Revised Manuscript August 5, 1999

Energy Levels of Light Nuclei $A = 13$

F. Ajzenberg-Selove

University of Pennsylvania, Philadelphia, Pennsylvania 19104-6396

Abstract: An evaluation of $A = 13$–15 was published in Nuclear Physics A523 (1991), p. 1. This version of $A = 13$ differs from the published version in that we have corrected some errors discovered after the article went to press. Figures and introductory tables have been omitted from this manuscript. Also, reference key numbers have been changed to the NNDC/TUNL format.

(References closed July 1, 1990)

The original work of Fay Ajzenberg-Selove was supported by the US Department of Energy [DE-FG02-86ER40279]. 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).

^{13}Li
(Not illustrated)

^{13}Li has not been observed: see (86AJ01). The calculated value of its mass excess is 60.34 MeV [see (81AJ01)]: ^{13}Li would then be unstable with respect to ^{11}Li + 2n by 3.34 MeV. (85PO10) calculate [in a $(0+1)\hbar\omega$ model space] that the first four states of ^{13}Li at 0, 1.42, 2.09 and 2.77 MeV have, respectively, $J^\pi = \frac{3}{2}^-, \frac{7}{2}^-, \frac{1}{2}^-, \frac{5}{2}^-$. See also (87PE1C, 89OG1B) and (88POZS, 88ZV1A; theor.).

^{13}Be
(Not illustrated)

^{13}Be is reported to have been populated in the ^{14}C(^{7}Li, ^{8}B) reaction at $E(^7\text{Li}) = 82$ MeV. Its atomic mass excess is reported to be 35.0 ± 0.5 MeV and $\Gamma = 0.9 \pm 0.5$ MeV (83AL20, 85AL1G). It is then unstable with respect to breakup into ^{12}Be + n by 1.9 ± 0.5 MeV. However, the reported state may not be the ground state of ^{13}Be (89OG1B). See also (89DE52). ^{13}Be has not been observed in the interaction of 44 MeV/A ^{40}Ar ions on Ta, as would be expected since it is unstable (86GI10). A calculation in a $(0+1)\hbar\omega$ model suggests that the first four states of ^{13}Be calculated to be at 0, 0.05, 1.28 and 1.55 MeV have $J^\pi = \frac{1}{2}^-$, $\frac{5}{2}^+$, $\frac{5}{2}^-$ and $\frac{1}{2}^+$ (85PO10). See also (85GA1C, 86DO01, 86GA1J; hypernuclei), (87PE1C), (86AN07) and (87SA15, 89PO1K; theor.).

^{13}B
(Figs. 1 and 4)

GENERAL (See also 86AJ01).

Model calculations: (88WO04, 89PO1K, 89WO1E)

Complex reactions involving ^{13}B: (85BO1A, 86AV1B, 86BI1A, 86UT01, 87AN1A, 87BA38, 87SA25, 87VI02, 88CA06, 88RU01, 88SA19, 89KI13, 89SA10, 89YO02, 90HA46)

Muon and neutrino capture and reactions: (85KO39).

Pion capture and reactions (See also reactions 5 and 6): (85SA06, 88HA12, 89JE02).

Hypernuclei: (86FE1A, 86ME1F, 86WU1D, 88MA1G, 89BA92).

Antinucleon interactions: (88MA48).

Other topics: (85AN28, 86AN07)

Ground-state properties of ^{13}B: (85AN28, 88VA03, 88WO04, 89SA10, 89WO1E, 90LO10)

Table 13.1: Energy levels of ^{13}B

E_x (MeV $\pm$ keV)	$J^\pi; T$	τ or Γ_{cm} (keV)	Decay	Reactions
g.s.	$\frac{3}{2}^-; \frac{3}{2}$	$\tau_{1/2} = 17.36 \pm 0.16$ ms	β^-	1, 2, 3, 4, 5, 6, 7, 8, 9, 11
3.4828 ± 4.5	[a]		(γ)	3
3.5346 ± 3.1	[a]	$\tau_m > 0.3$ ps	γ	2, 3, 5, 6
3.6810 ± 4.5	[a]		(γ)	3, 6
3.7126 ± 4.5	[a]	$\tau_m < 0.38$ ps	γ	2, 3
4.131 ± 6	[a]	$\tau_m = 0.062 \pm 0.050$ ps	γ	2, 3
4.829 ± 6			(γ)	2, 3
5.024 ± 6	[a]			2, 3
5.106 ± 10		$\Gamma = 60 \pm 10$ keV		3
5.388 ± 6		10 ± 10		2, 3
(5.557 ± 7)				2
6.167 ± 6				2, 3
6.425 ± 7		36 ± 5		2, 3, 5, 6
6.934 ± 9		55 ± 15		2, 3
(7.516 ± 8)				2, 6
(7.859 ± 20)				2, 6
8.133 ± 7		100 ± 15		2, 3
8.683 ± 7		89 ± 20		2, 3
9.44 ± 30		81 ± 25		3
(9.5)		broad		9
10.22 ± 20		210 ± 20		3, 6
10.89 ± 20				3
(11.80)				3

[a] See Table 13.3.

Table 13.2: Beta decay of ^{13}B [a]

Decay to ^{13}C* (MeV)	J^π	Branch (%)	log ft [b]
0	$\frac{1}{2}^-$	92.1 ± 0.8	4.034 ± 0.006
3.09	$\frac{1}{2}^+$	≤ 0.7	≥ 5.6
3.68	$\frac{3}{2}^-$	7.6 ± 0.8	4.45 ± 0.05
3.85	$\frac{5}{2}^+$	≤ 0.7	≥ 5.5
7.55	$\frac{5}{2}^-$	0.094 ± 0.020	5.33 ± 0.10
8.86	$\frac{1}{2}^-$	0.16 ± 0.03	4.59 ± 0.09
9.90	$\frac{3}{2}^-$	0.022 ± 0.007	4.95 ± 0.14

[a] For references see Table 13.2 in (81AJ01).
[b] M.J. Martin, private communication. I am very grateful to Dr. Martin for sending me his calculations.

$$Q = 47.8 \pm 4.6 \text{ mb (78LEZA). See also (89RA17).}$$
$$\mu = +3.17778(51) \text{ nm (78LEZA).}$$

Interaction cross sections at 790 MeV/A for ^{13}B ions with Be, C, and Al are reported by (88TA10). The interaction radius and the r.m.s. radius for the nucleon distribution in ^{13}B have also been derived (88TA10).

1. ^{13}B(β^-)^{13}C $\qquad Q_m = 13.437$

The half-life of ^{13}B is 17.36 ± 0.16 ms: see (81AJ01). See also (88SA04). The branching ratios to various ^{13}C states are shown in Table 13.2: they indicate $J^\pi = \frac{1}{2}^-$ or $\frac{3}{2}^-$ for ^{13}B$_{g.s.}$. See also (89PO1K, 89SA1P, 89WO1E; theor.).

2. ^{7}Li(^{7}Li, p)^{13}B $\qquad Q_m = 5.962$

Observed proton and γ-ray groups are shown in Table 13.3. See also ^{14}C.

3. ^{11}B(t, p)^{13}B $\qquad Q_m = -0.233$

Observed proton groups are displayed in Table 13.3.

Table 13.3: Proton groups from ^{7}Li(^{7}Li, p)^{13}B and ^{11}B(t, p)^{13}B [a]

^{7}Li(^{7}Li, p)^{13}B	^{11}B(t, p)^{13}B				
	$E_t = 11$ MeV			$E_t = 23$ MeV	
E_x (MeV ± keV)	E_x (MeV ± keV)	L	J^π	E_x (MeV ± keV)	Γ_{cm} (keV)
0	0	0	$\frac{3}{2}^-$	0	
	3.483 ± 5	1	$(\frac{1}{2}, \frac{3}{2}, \frac{5}{2})^+$ [f]	3.482 ± 10	
3.5363 ± 4.2 [b]	3.533 ± 5	2	$(\frac{1}{2}, \frac{5}{2}, \frac{7}{2})^-$ [f]	3.531 ± 10	
	3.681 ± 5	1	$(\frac{1}{2}, \frac{3}{2}, \frac{5}{2})^+$ [f]	3.681 ± 10	
[c]	3.712 ± 5	2	$(\frac{1}{2}, \frac{5}{2}, \frac{7}{2})^-$ [f]	3.715 ± 10	
4.1334 ± 7.8 [d]	4.13 ± 10	2	$(\frac{1}{2}, \frac{5}{2}, \frac{7}{2})^-$ [f]	4.128 ± 10	
4.833 ± 10 [e]	4.82 ± 10			4.834 ± 10	
5.033 ± 8	5.01 ± 10	1	$(\frac{1}{2}, \frac{3}{2}, \frac{5}{2})^+$ [f]	5.023 ± 10	
				5.106 ± 10	60 ± 10
5.391 ± 8	5.38 ± 10 [g]			5.393 ± 10	10 ± 10
5.557 ± 8				[h]	
6.169 ± 8	6.17 ± 20			6.164 ± 10	
6.419 ± 8				6.434 ± 10	36 ± 5
6.939 ± 15				6.932 ± 10 [i]	55 ± 15
7.516 ± 8				[h]	
7.859 ± 20				[h]	
8.129 ± 10				8.138 ± 10	100 ± 15
8.682 ± 9				8.684 ± 10	89 ± 20
				9.44 ± 30	81 ± 25
				10.22 ± 20	210 ± 20
				10.89 ± 20	
				(11.80)	

[a] For references see (81AJ01).
[b] E_γ; $\tau_m > 0.3$ ps.
[c] The decay is primarily by γ_0: the upper limit to the cascade via ^{13}B*(3.5) is 10%; $\tau_m < 0.38$ ps.
[d] The γ-decay is (75 ± 10)%, (25 ± 10)% and < 10%, respectively to ^{13}B*(0, 3.5, 3.7); $\tau_m = 62 \pm 50$ fs.
[e] All values in this column from this entry down are based on $E_x = 4131$ keV for ^{13}B*(4.13).
[f] See, however, (78AJ02), page 1289.
[g] $\Gamma = 15 \pm 5$ keV.
[h] Not observed.
[i] $L \geq 4$.

4. ^{12}C(^{13}C, ^{12}N)^{13}B $\qquad Q_m = -30.776$

See (86VO02, 88VO06) and ^{12}N in (90AJ01).

5. ^{13}C(γ, π^+)^{13}B $\qquad Q_m = -153.006$

At $E_e = 195$ MeV the ^{13}B E_x region to 12 MeV has been studied by (83MI06): they find that the photopion reaction predominantly excites M2 states at low q and M4 states at high q. Fits to the data are obtained by assuming the excitation of ^{13}B$_{g.s.}$ and ^{13}B*(3.5, 6.4, 9.0) [the latter are clearly due to unresolved groupings of levels]. Comparisons are made with the ^{13}C(e, e′) work in the analog region in ^{13}C (83MI06). [For $T = \frac{3}{2}$ states see Table 13.6.] For other work on this reaction see (80AJ01). See also reaction 40 in ^{13}C, the "General" section and (86SI07; theor.).

6. ^{13}C(π^-, γ)^{13}B $\qquad Q_m = 126.131$

Gamma rays have been observed which are associated with the ^{13}B ground state; an unresolved doublet at $E_x \approx 3.5$–3.7 MeV; sharp states at $E_x \approx 6.5$ and 7.6 MeV; a broad level (or unresolved levels) at ≈ 10.2 MeV (83MA16; see for radiative capture branching ratios). The analogs of the peaks at $E_x = 6.5$, 7.6 and 10.2 MeV, calculated to be at ^{13}C*(21.6, 22.7, 25.3), are attributed to a $\Delta L = 1$, $\Delta S = 1$, $\Delta T = 1$ spin-isospin giant dipole resonance of ^{13}C (83MA16). See also the "General" section.

7. ^{13}C(n, p)^{13}B $\qquad Q_m = -12.655$

The 0° ground-state differential cross section has been measured at $E_n = 198$ MeV (88JA01). At $E_n = 65$ MeV, ^{13}B*(0, 3.5) and the region from 6–10 MeV have been studied (86WAZU; prelim.). See also (86FO1E, 87BR32, 89SOZY, 89SOZW) and (86AL1K).

8. ^{13}C(d, 2p)^{13}B $\qquad Q_m = -14.880$

At $E_d = 70$ MeV the angular distribution to ^{13}B$_{g.s.}$ has been reported. Structures at $E_x = 3.8$, 5.2, 6.6 MeV are also observed. For VAP measurements see ^{15}N (86MO27).

9. ^{13}C(^{7}Li, ^{7}Be)^{13}B $\qquad Q_m = -14.299$

At $E(^7\text{Li}) = 21$ MeV/A, forward angular distributions are reported to $^{13}\text{B}_{\text{g.s.}}$ and to unresolved structures at 3.5, 4.0, 5.1, 6.3, 7.0 and 7.6 MeV, and to a broad ($\Gamma \approx 2.3$ MeV) structure at 9.5 MeV. The latter is suggested to be due to the GDR (90NA1B) [see for possible J^π assignments].

10. $^{14}\text{C}(\gamma, \text{p})^{13}\text{B}$ $\qquad Q_{\text{m}} = -20.832$

See (87GO09; theor.).

11. $^{14}\text{C}(\text{t}, \alpha)^{13}\text{B}$ $\qquad Q_{\text{m}} = -1.017$

See (86AJ01).

^{13}C
(Figs. 2 and 4)

GENERAL (See also 86AJ01).

Nuclear models: (85KW02, 87KI1C, 88MI1J, 88WO04, 89AM02, 89PO1K, 89WO1E, 90FE01, 90HO01, 90VA01).

Special states: (84KO40, 85GO1A, 85RO1J, 85SH24, 86AN07, 86XU02, 87KI1C, 88KW1A, 88MI1J, 88RO1R, 88ZH1B, 89AM02, 89OR02, 89RO03, 90HO01).

Electromagnetic transitions and giant resonances: (84VA06, 85GO1A, 86AD1B, 86ER1A, 87KI1C, 89AM02).

Astrophysical questions: (82BU1A, 82CA1A, 82GR1A, 82WO1A, 85BR1E, 85HA1R, 85HE1F, 85MI1E, 85PR1D, 85RI1B, 86DO1L, 86FR1G, 86GO1Q, 86LA1C, 86MA2E, 86SN1C, 86SN1D, 86WI1H, 87AR1C, 87AU1A, 87BE1H, 87BO1B, 87BR1P, 87DO1A, 87HA1C, 87HA1U, 87KR1M, 87MA1C, 87MA2G, 87PI1E, 87PR1A, 87SO1F, 87WA1L, 87WA1F, 87ZI1C, 88AP1A, 88AR1H, 88AS1D, 88CR1A, 88DE1I, 88JA1B, 88JU1C, 88PI1C, 88SC1A, 88TR1H, 89AB1J, 89BA2I, 89BA2K, 89BO1S, 89BR1I, 89BR1M, 89CH1X, 89CH1Z, 89FR1J, 89GI1E, 89GU1L, 89HA1O, 89HO1F, 89JI1A , 89KA1K, 89LO1C, 89LO1D, 89ME1C, 89NO1A, 89SM1A, 89ST1K, 89WE1G, 89WH1B, 89WY1A, 90CA1O, 90FU03, 90HO1I, 90MO1I, 90PI1F, 90TU1A, 90WE1I).

Applied work: (86BR1Q, 86BU1R, 86DO1M, 86DR1E, 86EN1A, 86FO1D, 86FR1H, 86GE1C, 86HE1F, 86KI1J, 86KN1E, 86KR1F, 86MA2D, 86MA2G, 86NI1C, 86NO1C, 86SR1B, 86ST1K, 86XU1C, 87BO1U, 87DU1A, 87KI1I, 87NA1O, 87ST1C, 88AR1G, 88BU1C, 88DO1D, 88FA1A, 88GO1J, 88MA1A, 88PU1A, 88SC1C, 89CE1D, 89GR1F, 89KU1P, 89MU1A, 89RA1M, 90DO1C, 90FR1F).

Table 13.4: Energy levels of ^{13}C [a]

E_x in ^{13}C (MeV $\pm$ keV)	J^π; T	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
g.s.	$\frac{1}{2}^-$; $\frac{1}{2}$		stable	5, 6 ,7, 8, 10, 11, 13, 14, 15, 19, 20, 21, 22, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 67, 68, 69, 70, 71, 72, 73
3.089443 ± 0.020	$\frac{1}{2}^+$	$\tau_m = 1.55 \pm 0.15$ fs [c]	γ	5, 6, 7, 8, 11, 13, 19, 20, 21, 22, 27, 28, 29, 31, 32, 35, 36, 40, 41, 42, 43, 44, 45, 46, 47, 50, 59, 60, 61, 62, 63, 64, 65, 67, 69, 71
3.684507 ± 0.019	$\frac{3}{2}^-$	1.59 ± 0.13 fs [c]	γ	5, 6, 7, 8, 11, 13, 14, 19, 20, 21, 22, 27, 28, 29, 31, 32, 34, 37, 40, 41, 42, 43, 44, 45, 46, 47, 48, 59, 60, 61, 62, 63, 64, 67, 69
3.853807 ± 0.019	$\frac{5}{2}^+$	12.4 ± 0.2 ps [d]	γ	5, 6, 7, 8, 11, 13, 19, 20, 21, 27, 28, 29, 30, 32, 34, 37, 40, 41, 42, 43, 44, 45, 46, 50, 59, 60, 62, 64, 69, 71
6.864 ± 3 [f]	$\frac{5}{2}^+$	$\Gamma = 6$	γ, n	5, 6, 7, 8, 11, 12, 13, 19, 21, 23, 27, 28, 29, 40, 43, 45, 46, 59, 61, 64, 67
7.492 ± 10	$(\frac{7}{2}^+)$	< 5		5, 8, 12, 14, 19, 21, 28, 40, 45, 46, 63, 64

Table 13.4: Energy levels of ^{13}C [a] (continued)

E_x in ^{13}C (MeV ± keV)	$J^\pi; T$	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
7.547 ± 3	$\frac{5}{2}^-$	1.2 ± 0.3	γ, n	5, 8, 11, 12, 14, 19, 21, 23, 28, 37, 40, 41, 42, 43, 44, 45, 46, 47, 48, 59, 63, 64, 67
7.686 ± 6	$\frac{3}{2}^+$	70 ± 5	γ, n	11, 12, 19, 21, 28, 29, 38, 43, 45, 46, 59, 64
8.2 ± 100	$\frac{3}{2}^+$	1100 ± 300	γ, n	8, 23, 28, 29, 30, 43, 59
8.860 ± 20	$\frac{1}{2}^-$	150 ± 30	γ, n	19, 23, 28, 37, 40, 41, 43, 45, 46, 59, 60, 63, 64, 67
9.4998 ± 0.1[b]	$\frac{9}{2}^+$	≤ 5	γ, n	5, 8, 12, 19, 23, 27, 28, 29, 30, 40, 43, 45, 46, 59, 63, 64, 67
9.897 ± 5	$\frac{3}{2}^-$	26 ± 3	γ, n	5, 11, 12, 19, 23, 28, 37, 38, 40, 43, 45, 59, 64
10.46		200	n	23
10.753 ± 4	$\frac{7}{2}^-$	55 ± 2	γ, n	5, 12, 19, 23, 28, 29, 40, 43, 45, 64
10.818 ± 5	$(\frac{5}{2}^-)$	24 ± 3	γ, n	5, 12, 19, 23, 28, 40, 43, 45, 64
10.996 ± 6	$\frac{1}{2}^+$	37 ± 4	γ, n, α	2, 19, 23, 28, 38, 43, 59, 64
11.080 ± 5	$\frac{1}{2}^-$	< 4	γ, n, α	2, 19, 23, 28, 40, 43, 45, 46, 59, 64, 67
11.748 ± 10	$\frac{3}{2}^-$	110 ± 15	n	19, 23, 28, 43, 59, 64
11.848 ± 4	$\frac{7}{2}^+$	68 ± 4	γ, n	5, 23, 28, 40, 41, 43, 45, 46, 60, 67
11.95 ± 40	$\frac{5}{2}^+$	500 ± 80	n, α	2, 23, 28, 40, 43
12.106 ± 5	$\frac{3}{2}^+$	540 ± 70	(γ), n, (α)	2, 23, 28, 38, 43
12.13 ± 50	$\frac{5}{2}^-$	80 ± 30	n, (α)	2, 5, 23, 64
12.14 ± 70	$\frac{1}{2}^+$	430 ± 70	n, (α)	2, 23, 43
12.187 ± 10	$\frac{3}{2}^-$	150 ± 40	γ, n, (α)	2, 23, 40
12.438 ± 12	$\frac{7}{2}^-$	140 ± 30	γ, n, α	2, 23, 40, 43, 67

Table 13.4: Energy levels of ^{13}C [a] (continued)

E_x in ^{13}C (MeV $\pm$ keV)	$J^\pi; T$	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
13.0 ± 1000		broad	γ, n	38
(13.28)	$(\frac{3}{2}^-)$	340	α	4, 43, 59
13.41	$(\frac{9}{2}^-)$	35 ± 3	n, α	2, 4, 5, 43
13.57	$\frac{7}{2}^-$	620 ± 50	n, α	2, 4, 23, 43
13.76	$(\frac{5}{2}, \frac{3}{2})^+$	≈ 300	n, α	2, 4, 43
14.13	$\frac{3}{2}^-$	≈ 150	n, α	2, 4, 5, 23, 43
14.390 ± 15	$(\frac{1}{2}, \frac{5}{2})^-$	280 ± 70	γ, n, α	2, 40, 43
14.582 ± 10	$(\frac{7}{2}^+, \frac{9}{2}^+)$	230 ± 40	γ, n, α	2, 40, 43
14.983 ± 10	$(\frac{7}{2}^-)$	380 ± 60	γ, n, α	2, 23, 40, 43
15.1082 ± 1.2 [e]	$\frac{3}{2}^-; \frac{3}{2}$	5.49 ± 0.25	γ, n, α	2, 40, 19, 23, 40, 43, 45, 59, 67
15.27	$\frac{9}{2}^+$		n	23
15.526 ± 11	$(\frac{3}{2}^-)$	150 ± 30	γ, n, α	2, 23, 4, 43
16.080 ± 7	$(\frac{7}{2}^+)$	150 ± 15	γ, n, α	2, 23, 40, 41, 43, 45
16.15 ± 50	$(\frac{5}{2}^-)$	230	n, α	2, 43
(16.183 ± 28)		(40 ± 20)	γ	40
16.95 ± 50		330	n, α	2, 43
17.36 ± 100		190	n, α	2, 43
17.533 ± 3	$(T = \frac{3}{2})$	17 ± 6	n	23
17.699 ± 5	$(\frac{3}{2}, \frac{5}{2})$	170	n, α	2, 43
(17.92 ± 50)				41
18.082 ± 3	$(T = \frac{3}{2})$	12 ± 7	n	23
18.30 ± 50		300	n, α	2, 43
(18.497 ± 10)		(91 ± 23)	γ	40
18.699 ± 5	$(\frac{3}{2}^+, \frac{5}{2}^+)$	100 ± 15	γ, n, (p), α	2, 39, 40, 43
19.51	$(\frac{5}{2}^-)$	≥ 500	n, d	16, 23, 43
19.9		≈ 600	n, p, d	16, 43
20.021 ± 13		230 ± 30	γ	40, 43
20.057 ± 4		11 ± 8	n	23
(20.11)	$(\frac{1}{2}^-)$	1090	n	23

Table 13.4: Energy levels of ^{13}C [a] (continued)

E_x in ^{13}C (MeV ± keV)	$J^\pi; T$	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
(20.11)	$(\frac{5}{2}^+)$	440	n	23
20.20 ± 70	$(\frac{7}{2}^+)$	560 ± 90	γ, n, d, α	15, 16, 18, 22, 23
(20.30)	$(\frac{7}{2}^-)$	1560	n	23
(20.34)	$(\frac{9}{2}^+)$	320	n	23
20.429 ± 8		115 ± 25	γ, n, p, d	16, 40, 43
20.52 ± 70		510 ± 70	γ, n, p	16, 23
20.6 ± 800		5600 ± 400	γ, n, d	15, 22, 38
(20.93 ± 100)		(240 ± 100)		43
21.28 ± 15		159 ± 15	n, p, d	16, 17, 43
21.466 ± 8	$(\frac{7}{2}^+, \frac{9}{2}^+)$	270 ± 20	γ	40, 43
21.703 ± 4	$(T = \frac{3}{2})$	18 ± 9	n	23, 27
21.81 ± 20	$(\geq \frac{5}{2})$	114 ± 21	n, d	16, 43
22.2 ± 100	$(\leq \frac{5}{2})$	1100 ± 500	n, d	16, 43
23	$(\leq \frac{5}{2})$	≈ 1000	n	23, 43
24		≈ 4000	γ, n, p	38
(26)		broad	γ, p	39
26.8			n, d	16
27.5		≈ 1000	n, p, d, t	16
30			γ, n	38

[a] See also Table 13.5.
[b] See footnote [b] in Table 13.10.
[c] From Table 13.5 in (81AJ01).
[d] Weighted mean of values displayed in Table 13.5 in (81AJ01) and in (81RU04).
[e] See Table 13.6.
[f] See also footnote [c] in Table 13.11.

Complex reactions involving ^{13}C: (84BO1H, 85KI1E, 85KW03, 85PO11, 85PO14, 85UT01, 86AV1B, 86GR1A, 86HA1B, 86HO1K, 86MA19, 86MA1O, 86ME06, 86MO15, 86PO06, 86SA30, 86SO10, 86UT01, 86XU02, 86XU1B, 87AR19, 87BA38, 87BE1I, 87BU07, 87GA17, 87GE1B, 87LY04, 87NA01, 87PE1B, 87PO1I, 87RI03, 87SI1C, 87SN01, 87ST01, 87VI02, 87YA1F, 88BE56, 88CA06, 88GA11, 88HA03, 88JO1B, 88KI06, 88RU01, 88SA19, 89AJ1A,

89BA92, 89CH1U, 89GIZV, 89GRZQ, 89HO16, 89KI13, 89POZT, 89PR02, 89SA10, 89SE03, 89TE02, 90CH09).

Muon and neutrino capture and reactions: (85DE42, 85KO39, 85MI21, 86IS02, 86MI1K, 86MI1M, 87SU06, 90CH13, 90FU03, 90LU1D, 90MI1J).

Pion capture and reactions involving pions and ρ-mesons (See also reactions 27 and 41, and reaction 23 in ^{13}N): (83MA16, 84BO1H, 84CH1K, 85SA06, 86BO1N, 86CE04, 86DO01, 86ER1A, 86KO26, 86LI1N, 86LI1P, 86MI1M, 86SI07, 86SI13, 86SI22, 86SU18, 87DU08, 87GI1C, 87MI08, 87PI1B, 88BU1I, 88CH24, 88CH1L, 88CHZU, 88GIZU, 88HA12, 88KIZW, 88PE1F, 88PE1H, 88PO1H, 88POZV, 88US01, 89CH31, 89GE10, 89IT04, 89JE02, 89JO1B, 89KI25, 89MO09, 89PI11, 90BE12, 90CH12, ?, 90ER03, 90FE01, 90KO19, 90TA1K, 90TI1B).

Kaon capture and reactions: (84BO1H, 85GA1C, 86DO01, 86FE1A, 86GA1J, 86MA1C, 86MA1W, 87FA1A, 87PI1B, 87PO1H, 88FA1B, 88PE1F, 88PE1H, 88PO1H, 88ZH1H, 89CH2D, 89DO1K, 89PI11, 90FE01).

Hypernuclei: (84BO1H, 84ZH1B, 85BA1F, 85BA2D, 85GA1C, 85KO1W, 85KO1T, 85YA1C, 86AN1R, 86BA1H, 86DA1G, 86DA1B, 86DO01, 86ER1A, 86FE1A, 86GA1J, 86KO1A, 86LA1R, 86MA1C, 86MA1W, 86ME1F, 86WU1C, 86WU1D, 86YA1F, 87CO1E, 87FA1A, 87MA08, 87MI1A, 87PI1C, 87PO1H, 88CH48, 88FA1B, 88GA1A, 88GA1I, 88IT02, 88MA1G, 88MA58, 88MO1L, 88PE1H, 88PO1H, 88TA1B, 88WA1B, 88ZH1H, 89BA92, 89BA93, 89CH2D, 89DO1K, 89DO1N, 89FE07, 89IT04, 89KI25, 89KO1H, 89KO37, 89KO48, 89LA1H, 89LA1I, 89MA30, 89MI30, 89PI11, 90FE01, 90IT1A, 90OS1A).

Other topics: (85AN28, 85SH24, 86AN07, 88KW1A, 89FU05, 89OR02, 90MU10).

Ground state of ^{13}C: (85AN28, 85GO1A, 86GL1A, 86SI22, 87AB03, 87FU06, 87GI1C, 87KI1C, 87SA15, 88AR1I, 88KE1B, 88VA03, 88WA08, 88WO04, 89AM02, 89AN12, 89FU05, 89GOZQ, 89WO1E, 90VA01).

$$\mu = +0.702411(1) \text{ nm (78LEZA)}$$

$$\langle r^2 \rangle^{1/2} = 2.4628(39) \text{ fm (85DE42) [charge radius, from muonic } ^{13}\text{C]}$$

[The neutron r.m.s. radius is 2.35 (3) fm (79JO08).]

Natural abundance: $(1.10 \pm 0.03)\%$ (84DE1A)

^{13}C*(3.85): $g = -0.558 \pm 0.015$ (81RU04). From the γ-ray due to the transition ^{13}C*(3.85 $\rightarrow$ 3.68), $\Delta E_x = 169.356 \pm 0.020$ keV: see (86AJ01). See also (89RA17).

1. (a) ^{6}Li(^{7}Li, γ)^{13}C $Q_m = 25.868$
   (b) ^{6}Li(^{7}Li, n)^{12}C $Q_m = 20.921$ $E_b = 25.868$
   (c) ^{6}Li(^{7}Li, p)^{12}B $Q_m = 8.334$

Table 13.5: Summary of results: total radiation widths of low-lying levels of ^{13}C-^{13}N[a]

$J^\pi_i \rightarrow J^\pi_f$	^{13}C* (MeV)	Γ_γ (eV)	^{13}N* (MeV)	Γ_γ (eV)
$\frac{1}{2}^+ \rightarrow \frac{1}{2}^-$	3.09[b]	0.43 ± 0.04	2.37	0.50 ± 0.04[c]
$\frac{3}{2}^- \rightarrow \frac{1}{2}^-$	3.68 [d]	0.41 ± 0.04	3.51[e]	0.70
$\frac{5}{2}^+ \rightarrow \frac{1}{2}^-$	3.85 [f]	$(5.32 \pm 0.09) \times 10^{-5}$[g]	3.55	$< 2 \times 10^{-3}$

[a] See also Tables 13.12 and 13.17. For references see Table 13.6 in (81AJ01).
[b] $E_x = 3089.443 \pm 0.020$ keV, $E_\gamma = 3089.049 \pm 0.020$ keV* (80WA24: here, and in footnote [d], measured values are starred (*); the others are derived.)
[c] See the discussion in (85BA75).
[d] Branching ratio for cascade via ^{13}C*(3.09) is (0.75 ± 0.04)% (80WA24), (0.74 ± 0.05)% (82MU14). $E_x = 3684.482 \pm 0.023$ keV, $E_\gamma = 3683.921 \pm 0.023$ keV. δ(E2/M1) $= -0.094 \pm 0.009$. E_γ for the transition to ^{13}C*(3.09) is 595.013 ± 0.011 keV (80WA24).
[e] Branching ratio for cascade via ^{13}N*(2.37) is (8 ± 1)% (74RO29). See also footnote [g] in Table 13.17.
[f] Branching ratios for cascades via ^{13}C*(3.68, 3.09) are (36.3 ± 0.6)% and (1.20 ± 0.04)%, respectively (80WA24). $E_x = 3853.783 \pm 0.022$ keV, $E_\gamma = 3853.170 \pm 0.022$ keV; E_γ for the transition to ^{13}C*(3.09, 3.68) are 764.316 ± 0.010 keV* and 169.300 ± 0.004 keV* (80WA24) [169.356 ± 0.020 keV* (84SC09)].
[g] The ground-state branching ratio is (62.5 ± 0.6)% (80WA24) and δ(E3/M2) $= +0.12 \pm 0.03$ (66PO11).

(d) ^{6}Li(^{7}Li, d)^{11}B $\qquad Q_m = 7.189$
(e) ^{6}Li(^{7}Li, t)^{10}B $\qquad Q_m = 1.992$
(f) ^{6}Li(^{7}Li, α)^{9}Be $\qquad Q_m = 15.220$

The yield curves for d_0 ($E(^6$Li$) = 4$ to 14 MeV), t_0 ($E(^7$Li$) = 5$ to 14 MeV) and α_0 ($E(^6$Li$) = 4$ to 14 MeV) show broad, uncorrelated structures. Energy-averaged differential cross sections are also reported for a number of ^{12}B, ^{11}B and ^{10}B states. Total cross sections have been measured for $E(^7$Li$) = 3.8$ to 6.0 MeV for $p_0 \rightarrow p_2$, p_{3+4}, p_5; $d_0 \rightarrow d_3$, d_{4+5}, d_6; $t_0 \rightarrow t_2$; and α_0: the total cross sections generally increase smoothly with energy without showing any structure: see (81AJ01). For reaction (b) see (87SC11).

2. (a) ^{9}Be(α, n)^{12}C $\qquad Q_m = 5.7012 \qquad E_b = 10.6476$
(b) ^{9}Be(α, 2n)^{11}C $\qquad Q_m = -13.021$

Resonances for n_0 and n_1, for γ-rays from ^{12}C*(4.4, 12.7, 15.1) and resonances in the total neutron cross section are given in Table 13.7. In addition the yield of neutrons to ^{12}C*(7.65, 9.64) has been measured in the range $E_\alpha = 2.9$–6.4 MeV. The n_0 and n_1 excitation functions exhibit weak resonance anomalies at $E_\alpha = 6.44$ MeV corresponding to the $J^\pi = \frac{3}{2}^-$, $T = \frac{3}{2}$ state at $E_x = 15.11$ MeV: see Tables 13.06 and 13.07 (78HI06). For thick target yields

Table 13.6: Parameters of the first $T = \frac{3}{2}$ states in ^{13}C and ^{13}N [a]

	^{13}C*(15.11)	^{13}N*(15.06)
E_x (MeV)	15.1082 ± 0.0012	15.06457 ± 0.0004
J^π	$\frac{3}{2}^-$	$\frac{3}{2}^-$
$\Gamma_{c.m.}$ (keV)	5.49 ± 0.25	0.932 ± 0.028
Γ_{γ_0} (eV)	22.4 ± 1.5 (M1),	24.2 ± 1.5 (M1) [b] ,
	0.6 ± 0.1 (E2)	0.32 ± 0.12 (E2) [c]
Γ_{γ_1} (eV)	4.12 ± 0.74	$\leq 2.82 \pm 0.30$ [d]
$\Gamma_{\gamma_{2+3}}$ (eV)	18.2 ± 2.4	19.6 ± 1.4 [e]
Γ_{γ_0}/Γ (%)	0.396 ± 0.030	
	[f]	
$\Gamma_{p_0}\Gamma_{\gamma_0}/\Gamma$ (eV)		5.79 ± 0.20
$\Gamma_{\gamma_0}/\Gamma_{p_0}$ (%)		12.1 ± 1.1
Γ_{n_0} or Γ_{p_0} (keV) [g]	0.38 ± 0.10	0.228 ± 0.016 [h]
Γ_{n_1} or Γ_{p_1} (keV) [g]	1.43 ± 0.18	0.140 ± 0.014 [h]
Γ_{n_2} or Γ_{p_2} (keV) [g]	0.14 ± 0.10	0.049 ± 0.015 [h]
Γ_{p_3} (keV) [g]		0.089 ± 0.014 [h]
Γ_{p_5} (keV) [g]		0.15 ± 0.04 [h]
		[i]
Γ_{α_0} (keV) [j]	0.104 ± 0.028	0.046 ± 0.026 [h]
Γ_{α_1} (keV) [j]		0.036 ± 0.036 [h]
Γ_{α_2} (keV) [j]		0.067 ± 0.042 [h]

[a] For references see Table 13.7 in (81AJ01).
[b] $\delta = -0.15 \pm 0.07$. Here $\delta = B(^{13}\mathrm{C})/B(^{13}\mathrm{N})$-1.
[c] $\delta = 1.0 \pm 0.6$.
[d] $\delta \geq 0.83 \pm 0.29$.
[e] $\delta = -0.04 \pm 0.14$.
[f] The decay width to ^{13}C*(7.55) is < 0.9 eV.
[g] Widths for ^{13}C*(15.11)→^{12}C$_{g.s.}$ + n_0 or ^{13}N*(15.06)→*^{12}C$_{g.s.}$ + p_0 (n_1, p_1, n_2, p_2; and p_3 and p_5 refer to the decays to ^{12}C*(4.4, 7.7, 9.6, 10.8), respectively).
[h] Based on measured branching ratios and on $\Gamma_{c.m.} = 0.932 \pm 0.028$ keV. See also footnote [d] in Table 13.18.
[i] The decay width to ^{12}C*(12.71) is < 0.13 keV. It is expected to be ≈ 0.03 keV. The sum of the branching ratios for all measured decays of ^{13}N*(15.06) is (92 ± 8)%. It is apparent from the character of the decay modes of this state that 2s1d shell isospin admixtures are important.
[j] Widths for ^{13}C*(15.11)→^{9}Be$_{g.s.}$ + α_0 or ^{13}N*(15.06)→^{9}B$_{g.s.}$ + α_0 [α_1 and α_2 refer to the decays to ^{9}B*((1.6), 2.4)].

see (82WE16). See also (89HE04). For polarization measurements (E_α to 100 MeV) see (81AJ01). Reaction (b) has been studied at a number of energies for $E_\alpha = 17$ to 44 MeV: see (81AJ01, 86AJ01). See also ^{12}C in (90AJ01), (87EL1B, 89CR07; applied) and (85CA41; astrophysics).

3. (a) ^{9}Be(α, d)^{11}B $\quad Q_m = -8.0314 \quad E_b = 10.6476$
   (b) ^{9}Be(α, t)^{10}B $\quad Q_m = -13.2283$

Excitation curves have been measured for $E_\alpha = 15$ to 27.5 MeV for reaction (a) [involving d_0, d_1 and at the higher energies d_2, d_3, d_{4+5}, d_6] and at 26.0 to 27.5 MeV for reaction (b) [t_0, t_1, t_3]: no structures are observed: see (81AJ01). See also ^{11}B in (90AJ01) and ^{10}B in (88AJ01).

4. ^{9}Be(α, α)^{9}Be $\quad E_b = 10.6476$

A number of excitation functions have been measured for elastically scattered α-particles for $E_\alpha = 1.4$ to 20 MeV: these show considerable resonance structure with the variations being most prominent below 10 MeV but persisting up to 20 MeV. The parameters resulting from a best-fit of the excitation functions are displayed in Table 13.8: see the footnotes to that table for a summary of the most important caveats. A weak resonance is observed in the α_0 yield at $E_\alpha = 6.44$ MeV corresponding to the excitation of the first $T = \frac{3}{2}$ state at $E_x = 15.11$ MeV: see Table 13.6 for the parameters of that state. For a measurement of the total reaction cross section at $E_\alpha = 100$ MeV see (86DU15). See also (87BU27) and (86SA30; theor.).

5. ^{9}B(^{6}Li, d)^{13}C $\quad Q_m = 9.1725$

Angular distributions have been studied at $E(^6\mathrm{Li}) = 32$ MeV to ^{13}C*(0, 3.09, 3.68+3.85, 6.86, 7.5, 9.5, 9.9, 10.75, 13.42). The spectra are dominated by the deuteron group to a state (or states) at $E_x = 10.75 \pm 0.018$ MeV, with $\Gamma = 130$ keV [suggesting that both ^{13}C*(10.75, 10.82) are populated]. Two states, consistent with ^{13}C*(11.35, 12.13) are also populated, as is a broad group at 14.13 MeV (89AS01; see for spectroscopic factors).

6. ^{9}Be(^{7}Li, t)^{13}C $\quad Q_m = 8.1798$

Angular distributions for t_0, t_1, t_{2+3}, t_4 are reported at $E(^7\mathrm{Li}) = 5.6$ to 6.2 MeV: see (76AJ04).

Table 13.7: Resonances in $^{9}Be(\alpha, n)^{12}C$ [a]

E_α [b] (MeV)	E_α [c] (MeV)	E_α [d] (MeV)	$\Gamma_{c.m.}$ (keV)	J^π	$^{13}C^*$ [e] (MeV)
0.52	0.52		≈ 55 [f]	$(\frac{1}{2}^+)$	11.01
0.60	0.60		< 4 [f]		11.06
1.9	1.905	1.92	130	$(\frac{7}{2}^-)$	11.97
2.24		2.25	280		12.20
2.58	2.6	2.58	≈ 200	$(\frac{1}{2}^-)$	12.43
4.00	3.98	4.00	35 ± 3		13.41
4.18			570	$(\frac{3}{2}^+)$	13.54
4.50	4.47	4.50	≈ 350	$(\frac{5}{2}^+)$	13.75
5.0	5.02	5.0	≈ 200		14.12
5.40 ± 0.10	5.3		260	$(\frac{1}{2}^-, \frac{5}{2}^-)$	14.39 ± 0.1
	5.75	5.75	210		14.63
6.20 ± 0.05			380	$(\frac{3}{2}^+)$	14.94 ± 0.05
	6.44 [g]			$(\frac{3}{2}^-; T = \frac{3}{2})$	15.1086
7.10 ± 0.05	7.00		220		15.56 ± 0.05
	7.75	7.8	210		16.01
7.95 ± 0.05			230		16.15 ± 0.05
9.10 ± 0.05		9.1	330		16.95 ± 0.05
9.7 ± 0.10	9.70		190		17.36 ± 0.1
10.2 ± 0.05			170		17.71 ± 0.05
11.05 ± 0.05			300		18.30 ± 0.05
11.70 ± 0.03	11.60		70		18.75 ± 0.03

[a] For references see (81AJ01).
[b] Resonances in total neutron yield.
[c] Resonances in n_1 group and for 4.4 MeV γ-rays.
[d] Resonances in total cross section.
[e] Not corrected for effects of Coulomb barrier penetration.
[f] $\omega\gamma = 3.79$ and 0.88 eV, respectively.
[g] Anomalies in n_0 and n_1 yields at $E_\alpha = 6443.5 \pm 2.0$ keV: see Table 13.6 for parameters of 15.11 MeV state.

Table 13.8: Resonances in ^{9}Be(α, α_0) [a]

E_α (MeV)	$\Gamma_{\text{c.m.}}$ (keV)	l_α	J^π	^{13}C* (MeV)
3.80	343	0, 2	$\frac{3}{2}^-$ [b]	13.28
4.00	58	(4, 6)	$(\frac{9}{2}^-)$	13.42
4.20	685	1, 3	$\frac{5}{2}^+$ [c]	13.56
4.50	247	1, 3	$\frac{3}{2}^+$ [c]	13.76
5.00	75	2, 4	$\frac{5}{2}^-$ [d]	14.11
5.075	73	3, 5	$\frac{7}{2}^+$ [d]	14.161
(5.50)	400	(1, 3)	$(\frac{5}{2})^+$	(14.46)
6.44	[e]		$\frac{3}{2}^-$; $T = \frac{3}{2}$	15.11

[a] (73GO15): from analysis in the single-level approximation. This assumes the J^π ordering suggested by (65LI09). See also (81AJ01).
[b] Favored by the analysis but the assignment is not certain and more than one state may be involved.
[c] The ordering of these two J^π values is not clear.
[d] An equally good fit to the data is obtained with a $\frac{7}{2}^-$ state at 5.0 MeV and a $(\frac{3}{2}, \frac{5}{2}, \frac{7}{2})^+$ state at 5.08 MeV.
[e] Weak anomaly at $E_\alpha = 6443.5 \pm 2.0$ keV: see Table 13.6 for parameters of 15.11 MeV state, and reaction 2.

7. ^{9}Be(^{9}Be, nα)^{13}C $\qquad Q_m = 9.0741$

Cross sections for gamma rays from the decay of ^{13}C*(3.09, 3.68, 3.84) are reported by (88LA25) for $E(^{9}\text{Be}) = 2.8$ to 6 MeV.

8. ^{9}Be(^{12}C, ^{8}Be)^{13}C $\qquad Q_m = 3.2810$

Angular distributions have been measured for $E(^{12}\text{C}) = 10.5$ to 15 MeV and at $E(^{9}\text{Be}) =$ 20 MeV: (see (81AJ01, 86AJ01).

9. (a) ^{10}B(t, p)^{12}B $\qquad Q_m = 6.342 \qquad E_b = 23.8759$
   (b) ^{10}B(t, d)^{11}B $\qquad Q_m = 5.1969$
   (c) ^{10}B(t, α)^{9}B $\qquad Q_m = 13.2282$

Yields have been measured for $E_t = 0.5$ to 2.0 MeV. There is no evidence of resonance behavior: see (81AJ01). In the range $E_t = 3.0$ to 7.3 MeV a broad structure is reported in the activation cross section (reaction (a)) at $E_t \approx 5.5$ MeV, $\Gamma \approx 2.7$ MeV (85AB10). See also ^{9}Be in (88AJ01).

10. ^{10}B(^{3}He, π^{+})^{13}C $\qquad Q_m = -115.711$

At $E(^{3}\text{He}) = 260$ and 280 MeV, $^{13}\text{C}_{\text{g.s.}}$ and an unresolved group at $E_x \approx 3.6$ MeV are observed: see (86AJ01).

11. ^{10}B(α, p)^{13}C $\qquad Q_m = 4.0618$

Angular distributions have been measured at many energies up to $E_\alpha = 31.2$ MeV: see (70AJ04, 86AJ01). For γ-decay measurements see Table 13.6. At $E_\alpha = 218$ MeV, ^{13}C* (0, 3.09, 3.7, 6.9, 7.6, 9.9) are populated (87BI1C; prelim.). For a study of high E_x states see (87BRZV, 87MIZY, 88BRZY; prelim.). See also ^{14}N, (89BR1J) and (86BA58; axion search).

12. ^{10}B(^{6}Li, ^{3}He)^{13}C $\qquad Q_m = 8.0803$

Comparisons of the relative intensities of the ^{3}He groups in this reaction and of the triton groups in the mirror reaction (see reaction 6 in ^{13}N) at $E(^6\text{Li}) = 18$ MeV suggest that the following states are analogs: 6.86–6.36, 7.49–7.16, 9.50–9.00, 9.90–9.48, (10.82 + 10.75)–(10.36 + 10.36) [the first (set of) E_x is in ^{13}C, the second in ^{13}N]: see (81AJ01).

13. $^{10}\text{B}(^7\text{Li}, \alpha)^{13}\text{C}$ $\qquad Q_m = 21.4080$

Angular distributions have been measured at $E(^7\text{Li}) = 5.20$ MeV for the α_0, α_1, α_{2+3} and α_4 groups: see (81AJ01).

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

At $E(^{10}\text{B}) = 100$ MeV angular distributions are reported for the transitions to ^{13}C*(0, 3.7, 7.5, 11.8): see (81AJ01).

15. $^{11}\text{B}(\text{d}, \gamma)^{13}\text{C}$ $\qquad Q_m = 18.6790$

The 90° γ_0 excitation curve measured for $E_d = 1.0$ to 12.0 MeV shows resonant structure at $E_d = 2.0 \pm 0.1$ and 4.0 ± 0.1 MeV, $\Gamma \approx 0.6$ and ≈ 1 MeV, corresponding to states at $E_x = 20.4$ and 22.1 MeV: see Table 13.9 and (86AJ01). More recently (85AU10) have studied the 90° γ_0 differential cross sections at $E_{\vec{d}} = 1.65$ to 3.5 MeV, angular distributions at 1.6, 1.8, 2.0 and 4.0 MeV, and analyzing powers at $E_{\vec{d}} = 2.0$ and 4.0 MeV (90°) and 1.6 and 1.8 MeV (125°). The data are interpreted in terms of two doorway states at $E_x = 20.57 \pm 0.84$ and 20.20 ± 0.07 MeV with $\Gamma_{\text{c.m.}} = 5.64 \pm 0.43$ and 0.56 ± 0.09 MeV, respectively (85AU10). See also reaction 22 and (90HO06).

16. (a) $^{11}\text{B}(\text{d}, \text{n})^{12}\text{C}$ $\qquad Q_m = 13.7326$ $\qquad E_b = 18.6790$
(b) $^{11}\text{B}(\text{d}, 2\text{n})^{11}\text{C}$ $\qquad Q_m = -4.989$

The yields of neutron and 15.1 MeV γ-rays have been measured in the range $E_d = 0.2$ to 11 MeV: see Table 13.9. At $E_{\vec{d}} = 79$ MeV, VAP measurements are reported for ^{12}C*(0, 4.4, 9.6, 12.7, 15.1) (87FO22, 86FO08). See also (81AJ01). The thick-target yield in reaction (b) has been measured for $E_d = 7.00$ to 16.01 MeV: see (86AJ01). See also ^{12}C in (90AJ01).

17. (a) $^{11}\text{B}(\text{d}, \text{p})^{12}\text{B}$ $\qquad Q_m = 1.145$ $\qquad E_b = 18.6790$
(b) $^{11}\text{B}(\text{d}, \text{d})^{11}\text{B}$

Table 13.9: Resonant structure in $^{11}B + d$ [a]

Resonant structure in yield of (MeV ± keV)							$\Gamma_{c.m.}$ (keV)	E_x (MeV)
γ_0	n_0	n_1	n_2	n_3	$\gamma_{15.1}$	α [b]		
		1.2						19.7 [c]
	1.45						≈ 600	19.90
	1.6	1.8				1.85	≈ 200	20.24
2.0 ± 100[d]								20.4
		2.2			2.180 ± 10		116 ± 10	20.52
					3.080 ± 15		159 ± 15	21.28
	3.6				3.71 ± 20		114 ± 21	21.81
4.0 ± 100[c]	4.23	4.0	4.1		4.4		≈ 1000	22.1
		(5.2)						(23.1)
	9.6	9.6	9.6	9.6				26.8
	10.4		10.4	10.4				27.5

[a] For references see Table 13.10 in (81AJ01).
[b] Yield of α_0, α_1, α_2, α_3.
[c] $J^\pi = \frac{5}{2}^-$ is suggested.
[d] (81KA16): part of the GDR. More recent work (see reaction 15) suggests two states at $E_x = 20.20 \pm 0.07$ and 20.57 ± 0.84 MeV with $\Gamma_{c.m.} = 0.56 \pm 0.09$ and 5.64 ± 0.43 MeV, respectively (85AU10).

For reaction (a) see (81AJ01, 86AJ01). For $E_d = 2.99$ to 6.99 MeV the activation cross section does not show any evidence of structure (85AB10). For reaction (b) see (81AJ01). See also ^{12}B in (90AJ01).

18. ^{11}B(d, α)^{9}Be $\quad Q_m = 8.0314 \quad E_b = 18.6790$

At low energies the excitation functions for α_0 and α_1 increase monotonically: see (70AJ04). Then at $E_d = 1.85$ MeV a pronounced resonance is observed in the α_0, α_1, α_2 and α_3 yields: see Table 13.9. Some gross structure is also observed in these yields for $E_d = 1.0$ to 3.2 MeV: see (81AJ01). See also ^{9}Be in (88AJ01).

19. ^{11}B(^{3}He, p)^{13}C $\quad Q_m = 13.1855$

Levels derived from proton groups are displayed in Table 13.11 of (81AJ01). [The only level parameters included in the values of Table 13.4 are $E_x = 7500 \pm 12$ keV and $\Gamma_{\rm c.m.} < 5$, 70 ± 10 and 150 ± 30 keV for ^{13}C*(7.49, 7.69, 8.86).] The neutron decays of ^{13}C*(6.86, 9.90, 11.75) are to ^{12}C$_{\rm g.s.}$ (99 ± 9)% and (100 ± 20)% for the first two states, and to ^{12}C*(0, 4.4) (67 ± 16)% and (33 ± 8)% for the third (73AD1A). The decay parameters for the first $T = \frac{3}{2}$ state, ^{13}C*(15.11), are shown in Table 13.6. See also (86AJ01).

20. ^{11}B(α, d)^{13}C $\quad Q_m = -5.1677$

Angular distributions have been measured at $E_\alpha = 15.1$ to 31.2 MeV: see (81AJ01, 86AJ01). See also (87BRZV) and (84BE23; theor.).

21. (a) ^{11}B(^{6}Li, α)^{13}C $\quad Q_m = 17.2040$
(b) ^{11}B(^{7}Li, ^{5}He)^{13}C $\quad Q_m = 9.06$

For reaction (a) see (81AJ01). For reaction (b) see ^{5}He in (88AJ01) and (90DA03).

22. ^{12}C(n, γ)^{13}C $\quad Q_m = 4.94635$

The thermal capture cross section is 3.53 ± 0.07 mb. The capture is $(67.47 \pm 0.92)\%$, $(0.16 \pm 0.01)\%$ and $(32.36 \pm 0.44)\%$ via ^{13}C*(0, 3.09, 3.68): see (86AJ01) for references and additional information. Based on unpublished measurements quoted in (86AJ01), the energies of the γ-rays involved in C $\rightarrow$ 0, C $\rightarrow$ 3.68 and 3.68 $\rightarrow$ 0 are 4946.362 ± 0.021, 1261.855 ± 0.006 and 3684.507 ± 0.019 keV. The branching ratios for the decay of ^{13}C*(3.68) to ^{13}C*(0, 3.09) are $(99.3 \pm 2.0)\%$ and $(0.74 \pm 0.05)\%$, respectively: see (86AJ01). (90WA22) proposes 3683.915 ± 0.015 keV for $E_\gamma[3.68 \rightarrow 0]$.

Differential cross sections for γ_0 (90°) have been studied for E_n = 6.5 to 18.5 MeV (87AU02), 7.0 to 19.5 MeV (86BE17) and at 7.8, 9.3 and 10.8 MeV (90HA19). Broad structures are seen at ≈ 9 and 17.2 MeV (^{13}C*(13.2, 20.8)) [the latter has $\Gamma \approx 2.5$ MeV]. It should be noted that the cross sections reported by (87AU02) are substantially higher than those reported in the other two references. The variation of the cross section with energy is similar to that from the ^{13}C(γ, n$_0$) reaction but the magnitudes of the cross section are smaller: see, for instance, (90HA19). Angular distributions and analyzing powers of γ_0 for $E_n = 12.0$ to 18.8 MeV suggest two doorway states at $E_x = 21.1 \pm 0.6$ and 20.52 ± 0.07 MeV with $\Gamma = 4.2 \pm 0.4$ and 0.51 ± 0.07 MeV, respectively (84WO05). See also (89HU15). For work to 50 MeV see (88DO1E; prelim.). See also (86MU1B, 86RA1B, 86WE1D, 88MCZT), (88MA1U, 89GU1J; astrophysics) and (87HO23, 87LY01: theor.).

23. (a) ^{12}C(n, n)^{12}C $\qquad E_b = 4.94635$

(b) ^{12}C(n, n′)^{12}C*

(c) ^{12}C(n, n′)3^{4}He $\qquad Q_m = -7.27473$

(d) ^{12}C(n, 2n)^{11}C $\qquad Q_m = -18.7215$

The coherent scattering length (thermal, bound) $a_{coh} = 6.6535 \pm 0.0014$ fm; $\sigma_{scatt} = 4.7456 \pm 0.0020$ (79KO26).

Total cross sections have been measured in the range E_n = 1 keV to 273 GeV/c [see (81AJ01, 86AJ01)] and at 0.14, 1.3 and 2.1 MeV (88KO18) and 160 to 575 MeV (88FR23): see the compilation of (88MCZT). See also (86BA40). Various elastic, inelastic and nonelastic cross sections have been reported over a wide range of energies: [see (88MCZT, 86AJ01)], most recently at 6.23 to 13.75 MeV (86BO1M; prelim.; elastic and inelastic scattering cross sections), from 16.5 to 22.0 MeV (89OL02, 89OL1C; σ_t, σ_{el} and σ to ^{12}C*(4.4, 7.7, 9.6)) and from threshold to 25 MeV (88WE06; prelim.; cross section for scattering to ^{12}C*(4.4)). Polarization measurements have been reported for E_n = 1.5 to 16.3 MeV [see (76AJ04, 81AJ01, 86AJ01)] and at E_n = 15.55 to 17.35 MeV (87TO03, 87TO07) and 18.2 MeV (88TO01). See also (86BE2D, 87BEYP).

Observed resonances are displayed in Table 13.10 here, and in Table 13.13 in (81AJ01) [the latter for (n, n′$\gamma_{4.4}$)]. In Table 13.10 the assignment of the broad states above $E_x = 11.7$ MeV are from phase-shift analyses ($\sigma(\theta)$ and A_y) referred to here and in (86AJ01). Five weak anomalies in the total cross section are thought to be due to $T = \frac{3}{2}$ states (87HI03).

For reactions (c) and (d) see reactions 23 and 24 in (86AJ01) and (88MCZT). For pion production see (88BU16). See also ^{12}C in (90AJ01) and (84BE1L, 85FI09, 85KU1F, 85ME16, 85RA1E, 86BAYL, 86DR1D, 86HOZY, 87NEZY, 88AN1F, 89SA1J), (86AL1N, 86WE1B, 86WI1B, 89OL1C; applied), (88FR1M; astrophys.), (87BR06, 88MA1H) and (85KO1U, 85TI07, 86BE2F, 86LI1R, 88BA1P, 88RU1C, 89MI20, 90LE1Q; theor.).

24. ^{12}C(n, p)^{12}B $\qquad Q_m = -12.587 \qquad E_b = 4.94635$

Table 13.10: Resonances in ^{12}C(n, n)^{12}C [a]

E_{res} (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	^{13}C* (MeV)	J^π	Γ_n/Γ
2.079 ± 3	6	6.864[b]	$\frac{5}{2}^+$	
2.819 ± 3	1.2 ± 0.3	7.546[b]		
2.94 ± 10	124 ± 7	7.66[b]	$\frac{3}{2}^+$	
3.472 ± 15	1000 ± 50	8.149	$\frac{3}{2}^+$	
4.259 ± 15	210 ± 15	8.874	$\frac{1}{2}^-$	1.00
4.93707 ± 0.07[c]	1.9 ± 0.15[c]	9.4998[b]	$(\frac{9}{2}^+)$	1.00
5.368 ± 5	26 ± 3	9.897	$\frac{3}{2}^-$	0.70 ± 0.10
6.294 ± 5	53 ± 4	10.751	$\frac{7}{2}^-$	0.70 ± 0.10
6.5		10.9		
6.558 ± 8	37 ± 4	10.994	$(\frac{1}{2}^+)$	0.40 ± 0.10
6.7		11.1		
7.35 ± 50	129 ± 40	11.72	$\frac{3}{2}^-$	0.80 ± 0.08
7.62 ± 90	494 ± 80	11.97	$\frac{5}{2}^+$	0.51 ± 0.06
7.78 ± 80	538 ± 65	12.12	$\frac{3}{2}^+$	0.28 ± 0.05
7.79 ± 50	77 ± 30	12.13	$\frac{5}{2}^-$	0.43 ± 0.06
7.80 ± 70	426 ± 70	12.14	$\frac{1}{2}^+$	0.50 ± 0.07
7.94 ± 70	186 ± 50	12.27	$\frac{3}{2}^-$	0.73 ± 0.08
8.12 ± 50	114 ± 40	12.43	$\frac{7}{2}^-$	0.42 ± 0.06
9.35	619 ± 50	13.57	$\frac{7}{2}^-$	0.18 ± 0.03
9.96		14.13	$\frac{3}{2}^-$	
10.88	450	14.98	$\frac{7}{2}^-$	
11.02[d]		15.11	$\frac{3}{2}^-; T = \frac{3}{2}$	0.062 ± 0.016

Table 13.10: Resonances in ^{12}C(n, n)^{12}C^{a} (continued)

E_{res} (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	^{13}C* (MeV)	J^{π}	Γ_n/Γ
11.20		15.27	$\frac{9}{2}^{+}$	
11.40		15.46	$\frac{3}{2}^{-}$	
12.1	230	16.1	$(\frac{5}{2}^{-}+\frac{7}{2}^{-})$	
13.65^{d}	17 ± 6	17.533 ± 3		
14.25^{d}	12 ± 7	18.082 ± 3		
15.80^{e}	≥ 500	19.51	$\frac{5}{2}^{-}$	
16.39^{d}	11 ± 8	20.057 ± 4		
16.45^{e}	1090	20.11	$\frac{1}{2}^{-}$	0.16
16.45^{e}	440	20.11	$\frac{5}{2}^{+}$	0.05
16.53^{e}	630	20.19	$\frac{7}{2}^{+}$	0.11
16.65^{e}	1560	20.30	$\frac{7}{2}^{-}$	0.08
16.70^{e}	320	20.34	$\frac{9}{2}^{+}$	0.06
16.90^{e}	≈ 500	20.53	$\frac{5}{2}^{-}$	
18.18^{d}	18 ± 9	21.703 ± 4		
19.6 ± 200	≈ 1000	23.0		

a For earlier references and additional information see Tables 13.10 in (70AJ04), 13.16 in (76AJ04), 13.12 in (81AJ01) and 13.10 in (86AJ01). See the discussions in (82KN02, 85TO02, 87TO03).
b For the decay of these states, reported in the interaction of ^{14}N ions (35 MeV/A) with a silver target, see (89HE24).
c Derived from a lorentzian probability plot (80CI03).
d Weak resonance anomaly attributed to $T = \frac{3}{2}$ state (87HI03) [and see for $(J+\frac{1}{2})\ \Gamma_{n0}/\Gamma$].
e From phase-shift analysis by (87TO03).

The cross section exhibits a weak resonance corresponding to $E_x \approx 20.5$ MeV and a stronger structure at $E_x \approx 21.5$ MeV: see (76AJ04). See also the compilation of (88MCZT). The excitation function for $E_n = 30$ to 150 MeV is being studied (88RAZX; prelim.). For proton production for $E_n = 300$ to 580 MeV see (87FR16). See also ^{12}B in (90AJ01) and (85AZ1A, 86FO1E, 89BE2P, 89SOZY), (86RO1F; applied), (88FR1M; astrophysics), (88MA1H) and (86KO26, 88PE01; theor.).

25. (a) ^{12}C(n, d)^{11}B $\quad Q_m = -13.7326 \quad E_b = 4.94635$
(b) ^{12}C(n, t)^{10}B $\quad Q_m = -18.9295$

For deuteron and triton emission at E_n = 300 to 580 MeV, see (87FR16). See also (86RO1F; applied), (88FR1M; astrophysics), (88MA1H) and (86KO26; theor.).

26. ^{12}C(n, α)^{9}Be $\quad Q_m = -5.7012 \quad E_b = 4.94635$

The cross section for the α_0 group shows a broad structure at $E_n \approx 8$ MeV: see (81AJ01). For other work see (88MCZT, 86AJ01). See also (88DRZZ), (86RO1F, 86WI1B; applied) and (88MA1H).

27. ^{12}C(p, π^+)^{13}C $\quad Q_m = -135.4045$

Angular distributions have previously been reported for E_p = 147 to 250 MeV: see (86AJ01). ^{13}C*(0, 3.09, 3.68, 3.85, 6.86, 9.50) have been populated. In the more recent work at E_p = 354 MeV it is found that at 21° the π^+ spectrum is dominated by the group to the (2p1h) $\frac{9}{2}^+$ state at 9.50 MeV. Angular distributions have been measured to ^{13}C*(0, 3.09 + 3.68 + 3.85, 9.50) (87HU08) [see also for a discussion of the energy dependence of the total cross section, and of the influence of the Δ-resonance]. (87HO21) report a measurement of ground-state differential cross sections at E_p = 186 MeV.

At $E_{\vec{p}}$ = 200 MeV angular distributions and A_y measurements have been reported to ^{13}C*(0, 3.09, 3.7 [u], 6.86, 7.5 [u], 9.5, 21.4) (89KO21). For the strongly populated group to ^{13}C*(21.4) $A_y \approx 0$ at all angles. The results are suggestive of those for a $\frac{7}{2}^+$; $T = \frac{3}{2}$ state, but other explanations are also possible (87KO01, 89KO21). See also (90JAZZ). For inclusive differential cross sections and A_y at $E_{\vec{p}}$ = 400 and 450 MeV see (86FA03). For other polarization measurements see (86AJ01). For total cross sections at E_p = 180 and 201 MeV see (85BI04). See also (81AJ01), the "General" section, (87SEZY, 88SEZT), (86JA1H) and (85IQ01, 86MI1K, 87KU06; theor.).

28. ^{12}C(d, p)^{13}C $\quad Q_m = 2.7218$

Measurements of proton groups and γ-rays are summarized in Table 13.11. Angular distributions have been studied at many energies to E_d = 80.2 MeV [see (81AJ01, 86AJ01)] as well as at $E_{\vec{d}}$ = 12 MeV (88LA03; to ^{13}C*(0, 3.09, 3.68, 3.85, 6.86, 7.50, 7.55, 7.69)) and at E_d = 30 MeV (86OH01; to all even-parity states below E_x = 10 MeV and to ^{13}C*(0, 3.68, 7.55, 10.75, 11.08)). See also (89BE2K, 89IE01, 89NA1R).

For τ_m measurements see Table 13.5 and for γ-decay see Table 13.6. For work at very high energies see (87AZ1C, 89AV02). See also ^{14}N, (85LI1H, 88VI1A, 89VI1E, 90CH1J; applied), (86SI1D; computer program) and (84BL21, 86IS1F; theor.).

Table 13.11: Levels of ^{13}C from ^{12}C(d, p)^{13}C [a]

^{13}C (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	l_n	J^π	S [b]
0		1	$\frac{1}{2}^-$	0.77
3.089443 ± 0.020 [c]		0	$\frac{1}{2}^+$	0.65
3.684482 ± 0.023 [c]		1	$\frac{3}{2}^-$	0.14
3.853783 ± 0.022 [c]		2	$\frac{5}{2}^+$	0.58
6.86		2	$\frac{5}{2}^+$	0.017
7.470 ± 20				
7.533 ± 20				0.009
7.641 ± 20	70 ± 15			0.11
8.4 ± 300	1100 ± 300	2	$\frac{3}{2}^+$	
8.86		1	$\frac{1}{2}^-$	[d]
9.500 ± 20		(1)	$(\frac{3}{2}^-)$ [e]	
9.897 ± 20		1	$\frac{3}{2}^-$	[d]
10.755 ± 5	56 ± 2			0.026
10.818 ± 5	24 ± 3			
10.997 ± 8	82 ± 15			
11.080 ± 5	< 8			
11.748 ± 10	107 ± 14			
11.851 ± 5	68 ± 4			
11.97 ± 40 [f]	≈ 260			
12.108 ± 5	81 ± 8			

[a] For references and additional information see Tables 13.14 in (81AJ01) and 13.11 in (86AJ01).
[b] DWBA fit at $E_d = 30$ MeV (86OH01). For earlier results see (81AJ01, 86AJ01).
[c] (80WA24): E_γ for the 3.85 → 3.68 transition is 169.300±0.004 keV. Using $E_x = 3684.507 \pm 0.019$ keV [see reaction 22] and this value for E_γ, E_x for the higher state is 3853.807 ± 0.019 keV, which we adopt. I am indebted to Dr. E.K. Warburton for his comments. See also Table 13.5 and the "General" section. (90PI05) report $E_x = 3089.42 \pm 0.07$, 3684.50 ± 0.06, 3853.67 ± 0.20 and 6864.07 ± 0.46 keV from measurements of proton groups in a spectrograph.
[d] Not observed (86OH01).
[e] Known to be $\frac{9}{2}^+$.
[f] May correspond to unresolved states.

29. ^{12}C(t, d)^{13}C $\qquad Q_m = -1.3109$

At $E_t = 38$ MeV angular distributions have been measured to ^{13}C*(0, 3.09, 3.68, 3.85, 6.86, 7.5, 7.69, 8.2, 9.5, 10.7) (88SI08). See also (81AJ01).

30. ^{12}C(^{3}He, 2p)^{13}C $\qquad Q_m = -2.7718$

At $E(^3\vec{\rm He}) = 33$ MeV ^{13}C*(3.85) is strongly populated. ^{13}C*(0, 8.0 (broad), 9.5) have also been studied (86KA44). See also (81AJ01) and ^{15}O.

31. ^{12}C(α, ^{3}He)^{13}C $\qquad Q_m = -15.6314$

Angular distributions of the ^{3}He particles to the first three states of ^{13}C have been measured in the range $E_\alpha = 56$ to 139 MeV. The ground-state distributions in this, and in the mirror reaction ^{12}C(α, t)^{13}N, have also been compared: see (81AJ01). See also (89KU1E; $E_\alpha = 94$ MeV; g.s.; prelim.) and (89GA1H).

32. ^{12}C(^{7}Li, ^{6}Li)^{13}C $\qquad Q_m = -2.304$

At $E(^7\rm{Li}) = 34$ MeV angular distributions have been studied to ^{13}C*(0, 3.09, 3.85). The analysis by FRDWBA leads to $S = 0.65 \pm 0.06$, 0.75 ± 0.08 and 0.68 ± 0.10, respectively (86CO02). See also (88KE07; theor.). For the earlier work at $E(^7\rm{Li}) = 21.1$ and $E(^7\rm{Li}) = 48$ MeV see (81AJ01, 86AJ01).

33. ^{12}C(^{8}Li, ^{7}Li)^{13}C $\qquad Q_m = 2.9136$

At $E(^8\rm{Li}) = 14.3$ MeV, an angular distribution is reported involving $^{13}\rm{C}_{g.s.}$ (89BE28): at $\theta_{\rm lab} = 15°$, the differential cross section is ≈ 15 mb/sr.

34. ^{12}C(^{12}C, ^{11}C)^{13}C $\qquad Q_m = -13.7754$

Angular distributions have been reported at $E(^{12}\rm{C}) = 72.5$ and 93.8 MeV [see (81AJ01, 86AJ01)], at 240 MeV (85BO39; ^{13}C*(0, 3.85)) and at 300, 420 and 600 MeV (88WI09, 89WI07; $^{13}\rm{C}_{g.s.}$). See also ^{11}C in (90AJ01) and (89SA44; theor.).

35. ^{12}C(^{14}N, ^{13}N)^{13}C $\quad Q_m = -5.6071$

Angular distributions have been reported in the range $E(^{14}\text{N}) = 28$ to 154.8 MeV involving ^{13}C*(0, 3.09, 3.85, 7.3 ± 0.3): see (81AJ01). See also (86AJ01) and (87OS1E, 88KA27; theor.).

36. (a) ^{12}C(^{17}O, ^{16}O)^{13}C $\quad Q_m = 0.8029$
(b) ^{12}C(^{18}O, ^{17}O)^{13}C $\quad Q_m = -3.0982$

Angular distributions involving $^{16}\text{O}_{\text{g.s.}} + {}^{13}\text{C}_{\text{g.s.}}$ are reported at $E(^{17}\text{O}) = 40$ to 70 MeV (86FR04). For the earlier work see (81AJ01). For reaction (b) see ^{18}O in (87AJ02).

37. ^{13}B(β^-)^{13}C $\quad Q_m = 13.437$

See ^{13}B and Table 13.2.

38. (a) ^{13}C(γ, n)^{12}C $\quad Q_m = -4.94635$
(b) ^{13}C(γ, 2n)^{11}C $\quad Q_m = -23.668$

The main features of the cross sections are a sharp peak corresponding to the $T = \frac{3}{2}$ state ^{13}C*(15.11) [$\Gamma_{\gamma_0} = 19.7 \pm 2.0$ eV], the broad pigmy resonance at $E_x = 13$ MeV [on which peaks are superimposed at $E_x = 11.0$, 13.8, 16.5 and 17.8 MeV] and the giant resonance at $E_x = 24$ MeV ($\sigma_{\text{max}} = 9.5$ mb) [surrounded by shoulder resonances at $E_x = 20.8$ and ≈ 30 MeV, both of which appear to decay substantially to highly excited states of ^{12}C]. There is also some evidence for a weak resonance at ≈ 37 MeV superimposed on the high-energy tail of the GDR. A study of the angular distributions of n_0 suggests states at $E_x = 7.70$ ($\frac{3}{2}^+$), 7.95 ($\frac{3}{2}^+$), 8.95(($\frac{1}{2}^-$)), 10.0 (($\frac{3}{2}^-$)), 11.0 (($\frac{1}{2}^+$)) and 12.05 MeV (($\frac{3}{2}^+$)). See (81AJ01) for references and for additional information. See also the atlas in (88DI02), (85PY01, 88BE1T, 88HA12) and (85GO1A, 87KI1C; theor.). For comparisons with ^{12}C(n, γ) see reaction 22 and (85AU10, 86BE17).

39. (a) ^{13}C(γ, p)^{12}B $\quad Q_m = -17.533$
(b) ^{13}C(γ, d)^{11}B $\quad Q_m = -18.6790$

The integrated cross section (reaction (a)) from $E_\gamma = 17.5$ (threshold) to 28 MeV is 36 ± 5 MeV · mb. Resonances are observed at $E_x = 18.6$, (19.7), 20.7, (22), 23.5, 24.5 and (26) MeV. [σ_{max} at $E_x \approx 23$ MeV is 8 mb]. Below ≈ 18 MeV the cross section is dominated by transitions involving $T_<$ states. The states at 18.6 and 20.7 MeV have a significant $T_>$ component. The two isospin components of the GDR appear to be split by 6.8 MeV (83ZU02). For the earlier work see (81AJ01). See also (88HA12) and (87KI1C; theor.). For the cross section of reaction (b) from detailed balance calculations from ^{11}B(d, γ) see reaction 15 and (85AU10).

40. ^{13}C(e, e)^{13}C

The elastic scattering has been studied for $E_e = 80$ to 750 MeV [see (81AJ01, 86AJ01)] and (87HI09, 89MI01). The form factor for M1 elastic scattering is enhanced above $q \approx 2.5$ fm^{-1} (82HI07, 87HI09). See also (87DE1A). A number of inelastic groups have been seen: see Tables 13.12 and 13.13 (70WI04, 86HI06, 87HI09, 89MI01).

A distinct splitting of the giant resonance into two large peaks near $E_x = 20.5$ and 24.5 MeV, with widths of ≈ 3 and ≈ 4 MeV, respectively, is observed. It is suggested that these are groupings of narrower peaks. The $E_x = 20.5$ and 24.5 MeV groups are probably $T = \frac{1}{2}$ and $T = \frac{3}{2}$, although the 4 MeV splitting is somewhat smaller than expected: see (81AJ01). See also (84CH1K, 85SA06, 86CH2E, 86DO11, 87HO23, 88MI1J, 89AM02, 89WO1E, 90JE1B; theor.).

41. ^{13}C($\pi^\pm$, $\pi^\pm$)^{13}C

Angular distributions have been measured at $E_\pi = 20$ to 180 MeV [see (81AJ01) and Table 13.13 in (86AJ01)], at 65 MeV (88MI02; several states up to $E_x = 11.8$ MeV) and at $E_{\pi^-} = 30$ and 50 MeV (90SE04; elastic). Enhanced in π^- scattering are ^{13}C*(0, 3.09, 3.85, 9.50, 21.60 ± 0.05), the latter very strongly but with a large uncertainty. Enhanced in π^+ scattering are ^{13}C*(3.68, 7.55, 8.86, 11.82, 16.05 ± 0.05, 17.92 ± 0.05, 21.37 ± 0.05). The data for ^{13}C*(9.50, 21.60, 16.05, 21.37) indicate pure neutron particle-hole excitations for the first two states and pure proton excitation for the latter two, however with large uncertainties except for ^{13}C*(9.5). Spin assignments are $\frac{9}{2}^+$ for ^{13}C*(9.50); $\frac{7}{2}^+$ or $\frac{9}{2}^+$ for ^{13}C*(16.05, 17.92, 21.37, 21.60); $\frac{5}{2}^+$ and/or $\frac{7}{2}^+$ for ^{13}C(11.82) [unresolved doublet?]. The π^-/π^+ asymmetry near 21.5 MeV suggests that there is isospin mixing between $T = \frac{1}{2}$ and $\frac{3}{2}$ states of $J^\pi = \frac{7}{2}^+$ and/or $\frac{9}{2}^+$ (82SE04, 83SE15). Analyzing powers for elastic scattering on $^{13}\vec{\mathrm{C}}$ have been studied at $E_{\pi^\pm} = 100$ MeV (90SM1B) and 114 to 226 MeV (90YE1C) [both preliminary]. See also the “General” section and (86AMZX; theor.).

Table 13.12: Electromagnetic transitions [a] in ^{13}C from ^{13}C(e, e$'$)^{13}C

E_x (MeV)	J^π	Mult.	$\Gamma_{\gamma 0}$ (eV)	$\Gamma_{\gamma 0}/\Gamma_w$ (W.u.)
3.09	$\frac{1}{2}^+$	C1	0.52	0.047 ± 0.010 [a]
3.68	$\frac{3}{2}^-$	M1	0.36 ± 0.05 [b]	0.34
		C2	3.6 ± 0.4 [b]	3.5
3.85	$\frac{5}{2}^+$	C3	6×10^{-8}	1.3 ± 0.2 [a]
6.86	$\frac{5}{2}^+$	M2	$(6.9 \pm 3.6) \times 10^{-5}$ [b]	0.055
		C3	3×10^{-7}	0.10 ± 0.06 [a]
7.55 [c]	$\frac{5}{2}^-$	C2	0.115 ± 0.006 [b]	3.2
8.86 [d]	$\frac{1}{2}^-$	C0	2.1 ± 0.4 [b,e]	
		M1	3.4 ± 0.5 [b]	0.23
9.50 [f]	$\frac{9}{2}^+$	M4		
9.90	$\frac{3}{2}^-$	M1	0.32 ± 0.05 [b]	0.016
		C2	$(6.3 \pm 2.1) \times 10^{-3}$ [b]	0.045
11.08	$\frac{1}{2}^-$	C0	2.6 ± 0.3 [b,e]	
		M1	1.0 ± 0.2 [b]	0.036
11.85 [g]	$\frac{7}{2}^+$	C3		
11.95 [g]	$(\frac{5}{2}^+)$	C3		
15.11	$\frac{3}{2}^-$	M1	22.7 ± 2.6 [b]	0.31
		C2	[h]	
16.08 [i]	$(\frac{7}{2}^+)$	M4		
21.47 [i]	$\frac{9}{2}^+$	M4		

[a] (89MI01) [see for form factors up to multipolarity three]. Table V in (89MI01) shows $B(C\lambda, \uparrow)$. B(C1, $\downarrow$) and B(C3, $\downarrow$) are given here with errors double the statistical errors given in (89MI01) [see also footnote [g]]. I am greatly indebted to Dr. D.J. Millener for this table, which he prepared. For the earlier work see Tables 13.15 in (81AJ01) and 13.12 in (86AJ01) [see also footnotes [d,e]].

[b] (69WI22, 70WI04).

[c] The dominant 7.55 MeV $\frac{5}{2}^-$ level is not resolved from the much weaker 7.49 and 7.69 MeV levels [see (89MI01)].

[d] $\Gamma = 190 \pm 35$ keV.

[e] Monopole matrix element in fm^2.

[f] For form factors see (86HI06, 87HI09).

[g] Unresolved doublet, B(C3, $\uparrow$) ≈ 27.5 W.u. [see (89MI01)].

[h] The low q (e, e$'$) data give a C2 transition strength of 0.5 W.u. (70WI04, 69WI22). However, data points near the peak of the C2 form factor (89MI01) suggest that B(C2, $\downarrow$) is about a factor of two smaller, consistent with 0.28 ± 0.10 W.u. for the analog transition in ^{13}N (see Table 13.6).

[i] Probably unresolved [see (HI86C) for discussion and for form factors].

Table 13.13: Additional states of ^{13}C from ^{13}C(e, e$'$)^{13}C* (89MI01) [a]

E_x (MeV±keV)	$\Gamma_{c.m.}$ (keV)	E_x (MeV±keV)	$\Gamma_{c.m.}$ (keV)
11.845 ± 5	144 ± 5	16.080 ± 7	148 ± 13
12.187 ± 10	109 ± 48	(16.183 ± 28)	(40 ± 20)
12.438 ± 12	160 ± 37	(18.497 ± 10)	(91 ± 23)
14.390 ± 15	281 ± 65	18.699 ± 5	98 ± 11
14.582 ± 10	227 ± 41	20.021 ± 13	232 ± 27
14.983 ± 10	380 ± 53	20.429 ± 8	112 ± 23
15.526 ± 11	147 ± 23	21.466 ± 8	268 ± 14

[a] Some other states may also have been observed: see (89MI01).

42. ^{13}C(n, n)^{13}C

Angular distributions have been measured at $E_n = 4.5$ to 17.92 MeV [see (86AJ01)], at 4.55 to 10.99 MeV (RE89, $n_0 \rightarrow n_3$) and at 24 MeV (85PE10; n_0). At $E_n = 8.1$ to 11 MeV ^{13}C*(7.55) [$J^\pi = \frac{5}{2}^-$] is involved in the sequential decay to ^{12}C$_{g.s.}$ (87RE01). See also ^{14}C, (88RE09; computer) and (86AL1L; theor.).

43. ^{13}C(p, p)^{13}C

Angular distributions have been studied at $E_p = 1.37$ MeV to 1 GeV [see (81AJ01, 86AJ01)] and at 30.95 MeV (88BA30); p_0), 35 MeV (86OH03: $p_0 \rightarrow p_3$), 71.8 MeV (89VO05, 90VO02; p_0; polarized protons), 135 MeV (88CO05, to 33 states below$E_x = 23$ MeV), 500 MeV (90HO06; p_0; polarized protons), 0.8 GeV (85BL22; p_0) and 1 GeV (85AL1F; p_0). (88CO05) assign $\frac{7}{2}^+$ for ^{13}C*(11.85) [in agreement with the (e, e) work]. $(\frac{5}{2}^+)$ for^{13}C*(11.95, 14.98), $\leq \frac{5}{2}$ for ^{13}C*(12.11, 12.19), $(\frac{7}{2}, \frac{9}{2})^+$ for ^{13}C*(14.58, 21.47), $(\frac{7}{2}^+)$ for ^{13}C*(16.08), $(\frac{3}{2}, \frac{5}{2})$ for ^{13}C*(17.70), $(\frac{3}{2}, \frac{5}{2})^+$ for ^{13}C*(18.70), $(\frac{7}{2}, \frac{9}{2})^+$ for ^{13}C*(21.47), $\geq \frac{5}{2}$ for ^{13}C*(21.81) and $\leq \frac{5}{2}$ for ^{13}C*(22.2, 23). The widths of ^{13}C*(12.19 ± 0.01, 22.2 ± 0.1) are 110 ± 50 keV and 1100 ± 500 keV, respectively. [The widths for ^{13}C*(11.95, 12.11, 12.19) are appreciably smaller than those reported in Table 13.10.] A state at $E_x = 20.93 \pm 0.1$ MeV with $\Gamma = 240 \pm 100$ keV is suggested (88CO05, S. Collins, Ph.D. thesis, and B. Spicer, private communication). See also ^{14}N, (85PE10) and (86AMZX, 86RA05, 87BE1M, 87BE1P, 88GOZH, 88RA08, 89AM02, 89AM05, 89BEXT, 89GO14, 89KU14, 89KU32, 89RA1O, 90DU01; theor.).

44. (a) ^{13}C(d, d)^{13}C
(b) ^{13}C(t, t)^{13}C

Angular distributions (reaction (a)) have been measured at $E_d = 0.71$ to 56 MeV: see (81AJ01, 86AJ01). See also ^{15}N. Angular distributions for the tritons to ^{13}C*(0, 3.09, 3.68, 3.85, 7.55) have been studied at $E_t = 38$ MeV (SI88C). See also (81AJ01).

45. ^{13}C(^{3}He, ^{3}He)^{13}C

Angular distributions of elastically scattered ^{3}He ions have been studied at $E(^3\text{He}) = 12$ to 41 MeV [see (81AJ01)] and at 39.6 MeV (87BUZR; prelim.) as well as at $E(^3\text{He}) = 33$ MeV (86DR03). Angular distributions have also been reported at $E(^3\text{He}) = 43.6$ MeV for the ^{3}He ions to ^{13}C*(3.09, 3.68, 3.85, 6.86, 7.49 + 7.55, 7.69, 8.86, 9.50, 9.90, 10.75 + 10.82, 11.08, 11.85, 15.11, 16.0) [and these have been compared to the analog states reached in the ^{13}C(^{3}He, t)^{13}N reaction] (81PE08). See also (89DE1Q) and (86ZE04, 87RA36; theor.).

46. ^{13}C(α, α)^{13}C

Angular distributions have been studied at $E_\alpha = 15$ to 40.5 MeV [see (81AJ01)], at $E_\alpha = 35.5$ MeV (81PE08; to ^{13}C*(3.09, 3.68, 3.85, 6.86, 7.49 + 7.55, 7.69, 8.86, 9.50, 11.08, 11.85)) as well as at $E_\alpha = 48.7$ and 54.1 MeV (87AB03; α_0). For ^{13}C*(7.69), $E_x = 7686 \pm 6$ keV, $\Gamma_{\text{c.m.}} = 70 \pm 5$ keV (80FU04; also line shapes). An angular correlation study at $E_\alpha = 24.35$ MeV of the (α, αn) reaction to $^{12}\text{C}_{\text{g.s.}}$ has determined the substate population of ^{13}C*(6.86), $J^\pi = \frac{5}{2}^+$ (84DE1L). $\Gamma_\gamma/\Gamma \leq 3 \times 10^{-4}$ for ^{13}C*(6.86). The evidence for states near 7.5 MeV is less clear cut (85DE11). See also (87BU27) and (85SH1D; theor.).

47. (a) ^{13}C(^{6}Li, ^{6}Li)^{13}C
    (b) ^{13}C(^{7}Li, ^{7}Li)^{13}C

Angular distributions of elastically scattered Li ions have been studied at $E(\text{Li}) = 4.5$ to 40 MeV [see (81AJ01, 86AJ01)] as well as at $E(^7\text{Li}) = 34$ MeV (87CO02, 87CO16). At $E(^7\text{Li}) = 34$ MeV angular distributions involving ^{13}C*(3.09, 3.68, 7.55) are also reported (87CO02). For the (^{6}Li, αd) breakup via states of ^{17}O see (86AJ01) and (87CA30, 89WUZX). For fusion and breakup cross sections see (86AJ01). See also (89DE34) and (88DEZU, 88DE1F; theor.).

48. ^{13}C(^{9}Be, ^{9}Be)^{13}C

The elastic scattering has been studied at $E(^{13}C) = 28.1$ and 36.2 MeV [see (81AJ01)] and at $E(^{9}Be)= 50.5$ MeV (90BA16; also to $^{13}C^*(3.68, 7.55)$). For cross section measurements see (84DA17, 86CU02). See also (86MI24; theor.).

49. (a) $^{13}C(^{10}B, ^{10}B)^{13}C$
(b) $^{13}C(^{11}B, ^{11}B)^{13}C$

Elastic angular distributions have been measured at $E(^{10}B) = 18$ to 80.9 MeV: see (86AJ01). For fusion and other cross section measurements see (86AJ01) and (88MA07). See also (85CU1A).

50. (a) $^{13}C(^{12}C, ^{12}C)^{13}C$
(b) $^{13}C(^{13}C, ^{13}C)^{13}C$
(c) $^{13}C(^{14}C, ^{14}C)^{13}C$

Angular distributions for reaction (a) have been reported for $E(^{12}C) = 10$ to 87 MeV and $E(^{13}C) = 12$ to 36 MeV [see (81AJ01, 86AJ01)], and at $E(^{12}C) = 94.5$ MeV (86BA80; elastic) and $E(^{13}C) = 16.3$ to 26.5 MeV (88VO01; $^{13}C^*(0, 3.09, 3.85)$) and 260 MeV (85BO39; $^{13}C_{g.s.} + ^{12}C^*(0, 4.4)$). Elastic distributions for reaction (b) have been studied at $E(^{13}C) = 15$ to 24 MeV [see (81AJ01)] and at 14 and 16 MeV (88TR01). Angular distributions for reaction (c) have been measured at $E(^{13}C) = 15$ MeV [see (81AJ01)] and at 20 to 27.5 MeV (88BI11; $^{13}C(0, 3.09, 3.85)$). For excitation functions, fusion and evaporation cross sections see (86AJ01) and (86HA30, 88TR01). For a spin-flip probability study see (85BY1A) and ^{12}C in (90AJ01).

See also (82BA1D, 85BA1T, 88TR01; astrophysics), (84FR05, 85BE1A, 85CU1A, 85KO1J, 86SN1B, 86ST1A, 87GR1K, 87IM1C, 88BE1W, 89VO1D, 90VO1E) and (85HU04, 85IM1B, 85SA1D, 86BA1D, 86BA69, 86EL02, 86HA13, 86KA1B, 86SA1D, 86VI08, 87AR1E, 87BO48, 87FR06, 87IM01, 87MA22, 87TH04, 88BR29, 88JA14, 88KA27, 88MI25, 88PA07, 89ER1B, 89FR08, 89HA19, 90BA03; theor.).

51. (a) $^{13}C(^{14}N, ^{14}N)^{13}C$
(b) $^{13}C(^{15}N, ^{15}N)^{13}C$

Elastic angular distributions have been measured at $E(^{14}N) = 19.3$ to 35 MeV and at $E(^{13}C) = 105$ MeV: see (81AJ01, 86AJ01). See also (89BEZC: γ-ray yields, reaction (b)) and (86BA69; theor.).

52. (a) $^{13}C(^{16}O, ^{16}O)^{13}C$
(b) $^{13}C(^{17}O, ^{17}O)^{13}C$
(c) $^{13}C(^{18}O, ^{18}O)^{13}C$

Elastic angular distributions have been measured for reaction (a) at $E(^{16}O)$ = 10 to 30 MeV and at $E(^{13}C)$ = 36 and 105 MeV [see (81AJ01)] as well as at $E(^{16}O)$ = 42 to 65 MeV (89FR04) and at 108.15 MeV (86BA80). Those for reaction (b) are reported at $E(^{17}O)$ = 29.8, 85.4, 120 and 140 MeV; and those for reaction (c) at $E(^{18}O)$ = 15 to 31 MeV: see (81AJ01, 86AJ01). For excitation functions, breakup yields and fusion measurements see (81AJ01, 86AJ01) and (83FR17 [see, however, 88FR15], 85BE40, 85BE37, 86GA13, 86PA10). See also (85CU1A, 85HU04, 85KO1J, 85RE1C, 86ST1A, 89BEZC, 90SN1A) and (85MI13, 86BA69, 86CI01, 86MI1A, 86PA04, 87AR13, 87BA01, 87MO27, 87DA34, 87NU02, 87RE1C, 89CH2B, 89TH1A, 90IM01; theor.).

53. $^{13}C(^{24}Mg, ^{24}Mg)^{13}C$

See (86AJ01) and (86OS05; theor.).

54. (a) $^{13}C(^{27}Al, ^{27}Al)^{13}C$
(b) $^{13}C(^{28}Si, ^{28}Si)^{13}C$

For reaction (a) see (88SN1A). The elastic angular distribution for reaction (b) has been studied at $E(^{13}C)$ = 60 MeV (88YA06). For the earlier work see (81AJ01, 86AJ01). See also (89CH1K; theor.).

55. (a) $^{13}C(^{32}S, ^{32}S)^{13}C$
(b) $^{13}C(^{40}Ar, ^{40}Ar)^{13}C$

For reaction (a) see (90ME07); for (b) see (88GO12, 89RA1K). See also (86AJ01).

56. (a) $^{13}C(^{40}Ca, ^{40}Ca)^{13}C$
(b) $^{13}C(^{48}Ca, ^{48}Ca)^{13}C$

See (81AJ01, 86AJ01) and (85EL07, 86OS05; theor.).

57. ^{13}N(β^+)^{13}C $\qquad Q_m = 2.2205$

See ^{13}N.

58. ^{14}C(γ, n)^{13}C $\qquad Q_m = -8.1765$

See ^{14}C and (85PY01). See also (87GO09; theor.).

59. (a) ^{14}C(p, d)^{13}C $\qquad Q_m = -5.9519$
(b) ^{14}C(d, t)^{13}C $\qquad Q_m = -1.9192$
(c) ^{14}C(^{3}He, α)^{13}C $\qquad Q_m = 12.4013$

At $E_p = 35.0$ and 40.1 MeV angular distributions (reaction (a)) have been reported [and integrated cross sections and spectroscopic factors have been derived] for the deuterons to the $\frac{1}{2}^-$ states ^{13}C*(0, 8.86, 11.08), the $\frac{3}{2}^-$ states ^{13}C*(3.68, 9.90, 11.75, (13.28), 15.11), the $\frac{5}{2}^+$ states ^{13}C*(3.85, 6.86), the $\frac{1}{2}^+$ states ^{13}C*(3.09, 11.0), the $\frac{3}{2}^+$ states ^{13}C*(7.69, 8.2), ^{13}C*(7.5) [$J^\pi = \frac{5}{2}^-$] and ^{13}C*(9.50) [$\frac{9}{2}^+$] (90YA01). See also (81AJ01).

60. ^{14}N(γ, p)^{13}C $\qquad Q_m = -7.5506$

Angular distributions measured in the giant resonance region of ^{14}N are consistent with the proton decay of $(p_{1/2})^{-1}$ (2s1d) giant dipole states to ^{13}C$_{\rm g.s.}$ and of $(p_{3/2})^{-1}$ (2s1d) states to ^{13}C*(3.68). The population of ^{13}C*(3.09, 3.85) is also reported. For $E_{\rm b.s.} = 15.5$ to 29.5 MeV a large fraction of the neutron yield appears to be associated with sequential decay to ^{12}C via ^{13}C*(7.75, 8.86, 11.80): see (81AJ01). See also ^{14}N.

61. ^{14}N(n, d)^{13}C $\qquad Q_m = -5.3260$

Angular distributions have been determined at $E_n = 10.1$ to 14.7 MeV: see (81AJ01). See also (88YOZX; $E_n = 60$ MeV; prelim.).

62. ^{14}N(p, 2p)^{13}C $\qquad Q_m = -7.5506$

At $E_p = 46$ MeV, the summed proton spectrum shows transitions to ^{13}C*(0, 3.68, 7.5, 11.9): see (81AJ01). At $E_p = 50$ MeV ^{13}C*(0, 3.1, 3.7) are populated (84VD1A, 86VD1C). See also (87VD1A).

63. ^{14}N(d, ^{3}He)^{13}C $\qquad Q_m = -2.0571$

At $E_d = 52$ MeV, angular distributions have been measured for the ^{3}He particles to ^{13}C*(0, 3.09, 3.68, 6.86, 7.5, 8.86, 9.50, 11.9 ± 0.15) and analysed by DWBA: $J^\pi = \frac{5}{2}^-$, $\frac{1}{2}^-$, $\frac{3}{2}^-$ and $\frac{3}{2}^-$, respectively, are assigned to ^{13}C*(7.5, 8.86, 9.50, 11.9). [However, ^{13}C*(9.50) is known to have $J^\pi = \frac{9}{2}^+$.] As expected, angular distributions of ^{3}He and of tritons (from ^{14}N(d, t)^{13}N) to analog states are closely the same: this has been shown for the ground-state ^{3}He and triton groups as well as groups to ^{13}C*(8.9 + 9.5) and ^{13}N*(9.2): see (81AJ01).

64. ^{14}N(t, α)^{13}C $\qquad Q_m = 12.2634$

Observed α groups at $E_t = 2.6$ MeV are displayed in Table 13.22 of (76AJ04).

65. ^{14}N(^{6}Li, ^{7}Be)^{13}C $\qquad Q_m = -1.945$

See (81AJ01, 86AJ01).

66. ^{14}N(^{10}B, ^{11}C)^{13}C $\qquad Q_m = 1.1390$

See (87OS1E; theor.).

67. ^{15}N(p, ^{3}He)^{13}C $\qquad Q_m = -10.6658$

At $E_p = 43.7$ MeV ^{3}He groups have been observed to eleven states of ^{13}C: see Table 13.17 in (81AJ01).

68. ^{15}N(α, ^{6}Li)^{13}C $\qquad Q_m = -14.6843$

At $E_\alpha = 42$ MeV the angular distribution to $^{13}C_{g.s.}$ has been measured: see (81AJ01). See also (88SH1E; theor.).

69. $^{16}O(n, \alpha)^{13}C$ $Q_m = 2.2156$

Angular distributions have been measured for E_n to 18.8 MeV for α_0, α_1, α_{2+3}: see (81AJ01). See also (87MA1C; astrophysics).

70. $^{16}O(\alpha, {}^7Be)^{13}C$ $Q_m = -21.2061$

At $E_\alpha = 42$ MeV the angular distributions involving $^{13}C_{g.s.}$ have been measured: see (81AJ01).

71. $^{16}O({}^9Be, {}^{12}C)^{13}C$ $Q_m = 3.4856$

Angular distributions are reported at $E(^{16}O) = 20.0$ to 28.3 MeV to $^{13}C^*(0, 3.09, 3.85)$ (88WE17). See also (89VO1D).

72. (a) $^{18}O(d, {}^7Li)^{13}C$ $Q_m = -5.678$
(b) $^{19}F(d, {}^8Be)^{13}C$ $Q_m = 3.5817$

Angular distributions have been measured in both reactions at $E_d = 13.6$ MeV involving $^{13}C_{g.s.}$: see (86AJ01).

73. $^{23}Na(d, {}^{12}C)^{13}C$ $Q_m = 0.4785$

At $E_d = 13.6$ MeV an angular distribution has been reported by (86GO1C).

^{13}N
(Figs. 3 and 4)

GENERAL (See also 86AJ01).

Table 13.14: Energy levels of ^{13}N

E_x (MeV±keV)	J^π; T	$\Gamma_{c.m.}$ (keV)	Decay	Reactions
g.s.	$\frac{1}{2}^-$; $\frac{1}{2}$	$\tau_{1/2} = 9.965 \pm 0.004$ min	β^+	1, 2, 5, 7, 8, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 33, 34, 35, 36
2.3649 ± 0.6	$\frac{1}{2}^+$	$\Gamma_{c.m.} = 31.7 \pm 0.8$	γ, p	5, 7, 8, 9, 13, 14, 24, 25, 28, 30, 31, 35, 36
3.502 ± 2 [a]	$\frac{3}{2}^-$	62 ± 4 [a]	γ, p	2, 5, 7, 8, 9, 13, 14, 17, 18, 19, 24, 25, 26, 27, 28, 29, 30, 34, 35
3.547 ± 4	$\frac{5}{2}^+$	47 ± 7	p	2, 5, 7, 9, 13, 14, 17, 18, 19, 24, 25, 26, 28, 30
6.364 ± 9	$\frac{5}{2}^+$	11	p	6, 7, 9, 14, 25, 30, 34
6.886 ± 8	$\frac{3}{2}^+$	115 ± 5	p	6, 7, 9, 14, 25, 30
7.155 ± 5	$\frac{7}{2}^+$	9 ± 0.5	p	6, 7, 9, 14, 25, 30
7.376 ± 9	$\frac{5}{2}^-$	75 ± 5	p	6, 7, 9, 14, 25, 27, 28, 29, 30, 34
7.9	$\frac{3}{2}^+$	≈ 1500	p	9, 14
8.918 ± 11	$\frac{1}{2}^-$	230	p	7, 9, 14, 27, 28, 29, 34
9.00	$\frac{9}{2}^+$	280 ± 30		6, 14, 24, 25, 29
9.476 ± 8	$\frac{3}{2}^-$	30	p	6, 7, 9, 14, 25, 27, 29
10.25 ± 150	$(\frac{1}{2}^+)$	≈ 280	γ, p	8
10.36	$\frac{5}{2}^-$	30	p	6, 7, 9, 14, 25, 27
10.36	$\frac{7}{2}^-$	76	p	6, 7, 9, 14, 25

Table 13.14: Energy levels of ^{13}N (continued)

E_x (MeV±keV)	J^π; T	$\Gamma_{c.m.}$ (keV)	Decay	Reactions
10.833 ± 9	$\frac{1}{2}^-$			6, 7, 14, 25, 34
11.530 ± 12	$\frac{5}{2}^+$	430 ± 35	p	6, 7, 9
11.70 ± 30	$\frac{5}{2}^-$	115 ± 30	p	9
11.74 ± 40	$\frac{3}{2}^+$	240 ± 30	γ, p	8, 9
11.74 ± 50	$\frac{3}{2}^-$	530 ± 80	p	7, 9, 28, 29, 34
11.86 ± 40	$\frac{1}{2}^+$	380 ± 50	p	9, 28
12.13 ± 50	$\frac{7}{2}^-$	250 ± 30	p	9, 35
12.558 ± 23		> 400		7
12.937 ± 24		> 400		7
13.5 ± 200	$\frac{3}{2}^+$	≈ 6500	γ, p	8, 9
14.05 ± 20	$\frac{3}{2}^+$; $\frac{1}{2}$	165 ± 20	γ, p, α	8, 9, 12
15.06457 ± 0.4 [b]	$\frac{3}{2}^-$; $\frac{3}{2}$	0.86 ± 0.12	γ, p, α	7, 8, 9, 12, 18, 24, 25,
				34
15.3 ± 200	$(\frac{3}{2}^+)$	350 ± 150	γ, p	8
15.99 ± 30	$\frac{7}{2}^+$; $\frac{1}{2}$	135 ± 90	p, α	9, 12, 25
16.0		≈ 500	p	9
17.5			γ, p	8, 9
18.15 ± 30	$\frac{3}{2}^+$; $\frac{1}{2}$	320 ± 80	p	9
18.17 ± 20	$\frac{1}{2}^-$; $\frac{1}{2}$	225 ± 50	p, α	9, 12
18.406 ± 5	$\frac{3}{2}^+$; $\frac{3}{2}$	66 ± 8	p, α	7, 9, 12
18.961 ± 10	$\frac{3}{2}^-$ or $\frac{7}{2}^+$; $\frac{3}{2}$	23 ± 5	p, α	7, 9, 12
19.83	$\frac{5}{2}^-$; $\frac{1}{2}$	1000	p, α	9, 12
19.88	$\frac{7}{2}^+$; $\frac{1}{2}$	750	p	9
20.2	$\frac{5}{2}^-$	1000	p	9
20.9 ± 300	$\frac{1}{2}^+$	1200	γ, p	8, 9
21.4	$\frac{5}{2}^-$	750	p	9
21.7	$\frac{3}{2}^+$		p	9
22.4 ± 500	$\frac{1}{2}^+$		p	9
23			γ, p	8
23.3	$(\frac{3}{2}^-)$	400	p, ^{3}He	3, 4

Table 13.14: Energy levels of ^{13}N (continued)

E_x (MeV±keV)	$J^\pi; T$	$\Gamma_{c.m.}$ (keV)	Decay	Reactions
23.83 ± 50	$(\frac{3}{2}^-)$	350 ± 50	p, ^{3}He	3, 4
(23.9)	$(\frac{11}{2}^-)$	20	^{3}He	4
(24.4)		700	p, ^{3}He	3
(24.6)		120	p, ^{3}He	3
25.6 ± 100	$(\frac{3}{2}^-)$	240 ± 80	p, ^{3}He	3, 9
25.9		1000	(n), p, d, ^{3}He, α	3, 4
26.84			p	9
28			(γ), p, ^{3}He, (α)	2, 3, 4
(31)			p	9
32		≈ 2000	γ, d, ^{3}He, α	2, 4, 8

[a] See also footnotes [b,f] in Table 13.17.

[b] See also Table 13.6.

Nuclear models: (89AM02)

Special states: (84KO40, 85RO1J, 86AN07, 88RO1R, 89RO03)

Electromagnetic transitions: (84VA06, 87HO1L).

Astrophysical questions: (85TA1A, 87RA1D, 89ST14).

Applied work: (86HI1B, 86MA2F, 86MA1T, 86WE1E, 87BU12, 87LE1H, 88HI1F, 88VO1D, 89AR1J, 89AR1N, 89AR1Q, 89TR1B, 89WO1B, 90DA1J)

Complex reactions involving ^{13}N: (85AR1G, 85PO11, 86HA1B, 86PO06, 86UT01, 87BA38, 87FE1A,87NA01, 87RI03, 87ST01, 88SA19, 89BA92, 89WA16, 89KI13, 89LY1A, 89SA10, 89TA1O, 89YO02, 90GL01, 90WE14)

Muon and neutrino reactions: (85MI21, 90FU03, 90MI1J)

Reactions involving pions, kaons and other mesons: (85SA06, 86KU1J, 86LI1N, 86SI13, 86SI22, 86SU18, 87MI08, 88AB05, 88BU1I, 88CH1L, 88HA12, 88KO1V, 89AG1B, 89BE2O, 90BE12, 90CA15, 90KO19, 90TI1B)

Hypernuclei: (85BA2D, 89BA93)

Other topics: (85AN28, 86AN07, 90MU10)

Ground state of ^{13}N: (85AN28, 86GL1A, 86SI22, 87FU06, 88WA08, 89AM02, 89SA10)

$\mu = -0.32224(35)$ nm (78LEZA). See also (89RA17).

1. ^{13}N(β^+)^{13}C $Q_m = 2.2205$

The weighted mean of $\tau_{1/2}$ measurements is 9.965 ± 0.0004 min. The decay is entirely to ^{13}C$_{g.s.}$; log $ft = 3.667 \pm 0.001$: see (81AJ01). See also (89KA1S: $\tau_m = 9.962 \pm 0.020$ min), (89SE1C, 89SE1G, 90ST08), (85BA1N, 86GR04, 87BA1U, 87FR1C, 87RI1E, 87WE1C, 88BA1H, 88BA1Y, 88BA2D, 89DA1H, 89GU28, 89KA24; astrophysics) and (84BO03, 86SI22, 89AM02, 89SA1P, 89WO1E; theor.).

2. ^{10}B(^{3}He, γ)^{13}N $Q_m = 21.6368$

The 90° cross sections for γ_0 and γ_{2+3} have been measured for $E(^3\text{He}) = 4.8$ to 14 MeV: no pronounced structures are observed: see (81AJ01).

3. (a) ^{10}B(^{3}He, n)^{12}N $Q_m = 1.573$ $E_b = 21.6368$
(b) ^{10}B(^{3}He, p)^{12}C $Q_m = 19.6933$

Activation cross sections (reaction (a)) have been reported for $E(^3\text{He}) = 1$ to 30.6 MeV: there is some evidence for broad structures. Observed resonances in the yield of proton groups and of 12.7 and 15.1 MeV γ-rays are displayed in Table 13.15. See also (81AJ01).

4.(a) ^{10}B(^{3}He, d)^{11}C $Q_m = 3.1961$ $E_b = 21.6368$
(b) ^{10}B(^{3}He, ^{3}He)^{10}B
(c) ^{10}B(^{3}He, α)^{9}B $Q_m = 12.141$

For observed resonances and anomalies see Table 13.15. See also (81AJ01).

5. ^{10}B(α, n)^{13}N $Q_m = 1.0590$

Angular distributions have been measured in the range $E_\alpha = 1.5$ to 20.2 MeV: see (81AJ01). See also (87EL1B; applied) and (88CA26; astrophysics).

Table 13.15: Structures in $^{10}B + ^{3}He$ [a]

E_{res} (MeV ± keV)	Γ (keV)	Res. in	$^{13}N^*$ (MeV)
2.1 [b]	500	p_0, (p_1), ^{3}He	23.3
2.85 ± 50 [b]	450 ± 50	$\gamma_{15.1}$, ^{3}He	23.83
2.975 [b]	20	^{3}He	23.9
3.6 [b]	700	p_0, p_1	24.4
3.9	120	p_0	24.6
(4.6)	150	p_0, (p_1)	(25.2)
5.2 ± 100	240 ± 80	p_0, $\gamma_{15.1}$,p_2, p_3	25.6
5.6	1000 [c]	(n), p_0, p_2, p_3, $\gamma_{12.7}$, $\gamma_{15.1}$, d_0, α_0	25.9
8.5	[d]	(γ_0), p_0, $\gamma_{12.7}$, $\gamma_{15.1}$, (α_0)	28
13.5 [e]	≈ 2000	(γ_0), d_{4+5}, α_1	32

[a] For references and comments see Table 13.19 in (81AJ01). For ^{3}He elastic scattering anomalies see (87BA34).

[b] (87BA34) report $\Gamma(^{3}He)/\Gamma = 0.5$, 0.3 and ≈ 1 for $^{3}N^*(23.3, 23.83, 23.9)$; $J^\pi = \frac{3}{2}^-, \frac{3}{2}^-, \frac{11}{2}^-$ for these three states.

[c] $J \geq \frac{3}{2}$.

[d] $J \geq \frac{7}{2}$.

[e] This may correspond to more than one state.

6. (a) ^{10}B(^{6}Li, t)^{13}N $\qquad Q_m = 5.8413$
(b) ^{10}B(^{9}Be, ^{6}He)^{13}N $\qquad Q_m = 0.4606$

At $E(^6\text{Li}) = 18$ MeV the known states of ^{13}N with $6.3 < E_x < 11.7$ MeV are observed, with the exception of ^{13}N*(7.9, 8.92). In addition, evidence is presented for a ^{13}N state at $E_x = 9.00$ MeV with $\Gamma_{c.m.} = 280 \pm 30$ keV: it is very strongly excited and its angular distribution is similar to that for ^{13}C*(9.50) in the mirror reaction (^{6}Li, ^{3}He), suggesting that these two states are analogs. Other analog assignments made on the basis of corresponding intensities in the mirror reaction are given in reaction 12 of ^{13}C. The widths of ^{13}N*(6.89, 7.38) are, respectively, 120 ± 30 and 70 ± 30 keV (84HO06). For reaction (b) see (90JAZZ).

7. ^{11}B(^{3}He, n)^{13}N $\qquad Q_m = 10.1826$

Neutron groups have been observed to a number of states of ^{13}N: see Table 13.16. The parameters of the first $T = \frac{3}{2}$ state at $E_x = 15.06$ MeV are displayed in Table 13.6 where they are compared with the corresponding quantities for ^{13}C*(15.11): see (81AJ01).

8. (a) ^{12}C(p, γ)^{13}N $\qquad Q_m = 1.9435$
(b) ^{12}C(p, π^0)^{13}N $\qquad Q_m = -133.021$

Resonances for capture radiation are displayed in Table 13.17. No resonance is observed at $E_p = 1.73$ MeV [^{13}N*(3.55)]: $\omega\Gamma_\gamma < 0.006$ eV. Excitation functions have been measured for $E_p = 150$ to 2500 keV. In addition to the first two resonances, direct radiative capture is observed. The capture γ-ray yield, studied for $E_p = 610$ to 2700 keV, is dominated by a direct capture process to ^{13}N*(2.36). The cascade decay ^{13}N*(3.50 $\rightarrow$ 2.36) has an intensity of (8 ± 1)%. Extrapolating the cross section to $E_{c.m.} = 25$ keV yields a cross section factor $S = 1.45 \pm 0.20$ keV·b: see (81AJ01). [A reanalysis of the data by (80BA54) suggests $S = 1.54^{+0.15}_{-0.10}$ kev·b].

Differential cross sections for the transitions to the ground state have been measured for $E_{\vec{p}} = 10$ to 17 MeV. The total E2 capture cross section is ≈ 0.2 μb and no resonance effects are observed. The E2 energy-weighted sum rule depleted over this energy range is (8.5 ± 3.3)% (80HE04). At $E_p = 14.2$ MeV, capture radiation from the first $T = \frac{3}{2}$ state, ^{13}N*(15.06) is reported: see Table 13.6 for the parameters and the decay modes of this state. The angular distributions of the γ-rays determine $J = \frac{3}{2}$ for ^{13}N*(15.06). The interference between the M1(E2) $T = \frac{3}{2}$ resonance (^{13}N*(15.06)) and the E1 GDR has been studied by (80SN01): the E1 capture is found to be predominantly d-wave. See (81AJ01) for the earlier references.

Excitation functions for γ-rays have also been measured at $E_p = 8.7$ to 37 MeV (γ_0), 19.9 to 24.4 MeV (γ_1, γ_{2+3}) and 23 to 37 MeV (γ_{2+3}). At $E_p = 40$ to 100 MeV most of the

Table 13.16: States of ^{13}N from ^{11}B(^{3}He, n)^{13}N [a]

E_x (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	L	J^π
0		2	$\frac{1}{2}^-$
2.358 ± 10		1	$\frac{1}{2}^+$
3.502 ± 10		0, 2	$\frac{3}{2}^-$
3.55 ± 18			
6.353 ± 9		1, 3	$\frac{5}{2}^+$
6.875 ± 10		1, 3	$\frac{3}{2}^+$
7.145 ± 9		3, 5	$\frac{7}{2}^+$
7.363 ± 8		2, 4	$\frac{5}{2}^-$
8.2 ± 22			
8.918 ± 11			
9.476 ± 8		0, 2	$\frac{3}{2}^-$
10.381 ± 8		2, 4	$\frac{5}{2}^-$
10.833 ± 9			
11.530 ± 12			
11.878 ± 12		0, 2	$\frac{3}{2}^-$
12.558 ± 23	> 400		
12.937 ± 24	> 400		
15.068 ± 8 [b]	< 15		$\frac{3}{2}^-; T = \frac{3}{2}$
18.44 ± 40			$T = \frac{3}{2}$
18.98 ± 20	40 ± 20		$T = \frac{3}{2}$

[a] For references see Table 13.20 in (81AJ01).
[b] See also Table 13.6.

Table 13.17: Resonances in $^{12}C(p, \gamma)^{13}N$ [a]

E_p (MeV±keV)	$\Gamma_{c.m.}$ (keV)	Γ_{γ_0} (eV)	$^{13}N^*$ (MeV)	Res. in yield of	J^π
0.4568 ± 0.5	31.7 ± 0.8	0.50 ± 0.04 [b]	2.3649 $\pm$ 0.0006	γ_0	$\frac{1}{2}^+$
1.689 ± 2 [c]	62 ± 4 [d]	0.64	3.502	γ_0	$\frac{3}{2}^-$
9.01 ± 150	≈ 280		10.25	γ_0	$(\frac{1}{2}^+)$
10.62 ± 120	200 ± 50	≈ 4.2 [e]	11.74	γ_0	$\frac{3}{2}^+$
12.5 ± 200	6500	≥ 1100	13.5	γ_0	$\frac{3}{2}^+$
13.12 ± 90	160 ± 20	3.7 ± 1.0 [f]	14.04	γ_0	$\frac{3}{2}^+$
14.2	[see Table 13.6]		15.0	γ_0, γ_{2+3}	$\frac{3}{2}^-$; $T = \frac{3}{2}$
14.5 ± 200 [g]	350 ± 140	≥ 0.5	15.3	γ_1	$(\frac{3}{2}^+)$
16.9			17.5	γ_0	
20 [h]			20	γ_1, γ_{2+3}	
20.5 [i]	≈ 3700		20.8	γ_0	
23			23	γ_0	
24.5			24.5	γ_{2+3}	
32.5	broad		31.9	γ_0, γ_{2+3}	

[a] For references and other comments see Tables 13.21 in (81AJ01) and 13.17 in (86AJ01).
[b] See the discussion in (85BA75).
[c] (89KI21) [see for additional comments]. See also (84PO1D, 87PO1C). Please note: The earlier work [see, e.g., 74RO29] led to $E_p = 1699 \pm 2$ keV. It would be useful to confirm the new value of (89KI21). I am indebted to Prof. Robert Zurmuhle for a very helpful discussion.
[d] (85BR06) have studied this resonance with polarized protons and analyzed the results with R-matrix theory: the E2/M1 mixing ratio is -0.102 ± 0.003 and the total width (lab.) is calculated to be 62 keV. An extranuclear direct capture background appears to be necessary to explain the data. (89KI25) suggest 65.6 ± 1.8 keV but it is not clear whether that value is Γ_{lab} or $\Gamma_{c.m.}$.
[e] A value of 0.30 ± 0.05 is assumed for Γ_{p_0}/Γ: see Table 13.18.
[f] A value of 126 keV is taken for Γ_{p_0}.
[g] This peak may be due to an unresolved doublet.
[h] Giant resonance for γ_1.
[i] Main dipole strength is concentrated in this peak.

γ-strength is due to transitions to ^{13}N*(3.5), probably to ^{13}N*(3.55) [$J^\pi = \frac{5}{2}^+$] because of its single-particle character. Transitions to higher states may also be indicated. Excitation functions, γ-ray angular distributions and analyzing powers for γ_0, γ_{2+3} are reported by (84BL10) for $E_p \approx 25$ to 40 MeV. Differential cross sections (γ_0) have also been measured for $E_p = 28.35$ to 90 MeV (88HA04) [also angular distribution and A_y at $E_{\vec{p}} = 28.35$ MeV]. At $E_p = 40$ to 80 MeV A_y measurements are reported for the γ_0 and "γ_1" transitions (86EJ1A, 86SH1Y; prelim). See also (89ZU1A).

The photon production cross section has been studied at $E_p = 168$ and 200 MeV (89PI02). For other high-energy γ-ray emission results see (90CLZZ). The π^0 production cross section to ^{13}N$_{\text{g.s.}}$ has been determined for $E_p = 154.5$ to 204 MeV (87HO21, 88SEZT) and at 200 MeV (89BE25). See also (88AB05) [$E_p = 1$ GeV; charged pion production].

See also (82AN1D, 84NA1F, 89IZ1A), (86AI04, 88PO1G; applied), (85AR1A, 85CA41, 87RO1D, 87WE1C, 88CA26, 89BA2P, 89GU1J, 89KA24; astrophysics), (86BE17, 86SN1B, 86WE1D, 87HE1B, 89BL1D) and (86DI1C, 86MI1K, 86MI1M, 87RE11, 90HA46; theor.).

9. (a) ^{12}C(p, p)^{12}C $\qquad E_b = 1.9435$

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

(c) ^{12}C(p, pα)^{8}Be $\qquad Q_m = -7.3666$

Yields curves for elastic protons, protons inelastically scattered to ^{12}C*(4.4, 7.7, 9.6, 12.7, 15.1) and for γ-rays from ^{12}C*(4.4, 12.7, 15.1) have been studied at many energies: see Table 13.18 for a display of the observed structure. Elastic excitation functions have recently been measured at $E_p = 0.35$ to 0.55 MeV (86HO26), 1.6 to 1.9 MeV (86ER1D, 87ER01) and 5.0 to 7.5 MeV (87RO1F; prelim.). A phase-shift analysis of the elastic scattering analyzing power for $E_{\vec{p}} = 11.5$ to 18.1 MeV shows four $T = \frac{1}{2}$ states with $E_x = 14.06$, 16.00, 18.16 and 18.18 MeV, with $J^\pi = \frac{3}{2}^+, \frac{7}{2}^+, \frac{3}{2}^+, \frac{1}{2}^-$: see Table 13.18. At $E_{\vec{p}} = 19.15$ to 23.34 MeV, measurements of the elastic group and the protons to ^{12}C*(4.4, 12.7) locate $\frac{1}{2}^+$ (E1), $\frac{5}{2}^-$ (E2) and $\frac{7}{2}^+$ (E3) resonances below 21 MeV, $\frac{3}{2}^+$ (E1) and $\frac{5}{2}^-$ resonances with $21 < E_x < 22$ MeV and $\frac{1}{2}^+$ and $\frac{3}{2}^+$ resonances above 22 MeV: see Table 13.18. For other polarization measurements see Table 13.19. See also (85BL22, 89OPZY, 90CHZY) and (89SR1C; theor.).

Cross sections for production of 4.4 MeV γ-rays have been determined for $E_p = 5.1$ to 23 MeV (81DY03), 8.9, 20, 33, 40 and 50 MeV (88LE08) and 22 to 85 MeV (87LA11, 88SA1B). In the latter work, cross sections have also been measured for the 15.1 MeV γ-ray, and for the 2.1 MeV γ-ray [unresolved; from the decay of the first excited states of ^{11}B/^{11}C reached in the (p, 2p) and (p, pn) reactions]. These measurements are of considerable interest in astrophysics: see, e.g., (87LA11). The cross sections for the (p, 2p) process (reaction (b)) from the 1p$_{3/2}$ orbital and from the continuum have been measured at $E_p = 200$ MeV by (89C017, 89PI12). See also (89TEZZ; prelim.). For other breakup processes see (86AJ01). For high-energy gamma-ray emission see (90CLZZ). Total and inelastic cross sections have been measured at $E_p = 1.52$ and 1.8 GeV/c (84AF1A). For a study of inclusive proton spectra at 150 MeV see (85SE15). For π^+ emission see reaction 27 in ^{13}C. For an anti-proton study see (89TA24). For a study at $E(^{12}\text{C}) = 296$ to 1572 MeV/A see (90WE14).

Table 13.18: ^{13}N levels from ^{12}C(p, p), ^{12}C(p, p′), ^{12}C(p, α)[a]

E_p (MeV ± keV)	^{13}N* (MeV)	$\Gamma_{c.m.}$ (keV)	l_p	J^π	
					[b]
0.461 ± 3	2.369 [c]	31 [c]	0	$\frac{1}{2}^+$	$\theta^2 = 0.54$
1.686 ± 6	3.499 [c]	60 [c]	1	$\frac{3}{2}^-$	0.031
1.734 ± 6	3.543 [c]	50 [c]	2	$\frac{5}{2}^+$	0.21
4.808 ± 10	6.378	11	2	$\frac{5}{2}^+$	0.0031
5.370 ± 10	6.896	115 ± 5	2	$\frac{3}{2}^+$	0.13
5.65 ± 10	7.155	9 ± 0.5	4	$\frac{7}{2}^+$	0.016
5.891	7.38	75 ± 5	3	$\frac{5}{2}^-$	0.069
6.5	7.9	≈ 1500	2	$\frac{3}{2}^+$	0.14
7.54	8.90	230	1	$\frac{1}{2}^-$	0.02
8.18	9.49	30	1	$\frac{3}{2}^-$	0.001
9.13	10.36	30	3	$\frac{5}{2}^-$	
9.13	10.36	76	3	$\frac{7}{2}^-$	
					$\Gamma_p/\Gamma =$
10.35 ± 50	11.49	430 ± 35	2	$\frac{5}{2}^+$	0.70 ± 0.05
10.58 ± 30	11.70	115 ± 30	3	$\frac{5}{2}^-$	0.60 ± 0.04
10.62 ± 40	11.74	250 ± 30	2	$\frac{3}{2}^+$	0.30 ± 0.05
10.62 ± 50	11.74	530 ± 80	1	$\frac{3}{2}^-$	0.55 ± 0.05
10.75 ± 40	11.86	380 ± 50	0	$\frac{1}{2}^+$	0.35 ± 0.05
11.05 ± 50	12.13	250 ± 30	3	$\frac{7}{2}^-$	0.30 ± 0.05
12.5	13.5	≈ 500			
13.13 ± 20	14.05	180 ± 35	2	$\frac{3}{2}^+; T = \frac{1}{2}$	0.29 ± 0.07
14.23075 ± 0.2	15.06457 ± 0.4	0.932 ± 0.028[d]	1	$\frac{3}{2}^-; T = \frac{3}{2}$	
15.24 ± 40[e]	15.99	135 ± 90	4	$\frac{7}{2}^+; T = \frac{1}{2}$	0.05 ± 0.04
15.2	16.0	≈ 500			
16.8[e]	17.4				
17.58 ± 30	18.15	322 ± 75	2	$\frac{3}{2}^+; T = \frac{1}{2}$	0.08 ± 0.02
17.60 ± 20	18.17	225 ± 50	1	$\frac{1}{2}^-; T = \frac{1}{2}$	0.24 ± 0.06
17.857 ± 5 [f]	18.406	66 ± 8	2	$\frac{3}{2}^+; T = \frac{3}{2}$	

Table 13.18: ^{13}N levels from ^{12}C(p, p), ^{12}C(p, p′), ^{12}C(p, α)[a] (continued)

E_p (MeV ± keV)	^{13}N* (MeV)	$\Gamma_{c.m.}$ (keV)	l_p	J^π	
18.460 ± 10[f]	18.961	23 ± 5		$\frac{3}{2}^-$ or $\frac{7}{2}^+$; $T = \frac{3}{2}$	
19.40[g]	19.83	1000	3	$\frac{5}{2}^-$; $T = \frac{1}{2}$	
19.46	19.88	750	4	$\frac{7}{2}^+$; $T = \frac{1}{2}$	
19.8[f]	20.2	1000		$\frac{5}{2}^-$	
20.6 ± 300 [e,f]	20.9	1200		$\frac{1}{2}^+$	
21.1	21.4	750		$\frac{5}{2}^-$	
21.4	21.7			$\frac{3}{2}^+$	
22.2 ± 500	22.4	≈ 1000		$\frac{1}{2}^+$	
[h]					
24.0	24.1	≤ 500			
25.7	25.6			$(\frac{3}{2}^-)$	
27.02	26.84				
32 [g]	31				

[a] For references see Tables 13.22 in (81AJ01) and 13.27 in (76AJ04).

[b] A dispersion analysis leads to a spectroscopic factor of 0.53 ± 0.08 for ^{13}N$_{g.s.}$.

[c] The older values for ^{13}N*(3.50, 3.54) have been reanalyzed by (80BA54). An R-matrix analysis had led to $E_x = 2.367$, 3.501 and 3.547 MeV, and $\Gamma_{c.m.} = 33$, 55 and 50 keV for these states. ^{13}N$_{g.s.}$ appears to have an appreciable effect on the low-energy scattering: see (81AJ01). See also (86ADZY).

[d] $\Gamma_p = 263 \pm 15$ eV (80TH05). See discussion in (81BR24): if the ^{12}C nucleus were part of an atom the width of the resonance would be smeared out by an amount of the order of ≈ 0.5 keV (A.M. Lane, private communication). See also Table 13.6.

[e] Resonance in yield of 12.7 MeV γ-rays.

[f] Resonance in yield of 15.1 MeV γ-rays.

[g] Resonance in yield of 4.4 MeV γ-rays.

[h] A $\frac{3}{2}^+$ state is indicated in this region.

The yield of bremsstrahlung and the shape of the energy spectrum have been studied for $E_p = 1.74$ to 1.93 MeV by (86ER1D, 87ER01, 90ER02). For other bremsstrahlung studies see (81AJ01, 86AJ01) and (87YAZZ, 88YAZZ).

See also ^{12}C in (90AJ01), (85BA2F, 86CH2H, 86NO1E, 86SA2F, 86VD1C, 87BA33, 87LIZZ, 87MOZZ, 88LYZZ, 89AG1B, 89SU1F), (86ZE1E, 90BO10; applied), (86BA88, 86CA1N, 86CL1C, 86GL1G, 86MO1L, 86ST1F, 87HE1B, 88BO46, 88HI1H) and (84ZA1D, 85BO1A, 85PI11, 85SH1H, 85ZH07, 86DE1M, 86HA1K, 86HO10, 86KA1Y, 86LO1A, 86SA30, 86VD01, 86VI1D, 86ZA06, 86ZH04, 87HO1G, 87LI01, 87MI01, 87PL1C, 87RE03, 87RO02,

Table 13.19: Polarization measurements in ^{12}C(p, p) [a]

E_p (MeV)	A_y to ^{12}C* (MeV)	Refs.
2.1→83.8	g.s.	(87IE01)
35	12.7, 15.1, 16.1	(90IE01)
40	15.1	(86SH1X) [b]
65	g.s.: spin rotation parameter	(86SA1J) [b]
65	0, 4.4, 7.7, 9.6, 14.1	(85KA10)
71.2	g.s. $[A_\gamma = 0.968 \pm 0.001]$	(90EV01)
71.7	g.s.	(89VO05)
79→584	inclusive protons	(85MC07)
80	12.7, 15.1: spin transfer	(86HO1H) [b]
156	(p, pα)	(89MUZZ) [b]
180, 190, 200	g.s. $[D_{LL}, D_{SL}]$	(90WEZY) [b]
200	g.s.: spin rotation parameter	(85ST1C, 86ST1G)
200	12.7: pol. transfer coeff.	(85WI1F, 86OL1A) [b]
250	g.s.	(88ME02)
290, 420	quasielastic; spin observables	(89CH01, 90CH16)
300, 500	15.1: angular correlation	(86LI1Q) [b]
303	inclusive	(87MO04)
319	inclusive inelastic $[S_{nn}]$	(90BA14)
400	12.7, 15.1, 16.1 $[P - A_y]$	(88HI03)
500	g.s.	(90HO06)
500	12.7, 15.1, 16.1: pol. transfer observables	(90CH1R) [b]
800	pol. transfer observables	(88FE09)
80→250 MeV/c	12.7: spin observables	(89OPZZ) [b]

[a] For earlier work see Tables 13.26 in (70AJ04), 13.28 in (76AJ04), (81AJ01), and Table 13.19 in (86AJ01).
[b] Preliminary report.

87MEZU, 87ZA1F, 87ZH08, 88AZ1B, 88BEYI, 88HO1K, 88KU16, 88NA04, 88RU1C, 88ST1G, 89BE2B, 89MI20, 89YA10, 90CA1S, 90PH02, 90PI06; theor.).

10. (b) ^{12}C(p, n)^{12}N $Q_m = -18.120$ $E_b = 1.9435$

(b) ^{12}C(p, pn)^{11}C $Q_m = -18.7215$

The cross section for reaction (a) has been measured from threshold to $E_p = 50$ MeV. Resonant structure is observed corresponding to $E_x = 21$, 24 and, possibly, ≈ 27 MeV: see (81AJ01). The cross section at 0° for the transition to $^{12}N_{g.s.}$ has been measured at $E_p = 62$, 99 and 120 to 160 MeV (82AN1C), at 120, 160 and 200 MeV (81RA12) [see ref. 14 in (89WA15)], at 135 amd 160 MeV (83WA29), at 144 MeV (79MO16), at 200, 300 and 400 MeV (89WA15) and at 492 MeV (89RA09). Polarization measurements are reported at $E_{\vec{p}} = 160$ MeV (84TA07; $D_{NN}(0^o)$; g.s.), 160 MeV (87RA15; A_y; g.s.), 290 and 420 MeV (89HI10; A_y, quasifree), 494 MeV (88TAZY, 90TA1J; A_y, quasielastic; prelim.) and at 590 MeV (89BI06). See also (89GA1N) and (86AJ01). For continuum spectra at 200 MeV, see (88NI1C; prelim.). For neutron yields at $E_p = 113$, 318 and 800 MeV, see (86MEZZ, 86ME1K, 89ME1D; prelim.). For neutron production cross sections at $E_p = 585$ MeV, see (87CI08, 87FI09). See also reaction 9, and ^{12}C in (90AJ01).

Cross sections for reaction (b) have been measured to 300 GeV: see (81AJ01). See also ^{12}N in (90AJ01), (84NA1F, 86IE1A, 88LE08), (85KI1A, 87TA22, 88HI1F, 90QU1B) and (88BA83; theor.).

11. ^{12}C(p, d)^{11}N $Q_m = -16.4972$ $E_b = 1.9435$

See (86AJ01).

12. ^{12}C(p, α)^{9}B $Q_m = -7.552$ $E_b = 1.9435$

Yield curves for α_0 have been measured over the 14.2 MeV resonance, corresponding to the first $T = \frac{3}{2}$ state at $E_x = 15.06$ MeV, and from $E_x = 17$ to 20 MeV. The yield for the α_1 group has been determined for $E_p = 17$ to 21.5 MeV. Parameters of observed resonances are displayed in Table 13.18. Excitation functions for α_0 have also been measured for $E_p = 18.5$ to 44 MeV at a number of angles: they exhibit structures which are typically 1 MeV broad: see (81AJ01). For polarization measurements see Table 13.19 in (86AJ01). For α and ^{3}He emission at $E_p = 72$ MeV see (86WA26).

13. (a) ^{12}C(d, n)^{13}N $\qquad Q_m = -0.2811$
(b) ^{12}C(d, pn)^{12}C $\qquad Q_m = -2.24585$

Angular distributions have been measured at $E_d = 0.5$ to 17 MeV [see (81AJ01, 86AJ01)] and at 18 MeV (87KAZL, 88KA1Y: n_0, n_1). Reaction (b) is dominated at $E_d = 5.0$ to 6.5 MeV and at 9.20 and 9.85 MeV by sequential decay via ^{13}N*(3.50 + 3.55). At the lower energies ^{13}N*(2.36) participates also: see (76AJ04). See also ^{14}N, (88MAZP), (86WE1E, 88VI1A, 90BA1S; applied) and (84BL21; theor.).

14. ^{12}C(^{3}He, d)^{13}N $\qquad Q_m = -3.5500$

Angular distributions have been studied at $E(^3\text{He})$ to 81.4 MeV: see (81AJ01, 86AJ01). The spectroscopic factors derived by (80PE13) for ^{13}N*(0, 2.36, 3.55, 6.36, 6.89, 7.16, 7.38, 8.0, 8.92, 9.0, 9.48, 10.36, 10.78) are $S = 0.48$, 0.14, 0.53, 0.007, 0.015, < 0.009, 0.024, 0.13, < 0.005, < 0.005, < 0.002, < 0.001, 0.064, respectively. Evidence is presented for the assignment of $J^\pi = \frac{9}{2}^+$ to ^{13}N*(9.0) (80PE13). For other values of S, see (81AJ01). The energies and widths for the first three excited states are $E_x = 2368.2 \pm 2.8$, 3507.8 ± 7.6 and 3549.1 ± 5.0 keV, with $\Gamma_{c.m.} = 36.1 \pm 2.8$, 54.8 ± 11.5 and 46.5 ± 7.1 keV respectively: see (81AJ01). For work at very high energies see (87AB1J). See also (86AJ01) and (84BL21, 89KA1N; theor.).

15. ^{12}C(α, t)^{13}n $\qquad Q_m = -17.8705$

See (81AJ01) and (89GA1H).

16. ^{12}C(^{6}Li, ^{5}He)^{13}N $\qquad Q_m = -2.65$

(WO88A) [and see reaction 9 in ^{5}He (88AJ01)].

17. (a) ^{12}C(^{7}Li, ^{6}He)^{13}N $\qquad Q_m = -8.031$
(b) ^{12}C(^{13}C, ^{12}B)^{13}N $\qquad Q_m = -15.590$

Angular distributions have been obtained (reaction (a)) at $E(^7\text{Li}) = 36$ MeV [see (81AJ01)] and at 34 MeV (86CO02; ^{13}N*(0, 3.5[u])). $S_{g.s.} = 0.38 \pm 0.05$ (86CO02). See also (88AL1G). For reaction (b) see ^{12}B in (90AJ01).

18. $^{12}C(^{12}C, ^{11}B)^{13}N$ $\qquad Q_m = -14.0134$

At $E(^{12}C) = 93.8$ MeV angular distributions involving $^{13}N^*(0, 3.5[u])$ have been measured: see (86AJ01). See also (87WIZW, 88HA23).

19. $^{12}C(^{13}C, ^{12}B)^{13}N$ $\qquad Q_m = -15.590$

At $E(^{13}C) = 390$ MeV angular distributions have been studied involving $^{13}N^*(0, 3.5[u])$ and broad states at $E_x \approx 16$ and 22 MeV. It is suggested that the latter are the $\frac{5}{2}^+$ and $\frac{3}{2}^+$ components of the giant dipole resonance in ^{13}N (87AD07, 88VO08). See also the discussion in reaction 26 in ^{12}B (90AJ01) and (89LE14).

20. $^{12}C(^{14}C, ^{13}C)^{13}N$ $\qquad Q_m = -5.6071$

See ^{13}C.

21. $^{13}C(\gamma, \pi^-)^{13}N$ $\qquad Q_m = -141.789$

Angular distributions have been studied at $E_\gamma = 163$ MeV (86SH13) and 223 MeV (87DU08). (86SH13) find that the M1 component reproduces the experimental data, suggesting some supression of the E0 component. See also (86AJ01) and (?; theor.).

22. $^{13}C(\pi^+, \pi^0)^{13}N$ $\qquad Q_m = 2.384$

The excitation function involving $^{13}N_{g.s.}$ (the isobaric analog state) has been studied at $E_{\pi^+} = 50$ to 343 MeV (88US01). An angular distribution is reported at $E_{\pi^+} = 165$ MeV involving the Δ-resonance (88KIZW; prelim.). See also (86AJ01).

23. $^{13}C(\pi^+, \gamma)^{13}N$ $\qquad Q_m = 137.348$

Differential cross sections for γ_0 have been measured at $E_{\pi^+} = 115.5$ MeV: no evidence is observed for pion condensation (84MA45).

24. (a) ^{13}C(p, n)^{13}N $\quad Q_m = -3.0028$

(b) ^{13}C(p, pn)^{12}C $\quad Q_m = -4.94635$

Angular distributions have been measured for $E_p = 3.1$ to 800 MeV [see (81AJ01, 86AJ01)] and at 18.6 MeV (88KA1Y; n_0, n_1), and 35 MeV (86OH03, 87OR01; n_0, n_1, n_{2+3}) [also comparison with ^{13}C(p, p′) to mirror states], and at $E_{\vec{p}} = 160$ MeV (87RA15; n_0, n_{2+3}) [^{13}N*(11.7, 15.1) are also populated]. Forward-angle cross sections have been measured at $E_p = 318$ and 800 MeV (86KI12) and at 492 and 590 MeV (89RA09). For discussions of the Gamow-Teller strength see (85WA24, 86KI12, 87TA13, 89RA09). For reaction (b) see (81AJ01). See also (86AJ01), ^{14}N, (85GU1C, 87ALZW, 89WA16), (86MA1P, 89AR1G; applied), (88CA26; astrophysics), (85GO1Q, 86CA1N, 86TA1E, 86VO1G, 87BE25, 87GO1V, 87LI29, 87RA32, 87TA22, 88RO17, 88US01, 89RA1G) and (86PE1E, 89AM02, 89RA15; theor.).

25. ^{13}C(^{3}He, t)^{13}N $\quad Q_m = -2.2391$

At $E(^3\text{He}) = 43.6$ MeV angular distributions are reported to ^{13}N*(0, 2.36, 3.50 + 3.55, 6.36, 6.89, 7.16, 7.38, 9.0, 9.48, 10.36, 10.83, 11.8, 15.07, 16.02). The results are compared with those from the reaction ^{13}C(^{3}He, ^{3}He)^{13}C to the analog states [see reaction 45 in ^{13}C]; they are consistent with $J^\pi = \frac{9}{2}^+$ for one of the unresolved states at $E_x = 9.0$ MeV and with $\frac{1}{2}^-$ and $\frac{7}{2}^+$ for ^{13}N*(10.83, 16.02) (81PE08). An angular distribution has also been determined at $E(^3\text{He}) = 39.6$ MeV (87BUZQ; t_0). Cross sections (0°) involving ^{13}N*(0, 3.5) have been measured for $E(^3\text{He}) = 0.6$ to 2.3 GeV (87BE25; see for ratios of the isovector strengths.). For the earlier work see (81AJ01). See also (89DE1Q, 89JAZY) and (88RO17).

26. (a) ^{13}C(^{6}Li, ^{6}He)^{13}N $\quad Q_m = -5.727$

(b) ^{13}C(^{7}Li, ^{7}He)^{13}N $\quad Q_m = -13.42$

Angular distributions to ^{13}N*(0, 3.50 + 3.55) have been measured at $E(^6\text{Li}) = 31.8$ MeV: see (81AJ01). These two reactions have been studied at $E(^6\text{Li}) = 93$ MeV and $E(^7\text{Li}) = 78$ MeV by (84GL1E): ^{13}N*(0, 3.5, 7.3) are most intensely populated. Angular distributions to ^{13}N*(0, 3.5[u]) have also been reported (89DE34; $E(^6\text{Li}) = 93$ MeV). See also (87GOZM; theor.).

27. ^{13}O(β^+)^{13}N $\quad Q_m = 17.767$

See ^{13}O and Table 13.21.

28. ^{14}N(p, d)^{13}N $Q_m = -8.3289$

Angular distributions have been measured for deuteron groups to ^{13}N*(0, 2.36, 3.50+3.55, 7.38, 8.92, 11.86) at many energies up to E_p = 155.6 MeV [see (81AJ01, 86AJ01)] and at E_p = 18.6 MeV (87VA28, 89BE1N; d_0). See also (89AR1G; applied), (89GU28; astrophysics) and (88GUZW; theor.).

29. ^{14}N(d, t)^{13}N $Q_m = -4.2962$

Angular distributions of the tritons to ^{13}N*(0, 3.50, 7.38, 8.92 + (9.00) + 9.48, 11.8) have been obtained at E_d = 52 MeV and analyzed by DWBA. The spectroscopic factors for the ^{13}N states [and the mirror states reached in the ^{14}N(d, ^{3}He)^{13}C reaction] are in good agreement with theory and are additional evidence for the J^π assignments of $\frac{1}{2}^-$, $\frac{3}{2}^-$, $\frac{5}{2}^-$, $\frac{1}{2}^-$, $\frac{3}{2}^-$ and $\frac{3}{2}^-$ to these states: see (81AJ01). See also (87GUZZ, 88GUZW, 89BE1N).

30. (a) ^{14}N(^{3}He, α)^{13}N $Q_m = 10.0243$
(b) ^{14}N(^{3}He, pα)^{12}C $Q_m = 8.0808$

Alpha-particle groups have been observed to the first seven excited states of ^{13}N, including two at E_x = 7.166 and 7.388 MeV [±8 keV]. Angular distributions have been studied at many energies up to E(^{3}He) = 45 MeV [see (81AJ01)] and at E(^{3}He) = 22.7, 36.9 and 40.0 MeV (87VA1I, 89BE1N; α_0). Reaction (b), studied at E(^{3}He) = 8 MeV, appears to involve some states of ^{13}N, possibly ^{13}N*(7.93, 8.92, 11.87): see (81AJ01). See also (88GO1E; theor.).

31. ^{14}N(^{6}Li, ^{7}Li)^{13}N $Q_m = -3.303$

An angular distribution has been measured at E(^{6}Li) = 32 MeV for the transition to ^{13}N$_{\rm g.s.}$ and ^{7}Li*(0, 0.48). ^{13}N*(2.36) was also populated: see (81AJ01).

32. ^{14}N(^{14}N, ^{15}N)^{13}N $Q_m = 0.2799$

See (88DA12; theor.).

33. ^{15}N(γ, 2n)^{13}C $Q_m = -21.3868$

See ^{15}N (88MC01).

34. ^{15}N(p, t)^{13}N $\qquad Q_m = -12.9049$

At $E_p = 43.7$ MeV, angular distributions have been obtained for the tritons corresponding to the ground state of ^{13}N and the excited states at 3.50 ($\frac{3}{2}^-$), 6.38 ± 0.03 ($\frac{5}{2}^+$), 7.38 ($\frac{5}{2}^-$), 8.93 ± 0.05 ($\frac{1}{2}^-$), 10.78 ± 0.06 ($\frac{1}{2}^-$), 11.88 ± 0.04 ($\frac{3}{2}^-$) and 15.06 ($\frac{3}{2}^-$; $T = \frac{3}{2}$) MeV [J^π values in parentheses, as determined by DWBA analyses using intermediate-coupling wave functions to obtain the two-nucleon structure factors]. Detailed comparisons have been made with the (p, ^{3}He) reaction to the mirror states in ^{13}C: see (81AJ01) for references and other information.

35. ^{16}O(p, α)^{13}N $\qquad Q_m = -5.2184$

Angular distributions of the α_0, α_1 and α_2 groups have been measured for E_p to 54.1 MeV: see (70AJ04, 76AJ04). In addition the distribution of the α-particles to a state with $E_x = 12.13 \pm 0.06$ MeV, $\Gamma_{c.m.} \approx 300$ keV [$J^\pi = \frac{7}{2}^-$] is reported at 54.1 MeV: see (81AJ01). For additional work see (86AJ01). See also (89WA16), (89AR1G, 90BA1S; applied), (88CA26, 89GU28; astrophysics) and (85MA1F; theor.). For the (p, pt) reaction see (86GO28; theor.).

36. ^{17}Ne(β^+)^{17}F$\xrightarrow{\alpha}$^{13}N $\qquad Q_m = 8.71$

See (88BO39).

^{13}O
(Figs. 3 and 4)

GENERAL (85AN28, 86AN07, 87SA15, 89AYZU). (See also (86AJ01)).

Mass of ^{13}O: We adopt the atomic mass excess of 23113 ± 10 keV of (88WO1C). See also (81AJ01). ^{13}O is then bound with respect to ^{12}N + p and ^{11}C + 2p by 1.514 and 2.115 MeV, respectively.

1. ^{13}O(β^+)^{13}N $\qquad Q_m = 17.767$

Table 13.20: Energy levels of ^{13}O

E_x in ^{13}O (MeV)	J^π; T	$\tau_{1/2}$ (ms) or Γ (MeV)	Decay	Reactions
g.s.	$(\frac{3}{2}^-)$; $\frac{3}{2}$	$\tau_{1/2} = 8.58 \pm 0.05$	β^+	1, 2, 3, 4, 5
2.75 ± 0.04				3, 4
4.21				4
6.02 ± 0.08 [a]		$\Gamma = 1.2$ MeV		4

[a] Corresponds to broad or unresolved states.

The half-life of ^{13}O has been reported to be 8.7 ± 0.4 ms (65MC09), 8.95 ± 0.20 ms (70ES03), 8.55 ± 0.05 ms (90AS01): the weighted mean is 8.58 ± 0.05 ms and we adopt it. ^{13}O decays to a number of states of ^{13}N, some of which subsequently decay to ^{12}C* (0, 4.4): see Table 13.21. See also (89WI1E; astrophys.) and (89WO1E; theor.).

2. ^{9}Be(^{13}C, ^{9}He)^{13}O $\qquad Q_m = -49.440$

At $E(^{13}\mathrm{C}) = 380$ MeV ^{9}He* (0, 3.8) are populated (88BO20). The atomic mass excess of ^{9}He derived from this work is 41.5 ± 0.6 MeV. In calculating Q_m, we used the value 40.8 ± 0.1 MeV (87SE05): see ^{9}He in (88AJ01).

3. ^{12}C(p, π^-)^{13}O $\qquad Q_m = -155.392$

At $E_p = 613$ MeV the ground state of ^{13}O and an excited state at $E_x = 2.82 \pm 0.24$ MeV are observed in addition to unresolved structures (78CO15). [See Fig. 4 for analog region in ^{13}B.] The angular distribution of the π^- to $^{13}\mathrm{O}_{\mathrm{g.s.}}$ has been measured at $E_p = 200$ MeV (80HO20), as has A_y at $E_{\vec{p}} = 183$ MeV: see (86AJ01). For a study of inclusive pion production at $E_p = 180$ and 201 MeV see (85BI04). See also (85CO11, 86KU1J, 90KU1H; theor.).

4. ^{13}C(π^+, π^-)^{13}O $\qquad Q_m = -19.988$

At $E_{\pi^+} = 164$ MeV excited states are reported at $E_x = 2.75 \pm 0.04$ and 4.21 MeV, as is a broad [$\Gamma = 1.2$ MeV] structure corresponding to one or more states at $E_x = 6.02 \pm 0.08$ MeV. At $E_{\pi^+} = 292$ MeV these states are not observed. Angular distributions have been

Table 13.21: Beta decay of ^{13}O [a]

Decay to		E_p (c.m.) (MeV) to		Relative intensity [a]	% of all β-decays [a]	log ft [b]
^{13}N* (MeV)	J^π	^{12}C (g.s.)	^{12}C*(4.4)			
g.s.	$\frac{1}{2}^-$				89.2 ± 2.2	4.08 ± 0.02 [c]
3.50	$\frac{3}{2}^-$	observed		100	9.8 ± 2.0	4.55 ± 0.09
7.38	$\frac{5}{2}^-$	5.48 ± 0.05		0.17 ± 0.07	0.18 ± 0.09	5.56 ± 0.22
			0.99	1.7 ± 0.8 [d]		
8.92	$\frac{1}{2}^-$	observed		4.83 ± 0.51		
					0.61 ± 0.14	4.66 ± 0.10
			2.56 ± 0.05	1.44 ± 0.25		
9.48	$\frac{3}{2}^-$	observed		0.98 ± 0.14		
					0.16 ± 0.04	5.09 ± 0.11
			3.12 ± 0.05	0.61 ± 0.15		
10.36	$\frac{5}{2}^-$	not seen		0.05 ± 0.03 [e]		
					0.02 ± 0.01	$5.7^{+0.3}_{-0.2}$
			3.97 ± 0.05	0.12 ± 0.08		

[a] (90AS01). See also the earlier work by (70ES03). I am indebted to Dr. A.M. Poskanzer for his comments.
[b] M.J. Martin, private communication.
[c] Estimated.
[d] Calculated value from the known ratio of the elastic and inelastic widths.
[e] Includes a calculated relative intensity of 3.4 ± 1.4 to ^{12}C*(4.4). I am indebted to Prof. F.C. Barker for this observation.

studied at $E_{\pi^+} = 164$ and 292 MeV to $^{13}O_{g.s.}$ and at 164 MeV to $^{13}O^*$ (4.21) (84SE15). At $E_{\pi^+} = 292$ MeV ($\theta = 5°$) a structure with a width of 2.0 ± 1.0 MeV is suggested to be due to a state at $E_x = 7.4 \pm 0.5$ MeV $Q = -27.4 \pm 0.5$ MeV] (89MO09). See also (90MO02).

5. $^{16}O(^3He, ^6He)^{13}O$ $\qquad Q_m = -30.511$

See (81AJ01).

^{13}F, ^{13}Ne, ^{13}Na
(Not illustrated)

These nuclei have not been observed. See (86AN07; theor.).

References

(Closed 01 July 1990)

65LI09 G.P. Lietz, S.F. Trevino, A.F. Behof and S.E. Darden, Nucl. Phys. 67 (1965) 193

65MC09 R. McPherson, R.A. Esterlund, A.M. Poskanzer and P.L. Reeder, Phys. Rev. 140 (1965) B1513

66PO11 A.R. Poletti, J.W. Olness and E.K. Warburton, Phys. Rev. 151 (1966) 812

69WI22 G. Wittwer, H.-G. Clerc and G.A. Beer, Phys. Lett. B30 (1969) 634

70AJ04 F. Ajzenberg-Selove, Nucl. Phys. A152 (1970) 1

70ES03 J.E. Esterl, J.C. Hardy, R.G. Sextro and J. Cerny, Phys. Lett. 33B (1970) 287

70WI04 G. Wittwer, H.-G. Clerc and G.A. Beer, Z. Phys. 234 (1970) 120

73AD1A Adelberger, In Proc. of the Int. Cong. on Nucl. Phys., Florence, Aug.-Sept. 1983, Vol. 2, Editors: P. Blasi and Ricci; Tipografia Compositori Bologna (1983) 499

73GO15 J.D. Goss, S.L. Blatt, D.R. Parsignault, C.D. Porterfield and F.L. Riffle, Phys. Rev. C7 (1973) 1837

74RO29 C. Rolfs and R.E. Azuma, Nucl. Phys. A227 (1974) 291

76AJ04 F. Ajzenberg-Selove, Nucl. Phys. A268 (1976) 1

78AJ02 F. Ajzenberg-Selove, E.R. Flynn and O. Hansen, Phys. Rev. C17 (1978) 1283

78CO15 P. Couvert, G. Bruge, R. Beurtey, A. Boudard, A. Chaumeaux, M. Garcon, D. Garreta, P.C. Gugelot, G.A. Moss, S. Platchkov, J.P. Tabet et al, Phys. Rev. Lett. 41 (1978) 530

78HI06 F. Hinterberger, R. Schonhagen, P. von Rossen, B. Schuller, F.E. Blumenberg, P.D. Eversheim and R. Gorgen, Nucl. Phys. A308 (1978) 61

78LEZA C.M. Lederer, V.S. Shirley, E. Browne, J.M. Dairiki, R.E. Doebler, A.A. Shihab-Eldin, L.J. Jardine, J.K. Tuli and A.B. Buyrn, Table of Isotopes 7th ed. (New York: John Wiley & Sons, 1978)

79JO08 R.R. Johnson, T. Masterson, B. Bassalleck, W. Gyles, T. Marks, K.L. Erdman, A.W. Thomas, D.R. Gill, E. Rost, J.J. Kraushaar et al, Phys. Rev. Lett. 43 (1979) 844

79KO26 L. Koester, K. Knopf and W. Waschkowski, Z. Phys. A292 (1979) 95

79MO16 G.L. Moake, L.J. Gutay, R.P. Scharenberg, P.T. Debevec and P.A. Quin, Phys. Rev. Lett. 43 (1979) 910

80AJ01 F. Ajzenberg-Selove and C.L. Busch, Nucl. Phys. A336 (1980) 1

80BA54 F.C. Baker and N. Ferdous, Aust. J. Phys. 33 (1980) 691

80CI03 S. Cierjacks, F. Hinterberger, G. Schmalz, D. Erbe, P.V. Rossen and B. Leugers, Nucl. Instrum. Meth. 169 (1980) 185

80FU04 H. Fuchs, J.A. Nolen, G.J. Wagner, H. Lenske and G. Baur, Nucl. Phys. A343 (1980) 133

80HE04 R.L. Helmer, M.D. Hasinoff, J.E. Bussoletti, K.A. Snover and T.A. Trainor, Nucl. Phys. A336 (1980) 219

80HO20 B. Hoistad, P.H. Pile, T.P. Sjoreen, R.D. Bent, M.C. Green and F. Soga, Phys. Lett. B94 (1980) 315

80PE13 R.J. Peterson and J.J. Hamill, Phys. Rev. C22 (1980) 2282

80SN01 K.A. Snover, P. G.Ikossi, E.G. Adelberger and K.T. Lesko, Phys. Rev. Lett. 44 (1980) 927

80TH05 W.J. Thompson, J.F. Wilkerson, T.B. Clegg, J.M. Feagin, E.J. Ludwig and E. Merzbacher, Phys. Rev. Lett. 45 (1980) 703

80WA24 E.K. Warburton, D.E. Alburger and D.J. Millener, Phys. Rev. C22 (1980) 2330

81AJ01 F. Ajzenberg-Selove, Nucl. Phys. A360 (1981) 1

81BR24 J.S. Briggs and A.M. Lane, Phys. Lett. B106 (1981) 436

81DY03 P. Dyer, D. Bodansky, A.G. Seamster, E.B. Norman and D.R. Maxson, Phys. Rev. C23 (1981) 1865

81KA16 G. Kajrys, W. Del Bianco, J. Kim, S. Landsberger, R. Lecomte, S. Monaro and P. Paradis, Can. J. Phys. 59 (1981) 781

81PE08 R.J. Peterson, J.R. Shepard and R.A. Emigh, Phys. Rev. C24 (1981) 826

81RA12 J. Rapaport, T. Taddeucci, C. Gaarde, C.D. Goodman, C.C. Foster, C.A. Goulding, D. Horen, E. Sugarbaker, T.G. Masterson and D. Lind, Phys. Rev. C24 (1981) 335

81RU04 A.J. Rutten, A. Holthuizen, W.A. Sterrenburg, C.P.M. Van Engelen and G. Van Middelkoop, Nucl. Phys. A359 (1981) 442

82AN1C B.D. Anderson, R.J. McCarthy, M. Ahmad, A. Fazely, A.M. Kalenda, J.N. Knudson, J.W. Watson, R. Madey and C.C. Foster, Phys. Rev. C26 (1982) 8

82AN1D Anghinolfi et al, Workshop on Medium Energy Interactions in Nucl. Phys., Pavia, Italy (1982) 16; Phys. Abs. 55048 (1983)

82BA1D Barnes, Essays in Nucl. Astrophys. (1982) 193

82BU1A Burbidge and Burbidge, Essays in Nucl. Astrophys. (1982) 11

82CA1A Cameron, Essays in Nucl. Astrophys. (1982) 23

82GR1A Greenstein, Essays in Nucl. Astrophys. (1982) 45

82HI07 R.S. Hicks, J. Dubach, R.A. Lindgren, B. Parker and G.A. Peterson, Phys. Rev. C26 (1982) 339

82KN02 H.D. Knox and R.O. Lane, Nucl. Phys. A378 (1982) 503

82MU14 S.F. Mughabghab, M.A. Lone and B.C. Robertson, Phys. Rev. C26 (1982) 2698

82SE04 S.J. Seestrom-Morris, D. Dehnhard, M.A. Franey, G.S. Kyle, C.L. Morris, R.L. Boudrie, J. Piffaretti and H.A. Thiessen, Phys. Rev. C26 (1982) 594

82WE16 D. West and A.C. Sherwood, Ann. Nucl. Energy 9 (1982) 551

82WO1A Woosley and Weaver, Essays in Nucl. Astrophys. (1982) 377

83AL20 D.V. Aleksandrov, E.A. Ganza, Yu.A. Glukhov, V.I. Dukhanov, I.B. Mazurov, B.G. Novatsky, A.A. Ogloblin, D.N. Stepanov, V.V. Paramonov and A.G. Trunov, Yad. Fiz. 37 (1983) 797; Sov. J. Nucl. Phys. 37 (1983) 474

83FR17 R.M. Freeman, C. Beck, F. Haas, B. Heusch and J.J. Kolata, Phys. Rev. C28 (1983) 437

83MA16 C.J. Martoff, J.A. Bistirlich, C.W. Clawson, K.M. Crowe, M. Koike, J.P. Miller, S.S. Rosenblum, W.A. Zajc, H.W. Baer, A.H. Wapstra et al, Phys. Rev. C27 (1983) 1621

83MI06 K. Min, E.J. Winhold, K. Shoda, M. Torikoshi, M. Yamazaki, O. Sasaki, H. Tsubota and B.N. Sung, Phys. Rev. C28 (1983) 464

83SE15 S.J. Seestrom-Morris, D. Dehnhard, M.A. Franey, C.L. Morris, R.L. Boudrie and H.A. Thiessen, Phys. Rev. C28 (1983) 1301

83WA29 J.W. Watson, B.D. Anderson, A.R. Baldwin, C. Lebo, B. Flanders, W. Pairsuwan, R. Madey and C.C. Foster, Nucl. Instrum. Meth. 215 (1983) 413

83ZU02 D. Zubanov, R.A. Sutton, M.N. Thompson and J.W. Jury, Phys. Rev. C27 (1983) 1957

84AF1A Afonas'ev et al, Sov. J. Nucl. Phys. 40 (1984) 22

84BE1L Benerskii et al, Sov. Phys.-Lebedev Inst. Rep. 9 (1984) 23; Phys. Abs. 24920

84BE23 T.L. Belyaeva, Izv. Akad. Nauk SSSR, Ser.Fiz. 48 (1984) 383

84BL10 S.L. Blatt, H.J. Hausman, L.G. Arnold, R.G. Seyler, R.N. Boyd, T.R. Donoghue, P. Koncz, M.A. Kovash, A.D. Bacher and C.C. Foster, Phys. Rev. C30 (1984) 423

84BL21 L.D. Blokhintsev, A.M. Mukjamedzhanov, A.N. Safronov, Fiz. Elem. Chastits At. Yadra 15 (1984) 1296; Sov. J. Part. Nucl 15 (1984) 580

84BO03 A.I. Boothroyd, J. Markey, P. Vogel, Phys. Rev. C29 (1984) 603

84BO1H Bogdanova and Markushin, Sov. J. Part. and Nucl. 15 (1984) 361

84CH1K Cheon, J. Korean Phys. Soc. 17 (1984) 114; Phys. Abs. 120695 (1986)

84DA17 B. Dasmahapatra, B. Cujec and F. Lahlou, Nucl. Phys. A427 (1984) 186

84DE1A P. De Bievre, M. Gallet, N.E. Holden and I.L. Barnes, J. Phys. Chem. Ref. Data 13 (1984) 809

84DE1L A.E. Denisov, R.P. Kolalis, S.I. Lashaev, V.S. Sadkovsky, Yu.V. Sobolev and G.A. Feofilov, Yad. Fiz. 40 (1984) 597; Sov. J. Nucl. Phys. 40 (1984) 382

84FR05 H. Frohlich, N. Bischof, W. Tiereth, H. Voit, W. Von Oertzen and B. Imanishi, Nucl. Phys. A420 (1984) 124

84GL1E Glukhov et al, Sov. J. Nucl. Phys. 40 (1984) 41

84HO06 C.H. Holbrow, H.G. Bingham, R. Middleton and J.D. Garrett, Phys. Rev. C9 (1974) 902

84KO40 V.Ya. Kostin and V.Ya. Migalenya, Izv. Akad. Nauk SSSR, Ser. Fiz. 48 (1984) 1021; Bull. Acad. Sci. USSR, Phys. Ser. 48 (1984) 184

84MA45 C.J. Martoff, L. Van Elmbt, M. Lebrun, M. Schaad, U. Straumann, P. Truol, K.M. Crowe, C. Joseph, J.P. Perroud, D. Ruegger et al, Nucl. Phys. A430 (1984) 557

84NA1F Nakamura, Indian J. Phys. A58 (1984) 12

84PO1D V.A. Poyarkov and I.V. Sizov, Yad. Fiz. 40 (1984) 21; Sov. J. Nucl. Phys. 40 (1984) 13

84SC09 I. Schwanner, G. Backenstoss, W. Kowald, L. Tauscher, H.-J. Weyer, D. Gotta, H. Ullrich, Nucl. Phys. A412 (1984) 253

84SE15 P.A. Seidl, M.D. Brown, R.R. Kiziah, C.F. Moore, H. Baer, C.L. Morris, G.R. Burleson, W.B. Cottingame, S.J. Greene, L.C. Bland et al, Phys. Rev. C30 (1984) 1076

84TA07 T.N. Taddeucci, T.A. Carey, C. Gaarde, J. Larsen, C.D. Goodman, D.J. Horen, T. Masterson, J. Rapaport, T.P. Welch and E. Sugarbaker, Phys. Rev. Lett. 52 (1984) 1960

84VA06 A.G.M. van Hees, P.W.M. Glaudemans, Z. Phys. A315 (1984) 223

84VD1A Vdovin, Golikov and Loshcharkov, Sov. J. Nucl. Phys. 39 (1984) 832

84WO05 J.G. Woodworth, R.A. August, N.R. Roberson, D.R. Tilley, H.R. Weller and J.W. Jury, Phys. Rev. C29 (1984) 1186

84ZA1D Zavarzina, Sov. Phys.-Lebedev Inst. Rep. 10 (1984) 1; Phys. Abs. 24921 (1986)

84ZH1B Zhuang, Chen and Jin, Phys. Energ. Fortis and Phys. Nucl. 8 (1984) 215

85AB10 S.N. Abramovich, B.Ya. Guzhovsky and V.A. Pereshivkin, Izv. Akad. Nauk SSSR, Ser. Fiz. 49 (1985) 917; Bull. Acad. Sci. USSR, Phys. Ser. 49 (1985) 77

85AL1F Alkhazov et al, Sov. J. Nucl. Phys. 42 (1985) 4

85AL1G Aleksandrov et al, In Questions in Atomic Physics and in Tech., USSR (1985) 3

85AN28 M.S. Antony, J. Britz, J.B. Bueb and A. Pape, At. Data Nucl. Data Tables 33 (1985) 447

85AR1A Arnett and Thielmann, Astrophys. J. 295 (1985) 589

85AR1G A.A. Arakelyan, A.R. Balabekyan, A.S. Danagulyan and A.G. Khudaverdyan, Yad. Fiz. 41 (1985) 833; Sov. J. Nucl. Phys. 41 (1985) 533

85AU10 R.A. August, H.R. Weller and D.R. Tilley, Phys. Rev. C32 (1985) 1420

85AZ1A Azimov et al, Czech. J. Phys. 35 (1985) 832

85BA1F Bando, Suppl. Prog. Theor. Phys. 81 (1985) 181

85BA1N Bahcall, In AIP Conf. Proc. 126 (1985) 60

85BA1T Barnes, In Lecture Notes in Physics 219, Springer-Verlag (1985) 70

85BA2D Bando, Suppl. Prog. Theor. 81 (1985) 197

85BA2F Bayukov et al, Sov. J. Nucl. Phys. 42 (1985) 116

85BA75 F.C. Barker, Aust. J. Phys. 38 (1985) 657

85BE1A Beckerman, Phys. Rep. 129 (1985) 145

85BE37 C. Beck, R.M. Freeman, F. Haas, B. Heusch and J.J. Kolata, Nucl. Phys. A443 (1985) 157

85BE40 C. Beck, F. Haas, R.M. Freeman, B. Heusch, J.P. Coffin, G. Guillaume, F. Rami and P. Wagner, Nucl. Phys. A442 (1985) 320

85BI04 L. Bimbot, V. Bellini, M. Bolore, X. Charlot, C. Guet, J.M. Hisleur, J.C. Jourdain, J. Julien, P. Kristiansson, G. Lanzano et al, Nucl. Phys. A440 (1985) 636

85BL22 G.S. Blanpied, B.G. Ritchie, M.L. Barlett, G.W. Hoffmann, J.A. McGill, M.A. Franey and M. Gazzaly, Phys. Rev. C32 (1985) 2152

85BO1A Boal, Adv. Nucl. Phys. 15 (1985) 85

85BO39 H.G. Bohlen, X.S. Chen, J.G. Cramer, P. Frobrich, B. Gebauer, H. Lettau, A. Miczaika, W. von Oertzen, R. Ulrich and T. Wilpert, Z. Phys. A322 (1985) 241

85BR06 J.C. Brown, R.G. Seyler, T.L. Tsin and S.L. Blat, Phys. Rev. C31 (1985) 1607

85BR1E Brown, Astrophys. J. 297 (1985) 233

85BY1A D.P. Bybell, W.K. Wells and D.P. Balamuth, Phys. Rev. C32 (1985) 452

85CA41 G.R. Caughlan, W. A. Fowler, M.J. Harris and B.A. Zimmerman, At. Data Nucl. Data Tables 32 (1985) 197

85CO11 P. Couvert and M. Dillig, Phys. Rev. C32 (1985) 352

85CU1A B. Cujec, Lecture Notes in Phys. 219 (1985)108

85DE11 A.E. Denisov, R.P. Kolalis, S.I. Lashaev, V.S. Sadkovsky and G.A. Feofilov, Izv. Akad. Nauk SSSR, Ser. Fiz. 49 (1985) 150; Bull. Acad. Sci. USSR, Phys. Ser. 49 (1985) 1

85DE42 F.W.N. De Boer, B. Aas, P. Baertschi, W. Beer, I. Beltrami, K. Bos, P.F.A. Goudsmit, U. Kiebele, B. Jeckelmann, H.J. Leisi et al, Nucl. Phys. A444 (1985) 589

85EL07 Z. El-Itaoui, P.J. Ellis and B.A. Mughrabi, Nucl. Phys. A441 (1985) 511

85FI09 R.W. Finlay, A.S. Meigooni, J.S. Petler and J.P. Delaroche, Nucl. Instrum. Meth. Phys. Res. B10-11 (1985) 396

85GA1C Gal, AIP Conf. Proc. 133 (1985) 30

85GO1A Goncharova, Kissener and Eramzhyan, Sov. J. Part. and Nucl. 16 (1985) 337

85GO1Q Goodman, AIP Conf. Proc. 126 (1985) 109

85GU1C Gulyamov et al, in Leningrad (1985) 291

85HA1R Harris, Lambert and Smith, Astrophys. J. 299 (1985) 375

85HE1F Henkel, Giusten and Gardner, Astron. Astrophys. 143 (1985) 148

85HU04 M.S. Hussein, B.V. Carlson, O. Civitarese and A. Szanto De Toledo, Phys. Rev. Lett. 54 (1985) 2659

85IM1B Imanishi and Von Oertzen, J. Phys. Soc. Jpn. 54 (1985) 183

85IQ01 M.J. Iqbal and G.E. Walker, Phys. Rev. C32 (1985) 556

85KA10 S. Kato, K. Okada, M. Kondo, K. Hosono, T. Saito, N. Matsuoka, K. Hatanaka, T. Noro, S. Nagamachi, H. Shimizu et al, Phys. Rev. C31 (1985) 1616

85KI1A Kitching et al, Adv. Nucl. Phys. 15 (1985) 43

85KI1E Kim, Lett. Nuovo Cim. 43 (1985) 373

85KO1J Koonin, in Lecture Notes in Physics 219, Springer-Verlag (1985) 129

85KO1T Kong, Mo and Liu, Chin. Phys. 5 (1985) 943

85KO1U Kovacs and Muller, Report KFKI-1985-111 (1985)

85KO1W Kong, mo and Liu, Chin. J. Nucl. Phys. 7 (1985) 19

85KO39 K. Koshigiri, Y. Kakudo, H. Ohtsubo and M. Morita, Prog. Theor. Phys.74 (1985) 736

85KU1F Kudo and Dietze, Bull. Electrotech. Lab. 49 (1985) 23

85KW02 E. Kwasniewicz, L. Jarczyk, Nucl. Phys. A441 (1985) 77

85KW03 E. Kwasniewicz, J. Kisiel and L. Jarczyk, Acta Phys. Pol. B16 (1985) 947

85LI1H Liubinskii et al, in Leningrad (1985) 500

85MA1F Mazitov and Rasulov, in Leningrad (1985) 298

85MC07 M.W. McNaughton, B.E. Bonner, H. Ohnuma, O.B. Van Dijk, Sun Tsu-Hsun, C.L. Hollas, D.J. Cremans, K.H. McNaughton, P.J. Riley, R.F. Rodebaugh et al, Nucl. Instrum. Meth. 241 (1985) 435

85ME16 A.S. Meigooni, R.W. Finlay, J.S. Petler and J.P. Delaroche, Nucl. Phys. A445 (1985) 304

85MI13 B. Milek and R. Reif, Phys. Lett. B157 (1985) 134

85MI1E Michaud, AIP Conf. Proc. 126 (1985) 75

85MI21 S.L. Mintz, Phys. Rev. C32 (1985) 2179

85PE10 J.S. Petler, M.S. Islam, R.W. Finlay and F.S. Dietrich, Phys. Rev. C32 (1985) 673

85PI11 J. Piekarewicz, Phys. Rev. C32 (1985) 1693

85PO10 N.A.F.M. Poppelier, L.D. Wood and P.W.M. Glaudemans, Phys. Lett. B157 (1985) 120

85PO11 D.N. Poenaru, M. Ivascu, A. Sandulescu and W. Greiner, Phys. Rev. C32 (1985) 572

85PO14 D.N. Poenaru and M. Ivascu, J. Phys. Lett. 46 (1985) L591

85PR1D Prombo and Clayton, Science 230 (1985) 935

85PY01 R.E. Pywell, B.L. Berman, J.G. Woodworth, J.W. Jury, K.G. McNeill and M.N. Thompson, Phys. Rev. C32 (1985) 384

85RA1E Radev et al, Yad. Energ. (Bulgaria) 21 (1985)

85RE1C Reisdorf, in Lecture Notes in Physics 219, Springer-Verlag (1985) 43

85RI1B Rickard and Blitz, Astrophys. J. 292 (1985) L57

85RO1J Rotter, J. Phys. G11 (1985) L219

85SA06 T. Sato, K. Koshigiri and H. Ohtsubo, Z. Phys. A320 (1985) 507

85SA1D Sakuragi et al, J. Phys. Soc. Jpn. 54 (1985) 88

85SE15 R.E. Segel, S.M. Levenson, P. Zupranski, A.A. Hassan, S. Mukhopadhyay and J.V. Maher, Phys. Rev. C32 (1985) 721

85SH1D Shvedov and Nemets, in Leningrad (1985) 317

85SH1H Shepard, AIP Conf. Proc. 133 (1985) 48

85SH24 R. Sherr and G. Bertsch, Phys. Rev. C32 (1985) 1809

85ST1C E.J. Stephenson, S.W. Wissink, A.D. Bacher, J.D. Brown, M.S. Cantrell, V.R. Cupps, D.L. Friesel, J.A. Gering, W.P. Jones, D.A. Low et al, Bull. Am. Phys. Soc. 30 (1985) 1160

85TA1A Taam, Ann. Rev. Nucl. Part. Sci. 35 (1985) 1

85TI07 Tian Ye, Han Yinlu, Shen Qingbiao, Zhuo Yizhong, Liu Wei, Guo Dongmin, Li Fei, Chin. J. Nucl. Phys. 7 (1985) 154

85TO02 W. Tornow, R.L. Walter and R.C. Byrd, J. Phys. G11 (1985) 379

85UT01 H. Utsunomiya, Phys. Rev. C32 (1985) 849

85WA24 J.W. Watson, W. Pairsuwan, B.D. Anderson, A.R. Baldwin, B.S. Flanders, R. Madey, R.J. McCarthy, B.A. Brown, B.H. Wildenthal and C.C. Foster, Phys. Rev. Lett. 55 (1985) 1369

85WI1F E.J. Stephenson, S.W. Wissink, A.D. Bacher, J.D. Brown, M.S. Cantrell, V.R. Cupps, D.L. Friesel, J.A. Gering, W.P. Jones, D.A. Low et al, Bull. Am. Phys. Soc. 30 (1985) 1160

85YA1C Yamada et al, Suppl. Prog. Theor. Phys. 81 (1985) 104

85ZH07 X. Zhu, R.E. Azuma, T.E. Drake, J.D. King and S.S.M. Wong, Nucl. Phys. A439 (1985) 619

86AD1B Adhikari, Phys. Rev. C33 (1986) 471

86ADZY E.G. Adelberger, C.A. Gossett, V.J. Zeps and J. Sromicki, Bull. Am. Phys. Soc. 31 (1986) 1209

86AI04 A.A. Haddou, M. Berrada and G. Paic, J. Radioanal. & Nucl. Chem. Artic. 102 (1986) 159

86AJ01 F. Ajzenberg-Selove, Nucl. Phys. A449 (1986) 1

86AL1K Alford, AIP Conf. Proc. 150 (1986) 710

86AL1L Al Mamma et al, in Kharkov (1986) 463

86AL1N Alnajjar, Abdelnaby and Durrani, Nucl. Track Radiat. Meas. 12 (1986) 611

86AMZX K. Amos, L. Berge and D.J. Millener, Proc. Intern. Nucl. Phys. Conf., Harrogate, U.K., (1986) 199

86AN07 M.S. Antony, J. Britz and A. Pape, At. Data Nucl. Data Tables 34 (1986) 279

86AN1R Ansari, Shoeb and Rahman Khan, J. Phys. G12 (1986) 1369

86AV1B Avseichikov, in Dubna (1986) 122

86BA1D Barrette, J. Physique 47 (1986) C4

86BA1H Bando, Czech. J. Phys. 36 (1986) 915

86BA40 F.M. Baumann, G. Domogala, H. Freiesleben, H.J. Paul, S. Puhlvers and H. Sohlbach, Nucl. Instrum. Meth. Phys. Res. A247 (1986) 359

86BA58 C.V.K. Baba, D. Indumathi, A. Roy and S.C. Vaidya, Phys. Lett. B180 (1986) 406

86BA69 D. Baye, Nucl. Phys. A460 (1986) 581

86BA80 A. Barbadoro, D. Consolaro, F. Pellegrini, L. Taffara, D. Trivisonno, M. Bruno and I. Gabrielli, Nuovo Cim. 95A (1986) 197

86BA88 W. Bauhoff, At. Data Nucl. Data Tables 35 (1986) 429

86BAYL M. Baba, M. Ono, N. Yabuta, T. Kikuti and N. Hirakawa, Proc. Inter. Conf. Nucl. Data for Basic and Appl. Sci., Santa Fe, New Mexico, 1 (1986) 223

86BE17 I. Bergqvist, D.M. Drake, D.K. McDaniels, S.A. Wender, A. Lindholm, L. Nilsson, N. Olsson, R. Zorro and F.S. Dietrich, Nucl. Phys. A456 (1986) 426

86BE2D Benetskii et al, J. Phys. Soc. Jpn. Suppl. 55 (1986) 566

86BE2F Begum et al, J. Bangladesh Acad. Sci. 10 (1986) 147

86BI1A Bimbot et al, J. Physique 47 (1986) C4-241

86BO1M Bottger et al, in Santa Fe 85 (1986) 1455

86BO1N Bowman, in Proc. Int. Nucl. Phys. Conf., Harrogate, U.K., no. 68, vol. 2 (1986) 83

86BR1Q Bruynseels and Van Grieken, Int. J. Mass Spectrom. Ion Proc. 74 (1986) 161

86BU1R Burrows, Wood and Spooner, Nature 321 (1986) 851

86CA1N Carey, J. Phys. Soc. Jpn. Suppl. 55 (1986) 172

86CE04 C. Cernigoi, N. Grion, G. Pauli, R. Rui and R. Cherubini, Nucl. Phys. A456 (1986) 599

86CH2E Cheon and Jeong, J. Korean Phys. Soc. 19 (1986) 174

86CH2H Cheplakov et al, Z. Phys. A324 (1986) 465

86CI01 N. Cindro, R.M. Freeman and F.Haas, Phys. Rev. C33 (1986) 1280

86CL1C Clegg, J. Phys. Soc. Jpn. Suppl. 55 (1986) 535

86CO02 J. Cook, M.N. Stephens, K.W. Kemper and A.K. Abdallah, Phys. Rev. C33 (1986) 915

86CU02 B. Cujec, B. Dasmahapatra, Q. Haider, F. Lahlou and R.A. Dayras, Nucl. Phys. A453 (1986) 505

86DA1B Davis and Pniewski, Contemp. Phys. 27 (1986) 91

86DA1G Dalitz, Davis and Tovee, Nucl. Phys. A450 (1986) 311C

86DE1M De Swiniarski, in Harrogate (1986) C183

86DI1C Ding and Liou, Bull. Amer. Phys. Soc. 31 (1986) 774

86DO01 C.B. Dover, A. Gal, L. Klieb and D.J. Millener, Phys. Rev. Lett. 56 (1986) 119

86DO11 T.W. Donnelly and A.S. Raskin, Ann. Phys. 169 (1986) 247

86DO1L Dominy, Wallerstein and Suntzeff, Astrophys. J. 300 (1986) 325

86DO1M Donahue, Bull. Amer. Phys. Soc. 31 (1986) 1266

86DR03 P.V. Drumm, O. Karban, A.K. Basak, P.M. Lewis, S. Roman and G.C. Morrison, NUCL. PHYS. A448 (1986) 93

86DR1D Drosg et al, in Santa Fe (1985) 145

86DR1E Druffel and Benavides, Nature 321 6065 (1986) 58

86DU15 L.V. Dubar, V.S. Zaritsky, V.A. Zybin, D.Sh. Eleukenov, O.F. Nemets, L.I. Slyusarenko, V.A. Stepanenko, V.V. Tokarevsky and N.P. Yurkuts, Izv. Akad. Nauk SSSR, Ser.Fiz. 50 (1986) 2034; Bull. Acad. Sci. USSR, Phys. Ser. 50 (1986) 160

86EJ1A Ejiri et al, J. Phys. Soc. Jpn. Suppl. 55 (1986) 630

86EL02 P.J. Ellis, Q.K.K. Liu and S. Chakravarti, Phys. Rev. C34 (1986) 348

86EN1A Engelmann and Bardy, Report CEA-R-5340 (1986)

86ER1A Eramzhyan et al, Phys. Rep. 136 (1986) 229

86ER1D N.V. Eremin, Yu.V. Melikov, V.F. Strizhov and A.F. Tulinov, Yad. Fiz. 44 (1986) 16; Sov. J. Nucl. Phys. 44 (1986) 11

86FA03 W.R. Falk, E.G. Auld, G. Giles, G. Jones, G.J. Lolos, W. Ziegler and P.L. Walden, Phys. Rev. C33 (1986) 988

86FE1A Fetisov et al, Czech. J. Phys. 36 (1986) 451

86FO08 P.B. Foot, G.G. Shute and B.M. Spicer, Can. J. Phys. 64 (1986) 1348

86FO1D Fowler, Bull. Amer. Phys. Soc. 31 (1986) 1267

86FO1E Ford et al, in Santa Fe 85 (1986) 1419

86FR04 R.M. Freeman, C. Beck, F. Haas, A. Morsad and N. Cindro, Phys. Rev. C33 (1986) 1275

86FR1G Franchi, Wright and Pillinger, Nature 323 (1986) 138

86FR1H Friedli et al, Nature 324 (1986) 237

86GA13 E.N. Gazis, C.T. Papadopoulos, R. Vlastou and A.C. Xenoulis, Phys. Rev. C34 (1986) 872

86GA1J Gal, Nucl. Phys. A450 (1986) 23C

86GE1C Gerlach and Thomas, Nature 319 (1986) 480

86GI10 A. Gillibert, L. Bianchi, A. Cunsolo, B. Fernandez, A. Foti, J. Gastebois, Ch. Gregoire, W. Mittig, A. Peghaire, Y. Schutz et al, Phys. Lett. B176 (1986) 317

86GL1A Glaudmans, AIP Conf. Proc. 142 (1986) 316

86GL1G Glashausser, J. Phys. Soc. Jpn. Suppl. 55 (1986) 293

86GO1C O.Yu. Goryunov, E.I. Koshchy, Yu.G. Mashkarov, O.F. Nemetz, A.T. Rudchik, V.A. Stepanenko and Yu.M. Tchuvilsky, Yad. Fiz. 44 (1986) 573; Sov. J. Nucl. Phys. 44 (1986) 369

86GO1Q Gomez-Gonzalez et al, Astron. Astrophys. 168 (1986) L11

86GO28 N.F. Golovanova and V.V. Kurovsky, Izv. Akad. Nauk SSSR, Ser. Fiz. 50 (1986) 963; Bull. Acad. Sci. USSR, Phys. Ser. 50 (1986) 131

86GR04 K. Grotz, H.V. Klapdor and J. Metzinger, Phys. Rev. C33 (1986) 1263

86GR1A Gregoire and Tamain, Ann. Physique 11 (1986) 323

86HA13 Q. Haider and F.B. Malik, J. Phys. G12 (1986) 537

86HA1B Harvey, J. Physique 47 (1986) C4-29

86HA1K Haneishi and Fujita, Phys. Rev. C33 (1986) 260

86HA30 M.N. Harakeh, D.H. Dowell, G. Feldman, E.F. Garman, R. Loveman, J.L. Osborne and K.A. Snover, Phys. Lett. 176B (1986) 297

86HE1F Heaton et al, Nature 322 (1986) 822

86HI06 R.S. Hicks, R.A. Lindgren, M.A. Plum, G.A. Peterson, H. Crannell, D.I. Sober, H.A. Thiessen and D.J. Millener, Phys. Rev. C34 (1986) 1161

86HI1B Hichwa, Bull. Amer. Phys. Soc. 31 (1986) 1335

86HO10 C.J. Horowitz and M.J. Iqbal, Phys. Rev. C33 (1986) 2059; Erratum Phys. Rev. C34 (1986) 2012

86HO1H Hosono et al, Phys. Soc. Jpn. Suppl. 55 (1986) 618

86HO1K Horn et al, J. Physique 47 (1986) C4-83

86HO26 B. Hoheisel, D. Kamke and M. Schluckebier, Z. Phys. A325 (1986) 317

86HOZY C.R. Howell, W. Tornow, I. Slaus, P.A. Treado, K. Murphy, H.G. Pfutzner, M.L. Roberts, P.I. Felsher and R.L. Walter, Bull. Am. Phys. Soc. 31 (1986) 854

86IE1A Ieke et al, J. Phys. Soc. Jpn. Suppl. 55 (1986) 1114

86IS02 K. Ishida, J.H. Brewer, T. Matsuzaki, Y. Kuno, J. Imazato and K. Nagamine, Phys. Lett. B167B (1986) 31

86IS1F Iseri, Yahiro and Kamimura, Prog. Theor. Phys. Suppl. 89 (1986) 84

86JA1H Jacobs, AIP Conf. Proc. 142 (1986) 181

86KA1B Kamimura et al, Prog. Theor. Phys. Suppl. 89 (1986) 1

86KA1Y Kato and Wakai, J. Phys. Soc. Jpn. Suppl. 55 (1986) 602

86KA44 O. Karban, L. Potvin and I.M. Turkiewicz, Nucl. Phys. A460 (1986) 529

86KI12 N.S.P. King, P.W. Lisowski, G.L. Morgan, P.N. Craig, R.G. Jeppesen, D.A. Lind, J.R. Shepard, J.L. Ullmann, C.D. Zafiratos, C.D. Goodman et al, Phys. Lett. B175 (1986) 279

86KI1J Kiesere et al, Nucl. Instr. Meth. Phys. Res. B15 (1986) 718

86KN1E Knoll et al, Nature 321 (1986) 832

86KO1A Kolesnikov et al, in Kharkov (1986) 225

86KO26 Zs. Kovacs and H. Muller, J. Phys. G12 (1986) 1355

86KR1F Krishamurthy, Bhattacharya and Kusmugar, Nature 323 (1986) 150

86KU1J Kume, J. Phys. Soc. Jpn. Suppl. 55 (1986) 920

86LA1C Lambert et al, Astrophys. J. Suppl. 62 (1986) 373

86LA1R Lalazissis, Grypeos and Massen, in Harrogate (1986) H2

86LI1N Li and Chiang, Nucl. Phys. A454 (1986) 720

86LI1P Li and Jiang, Chin. Phys. Lett. 3 (1986) 41

86LI1Q Lieb et al, Bull. Amer. Phys. Soc. 31 (1986) 1086

86LI1R E.P. Lifshits, Yad. Fiz. 44 (1986) 926 ; Sov. J. Nucl. Phys. 44 (1986) 597

86LO1A Love and Klein, J. Phys. Soc. Jpn. 55 (1986) 78

86MA19 J.F. Mateja, A.D. Frawley, L.C. Dennis and K. Sartor, Phys. Rev. C33 (1986) 1649

86MA1C Majling et al, Nucl. Phys. A450 (1986) 189C

86MA1O MacDonald et al, in Harrogate (1986) C214

86MA1P Martin et al, Bull. Amer. Phys. Soc. 31 (1986) 1304

86MA1T Mathews et al, in Santa Fe (1985) 835

86MA1W May, Nucl. Phys. A450 (1986) 179C

86MA2D Magaritz, Holser and Kirschvink, Nature 320 (1986) 258

86MA2E Madden, Irvine and Matthews, Astrophys. J. 311 (1986) L27

86MA2F Mao, Ehmann and Markesbery, Bull. Amer. Phys. Soc. 31 (1986) 1293

86MA2G Martens et al, Science 233 (1986) 1300

86ME06 M.C. Mermaz, T. Suomijarvi, R. Lucas, B. Berthier, J. Matuszek, J.P. Coffin, G. Guillaume, B. Heusch, F. Jundt and F. Rami, Nucl. Phys. A456 (1986) 186

86ME1F Measday, Czech. J. Phys. 36 (1986) 395

86ME1K Meier et al, in Santa Fe (1986) 1415

86MEZZ M. Meier, D. Holtkamp, G. Morgan, H. Robinson, G. Russell, R. Whitaker, W. Amian and N. Paul, Bull. Am. Phys. Soc. 31 (1986) 1111

86MI1A Milek and Reif, in Dubna (1986) 104

86MI1K Mintz, Phys. Rev. C33 (1986) 594

86MI1M Mintz, AIP Conf. Proc. 150 (1986) 597

86MI24 K. Mikulas, K.A. Gridnev, E.F. Hefter, V.M. Semjonov and V.B. Subbotin, Nuovo Cim. A93 (1986) 135

86MO15 H. Morgenstern, W. Bohne, W. Galster and K. Grabisch, Z. Phys. A324 (1986) 443

86MO1L Moss, in Proc. Int. Nucl. Phys. Conf., Harrogate, U.K. (1986) 41

86MO27 T. Motobayashi, H. Sakai, N. Matsuoka, T. Saito, K. Hosono, A. Okihana, M. Ishihara, S. Shimoura and A. Sakaguchi, Phys. Rev. C34 (1986) 2365

86MU1B Mughabghab, Phys. Rev. Lett. 56 (1986) 399

86NI1C Nitz et al, AIP Conf. Proc. 150 (1986) 1143

86NO1C Nojiri et al, J. Phys. Soc. Jpn. Suppl. 55 (1986) 391

86NO1E Noro et al, J. Phys. Soc. Jpn. Suppl. 55 (1986) 470

86OH01 H. Ohnuma, N. Hoshino, O. Mikoshiba, K. Raywood, A. Sakaguchi, G.G. Shute, B.M. Spicer, M.H. Tanaka, M. Tanifuji, T. Terasawa et al, Nucl. Phys. A448 (1986) 205

86OH03 H. Ohnuma, B.A. Brown, D. Dehnhard, K. Furukawa, T. Hasegawa, S. Hayakawa, N. Hoshino, K. Ieki, M. Kabasawa, K. Maeda et al, Nucl. Phys. A456 (1986) 61

86OL1A Olmer et al, J. Phys. Soc. Jpn. Suppl. 55 (1986) 928

86OS05 A. Osman and S.S. Abdel-AzizIndian, J. Pure Appl. Phys. 21 (1986) 65

86PA04 J.Y. Park, K. Gramlich, W. Scheid and W. Greiner, Phys. Rev. C33 (1986) 1674

86PA10 C.T. Papadopoulos, R. Vlastou, E.N. Gazis, P.A. Assimakopoulos, C.A. Kalfas, S. Kossionides and A.C. Xenoulis, Phys. Rev. C34 (1986) 196

86PE1E Petrovich, Carr and McManus, Ann. Rev. Nucl. Part. Sci. 36 (1986) 29

86PO06 D.N. Poenaru, W. Greiner, K. Depta, M. Ivascu, D. Mazilu and A. Sandulescu, At. Data Nucl. Data Tables 34 (1986) 423

86RA05 L. Ray, G.W. Hoffmann, M.L. Barlett, J.J. Jarmer, B.C. Clark, R.E. Kozack, R.L. Mercer, G.R. Burleson and S. Hama, Phys. Rev. Lett. 56 (1986) 2465

86RA1B Raman and Lynn, Phys. Rev. Lett. 56 (1986) 398

86RO1F Romero, Brady and Subramanian, in Santa Fe (1985) 687

86SA1D Sakuragi, Yahiro and Kamimura, Prog. Theor. Phys. Suppl. 89 (1986) 136

86SA1J Sakaguchi et al, J. Phys. Soc. Jpn. Suppl. 55 (1986) 61

86SA2F Sakaguchi et al, J. Phys. Soc. Jpn. Suppl. 55 (1986) 584

86SA30 H. Sato, Y. Okuhara, Phys. Rev. C34 (1986) 2171

86SH13 K. Shoda, A. Kagaya, O. Sasaki, S. Toyama, T. Kobayashi and H. Tsubota, Phys. Lett. B169 (1986) 17

86SH1X Shibata et al, J. Phys. Soc. Jpn. Suppl. 55 (1986) 626

86SH1Y Shibata et al, J. Phys. Soc. Jpn. Suppl. 55 (1986) 628

86SI07 M.K. Singham, Phys. Rev. C33 (1986) 2194

86SI13 M.K. Singham and F. Tabakin, Phys. Rev. C34 (1986) 637

86SI1D Simpson and Earwaker, Nucl. Instr. Meth. Phys. Res. B15 (1986) 502

86SI22 M.K. Singham, Nucl. Phys. A460 (1986) 597

86SN1B Snover, Ann. Rev. Nucl. Part. Sci. 36 (1986) 545

86SN1C Sneden and Pilachowski, Astrophys. J. 301 (1986) 860

86SN1D Sneden, Pilachowski and Vandenberg, Astrophys. J. 311 (1986) 826

86SO10 L.G. Sobotka, D.G. Sarantites, H. Puchta, F.A. Dilmanian, M. Jaaskelainen, M.L. Halbert, J.H. Barker, J.R. Beene, R.L. Ferguson, D.C. Hensley et al, Phys. Rev. C34 (1986) 917

86SR1B Srdoc, Nucl. Instr. Meth. Phys. Res. B17 (1986) 545

86ST1A Steadman and Rhoades-Brown, Ann. Rev. Nucl. Part. Sci. 36 (1986) 649

86ST1F Stephenson, J. Phys. Soc. Jpn. Suppl. 55 (1986) 316

86ST1G Stephenson et al, J. Phys. Soc. Jpn. Suppl. 55 (1986) 926

86ST1K Stevenson et al, Nature 323 (1986) 522

86SU18 T. Suzuki, T. Takaki and J.H. Koch, Nucl. Phys. A460 (1986) 607

86TA1E Taddeucci, J. Phys. Soc. Jpn. Suppl. 55 (1986) 156

86UT01 H. Utsunomiya, E.C. Deci, R.A. Blue, L.H. Harwood, R.M. Ronningen, K. Siwek-Wilczynska, J. Wilczynski and D.J. Morrissey, Phys. Rev. C33 (1986) 185

86VD01 A.I. Vdovin, A.V. Golovin and I.I. Loshchakov, Yad. Fiz. 43 (1986) 1443; Sov. J. Nucl. Phys. 43 (1986) 930

86VD1C Vdovin et al, in Kharkov (1986) 290

86VI08 A. Vitturi and C.H. Dasso, Nucl. Phys. A458 (1986) 157

86VI1D Vinogradov et al, in Kharkov (1986) 288

86VO02 W. von Oertzen, M. Buenerd, J. Chauvin, D. Lebrun, J.Y. Hostachy, Ph. Martin, G. Perrin and P. De Saintignon, Z. Phys. A323 (1986) 373

86VO1G Vogt, in Proc. Int. Nucl. Phys. Conf., Harrogate, U.K., no.68, vol. 2 (1986) 23

86WA26 R. Wagner, Z. Lewandowski and H.H. Muller, Nucl. Phys. A459 (1986) 605

86WAZU K. Wang, D. Pocanic, C.J. Martoff, S.S. Hanna, F.P. Brady, J.L. Romero, C.M. Castaneda, J.R. Drummond and B.C. McEachern, Bull. Am. Phys. Soc. 31 (1986) 1215

86WE1B Weigmann, in Santa Fe (1985) 853

86WE1D Weller, J. Phys. Soc. Jpn. Suppl. 55 (1986) 113

86WE1E Wei et al, Bull. Amer. Phys. Soc. 31 (1986) 1294

86WI1B Winn, IEEE Trans. Nucl. Sci. 33 (1986) 213

86WI1H Willems and Dejong, Astrophys. J. 309 (1986) L39

86WU1C Wunsch, Majling and Zofka, Nucl. Phys. A450 (1986) 329C

86WU1D Wunsch, Majling and Zofka, Czech. J. Phys. 36 (1986) 441

86XU02 H.M. Xu, D.J. Fields, W.G. Lynch, M.B. Tsang, C.K. Gelbke, M.R. Maier, D.J. Morrissey, J. Pochodzalla, D.G. Sarantites, L.G. Sobotka et al, Phys. Lett. B182 (1986) 155

86XU1B Xu and Lynch, Int. Conf. on Nucl. & Radiochem. (Beijing, China: Chinese Nucl. Soc. 1986) 54

86XU1C Xu et al, Nature 321 (1986) 854

86YA1F Yamamoto, Prog. Theor. Phys. 75 (1986) 639

86ZA06 V.P. Zavarzina and A.V. Stepanov, Yad. Fiz. 43 (1986) 854; Sov. J. Nucl. Phys. 43 (1986) 543

86ZE04 N.S. Zelenskaya and A.K. Morzabaev, Izv. Akad. Nauk SSSR, Ser. Fiz. 50 (1986) 1840; Bull. Acad. Sci. USSR, Phys. Ser. 550 (1986) 170

86ZE1E Zeps et al, Bull. Amer. Phys. Soc. 31 (1986) 1226

86ZH04 X. Zhu, S.S.M. Wong and N. Mobed, Phys. Lett. B174 (1986) 142

87AB03 H. Abele, H.J. Hauser, A. Korber, W. Leitner, R. Neu, H. Plappert, T. Rohwer, G. Staudt, M. Strasser, S. Welte et al, Z. Phys. A326 (1987) 373

87AB1J Ableev et al, JETP Lett. 45 (1987) 596

87AD07 E. Adamides, H.G. Bohlen, W. von Oertzen, M. Buenerd, J. Chauvin, D. Lebrun, J.Y. Hostachy, Ph. Martin, G. Perrin and P. de Saintignon, Nucl. Phys. A475 (1987) 598

87AJ02 F. Ajzenberg-Selove, Nucl. Phys. A475 (1987) 1

87ALZW W.P. Alford, R. Helmer, J.W. Watson, C. Zafiratos, R. Abegg, A. Celler,S. El-Kateb, D. Frekers, O. Hausser, R. Henderson et al, Bull. Am. Phys. Soc. 32 (1987) 1578

87AN1A R. Anne, D. Bazin, A.C. Mueller, J.C. Jacmart and M. Langevin, Nucl. Instr. Meth. Phys. Res. A257 (1987) 215

87AR13 A.E. Aravantinos and A.C. Xenoulis, Phys. Rev. C35 (1987) 1746

87AR19 S.E. Arnell, S. Mattsson, H.A. Roth, M. Rydehell, O. Skeppstedt, A. Johnson, J. Nyberg, A. Kerek and A. Nilsson, Phys. Scr. 36 (1987) 214

87AR1C Arnould, Phil. Trans. Roy. Soc. London 323 (1987) 251

87AR1E Arima, in Beijing (1987) 3

87AU02 R.A. August, H.R. Weller and D.R. Tilley, Phys. Rev. C35 (1987) 393

87AU1A Audouze, J. Astrophys. Astron. 8 (1987) 147

87AZ1C Azhgirei et al, Sov. J. Nucl. Phys. 46 (1987) 661

87BA01 D. Bandyopadhyay, S.R. Samaddar, K. Krishan and J.N. De, Nucl. Phys. A462 (1987) 587

87BA1U Bahcall, Rev. Mod. Phys. 59 (1987) 505

87BA33 O.K. Baker, C. Stoller, W.E. Meyerhoff and J.N. Scheurer, Nucl. Instrum. Methods Phys. Res. B24/25 (1987) 89

87BA34 S. Barhoumi, M. Allab, H. Beaumevieille, A.C. Chami and Z. Meliani, Nucl. Instrum. Meth. Phys. Res. B24/25 (1987) 477

87BA38 G.J. Balster, P.C.N. Crouzen, P.B. Goldhoorn, R.H. Siemssen and H.W. Wilschut, Nucl. Phys. A468 (1987) 93

87BE1H B. Bezard, J.P. Baluteau, A. Marten and N. Coron, ICARUS 72 (1987) 623

87BE1I M. Bedjidian, D. Contardo, E. Descroix, S. Gardien, J.Y. Grossiord, A. Guichard, M. Gusakow, R. Haroutunian, M. Jacquin, J.R. Pizzi et al, Z. Phys. A327 (1987) 337

87BE1M Berezhnoi, Kudryatsev and Soznik, in Yurmala (1987) 302

87BE1P Berezhnoi, Kudryavtsev and Soznik, Dopov. Akad. Nauk. Ukr Rsr A-Fiz. no. 5 (1987) 54

87BE25 I. Bergqvist, A. Brockstedt, L. Carlen, L.P. Ekstrom, B. Jakobsson, C. Ellegaard, C. Gaarde, J.S. Larsen, C. Goodman, M. Bedjidian et al, Nucl. Phys. A469 (1987) 648

87BEYP B.A. Benetsky, A.V. Klyachko, M.N. Lifanov, M.V. Plotnikova and R.P. Radev, Prog. and Theses, Proc. 37th Ann. Conf. Nucl. Spectrosc. Struct. At. Nucl., Yurmala, (1987) 303

87BI1C Bimbot et al, in Panic (1987) 370

87BO1B Bond and Luck, Astrophys. J. 312 (1987) 203

87BO1U Bonani et al, Nucl. Instr. Meth. Phys. Res. B29 (1987) 87

87BO48 A. Bonaccorso, D.M. Brink and L. Lo Monaco, J. Phys. G13 (1987) 1407

87BR06 D.J. Brenner, M. Zaider, J.J. Coyne, H.G. Menzel and R.E. Prael, Nucl. Sci. Eng. 95 (1987) 311

87BR1P Brown, Astrophys. J. 317 (1987) 701

87BR32 F.P. Brady, Can. J. Phys. 65 (1987) 578

87BRZV J.D. Brown, L. Herold, K.E. Luther, A. Middleton, M.L. Pitt, D. Barker and S. Aziz, Bull. Am. Phys. Soc. 32 (1987) 1580

87BU07 M. Burgel, H. Fuchs, H. Homeyer, G. Ingold, U. Jahnke and G. Thoma, Phys. Rev. C36 (1987) 90

87BU12 L. Buchmann, J.M. D'Auria, J.D. King, G. Mackenzie, H. Schneider, R.B. Moore and C. Rolfs, Nucl. Instr. Meth Phys. Res. B26 (1987) 151

87BU27 N.T. Burtebaev, A.D. Duisebaev, V.S. Sadkovskii and G.A. Feofilov, Izv. Akad. Nauk SSSR Ser. Fiz. 51 (1987) 615; Bull. Acad. Sci. USSR Phys. Ser. 51:3 (1987) 191

87BUZQ N. Burtebaev, S.A. Goncharov, A.S. Demyanova, G.N. Ivanov, Yu.V. Lyashko and A.A. Ogloblin, Prog. and Theses, Proc.37th Ann. Conf. Nucl. Spectrosc. Struct. At. Nucl., Yurmala, (1987) 328

87BUZR N. Burtebaev, S.A. Goncharov, A.S. Demyanova, G.N. Ivanov, Yu.V. Lyashko and A.A. Ogloblin, Prog. and Theses, Proc.37th Ann. Conf. Nucl. Spectrosc. Struct. At. Nucl., Yurmala, (1987) 327

87CA30 G. Cardella, A. Cunsolo, A. Foti, G. Imme, G. Pappalardo, G. Raciti, F. Rizzo, N. Alamanos, B. Berthier and N. Saunier, Phys. Rev. C36 (1987) 2403

87CI08 S. Cierjacks, Y. Hino, F. Raupp, L. Buth, D. Filges, P. Cloth and T.W. Armstrong, Phys. Rev. C36 (1987) 1976

87CO02 J. Cook, A.K. Abdallah, M.N. Stephens and K.W. Kemper, Phys. Rev. C35 (187) 126

87CO16 J. Cook, M.N. Stephens and K.W. Kemper, Nucl. Phys. A466 (1987) 168

87CO1E Cohen and Furnstahl, Phys. Rev. C35 (1987) 2231

87DA34 S. Datta, N. Cindro, R.M. Freeman, C. Beck, F. Haas and A. Morsad, Fizika 19 (1987) 445

87DE1A De Vries, De Jager and De Vries, At. Data Nucl. Data Tables 36 (1987) 495

87DO1A Dominy and Wallerstein, Astrophys. J. 317 (1987) 810

87DU08 P.C. Dunn, A. Kaarsgaarn, J.H. Koch, P.K.A. De Witt Huberts, P. Stoler, P.F. Yergin, M. Seneviratne and B. Schoch, Phys. Lett. 196B (1987) 434

87DU1A Duncan, J. Phys. Chem. Ref. Data 16 (1987) 125

87EL1B Elevant and Andersson, Phys. Scr. T16 (1987) 148

87ER01 N.V. Eremin, V.F. Strizhov and A.F. Tulinov, Izv. Akad. Nauk SSSR, Ser. Fiz. 51 (1987) 115; Bull. Acad. Sci. USSR, Phys. Ser. 51 (1987) 107

87FA1A Faessler, Nucl. Phys. B279 (1987) 335

87FE1A Feng et al, Chin. Phys. 7 (1987) 121

87FI09 D. Filges, P. Cloth, T.W. Armstrong, S. Cierjacks, Y. Hino, F. Raupp and L. Buth, Phys. Rev. C36 (1987) 1988

87FO22 P.B. Foot, G.G. Shute, B.M. Spicer, C.C. Foster, J.D. Brown, D.L. Friesel, H. Nann, J.W. Seubert, E.J. Stephenson, B.D. Anderson et al, Aust. J. Phys. 40 (1987) 611

87FR06 S.H. Fricke and K.W. McVoy, Nucl. Phys. A467 (1987) 291

87FR16 J. Franz, E. Rossle, C. Sauerwein, H. Schmitt, H.L. Woolverton, J. Ero, Z. Fodor, J. Kecskemeti, P. Koncz, Zs. Kovacs et al, Nucl. Phys. A472 (1987) 733

87FR1C Friedlander and Weneser, Science 235 (1987) 760

87FU06 R.J. Furnstahl and B.D. Serot, Nucl. Phys. A468 (1987) 539

87GA17 A. Galonsky, G. Caskey, L. Heilbronn, B. Remington, H. Schelin, F. Deak, A. Kiss, Z. Seres and J. Kasagi, Phys. Lett. 197B (1987) 511

87GE1B Gelbke and Boal, Prog. Part. Nucl. Phys. 19 (1987) 33

87GI1C W.R. Gibbs and B.F. Gibson, Ann. Rev. Nucl. Part. Sci. 37 (1987) 411

87GO09 N.G. Goncharova, A.N. Golzov and H.R. Kissener, Nucl. Phys. A462 (1987) 367

87GO1V C.D. Goodman, Can. J. Phys. 65 (1987) 549

87GOZM S.A. Goncharov, A.S. Demyanova, A.L. Lebedev and A.A. Ogloblin, Prog. and Theses, Proc. 37th Ann. Conf. Nucl. Spectrosc. Struct. At. Nucl., Yurmala (1987) 329

87GR1K Greiner, Symp. in Honor of D. Allan Bromley, Yale Univ. (1987) 66

87GUZZ I.R. Gulamov, T. Iskhakov, A.M. Mukhamedzhanov, Sh. Kayumov, A.A. Karakhodzhaev, G.K. Ni, E.A. Romanovsky and G.S. Valiev, Prog. and Theses, Proc. 37th Ann. Conf. Nucl. Spectrosc. Struct. At. Nucl., Yurmala (1987) 344

87HA1C Harris, Lambert and Goldman, Mon. Notic. Roy. Astron. Soc. 224 (1987) 237

87HA1U Hawkins and Jura, Astrophys. J. 317 (1987) 926

87HE1B Heinz, Rep. Prog. Phys. 50 (1987) 145

87HI03 F. Hinterberger, P. von Rossen, S. Cierjacks and G. Schmalz, Z. Phys. A326 (1987) 407

87HI09 R.S. Hicks, R.L. Huffman, R.A. Lindgren, G.A. Peterson, M.A. Plum and J. Button-Shafer, Phys. Rev. C36 (1987) 485

87HO1G Horowitz, Bull. Amer. Phys. Soc. 32 (1987) 1093

87HO1L Ho, Chin. Phys. Lett. 4 (1987) 69

87HO21 J. Homolka, W. Schott, W. Wagner, W. Wilhelm, R.D. Bent, M. Fatyga, R.E. Pollock, M. Saber, R.E. Segel, P. Kienle et al, Nucl. Instrum. Meth. Phys. Res. A260 (1987) 418

87HO23 Y. Ho, Chin. J. Nucl.Phys. 9 (1987) 133

87HU08 G.M. Huber, G.J. Lolos, E.L. Mathie, Z. Papandreou, K.H. Hicks, P.L. Walden, S. Yen, X. Aslanoglou, E.G. Auld and W.R. Falk, Phys. Rev. C36 (1987) 1058

87IE01 M. Ieiri, H. Sakaguchi, M. Nakamura, H. Sakamoto, H. Ogawa, M. Yosoi, T. Ichihara, N. Isshiki, T. Nakano, S. Kobayashi et al, Nucl. Instrum. Meth. Phys. Res. A257 (1987) 253

87IM01 B. Imanishi, W. von Oertzen and H. Voit, Phys. Rev. C35 (1987) 359

87IM1C Imanishi and Von Oertzen, Phys. Rep. 155 (1987) 29

87KAZL F. Kadirov, M.A. Kayumov, Sh. Kayumov, A.M. Mukhamedzhanov, U.I. Faizullaev, K. Khamidova and R. Yarmukhamedov, Prog. and Theses, Proc. 37th Ann. Conf. Nucl. Spectrosc. Struct. At. Nucl., Yurmala (1987) 343

87KI1C Kissener, Rotter and Goncharova, Fortschr. Phys. 35 (1987) 277

87KI1I Kieser et al, Nucl. Instr. Meth. Phys. Res. B24-25 (1987) 667

87KO01 E. Korkmaz, L.C. Bland, W.W. Jacobs, T.G. Throwe, S.E. Vigdor, M.C. Green, P.L. Jolivette and J.D. Brown, Phys. Rev. Lett. 58 (1987) 104

87KR1M Kraft, J. Astrophys. Astron. 8 (1987) 89

87KU06 D. Kurath, Phys. Rev. C35 (1987) 2247

87LA11 F.L. Lang, C.W. Werntz, C.J. Crannell, J.I. Trombka and C.C. Chang, Phys. Rev. C35 (1987) 1214

87LE1H Lesko, Clark and Norman, Bull. Amer. Phys. Soc. 32 (1987) 1557

87LI01 M.K. Liou and Z.M. Ding, Phys. Rev. C35 (1987) 651

87LI29 D.A. Lind, Can. J. Phys. 65 (1987) 637

87LIZZ A. Ling, D. Adams, J. Bystricky, G. Igo, M. Moshi, C. Whitten, D. Ciskowski and M. Barlett, Bull. Am. Phys. Soc. 32 (1987) 1121

87LY01 J.E. Lynn, S. Kahane and S. Raman, Phys. Rev. C35 (1987) 26

87LY04 W.G. Lynch, Nucl. Phys. A471 (1987) 309c

87MA08 L. Majling, J. Zofka, V.N. Fetisov and R.A. Eramzhyan, Phys. Lett. B183 (1987) 263

87MA1C Malaney and Boothroyd, Subm. to Ap. J. Lett. (1987)

87MA22 E. Maglione, G. Poullarolo, A. Vitturi, R.A. Broglia and A. Winther, Phys. Lett. B191 (1987) 237

87MA2G Malaney, A.J. 321 (1987) 832

87MEZU H.O. Meyer, P. Schwandt, R. Abegg, D. Frekers, G. Gaillard, M. Hugi, C.A. Miller, S. Yen, R. Helmer and K.P. Jackson, Bull. Am. Phys. Soc. 32 (1987) 1559

87MI01 S.L. Mintz, Phys. Rev. C35 (1987) 263

87MI08 S.L. Mintz, J. Phys. G13 (1987) 591

87MI1A Mian, Phys. Rev. C35 (1987) 1463

87MIZY A. Middleton, J.D. Brown, L. Herold, K.E. Luther, M.L. Pitt, D. Barker, H.S. Camarda and S. Aziz, Bull. Amer. Phys. Soc. 32 (1987) 1578

87MO04 A. Moalem, D. Frekers, S.A. Gurvitz, R. Abegg, C. Davis, K.P. Jackson, C.A. Miller, R.S. Henderson, S. Yen, R.L. Helmer et al, Phys. Lett. B183 (1987) 269

87MO27 M.H. Cha, J.Y. PARK AND W. Scheid, Phys. Rev. C36 (1987) 2341

87MOZZ C.E. Moss, R.O. Nelson, S.J. Seestrom-Morris and S.A. Wender, Bull. Am. Phys. Soc. 32 (1987) 1121

87NA01 M.N. Namboodiri, R.K. Choudhury, L. Adler, J.D. Bronson, D. Fabris, U. Garg, P.L. Gonthier, K. Hagel, D.R. Haenni, Y.W. Lui et al, Phys. Rev. C35 (1987) 149

87NA1O Nakai et al, Nucl. Instr. Meth. Phys. Res. B29 (1987) 228

87NEZY R.O. Nelson, S.J. Seestrom-Morris, S.A. Wender and N.W. Hill, Bull. Am. Phys. Soc. 32 (1987) 1061

87NU02 G. Nuhn, W. Scheid and Jae Young Park, Phys. Rev. C35 (1987) 2146

87OR01 H. Orihara, M. Kabasawa, K. Furukawa, T. Kawamura, Y. Takahashi, A. Satoh, T. Niizeki, T. Nakagawa, K. Maeda, K. Ishii et al, Phys. Lett. B187 (1987) 240

87OS1E Osman and Saleh, Nucl. Sci. J. (Taiwan) 24 (1987) 146

87PE1B Peter, Dubna (1987) 562

87PE1C Penionshkevich, Dubna (1987) 364

87PI1B Pile et al, in Panic (1987) 594

87PI1C Pile et al, Bull. Amer. Phys. Soc. 32 (1987) 1560

87PI1E Pillinger, Phil. Trans. Roy. Soc. London A323 (1987) 313

87PL1C Plyuiko, in Yurmala (1987) 510

87PO1C V.A. Poyarkov and I.V. Sizov, Yad. Fiz. 45 (1987) 1515; Sov. J. Nucl. Phys. 45 (1987) 940

87PO1H Povh, Prog. Part. Nucl. Phys. 18 (1987) 183

87PO1I Pochodzalla, Nucl. Phys. A471 (1987) C289

87PR1A Prapkos, Arnould and Arcoragi, Astrophys. J. 315 (1987) 209

87RA15 J. Rapaport, D. Wang, J.A. Carr, F. Petrovich, C.C. Foster, C.D. Goodman, C. Gaarde, J. Larsen, C.A. Goulding, T.N. Taddeucci et al, Phys. Rev. C36 (1987) 500

87RA1D R. Ramaty and R.J. Murphy, Space Sci. Rev. 45 (1987) 213

87RA32 J. Rapaport, Can. J. Phys. 65 (1987) 574

87RA36 M. Rahman, H.M. Sen Gupta, Md.A. Rahman and A.B. Siddique, Nuovo Cim A98 (1987) 513

87RE01 D.A. Resler, R.O. Lane and H.D. Knox, Phys. Rev. C35 (1987) 855

87RE03 B.A. Remington, M. Blann and G.F. Bertsch, Phys. Rev. C35 (1987) 1720

87RE11 B.A. Remington and M. Blann, Phys. Rev. C36 (1987) 1387

87RE1C Reif, Dubna (1987) 540

87RI03 J. Richert and P. Wagner, Nucl. Phys. A466 (1987) 132

87RI1E Rich, Owen and Spiro, Phys. Rep. 151 (1987) 239

87RO02 E. Rost and J.R. Shepard, Phys. Rev. C35 (1987) 681

87RO1D C. Rolfs, H.P. Trautvetter and W.S. Rodney, Rep. Prog. Phys. 50 (1987) 233

87RO1F Romanovsky et al, in Jurmala (1987) 286

87SA15 H. Sagawa and H. Toki, J. Phys. G13 (1987) 453

87SA25 M.G. Saint-Laurent, Nucl. Instr. Meth. Phys. Res. B26 (1987) 273

87SC11 L. Schmieder, D. Hilscher, H. Rossner, U. Jahnke, M. Lehmann, K. Ziegler and H.-H. Knitter, Nucl. Instr. Meth. Phys. Res. A256 (1987) 457

87SE05 K.K. Seth, M. Artuso, D. Barlow, S. Iversen, M. Kaletka, H. Nann, B. Parker and R. Soundranayagam, Phys. Rev. Lett. 58 (1987) 1930

87SEZY R.E. Segel, J. Homolka, W. Schott, W. Wilhelm, W. Wagner, R.D. Bent, M. Fatyga, R.E. Pollock, P. Kienle, K.E. Rehm et al, Bull. Am. Phys. Soc. 32 (1987) 1117

87SI1C Seimssen, Proc. Beijing Int. Symp. on Phys. at Tandem 1986 (World Scientific 1987) 317

87SN01 K. Sneppen, Nucl. Phys. A470 (1987) 213

87SO1F Solc, Vanysek and Kissel, Astron. Astrophys. 187 (1987) 385

87ST01 G.S.F. Stephans, R.V.F. Janssens, D.G. Kovar and B.D. Wilkins, Phys. Rev. C35 (1987) 614

87ST1C Stuiver and Braziunas, Nature 328 (1987) 58

87SU06 T. Suzuki, D.F. Measday and J.P. Roalsvig, Phys. Rev. C35 (1987) 2212

87TA13 T.N. Taddeucci, C.A. Goulding, T.A. Carey, R.C. Byrd, C.D. Goodman, C. Gaarde, J. Larsen, D. Horen, J. Rapaport and E. Sugarbaker, Nucl. Phys. A469 (1993) 125

87TA22 T.N. Taddeucci, Can. J. Phys. 65 (1987) 557

87TH04 A. Thiel, W. Greiner, J.Y. Park and W. Scheid, Phys. Rev. C36 (1987) 647

87TO03 W. Tornow, E. Woye and R.L. Walter, J. Phys. G13 (1987) 177

87TO07 W. Tornow, C.R. Howell, H.G. Pfutzner, M.L. Roberts, P.D. Felsher, Z.M. Chen and R.L. Walter, Phys. Rev. C35 (1987) 1578

87VA1I Valiev et al, 37th Meeting on Nuclear Spectroscopy and the Structure of the At. Nucl., Jurmala, USSR, 14-17 April 1987 (Nauka, 1987) 346

87VA28 G.S. Valiev, I.R. Gulamov, Yu.I. Denisov, T. Iskhakov, A.M. Mukhamedzhanov, G.K. Ni, E.A. Romanovskii, V.A. Stepanenko and R.Ya. Yarmukhamedov, Izv. Akad. Nauk. SSSR Ser. Fiz. 51 (1987) 964; Bull. Acad. Sci. USSR, Phys. Ser. 51 (1987) 124

87VD1A A.I. Vdovin, A.V. Golovin and I.I. Loschakov, Sov. J. Part. Nucl. 18 (1987) 573

87VI02 F. Videbaek, S.G. Steadman, G.G. Batrouni and J. Karp, Phys. Rev. C35 (1987) 2333

87WA1F P.G. Wannier and R. Sahai, Astrophys. J. 319 (1987) 367

87WA1L Walsh and Roy, Astrophys. J. 319 (1987) L57

87WE1C Weneser and Friedlander, Science 235 (1987) 755

87WIZW J.S. Winfield, S.M. Austin, G.M. Crawley, C. Djalali, R.J. Smith, Z. Chen and M. Torres, Bull. Am. Phys. Soc. 32 (1987) 1076

87YA1F Yu.P. Yakovlev, Yad. Fiz. 46 (1987) 459; Sov. J. Nucl. Phys. 46 (1987) 244

87YAZZ D. Yan, P.M.S. Lesser, M.K. Liou and C.C. Trail, Bull. Am. Phys. Soc. 32 (1987) 1578

87ZA1F Zavarzina and Stepanov, Sov. Phys.-Lebedev Inst. Rep. no. 7 (1987) 55

87ZH08 X.Q. Zhu, N. Mobed and S.S.M. Wong, Nucl. Phys. A466 (1987) 623

87ZI1C Zinner, Tang and Anders, Nature 330 (1987) 730

88AB05 V.V. Abaev, E.P. Fedorova-Koval, A.B. Gridnev, V.P. Koptev, S.P. Kruglov,Yu.A. Malov, G.V. Scherbakov, I.I. Strakovsky and N.A. Tarasov, J. Phys. G14 (1988) 903

88AJ01 F. Ajzenberg-Selove, Nucl. Phys. A490 (1988) 1

88AL1G Aleksandrov et al, Baku (1988) 377

88AN1F Antolkovic and Turk, Radiat. Prot. Dosim. 23 (1988) 19

88AP1A J.H. Applegate, Phys. Rep. 163 (1988) 141

88AR1G Arneth and Hoefs, Naturwissenschaften 75 (1988) 515

88AR1H Arnault et al, Astron. Astrophys. 205 (1988) 41

88AR1I A. Arima, Hyperfine Interactions 43 (1988) 47

88AS1D Ash et al, Nature 336 (1988) 228

88AZ1B Azzam, Indian J. Phys. A62 (1988) 528

88BA1H Bahcall and Ulrich, Rev. Mod. Phys. 60 (1988) 297

88BA1P Batkin et al, Baku (1988) 267

88BA1Y Bahcall, Davis and Wolfenstein, Nature 334 (1988) 487

88BA2D Baer et al, AIP Conf. Proc. 163 (1988) 67

88BA30 A. Barbadoro, D. Consolaro, F. Pellegrini, G.F. Segato and I. Gabrielli, Phys. Rev. C38 (1988) 517

88BA83 S. Banik, Ind. J. Pure Appl. Phys. 26 (1987) 387

88BE1T B.L. Berman, "Energy in Physics, War, and Peace", A Festschrift Celebrating E. Teller's 80th Birthday , ED. Hans Mark and Lowell Wood (Kluwer Acacmic Publ., Norwell, MA 1988) 49

88BE1W M. Beckerman, Rep. Prog. Phys. 51 (1988) 1047

88BE56 A.V. Belozerov, K.C. Borcea, J. Wincour, M. Lewitowicz, N.H. Chau, Yu.E. Penionzhkevich, N.K. Skobelev and A. Chasha, Izv. Akad. Nauk SSSR 52 (1988) 2171

88BEYI Ya.A. Berdnikov, A.M. Makhov and V.I. Ostroumov, Prog. and Theses, Proc. 38th Ann. Conf. Nucl. Spectrosc. Struct. At. Nucl., Baku (1988) 441

88BI11 N. Bischof, W. Tiereth, I. Weitzenfelder, H. Voit, W. von Oertzen and H.H. Wolter, Nucl. Phys. A490 (1988) 485

88BO20 H.G. Bohlen, B. Gebauer, D. Kolbert, W. von Oertzen, E. Stiliaris, M. Wilpert and T. Wilpert, Z. Phys. A330 (1988) 227

88BO39 M.J.G. Borge, H. Cronberg, M. Cronqvist, H. Gabelmann, P.G. Hansen,L. Johannsen, B. Jonson, S. Mattsson, G. Nyman, A. Richter et al, Nucl. Phys. A490 (1988) 287

88BO46 J. Bogdanowicz, Nucl. Phys. A479 (1988) 323C

88BR29 M.E. Brandan and G.R. Satchler, Nucl. Phys. A487 (1988) 477

88BRZY J.D. Brown, A. Middleton and S.M. Aziz, Bull. Amer. Phys. Soc. 33 (1988) 1022

88BU16 R. Buchle, J. Franz, P. Koncz, M. Marx, E. Rossle, C. Sauerwein, H. Schmitt, J. Ero, Z. Fodor, J. Kecskemeti et al, Phys. Lett. 213B (1988) 125

88BU1C Burke, Martens and Sackett, Nature 332 (1988) 829

88BU1I Burleson, AIP Conf. Proc. 163 (1988) 384

88CA06 G. Caskey, L. Heilbronn, B. Remington, A. Galonsky, F. Deak, A. Kiss and Z. Seres, Phys. Rev. C37 (1988) 696

88CA26 G.R. Caughlan and W.A. Fowler, At. Data Nucl. Data Tables 40 (1988) 283

88CH1L Chen and Chiang, High Energy Phys. 12 (1988) 63

88CH24 N.S. Chant and P.G. Roos, Phys. Rev. C38 (1988) 787

88CH48 R.E. Chrien, Nucl. Phys. A478 (1988) 705C

88CHZU S. Chakravarti and P.B. Siegel, Bull. Am. Phys. Soc. 33 (1988) 1581

88CO05 S.F. Collins, G.G. Shute, B.M. Spicer, V.C. Officer, D.W. Devins, D.L. Friesel and W.P. Jones, Nucl. Phys. A481 (1988) 494

88CR1A Crane and Hegyi, Astrophys. J. 326 (1988) L35

88DA12 R. da Silveira and Ch. Leclercq-Willain, Phys. Rev. C38 (1988) 543

88DE1F Demyanova et al, Baku (1988) 332

88DE1I A.H. Delsemme, Phil Trans. Roy. Soc. London A325 (1988) 509

88DEZU A.S. Demyanova, A.A. Ogloblin, F.A. Gareev, S.N. Ershov and S.A. Goncharov, Prog. and Theses, Proc. 38th Ann. Conf. Nucl. Spectrosc. Struct. At. Nucl., Baku (1988) 330

88DI02 S.S. Dietrich and B.L. Berman, At. Data Nucl. Data Tables 38 (1988) 199

88DO1D Donahue, Bull. Amer. Phys. Soc. 33 (1988) 1752

88DO1E Doll et al, Proc. 6th Conf. on Gamma-Ray Spectroscopy, Belgium 1987 (Bristol, UK: IOP 1988) 727

88DRZZ J.R. Drummond, F.P. Brady, C.M. Castaneda, E.L. Hjort, B. McEachern, J.L. Romero and D.S. Sorenson, Bull. Am. Phys. Soc. 33 (1988) 1568

88FA1A G. Faure, J. Hoefs, L.M. Jones, J.B. Curtis and D.E. Pride, Nature 332 (1988) 352

88FA1B Faessler, Nucl. Phys. A479 (1988) 3C

88FE09 R. Fergerson, J. McGill, C. Glashausser, K. Jones, S. Nanda, Sun Zuxun, M. Barlett, G. Hoffmann, J. Marshall and J. McClelland, Phys. Rev. C38 (1988) 2193

88FR15 R.M. Freeman, Z. Basrak, F. Haas, A. Hachem, G.A. Monnehan, A. Morsad and M. Youlal, Phys. Rev. C38 (1988) 1081

88FR1M Frye et al, Solar Phys. 118 (1988) 321

88FR23 J. Franz, H.P. Grotz, L. Lehmann, E. Rossle, H. Schmitt and L. Schmitt, Nucl. Phys. A490 (1988) 667

88GA11 S.B. Gazes, Y.D. Chan, E. Chavez, A. Dacal, M.E. Ortiz, K. Siwek-Wilczynska, J. Wilczynski and R.G. Stokstad, Phys. Lett. 208B (1988) 194

88GA1A Gal, Nucl. Phys. A479 (1988) 97C

88GA1I Gal, AIP Conf. Proc. 163 (1988) 144

88GIZU Yu.R. Gismatullin, A.A. Melentev, V.I. Ostroumov, A.M. Petukhov and M.A. Stalevich, Prog. and Theses, Proc.38th Ann. Conf. Nucl. Spectrosc. Struct. At. Nucl., Baku (1988) 293

88GO12 M. Gonin, J.P. Coffin, G. Guillaume, F. Jundt, P. Wagner, P. Fintz, B. Heusch, A. Malki, A. Fahli, S. Kox et al, Phys. Rev. C38 (1988) 135

88GO1E Goncharov, Romanovsky and Timofeyok, 38th Meeting on Nucl. Spectroscopy and the Structure of the At. Nucl., Baku, USSR, 12-14 April 1988 (Nauka, 1988) 349

88GO1J Goodfriend, Nature 333 (1988) 757

88GOZH S.A. Goncharov, I.R. Gulamov, E.A. Romanovsky, N.K. Timofeyuk and K.V. Shitikova, Prog. and Theses, Proc. 38th Ann. Conf. Nucl. Spectrosc. Struct. At. Nucl., Baku, (1988) 288

88GUZW I.R. Gulamov, A.M. Mukhamedzhanov and G.K. Ni, Prog. and Theses, Proc. 38th Ann. Conf. Nucl. Spectrosc. Struct. At. Nucl., Baku (1988) 300

88HA03 H. Hashim and D.M. Brink, Nucl. Phys. A476 (1988) 107

88HA04 H.J. Hausman, S.L. Blatt, T.R. Donoghue, J. Kalen, W. Kim, D.G. Marchlenski, T.W. Rackers, P. Schmalbrock, M.A. Kovash and A.D. Bacher, Phys. Rev. C37 (1988) 503

88HA12 S.S. Hanna, J. Phys. G14 (1988) S283

88HA23 K. Hanold and D.J. Morrissey, Phys. Rev. C38 (1988) 165; Erratum Phys. Rev. C38 (1988) 2465

88HI03 K.H. Hicks, O. Hausser, R. Abegg, W.P. Alford, A. Celler, R.L. Helmer, R.S. Henderson, K.P. Jackson, J. Lisantti, C.A. Miller et al, Phys. Lett. B201 (1988) 29

88HI1F R.D. Hichwa, Bull. Amer. Phys. Soc. 33 (1988) 1747

88HI1H Hicks, AIP Conf. Proc. 176 (1988) 26

88HO1K Horowitz, AIP Conf. Proc. 176 (1988) 1140

88IT02 K. Itonaga, T. Motoba and H. Bando, Z. Phys. A330 (1988) 209

88JA01 K.P. Jackson, A. Celler, W.P. Alford, K. Raywood, R. Abegg, R.E. Azuma, C.K. Campbell, S. El-Kateb, D. Frekers, P.W. Green et al, Phys. Lett. B201 (1988) 25

88JA14 L. Jarczyk, B. Kamys, J. Romanski, A. Strzalkowski, M. Godlewski, J. Lang, R. Muller, J. Smyrski, J. Sromicki and H.H. Wolter, Acta Phys. Pol. B19 (1988) 951

88JA1B Jacq, Despois and Baudry, Astron. Astrophys. 195 (1988) 93

88JO1B G. A. Jones, Interactions and Structures in Nucl, Proc. in Honor of D.H. Wilkinson, Sussex, 9/87; Adam Hilger Publ. (1988) 9

88JU1C Jura, Kahane and Omont, Astron. Astrophys. 201 (1988) 80

88KA1Y M.A. Kayumov, Sh.S. Kayumov, S.P. Krekoten, A.M. Mukhamedzhanov, Kh.D. Razikov, K. Khamidova and R. Yarmukhamedov, Yad. Fiz. 48 (1988) 629; Sov. J. Nucl. Phys. 48 (1988) 403

88KA27 Sh.S. Kayumov, A.M. Mukhamedzhanov and R. Yarmukhamedov, Z. Phys. A331 (1988) 315

88KE07 K.W. Kemper, G.A. Hall, S.P. Van Verst and J. Cook, Phys. Rev. C38 (1988) 2664

88KE1B Kessler et al, J. Phys. G14 (1988) S167

88KI06 A. Kiss, F. Deak, Z. Seres, G. Caskey, A. Galonsky, L. Heilbronn and B. Remington, Phys. Rev. C38 (1988) 170

88KIZW B.H. King, D. Pocanic, G.E. Dodge, W.J. Cummings, C.J. Martoff, S.S. Hanna, J.D. Bowman, J.N. Knudson, J.R. Tinsley, J.R. Comfort et al, Bull. Am. Phys. Soc. 33 (1988) 1606

88KO18 L. Koester, W. Waschkowski, J. Meier, G. Rau and M. Salehi, Z. Phys. A330 (1988) 387

88KO1V Koch, AIP Conf. Proc. 176 (1988) 527

88KU16 Y. Kudo, N. Kanayama and T. Wakasugi, Phys. Rev. C38 (1988) 1126

88KW1A Kwasniewicz and Kisiel, Acta Phys. Pol. B19 (1988) 141

88LA03 J. Lang, J. Liechti, R. Muller, P.A. Schmelzbach, J. Smyrski, M. Godlewski, L. Jarczyk, A. Stralkowski and H. Witala, Nucl. Phys. A477 (1988) 77

88LA25 F. Lahlou, B. Cujec and B. Dasmahapatra, Nucl. Phys. A486 (1988) 189

88LE08 K.T. Lesko, E.B. Norman, R.-M. Larimer, S. Kuhn, D.M. Meekhof, S.G. Crane and H.G. Bussell, Phys. Rev. C37 (1988) 1808

88LYZZ C. Lyndon, H. Funsten, J.M. Finn, C.F. Perdrisat, V. Punjabi, B.J. Lieb, S. Wender, P. Koehler, C.E. Stronach, N. Fuqua et al, Bull. Am. Phys. Soc. 33 (1988) 961

88MA07 J.F. Mateja, G.L. Gentry, N.R. Fletcher, L.C. Dennis and A.D. Frawley, Phys. Rev. C37 (1988) 1004

88MA1A Magaritz et al, Nature 331 (1988) 337

88MA1G Majling et al, Phys. Lett. B202 (1988) 489

88MA1H Manokhin, INDC(CCP)-283 (1988)

88MA1U R.A. Malaney and W.A. Fowler, Astrophys. J. 333 (1988) 14

88MA48 A. Martin, R. Birsa, K. Bos, F. Bradamante, D.V. Bugg, S. Dalla Torre-Colautti, J.R. Hall, E. Heer, R. Hess, J.C. Kluyver et al, Nucl. Phys. A487 (1988) 563

88MA58 R. Mach, J. Zofka, K. Itonaga, T. Motoba and H. Bando, Z. Phys. A331 (1988) 89

88MAZP J.B. Martin, D.A. Rutherford, W.G. Wilson, R.R. Kiziah, B.D. Johnston and N.A. Miller, Bull. Am. Phys. Soc. 33 (1988) 1568

88MC01 K.G. McNeill, A.D. Bates, R.P. Rassool, E.A. Milne and M.N. Thompson, Phys. Rev. C37 (1988) 1403

88MCZT V. McLane, C.L. Dunford and P.F. Rose, Neutron Cross Sect., Vol. 2 (Academic Press, Inc. 1988)

88ME02 H.O. Meyer, P. Schwandt, R. Abegg, C.A. Miller, K.P. Jackson, S. Yen, G. Gaillard, M. Hugi, R. Helmer, D. Frekers et al, Phys. Rev. C37 (1988) 544

88MI02 J.H. Mitchell, J.T. Brack, R.J. Peterson, R.A. Ristinen, J.L. Ullmann, R.L. Boudrie, B.G. Ritchie and J. Escalante, Phys. Rev. C37 (1988) 710

88MI1J D.J. Millener, AIP Conf. Proc. 163 (1988) 402

88MI25 B. Milek and R. Reif, Yad. Fiz. 48 (1988) 378; Sov. J. Nucl. Phys. 48 (1988) 237

88MO1L Motoba, Itonaga and Bando, Nucl. Phys. A489 (1988) 683

88NA04 K. Nakayama and W.G. Love, Phys. Rev. C38 (1988) 51

88NI1C Nimnual et al, Bull. Amer. Phys. Soc. 33 (1988) 1596

88PA07 M.P. Pato and M.S. Hussein, Phys. Lett. B207 (1988) 121

88PE01 J.J. Perez-Padilla and M.E. Brandan, Nucl. Instrum. Meth. Phys. Res. A263 (1988) 480

88PE1F Peng, AIP Conf. Proc. 163 (1988) 160

88PE1H Peng, AIP Conf. Proc. 176 (1988) 39

88PI1C C.T. Pillinger, Phil. Trans. Roy. Soc. London A325 (1988) 525

88PO1G Poyarkov, Baku (1988) 457

88PO1H Povh, Prog. Part. Nucl. Phys. 20 (1988) 353

88POZS N.A.F.M. Poppelier, J.H. de Vries, A.A. Wolters and P.W.M. Glaudemans, AIP Conf. Proc. 164 (1988) 334

88POZV D. Pocanic, B.H. King, G.E. Dodge, W.J. Cummings, C.J. Martoff, S.S. Hanna, J.D. Bowman, J.R. Tinsley, J.R. Comfort, E.P. Gavathas et al, Bull. Am. Phys. Soc. 33 (1988) 1607

88PU1A Purser et al, Nucl. Instr. Meth. Phys. Res. B35 (1988) 284

88RA08 L. Ray, G.W. Hoffmann, M.L. Barlett, J.D. Lumpe, B.C. Clark, S. Hama and R.L. Mercer, Phys. Rev. C37 (1988) 1169; Erratum Phys. Rev. C39 (1989) 2089

88RAZX J. Rapaport, J.L. Ullmann, R.C. Haight, S.A. Wender, F.P. Brady, J. Drummond, E. Hjort, J.L. Romero, D. Sorenson and C. Howell, Bull. Am. Phys. Soc. 33 (1988) 1062

88RE09 D.A. Resler and E.T. Sadowski, Nucl. Instrum. Meth. Phys. Res. A269 (1988) 607

88RO17 M. Roy-Stephan, Nucl. Phys. A488 (1988) 187C

88RO1R Rotter, Fortschr. Phys. 36 (1988) 781

88RU01 V.A. Rubchenya and S.G. Yavshits, Z. Phys. A329 (1988) 217

88RU1C Rutgauzer, Kukulin and Krasnopolsky, Baku (1988) 162

88SA04 M. Samuel, B.A. Brown, D. Mikolas, J. Nolen, B. Sherrill, J. Stevenson, J.S. Winfield and Z.Q. Xie, Phys. Rev. C37 (1988) 1314

88SA19 H. Sato, Phys. Rev. C37 (1988) 2902

88SA1B Saltzberg et al, Bull. Amer. Phys. Soc. 33 (1988) 988

88SC1A Schonberg, Astron. Astrophys. 195 (1988) 198

88SC1C Schidlowski, Nature 333 (1988) 313

88SEZT R.E. Segel, M. Saber, Z. Yu, R.D. Bent, M. Fatyga, R.E. Pollock, J. Homolka, W. Schott, W. Wagner, W. Wilhelm et al, Bull. Am. Phys. Soc. 33 (1988) 1587

88SH1E Shvedov, Nemets and Rudchik, Baku (1988) 351

88SI08 P.J. Simmonds, K.I. Pearce, P.R. Hayes, N.M. Clarke, R.J. Griffiths, M.C. Mannion and C.A. Ogilvie, Nucl. Phys. A482 (1988) 653

88SN1A K.A. Snover, Nucl. Phys. A482 (1988) 13C

88ST1G Stewart and Zieminski, AIP Conf. Proc. 176 (1988) 630

88TA10 I. Tanihata, T. Kobayashi, O. Yamakawa, S. Shimoura, K. Ekuni, K. Sugimoto, N. Takahashi, T. Shimoda and H. Sato, Phys. Lett. B206 (1988) 592

88TA1B Tamura et al, Nucl. Phys. A479 (1988) 161C

88TAZY T.N. Taddeucci, T.A. Carey, J.B. McClelland, L.J. Rybarcyk, D.E. Ciskowski, M.R. Barlett, E. Sugarbaker, D. Marchlenski, C.D. Goodman, W. Huang et al, Bull. Am. Phys. Soc. 33 (1988) 1597

88TO01 W. Tornow, C.R. Howell, H.G. Pfutzner, M.L. Roberts, P.D. Felsher, Z.M. Chen, M. Al Ohali, G.J. Weisel, R.L. Walter and A.A. Naqvi, J. Phys. G14 (1988) 49

88TR01 S. Trentalange, S.-C. Wu, J.L. Osborne and C.A. Barnes, Nucl. Phys. A483 (1988) 406

88TR1H Trimble, Rev. Mod. Phys. 60 (1988) 859

88US01 L.E. Ussery, D.J. Vieira, J.J.H. Berlijn, G.W. Butler, B.J. Dropesky, G.C. Giesler, N. Imanishi, M.J. Leitch and R.S. Rundberg, Phys. Rev. C38 (1988) 2761

88VA03 A.G.M. van Hees, A.A. Wolters and P.W.M. Glaudemans, Nucl. Phys. A476 (1988) 61

88VI1A Vinogradova et al, 38th Meeting on Nucl. Spectroscopy and the Structure of the At. Nucl., Baku, USSR, 12-14 April 1988 (Nauka, 1988) 567

88VO01 H. Voit, N. Bischof, W. Tiereth, I. Weitzenfelder, W. von Oertzen and B. Imanishi, Nucl. Phys. A476 (1988) 491

88VO06 W. von Oertzen, Nucl. Phys. A482 (1988) 357C

88VO08 W. von Oertzen, E. Adamides, M. Buenerd, J. Chauvin, D. Lebrun, J.Y. Hostachy, G. Duhamel, Ph. Martin, G. Perrin and P. de Saintignon, Nucl. Phys. A487 (1988) 195

88VO1D J.R. Votaw, Bull. Amer. Phys. Soc. 33 (1988) 1748

88WA08 F. Wang, C.W. Wong and S.-Q. Lu, Nucl. Phys. A480 (1988) 490

88WA1B Walcher, Nucl. Phys. A479 (1988) 63C

88WE06 S.A. Wender, S.J. Seestrom-Morris and R.O. Nelson, J. Phys. G14, Suppl. (1988) S417

88WE17 I. Weitzenfelder, N. Bischof, W. Tiereth, H. Voit, W. von Oertzen and H.H. Wolter, Nucl. Phys. A489 (1988) 125

88WI09 J.S. Winfield, S.M. Austin, G.M. Crawley, C. Djalali, C.A. Ogilvie, R.J. Smith, Z. Chen and M. Torres, Phys. Lett. B203 (1988) 345

88WO04 A.A. Wolters, A.G.M. van Hees and P.W.M. Glaudemans, Europhys. Lett. 5 (1988) 7

88WO1C Woosley and Haxton, nature 334 (1988) 45

88YA06 T. Yamaya, O. Satoh, S.M. Morita, K. Kotajima, K. Hasegawa, T. Shinozuka and M. Fujioka, Phys. Rev. C37 (1988) 2585

88YAZZ D. Yan, P.M.S. Lesser, M.K. Liou and C.C. Trail, Bull. Am. Phys. Soc. 33 (1988) 1062

88YOZX J.C. Young, F.P. Brady, J.L. Romero, G.A. Needham and J.L. Ullmann, Bull. Am. Phys. Soc. 33 (1988) 1568

88ZH1B Zhusupov and Usmanov, Baku (1988) 167

88ZH1H Zhang and Zhang, Commun. Theor. Phys. 10 (1988) 425

88ZV1A Zverev, Lyotostansky and Panov, Baku (1988) 52

89AB1J Abia and Rebolo, Astrophys. J. 347 (1989) 186

89AG1B Agakishiev et al, Sov. J. Nucl. Phys. 49 (1989) 300

89AJ1A Ajzenberg-Selove, "Heavy ions in Nucl. and At. Phys." (1988 Mikolajki Summer Sch. on Nucl. Phys.); Ed. Wilhelm and Szeflinska; Adam Hilger Publ (1989) 1

89AM02 K. Amos, L. Berge and D. Kurath, Phys. Rev. C40 (1989) 1491

89AM05 K. Amos and J. Raynal, Aust. J. Phys. 42 (1989) 591

89AN12 I. Angeli, Z. Phys. A334 (1989) 377

89AR1G Arnould et al, Tokyo (1988) 287

89AR1J M. Arnould, F. Baeten, D. Darquennes, Th. Delbar, C. Dom, M. Huyse, Y. Jongen, P. Leleux, M. Lacroix, P. Lipnik et al, Nucl. Instr. Meth. Phys. Res. B40-41 (1989) 498

89AR1N Arnould et al, Sao Paulo (1989) 254

89AR1Q Arnould et al, Nucl. Instr. Meth. Phys. Res. A282 (1989) 99

89AS01 X. Aslanoglou, K. W. Kemper, P. C. Farina and D. E. Trcka, Phys. Rev. C40 (1989) 73

89AV02 V.V. Avdeichikov, A.I. Bogdanov, V.A. Budilov, V.Ya. Volkov, N.L. Gorshkova, K.G. Denisenko, V.N. Emelyanenko, N.K. Zhidkov, A. Kotus, S. Mruvchinsky et al,Yad. Fiz. 50 (1989) 409; Sov. J. Nucl. Phys. 50 (1989) 255

89AYZU J. Aysto and J. Cerny, Treatise on Heavy-Ion Sci.8 (1989) 207

89BA2I Barbuy et al, Sao Paulo (1989) 464

89BA2K Bazan, Truran and Mathews, Bull. Amer. Phys. Soc. 34 (1989) 1802

89BA2P J.N. Bahcall, Neutrino Astrophys. (Publ. Cambridge Univ. Press 1989)

89BA92 H. Bando, Nuovo Cim. A102 (1989) 627

89BA93 H. Bando, M. Sano, J. Zoofka and M. Wakai, Nucl. Phys. A501 (1989) 900

89BE1N Bekbaev et al, Tashkent (1989) 273

89BE25 V. Bellini, M. Bolore, J. Julien, J.M. Hisleur, A. Fallica, A.S. Figuera, R. Fonte, A. Insolia, C. Milone, G.F. Palama et al, Z. Phys. A333 (1989) 393

89BE28 F.D. Becchetti, W.Z. Liu, D.A. Roberts, J.W. Janecke, J.J. Kolata, A. Morsad, X.J. Kong and R.E. Warner, Phys. Rev. C40 (1989) R1104

89BE2B Benesh, Cook and Vary, Phys. Rev. C40 (1989) 1198

89BE2K Besnogikh et al, AIP Conf. Proc. 187 (1989) 688

89BE2O Belyaev et al, Sov. J. Nucl. Phys. 49 (1989) 295

89BE2P Bekmirzaev et al, Sov. J. Nucl. Phys. 49 (1989) 305

89BEXT Yu.A. Berezhnoi, I.N. Kudryavtsev and A.P. Soznik, Ukr. Fiz. Zh. 34 (1989) 1481

89BEZC J.A. Behr, K.A. Snover, C.A. Gossett, J.H. Gundlach, W. Hering, Bull. Am. Phys. Soc. 34 (1989) 1832

89BI06 R. Binz, R. Buchle, M. Daum, J. Franz, G. Gaillard, N. Hamann, R. Hess, S. Jaccard, F. Lehar, C. Lechanoine-Leluc et al, Phys. Lett. 231B (1989) 323

89BL1D Blann and Remington, "Heavy Ions in Nucl. and At. Phys." (1988 Mikolajki Summer Sch. on Nucl. Phys.); Eds. Wilhelmi and Szeflinska; Adam Hilger Publ. (1989) 97

89BO1S Bockelee-Morvan, Ann. Physique 14 (1989) 89

89BR1I Briley et al, Astrophys. J. 341 (1989) 800

89BR1J Brown, Sao Paulo (1989) 187

89BR1M Brown et al, Astrophys. J. 71 (1989) 293

89C017 A.A. Cowley, J.V. Pilcher, J.J. Lawrie and D.M. Whittal, Phys. Rev. C40 (1989) 1950

89CE1D Cerling et al, Nature 341 (1989) 138

89CH01 A.E. Champagne, R.T. Kouzes, A.B. McDonald, M.M. Lowry, D.R. Benton, K.P. Coulter and Z.Q. Mao, Phys. Rev. C39 (1989) 248

89CH1K Chuvilsky, Tashkent (1989) 414

89CH1U Chrien, Nuovo Cim. A102 (1989) 727

89CH1X Chen and Li, Astrophys. Space Sci. 158 (1989) 153

89CH1Z Charbonneau, Michaud and Proffitt, Astrophys. J. 347 (1989) 821

89CH2B Cha et al, J. Korean Phys. Soc. 22 (1989) 164

89CH2D Chrein and Dover, Ann. Rev. Nucl. Part. Sci. 39 (1989) 113

89CH31 A.A. Chumbalov, R.A. Eramzhyan and S.S. Kamalov, Czech. J. Phys. B39 (1989) 853

89CR07 S. Croft, Nucl. Instrum. Meth. Phys. Res. A281 (1989) 103

89DA1H Davis, Mann and Wolfenstein, Ann. Rev. Nucl. Part. Sci. 39 91989) 467

89DE1Q DemYanova and Ogloblin, Sao Paulo (1989) 278

89DE34 A. S. Demyanova, J. M. Bang, F. A. Gareev, S. A. Goncharov, S. N. Ershov, A. A. Ogloblin and P. P. Korovin, Nucl. Phys. A501 (1989) 336

89DE52 C. Detraz and D.J. Viera, Ann. Rev. Nucl. Part. Sci. 39 (1989) 407

89DO1K Dover, Millener and Gal, Phys. Rep. 184 (1989) 1

89DO1N Dover, Proc. 6th Course Int. Schl. of Intermed. Energy Nucl. Phys., Venice, Italy 1988 (Singapore: World Scientific 1989) 164

89ER1B Eremin, Kamanin and Strichov, Tashkent (1989) 393

89FE07 F. Fernandez, T. Lopez-Arias and C. Prieto, Z. Phys. A334 (1989) 349

89FR04 R.M. Freeman, F. Haas, A. Morsad and C. Beck, Phys. Rev. C39 (1989) 1335

89FR08 S.H. Fricke, P.J. Hatchell, K.W. McVoy and G.R. Satchler, Nucl. Phys. A500 (1989) 399

89FR1J Fridlund and White, Astron. Astrophys. 223 (1989) L13

89FU05 R.J. Furnstahl and C.E. Price, Phys. Rev. C40 (1989) 1398

89GA1H Gaydaenko et al, Tashkent (1989) 366

89GA1N Gaillard et al, AIP Conf. Proc. 187 (1989) 684

89GE10 P.M. Gensini, Nuovo Cim. A102 (1989) 1563

89GI1E Gilroy, Astrophys. J. 347 (1989) 835

89GIZV Yu. R. Gismatullin, A. A. Melentev, A. M. Petukhov and V. I. Ostroumov, Program and Thesis, Proc. 39th Ann. Conf. Nucl. Spectrosc. Struct. At. Nucl., Tashkent, (1989) 306

89GO14 S.A. Goncharov, I.R. Gulamov, E.A. Romanovsky, N.K. Timofeyuk and K.V. Shitikova, J. Phys. G15 (1989) 1431

89GOZQ N.G. Goncharova, Prog. and Thesis, Proc. 39th Ann. Conf. Nucl. Spectrosc. Struct. At. Nucl., Tashkent (1989) 154

89GR1F Gruszcynski et al, Nature 337 (1989) 64

89GRZQ W. Greiner, M. Ivascu, D.N. Poenaru and A. Sandulescu, Treatise on Heavy-Ion Sci. (1989) 641

89GU1J Guessoum, Astrophys. J. 345 (1989) 363

89GU1L Gustafsson, Ann. Rev. Astron. Astrophys. 27 (1989) 701

89GU28 N. Guessoum and R.J. Gould, Astrophys. J. 345 (1989) 356

89HA19 P.J. Hatchell, Phys. Rev. C40 (1989) 27

89HA1O Hawkins and Meyer, Astrophys. J. 338 (1989) 888

89HE04 R. Heaton, H. Lee, P. Skensved and B.C. Robertson, Nucl. Instrum. Meth. Phys. Res. A276 (1989) 529

89HE24 L. Heilbronn, A. Galonsky, X. Yang, F. Deak, A. Kiss and Z. Seres, Phys. Rev. C40 (1989) 2576; Erratum Phys. Rev. C43 (1991) 2898

89HI10 K.H. Hicks, M.C. Vetterli, A. Celler, R.L. Helmer, R.S. Henderson, K.P. Jackson, R.G. Jeppesen, A. Trudel and S. Yen, Phys. Rev. C40 (1989) R2445

89HO16 E. Hourani, M. Hussonnois and D.N. Poenaru, Ann. Phys. 14 (1989) 311

89HO1F Hollowell and Iben, Astrophys. J. 340 (1989) 966

89HU15 Z. Huang, J. Liu, Z. Cao, H. Wang and D. Ding, Chin. J. Nucl. Phys. 11 (1989) 55

89IE01 M. Ieiri, H. Sakaguchi, M. Nakamura, M. Yosoi, T. Ichihara, Y. Takeuchi, H. Togawa, T. Tsutsumi, S. Hirata, T. Nakano et al, Nucl. Phys. A504 (1989) 477

89IT04 K. Itonaga, Nuovo Cim. 102A (1989) 501

89IZ1A Izosimov and Petrov, Tashkent (1989) 495

89JAZY J. Janecke, D. Roberts, F. Becchetti, A. Nadasen, M.N. Harakeh, G.P. Berg, R. Sawafta, E.J. Stephenson, S.Y. van der Werf and A. van den Berg, Bull. Am. Phys. Soc. 34 (1989) 1232

89JE02 M.T. Jeong and Il.T. Cheon, Phys. Rev. C39 (1989) 2295

89JI1A L. Jin, W.D. Arnett and S.K. Chakrabarti, Astrophys. J. 336 (1989) 572

89JO1B Johnson, Czech. J. Phys. 39 (1989) 822

89KA1K Kajino, Mathews and Fuller, Tokyo 1988 (1989) 51

89KA1N Kayomov, Mukhamedzhanov and Yarmukhamedov, Tashkent (1989) 408

89KA1S Katoh, Kawade and Yamamoto, JAERI-M 89-083 (1989)

89KA24 F. Kappeler, H. Beer and K. Wisshak, Rep. Prog. Phys. 52 (1989) 945

89KI13 A. Kiss, F. Deak, Z. Seres, G. Caskey, A. Galonsky, B. Remington and L. Heilbronn, Nucl. Phys. A499 (1989) 131

89KI21 A.Z. Kiss, E. Koltay and E. Somorjai, Acta Phys. Acad. Sci. Hung. 65 (1989) 277

89KI25 T. Kishimoto, Phys. Rev. Lett. 62 (1989) 2456

89KO1H Koutroulos and Grypeos, Phys. Rev. C40 (1989) 275

89KO21 E. Korkmaz, S.E. Vigdor, W.W. Jacobs, T.G. Throwe, L.C. Bland, M.C. Green, P.L. Jolivette and J.D. Brown, Phys. Rev. C40 (1989) 813

89KO37 C.G. Koutroulos, J. Phys. G15 (1989) 1659

89KO48 C.G. Koutroulos, Z. Naturforsch. 44a (1989) 1234

89KU14 I.N. Kudryavtsev and A.P. Soznik, J. Phys. G15 (1989) 1377

89KU1E Kuznichenko et al, Tashkent (1989) 338

89KU1P Kudziev, Nucl. Instr. Meth. Phys. Res. A282 (1989) 267

89KU32 I.N. Kudryavtsev and A.P. Soznik, Ukr. Fiz. Zh. 34 (1989) 1642

89LA1H Lanskoi and Tretyakova, Taskent (1989) 150

89LA1I Lanskoi, Sov. J. Nucl. Phys. 49 (1989) 41

89LE14 H. Lenske, Nucl. Phys. A495 (1989) 127C

89LO1C Loren, Astrophys. J. 338 (1989) 902

89LO1D Loren, Astrophys. J. 338 (1989) 925

89LY1A Lyubinsky et al, Tashkent (1989) 557

89MA30 J. Mares and J. Zofka, Z. Phys. A333 (1989) 209

89ME1C Mewaldt and Stone, Astrophys. J. 337 (1989) 959

89ME1D Meier et al, Bull. Amer. Phys. Soc. 34 (1989) 1232

89MI01 D.J. Millener, D.I. Sober, H. Crannell, J.T. O'Brien, L.W. Fagg, S. Kowalski, C.F. Williamson and L. Lapikas, Phys. Rev. C39 (1989) 14

89MI20 K. Miyagawa and Y. Koike, Prog. Theor. Phys. 82 (1989) 329

89MI30 M. Mian, Phys. Rev. C39 (1989) 279

89MO09 S. Mordechai, N. Auerbach, S. Greene, C.L. Morris, J.M. O'Donnell, H.T. Fortune, G. Liu, M. Burlein, A. Wuosmaa, S.H. Yoo et al, Phys. Rev. C40 (1989) 850

89MU1A Murphy et al, Nature 337 (1989) 153

89MUZZ K. Murphy, W.D. Anderson, L.C. Bland, G.M. Huber, D.S. Carman, B.H. Markham, D.W. Miller, B.A. Raue, P.S. Schwandt and J.A. Templon, Bull. Am. Phys. Soc. 34 (1989) 1142

89NA1R Nakashima et al, Int. Conf. Nucl. Reaction Mech., Calcuta, India (Singapore: World Scientific 1989) 422

89NO1A Nomoto, Hashimoto, Arai and Kaminisi, Proc. int. Symp. on Heavy Ion Phys. and Nucl. Astrophys. Problems, Tokyo, 21-23 July 1988, ed. S. Kubono, M. Ishihara, T. Nomura (World Scientific, 1989) 9

89OG1B Ogloblin and Penionzhkevich, Treatise on Heavy-Ion Science, vol. 8, Ed. D.A. Bromley (Plenum Publ. Corp. 1989) 261

89OL02 N. Olsson, B. Trostell and E. Ramstrom, Nucl. Phys. A496 (1989) 505

89OL1C Olsson, Trostell and Ramstrom, Phys. Med. Biol. 34 (1989) 909

89OPZY A.K. Opper, S.W. Wissink, A.D. Bacher, J. Lisantti, C. Olmer, T. Rinckel, R. Sawafta, E.J. Stephenson and S.P. Wells, Bull. Am. Phys. Soc. 34 (1989) 1829

89OPZZ A.K. Opper, S.W. Wissink, A.D. Bacher, J. Lisantti, C. Olmer, T. Rinckel, R. Sawafta, E.J. Stephenson and S.P. Wells, Bull. Am. Phys. Soc. 34 (1989) 1141

89OR02 W.E. Ormand and B.A. Brown, Nucl. Phys. A491 (1989) 1

89PI02 J.A. Pinston, D. Barneoud, V. Bellini, S. Drissi, J. Guillot, J. Julien, M. Kwato Njock, M. Maurel, H. Nifenecker, F. Schussler et al, Phys. Lett. B218 (1989) 128

89PI11 P.H. Pile, Nuovo Cim. A102 (1989) 413

89PI12 J.V. Pilcher, A.A. Cowley, D.M. Whittal and J.J. Lawrie, Phys. Rev. C40 (1989) 1937

89PO1K Poppelier, Ph.D. Thesis, Univ. of Utrecht (1989)

89POZT I.V. Poplavsky Prog. and Thesis, Proc. 39th Ann. Conf. Nucl. Spectrosc. Struct. At. Nucl., Tashkent, (1989) 210

89PR02 C. Pruneau, L. Potvin, R. Roy, C. St-Pierre, G.C. Ball, R. Bougault, E. Hagberg, D. Horn, D. Cebra, D. Fox et al, Nucl. Phys. A500 (1989) 168

89RA09 J. Rapaport, P.W. Lisowski, J.L. Ullmann, R.C. Byrd, T.A. Carey, J.B. McClelland, L.J. Rybarcyk, T.N. Taddeucci, R.C. Haight, N.S.P. King et al, Phys. Rev. C39 (1989) 1929

89RA15 L. Ray and J.R. Shepard, Phys. Rev. C40 (1989) 237

89RA17 P. Raghavan, At. Data Nucl. Data Tables 42 (1989) 189

89RA1G J. Rapaport, Fundamental Symmetries and Nucl. Struct., eds. J.N. Ginocchio & S. P. Rosen, Santa Fe, NM 1988 (World Sci. 1989) 186

89RA1K Rastegar et al, Sao Paulo (1989) 412

89RA1M Rau, Takahashi and Des Marais, Nature 341 (1989) 516

89RA1O Ray, Proc. Wkshp. Relativistic Nucl. Many-Body Phys., Columbus, OH 1988 (Singapore: World Scientific 1989) 427

89RO03 I. Rotter, J. Phys. G15 (1989) 251

89SA10 M.G. Saint-Laurent, R. Anne, D. Bazin, D. Guillemaud-Mueller, U. Jahnke, Jin Gen-Ming, A.C. Mueller, J.F. Bruandet, F. Glasser, S. Kox et al, Z. Phys. A332 (1989) 457

89SA1J Sal'Nikov et al, INDC(CCP)-290/LJ (1989)

89SA1P Sakutal, Tashkent (1989) 380

89SA44 G.R. Satchler, Nucl. Phys. A505 (1989) 103

89SE03 Z. Seres, F. Deak, A. Kiss, G. Caskey, A. Galonsky, L. Heilbronn and B. Remington, Nucl. Phys. A492 (1989) 315

89SE1C Severijns et al, Weak and Electromagnetic Interactions in Nucl., Proc. of the Int. Symp. (Wein-89 Paper PB07), Montreal, Que., Canada, May 1989 (Gif Sur Yvette, France: Eds. Frontieres 1989) 615

89SE1G Severijns et al, Sao Paulo (1989) 63

89SM1A Smith and Suntzeff, Astron. J. 97 (1989) 1699

89SOZW D.S. Sorenson, X. Aslanoglou, F.P. Brady, J.R. Drummond, R.W. Finlay, R.C. Haight, C.R. Howell, N.S.P. King, A. Ling, P.W. Lisowski et al, Bull. Am. Phys. Soc. 34 (1989) 1834

89SOZY D.S. Sorenson, X. Aslanoglou, F.P. Brady, J.R. Drummond, R.W. Finlay, R.C. Haight, C. Howell, N.S.P. King, A. Ling, P.W. Lisowski et al, Bull. Am. Phys. Soc. 34 (1989) 1233

89SR1C Sromicki et al, Phys. Rev. C40 (1989) R1111

89ST14 A. Staudt, E. Bender, K. Muto and H.V. Klapdor, Z. Phys. A334 (1989) 47

89ST1K Stahl et al, Astron. Astrophys. 221 (1989) 321

89SU1F Sulema et al, Tashkent (1989) 388

89TA1O I. Tanihata, Treatise on Heavy-Ion Sci., vol. 8, Ed. D.A. Bromley (Plenum Publ. Corp. 1989) 443

89TA24 Z.-Q. Tan and Y.-T. Gu, J. Phys. G15 (1989) 1699

89TE02 F. Terrasi, A. Brondi, G. La Rana, G. De Angelis, A. D'Onofrio, R. Moro, E. Perillo and M. Romano, Phys. Rev. C40 (1989) 742

89TEZZ J.A. Templon, L.C. Bland, K. Murphy, B.A. Raue, W. Anderson, D.S. Carman, G.M. Huber, B.C. Markham, D.W. Miller and P. Schwandt, Bull. Am. Phys. Soc. 34 (1989) 1142

89TH1A Thiel et al, Bull. Amer. Phys. Soc. 34 (1989) 69

89TR1B Tribble, Burch and Gagliardi, Tokyo (1988) 261

89VI1E Vinogradova et al, Tashkent (1989) 556

89VO05 B. von Przewoski, P.D. Eversheim, F. Hinterberger, L. Doberitz, J. Campbell, M. Hammans, R. Henneck, W. Lorenzon, M.A. Pickar and I. Sick, Nucl. Phys. A496 (1989) 15

89VO1D Von Oertzen, Tokyo (1988) 373

89WA15 J.W. Watson, R. Pourang, R. Abegg, W.P. Alford, A. Celler, S. El-Kateb, D. Frekers, O. Hausser, R. Helmer, R. Henderson et al, Phys. Rev. C40 (1989) 22

89WA16 S. Wa-Kitwanga, P. Leleux, P. Lipnik and J. Vanhorenbeeck, Phys. Rev. C40 (1989) 35

89WE1G Webber ans Soutoul, Astron. Astrophys. 215 (1989) 128

89WH1B Wheeler, Sneden and Truran, Ann. Rev. Astron. Astrophys. 27 (1989) 279

89WI07 J.S. Winfield, E. Adamides, S.M. Austin, G.M. Crawley, M.F. Mohar, C.A. Ogilvie, B. Sherrill, M. Torres, G. Yoo and A. Nadasen, Phys. Rev. C39 (1989) 1395

89WI1E Wiescher et al, Astrophys. J. 343 (1989) 352

89WO1B Wood, Bull. Amer. Phys. Soc. 34 (1989) 1133

89WO1E Wolters, Ph.D. Thesis, UIniv. of Utrecht (1989)

89WUZX A. H. Wuosmaa and R. W. Zurmuhle, Bull. Am. Phys. Soc. 34 (1989) 1800

89WY1A Wycjoff et al, Astrophys. J. 339 (1989) 488

89YA10 K. Yabana and H. Horiuchi, Prog. Theor. Phys. 82 (1989) 86

89YO02 A. Yokoyama, T. Saito, H. Baba, K. Hata, Y. Nagame, S. Ichikawa, S. Baba, A. Shinohara and N. Imanishi, Z. Phys. A332 (1989) 71

89ZU1A Zucchiatti et al, Sao Paulo (1989) 15

90AJ01 F. Ajzenberg-Selove, Nucl. Phys. A506 (1990) 1

90AS01 K. Asahi, K. Matsuta, K. Takeyama, K.H. Tanaka, Y. Nojiri and T. Minamisono, Phys. Rev. C41(1990) 358

90BA03 D. Baye and P. Descouvemont, Nucl. Phys. A507 (1990) 497

90BA14 F.T. Baker, L. Bimbot, B. Castel, R.W. Fergerson, C. Glashausser, A. Green, O. Hausser, K. Hicks, K. Jones, C.A. Miller et al, Phys. Lett. 237B (1990) 337

90BA16 A. Barbadoro, F. Pellegrini, G.F. Segato, L. Taffara, I. Gabrielli and M. Bruno, Phys. Rev. C41 (1990) 2425

90BA1S E.H. Bakraji, A. Giovagnoli, G. Blondiaux and J.-L. Debrun, Nucl. Instr. Meth Phys. Res. B50 (1990) 65

90BE12 C. Bennhold and L. Tiator, Phys. Lett. 238B (1990) 31

90BO10 B. Bonin, A. Boudard, H. Fanet, R.W. Fergerson, M. Garcon, C. Giorgetti, J. Habault, J. Le Meur, R.M. Lombard, J.C. Lugol et al, Nucl. Instrum. Meth. Phys. Res. A288 (1990) 379

90CA15 W. Cassing, G. Batko, U. Mosel, K. Niita, O. Schult and Gy. Wolf, Phys. Lett. 238B (1990) 25

90CA1O Cambell, Lambert and Maillard, Publ. Astron. Soc. Pac. 102 (1990) 79

90CA1S Cassing et al, Phys. Rep. 188 (1990) 363

90CH09 S.K. Charagi and S.K. Gupta, Phys. Rev. C41 (1990) 1610

90CH12 H.C. Chiang, E. Oset, R.C. Carrasco, J. Nieves and J. Navarro, Nucl. Phys. A510 (1990) 573; Errata Nucl. Phys. A514 (1990) 749

90CH13 H.C. Chiang, E. Oset and P. Fernandez de Cordoba, Nucl. Phys. A510 (1990) 591

90CH16 C. Chan, T.E. Drake, R. Abegg, D. Frekers, O. Hausser, K. Hicks, D.A. Hutcheon, L. Lee, C.A. Miller, R. Schubank et al, Nucl. Phys. A510 (1990) 713

90CH1J Chou et al, Nucl. Instr. Meth. Phys. Res. B45 (1990) 86

90CH1R Chen et al, Panic XII (1990) Paper II-59

90CHZY X.Y. Chen, J.R. Shepard, M.R. Braunstein, P.L. McGrath, T.A. Carey, K.W. Jones, J.B. McClelland, L. Rees, T.N. Taddeucci, N. Tanaka et al, Bull. Am. Phys. Soc. 35 (1990) 1038

90CLZZ J. Clayton, W. Benenson, M. Cronqvist, R. Fox, D. Krofcheck, M.F. Mohar, R. Pfaff, T. Reposeur, J. Stevenson, B. Young et al,Bull. Am. Phys. Soc. 35 (1990) 1039

90DA03 B. Dasmahapatra, B. Cujec, F. Lahlou, I.M. Szoghy, S.C. Gujrathi, G. Kajrys and J.A. Cameron, Nucl. Phys. A509 (1990) 393

90DA1J Darquennes, Delbar and Lipnik, Nucl. Instr. Meth. Phys. Res. B47 (1990) 311

90DO1C Donahue, Jull and Linick, Nucl. Instr. Meth. B45 (1990) 561

90DU01 O. Dumitrescu, M. Horoi, F. Carstoiu and G. Stratan, Phys. Rev. C41 (1990) 1462

90ER02 N.V. Eremin, V.F. Strizhov and B.V. Govorov, Nucl. Phys. A510 (1990) 125

90ER03 R.A. Eramzhyan, M. Gmitro and S.S. Kamalov, Panic XII (1990) Paper III-60; Phys. Rev. C41 (1990) 2865

90EV01 P.D. Eversheim, F. Hinterberger, U. Lahr, B. von Przewoski, J. Campbell, J. Gotz, M. Hammans, R. Henneck, G. Masson and I. Sick, Phys. Lett. 234B (1990) 253

90FE01 H. Feshbach, Nucl. Phys. A507 (1990) 219C

90FR1F Freeman et al, Nature 343 (1990) 254

90FU03 M. Fukugita, Y. Kohyama, K. Kubodera and T. Kuramoto, Phys. Rev. C41 (1990) 1359

90GL01 A. Glaesner, W. Dünnweber, M. Bantel, W. Hering, D. Konnerth, R. Ritzka, W. Trautmann, W. Trombik and W. Zipper, Nucl. Phys. A509 (1990) 331

90HA19 A. Hakansson, A. Lindholm, L. Nilsson, J. Blomgren, P.-O. Soderman, D.M. Drake, S.A. Wender and N. Olsson, Phys. Rev. C41 (1990) 2556

90HA46 D. Harley, B. Muller and J. Rsfelski, J. Phys. G16 (1990) 281

90HO01 T. Hoshino, H. Sagawa and A. Arima, Nucl. Phys. A506 (1990) 271

90HO06 G.W. Hoffmann, M.L. Barlett, D. Ciskowski, G. Pauletta, M. Purcell, L. Ray, J.F. Amann, J.J. Jarmer, K.W. Jones, S. Pentilla et al, Phys. Rev. C41 (1990) 1651

90HO1I Hollowell and Iben, Astrophys. J. 349 (1990) 208

90IE01 K. Ieki, J. Iimura, M. Iwase, H. Ohnuma, H. Shimizu, H. Toyokawa, K. Furukawa, H. Kabasawa, T. Nakagawa, T. Tohei et al, Phys. Rev. C42 (1990) 457

90IM01 B. Imanishi, S. Misono and W. von Oertzen, Phys. Lett. 214B (1990) 13

90IT1A Itonaga, Motoba and Bando, Panic XII (199) Paper IV-15

90JAZZ E.R. Jacobsen, J.D. Brown, M. Grimes and K.W. Kemper, Bull. Am. Phys. Soc. 35 (1990) 1058

90JE1B Jeong and Cheon, Panic XII (1990) Paper I-52

90KO19 J.H. Koch and T. Takaki, Nucl. Phys. A512 (1990) 699

90KU1H Kume and Nose, Int. Conf. on Particles and Nucl., Cambridge, Mass., 25-29 June 1990 (Organizing Committee, 1990) Paper III-81, 82

90LE1Q Leeb and Schmiedmayer, Panic XII (1990) Paper XII-26

90LO10 R.J. Lombard, Europhys. Lett. 12 (1990) 119

90LU1D Lu et al, Panic XII (1990) Paper XII-12

90ME07 A. Menchaca-Rocha, E. Belmont-Moreno, M.E. Brandan, A. Martinez, D. Abriola, M. Elgue, A. Etchegoyen, M.C. Etchegoyen, J.O. Fernandez-Niello, D.E. DiGregorio et al, Phys. Rev. C41 (1990) 2654

90MI1J Mintz and Pourkaviani, Panic XII (1990) Paper XV-13

90MO02 S. Mordechai, H.T. Fortune, J.M. O'Donnell, G. Liu, M. Burlein, A.H. Wuosmaa, S. Greene, C.L. Morris, N. Auerbach, S.H. Yoo et al, Phys. Rev. C41 (1990) 202

90MO1I Mollaaghababa et al, Astrophys. J. 352 (1990) L21

90MU10 A.M. Mukhamedzhanov and N.K. Timofeyuk, Yad. Fiz. 51 (1990) 679; Sov. J. Nucl. Phys. 51 (1990) 431

90NA1B S. Nakayama, T. Yamagata, K. Yuasa, M. Tanaka, H.G. Bohlen, H. Lenske, H.H. Wolter, M. Inoue, T. Itahashi and H. Ogata, Nucl. Phys. A507 (1990) 515

90OS1A Oset et al, Phys. Rep. 188 (1990) 79

90PH02 D.L. Pham and R. de Swiniarski, Nuovo Cim. A103 (1990) 375

90PI05 S. Piskor and W. Schaferlingova, Nucl. Phys. A510 (1990) 301

90PI06 J. Piekarewicz, E. Rost and J.R. Shepard, Phys. Rev. C41 (1990) 2277

90PI1F Pilachowski, Sneden and Hudek, Astron. J. 99 (1990) 1225

90QU1B Quin, Panic XII (1990) Paper XII-10

90SE04 K.K. Seth, D. Barlow, S. Iversen, M. Kaletka, H. Nann, D. Smith, M. Artuso, G. Burleson, G. Blanpied, G. Daw et al, Phys. Rev. C41 (1990) 2800

90SM1B Smith et al, Panic XII (1990) Paper III-66

90SN1A K. Snover, Bull. Amer. Phys. Soc. 35 (1990) 1032

90ST08 A. Staudt, E. Bender, K. Muto and H.V. Klapdor-Kleingrothaus, At. Data Nucl. Data Tables 44 (1990) 79

90TA1J Taddeucci et al, Panic XII (1990) Paper II-1

90TA1K Tacik, Panic XII (1990) Paper III-8

90TI1B Tiator and Bennhold, Panic XII (1990) Paper I-61

90TU1A Turner, Martin and Ho, Astrophys. J. 351 (1990) 418

90VA01 A.G.M. Van Hees, J.G.L. Booten and P.W.M. Glaudemans, Nucl. Phys. A507 (1990) 55C

90VO02 B. von Przewoski, P.D. Eversheim, F. Hinterberger, U. Lahr, J. Campbell, J. Gotz, M. Hammans, R. Henneck, G. Masson, I. Sick et al, Phys. Rev. Lett. 64 (1990) 368

90VO1E Von Oertzen, Nucl. Instr. Meth. Phys. Res. A287 (1990) 188

90WA22 A.H. Wapstra, Nucl. Instrum. Meth. Phys. Res. A292 (1990) 671

90WE14 W.R. Webber, J.C. Kish and D.A. Schrier, Phys. Rev. C41 (1990) 520

90WE1I W.R. Webber, A. Soutoul, P. Ferrando and M. Gupta, Astrophys. J. 348 (1990) 611

90WEZY S.P. Wells, S.W. Wissink, A.D. Bacher, P. Li, J. Lisantti, C. Olmer, A.K. Opper, R. Sawafta, P. Schwandt, J. Sowinski and E.J. Stephenson, Bull. Am. Phys. Soc. 35 (1990) 1037

90YA01 M. Yasue, M.H. Tanaka, T. Hasegawa, K. Nisimura, H. Ohnuma, H. Shimizu, K. Ieki, H. Toyokawa, M. Iwase, J. Iimura et al, Nucl. Phys. A509 (1990) 141

90YE1C Yen et al, Panic XII (1990) Paper III-65