = 1.5$ to 4.1 MeV (1952DA05, 1954DA20, 1957HU79, 1964BE31) and then shows resonance behavior at $E_p = 4.35$ and 5.73 MeV (1962OP03: see Table 11.23). 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 (1966SE03). [The cross section below $E_p = 10$ MeV appears to be in error: see (1969WA23).] 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 by (1966SE03) in the range $E_p = 4$ to 12 MeV.

Yield curves for inelastically scattered protons have 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) with widths of ≈ 500 keV (1969WA23). It had previously been suggested by (1966SE03) that the formation of $T = 1$ states was relatively suppressed in this reaction. (1969WA23) find that the isotopic spin effect disappears when a correction factor $(2J_f+1)$ is included. 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 $E_x = 12.16$ and 12.50 MeV [see Table 11.22]: these do not occur in the yield of p_1 and p_3 (1971WA21).

9. ^{10}B(p, d)^{9}B $Q_m = -6.211$ $E_b = 8.691$

Polarization measurements have been carried out at $E_p = 49.6$ MeV for the deuterons to ^{9}B*(0, 2.36) (1971SQ02). See also ^{9}B in (1974AJ01).

10. ^{10}B(p, ^{3}He)^{8}Be $Q_m = -0.532$ $E_b = 8.691$

The ground-state yield shows slight maxima at energies similar to those in the (p, α) yield in the range $E_p = 4$ to 10 MeV. However, the angular distributions do not vary strongly over the region and it is suggested that a direct interaction mechanism dominates (1963JE01). (1966SE03) report two strong maxima at $E_p \approx 4.5$ and 6.5 MeV. See also ^{8}Be in (1974AJ01).

Table 11.23: Resonances in $^{10}B + p$ [a]

E_{res} (MeV ± keV)	E_x (MeV)	J^π	Γ_{lab} (keV)	Decay	Refs.
1.145 ± 5	9.732	$(\frac{5}{2}^+)$	500 ± 50	γ, p_0, α_0	(1951BR10, 1956CH20, 1956CR07, 1957HU79, 1967PA19)
1.533 ± 5	10.084	$\frac{7}{2}^+$	≈ 250	p_0, α_0, α_1	(1951BR10, 1956AL23, 1956CH20, 1956CR07, 1957HU79, 1962OV02)
2.189 ± 5	10.680	$\frac{9}{2}^+$	220 ± 30	p_0, α_0, α_1	(1962OV02, 1964BE31, 1964JE01)
2.320 ± 5	(10.799)			p_0, α_1	(1964BE31)
2.574 ± 5	(11.030)			p_0, α_1	(1964BE31)
3.03 ± 10	11.44		400	p_0, α_0, α_1	(1962OP03, 1964JE01)
3.592 ± 7	11.954			p_0, α_1	(1964BE31, 1970BO17)
3.9 ± 100	12.20	$T = \frac{3}{2}$		p_2	(1971WA21)
4.1 ± 100	12.45	$T = \frac{3}{2}$	440 ± 100	p_2	(1971WA21)
4.1 [b,c]	12.4	$\pi = -$	$1 - 2$ MeV	γ_0	(1970KU09)
4.36 ± 20	12.65	$(\frac{7}{2}^+)$	400	p, α_0, α_1, ^3He	(1962OP03, 1964JE01, 1966SE03, 1970BO17)
(4.75)	(13.01)			γ_0	(1970KU09)
5.2	13.4		1200 ± 100	p_0, α_0, α_1	(1962OP03, 1964JE01, 1966SE03, 1969WA11, 1970BO17)
5.73 ± 20	13.90		≈ 500	p	(1962OP03, 1969WA23, 1970BO17)
5.92 ± 20	14.07		broad	n, p_0	(1963EA01, 1964JE01, 1966SE03, 1970BO17)
6.68 ± 40	14.76		≈ 500	n, p, ^3He	(1963EA01, 1964JE01, 1966SE03, 1969WA23, 1970BO17)
7.33 ± 50 [c]	15.35	$\pi = -$	broad	γ_0, n, p	(1963EA01, 1966SE03, 1969WA23, 1970KU09)
7.60 ± 50	15.59		≈ 500	n, p	(1963EA01, 1969WA23, 1970BO17)
8.8 [c]	16.7	$\pi = -$	900 ± 100	γ_0	(1970BO17, 1970KU09)
(10.5)	(18.2)			γ_0	(1970KU09)

[a] See also Table 11.24.
[b] $\Gamma_p \Gamma_\gamma / \Gamma \approx 200$ eV (1970KU09).
[c] Probably part of the E1 giant resonance (1970KU09).

Table 11.24: Level parameters for ^{10}B(p, p)^{10}B and ^{10}B(p, α)^{7}Be [a]

E_r (MeV)	E_x (MeV)	J^π	Γ_p (MeV)	$\Gamma_{\alpha 0}$ (MeV)	$\Gamma_{\alpha 1}$ (MeV)	θ^2_p	$\theta^2_{\alpha 0}$	$\theta^2_{\alpha 1}$
1.17 [b]	9.75	$(\frac{5}{2}^+)$	0.045	0.255				
1.50 [c]	10.05	$\frac{7}{2}^+$	0.090	0.100	0.060	0.02	0.26	0.35
2.18 [c]	10.67	$\frac{9}{2}^+$	0.100	0.100		0.17	0.11	
4.36 [d]	12.65	$(\frac{7}{2}^+)$	0.20	0.15	0.05	0.02	0.29	0.08

[a] See also Table 11.23.
[b] (1956CR07, 1962OV02).
[c] (1962OV02).
[d] (1964JE01).

11. ^{10}B(p, α)^{7}Be $\quad$ $Q_m = 1.1462$ $\quad$ $E_b = 8.691$

The total cross section for this reaction has been measured for $E_p = 60$ to 180 keV by (1972SZ02): the extrapolated cross section at the Gamow energy, taken to be 19.1 keV, is $\approx 10^{-12}$ b.

The parameters of observed resonances are displayed in Tables 11.23 and 11.24. 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 (see (1962OV02, 1964JE01) and (1959AJ76)). Alpha particles to the 0.43 MeV ^{7}Be state (α_1) and 0.43 MeV γ-rays exhibit all but the 1.2 MeV resonance (see (1962OP03, 1964BE31, 1964JE01, 1966SE03) and (1959AJ76)). Weak resonances are also reported at 2.32, 2.57 and 3.59 MeV (1964BE31). A broad maximum dominates the region from $E_p = 4$ MeV to about 7.5 MeV (1966SE03). See also (1968HA1B), (1973ZW1A; theor.) and (1974PE1C; applied).

12. ^{10}B(d, n)^{11}C $\quad$ $Q_m = 6.467$

Angular distribution measurements have recently been reported at $E_d = 0.5$ to 0.8 MeV (1969CH04: n to ^{11}C*(6.35 + 6.49)), 5.8 MeV (1970BO34: see Table 11.25) and 11.8 MeV (1971MU18: n_0). See also (1969JO1F). For recent angular correlation measurements see (1972TH14, 1973PA1N). A great deal of work had previously been done on this reaction: see (1959AJ76, 1968AJ02 [particularly Table 11.20]) for a discussion of the earlier work. Information on the γ-decay of ^{11}C states has been summarized by (1965OL03) and is incorporated in Table 11.21.

Table 11.25 summarizes results obtained in this reaction and in the (^{3}He, d) reaction (1955MA76, 1963OV02, 1970BO34). See also (1967CO30, 1973BR24) and ^{12}C.

Table 11.25: Energy levels of ^{11}C from ^{10}B(d, n)^{11}C and ^{10}B(^{3}He, d)^{11}C

E_x (MeV ± keV)	J^π	l [f]	l [g]	$S_{d,n}$ [g]	$S_{^3He,d}$ [g]	l [i]	$S_{^3He,d}$ [i]
0	$\frac{3}{2}^-$	1	1	1.12	0.88	1	1.09
2.0006 ± 0.9 [a]	$\frac{1}{2}^-$	(1)	(1)	(0.18)	(0.036)		
			(3)		≤ 0.09	(3)	< 0.40
4.322 ± 10 [b]	$\frac{5}{2}^-$	1	1	0.27	0.20	1	0.17, 0.19
4.808 ± 10 [b]	$\frac{3}{2}^-$	1	1	< 0.02		(1)	< 0.08
						(3)	< 0.35
6.345 ± 10 [b]	$\frac{1}{2}^+$		2		0.07	2	0.08
6.476 ± 10 [b]	$\frac{7}{2}^-$	1	1	0.86	0.56	1	0.73, 0.79
6.903 ± 10 [b]	$\frac{5}{2}^+$	(1)				2	0.06
						0	< 0.04
7.498 ± 10 [b]	$\frac{3}{2}^+$					2	0.08
8.107 ± 10 [b]	$\frac{3}{2}^-$ [k]					1	0.07
8.425 ± 8 [c]	$\frac{5}{2}^-$	1	1	0.65	0.46	1	0.73, 0.79
8.655 ± 8 [c, d]	$\frac{5}{2}^+$	0	0	$\underline{0.84}$	0.45		
			2	0.8	$\underline{0.32}$		
	$\frac{7}{2}^+$ [j]		0	$\underline{0.63}$	0.33	2	0.41
			2	0.6	$\underline{0.24}$	0	< 0.34
8.701 ± 20 [d]	$\frac{5}{2}^+$ [j]	(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 [h]							
10.68 [d, e]		(0, 2)					

[a] (^{3}He, d): (1970BR23).
[b] (^{3}He, d): (1961HI08).
[c] (d, n): neutron threshold measurements (1955MA76); based on Q_m.
[d] (d, n): observed by time-of-flight technique (1963OV02).
[e] $\Gamma \approx 200$ keV (1963OV02).
[f] From (d, n) work summarized in Table 11.20 of (1968AJ02).
[g] 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.
[h] See (1971CO07).
[i] From $E(^3He) = 21$ MeV work of (1971CO07); when two values are shown for $S_{^3He,d}$, they are in order of descending j.
[j] Value determined by (1973FO02).
[k] See (1970FO05).

13. ^{10}B(t, 2n)^{11}C $\qquad Q_{\rm m} = 0.209$

See (1961RO21).

14. ^{10}B(^{3}He, d)^{11}C $\qquad Q_{\rm m} = 3.198$

Angular distributions have been measured recently at $E(^3{\rm He}) = 1.38$ MeV (1970BE1F: d_0), 11.0 MeV (1970BO34: see Table 11.25), 18.0 MeV (1973FO02: deuterons to ^{11}C*(8.66, 8.70)) and 21.0 MeV (1970FO05, 1971CO07: see Table 11.25). Table 11.25 displays also the spectroscopic factors 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, 9.28) whose J^π are $\frac{7}{2}^+$ and $\frac{5}{2}^+$ [the ^{11}B states were studied in the (d, p) reaction]: $\Gamma_{\rm c.m.}$ are $\ll 9$ keV and 15 ± 1 keV, respectively, for ^{11}C*(8.66, 8.70) (1973FO02).

Singlet deuteron emission has been studied at $E(^3{\rm He}) = 8$, 10 and 11 MeV by (1970BO07).

15. ^{10}B(α, t)^{11}C $\qquad Q_{\rm m} = -11.123$

Angular distributions have been measured at $E_\alpha = 46$ MeV (1969FO1C; abstract; for tritons to ^{11}C states with $E_{\rm x} \leq 8.1$ MeV) and at 56 MeV (1968GA1C, 1969GA11; t_0).

16. ^{10}B(^{6}Li, ^{5}He)^{11}C $\qquad Q_{\rm m} = 4.10$

See (1957NO17).

17. ^{10}B(^{7}Li, ^{6}He)^{11}C $\qquad Q_{\rm m} = -1.287$

Angular distributions of ^{6}He ions corresponding to the transition to $^{11}{\rm C}_{\rm g.s.}$ have been measured at $E(^7{\rm Li}) = 3.0$, 3.5 and 3.8 MeV (1968ST12). At $E(^7{\rm Li}) = 24$ MeV, the population of ^{11}C*(0, 2.00, 4.32, 4.80, $6.34 + 6.48$, 6.90, 7.50, 8.10, 8.43, 8.66) is reported (1974KO1G).

18. ^{10}B(^{14}N, ^{13}C)^{11}C $\qquad Q_{\rm m} = 1.141$

See (1968BU1B, 1969BR1D, 1970GO1B) and (1968AJ02).

19. ^{10}B(^{16}O, ^{15}N)^{11}C $Q_{\rm m} = -3.436$

See (1968OK06).

20. ^{10}B(^{19}F, ^{18}O)^{11}C $Q_{\rm m} = 0.699$

See (1968GA03).

21. ^{11}B(p, n)^{11}C $Q_{\rm m} = -2.765$

Neutron groups have been observed to ^{11}C*(0, 2.008, 4.320, 4.806, 6.330, 6.481) (±20 keV) (1965OV01). See also (1970CL01). Angular distributions of the n_0 group have been measured at many energies up to $E_{\rm p} = 18.5$ MeV [see (1968AJ02)] and at 30.5 and 49.5 MeV (1970CL01: also n_1 and $n_2 + n_3$). See also (1969MO32, 1973GO1V), (1969BA1N; astrophys. considerations) and ^{12}C.

22. ^{11}B(^{3}He, t)^{11}C $Q_{\rm m} = -2.001$

Angular distributions of t_0 and t_1 have been measured at $E(^3\text{He}) = 10$ MeV (1967CR04) and 14 MeV (1970NU02). See also (1969OP1A, 1970OP1B). At $E(^3\text{He}) = 26$ MeV the known states of ^{11}C below $E_{\rm x} = 11$ MeV are populated and triton groups are also observed to states, assumed to be $T = \frac{3}{2}$, at $E_{\rm x} = 12.15$, 12.57 and 13.92 MeV [see Table 11.22] and, possibly, 14.15 MeV (1971WA21). See also (1968BR23).

23. ^{11}B(^{6}Li, ^{6}He)^{11}C $Q_{\rm m} = -5.492$

At $E(^6\text{Li}) = 30$ MeV, ^{6}He groups are observed corresponding to ^{11}C*(0, 2.00, 4.32, 4.80, 6.48, 6.90) and the angular distribution to $^{11}\text{C}_{\rm g.s.}$ is reported (1972LE1P).

24. ^{12}C(γ, n)^{11}C $Q_{\rm m} = -18.722$

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 $6 < E_x < 8$ 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 the discussion in (1973DI1C, 1973SP03). See also (1969DE12, 1973GL1C, 1974SC23), (1970MU1D, 1971BI01, 1973MS01, 1973MS02; theor.) and ^{12}C.

25. (a) ^{12}C(e, en)^{11}C $\quad Q_m = -18.722$

(b) ^{12}C(π^+, πN)^{11}C $\quad Q_m = -18.722$

^{12}C(π^-, π^-n)^{11}C

(c) ^{12}C(n, 2n)^{11}C $\quad Q_m = -18.722$

(d) ^{12}C(p, pn)^{11}C $\quad Q_m = -18.722$

For reaction (a) see (1969BA1F; theor.) and ^{12}C. For reaction (b) see (1973HO43). See also (1970LI1H) and the "*Pion capture and pion reactions*" section in ^{12}C. For reaction (c) see ^{13}C. For reaction (d) see (1968DE22, 1968PA05, 1969PO01) and ^{12}C.

26. ^{12}C(p, d)^{11}C $\quad Q_m = -16.497$

Angular distributions have been recently measured at $E_p = 55$ MeV (1974SH1N: d_0, d_1, d_{2+3}), 100 MeV (1968LE01, 1969LI01: d_0, d_1, d_{2+3}, d_{4+5+6}), 155.6 MeV (1969BA05: d to ^{11}C*(0, 2.0, 4.3, 4.8, 6.7, 8.0, 11.0)), 185 MeV (1971KA56: see Table 11.26) and 700 MeV (1973TH1A, 1974BA58: $d_0 \rightarrow d_4$, d_6). The broad peak at $E_x = 15 \pm 0.7$ MeV and the weak [$\approx$ 7 MeV broad] structure at $E_x = 18-23$ MeV reported by (1969BA05) are not observed by (1971KA56). See also (1969SU02, 1973FA10). For a listing of earlier angular distribution measurements [$E_p = 19$ to 60 MeV] see (1968AJ02). See also (1968TI1A, 1972RO1K, 1974KI1A) and (1968JA1D, 1969DO08, 1969TO1A, 1970BA1N, 1971LO28 [pion], 1971MC15, 1972ST33, 1973TA27, 1974IN07; theor.).

27. ^{12}C(d, t)^{11}C $\quad Q_m = -12.464$

At $E_d = 28$ MeV the t_0 angular distribution has been measured and a detailed comparison has been made with the results from the mirror reaction ^{12}C(d, ^{3}He)^{11}B (1966DE1C, 1968GA13). Angular distributions of the t_0 group have also been measured at $E_d = 20.0$, 24.0 and 28.0 MeV by (1971IN1C; unpublished thesis): at the highest energy angular distributions of several triton groups to excited states of ^{11}C are also reported. See also (1971BO50; theor.) and (1968AJ02).

28. ^{12}C(^{3}He, α)^{11}C $\quad Q_m = 1.857$

Table 11.26: Levels of ^{11}C from ^{12}C(p, d)^{11}C [a]

E_x (MeV ± keV)	J^{π} [c]	S_{rel}
0	$\frac{3}{2}^-$	100
1.9997 ± 0.5 [b]	$\frac{1}{2}^-$	17.4
4.30 ± 50	$\frac{5}{2}^-$	< 0.06
4.80 ± 50	$\frac{3}{2}^-$	9.7
(6.34)	$\frac{1}{2}^+$	< 0.03
6.49 ± 50	$\frac{7}{2}^-$	0.6
6.92 ± 50	$\frac{5}{2}^+$	0.7
7.53 ± 50	$\frac{3}{2}^+$	0.4
8.13 ± 50	$\frac{3}{2}^-$	0.7
8.43 ± 50	$\frac{5}{2}^-$	0.08
8.67 ± 80	$\frac{7}{2}^+ + \frac{5}{2}^+$	
9.3 ± 100		
9.7 ± 100	$(\frac{5}{2}^+)$	
10.1 ± 200	$\frac{7}{2}^+$	
10.7 ± 200	$\frac{9}{2}^+$	
11.0 ± 100		
11.5 ± 200		

[a] (1971KA56): $E_p = 185$ MeV.
[b] (1974NO07).
[c] From Table 11.20.

Angular distributions have been measured at many energies. Recent experiments are reported at $E(^3\text{He}) = 9.5$, 10.5 and 11.5 MeV (1970BO34), 13.9 MeV (1968OB01: $\alpha_0 \to \alpha_3$), 16, 17 and 18 MeV (1970GR08), 19.1, 27.1 and 35.7 MeV (1968AR12), 24 and 28 MeV (1973FU02), 24.0, 29.2, 34.7 and 39.6 MeV (1974YA10: α_0, α_1, α_2), 35.6 MeV (1970FO05: α_0 and α to ^{11}C*(8.10, 8.43)), 42 MeV (1973SI11: $\alpha_0 \to \alpha_4$), 44.8 MeV (1966BA13: α_0) and 217 MeV (1974GE09: α_0, α_1, α_2, α_3). See Table 11.27 for a display of the results and (1968AJ02) for a summary of the extensive earlier work. For discussions of the reaction mechanisms see, e.g. (1970BO34, 1973FU02).

Alpha-γ correlations have been studied for $E(^3\text{He}) = 4.7$ to 12 MeV: see, in particular, (1968EA03). Their results are summarized in Table 11.21 and are discussed in detail in reaction 22 (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). See also (1970CA28,

Table 11.27: Levels of ^{11}C from ^{12}C(^{3}He, α)^{11}C [a]

E_x (MeV ± keV)	l [d]	S_{rel}		
		$E(^3$He$) = 16$ MeV [f]	24 MeV [g]	28 MeV [g]
0	1	1	1	1
1.999 ± 4 [b]	1	0.10	≤ 0.6	≤ 0.6
4.3188 ± 1.2 [c]	3	0.057	(0.04)	(0.06)
4.8042 ± 1.2 [c]	1	0.11	0.22	0.22
6.3392 ± 1.4 [c]	0	0.003 [h]	≤ 0.07	≤ 0.07
6.4782 ± 1.3 [c]	3	0.11 [h]	0.06	(0.06)
6.9048 ± 1.4 [c]	2	0.018	(0.15)	(0.17)
7.4997 ± 1.5 [c]	2	0.006 [h]	(0.07)	(0.09)
8.1045 ± 1.7 [c]	1 [e]	0.017 [h,i]		
8.43	3 [e]	0.034 [h,j]		

[a] See Table 11.21 for γ-decay work (1968EA03).
[b] (1968EA03).
[c] (1970BR23).
[d] (1970BO34). See also (1968AR12, 1970GR08).
[e] (1970FO05).
[f] (1970GR08).
[g] (1973FU02).
[h] At $E(^3\text{He}) = 18$ MeV.
[i] Assuming $J^\pi = \frac{3}{2}^-$.
[j] Assuming $J^\pi = \frac{5}{2}^-$.

1970JA1E), (1969DO08, 1972WE1F, 1974DO15; theor.) and ^{15}O in (1976AJ04).

29. ^{12}C(^{6}Li, ^{7}Li)^{11}C $\quad Q_m = -11.471$

At $E(^6\text{Li}) = 36$ MeV 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 by (1973SC26).

30. (a) ^{12}C(^{10}B, ^{11}B)^{11}C $\quad Q_m = -7.266$
(b) ^{12}C(^{12}C, ^{13}C)^{11}C $\quad Q_m = -13.775$

Reaction (a) has been observed at $E(^{10}\mathrm{B}) = 100$ MeV: $^{11}\mathrm{C}_{\mathrm{g.s.}}$ is much more strongly populated than ^{11}C*(2.00) (1973YO1C, 1973YO1D). See also reaction 58 in ^{11}B (1974HA1V). The angular distribution involving the ground state transitions has been measured for reaction (b) at $E(^{12}\mathrm{C}) = 114$ MeV (1974AN36).

31. ^{12}C(^{14}N, ^{15}N)^{11}C $\qquad Q_{\mathrm{m}} = -7.888$

See (1967BI06, 1974AN36). See also (1967VO1A, 1969BR1D, 1973SC1J) and ^{15}N in (1976AJ04).

32. ^{13}C(p, t)^{11}C $\qquad Q_{\mathrm{m}} = -15.186$

At $E_{\mathrm{p}} = 43.7$ 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 $E_{\mathrm{x}} = 12.47$ MeV [see Table 11.22] whose J^{π} is determined to be $\frac{1}{2}^{-}$ [it is thus the mirror of ^{11}Be*(0.32)] (1968CO26, 1968FL02). The state decays primarily by p $\rightarrow$ ^{10}B*(1.74). Alpha decay to $^{7}\mathrm{Be}^{*}_{\mathrm{g.s.}+0.4}$ is also observed (1968CO26). Angular distributions have also been measured for $E_{\mathrm{p}} = 26.9$ to 43.1 MeV (1975MI01: $\mathrm{t}_0 \rightarrow \mathrm{t}_3$). At $E_{\mathrm{p}} = 46.7$ MeV the $T = \frac{3}{2}$ state is also observed by (1974BE20) who, in addition, report the population of states with $E_{\mathrm{x}} = 11.03 \pm 0.03$, 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 $E_{\mathrm{x}} = 12.16$ MeV reported by (1971WA21) in reactions 4, 8 and 22 is not observed by (1974BE20). See also (1969SC1F) and (1971KA04; theor.).

33. ^{14}N(p, α)^{11}C $\qquad Q_{\mathrm{m}} = -2.922$

Angular distributions have been reported at $E_{\mathrm{p}} = 4.99$ to 5.55 MeV (1969WE02: α_0), 6.0 to 9.0 MeV (1968SH11: α_0) and 7.53, 8.03, 9.54 and 10.54 MeV (1970ME30: α_0, α_1) and 20.5 to 44.3 MeV (1974PI05: α_0, α_1). See also (1972MA21), (1968AJ02) and ^{15}O in (1976AJ04).

34. ^{16}O(γ, nα)^{11}C $\qquad Q_{\mathrm{m}} = -25.884$

See (1968AJ02).

35. ^{16}O(p, ^{6}Li)^{11}C $\qquad Q_{\mathrm{m}} = -22.185$

See (1969HO1H).

36. ^{16}O(α, ^{9}Be)^{11}C $\qquad Q_{\rm m} = -24.310$

At $E_\alpha = 42$ MeV, the angular distribution involving the transition to ^{9}Be$_{\rm g.s.}$ + ^{11}C$_{\rm g.s.}$ has been measured (1972RU03).

^{11}N
(Fig. 4)

The ^{14}N(^{3}He, ^{6}He)^{11}N reaction has been studied at $E(^{3}{\rm He}) = 70$ MeV (1974BE20). A ^{6}He group is observed which corresponds to a state in ^{11}N with an atomic mass excess of 25.23 ± 0.10 MeV and $\Gamma = 740 \pm 100$ keV. The cross section for forming this state is 0.5 μb/sr at $10°$. The observed state is interpreted as being the $J^\pi = \frac{1}{2}^-$ mirror of ^{11}Be*(0.32) because of its width; the $\frac{1}{2}^+$ mirror of ^{11}Be$_{\rm g.s.}$ would be expected to be much broader (1974BE20). The ^{11}N state is unbound with respect to decay into ^{10}C + p by 2.31 MeV. See also (1968AJ02, 1969LO1B, 1970WA1G, 1974IR04).

^{11}O
(Not illustrated)

This nucleus has not been observed: see (1972WA07, 1974IR04).

^{11}F
(Not illustrated)

This nucleus has not been observed: see (1974IR04).

References

(Closed 31 January 1975)

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.

1951BE13 W.E. Bennett, P.A. Roys and B.J. Toppel, Phys. Rev. 82 (1951) 20

1951BO45 C.K. Bockelman, D.W. Miller, R.K. Adair and H.H. Barschall, Phys. Rev. 84 (1951) 69

1951BR10 A.B. Brown, C.W. Snyder, W.A. Fowler and C.C. Lauritsen, Phys. Rev. 82 (1951) 159

1951VA1A Van Patter, Buechner and Sperduto, Phys. Rev. 82 (1951) 248

1952CA19 F.L. Canavan, Phys. Rev. 87 (1952) 136

1952DA05 R.B. Day and R.L. Walker, Phys. Rev. 85 (1952) 582

1953EL12 M.M. Elkind, Phys. Rev. 92 (1953) 127

1954DA20 R.B. Day and T. Huus, Phys. Rev. 95 (1954) 1003

1954HE22 N.P. Heydenberg and G.M. Temmer, Phys. Rev. 94 (1954) 1252

1954LI48 C.W. Li and R. Sherr, Phys. Rev. 96 (1954) 389

1955JU10 M.K. Juric, Phys. Rev. 98 (1955) 85

1955JU1B Juric, Bull. Inst. Nucl. Sci. Boris Kidrich 5 (1955) 7

1955MA76 J.B. Marion, T.W. Bonner and C.F. Cook, Phys. Rev. 100 (1955) 847

1955RA14 D.C. Ralph and F.E. Dunnam, Phys. Rev. 98 (1955) 249A

1956AL23 H.R. Allan, M. Govindjee and N. Sarma, Proc. Phys. Soc. A69 (1956) 350

1956CH20 G.B. Chadwick, T.K. Alexander and J.B. Warren, Can. J. Phys. 34 (1956) 381

1956CR07 J.W. Cronin, Phys. Rev. 101 (1956) 298

1957BA18 G.A. Bartholomew and P.J. Campion, Can. J. Phys. 35 (1957) 1347

1957BI84 H. Bichsel and T.W. Bonner, Phys. Rev. 108 (1957) 1025

1957HU79 S.E. Hunt, R.A. Pope and W.W. Evans, Phys. Rev. 106 (1957) 1012

1957MC35 J.H. McCrary, T.W. Bonner and W.A. Ranken, Phys. Rev. 108 (1957) 392

1957NO17 E. Norbeck, Jr. and C.S. Littlejohn, Phys. Rev. 108 (1957) 754

1957SC29 J. Scobie and G.M. Lewis, Phil. Mag. 2 (1957) 1089

1958FE70 A.J. Ferguson, H.E. Gove, J.A. Kuehner, A.E. Litherland, E. Almqvist and D.A. Bromley, Phys. Rev. Lett. 1 (1958) 414

1958JU38 M.K. Juric and N.D. Zarubica, Bull. Inst. Nucl. Sci. Boris Kidrich 8 (1958) 17

1958ME79 F.R. Metzger, C.P. Swann and V.K. Rasmussen, Phys. Rev. 110 (1958) 906

1958RA14 V.K. Rasmussen, F.R. Metzger and C.P. Swann, Phys. Rev. 110 (1958) 154

1959AJ76 F. Ajzenberg and T. Lauritsen, Nucl. Phys. 11 (1959) 1

1959CO95 L. Cohen, R.A. Tobin and J. McElhinney, Phys. Rev. 114 (1959) 590

1959GI47 J.H. Gibbons and R.L. Macklin, Phys. Rev. 114 (1959) 571

1959HI69 S. Hinds and R. Middleton, Proc. Phys. Soc. A74 (1959) 196

1959JO25 G.A. Jones, C.M.P. Johnson and D.H. Wilkinson, Phil. Mag. 4 (1959) 796

1959ME24 U. Meyer-Berkhout, K.W. Ford and A.E.S. Green, Ann. Phys. 8 (1959) 119

1960BI08 O.M. Bilaniuk and J.C. Hensel, Phys. Rev. 120 (1960) 211

1960DA08 R.B. Day and M. Walt, Phys. Rev. 117 (1960) 1330

1960HI08 S. Hinds and R. Middleton, Proc. Phys. Soc. 75 (1960) 754

1960OV1A Overley, Thesis, CalTech (1960)

1961BA10 F.De S. Barros, P.D. Forsyth, A.A. Jaffe and I.J. Taylor, Proc. Phys. Soc. 77 (1961) 853

1961DA16 E.A. Davis, F. Gabbard, T.W. Bonner and R. Bass, Nucl. Phys. 27 (1961) 448

1961DO03 P.F. Donovan, J.V. Kane, R.E. Pixley and D.H. Wilkinson, Phys. Rev. 123 (1961) 589.

1961FO07 D.B. Fossan, R.L. Walter, W.E. Wilson and H.H. Barschall, Phys. Rev. 123 (1961) 209

1961HI08 J. Hinds and R. Middleton, Proc. Phys. Soc. 78 (1961) 81

1961JA11 A.N. James, Nucl. Phys. 24 (1961) 675

1961JA23 A. Jaidar, G. Lopez, M. Mazari and R. Dominguez, Rev. Mex. Fisica 10 (1961) 247

1961RO21 J.C. Roy and J.J. Hawton, Can. J. Phys. 39 (1961) 1528

1962AN11 G.B. Andreev, A.S. Deineko and I.Y. Malakhov, Izv. Akad. Nauk SSSR Ser. Fi.z. 26 (1962) 1134; Bull. Acad. Sci. USSR Phys. Ser. 26 (1963) 1147

1962BE24 E. Berkowitz, S. Bashkin, R.R. Carlson, S.A. Coon and E. Norbeck, Phys. Rev. 128 (1962) 247

1962BI11 J.A. Biggerstaff, R.F. Hood, H. Scott and M.T. McEllistrem, Nucl. Phys. 36 (1962) 631

1962BR34 F.P. Brady and E.K. Warburton, Phys. Rev. 128 (1962) 790

1962DY1A Dyal and Hummel, Phys. Rev. 127 (1962) 2217

1962ED02 R.D. Edge and G.A. Peterson, Phys. Rev. 128 (1962) 2750

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

1962GU01 G.D. Gutsche, H.D. Holmgren, L.M. Cameron and R.L. Johnston, Phys. Rev. 125 (1962) 648

1962HI07 S. Hinds and R. Middleton, Nucl. Phys. 38 (1962) 114

1962OP03 T.R. Ophel, R.N. Glover and E.W. Titterton, Nucl. Phys. 33 (1962) 198

1962OV02 J.C. Overley and W. Whaling, Phys. Rev. 128 (1962) 315

1962PU01 D.J. Pullen, A.E. Litherland, S. Hinds and R. Middleton, Nucl. Phys. 36 (1962) 1

1963EA01 L.G. Earwaker, J.G. Jenkin and E.W. Titterton, Nucl. Phys. 42 (1963) 521

1963GR20 D.E. Groce, J.H. McNally and W. Whaling, Bull. Amer. Phys. Soc. 8 (1963) 486, T6

1963JE01 J.G. Jenkin, L.G. Earwaker and E.W. Titterton, Phys. Lett. 4 (1963) 142

1963MA24 B.B. Marsh and O.M. Bilaniuk, Phys. Rev. 130 (1963) 2373

1963ME08 M.K. Mehta, W.E. Hunt, H.S. Plendl and R.H. Davis, Nucl. Phys. 48 (1963) 90

1963OV02 J.C. Overley, Nucl. Phys. 49 (1963) 537

1963RE16 J.H. Renken, Phys. Rev. 132 (1963) 2627

1963SU09 M. Suffert, G. Costa and D. Magnac-Valette, J. Phys. 24 (1963) 1029

1963VA10 V.J. Vanhuyse and G.J. Vanpraet, Nucl. Phys. 43 (1963) 344

1964AL22 D.E. Alburger, C. Chasman, K.W. Jones, J.W. Olness and R.A. Ristinen, Phys. Rev. 136 (1964) B916

1964BE31 E.M. Bernstein, Nucl. Phys. 59 (1964) 525

1964BO22 E.C. Booth, B. Chasan and K.A. Wright, Nucl. Phys. 57 (1964) 403

1964CA18 R.R. Carlson and M. Throop, Phys. Rev. 136 (1964) B630

1964FO1A Fowler and Vogl, Lect. in Theor. Phys., Vol. 6 (1964) 379

1964HI08 S. Hinds and R. Middleton, Phys. Lett. 9 (1964) 149

1964JE01 J.G. Jenkin, L.G. Earwaker and E.W. Titterton, Nucl. Phys. 50 (1964) 516

1965AJ01 F. Ajzenberg-Selove, J.W. Watson and R. Middleton, Phys. Rev. 139 (1965) B592

1965CO25 S. Cohen and D. Kurath, Nucl. Phys. 73 (1965) 1; Erratum Nucl. Phys. 89 (1966) 707

1965HA17 D. Hasselgren, P.U. Renberg, O. Sundberg and G. Tibell, Nucl. Phys. 69 (1965) 81

1965HA19 E. Hayward and T. Stovall, Nucl. Phys. 69 (1965) 241

1965KA14 S. Kakigi, J. Phys. Soc. Jpn. 20 (1965) 1967

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

1965KO1A Kokame, Fukunaga, Nakamura and Inoue, Suppl. Bull. Inst. Chem. Res. Kyoto Univ. (1965) 26

1965MA1E Mazari, Private Communication (1965)

1965MA54 J.H.E. Mattauch, W. Thiele and A.H. Wapstra, Nucl. Phys. 67 (1965) 1

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

1965OV01 J.C. Overley, R.R. Borchers, Nucl. Phys. 65 (1965) 156

1965PU02 H.G. Pugh, D.L. Hendrie, M. Chabre and E. Boschitz, Phys. Rev. Lett. 14 (1965) 434.

1965RI1A Riou, Rev. Mod. Phys. 37 (1965) 375

1965RO07 M.L. Roush, A.A. Jaffe, A.S. Figuera and W.F. Hornyak, Nucl. Phys. 67 (1965) 577.

1965RY01 A. Rytz, Nucl. Phys. 70 (1965) 369

1966AG1A Agee and Rosen, LA-3538-MS (1966)

1966BA13 G.C. Ball and J. Cerny, Phys. Lett. 21 (1966) 551

1966BR18 C.P. Browne and F.H. O'Donnell, Phys. Rev. 149 (1966) 767

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

1966DE1C Detraz et al., Phys. Lett. 22 (1966) 638

1966DO1A Dolinov and Melikov, Vestnik Mos. Univ. Fiz. Astron. (USSR) (1966) 116

1966GA19 A. Gallmann, F. Haas and N. Balaux, Phys. Rev. 151 (1966) 735

1966IS1A Isabelle, J. Phys. (Paris) 27 (1966) C1-17

1966KI09 K.G. Kibler, Phys. Rev. 152 (1966) 932

1966KL1A Klyucharev, Titov and Vypirailenko, Sov. Phys. J. 9 (1966) 65

1966KO08 P. Kossanyi-Demay and G.J. Vanpraet, Nucl. Phys. 81 (1966) 529

1966MO09 F.P. Mooring, J.E. Monahan and C.M. Huddleston, Nucl. Phys. 82 (1966) 16

1966PO1B J.E. Poth, J. Birnbaum and D.A. Bromley, Phys. Rev. Lett. 17 (1966) 200

1966RA29 R.E. Rand, R. Frosch and M.R. Yearian, Phys. Rev. 144 (1966) 859; Erratum Phys. Rev. 148 (1966) 1246

1966SE03 R.E. Segel, P.P. Singh, S.S. Hanna and M.A. Grace, Phys. Rev. 145 (1966) 736

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

1966ST12 T. Stovall, J. Goldemberg and D.B. Isabelle, Nucl. Phys. 86 (1966) 225

1966SU05 M. Suffert, Nucl. Phys. 75 (1966) 226

1966SU1C Suffert, Ann. Phys. (Paris) 1 (1966) 547

1966TY01 H. Tyren, S. Kullander, O. Sundberg, R. Ramachandran, P. Isacsson and T. Berggren, Nucl. Phys. 79 (1966) 321; Erratum Nucl. Phys. A119 (1968) 692

1966WA10 E.K. Warburton, J.W. Olness, K.W. Jones, C. Chasman, R.A. Ristinen and D.H. Wilkinson, Phys. Rev. 148 (1966) 1072

1966ZI01 B. Ziegler, W. Buss and H. Waffler, Nucl. Phys. 83 (1966) 145

1967AM1A Amaldi, ISS 66/30 (1967)

1967BA53 R.M. Bahnsen and R.T. Carpenter, Phys. Rev. 164 (1967) 1235

1967BE1F Beery, Harper, Stovall and Rosen, Los Alamos Sci. Lab. Rept. LA-3788 (1967)

1967BI06 J. Birnbaum, J.C. Overley and D.A. Bromley, Phys. Rev. 157 (1967) 787

1967BL22 R.S. Blake, E.B. Paul, C.H. Sinex and S.T. Emerson, Nucl. Phys. A102 (1967) 305

1967CA09 J.L. Campbell, W. Leiper, K.W.D. Ledingham and R.W.P. Drever, Nucl. Phys. A96 (1967) 279

1967CH34 V.I. Chuev, V.V. Davidov, A.A. Ogloblin and S.B. Sakuta, Ark. Fys. 36 (1967) 263

1967CO1D Commins, Ann. Rev. Nucl. Sci. 17 (1967) 33

1967CO30 J.-P. Coffin, Ann. Phys. (Paris) 2 (1967) 273

1967CO32 S. Cohen and D. Kurath, Nucl. Phys. 101 (1967) 1

1967CR04 M.A. Crosby and J.C. Legg, Nucl. Phys. A95 (1967) 639

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

1967DE1E Deutsch et al., Nuovo Cim. B52 (1967) 557

1967FI07 W. Fitz, R. Jahr and R. Santo, Nucl. Phys. A101 (1967) 449

1967FL16 F. Flesch and P. Hille, Oesterr. Akad. Wiss. Math-Naturw. Kl. Sitzber. Abt. II, 176 (1967) 45

1967GA06 D.S. Gale and J.M. Blair, Phys. Rev. 161 (1967) 1061

1967GO27 Y.V. Gofman, N.I. Zaika, A.V. Mokhnach, O.F. Nemets, P.L. Shmarin and A.M. Yasnogorodskii, Yad. Fiz. 5 (1967) 718; Sov. J. Nucl. Phys. 5 (1967) 510

1967GU1A G. Gunther, K. Bethge and K.R. Schubert, Nucl. Phys. A101 (1967) 288

1967IR1A Irving, ORNL-TM-1872 (1967)

1967KI03 K.G. Kibler, Phys. Rev. 155 (1967) 1110

1967KO1B Kolybasov and Smorodinskaya, Yad. Fiz. 5 (1967) 777

1967MI1A Mitler, High Energy Nucl. Reactions in Astrophys.; Ed., B.S.P. Shen (1967) 59

1967NA06 H. Nakamura, J. Phys. Soc. Jpn. 22 (1967) 685

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

1967PU01 H.G. Pugh, D.L. Hendrie, M. Chabre, E. Boschitz and I.E. McCarthy, Phys. Rev. 155 (1967) 1054

1967RA24 N.C. Rasmussen, V.J. Orphan and Y. Hukai, Proc. 3rd Int. Conf. on At. Masses, Winnipeg, Canada, 1967 (1967) 278

1967SA06 L.S. Saltykov, Izv. Akad. Nauk SSSR Ser. Fiz. 31 (1967) 260; Bull. Acad. Sci. USSR Phys. Ser. 31 (1967) 244

1967SC29 J.P. Schiffer, G.C. Morrison, R.H. Siemssen and B. Zeidman, Phys. Rev. 164 (1967) 1274

1967SH14 V.S. Shirley, UCRL-17990 (1967)

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

1967SP09 A. Sperduto, Proc. 3rd Int. Conf. on At. Masses, Winnipeg, Canada,1967 (1967) 657

1967TH05 G.E. Thomas, D.E. Blatchley and L.M. Bollinger, Nucl. Instrum. Meth. 56 (1967) 325

1967VO1A Volkov, Proc. Problem Symp. on Nucl. Phys., Tbilisi, 1967 (1967) 226

1967WA1C Warburton, Nucl. Research with Low Energy Accelerators; Eds., Marion and van Patter (1967) 43

1967WI04 J. Wilczynski and V.V. Volkov, Nucl. Phys. A93 (1967) 133

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

1968AL1E Alder, Vaucher and Joseph, Helv. Phys. Acta 41 (1968) 433

1968AR12 K.P. Artemov, V.Z. Goldberg, V.P. Rudakov and I.N. Serikov, Yad. Fiz. 7 (1968) 500; Sov. J. Nucl. Phys. 7 (1968) 314

1968BA19 A.M. Baxter, J.A.R. Griffith and S. Roman, Phys. Rev. Lett. 20 (1968) 1114

1968BA30 R. Bachinger and M. Uhl, Nucl. Phys. A116 (1968) 673

1968BE1E Bertrand, Grenier and Pornet, Comm. A L'energie Atomique, Rept. CEA 3504 (1968)

1968BE1F H.W. Bertini, Phys. Rev. 171 (1968) 1261

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

1968BO1D S. Boffi, M. Bouten, C. Ciofi Degli Atti and J. Sawicki, Nucl. Phys. A120 (1968) 135

1968BO32 N.E. Booth, A. Beretvas, R.E.P. Davis, C. Dolnick, R.E. Hill, M. Raymond and D. Sherden, Nucl. Phys. A119 (1968) 233

1968BR23 H. Brunnader, J.C. Hardy and J. Cerny, Phys. Rev. 174 (1968) 1247

1968BU1B P.J.A. Buttle and L.J.B. Goldfarb, Nucl. Phys. A115 (1968) 461

1968CA1A Cassola and Koshel, Nuovo Cim. B55 (1968) 83

1968CI1B C. Ciofi Degli Atti, Nucl. Phys. A106 (1968) 215

1968CO04 R.L.A. Cottrell, J.C. Lisle and J.O. Newton, Nucl. Phys. A109 (1968) 288

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

1968DA1G O.D. Dalkarov, Phys. Lett. B26 (1968) 610

1968DA1H Daruga et al., Atomn. Energ. (USSR) 24 (1968) 66

1968DA20 V.V. Davydov, A.A. Ogloblin, S.B. Sakuta and V.I. Chuev, Yad. Fiz. 7 (1968) 758; Sov. J. Nucl. Phys. 7 (1968) 463

1968DE20 J.P. Deutsch, L. Grenacs, J. Lehmann, P. Lipnik and P.C. Macq, Phys. Lett. B28 (1968) 178

1968DE22 F.P. Denisov, V.P. Milovanov, V.N. Pokrovskii, P.A. Cerenkov and I.A. Yutlandov, Yad. Fiz. 7 (1968) 954; Sov. J. Nucl. Phys. 7 (1968) 574

1968DE26 A.E. Denisov, R.P. Kolalis, V. Sadkovskii and E.D. Teterin, Yad. Fiz. 8 (1968) 265; Sov. J. Nucl. Phys. 8 (1969) 153

1968DU01 Y. Dupont and M. Chabre, Phys. Lett. B26 (1968) 362

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

1968FI02 R.W. Fink, Nucl. Phys. A110 (1968) 379

1968FL02 D.G. Fleming, J. Cerny and N.K. Glendenning, Phys. Rev. 165 (1968) 1153

1968FOZY D.T. Fowler, Neutron Cross Sections Tech., NBS Special Pub. 299, Vol. 1 (1968) 1

1968FR12 D.E. Frederick, Nucl. Phys. A119 (1968) 347

1968GA03 R.M. Gaedke, K.S. Toth and I.R. Williams, Phys. Rev. 167 (1968) 957

1968GA13 M. Gaillard, R. Bouche, L. Feuvrais, P. Gaillard, A. Guichard, M. Gusakow, J.L. Leonhardt and J.-R. Pizzi, Nucl. Phys. A119 (1968) 161

1968GA1C Gaillard, Univ. Lyon Rept. LYCEN 6828 (1968)

1968GE04 B. Geoffrion, N. Marty, M. Morlet, B. Tatischeff and A. Willis, Nucl. Phys. A116 (1968) 209

1968GI1D Gibbons, Neutron Cross Sections and Tech., NBS Special Pub. 299 (1968) 111

1968GO01 P. Goldhammer, J.R. Hill and J. Nachamkin, Nucl. Phys. A106 (1968) 62

1968GO1J Goldemberg, Proc. Int. Conf. Nucl. Struct., Tokyo, Japan (1967); Suppl. J. Phys. Soc. Jpn. 24 (1968) 379

1968GO1K L.J.B. Goldfarb and J.W. Steed, Nucl. Phys. A116 (1968) 321

1968GR1C D. Griffiths and C.W. Kim, Nucl. Phys. B6 (1968) 49

1968GU1B Gubernator and Moret, Rept. Eur-3950.E, Geel, Belgium (1968)

1968HA1B Hasinoff, Kuan and Hanna, Bull. Amer. Phys. Soc. 13 (1968) 83

1968HA1C Hayakawa, Suppl. Prog. Theor. Phys. (1968) 156

1968HI01 F. Hinterberger, G. Mairle, U. Schmidt-Rohr, P. Turek and G.J. Wagner, Nucl. Phys. A106 (1968) 161

1968HS03 Y.-C. Hsu, C.-Y. Huang and C.-C. Chang, Chin. J. Phys. (Taiwan) 6 (1968) 1

1968JA08 R. Jambunathan and R.K. Hobbie, Phys. Rev. 172 (1968) 1065

1968JA1D Jackson, Adv. Phys. 17 (1968) 481

1968KA24 S. Kakigi, N. Fujiwara, K. Fukunaga, D.-C. Nguyen, S. Yamashita and T. Yanabu, J. Phys. Soc. Jpn. 25 (1968) 1214

1968KA38 N.N. Kaushal, E.J. Winhold, P.F. Yergin, H.A. Medicus and R.H. Augustson, Phys. Rev. 175 (1968) 1330

1968LE01 J.K.P. Lee, S.K. Mark, P.M. Portner and R.B. Moore, Nucl. Phys. A106 (1968) 357

1968LE11 B. Leroux, K. El-Hammami, J. Dalmas, R. Chastel, G. Lamot, C. Fayard and J. Hajj Boutros, Nucl. Phys. A116 (1968) 196

1968LO1A Locci and Picchi, Nuovo Cim. A57 (1968) 803

1968MA07 R.L. Macklin and J.H. Gibbons, Phys. Rev. 165 (1968) 1147

1968MA11 D.R. Maxson, R.D. Murphy and M.R. Zatzick, Nucl. Phys. A110 (1968) 609

1968MA1H Machali et al., Atomkernenergie 13 (1968) 29

1968ME13 R.O. Mead and F.C. Young, Nucl. Phys. A115 (1968) 161

1968MO1C Moskaleva, Fedoseev and Shcherbovskii, Izv. Akad. Nauk SSSR Ser. Fiz. 32 (1968) 703

1968MO1D Moxon, Neutron Cross Sections Tech., NBS Special Pub. 299 (1968) 641

1968NE1A NeuV.G. Neudatchin, N.S. Zelenskaya, E.Zh. Magzumov and E.A. Romanovsky, Phys. Lett. B27 (1968) 490

1968NO07 V.I. Noga, Y.N. Ranyuk and P.V. Sorokin, Ukr. Fiz. Zh. 13 (1968) 2003; Ukr. Phys. J. 13 (1969) 1429

1968NO1A M.E. Nordberg, K.F. Kinsey and R.L. Burman, Phys. Rev. 165 (1968) 1096

1968NY1A G. Nydahl and B. Forkman, Nucl. Phys. B7 (1968) 97

1968OB01 D.R. Ober and O.E. Johnson, Phys. Rev. 170 (1968) 924

1968OK06 Y. Okuma, J. Phys. Soc. Jpn. 25 (1968) 1

1968OK1B Okuma, J. Phys. Soc. Jpn. 24 (1968) 677

1968PA05 J.A. Panontin, L.L. Schwartz, A.F. Stehney, E.P. Steinberg and L. Winsberg, Phys. Rev. 169 (1968) 851

1968PA1E Parker, Pendlebury, Shepherd and Stanley, Neutron Cross Sections Tech., NBS Special Pub. 299 (1968) 315

1968PE16 A.K. Petrauskas and V.V. Vanagas, Yad. Fiz. 8 (1968) 463; Sov. J. Nucl. Phys. 8 (1969) 270

1968RI1H A. Richter and R.A. Chatwin, Phys. Lett. B27 (1968) 181

1968RO1E Rohl, Z. Phys. 215 (1968) 56

1968SC18 H.F. Schaefer III, R.A. Klemm and F.E. Harris, Phys. Rev. 176 (1968) 49

1968SH11 P.N. Shrivastava, F. Boreli and B.B. Kinsey, Phys. Rev. 169 (1968) 842

1968ST12 R.A. Stryk and J.M. Blair, Phys. Rev. 169 (1968) 767

1968ST1D Stewart, Bull. Amer. Phys. Soc. 13 (1968) 1421

1968TA1C Tanner, Proc. Symp. on Use of Nimrod, 1968, RHEL/R166 (1968) 91

1968TH04 T.D. Thomas, G.M. Raisbeck, P. Boerstling, G.T. Garvey and R.P. Lynch, Phys. Lett. B27 (1968) 504

1968TI1A Tibell, Proc. Symp. on Use of Nimrod for Nucl. Struct. Phys., Rutherford High Energy Lab. (1968) 127

1968VE11 A.N. Vereshchagin, I.N. Korostova, L.S. Sokolov, V.V. Tokarevskii and I.P. Chernov, Izv. Akad. Nauk SSSR Ser. Fiz. 32 (1968) 623; Bull. Acad. Sci. USSR Phys. Ser. 32 (1969) 573

1968VE1C A.N. Vereshchagin et al, Izv. Akad. Nauk SSSR Ser. Fiz. 32 (1968) 1956

1968WA1D A. Watt, Phys. Lett. B27 (1968) 190

1968WI1B Wilkinson, Proc. Int. Conf. Nucl. Struct., Tokyo, Japan (1967); Suppl. J. Phys. Soc. Jpn. 24 (1968) 469

1968YI01 F. Yiou, Ann. Phys. (Paris) 3 (1968) 169

1968YU01 T.J. Yule and W. Haeberli, Nucl. Phys. A117 (1968) 1

1969AD1C Adair, ORNL 4339 (1969)

1969AG1A A.O. Aganyants, Yu.D. Bayukov, V.N. Deza, S.V. Donskov, V.B. Fedorov, N.A. Ivanova, V.D. Khovansky, V.M. Kolybasov, G.A. Leksin, V.L. Stolin et al., Nucl. Phys. B11 (1969) 79

1969AN25 B. Antolkovic, J. Hudomalj, B. Janko, G. Paic and M. Turk, Nucl. Phys. A139 (1969) 10

1969AR13 A.G. Artukh, G.F. Gridnev, V.L. Mikheev and V.V. Volkov, Nucl. Phys. A137 (1969) 348

1969AR1B Armstrong, Beery, Keaton and Veeser, LA 4177 (1969)

1969AW02 M. Awschalom, F.L. Larsen and W. Schimmerling, Nucl. Instrum. Meth. 75 (1969) 93

1969BA05 D. Bachelier, M. Bernas, I. Brissaud, C. Detraz and P. Radvanyi, Nucl. Phys. A126 (1969) 60

1969BA1F V.V. Balashov, N.M. Kabachnik and V.I. Markov, Nucl. Phys. A129 (1969) 369

1969BA1J Balashov, Bochum Conf. STI/PUB/232 IAEA (1969) 59

1969BA1N Bahcall and Fowler, Astrophys. J. 157 (1969) 659

1969BA1P Bacon et al., Acta Cryst. A25 (1969) 391

1969BE09 D. Berenyi, T. Scharbert and E. Vatai, Nucl. Phys. A124 (1969) 464

1969BE41 J. Bernabeu and P. Pascual, Phys. Lett. B29 (1969) 555

1969BEYX J. Beyea, H. Lancman, F. Rosenthal, L.J. Lidofsky and M. Nessin, Bull. Amer. Phys. Soc. 14 (1969) 628, HG2

1969BO03 D. Bogart and L.L. Nichols, Nucl. Phys. A125 (1969) 463

1969BO1F Borbei, Dolinskii and Turovtsev, Sov. J. Nucl. Phys. 8 (1969) 287

1969BR1D Bromly, Proc. Enrico Fermi School of Phys., Course XL, Lake Como, 1967 (1969) 242

1969BR1G Bromley, Proc. Int. Conf., Montreal (1969) 147

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

1969BU1C Burman and Nordberg, Bull. Amer. Phys. Soc. 14 (1969) 537

1969CA1A R.R. Carlson and H.W. Wyborny, Phys. Rev. 178 (1969) 1529

1969CH04 P.W. Chudleigh, C.K. Gowers and E.G. Muirhead, Nucl. Phys. A123 (1969) 114

1969CU08 J.R. Curry, W.R. Coker and P.J. Riley, Phys. Rev. 185 (1969) 1416

1969CU10 H.-H. Cuno, G. Clausnitzer and R. Fleischmann, Nucl. Phys. A139 (1969) 657

1969DA1D C.N. Davids, H. Laumer and S.M. Austin, Phys. Rev. Lett. 22 (1969) 1388

1969DE12 F.P. Denisov, A. Duisebaev and P.A. Cerenkov, Yad. Fiz. 9 (1969) 3; Sov. J. Nucl. Phys. 9 (1969) 1

1969DE1F Deschamps. Rosier, Tamister and Avignon, Contrib., Montreal (1969) 308

1969DI1B Dickens and Perey, Nucl. Sci. Eng. 36 (1969) 280

1969DO08 E.I. Dolinskii and V.V. Turovtsev, Yad. Fiz. 9 (1969) 515; Sov. J. Nucl. Phys. 9 (1969) 295

1969EP01 M. Epstein, H.D. Holmgren, M. Jain, H.G. Pugh, P.G. Roos, N.S. Wall, C.D. Goodman and C.A. Ludemann, Phys. Rev. 178 (1969) 1698

1969ET01 K. Etoh, T. Murata, N. Kawai, R. Chiba and S. Takayanagi, J. Phys. Soc. Jpn. 26 (1969) 1335

1969FO1C Fortune, Dehnhard, Siemssen and Zeidman, Bull. Amer. Phys. Soc. 14 (1969) 487

1969FU09 N. Fujiwara, J. Phys. Soc. Jpn. 27 (1969) 1380

1969FU11 G.H. Fuller and V.W. Cohen, Nucl. Data Tables A5 (1969) 433

1969GA11 P. Gaillard, R. Bouche, L. Feuvrais, M. Gaillard, A. Guichard, M. Gusakow, J.L. Leonhardt and J.R. Pizzi, Nucl. Phys. A131 (1969) 353

1969GA18 J. Galin, B. Gatty, M. Lefort, J. Peter, X. Tarrago and R. Basile, Phys. Rev. 182 (1969) 1267

1969GA1G Garvey, Ann. Rev. Nucl. Sci. 19 (1969) 433

1969GA32 G.T. Garvey, W.J. Gerace, R.L. Jaffe, I. Talmi and I. Kelson, Rev. Mod. Phys. 41 (1969) S1

1969GU1D Gunther, Wiss. Z. Friedrich. Schiller U. Jena. Math. Naturwiss. Reihe (Germany) 18 (1969) 47

1969HA1F Hanna, Isospin in Nucl. Phys.; Ed., D.H. Wilkinson (1969) 591

1969HA1G Hanna, Proc. Int. Conf., Montreal (1969) 443

1969HE08 G.H. Herling, L. Cohen and J.D. Silverstein, Phys. Rev. 178 (1969) 1551

1969HI1A Higgins, AD 703259, Naval Postgrad. School, Monterey, CA (1969)

1969HO1F Honsaker, McDonald, Neilson and Hsu, Contrib., Montreal (1969) 299

1969HO1G Hopkins and Drake, Nucl. Sci. Eng. 36 (1969) 275

1969HO1H Holman et al., Bull. Amer. Phys. Soc. 14 (1969) 1168

1969JO1F Jones, Brooks and van Heerden, Contrib., Montreal (1969) 269

1969KA15 O. Karban, J. Lowe, P.D. Greaves and V. Hnizdo, Nucl. Phys. A133 (1969) 255; Erratum Nucl. Phys. A141 (1970) 675

1969KA1A G.Th. Kaschl, G.J. Wagner, G. Mairle, U. Schmidt-Rohr and P. Turek, Phys. Lett. B29 (1969) 167

1969KL08 R. Klapisch, C. Thibault-Philippe, C. Detraz, J. Chaumont, R. Bernas and E. Beck, Phys. Rev. Lett. 23 (1969) 652

1969LE1B Leonardi, Cargese Lect. in Phys.; Ed., M. Jean, Vol. 3 (1969) 97

1969LE1D Leonardi and Rosa-Clot, Lett. Nuovo Cim. 1 (1969) 829

1969LI01 T.Y. Li and S.K. Mark, Can. J. Phys. 47 (1969) 257

1969LO1B Loiseaux, Wozniak, Mendelson and Cerny, Bull. Amer. Phys. Soc. 14 (1969) 1237

1969MA39 S.C. Mathur, P.S. Buchanan and I.L. Morgan, Phys. Rev. 186 (1969) 1038

1969MC13 I.E. McCarthy and A.W. Thomas, Nucl. Phys. A135 (1969) 463

1969MI15 P.D. Miller, J.L. Duggan, M.M. Duncan, R.L. Dangle, W.R. Coker and J. Lin, Nucl. Phys. A136 (1969) 229

1969MO1E L. Moyer and D.S. Koltun, Phys. Rev. 182 (1969) 999

1969MO32 J.M. Morris and T.R. Ophel, Nucl. Instrum. Meth. 68 (1969) 344

1969MU10 K.M. Murray, Phys. Rev. Lett. 23 (1969) 1461

1969NA1C Nahabetian, Joseph, Elbaz and Lafoucriere, Compt. Rend. B268 (1969) 1109

1969OM1A Omarov, Daruga, Matusevich and Prokhorov, Atomn. Energ. (USSR) 26 (1969) 388, 390

1969OP1A Opelka, Brussel, Hoffswell and Yavin, Bull. Amer. Phys. Soc. 14 (1969) 506

1969PA11 J.Y. Park, J.L. Duggan, P.D. Miller, M.M. Duncan and R.L. Dangle, Nucl. Phys. A134 (1969) 277

1969PO01 N.T. Porile, Nucl. Phys. A130 (1969) 88

1969RO1F Roturier, Ann. Phys. 4 (1969) 289

1969ROZT F. Rosenthal, J. Beyea, H. Lancman, L.J. Lidofsky and M. Nessin, Bull. Amer. Phys. Soc. 14 (1969) 628, HG1

1969RU1A Ruhla, Proc. Enrico Fermi School of Phys., Course XL, Lake Como, 1967 (1969) 701

1969SC1F Schiffer, Isospin in Nucl. Phys.; Ed., D.H. Wilkinson (1969) 665

1969SI12 J.D. Silverstein and G.H. Herling, Phys. Rev. 181 (1969) 1512

1969SO06 Y.I. Sorokin, V.G. Shevchenko and B.A. Yurev, Yad. Fiz. 9 (1969) 254; Sov. J. Nucl. Phys. 9 (1969) 149

1969SU02 O. Sundberg and J. Kallne, Ark. Fys. 39 (1969) 323

1969SU03 O. Sundberg and G. Tibell, Ark. Fys. 39 (1969) 397

1969SU15 K. Sugimoto, Phys. Rev. 182 (1969) 1051

1969TA1D Tamura, Ann. Rev. Nucl. Sci. 19 (1969) 99

1969TH01 M.J. Throop, Phys. Rev. 179 (1969) 1011

1969TO1A I.S. Towner, Nucl. Phys. A126 (1969) 97

1969VE09 A.N. Vereshchagin, I.N. Simonov, K.O. Terenetskii, V.V. Tokarevskii and I.P. Chernov, Izv. Akad. Nauk SSSR Ser. Fiz. 33 (1969) 2064; Bull. Acad. Sci. USSR Phys. Ser. 33 (1970) 1880

1969VI02 D. Vinciguerra and T. Stovall, Nucl. Phys. A132 (1969) 410

1969VO07 W. Von Oertzen, H.H. Gutbrod, U.C. Voos and R. Bock, Nucl. Phys. A133 (1969) 101

1969VO10 U.C. Voos, W. von Oertzen and R. Bock, Nucl. Phys. A135 (1969) 207

1969VO1D Voos et al., The Phys. and Product. of Heavy Ions, La Plagne, France (1969)

1969WA11 B.A. Watson, P.O. Singh and R.E. Segel, Phys. Rev. 182 (1969) 977

1969WA1C Warburton and Weneser, Isospin in Nucl. Phys.; Ed., D.H. Wilkinson (1969) 173

1969WA23 B.A. Watson, R.E. Segel, J.J. Kroepfl and P.P. Singh, Phys. Rev. 187 (1969) 1351

1969WE02 M.L. West, C.M. Jones, J.K. Bair and H.B. Willard, Phys. Rev. 179 (1969) 1047; Erratum Phys. Rev. C1 (1970) 367

1969WE07 K.J. Wetzel, Phys. Rev. 181 (1969) 1465

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

1969WU1A Wu and Wilets, Ann. Rev. Nucl. Sci. 19 (1969) 527

1969YI1A Yiou, Seide and Bernas, J. Geophys. Res. 74 (1969) 2447

1970AJ04 F. Ajzenberg-Selove, Nucl. Phys. A152 (1970) 1

1970AL08 J.C. Alder and B. Vaucher, Nucl. Phys. A147 (1970) 657

1970AL1E Albert, Wagner, Uberall and Werntz, Proc. 3rd Int. Conf. on High Energy Phys. and Nucl. Struct., New York, 1969 (1970) 89

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

1970AN1D Anni and Taffara, Rivista Nuovo Cim. 2 (1970) 1

1970AR27 A.G. Artukh, V.V. Avdeichikov, J. Ero, G.F. Gridnev, V.L. Mikheev, V.V. Volkov and J. Wilczynski, Phys. Lett. B33 (1970) 407

1970AS10 A. Asami and M.C. Moxon, J. Nucl. Energy 24 (1970) 85.

1970AU02 D.L. Auton, Nucl. Phys. A157 (1970) 305

1970BA05 C.J. Batty and C. Tschalar, Nucl. Phys. A143 (1970) 151

1970BA1E Backenstoss, Ann. Rev. Nucl. Sci. 20 (1970) 467

1970BA1M Bahcall and Fowler, Astrophys. J. 161 (1970) 119

1970BA1N Baker and Goldfarb, Nucl. Phys. A146 (1970) 577

1970BA1P Barencoltz, Thesis, Univ. of Illinois (1970)

1970BA1Q Barashenkov and Abdinov, Acta Phys. Pol. B1 (1970) 65

1970BA1R Battleson, Thesis, Univ. of Oregon (1970)

1970BE1B Berurtey, Catollin and Schnabel, J. Phys. (Paris) 31 (1970) C2

1970BE1F Bennett, Thesis, Washington State Univ. (1970)

1970BE66 D. Berenyi, T. Scharbert and E. Vatai, Acta Phys. Hung. 28 (1970) 337

1970BI1B Bingham, Thesis, Florida State Univ. (1970)

1970BO07 W. Bohne, M. Hagen, H. Homeyer, H. Lettau, K.H. Maier, H. Morgenstern and J. Scheer, Phys. Rev. Lett. 24 (1970) 1028

1970BO17 F. Boreli, R. Little and A. Rego, Fizika 2 (1970) 19

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

1970BR23 C.P. Browne, G. Maille, R. Tarara and J.R. Duray, Nucl. Phys. A153 (1970) 289

1970CA28 J. Catala, A. Garcia, V. Martinez and F. Senent, An. Fis. 66 (1970) 297

1970CL01 A.S. Clough, C.J. Batty, B.E. Bonner and L.E. Williams, Nucl. Phys. A143 (1970) 385

1970CO12 J.A. Cookson and J.G. Locke, Nucl. Phys. A146 (1970) 417

1970CO1H Cohen and Kurath, Nucl. Phys. A141 (1970) 145

1970DA21 A. D’Andrea and M. Scalia, Nuovo Cim. A69 (1970) 702

1970DE1H Deruytter, 2nd Int. Conf. on Nucl. Data for Reactions, Helsinki, IAEA (1970) 127

1970DE35 R. Der, G. Otto, K.-D. Schmidt and K. Hehl, Acta Phys. Acad. Sci. Hung. 28 (1970) 17

1970DI1A Dickens and Perey, Nucl. Sci. Eng. 40 (1970) 346

1970DO07 E.I. Dolinsky, V.V. Turovtsev and R. Yarmukhamedov, Phys. Lett. B33 (1970) 147

1970DO13 E.I. Dolinskii, V.V. Turovtsev and R. Yarmukhamedov, Izv. Akad. Nauk SSSR Ser. Fiz. 34 (1970) 2188; Bull. Acad. Sci. USSR Phys. Ser. 34 (1970) 1952

1970DU07 J.L. Duggan, J.Y. Park, S.D. Danielopoulos, P.D. Miller, J. Lin, M.M. Duncan and R.L. Dangle, Nucl. Phys. A151 (1970) 107

1970EL16 M. El-Nadi, O. Zohni and H.M. Hussein, Ann. Phys. (Leipzig) 25 (1970) 1

1970EL17 M. El-Nadi, A. Osman and T.H. Rihan, Acta Phys. Acad. Sci. Hung. 29 (1970) 127

1970FA15 D. Favart, F. Brouillard, L. Grenacs, P. Igo-Kemenes, P. Lipnik and P.C. Macq, Phys. Rev. Lett. 25 (1970) 1348

1970FI07 D. Fick, R. Kankowsky, K. Kilian and E. Salzborn, Phys. Rev. Lett. 24 (1970) 1503

1970FO05 H.T. Fortune, J.R. Comfort, J.V. Maher and B. Zeidman, Phys. Rev. C2 (1970) 425

1970FR1C Frahn, Theory of Nucl. Struct., Trieste, 1969, IAEA STI/PUB/249 (1970) 297

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

1970GO11 D.R. Goosman and R.W. Kavanagh, Phys. Rev. C1 (1970) 1939

1970GO1B Goldfarb, Nucl. Reactions Induced by Heavy Ions, Heidelberg, 1969 (1970) 115

1970GR08 T.H. Gray, H.T. Fortune, W. Trost and N.R. Fletcher, Nucl. Phys. A144 (1970) 129

1970HA28 E. Hayward, R.B. Schwartz and K.M. Murray, Phys. Rev. C2 (1970) 761

1970HO07 A.J. Houdayer, T.Y. Li and S.K. Mark, Can. J. Phys. 48 (1970) 765

1970HU01 H. Hulubei, A. Berinde, N. Martalogu, I. Neamu, N. Scintei, C.M. Teodorescu and V. Zoran, Rev. Roum. Phys. 15 (1970) 3

1970HU1B Humphrey, Helms and McGimsey, Conf-700322, USAEC (1970) 133

1970JA1E Jackson and Weller, Bull. Amer. Phys. Soc. 15 (1970) 163

1970KA01 O. Karmon and P.A. Deutchman, Phys. Lett. B31 (1970) 113

1970KL04 R. Klabes, F. Baldeweg, V. Bredel, H. Guratzsch, G. Stiller and S. Tesch, Nucl. Phys. A152 (1970) 232

1970KO41 S.-I. Koyama, K. Takahashi and M. Yamada, Prog. Theor. Phys. 44 (1970) 663

1970KR1C Krasnov et al., Atomn. Energ. (USSR) 28 (1970) 503

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

1970LI1E Liebenauer, Silverstein, Kibler and Koral, Bull. Amer. Phys. Soc. 15 (1970) 521

1970LI1H Lieb, Funsten and Lankford, Bull. Amer. Phys. Soc. 15 (1970) 596

1970LK1A Lkhagva and Rotter, Sov. J. Nucl. Phys. 11 (1970) 576

1970MA38 E.Z. Magzumov, V.G. Neudachin and M.S. Belkin, Yad. Fiz. 11 (1970) 589; Sov. J. Nusl. Phys. 11 (1970) 331

1970MAZE K. Maluszynska, K. Nedvedyuk, M. Pshitula and V.I. Salatskii, JINR-P15-5148 (1970)

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

1970ME1F Meadows and Whalen, Nucl. Sci. Eng. 40 (1970) 12

1970ME30 S. Messelt, Phys. Norvegica 4 (1970) 191

1970MI04 T.G. Miller and J.A. Biggerstaff, Phys. Rev. C1 (1970) 763

1970MI1G Miller, Morrison and Westley, Bull. Amer. Phys. Soc. 15 (1970) 1315

1970MO38 L.P. Moskaleva, G.A. Fedoseev and A.N. Khalemskii, Yad. Fiz. 12 (1970) 871; Sov. J. Nucl. Phys. 12 (1971) 472

1970MU1D M.G. Mustafa and F.B. Malik, Phys. Rev. C1 (1970) 753

1970NE03 D.O. Nellis, W.E. Tucker and I.L. Morgan, Phys. Rev. C1 (1970) 847

1970NE05 R.K. Nesbet, Phys. Rev. Lett. 24 (1970) 1155.

1970NU02 F. Nusslin and P. Braun-Munzinger, Z. Phys. 240 (1970) 217

1970OG1A Ogloblin, Nucl. Reactions Induced by Heavy Ions, Heidelberg, 1969 (1970) 231

1970OP1B Opelka, Thesis, Univ. of Illinois (1970)

1970PO03 D.L. Powell, G.M. Crawley, B.V.N. Rao and B.A. Robson, Nucl. Phys. A147 (1970) 65

1970PO1E Porter, Coles and Wyld, Rept. AWRE 045/70, Aldermaston (1970)

1970SC1G F. Schmittroth, W. Tobocman and A.A. Golestaneh, Phys. Rev. C1 (1970) 377

1970SH1C Sherwood and Goswami, Bull. Amer. Phys. Soc. 15 (1970) 527

1970SO03 Y.I. Sorokin, A.K. Shardanov, V.G. Shevchenko and B.A. Yurev, Yad. Fiz. 11 (1970) 8; Sov. J. Nucl. Phys. 11 (1970) 4

1970SO1A Sowerby, Patrick, Uttley and Diment, J. Nucl. Energy 24 (1970) 323

1970SP1A Spalek et al., Bull. Amer. Phys. Soc. 15 (1970) 482

1970ST04 H.J. Strubbe and D.K. Callebaut, Nucl. Phys. A143 (1970) 537

1970TA1J Talmi, Theory of Nucl. Struct., Trieste, 1969, IAEA STI/PUB/249 (1970) 455

1970TH1F Theus et al., Bull. Amer. Phys. Soc. 15 (1970) 1695

1970VA24 V.A. Vartanyan, T.A. Dmitrieva, H.-U. Jager, H.R. Kissener and R.A. Eramzhyan, Yad. Fiz. 11 (1970) 528; Sov. J. Nucl. Phys. 11 (1970) 295

1970VE06 A.N. Vereshchagin, I.N. Korostova and I.P. Chernov, Izv. Vys. Ucheb. Zav. Fiz. 8 (1970) 105; Sov. Phys. J. 13 (1973) 1071

1970VO1F von Oertzen et al, Ncul. Reactions Induced by Heavy Ions, Heidelberg, 1969 (1970) 156

1970WA1G Walker and Stokes, LA-DC 11224 (1970)

1971AL07 D.E. Alburger and D.H. Wilkinson, Phys. Rev. C3 (1971) 1492

1971AN1M Antolkovic, Fizika 4 (1971) 35

1971AR02 A.G. Artukh, V.V. Avdeichikov, J. Ero, G.F. Gridnev, V.L. Mikheev, V.V. Volkov and J. Wilczynski, Nucl. Phys. A160 (1971) 511

1971AR1P Artukh et al., Proc. Int. Conf. on Heavy Ion Phys., Dubna (1971) 193

1971BA16 V.V. Balashov and V.I. Markov, Nucl. Phys. A163 (1971) 465

1971BA2Y Baus-Baghdikian, Univ. libre Bruxelles, Bull. No. 45 (1971)

1971BA72 K. Battleson and D.K. McDaniels, Phys. Rev. C4 (1971) 1601

1971BE57 J. Bernabeu, Nuovo Cim. A4 (1971) 715

1971BE85 J. Bernabeu and J.L. Sanchez-Gomez, An. Fis. 67 (1971) 477

1971BI01 J. Birkholz, Phys. Lett. B34 (1971) 1

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

1971BI22 R. Bimbot and H. Gauvin, Compt. Rend. B273 (1971) 1054

1971BL02 I. Blomqvist, G. Nydahl and B. Forkman, Nucl. Phys. A162 (1971) 193

1971BO1V Bock et al., Proc. Int. Conf. on Heavy Ion Phys., Dubna (1971) 494

1971BO50 I. Borbely, Phys. Lett. B37 (1971) 243

1971BR41 C.P. Browne and H. Stocker, Phys. Rev. C4 (1971) 1481

1971BR44 R.C. Brown, A.A. Debenham, G.W. Greenlees, J.A.R. Griffith, O. Karban, D.C. Kocher and S. Roman, Phys. Rev. Lett. 27 (1971) 1446

1971BU11 A.P. Bukhvostov, V.A. Vartanyan, Z. Oziewicz, N.P. Popov and R.A. Eramzhyan, Yad. Fiz. 13 (1971) 820; Sov. J. Nucl. Phys. 13 (1971) 468

1971BU1K Burymov et al., Izv. Akad. Nauk SSSR Ser. Fiz. 35 (1971) 159

1971CO07 J.R. Comfort, H.T. Fortune, J.V. Maher and B. Zeidman, Phys. Rev. C3 (1971) 1086

1971DA21 V.K. Daruga and N.N. Krasnov, Atomn. Energ. (USSR) 30 (1971) 399

1971DE2C Deschamps, FRNC TH 182 (1971)

1971DE2D Devons, Proc. Int. Conf. Hyperfine Interactions Detected by Nucl. Radiation, Israel, 1970 (1971) 619

1971DJ02 A. Djaloeis, H. Cords and J. Nurzynski, Nucl. Phys. A163 (1971) 131

1971DO1F Dogotar, Khok and Eramzhian, Proc. Int. Conf. on Heavy Ion Phys., Dubna (1971) 218

1971DU11 E.I. Dubovoi and V.G. Nadtochii, Izv. Akad. Nauk SSSR Ser. Fiz. 35 (1971) 1744; Bull. Acad. Sci. USSR Phys. Ser. 35 (1972) 1587

1971EL1B Elwyn, Monahan and Schiffer, Nucl. Fusion 11 (1971) 551

1971EP02 M. Epherre and C. Seide, Phys. Rev. C3 (1971) 2167; Erratum Phys. Rev. C4 (1971) 1494

1971FA09 J. Favier, T. Bressani, G. Charpak, L. Massonnet, W.E. Meyerhof and C. Zupancic, Nucl. Phys. A169 (1971) 540

1971GR20 J.A.R. Griffith, M. Irshad, O. Karban, S.W. Oh and S. Roman, Nucl. Phys. A167 (1971) 87

1971HA25 S.S. Hanna, K. Nagatani, W.R. Harris and J.W. Olness, Phys. Rev. C3 (1971) 2198

1971HA61 A.M. Hanna, R.J. Griffiths, N.M. Clarke and G.T.A. Squier, Phys. Lett. B37 (1971) 361

1971HIZF F. Hibou, Thesis, Univ. of Louis Pasteur (1971)

1971HO03 E. Hourany, T. Yuasa, J.P. Didelez, M. Hage Ali, F. Reide and F. Takeutchi, Nucl. Phys. A162 (1971) 624

1971IN1C Ingalls, Thesis, Princeton Univ. (1971)

1971KA04 S. Kahana and D. Kurath, Phys. Rev. C3 (1971) 543

1971KA56 J. Kallne and E. Hagberg, Phys. Scr. 4 (1971) 151

1971KA62 V.V. Karapetyan and G.Y. Korenman, Yad. Fiz. 14 (1971) 1199; Sov. J. Nucl. Phys. 14 (1972) 668

1971KA70 N.N. Kaushal, E.J. Winhold, R.H. Augustson, P.F. Yergin and H.A. Medicus, Nucl. Energy 25 (1971) 91

1971KN05 H. Knoth, P.H. Barker, A. Huber, U. Matter, P.M. Cockburn and P. Marmier, Nucl. Phys. A172 (1971) 25

1971KO41 M. Kozlowski, Acta Phys. Pol. B2 (1971) 515

1971LA10 R.O. Lane, S.L. Hausladen, J.E. Monahan, A.J. Elwyn, F.P. Mooring and A. Langsdorf, Jr., Phys. Rev. C4 (1971) 380

1971LA16 G. Landaud, J. Yonnet, S. Kullander, F. Lemeilleur, P.U. Renberg, B. Fagerstrom, A. Johansson and G. Tibell, Nucl. Phys. A173 (1971) 337

1971LI11 M. Liu, W. von Oertzen, J.C. Jacmart, F. Pougheon, M. Riou, J.C. Roynette and C. Stephan, Nucl. Phys. A165 (1971) 118

1971LI1K Liebenauer, Thesis, Case Western Reserve Univ. (1970)

1971LO05 J. Lowe, Nucl. Phys. A162 (1971) 438

1971LO28 G.A. Lobov and T.A. Lomonosova, Pisma Zh. Eksp. Teor. Fiz. 14 (1971) 605; JETP Lett. 14 (1971) 421

1971MC15 G.M. McAllen, W.T. Pinkston and G.R. Satchler, Part. Nucl. 1 (1971) 412

1971MI12 D. Miljanic and V. Valkovic, Nucl. Phys. A176 (1971) 110

1971MU18 G.S. Mutchler, D. Rendic, D.E. Velkley, W.E. Sweeney, Jr. and G.C. Phillips, Nucl. Phys. A172 (1971) 469

1971NO02 J.L. Norton and P. Goldhammer, Nucl. Phys. A165 (1971) 33

1971NO08 V.I. Noga, Y.N. Ranyuk, P.V. Sorokin and V.A. Tkachenko, Yad. Fiz. 14 (1971) 904; Sov. J. Nucl. Phys. 14 (1972) 506

1971NY03 K. Nyberg-Ponnert, B. Jonsson and I. Bergqvist, Phys. Scr. 4 (1971) 165

1971OT03 P.L. Ottaviani and L. Zuffi, Lett. Nuovo Cim. 1 (1971) 1114

1971PA10 B.H. Patrick, H.A. Medicus, G.K. Mehta, E.M. Bowey and D.B. Gayther, Phys. Lett. B34 (1971) 488

1971PO1D Pornet and Ulpat, CEA R 4252 (1971)

1971PU01 G.D. Putt, Nucl. Phys. A161 (1971) 547

1971RI1E Riskalla, LAL 1243 (1971)

1971SA27 A. Saganek, I. Sledzinska, A. Turos, Z. Wilhelmi and B. Zwieglinski, Acta Phys. Pol. B2 (1971) 473

1971SA31 W. Salathe, E. Baumgartner and P. Huber, Helv. Phys. Acta 44 (1971) 815

1971SC16 G. Schmidt, J. Mosner and J. Schintlmeister, Nucl. Phys. A173 (1971) 449

1971SH26 V.S. Shirley, Proc. Int. Conf. Hyperfine Interactions Detected by Nucl. Radiation, Israel, 1970 (1971) 1255

1971SP1C Spalek et al., Polarization Phenom. in Nucl. Reactions, Madison, 1970; Eds., H.H. Barschall and W. Haeberli (1971) 749

1971SQ02 G.T.A. Squier, A.R. Johnston, J.H.P.C. Megaw, R.J. Griffiths and F.G. Kingston, Nucl. Phys. A167 (1971) 465

1971TA1A Talmi, Proc. Int. Conf. Hyperfine Interactions Detected by Nucl. Radiation, Israel, 1970 (1971) 1133

1971TAZN J. Taylor, Thesis, Duke Univ. (1971); Diss. Abst. Int. 32B (1971) 3574

1971VA1C E. Vatai, Phys. Lett. B34 (1971) 395

1971VL01 V.G. Vlasenko, N.G. Afanasev, V.A. Goldstein, S.V. Dementii and E.L. Kuplennikov, Yad. Fiz. 13 (1971) 259; Sov. J. Nucl. Phys. 13 (1971) 144

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

1971WA37 A.H. Wapstra and N.B. Gove, Nucl. Data Tabels 9 (1971) 267

1971YO1E Young and Redish, Bull. Amer. Phys. Soc. 16 (1971) 1394

1971ZA04 N.I. Zaika, Y.V. Kibkalo, E.B. Levshin, G.B. Lyubanskii, O.F. Nemets, R.G. Ofengenden, P.L. Shmarin, A.M. Shchur and A.M. Yasnogorodskii, Yad. Fiz. 13 (1971) 928; Sov. J. Nucl. Phys. 13 (1971) 533

1971ZO03 J. Zofka and G. Ripka, Nucl. Phys. A168 (1971) 65

1972AB14 O.B. Abdinov and V.S. Barashenkov, Acta Phys. Pol. B3 (1972) 385

1972AJ01 F. Ajzenberg-Selove, R.F. Casten, O. Hansen and T.J. Mulligan, Phys. Lett. B40 (1972) 205

1972AN05 R.K. Anderson, M.R. Wilson and P. Goldhammer, Phys. Rev. C6 (1972) 136

1972AR31 N. Arena, G. Calvi, S. Cavallaro, R. Potenza, M. Sandoli and R. De Leo, Lett. Nuovo Cim. 5 (1972) 879

1972BA09 W.A. Bardeen and E.W. Torigoe, Phys. Lett. B38 (1972) 135

1972BA52 G. Bassani, N. Saunier, B.M. Traore, J. Raynal, A. Foti and G. Pappalardo, Nucl. Phys. A189 (1972) 353

1972BE59 J. Berthot and D.B. Isabelle, Lett. Nuovo Cim. 5 (1972) 155

1972BE71 J. Bernabeu, R. Guardiola and P. Pascual, Nuovo Cim. A9 (1972) 450

1972BO07 H. Bohlen, N. Marquardt, W. von Oertzen and P. Gorodetzky, Nucl. Phys. A179 (1972) 504

1972BO21 R. Bock and H. Yoshida, Nucl. Phys. A189 (1972) 177

1972BU1J Burlow and Forkman, LUNP 7208 (1972)

1972BU26 A. Budzanowski, L. Freindl, W. Karcz, J. Kuzminski, B. Lazarska and W. Zipper, Nucl. Phys. A195 (1972) 280

1972BU30 A.J. Buffa, Jr. and M.K. Brussel, Nucl. Phys. A195 (1972) 545

1972CA37 P. Camiz, E. Olivieri, M. Scalia and A. D'Andrea, Nuovo Cim. A12 (1972) 71

1972CE1A Cerny, At. Masses Fund. Constants, Teddington, 1971 (1972) 26

1972CH1G Chatterjee, Tobias and Smith, Bull. Amer. Phys. Soc. 17 (1972) 438

1972CL1A Clayton, Encyclopedia of the Twentieth Century (1972)

1972DA34 V.K. Daruga, E.S. Matusevich and K. Narziev, Atomn. Energ. (USSR) 33 (1972) 934; Sov. At. Energy 33 (1973) 1091

1972DE01 R.M. Devries, J.W. Sunier, J.-L. Perrenoud, M. Singh, G. Paic and I. Slaus, Nucl. Phys. A178 (1972) 417

1972DE02 R.M. Devries, J.-L. Perrenoud, I. Slaus and J.W. Sunier, Nucl. Phys. A178 (1972) 424

1972FI1E Fick, MPI H-1972-V17 (1972)

1972GA1F Garvey, Comments Nucl. Part. Phys. 5 (1972) 85

1972GL06 D. Glas, Z. Phys. 255 (1972) 175

1972HA04 S.L. Hausladen, R.O. Lane and J.E. Monahan, Phys. Rev. C5 (1972) 277

1972HU1A W.T. Huang, C.A. Levinson and M.K. Banerjee, Phys. Rev. C5 (1972) 651

1972KE36 G. Kernel, Fizika 4 (1972) 97

1972KI12 M.V. Kirichenko and Z.I. Soloveva, Yad. Fiz. 16 (1972) 17; Sov. J. Nucl. Phys. 16 (1973) 9

1972KL1A Klapisch and Thibault, At. Masses Fund. Constants, Teddington, 1971 (1972) 181

1972KO13 V.M. Kolybasov and N.Y. Smorodinskaya, Yad. Fiz. 15 (1972) 483; Sov. J. Nucl. Phys. 15 (1972) 269

1972KO1E Koike, Prog. Theor. Phys. 48 (1972) 66

1972LA1F Lane, COO-1717-3 (1972)

1972LE1L Lee and Cusson, Ann. Phys. 72 (1972) 353

1972LE1P Lee et al., Communications, Proc. Aix-en-Provence Conf. 2 (1972) 72

1972LI1J Lipperheide and Wille, Communications, Proc. Aix-en-Provence Conf. 2 (1972) 119

1972LO05 J.M. Lombaard and E. Friedland, Z. Phys. 249 (1972) 349

1972LU1B Lucas and Root, J. Appl. Phys. 43 (1972) 3886

1972MA21 C. Maples and J. Cerny, Phys. Lett. B38 (1972) 504

1972MI15 G.H. Miller, M. Eckhause, F.R. Kane, P. Martin and R.E. Welsh, Phys. Lett. B41 (1972) 50

1972MS01 E.D. Mshelia, R.F. Barrett and W. Greiner, Phys. Rev. Lett. 28 (1972) 847

1972MU1B Murty, Nucl. Phys. Solid State Phys. Symp. Ab., Bombay, 1972 (1972)

1972NA05 P.T. Nang, Nucl. Phys. A185 (1972) 413

1972NI05 L. Nichol and T.J. Kennett, Can. J. Phys. 50 (1972) 553.

1972NY02 G. Nystrom, H. Conde, B. Lundberg and L.G. Stromberg, Phys. Scr. 5 (1972) 175

1972PA1C Parker, Astrophys. J. 175 (1972) 261

1972PN1A Pniewski, Few Particle Problems, UCLA, 1972 (1972) 145

1972PU1A Pugh et al., Bull. Amer. Phys. Soc. 17 (1972) 443

1972RA1E Radvanyi, J. Phys. (Paris) 33 (1972) C5-141

1972RO1K Roos, Smith and Cheng, Bull. Amer. Phys. Soc. 17 (1972) 534

1972RU03 C. Rudy, R. Vandenbosch, P. Russo and W.J. Braithwaite, Nucl. Phys. A188 (1972) 430.

1972SC03 U.C. Schlotthauer-Voos, H.G. Bohlen, W. von Oertzen and R. Bock, Nucl. Phys. A180 (1972) 385

1972SE13 R. Seki, Nuovo Cim. A9 (1972) 235

1972SL1B Slutz et al., Bull. Amer. Phys. Soc. 17 (1972) 549

1972ST33 G.L. Strobel, Phys. Rev. C6 (1972) 2039

1972SZ02 J. Szabo, J. Csikai and M. Varnagy, Nucl. Phys. A195 (1972) 527

1972TA21 V.K. Tartakovskii and A.V. Fursaev, Yad. Fiz. 15 (1972) 51; Sov. J. Nucl. Phys. 15 (1972) 31

1972TH13 C. Thibault and R. Klapisch, Phys. Rev. C6 (1972) 1509

1972TH14 G. Thornton, T. Joy and J.M. Calvert, Nucl. Phys. A198 (1972) 397

1972TH1C Thompson, Thesis, Yale Univ. (1972)

1972THZF H. Theissen, Springer Tracts in Mod. Phys.; Ed., Hohler, Vol. 65 (1972) 1

1972VA02 L. van der Zwan and K.W. Geiger, Nucl. Phys. A180 (1972) 615

1972VA34 O.I. Vasileva, N.V. Karabanov, V.M. Lebedev, A.V. Spasskii and I.B. Teplov, Yad. Fiz. 16 (1972) 460; Sov. J. Nucl. Phys. 16 (1973) 257

1972VA36 J.F.A. Van Hienen and P.W.M. Glaudemans, Phys. Lett. B42 (1972) 301

1972VL1A Vlasenko et al., Ukr. Fiz. Zh. 17 (1972) 1440

1972VO06 A.A. Vorobyov, D.M. Seliverstov, V.T. Grachev, I.A. Kondurov, A.M. Nikitin, N.N. Smirnov and Y.K. Zalite, Phys. Lett. B40 (1972) 102

1972WA07 G.E. Walker and R.H. Stokes, Part. Nucl. 3 (1972) 1

1972WE1F Werby, Edwards and Kemper, Bull. Amer. Phys. Soc. 17 (1972) 611

1972YO02 F.C. Young and A.R. Knudson, Nucl. Phys. A184 (1972) 563

1973AL1D Alster et al., Contrib., Uppsala (1973) 75

1973AL1E Alster et al., Contrib., Uppsala (1973) 172

1973AR1B Arthur, Thesis LA 5230 T (1973)

1973AR1M Arthur, Drake and Halpern, Bull. Amer. Phys. Soc. 18 (1973) 1401

1973AU1G August et al., Bull. Amer. Phys. Soc. 18 (1973) 579

1973AU1H Audouze and Truran, OAP-310 (1973)

1973BA81 L.K. Batist, E.E. Berlovich, Y.S. Blinnikov, Y.V. Elkin, Y.N. Novikov, B.M. Ovchinnikov and V.K. Tarasov, Izv. Akad. Nauk SSSR Ser. Fiz. 37 (1973) 1944; Bull. Acad. Sci. USSR Phys. Ser. 37 (1974) 124

1973BI1G Bizard et al., Nucl. Instrum. Meth. 111 (1973) 445

1973BO26 M. Bormann, D. Kaack, V. Schroder, W. Scobel and L. Wilde, Z. Phys. 258 (1973) 285

1973BR1C Bromley, in Munich, 2 (1973) 22

1973BR24 G. Breuer and D. Muller, Z. Phys. 264 (1973) 201

1973CA1B Cameron, Explosive Nucleosynthesis (1973) 3

1973CA1H Cavaignac, FRNC TH 389 (1973)

1973CH1M D. Chattarji and P. Ghosh, Phys. Rev. C8 (1973) 2115

1973CH20 Il-Tong Cheon, Phys. Rev. C8 (1973) 534

1973CL09 C.F. Clement, Nucl. Phys. A213 (1973) 469

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

1973CO18 M.N.H. Comsan, Atomkernenergie 21 (1973) 41

1973CO1B Colgate, Explosive Nucleosynthesis (1973) 248

1973CO1P Cohen, J. Phys. Soc. Jpn. Suppl. 34 (1973) 63

1973CO1V Cohen, Phys. Med. Bio. (GB) 18 (1973) 286

1973DI1C Dixon, in Asilomar (1973) 727

1973DO01 T.W. Donnelly and J.D. Walecka, Nucl. Phys. A201 (1973) 81

1973EM1B B. Eman, B. Guberina and D. Tadic, Phys. Rev. C8 (1973) 1301

1973FA10 B. Fagerstrom and J. Kallne, Phys. Scr. 8 (1973) 14

1973FA1M Farrar and McElroy, Trans. Amer. Nucl. Soc. 17 (1973) 520

1973FI1C Fick, MPI H-1973-V27 (1973)

1973FL1A Fleming et al., Asilomar (1973) Paper 8A7

1973FO02 H.T. Fortune, H.G. Bingham, J.D. Garrett and R. Middleton, Phys. Rev. C7 (1973) 136

1973FU02 H. Fuchs and H. Oeschler, Nucl. Phys. A202 (1973) 396

1973GA19 S. Gamba, G. Ricco and G. Rottigni, Nucl. Phys. A213 (1973) 383

1973GL1C Glavish, in Asilomar (1973) 755

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

1973GO1V Goosman, Fielding and Lind, Bull. Amer. Phys. Soc. 18 (1973) 1419

1973GU18 R. Guardiola and P. Pascual, Nuovo Cim. A14 (1973) 132

1973GU1D Guardiola and Pascual, Contrib., Uppsala (1973) 175

1973HA1X Halpern, in Asilomar (1973) 909

1973HA2G Hausladen, Thesis, Ohio Univ. (1973); COO 1717-5 (1973)

1973HA49 P.S. Hauge and S. Maripuu, Phys. Rev. C8 (1973) 1609

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

1973HO43 K.R. Hogstrom, B.W. Mayes, L.Y. Lee, J.C. Allred, C. Goodman, G.S. Mutchler, C.R. Fletcher and G.C. Phillips, Nucl. Phys. A215 (1973) 598

1973HU09 R.J. Hughes and E.G. Muirhead, Nucl. Phys. A215 (1973) 147

1973HU1D Hughes and Spicer, Asilomar (1973) Paper 2B4

1973JA01 G. Jacob and T.A.J. Maris, Rev. Mod. Phys. 45 (1973) 6

1973JA1J P. Janecek, Phys. Scr. 7 (1973) 141

1973JO07 G.G. Jonsson and K. Lindgren, Phys. Scr. 7 (1973) 49

1973JO10 R.C. Johnson, F.D. Santos, R.C. Brown, A.A. Debenham, G.W. Greenlees, J.A.R. Griffith, O. Karban, D.C. Kocher and S. Roman, Nucl. Phys. A208 (1973) 221

1973JU2A M. Juric, G. Bohm, J. Klabuhn, U. Krecker, F. Wysotzki, G. Coremans-Bertrand, J. Sacton, G. Wilquet, T. Cantwell, F. Esmael et al., Nucl. Phys. B52 (1973) 1

1973KA04 V.V. Karapetyan, V.N. Mileev and N.N. Titarenko, Nucl. Phys. A203 (1973) 561

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

1973KLZN Klapisch et al., in Munich, 1 (1973) 325

1973KO1D Kovar, Symp. on Heavy Ion Transfer Reactions, ANL Phy-1973B, Vol. 1 (1973) 59

1973KU03 D. Kurath, Phys. Rev. C7 (1973) 1390

1973KU1L Kurath and Arima, J. Phys. Soc. Jpn. Suppl. 34 (1973) 529

1973LA19 H. Laumer, S.M. Austin, L.M. Panggabean and C.N. Davids, Phys. Rev. C8 (1973) 483

1973LI1E Lippincott, Pitner and Kellogg, Trans. Amer. Nucl. Soc. 17 (1973) 494

1973MA1K Maripuu, 5th Symp. Struct. Low-Medium Mass Nuclei (1973) 63

1973MA48 F. Malaguti and P.E. Hodgson, Nucl. Phys. A215 (1973) 243

1973MC17 C.A. McMahan and W. Tobocman, Nucl. Phys. A212 (1973) 465

1973MS01 E.D. Mshelia and R.F. Barrett, Nucl. Phys. A205 (1973) 581

1973MS02 E.D. Mshelia and R.F. Barrett, Z. Phys. 261 (1973) 313

1973MU14 S.F. Mughabghab and D.I. Garber, BNL 325, 3rd Edition, Vol. 1 (1973)

1973MU1B Mukgopadhyay, Lett. Nuovo Cim. 7 (1973) 460

1973MU1D N.C. Mukhopadhyay and L.D. Miller, Phys. Lett. B47 (1973) 415

1973NY04 E.M. Nyman, Nucl. Phys. A215 (1973) 397

1973OS03 A. Osman, Atomkernenergie 22 (1973) 62

1973PA14 Y.S. Park, A. Niiler and R.A. Lindgren, Phys. Rev. C8 (1973) 1557; Erratum Phys. Rev. C9 (1974) 1673

1973PA1N Parson, Ritter and Neal, Bull. Amer. Phys. Soc. 18 (1973) 549

1973PH1B Phelps and Weiland, Phys. Med. Bio. (GB) 18 (1973) 284

1973RE1G Reeves, Audouze, Fowler and Schramm, Astrophys. J. 179 (1973) 909

1973RO11 J. Ros and J. Bernabeu, Phys. Lett. B43 (1973) 178

1973RO1R Robson, Nucl. Phys. A204 (1973) 523

1973SA1Q Saganek, Sledzinska, Wilhelmi and Zwieglinski, in Munich, 1 (1973) 436

1973SA21 T. Saito, J. Phys. Soc. Jpn. 35 (1973) 1

1973SA30 R. Saayman, P.R. de Kock and J.H. van der Merwe, Z. Phys. 265 (1973) 69

1973SC1J Scott, Symp. on Heavy Ion Transfer Reactions, ANL Phy-1973B, Vol. 1 (1973) 97

1973SC26 P. Schumacher, N. Ueta, H.H. Duhm, K.-I. Kubo and W.J. Klages, Nucl. Phys. A212 (1973) 573

1973SI11 R.N. Singh, N. De Takacsy, S.I. Hayakawa, R.L. Hutson and J.J. Kraushaar, Nucl. Phys. A205 (1973) 97

1973SK01 L. Skoski, M. Merker and B.S.P. Shen, Phys. Rev. Lett. 30 (1973) 51

1973SP02 B.M. Spicer and R.F. Fraser, Aust. J. Phys. 26 (1973) 7

1973SP03 B.M. Spicer, Aust. J. Phys. 26 (1973) 269

1973ST16 G.L. Strobel and H.V. Geramb, Nucl. Phys. A210 (1973) 67

1973SU07 K.M. Subotic, D.M. Stanojevic, M.R. Aleksic, B.Z. Stepancic and R.V. Popic, Fizika 5 (1973) 103

1973SU1B Sugimoto, J. Phys. Soc. Jpn. Suppl. 34 (1973) 197

1973SU1C Sugimoto and Tanihata, J. Phys. Soc, Jpn. Suppl. 34 (1973) 245

1973SU1E Suffert, in Asilomar (1973) 741

1973SZ07 S. Szegedi, Acta Phys. Acad. Sci. Hung. 34 (1973) 215

1973TA27 M. Tanifuji and H. Noya, Prog. Theor. Phys. 50 (1973) 515

1973TH1A Thirion, in Munich, 2 (1973) 782

1973TI1A Tinsley, Explosive Nucleosynth. (1973) 22

1973TR1B Truran, Cosmochemistry; Ed., Cameron (1973) 23

1973VA12 G.A. Vartapetyan, A.S. Danagulyan, N.A. Demekhina and A.G. Khudaverdyan, Yad. Fiz. 17 (1973) 685; Sov. J. Nucl. Phys. 17 (1973) 356

1973VO1D Volkov, in Munich, 2 (1973) 280

1973WA1E Wagner, Lect. Notes in Phys. 23 (1973) 16

1973WE19 K.A. Weaver, J.D. Anderson, H.H. Barschall and J.C. Davis, Nucl. Sci. Eng. 52 (1973) 35

1973WE1D Webber, Lezniak, Kish and Damle, Astrophys. Space Sci. 24 (1973) 17

1973WE1N Welch, in Asilomar (1973) 1179

1973WE1T Weaver, Anderson, Barschall and Davis, Phys. Med. Bio. 18 (1973) 64

1973WI04 D.H. Wilkinson, Phys. Rev. C7 (1973) 930

1973WI11 D.H. Wilkinson, Nucl. Phys. A209 (1973) 470

1973WI15 J. Wilczynski, Phys. Lett. B47 (1973) 124

1973YO1C Youngblood, Nagatani, Kenefick and Bronson, in Munich, 1 (1973) 466

1973YO1D Youngblood, Nagatani, Kenefick and Bronson, Symp. on Heavy Ion Transfer Reactions, ANL Phy-1973B, Vol. 2 (1973) 689

1973ZW1A Zwieglinski, Piotrowski, Saganek and Sledzinska, Nucl. Phys. A209 (1973) 348

1974AJ01 F. Ajzenberg-Selove and T. Lauritsen, Nucl. Phys. A227 (1974) 1

1974AL11 D.E. Alburger and D.R. Goosman, Phys. Rev. C10 (1974) 912

1974AM01 J. Amato, R.L. Burman, R. Macek, J. Oostens, W. Shlaer, E. Arthur, S. Sobottka and W.C. Lam, Phys. Rev. C9 (1974) 501

1974AN01 H.J. Annegarn, D.W. Mingay and J.P.F. Sellschop, Phys. Rev. C9 (1974) 419

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

1974AR1K Arthur, Drake and Halpern, Bull. Amer. Phys. Soc. 19 (1974) 497

1974AS04 O. Aspelund, D. Ingham, A. Djaloeis, H. Kelleter and C. Mayer-Boricke, Phys. Lett. B50 (1974) 441

1974AS06 O. Aspelund, D. Ingham, A. Djaloeis, H. Kelleter and C. Mayer-Boricke, Nucl. Phys. A231 (1974) 115

1974AU1A Audouze and Tinsley, Astrophys. J. 192 (1974) 487

1974BA15 G.C. Ball, J.G. Costa, W.G. Davies, J.S. Forster, J.C. Hardy and A.B. McDonald, Phys. Lett. B49 (1974) 33

1974BA58 S.D. Baker, R. Bertini, R. Beurtey, F. Brochard, G. Bruge, H. Catz, A. Chaumeaux, G. Cvijanovich, J.M. Durand, J.C. Faivre et al., Phys. Lett. B52 (1974) 57

1974BA70 G. Baroni, S. Di Liberto, S. Petrera and G. Romano, Nucl. Phys. A231 (1974) 521

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

1974BE58 F.D. Becchetti, B.G. Harvey, D. Kovar, J. Mahoney and M.S. Zisman, Phys. Rev. C10 (1974) 1846

1974BI07 J. Birkholz and V. Heil, Nucl. Phys. A225 (1974) 429

1974BI1F Birchall et al., Bull. Amer. Phys. Soc. 19 (1974) 477

1974BO15 W. Bohne, C.K. Gelbke, P. Braun-Munzinger, W. Grochulski, H.L. Harney and H. Oeschler, Nucl. Phys. A222 (1974) 117

1974BO1K Boesgaard et al., Astrophys. J. 194 (1974) L143

1974BO42 I. Bondouk, F. Asfour and F. Machali, Rev. Roum. Phys. 19 (1974) 551

1974CE06 J. Cerny, R.B. Weisenmiller, N.A. Jelley, K.H. Wilcox and G.J. Wozniak, Phys. Lett. B53 (1974) 247.

1974CE1A Cerny, in Nashville, Vol. 2 (1974) 483

1974CH1Q Chechik, Stocker, Eyal and Fraenkel, Proc. Conf. Reactions between Complex Nuclei, Vol. 1 (1974) 6

1974DA1P Dayras, Stokstad, Switkowski and Wieland, Bull. Amer. Phys. Soc. 19 (1974) 549

1974DA27 S. Dahlgren and P. Grafstrom, Phys. Scr. 10 (1974) 104

1974DE01 W. Del Bianco, P. Boucher, S. Kundu and B. Rouben, Can. J. Phys. 52 (1974) 92.

1974DE17 G. Delic, Phys. Lett. B49 (1974) 412

1974DE39 W. Del Bianco, S. Kundu and B. Rouben, Nucl. Phys. A232 (1974) 333

1974DI16 V. di Napoli and M.L. Terranova, J. Inorg. Nucl. Chem. 36 (1974) 3633

1974DI17 J.M. Dixon and M.N. Thompson, Aust. J. Phys. 27 (1974) 301

1974DI1A Didelez et al., Bull. Amer. Phys. Soc. 19 (1974) 1022

1974DO15 G.A. Doskeev, M.A. Zhusupov and E.T. Ibraeva, Izv. Akad. Nauk SSSR Ser. Fiz. 38 (1974) 2157; Bull. Acad. Sci. USSR Phys. Ser. 38 (1974) 122

1974FI17 D.J.S. Findlay, S.N. Gardiner, J.L. Matthews and R.O. Owens, J. Phys. (London) A7 (1974) L157

1974FO22 J.L.C. Ford, Jr., K.S. Toth, G.R. Satchler, D.C. Hensley, L.W. Owen, R.M. DeVries, R.M. Gaedke, P.J. Riley and S.T. Thornton, Phys. Rev. C10 (1974) 1429

1974FR02 E. Friedland, H.W. Alberts and J.C. van Staden, Z. Phys. 267 (1974) 97

1974FU11 H. Fuchs, K. Grabisch, D. Hilscher, U. Jahnke, H. Kluge, T. Masterson and H. Morgenstern, Nucl. Phys. A234 (1974) 61

1974GE09 E. Gerlic, J. Van de Wiele, H. Langevin-Joliot, J.P. Didelez, G. Duhamel and E. Rost, Phys. Lett. B52 (1974) 39

1974GU13 V.B. Gubin and E.A. Romanovskii, Izv. Akad. Nauk SSSR Ser. Fiz. 38 (1974) 752; Bull. Acad. Sci. USSR Phys. Ser. 38 (1974) 76

1974HA14 T. Hasan and J.H. Naqvi, Nucl. Phys. A220 (1974) 114

1974HA1V Hamm et al., Proc. Conf. Reactions between Complex Nuclei, Vol. 1 (1974) 38

1974HA1W Hale, Young and Nisley, Trans. Amer. Nucl. Soc. 18 (1974) 327

1974HA27 S.R. Habbal and H.A. Mavromatis, Nucl. Phys. A223 (1974) 174

1974HA61 G.D. Harp, Phys. Rev. C10 (1974) 2387

1974HU14 J. Hufner, L. Tauscher and C. Wilkin, Nucl. Phys. A231 (1974) 455

1974IN07 A. Ingemarsson and G. Tibell, Phys. Scr. 10 (1974) 159

1974IR04 J.M. Irvine, G.S. Mani and M. Vallieres, Czech. J. Phys. B24 (1974) 1269

1974JA11 W.W. Jacobs, D. Bodansky, D. Chamberlin and D.L. Oberg, Phys. Rev. C9 (1974) 2134

1974JA29 P. Janecek, Phys. Scr. 10 (1974) 197

1974KA07 W.B. Kaufmann, J.C. Jackson and W.R. Gibbs, Phys. Rev. C9 (1974) 1340

1974KA15 E. Kashy, W. Benenson and J.A. Nolen, Jr., Phys. Rev. C9 (1974) 2102

1974KA32 D. Kamke, Z. Phys. 271 (1974) 367

1974KI1A King et al., Bull. Amer. Phys. Soc. 19 (1974) 432

1974KO1G Kohler and Bethge, Proc. Conf. Reactions between Complex Nuclei, Vol. 1 (1974) 35

1974KO1P Kohlmeyer et al., Proc. Conf. Reactions between Complex Nuclei, Vol. 1 (1974) 7

1974KU17 P.D. Kunz and E. Rost, Phys. Lett. B53 (1974) 9

1974LA18 H. Laumer, S.M. Austin and L.M. Panggabean, Phys. Rev. C10 (1974) 1045

1974LE12 Y. Le Bornec, B. Tatischeff, L. Bimbot, I. Brissaud, J.P. Garron, H.D. Holmgren, F. Reide and N. Willis, Phys. Lett. B49 (1974) 434

1974LE1G K.W.D. Ledingham, J.Y. Gourlay, M. Campbell, M.L. Fitzpatrick and A.D. Baillie, Phys. Lett. B50 (1974) 247

1974LE1K Lewis, Wessels and Miller, Bull. Amer. Phys. Soc. 19 (1974) 16

1974MA1E Maguin, Nuovo Cim. A19 (1974) 638

1974ME19 M.R. Meder and J.E. Purcell, Phys. Rev. C10 (1974) 84

1974MI11 G.A. Miller and S.C. Phatak, Phys. Lett. B51 (1974) 129

1974MO1G Morton, Smith and Stecher, Astrophys. J. 189 (1974) L109

1974MO1H A. Montwill, P. Moriarty, D.H. Davis, T. Pniewski, T. Sobczak, O. AdamoviImage, U. Krecker, G. Coremans-Bertrand and J. Sacton, Nucl. Phys. A234 (1974) 413

1974MU13 N.C. Mukhopadhyay and F. Cannata, Phys. Lett. B51 (1974) 225

1974NO07 J.A. Nolen, Jr., G. Hamilton, E. Kashy and I.D. Proctor, Nucl. Instrum. Meth. 115 (1974) 189

1974PE04 A.G. Perris, R.O. Lane, J.Y. Tong and J.D. Matthews, Int. J. Appl. Rad. Isotopes 25 (1974) 19

1974PE1C Peterson et al., Bull. Amer. Phys. Soc. 19 (1974) 1003

1974PI05 M. Pignanelli, S. Micheletti, I. Iori, P. Guazzoni, F.G. Resmini and J.L. Escudie, Phys. Rev. C10 (1974) 445

1974RE1A Reeves, Ann. Rev. Astron. Astrophys. 12 (1974) 437

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

1974SC23 H. Schier and B. Schoch, Nucl. Phys. A229 (1974) 93

1974SH1N Shepard, King and True, Bull. Amer. Phys. Soc. 19 (1974) 431

1974ST18 G.L. Strobel, Phys. Rev. C10 (1974) 2153

1974ST1C Stolovy, Namenson, Walker and Smith, Bull. Amer. Phys. Soc. 19 (1974) 529

1974ST1R Steinberg et al., Bull. Amer. Phys. Soc. 19 (1974) 1021

1974SW04 Z.E. Switkowski, R.M. Wieland and A. Winther, Phys. Rev. Lett. 33 (1974) 840

1974TA18 L. Tauscher and W. Schneider, Z. Phys. 271 (1974) 409

1974TH01 C. Thibault and R. Klapisch, Phys. Rev. C9 (1974) 793

1974TH02 S.T. Thornton, R.C. Jordan, C.L. Morris and R.P. Rotter, Z. Phys. 266 (1974) 329

1974TU1A Turk, Antolkovic, Dolenc and Winterhalter, Proc. 1973 Gaussig Conf., ZFK-271 (1974) 115

1974WE1R Wessels, Parrott, Justice and Miller, Bull. Amer. Phys. Soc. 19 (1974) 529

1974WI1M D.H. Wilkinson, Nucl. Phys. A225 (1974) 365

1974WO1D G.J. Wozniak, N.A. Jelley and J. Cerny, Nucl. Instrum. Meth. 120 (1974) 29

1974WO1G Wohl, Astron. Astrophys. 34 (1974) 41

1974YA10 S. Yamaji, T. Fujisawa, H. Kamitsubo, K. Matsuda, S. Motonaga, F. Yoshida, H. Sakaguchi and K. Masui, J. Phys. Soc. Jpn. 37 (1974) 1191

1975BA06 J. Barrette, W. Del Bianco, P. Depommier, S. Kundu, N. Marquardt and A. Richter, Nucl. Phys. A238 (1975) 176

1975CR01 H.J. Crawford, P.B. Price, J. Stevenson and L.W. Wilson, Phys. Rev. Lett. 34 (1975) 329

1975FO19 W.A. Fowler, G.R. Caughlan and B.A. Zimmerman, Ann. Rev. Astron. Astrophys. 13 (1975) 69

1975FR1B Friesenhahn et al., Bull. Amer. Phys. Soc. 20 (1975) 144

1975HA1G Hale, Bull. Amer. Phys. Soc. 20 (1975) 148

1975HI1D High and Cujec, Bull. Amer. Phys. Soc. 20 (1975) 56

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

1975KU01 D. Kurath and D.J. Millener, Nucl. Phys. A238 (1975) 269

1975MI01 S. Micheletti, M. Pignanelli and P. Guazzoni, Phys. Rev. C11 (1975) 64

1975PO02 F. Pougheon, P. Roussel, C. Detraz and G. Rotbard, Phys. Rev. C11 (1975) 287

1975PU01 R.J. Puigh, K.W. Kemper, G.E. Moore and R.L. White, Nucl. Phys. A237 (1975) 1

1976AJ04 F. Ajzenberg-Selove, Nucl. Phys. A268 (1976) 1

DE63Y Unknown Source