Revised Manuscript *22 April 2013*

Energy Levels of Light Nuclei
$A = 15$

F. Ajzenberg-Selove

University of Pennsylvania, Philadelphia, Pennsylvania 19104-6396

Abstract: An evaluation of $A = 13$–15 was published in *Nuclear Physics A*449 (1986), p. 1. This version of $A = 15$ differs from the published version in that we have corrected some errors discovered after the article went to press. Figures and introductory tables have been omitted from this manuscript. Reference key numbers have been changed to the NNDC/TUNL format.

(References closed June 1, 1985)

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

Table of Contents for $A = 15$

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

^{15}He

(Not illustrated)

^{15}He has not been observed. See also (1983ANZQ; theor.).

^{15}Li

(Not illustrated)

^{15}Li has not been observed. Its atomic mass excess is calculated to be 81.60 MeV: see (1981AJ01). It is then unstable with respect to decay into ^{14}Li + n and ^{13}Li + 2n by 1.24 and 3.90 MeV, repsectively.

^{15}Be

(Not illustrated)

^{15}Be has not been observed. The calculated mass excess is 51.18 MeV: see (1981AJ01). It is calculated to be particle unstable with respect to decay into ^{14}Be + n by 2.42 MeV. The binding energy of ^{13}Be + 2n is $+0.31$ MeV. See also (1981SE06, 1983ANZQ; theor.).

^{15}B

(Figs. 10 and 13)

The Q-value of the ^{48}Ca(^{18}O, ^{51}V)^{15}B reaction is -21.768 ± 0.025 MeV, leading to an atomic mass excess of 28969.5 ± 25 keV for ^{15}B (1983HO08) based on the masses of ^{18}O, ^{48}Ca and ^{51}V in (1985WA02). Wapstra adopts 28970 ± 22 keV and we shall also. ^{15}B is then stable with respect to ^{14}B + n by 2.765 MeV. At $E(^{18}\text{O}) = 108$ MeV, dσ/dΩ $= 2.0$ μb/sr at $5°$ (1983HO08). The β^- decay of ^{15}B has been reported: $\tau_{1/2} = 11 \pm 1$ msec. Upper limits have been set on the P_{0n} and P_{2n}: 5% and 1.5%, respectively (1984DU15). See also (1981AJ01) for the earlier work, (1984HI1A, 1984MU27), (1980AL1F) and (1981SE06, 1983ANZQ; theor.).

^{15}C

(Figs. 10 and 13)

GENERAL: (See also (1981AJ01).)

Model calculations: (1983ANZQ, 1984VA06).

Electromagnetic transitions: (1980RI06).

Complex reactions involving ^{15}C: (1981GR08, 1983BE02, 1983EN04, 1983FR1A, 1983HO08, 1983MA06, 1983OL1A, 1983WI1A, 1984HI1A, 1984HO23).

Table 15.1: Energy levels of ^{15}C

E_x (MeV ± keV)	$J^\pi; T$	τ or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
g.s.	$\frac{1}{2}^+; \frac{3}{2}$	$\tau_{1/2} = 2.449 \pm 0.005$ nsec	β^-	1, 2, 3, 4, 6, 7
0.7400 ± 1.5	$\frac{5}{2}^+$	$\tau_m = 3.76 \pm 0.10$ nsec	γ	2, 3, 4, 8
		$g = -0.703 \pm 0.012$		
3.103 ± 4	$\frac{1}{2}^-$	$\Gamma_{c.m.} \leq 40$		2, 3
4.220 ± 3	$\frac{5}{2}^-$	< 14		2, 3
4.657 ± 9	$\frac{3}{2}^-$			2, 3
5.833 ± 20	$\leq \frac{3}{2}$			2
5.866 ± 8	$\frac{1}{2}^-$			2, 3
6.358 ± 6	$(\frac{5}{2}, \frac{7}{2}^+, \frac{9}{2}^+)$	< 20		2, 3
6.417 ± 6	$(\frac{3}{2} \rightarrow \frac{7}{2})$	≈ 50		2, 3
6.449 ± 7	$(\frac{9}{2}^-, \frac{11}{2})$	< 14		2, 3
6.536 ± 4	[a]	< 14		2, 3
6.626 ± 8	$(\frac{3}{2})$	20 ± 10		2, 3
6.841 ± 4	[a]	< 14		2, 3
6.881 ± 4	$(\frac{9}{2})$ [a]	< 20		2, 3
7.095 ± 4	$(\frac{3}{2})$	< 15		2, 3
7.352 ± 6	$(\frac{9}{2}, \frac{11}{2})$	20 ± 10		2, 4
7.414 ± 20				2
7.75 ± 30 [b]				2
8.01 ± 30				2
8.11 ± 10 [b]				2
8.47 ± 15	$(\frac{9}{2} \rightarrow \frac{13}{2})$	40 ± 15		2
8.559 ± 15	$(\frac{7}{2} \rightarrow \frac{13}{2})$	40 ± 15		2
9.00 ± 30				2
(9.73 ± 30)				2
9.789 ± 20	$(\frac{9}{2} \rightarrow \frac{15}{2})$	20 ± 15		2
10.248 ± 20	$(\frac{5}{2} \rightarrow \frac{9}{2})$	20 ± 15		2
11.015 ± 25				2
11.123 ± 20	$(\frac{11}{2} \rightarrow \frac{19}{2})$	30 ± 20		2
(11.68 ± 30)				2
11.825 ± 20	$\geq \frac{13}{2}$	70 ± 30		2

[a] See also Tables 15.2 and 15.3 and reaction 8.

[b] Broad or unresolved states.

Pion capture and reactions: (1981OS04).

Hypernuclei: (1981WA1J, 1982KA1D, 1983DO1B, 1983FE07, 1983KO1V, 1984AS1D).

Other topics: (1984PO11).

Ground state of ^{15}*C:* (1984FR13).

1. ^{15}C(β^-)^{15}N $\qquad Q_{\rm m} = 9.7717$

The half-life of ^{15}C is 2.449 ± 0.005 sec (1979AL23). Transitions have been observed to ^{15}N$_{\rm g.s.}$ and to the upper of the 5.3 MeV states in ^{15}N which has $J^\pi = \frac{1}{2}^+$. Therefore J^π (^{15}C$_{\rm g.s.}$) $= \frac{1}{2}^+$ or $\frac{3}{2}^+$. Weak transitions are observed to ^{15}N*(7.30, 8.31, 8.57, 9.05) (1979AL23): see Table 15.15. The shape of the ^{15}C$_{\rm g.s.}$ $\rightarrow$ ^{15}N$_{\rm g.s.}$ transition differs appreciably from an allowed shape (1984WA07). See also (1981FR23), (1983SN03) and (1980RI06; theor.).

2. ^{9}Be(^{7}Li, p)^{15}C $\qquad Q_{\rm m} = 9.092$

Observed proton groups are displayed in Table 15.2.

3. ^{13}C(t, p)^{15}C $\qquad Q_{\rm m} = 0.9127$

Observed proton groups are displayed in Table 15.3 (1983TR12). $|{\rm g}| = 0.703 \pm 0.012$ for ^{15}C*(0.74) (1980AS01).

4. ^{13}C(α, 2p)^{15}C $\qquad Q_{\rm m} = -18.9013$

At $E_\alpha = 65$ MeV ^{15}C*(0.74, 6.74, 7.35) are strongly populated: see (1981AJ01).

5. (a) ^{14}C(n, γ)^{15}C $\qquad Q_{\rm m} = 1.2181$
   (b) ^{14}C(n, n)^{14}C $\qquad E_{\rm b} = 1.2181$

$\sigma_\gamma < 1$ μb (1981MUZQ). See also (1976AJ04).

6. ^{14}C(d, p)^{15}C $\qquad Q_{\rm m} = -1.0065$

Obserevd proton groups are displayed in Table 15.2.

Table 15.2: Proton groups from $^{9}Be(^{7}Li, p)^{15}C$ and $^{14}C(d, p)^{15}C$ [a]

$^{9}Be(^{7}Li, p)^{15}C$ [b]			$^{14}C(d, p)^{15}C$ [c]		
E_x (keV)	$\Gamma_{c.m.}$ (keV)	J^π [d]	E_x (keV)	$\Gamma_{c.m.}$ (keV)	J^π [e]
g.s.	bound		g.s.	bound	$\frac{1}{2}^+$ [n]
$\equiv 740$ [f]	bound		744.1 ± 2 [j]	bound	$\frac{5}{2}^+$ [o]
3100 ± 30	< 40	$(\frac{1}{2}^-)$ [h]	3105.3 ± 5	≈ 42	$(\frac{1}{2}^-)$
4223 ± 15	< 15	$(\frac{5}{2}^-)$	4221.1 ± 3	< 14	$(\frac{7}{2}^+, \frac{5}{2}^-)$
(4550 ± 30)			[k]		
5833 ± 20		[i]	[k]		
5858 ± 20		[i]	[k]		
6370 ± 15	< 20	$(\frac{5}{2})$	[l]	< 14	$(\frac{7}{2}, \frac{9}{2})^+$
6436 ± 20			6428.1 ± 7	≈ 50	$(\frac{3}{2}, \frac{5}{2}, \frac{7}{2})$
6461 ± 20			[l]	< 14	$(\frac{9}{2}^-, \frac{11}{2})$
6542 ± 15	< 20	$(\frac{3}{2})$	6539.8 ± 5	< 14	$(\frac{9}{2}^-, \frac{11}{2})$
6639 ± 15	20 ± 10	$(\frac{3}{2})$			
6847 ± 15	< 20	$(\frac{11}{2}, \frac{13}{2})$	6844.9 ± 5	< 14	$(\frac{13}{2}, \frac{11}{2})^+$
6894 ± 15	< 20	$(\frac{7}{2}, \frac{9}{2})$	6822.4 ± 5		$((\frac{9}{2}^+, \frac{11}{2}^+, \frac{13}{2}^+))$
7100 ± 15	< 15	$(\frac{3}{2})$	7097.2 ± 6		
7354 ± 15	20 ± 10	$(\frac{9}{2}, \frac{11}{2})$	7351.3 ± 6		
7414 ± 20					
7750 ± 30 [g]			7.81 ± 10 [m]		
8010 ± 30					
8130 ± 30 [g]			8.10 ± 10 [m]		
8491 ± 15	40 ± 15	$(\frac{9}{2}, \frac{11}{2}, \frac{13}{2})$	8.46 ± 10 [m]		
8559 ± 15	40 ± 15	$(\frac{7}{2} \to \frac{13}{2})$			
9000 ± 30					
(9730 ± 30)					
9789 ± 20	20 ± 15	$(\frac{9}{2} \to \frac{15}{2})$			
10248 ± 20	20 ± 15	$(\frac{5}{2}, \frac{7}{2}, \frac{9}{2})$			
11015 ± 25					
11123 ± 20	30 ± 20	$(\frac{11}{2} \to \frac{19}{2})$			
(11680 ± 30)					
11825 ± 20	70 ± 30	$(\frac{13}{2} \to \frac{31}{2})$			

[a] For references see Table 15.2 in (1981AJ01).
[b] $E(^7\mathrm{Li}) = 20$ MeV. E_x based on 740 keV for first excited state.
[c] $E_\mathrm{d} = 12 - 14$ MeV.
[d] Suggested J^π assignments based on angular distributions (and $2J_\mathrm{f} + 1$ dependence) and l_max from Γ_n.
[e] Analysis of the two bound states is done using DWUCK. For the unbound states DOXY was used.
[f] $E_\mathrm{x} = 739 \pm 1$ keV [from E_γ]; $\tau_\mathrm{m} = 3.77 \pm 0.11$ nsec.
[g] Broad or unresolved states.
[h] $\theta_\mathrm{n}^2 = 0.0075 \pm 0.0015$.
[i] Sum of the J for these two states is 2 [based on $(2J + 1)$ dependence of cross section].
[j] $\tau_\mathrm{m} = 3.73 \pm 0.23$ nsec.
[k] Not observed.
[l] Observed but E_x not determined.
[m] Observed at $E_\mathrm{d} = 27$ MeV.
[n] $S = 0.88$.
[o] $S = 0.69$ or 0.55. g $= -0.77 \pm 0.06$.

7. ^{14}C(^{14}C, ^{13}C)^{15}C $\quad Q_\mathrm{m} = -6.9584$

See (1981FR23, 1985KO04).

Table 15.3: Proton groups from ^{13}C(t, p) [a]

E_x (MeV $\pm$ keV)	J^π	E_x (MeV $\pm$ keV)	J^π
0	$\frac{1}{2}^+$	6.440 ± 6	
0.743 ± 9 [b]	$\frac{5}{2}^+$	6.529 ± 6	
3.100 ± 6 [b]	$\frac{1}{2}^-$	6.622 ± 9	
4.215 ± 9 [b]	$\frac{5}{2}^-$	6.835 ± 6 [b]	$(\frac{7}{2}, \frac{9}{2})^-$
4.657 ± 9 [b]	$\frac{3}{2}^-$	6.876 ± 7	
5.867 ± 8	$\frac{1}{2}^-$	7.093 ± 6	
6.356 ± 6		7.387 ± 7 [b]	$(\frac{9}{2}, \frac{7}{2})^-$
6.404 ± 7			

[a] (1983TR12); $E_\mathrm{t} = 18$ MeV; DWBA.
[b] Strong group.

8. ^{15}N(π^-, γ)^{15}C $\qquad Q_{\rm m} = 129.796$

Radiative pion capture shows evidence for $J^\pi = \frac{5}{2}^+$, $T = \frac{3}{2}$ giant magnetic quadrupole states: transitions are reported to ^{15}C*(0.74) as well as to ^{15}C*(6.7, 8.6, 12.0) (1983ST04).

^{15}N

(Figs. 11 and 13)

GENERAL: (See also (1981AJ01).)

Nuclear models: (1983PI03, 1983SH38, 1983VA31, 1984VA06, 1984ZW1A).

Special states: (1979ZA07, 1980FU1G, 1980RI06, 1981IS11, 1981LI19, 1982ZA1D, 1983GO1R, 1983PI03, 1983VA31, 1984GO1M, 1984VA06, 1984ZW1A, 1985HA1J).

Electromagnetic transitions: (1980RI06, 1981LI19, 1983TO08, 1984KU07).

Astrophysical questions: (1980AU1D, 1980WA1M, 1981AD1F, 1981GU1D, 1981WA1N, 1981WA1Q, 1982KE1B, 1983AL1M, 1983SI1B, 1985DR1A, 1985GU1A).

Complex reactions involving ^{15}N: (1978WU07, 1980RI06, 1980VO1D, 1981DE1W, 1981HU01, 1981ME13, 1981VA1D, 1981VO06, 1982HO10, 1982LE1N, 1982LO13, 1982LU02, 1982LY1A, 1983CH23, 1983DE26, 1983EN04, 1983FR1A, 1983JA05, 1983MA06, 1983OL1A, 1983PL1A, 1983SA06, 1983SI1A, 1983VO04, 1983WI1A, 1984GR08, 1984HI1A, 1984HO23, 1985GU1A, 1985MO08).

Applied work: (1980SE1E, 1981WA1K, 1982MA1R, 1983AM1A, 1983AM1D, 1983MA1Q, 1983MA83, 1983SC43, 1983SK1B, 1984HA1Q, 1984MA2H, 1985AL1N, 1985WA1R).

Muon and neutrino capture and reactions (See also reaction 59.): (1983GM1A, 1984WA07).

Pion capture and reactions (See also reactions 48 and 61.): (1981BA1P, 1981LE06, 1981OS04, 1981OS05, 1981RE04, 1982DO10, 1982OS01, 1983KA19, 1983KI01, 1983TO17, 1983TR1J, 1984GR27, 1984HAZV, 1984LEZX, 1985GU1A, 1985RE1D).

Reactions involving other mesons and hyperons: (1982DO1L, 1983FE07).

Antiproton reactions: (1983BA2R).

Hypernuclei: (1980IW1A, 1981WA1J, 1982ER1E, 1982GR1P, 1982KA1D, 1982RA1L, 1983CH1T, 1983DO1B, 1983FE07, 1983GA17, 1983KO1D, 1983SH38, 1983SH1E, 1984AS1D, 1984CH1G, 1984SH1J, 1985AH1A).

Other topics: (1981SH17, 1982NG01, 1982ZA1D, 1983GO1R, 1983KH1D, 1983MA38, 1983MA35, 1983SH1T, 1983TO08).

Ground-state properties of ^{15}N: (1981AV02, 1981DE1W, 1982LO13, 1982LU02, 1982NG01, 1982ZA1D, 1983ANZQ, 1983BA33, 1983BU07, 1983DE1X, 1983MA38, 1983TO08, 1983VA31, 1984AR1D, 1984BO11, 1984HUZZ, 1984KA25, 1984KU07, 1984WE04, 1985AR11, 1985GA06, 1985HA18, 1985FA01).

$$\mu = -0.2831892(3) \text{ nm (1978LEZA)},$$

$$\text{Natural abundance} = (0.366 \pm 0.009)\% \text{ (1984DE53)}.$$

Table 15.4: Energy levels of ^{15}N [a]

E_x (MeV ± keV)	$J^\pi; T$	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
0	$\frac{1}{2}^-; \frac{1}{2}$	—	stable	2, 3, 4, 12, 14, 15, 16, 17, 19, 20, 21, 25, 26, 27, 28, 29, 30, 32, 33, 34, 35, 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, 66, 67, 68, 69, 70, 71
5.27015 ± 0.02	$\frac{5}{2}^+$	$\tau_m = 2.58 \pm 0.14$ psec $g = +(0.94 \pm 0.07)$	γ	3, 4, 13, 17, 18, 20, 25, 26, 29, 32, 33, 35, 39, 47, 48, 51, 52, 58, 62, 63, 68, 69, 70
5.29880 ± 0.02	$\frac{1}{2}^+$	25 ± 7 fsec	γ	3, 4, 10, 11, 13, 17, 19, 20, 25, 26, 27, 29, 32, 33, 35, 39, 44, 47, 51, 52, 58, 62, 63, 69, 70
6.32389 ± 0.02	$\frac{3}{2}^-$	0.211 ± 0.012 fsec	γ	2, 3, 4, 10, 11, 14, 17, 19, 20, 25, 27, 29, 32, 33, 35, 39, 46, 47, 48, 51, 52, 58, 59, 61, 62, 63, 64, 66, 70
7.1551 ± 0.02	$\frac{5}{2}^+$	18 ± 8 fsec	γ	3, 4, 17, 18, 19, 20, 25, 26, 27, 32, 33, 35, 39, 42, 47, 51, 52, 62
7.30086 ± 0.02	$\frac{3}{2}^+$	0.61 ± 0.05 fsec	γ	3, 4, 17, 19, 20, 25, 26, 27, 32, 33, 35, 39, 44, 46, 47, 51, 52, 62

Table 15.4: Energy levels of ^{15}N [a] (continued)

E_x (MeV $\pm$ keV)	$J^\pi; T$	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
7.5671 ± 1.0	$\frac{7}{2}^+$	12^{+11}_{-6} fsec	γ	2, 3, 4, 10, 11, 17, 18, 19, 20, 25, 26, 27, 28, 32, 39, 42, 47, 48, 51, 52, 62
8.31260 ± 0.02	$\frac{1}{2}^+$	1.7 ± 1.1 fsec	γ	2, 3, 4, 19, 25, 26, 27, 32, 35, 39, 44, 46, 51, 52, 58
8.5714 ± 1.0	$\frac{3}{2}^+$	0.7 ± 0.7 fsec	γ	2, 3, 4, 10, 11, 17, 18, 19, 25, 26, 27, 32, 35, 39, 44, 46, 51, 52
9.0500 ± 0.7	$\frac{1}{2}^+$	0.50 ± 0.08 fsec	γ	3, 4, 25, 26, 32, 35, 39, 44, 46, 47, 58
9.15214 ± 0.06	$\frac{3}{2}^-$	1.40 ± 0.36 fsec	γ	3, 4, 10, 11, 25, 26, 32, 35, 39, 46, 47, 51, 52
9.15500 ± 0.04	$\frac{5}{2}^+$	7^{+6}_{-3} fsec	γ	3, 4, 19, 25, 32, 35, 39, 46
9.225 ± 3	$\frac{1}{2}^-$	< 130 fsec	γ	25, 27, 32, 39, 58
9.7575 ± 3.0	$\frac{5}{2}^-$	2.6 ± 0.9 fsec	γ	25, 35, 39, 46, 47
9.829 ± 3	$\frac{7}{2}^-$	17 ± 7 fsec	γ	3, 4, 10, 11, 18, 19, 20, 25, 27, 28, 32, 39, 51, 52
9.928 ± 4	$\frac{3}{2}^-$	0.31 ± 0.05 fsec	γ	19, 25, 32, 35, 39, 46, 62
10.070 ± 3	$\frac{3}{2}^+$	0.100 ± 0.006 fsec	γ	19, 25, 26, 27, 39, 46, 51, 52
10.4497 ± 0.3	$\frac{5}{2}^-$	$\Gamma < 0.5$ keV	γ, p	4, 10, 11, 20, 25, 30, 39
10.5333 ± 0.5	$\frac{5}{2}^+$		γ, p	4, 10, 11, 19, 25, 26, 30, 32, 39
10.6932 ± 0.3	$\frac{9}{2}^+$	$\tau_m = 18 \pm 9$ fsec	γ, p	4, 11, 17, 30, 48
10.7019 ± 0.3	$\frac{3}{2}^-$	$\Gamma = 0.2$ keV	γ, p	10, 11, 18, 19, 25, 27, 30, 39, 51, 62

Table 15.4: Energy levels of ^{15}N [a] (continued)

E_x (MeV $\pm$ keV)	$J^\pi; T$	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
10.804 ± 2	$\frac{3}{2}^+$	$< 1 \times 10^{-3}$	γ, p	3, 4, 10, 19, 20, 25, 30, 31, 47
11.235 ± 5	$\geq \frac{3}{2}$	3.3	n	17, 32, 36
11.2928 ± 0.7	$\frac{1}{2}^-$	8 ± 3	γ, n, p	17, 30, 31, 32, 36, 51
11.4376 ± 0.7	$\frac{1}{2}^+$	41.4 ± 1.1	γ, n, p, α	6, 10, 19, 26, 30, 31, 32, 36, 37
11.615 ± 4	$\frac{1}{2}^+; T = \frac{3}{2}$	405 ± 6	γ, n, p	30, 31
11.778 ± 5	$\frac{3}{2}^+$	40	n, p, α	6, 31, 36, 37
11.876 ± 3	$\frac{3}{2}^-$	25	γ, n, p, α	6, 31, 36, 37, 47
11.942 ± 6	$\frac{9}{2}^-$	≤ 3.0	n, α	4, 6, 17, 18, 19, 26, 27, 28, 36
11.965 ± 3	$\frac{1}{2}^-$	17	n, p	4, 10, 31, 36, 37
12.095 ± 3	$\frac{5}{2}^+$	14 ± 5	n, p, α	6, 7, 26, 31, 32, 36, 37
12.145 ± 3	$\frac{3}{2}^-$	41 ± 5	n, p, α	6, 7, 10, 31, 36, 37
12.327 ± 4	$\frac{5}{2}^{(+)}$	22	n, p	18, 19, 26, 31, 36, 37
12.493 ± 4	$\frac{5}{2}^+; \frac{1}{2}$	40 ± 5	n, p, α	6, 7, 26, 31, 36, 37
12.522 ± 8	$\frac{5}{2}^+; \frac{3}{2}$	58 ± 4	γ, p	30, 47
12.551 ± 10	$\frac{9}{2}^+$			4, 17, 18, 19, 26, 48
12.920 ± 4	$\frac{3}{2}^-$	56 ± 11	n, p, α	6, 7, 9, 19, 20, 31, 36, 37
12.940 ± 10	$\frac{5}{2}^+$	81	p, α	7, 9, 31
13.004 ± 10	$\frac{11}{2}^-$			4, 10, 11, 13, 17, 19, 26, 27, 28
13.149 ± 10		7 ± 3	n, p, α	6, 7, 20, 37
13.174 ± 7	$(\frac{9}{2})$	7 ± 3	n, p, α	4, 6, 7, 11, 17, 18, 19, 31, 36, 37
13.362 ± 8	$\frac{3}{2}^-$	16 ± 8	n, p, α	6, 7, 9, 31, 37
13.390 ± 10	$\frac{3}{2}^+$	56	γ, n, p, α	7, 9, 30, 31, 37
13.537 ± 10	$\frac{3}{2}^-$	85 ± 30	n, p, α	6, 9, 31

Table 15.4: Energy levels of ^{15}N [a] (continued)

E_x (MeV $\pm$ keV)	$J^\pi; T$	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
13.608 ± 7	$\frac{5}{2}^{(+)}$	18 ± 4	n, p, α	6, 7, 19, 31, 36, 37
(13.612 ± 10)	$(\frac{1}{2}^+)$	90	α	9
13.713 ± 10		26 ± 8	n, p, α	6, 31, 37
13.84 ± 30	$\frac{3}{2}^+$	75	n, p, α	4, 6, 9, 26, 36, 37
13.9	$\frac{1}{2}^+$	930	γ, p	30, 31
13.99 ± 30	$\frac{5}{2}^+$	98 ± 10	n, p, α	6, 31
14.090 ± 7	$(\frac{9}{2}^+, \frac{7}{2}^+)$	22 ± 6	n, p, α	4, 6, 10, 19, 26, 36, 37, 48
14.10 ± 30	$\frac{3}{2}^+$	≈ 100	n, α	4, 6, 9
14.162 ± 10	$\frac{3}{2}^{(+)}$	27 ± 6	n, α	4, 6, 36, 37
14.24 ± 40	$\frac{5}{2}^+$	150	α	9, 10
14.38 ± 40	$\frac{7}{2}^+$	100	α	9
14.4		≈ 1900	n, p, α	36, 37
14.55 ± 20		200 ± 50	n, (p), α	6
14.647 ± 10		33 ± 6	n, p, α	6, 36, 37
14.71		750	γ, p	30
14.720 ± 10	$\frac{5}{2}^-$	110 ± 50	γ, n, (p), α	6, 10, 19, 47
14.86 ± 20		48 ± 11	n, α	6, 9, 19
14.920 ± 10		12 ± 3	n, α	6, 10, 37
15.025 ± 10		13 ± 3	n, α	6, 19
15.09 ± 20		80 ± 25	n, α	6, 9, 36, 37, 51
15.288 ± 10		26 ± 6	n, α	6, 9
15.373 ± 10	$\frac{13}{2}^+$			4, 10, 11, 17, 18, 19, 20
15.38 ± 20		75 ± 25	n, t, α	6, 9, 15
15.43 ± 20		≈ 100	n, (α)	6, 9
15.45		750	γ, p	30
15.53 ± 20		≈ 35	n, α	6, 10, 11, 37
15.60 ± 20		95 ± 25	n, α	6
15.782 ± 10			p, t, α	15, 19, 20
15.93 ± 20		35 ± 5	n, t, α	6, 15, 18

Table 15.4: Energy levels of ^{15}N [a] (continued)

E_x (MeV $\pm$ keV)	$J^\pi; T$	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
15.944 ± 15		21 ± 6	n, t, α	6, 15
16.026 ± 10		62 ± 12	n, p, t, α	6, 9, 15, 19, 37
16.190 ± 10	$\frac{3}{2}^+$	450 ± 100	γ, n, p, t, α	15, 19
16.26 ± 20	$\frac{3}{2}^+$	150 ± 28	γ, n, t, α	5, 6, 9, 15, 18, 19, 20, 31
16.32 ± 20		≈ 30	n, p, t, α	6, 15
16.39 ± 20		44 ± 11	n, p, t, α	6, 15, 18, 37
16.46		560	γ, p, d	22, 30
16.576 ± 15		27 ± 15	n, α	6, 37
16.59 ± 25	$\frac{3}{2}^-$	490	γ, n, p, t, α	15
16.677 ± 15	$\frac{1}{2}^+; \frac{1}{2}$	80 ± 20	γ, n, p, d, t, α	5, 6, 15, 18, 21, 22, 24, 30, 31, 36, 37
16.85 ± 30	$\frac{5}{2}$	110 ± 50	t, α	15
16.91		≈ 350	n, p, d, t, α	15, 22, 36, 37
(17.05)			p, t	15
17.11		broad	d, α	24
17.15 ± 50	$(\frac{1}{2}^+, \frac{3}{2}^+)$	250 ± 60	γ, t, α	5, 15, 48
17.23 ± 40		≈ 175	d, t, (α)	24, 28
17.37 ± 40		≈ 250	p, d, t, α	15, 22, 24, 36, 37
17.58 ± 40	$\frac{3}{2}^+$	450 ± 120	γ, d, t, α	15, 24, 37
17.67 ± 40	$\frac{3}{2}^+; \frac{1}{2}$	600 ± 80	γ, n, d, α	5, 21, 22, 24
17.72 ± 10		48 ± 10	n, (p), d, t, α	19, 22, 24, 37
17.95 ± 20		167	n, α	19, 20, 36, 37
18.06 ± 10		19 ± 4	(n), d, α	18, 22, 24
18.09 ± 20		≈ 40	(n), p, d, t	22, 24
18.22		158	n, α	36, 37
18.27 ± 20		235 ± 60	n, p, d, α	19, 22, 24, 37
18.70 ± 20				19, 25
18.91 ± 150	$\frac{3}{2}^+ + \frac{1}{2}^+$	750 ± 70	γ, α	5
19.20 ± 35	$(\frac{1}{2}^+; \frac{1}{2})$	≈ 130	n, d	19, 22
19.5	$\frac{3}{2}^+; (\frac{3}{2})$	≈ 400	γ, p, t	15, 30, 31

Table 15.4: Energy levels of ^{15}N [a] (continued)

E_x (MeV ± keV)	$J^\pi; T$	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
19.72 ± 40		[b]		18, 19
20.12 ± 50	$(T = \frac{3}{2})$			17, 48
20.5	$\frac{3}{2}^+$	≈ 400	γ, n, p, d	30
20.96 ± 65	$\frac{3}{2}^+ + \frac{1}{2}^+$	1740 ± 150	γ, α	5, 19
21.82		≈ 600	γ, p, d	21, 30, 45
23.19 ± 60	$(T = \frac{3}{2})$		γ, p	30, 48
23.8		broad	γ, d	21
24.75 ± 150		[b]		19
25.5	$\frac{3}{2}^-; (T = \frac{3}{2})$		γ, p	30
(26.8)			t	15
≈ 37			γ, p	30

[a] See also Tables 15.5, 15.6 and 15.13.

[b] Wide or unresolved.

1. (a) ^{9}Be(^{6}Li, p)^{14}C $\quad Q_m = 15.1244 \quad E_b = 25.3318$
   (b) ^{9}Be(^{6}Li, t)^{12}C $\quad Q_m = 10.4834$
   (c) ^{9}Be(^{6}Li, α)^{11}B $\quad Q_m = 14.3404$

The yield of p_0 and p_1 (reaction (a)) for $E(^6\text{Li}) = 3.84$ to 6.40 MeV shows some broad structure: analysis in terms of Ericson fluctuation theory gives a value of ≈ 0.4 MeV for the average level width at $E_x = 28$ MeV in ^{15}N. The excitation functions for t_0 (reaction (b)), α_0, α_1 and α_2 (reaction (c)) show broad structures for $E(^6\text{Li}) = 4$ to 14 MeV. See (1976AJ04) for the references.

2. ^{9}Be(^{9}Be, t)^{15}N $\quad Q_m = 7.6440$

See (1981AJ01).

3. ^{10}B(^{6}Li, p)^{15}N $\quad Q_m = 18.7459$

At $E(^6\text{Li}) = 4.9$ MeV, thirty proton groups are observed corrresponding to ^{15}N states with $E_x < 16.8$ MeV. Angular distributions have been measured for the proton groups corresponding to ^{15}N*($5.27 + 5.30$, 6.32, $7.16 + 7.30$, 7.57, 8.31, 8.57, $9.05 + 9.15$): see (1976AJ04).

Table 15.5: Radiative decays in ^{15}N [a]

E_i (MeV)	J^π_i	E_f (MeV)	J^π_f	Branch (%)	Mult. mixing ratio δ
5.27	$\frac{5}{2}^+$	0	$\frac{1}{2}^-$	100	-0.131 ± 0.013
5.30	$\frac{1}{2}^+$	0	$\frac{1}{2}^-$	100	
6.32 [b]	$\frac{3}{2}^-$	0	$\frac{1}{2}^-$	100	$+\,0.132 \pm 0.004$ [p]
7.16 [c]	$\frac{5}{2}^+$	5.27	$\frac{5}{2}^+$	100 ± 0.4	$-0.014^{+0.012}_{-0.015}$
7.30	$\frac{3}{2}^+$	0	$\frac{1}{2}^-$	99.3 ± 0.7	$-0.017^{+0.005}_{-0.008}$
		5.27	$\frac{5}{2}^+$	0.6 ± 0.1	$+0.18 \pm 0.15$, or $+2.5 \pm 1.0$
		5.30	$\frac{1}{2}^+$	0.2 ± 0.1	-0.31 ± 0.15, or $+4.6 \pm 3.4$
		6.32	$\frac{3}{2}^-$	< 0.25	
7.57 [d]	$\frac{7}{2}^+$	0	$\frac{1}{2}^-$	1.3 ± 0.6	
		5.27	$\frac{5}{2}^+$	98.7 ± 1.0	-0.028 ± 0.012
8.31	$\frac{1}{2}^+$	0	$\frac{1}{2}^-$	79 ± 2	
		5.27	$\frac{5}{2}^+$	< 3	
		5.30	$\frac{1}{2}^+$	10 ± 2	
		6.32	$\frac{3}{2}^-$	4.4 ± 1.0	
		7.16	$\frac{5}{2}^+$	1.2 ± 0.6	
		7.30	$\frac{3}{2}^+$	4.4 ± 0.7	
8.57 [e]	$\frac{3}{2}^+$	0	$\frac{1}{2}^-$	33 ± 2	$-0.085^{+0.005}_{-0.009}$
		5.27	$\frac{5}{2}^+$	65 ± 3	-0.091 ± 0.007
		6.32	$\frac{3}{2}^-$	1.4 ± 0.6	
		7.16	$\frac{5}{2}^+$	3.6 ± 0.5	
9.05 [f]	$\frac{1}{2}^+$	0	$\frac{1}{2}^-$	92 ± 3	
		5.27	$\frac{5}{2}^+$	3.5 ± 1	
		6.32	$\frac{3}{2}^-$	4.5 ± 1	
		7.30	$\frac{3}{2}^+$	1.2 ± 0.4	
9.152	$\frac{3}{2}^-$	0	$\frac{1}{2}^-$	100 ± 3	$+0.015^{+0.041}_{-0.034}$
9.155	$\frac{5}{2}^+$	0	$\frac{1}{2}^-$	< 2	
		5.27	$\frac{5}{2}^+$	11 ± 1	
		5.30	$\frac{1}{2}^+$	10 ± 1	
		6.32	$\frac{3}{2}^-$	22 ± 2	
		7.16	$\frac{5}{2}^+$	57 ± 3	
9.23 [g]	$\frac{1}{2}^-$	0	$\frac{1}{2}^-$	22 ± 5	

Table 15.5: Radiative decays in ^{15}N [a] (continued)

E_i (MeV)	J_i^π	E_f (MeV)	J_f^π	Branch (%)	Mult. mixing ratio δ
		5.30	$\frac{1}{2}^+$	42 ± 8	
		6.32	$\frac{3}{2}^-$	35 ± 6	
		7.30	$\frac{3}{2}^+$	2.6 ± 0.7	
9.76 [h]	$\frac{5}{2}^-$	0	$\frac{1}{2}^-$	81.5 ± 2.8	
		$5.27 + 5.30$		7.5 ± 1.5	
		6.32	$\frac{3}{2}^-$	3.7 ± 0.8	
		7.16	$\frac{5}{2}^+$	2.3 ± 0.5	
		7.57	$\frac{7}{2}^+$	5.0 ± 0.6	
9.83 [i]	$\frac{7}{2}^-$	5.27	$\frac{5}{2}^+$	≈ 85	
		6.32	$\frac{3}{2}^-$	2.2 ± 0.9	
		7.16	$\frac{5}{2}^+$	2.4 ± 1.1	
		7.30	$\frac{3}{2}^+$	3.7 ± 0.9	
		7.57	$\frac{7}{2}^+$	7.3 ± 1.0	
9.93 [j]	$\frac{3}{2}^-$	0	$\frac{1}{2}^-$	77.6 ± 1.9	
		$5.27 + 5.30$		15.4 ± 1.5	
		6.32	$\frac{3}{2}^-$	4.9 ± 1.2	
		7.30	$\frac{3}{2}^+$	2.1 ± 0.8	
10.07 [k]	$\frac{3}{2}^+$	0	$\frac{1}{2}^-$	96.0 ± 0.7	
		$5.27 + 5.30$		4.0 ± 0.7	
10.45 [l]	$\frac{5}{2}^-$	5.27	$\frac{5}{2}^+$	55.0 ± 0.8	$+0.021 \pm 0.033$
		6.32	$\frac{3}{2}^-$	31.3 ± 1.7	-0.59 ± 0.13
		7.16	$\frac{5}{2}^+$	5.2 ± 0.1	$+0.13^{+0.03}_{-0.04}$
		8.57	$\frac{3}{2}^+$	3.8 ± 0.6	-0.3 ± 0.4
		9.152	$\frac{3}{2}^-$	4.7 ± 0.1	$-0.32^{+0.09}_{-0.10}$
10.53	$\frac{5}{2}^+$	0	$\frac{1}{2}^-$	< 0.1	
		5.27	$\frac{5}{2}^+$	38.7 ± 0.2	-0.27 ± 0.03
		6.32	$\frac{3}{2}^-$	7.7 ± 0.1	-0.028 ± 0.004
		7.16	$\frac{5}{2}^+$	19.4 ± 0.2	$+0.007^{+0.010}_{-0.008}$
		7.30	$\frac{3}{2}^+$	31.4 ± 0.5	$+0.066 \pm 0.005$
		8.57	$\frac{3}{2}^+$	2.4 ± 0.1	$+0.012^{+0.006}_{-0.005}$
		9.152	$\frac{3}{2}^-$	0.3 ± 0.1	$-0.20^{+0.03}_{-0.02}$

Table 15.5: Radiative decays in ^{15}N [a] (continued)

E_i (MeV)	J_i^π	E_f (MeV)	J_f^π	Branch (%)	Mult. mixing ratio δ
10.69	$\frac{9}{2}^+$	5.27	$\frac{5}{2}^+$	61.6 ± 0.3	
		7.16	$\frac{5}{2}^+$	2.1 ± 0.1	-0.03 ± 0.07
		7.57	$\frac{7}{2}^+$	36.3 ± 0.6	$+0.118 \pm 0.008$
10.70	$\frac{3}{2}^-$	0	$\frac{1}{2}^-$	52.6 ± 0.8	$+0.180^{+0.006}_{-0.002}$
		5.27	$\frac{5}{2}^+$	37.4 ± 0.6	$-0.24^{+0.004}_{-0.008}$
		5.30	$\frac{1}{2}^+$	0.8 ± 0.1	-0.13 ± 0.07
		6.32	$\frac{3}{2}^-$	3.8 ± 0.1	$+0.135 \pm 0.015$
		7.16	$\frac{5}{2}^+$	0.4 ± 0.1	0.3 ± 0.3
		7.30	$\frac{3}{2}^+$	2.3 ± 0.1	-0.027 ± 0.023
		8.31	$\frac{1}{2}^+$	0.8 ± 0.1	$-0.017^{+0.018}_{-0.016}$
		9.05	$\frac{1}{2}^+$	0.2 ± 0.1	-0.007 ± 0.12
		9.152	$\frac{3}{2}^-$	0.2 ± 0.1	-0.11 ± 0.03
		9.23	$\frac{1}{2}^-$	1.5 ± 0.1	$+0.049^{+0.006}_{-0.005}$
10.80 [m]	$\frac{3}{2}^+$	0	$\frac{1}{2}^-$	51.5 ± 0.4	-0.02 ± 0.01
		5.27	$\frac{5}{2}^+$	4.9 ± 0.1	-0.63 ± 0.04
		5.30	$\frac{1}{2}^+$	15.5 ± 0.2	-0.55 ± 0.02
		6.32	$\frac{3}{2}^-$	5.4 ± 0.2	-0.07 ± 0.05
		7.16	$\frac{5}{2}^+$	7.8 ± 0.1	$+0.14 \pm 0.03$
		7.30	$\frac{3}{2}^+$	5.8 ± 0.1	-0.12 ± 0.02
		8.31	$\frac{1}{2}^+$	3.6 ± 0.1	$+0.12 \pm 0.03$
		9.05	$\frac{1}{2}^+$	0.3 ± 0.1	
		9.152	$\frac{3}{2}^-$	0.9 ± 0.1	
		9.155	$\frac{5}{2}$	4.2 ± 0.1	
11.62 [n]	$\frac{1}{2}^+; T = \frac{3}{2}$	0	$\frac{1}{2}^-$	90.7 ± 3.0	
		5.27	$\frac{5}{2}^+$	< 1	
		5.30	$\frac{1}{2}^+$	7.4 ± 1.5	
		6.32	$\frac{3}{2}^-$	1.9 ± 1.5	
12.52	$\frac{5}{2}^+; T = \frac{3}{2}$	0	$\frac{1}{2}^-$	< 1	
		5.27	$\frac{5}{2}^+$	94.2 ± 0.6	-0.02 ± 0.04
		5.30	$\frac{1}{2}^+$	< 1	
		6.32	$\frac{3}{2}^-$	5.8 ± 0.6	-0.02 ± 0.04

Table 15.5: Radiative decays in ^{15}N [a] (continued)

E_i (MeV)	J^π_i	E_f (MeV)	J^π_f	Branch (%)	Mult. mixing ratio δ
13.39 [o]	$\frac{3}{2}^+$	0	$\frac{1}{2}^-$	100	

[a] See also Tables 15.6, 15.13 and 15.16. For references see Table 15.4 in (1981AJ01). Please note that (1976BE1B) is an unpublished Ph.D. thesis.
[b] Transitions to ^{15}N*(5.27, 5.30) are < 0.1% and < 0.05%, respectively (1975MO28).
[c] Transitions to ^{15}N*(0, 5.30, 6.32) are < 0.1%, < 4% and < 0.5%.
[d] Transitions to ^{15}N*(5.30, 6.32) are < 4% and < 0.6%.
[e] Transitions to ^{15}N*(5.30, 7.30, 7.57) are < 12%, < 0.7% and < 3%.
[f] Transitions to ^{15}N*(7.16, 7.57, 8.31) are < 10%, < 2% and < 0.5%.
[g] Transitions to ^{15}N*(7.16, 7.57, 8.31) are < 1%, < 20% and < 5%.
[h] Transitions to ^{15}N*(7.30, 8.31, 8.57) are < 2%, < 1% and < 2%.
[i] Transitions to ^{15}N*(0, 5.30) are < 4% and < 15%.
[j] Transitions to ^{15}N*(7.16, 7.57, 8.31, 8.57) are each < 1%.
[k] For upper limits for transitions to other states see Table 15.4 (1981AJ01).
[l] Transitions to ^{15}N*(0, 5.30, 9.83) are < 12%, < 2% and < 0.1%.
[m] π is $+$ because if π were – the Γ_γ and δ of the $10.80 \rightarrow 5.30$ MeV transition would lead to an unacceptably high M2 value (33 W.u.) (P.M. Endt, private communication).
[n] See footnote [g] in Table 15.4 (1981AJ01).
[o] $\Gamma_{\gamma_0} = 3.0\pm0.9$ eV, $\Gamma_p\Gamma_{\gamma_0}/\Gamma = 1.70\pm0.5$ eV; $\delta = 0.00\pm0.04$ (M2/E1); B(E1) $= (1.2\pm0.4)\times10^{-3}\,e^2\cdot$fm^2. Transitions to ^{15}N*(5.27, 5.30) < 8% and to ^{15}N*(6.32, 7.16, 7.30) < 5%.
[p] Weighted mean of all measurements (E.K. Warburton, private communication).

4. ^{10}B(^{7}Li, d)^{15}N $Q_m = 13.7203$

At $E(^7\text{Li}) = 24$ MeV angular distributions have been studied to many of the ^{15}N states with $E_x < 15.5$ MeV: see (1981AJ01).

5. ^{11}B(α, γ)^{15}N $Q_m = 10.9914$

The 90° differential cross section for γ_0 production has been measured for $E_\alpha = 5.74$ to 18.0 MeV [see (1981AJ01)] and for 6.89 to 8.0 and 12.8 to 15 MeV (1984DE09). For the observed resonances see Table 15.7. See also (1982DU1A; theor.).

6. ^{11}B(α, n)^{14}N $Q_m = 0.1581$ $E_b = 10.9914$

Table 15.6: Lifetimes of some ^{15}N states [a]

E_x (MeV)	τ_m	Reaction
5.27	2.47 ± 0.24 psec	^{1}H(^{18}O, α) [b]
	2.58 ± 0.14 psec	mean
5.30	25 ± 7 fsec	mean
6.32	0.211 ± 0.012 fsec	^{15}N(γ, γ) [c]
7.16	18 ± 8 fsec	mean
7.30	0.61 ± 0.05 fsec	^{15}N(γ, γ) [c]
7.57	12^{+11}_{-6} fsec	^{12}C(^{7}Li, α)
	60 ± 20 fsec	^{14}N(d, p)
8.31	1.7 ± 1.1 fsec	^{15}N(γ, γ) [c]
8.57	11 ± 7 fsec	^{12}C(^{7}Li, α)
	0.7 ± 0.7 fsec	^{15}N(γ, γ) [c]
9.05	0.50 ± 0.08 fsec	^{15}N(γ, γ) [c]
9.152	1.40 ± 0.36 fsec	^{15}N(γ, γ) [c]
9.155	7^{+6}_{-3} fsec	^{12}C(^{7}Li, α)
9.23	< 130 fsec	^{13}C(^{3}He, p)
9.76	2.6 ± 0.9 fsec	^{15}N(γ, γ) [c]
9.83	17 ± 7 fsec	^{12}C(^{7}Li, α)
9.93	0.31 ± 0.05 fsec	^{15}N(γ, γ) [c]
10.07	0.100 ± 0.006 fsec	^{15}N(γ, γ) [c]
10.69	18 ± 9 fsec	^{12}C(^{7}Li, α)

[a] See also Tables 15.12 and 15.16 for other states. See Table 15.5 in (1981AJ01) for references.

[b] (1983BI10).

[c] (1981MO09). See also Table 15.5 in (1981AJ01).

Table 15.7: Resonances in ^{11}B(α, γ_0)^{15}N [a]

E_α (MeV)	E_x (MeV)	$\Gamma_{c.m.}$ (keV)	Γ_γ [b] (eV)	J^π
7.20	16.27 ± 0.04	240 ± 30	≥ 11	$\frac{3}{2}^+$
7.70	16.64 ± 0.04	250 ± 30	≥ 11	$\frac{1}{2}^+$
8.40 [b,c]	17.15 ± 0.05	250 ± 60	≥ 2	$(\frac{1}{2}^+, \frac{3}{2}^+)$
9.11 [b,c]	17.67 ± 0.05	600 ± 80	≥ 7	$\frac{3}{2}^+$
10.80 [d]	18.91 ± 0.15	750 ± 70		$\frac{3}{2}^+ + \frac{1}{2}^+$
14.00 [d]	21.25 ± 0.15	1740 ± 150		$\frac{3}{2}^+ + \frac{1}{2}^+$

[a] (1984DE09) [also angular distributions]. See also Table 15.6 in (1981AJ01).

[b] (1978DE23).

[c] These E_α may be 100 keV too high: see (1984DE09).

[d] There is indication of M1/E2 transitions interfering with the predominant E1 transitions.

Reported resonances are displayed in Table 15.8. For thick-target yields ($E_\alpha = 3.5$ to 7.5 MeV) see (1979BA48).

7. ^{11}B(α, p)^{14}C $\quad Q_m = 0.7840 \quad E_b = 10.9914$

Reported resonances are listed in Table 15.8. The yield curve for ^{14}C is dominated by two strong resonances at $E_\alpha = 1.57$ and 2.64 MeV. At higher energies (to 25 MeV) the p_0 excitation functions show broad features. See (1981AJ01).

8. (a) ^{11}B(α, d)^{13}C $\quad Q_m = -5.1679 \quad E_b = 10.9914$
(b) ^{11}B(α, t)^{12}C $\quad Q_m = -3.8570$

Table 15.8: Resonances in ^{11}B + α [a]

E_α (MeV $\pm$ keV)	$\Gamma_{c.m.}$ (keV)	Particle out	J^π	E_x (MeV)
0.60		n		11.43
1.03		n		11.75
1.18		n		11.86
1.30		n		11.94

Table 15.8: Resonances in ^{11}B + α [a] (continued)

E_α (MeV $\pm$ keV)	$\Gamma_{\text{c.m.}}$ (keV)	Particle out	J^π	E_x (MeV)
1.51		n, p	$(\frac{5}{2}^+)$	12.10
1.58	41 ± 5	n, p	$(\frac{3}{2}^-)$	12.15
2.056 ± 10	34 ± 5	n_0, p_0	$\frac{5}{2}^+$	12.499
2.610 ± 13	56 ± 11	n_0, p_0, α	$\frac{3}{2}^-$	12.905
2.66 ± 30	81	p_0, α	$\frac{5}{2}^+$	12.94
2.942 ± 10	7 ± 3	n_0, p_0		13.149
2.984 ± 10	7 ± 3	n_0, p_0		13.180
3.239 ± 15	16 ± 8	n_0, p, α	$\frac{3}{2}^-$	13.366
3.31 ± 30	61	p, α	$\frac{3}{2}^+$	13.42
3.46 ± 30	85 ± 30	n_0, α	$\frac{3}{2}^-$	13.53
3.560 ± 10	18 ± 4	n_0, p	$(\frac{5}{2}, \frac{7}{2})^-$	13.602
3.57 ± 30	94	α	$\frac{1}{2}^+$	13.61
3.712 ± 10	26 ± 8	n_0		13.713
(3.78 ± 30)	70	α	$(\frac{1}{2}^+)$	(13.76)
3.89 ± 30	≈ 70	n_1, α	$(\frac{3}{2}^+)$	13.84
4.09 ± 30	≈ 100	n_1		13.99
4.232 ± 10	22 ± 6	n_0		14.094
4.24 ± 30	≈ 100	n_1, α	$\frac{3}{2}^+$	14.10
4.324 ± 10	27 ± 6	n_0		14.162
4.43 ± 40	150	α	$\frac{5}{2}^+$	14.24
4.62 ± 40	100	α	$\frac{7}{2}^+$	14.38
4.85 ± 20	200 ± 50	n_0		14.55
4.986 ± 10	33 ± 6	n_0		14.647
5.11 ± 30	110 ± 50	n_0		14.74
5.28 ± 20	48 ± 11	n_0, α		14.86
5.538 ± 10	12 ± 3	n_0		14.920
5.501 ± 10	13 ± 3	n_0		15.025
5.59 ± 20	80 ± 25	n_0, α		15.09
5.860 ± 10	22 ± 6	n_0, α		15.288
5.98 ± 20	75 ± 25	n_2, (α)		15.38
6.06 ± 20	≈ 100	n_0, (α)		15.43

Table 15.8: Resonances in ^{11}B + α [a] (continued)

E_α (MeV $\pm$ keV)	$\Gamma_{c.m.}$ (keV)	Particle out	J^π	E_x (MeV)
6.19 ± 20	≈ 35	n_0		15.53
6.29 ± 20	95 ± 25	n_2		15.60
(6.65 ± 40)		(α)		(15.87)
6.73 ± 20	35 ± 10	n_0, n_2		15.93
6.755 ± 15	21 ± 6	n_1		15.944
6.83 ± 20	60 ± 20	n_2		16.00
6.884 ± 15	62 ± 12	n_0, α		16.039
(6.98 ± 40)		(α)		(16.11)
7.18 ± 20	≈ 100	n_0, α		16.26
7.27 ± 20	≈ 30	n_0		16.32
7.37 ± 20	44 ± 11	n_2		16.39
7.616 ± 15	27 ± 15	n_0, (n_2)		16.576
7.754 ± 15	60 ± 10	n_0, (n_2)		16.677

[a] For references see Table 15.7 in (1981AJ01).

The yield of d_0 has been measured for $E_\alpha = 13.5$ to 25 MeV. The exciation functions for t_0 and t_1 (to 25 MeV) show strong uncorrelated structures. See (1976AJ04, 1981AJ01).

9. ^{11}B(α, α)^{11}B $\qquad E_b = 10.9914$

Observed resonances for $E_\alpha = 2.1$ to 7.9 MeV are shown in Table 15.8.

10. ^{11}B(^{6}Li, d)^{15}N $\qquad Q_m = 9.5163$

At $E(^6\text{Li}) = 34$ MeV angular distributions are reported to the states with $5.3 < E_x < 16.3$ MeV: this reaction appears to be less selective than reaction 11. The most strongly populated states are ^{15}N*(9.2, 10.5, 10.7, 13.1, 14.8, 15.5). See (1981AJ01).

11. ^{11}B(^{7}Li, t)^{15}N $\qquad Q_m = 8.5234$

At $E(^7\text{Li}) = 24$ and 34 MeV, angular distributions to states with $5.3 < E_x < 15.6$ MeV have been measured: ^{15}N*(9.8, 10.5, 10.7, 15.4, 15.5) are patricularly strongly populated at 34 MeV. $J^\pi = \frac{9}{2}^+, \frac{9}{2}, \frac{11}{2}, \frac{9}{2}, \frac{11}{2}, \frac{13}{2}, \frac{15}{2}$ are suggested for ^{15}N*(10.69, 12.56, 13.03, 13.19, 13.84, 14.11, 15.37). Only ^{15}N*(15.52) appears to have a large cluster component corresponding to $^{11}\text{B} + \alpha$. See (1981AJ01). The γ-decay of ^{15}N states populated in this reaction has been studied by (1979HA38): see Tables 15.5 and 15.6.

12. ^{11}B(^{9}Be, ^{5}He)^{15}N $\qquad Q_m = 8.524$

See (1984DA17) for cross sections and S-factors.

13. ^{11}B(^{11}B, ^{7}Li)^{15}N $\qquad Q_m = 2.3277$

See (1976AJ04).

14. ^{11}B(^{16}O, ^{12}C)^{15}N $\qquad Q_m = 3.8295$

Angular distributions have been measured at $E(^{16}\text{O}) = 27$ to 60 MeV involving the two proton-hole states of ^{15}N[^{15}N*(0, 6.32); $J^\pi = \frac{1}{2}^-, \frac{3}{2}^-$] and ^{12}C*(0, 4.4, 9.6): see (1976AJ04). See also (1983EL01; theor.).

15. (a) ^{12}C(t, γ)^{15}N $\qquad Q_m = 14.8484$
(b) ^{12}C(t, n)^{14}N $\qquad Q_m = 4.01511$ $\qquad E_b = 14.8484$
(c) ^{12}C(t, p)^{14}C $\qquad Q_m = 4.6410$
(d) ^{12}C(t, t)^{12}C
(e) ^{12}C(t, α)^{11}B $\qquad Q_m = 3.8570$

The 90° excitation function for γ_0 in the range 1.0 to 6.5 MeV [see (1981AJ01) and (1983DR13; polarized tritons and γ-rays; $E_{\vec{t}} = 2.3$ to 6.5 MeV)] shows one very strong resonance (at peak, 4.4 ± 0.5 μb/sr) corresponding to ^{15}N*(16.7) as well as two other strong (unresolved and/or broad resonances) at $E_t \approx 3.3$ and 6 MeV: Table 15.9 shows the derived parameters. Table 15.9 also displays the structures observed in reactions (b) $\rightarrow$ (e). At $E_{\vec{t}} = 17$ MeV the polarization and analyzing power for the transition to $^{14}\text{C}_{\text{g.s.}}$ (reaction (c)) are shown to be the same as required by the conservation of parity (1982HA06). The VAP for the elastic scattering (reaction (d)) has been measured at $E_{\vec{t}} = 9$ and 11 MeV (1984FI01). See (1981AJ01) for the earlier work. See also (1984SAZP, 1984SL04; theor.).

Table 15.9: Resonances in $^{12}C + t$ [a]

E_t (MeV ± keV)	E_x (MeV)	Particles out	J^π	Γ (keV)
0.66	15.38	α_0		
1.11	15.74	p_0, t_0, α_1		
1.21	15.82	t_0		
1.30 ± 20	15.89	n, α_0		
1.39 ± 20	15.96	n, t_0, α_0		
1.46	16.02	p_0		
1.54	16.08	n, α_0, α_1		
1.64 ± 40	16.16	γ_0, n, α_0	$\frac{3}{2}^+$	450 ± 100
1.78	16.27	α_0		
1.85 ± 20	16.33	n, p_0, α_0, α_1		
1.98 ± 20	16.43	n, p_0		
2.05 ± 30	16.49	p_0, t_0, α_0		
2.18 ± 25	16.59	γ_0, n, p_0, t_0, α_0, α_1	$\frac{3}{2}^-$	490
2.30	16.69 ± 0.01	γ_0, n, p_0, α_0, α_1	$\frac{3}{2}^+$	130 ± 15
2.39 ± 30	16.76	n, t_0, α_0, α_1		
2.50 ± 30	16.85	α_0, α_1		
2.60	16.93	α_0		
2.75	17.05	p_0		
2.82	17.10	γ_0, t_0, α_0, α_1	$\frac{3}{2}^-$	
2.89 ± 50	17.16	α_0		
3.14	17.36	α_1		
3.30	17.49 ± 0.09	γ_0	$\frac{3}{2}^+$	450 ± 120
≈ 6 [b]	19.6	γ_0		
15.0	26.8	t_0		

[a] For references see Tables 15.8 in (1976AJ04, 1981AJ01).

[b] (1983DR13); broad and/or unresolved state(s); E_t estimated by reviewer.

16. ^{12}C(^{3}He, π^{+})^{15}N $\qquad Q_{\rm m} - 124.7375$

See (1984BI08; E(^{3}He) $= 235$ MeV).

17. ^{12}C(α, p)^{15}N $\qquad Q_{\rm m} = -4.9656$

Angular distributions have been measured at many energies for $E_\alpha = 13.4$ to 96.8 MeV [see (1976AJ04, 1981AJ01)] and at $E_\alpha = 18.5$, 21.7 and 25.4 MeV (1981BE19; p$_0$) and 34.9 MeV (1983HA32). See also (1982AM02) in ^{16}O (1982AJ01, 1986AJ04). At $E_\alpha = 34.9$ MeV angular distributions are reported to ^{15}N*(0, 5.3, 6.3, 7.1, 7.3, 7.6, 8.6, 9.2, 9.8, 10.7, 11.2, 11.9, 12.6, 13.0, 13.2, 14.1, 15.3, 15.4, 20.15 ± 0.10). Those to the states with high spin ^{15}N*(10.7, 11.9, 12.6, 13.0, 13.2, 15.3, 15.4) have been analyzed with DWBA, the predictions depending strongly on the choice of the α-particle optical potential (1983HA32). See also Table 15.9 in (1981AJ01), (1984GA11) and (1981KA04, 1983PI03; theor.).

18. ^{12}C(^{6}Li, ^{3}He)^{15}N $\qquad Q_{\rm m} = -0.9472$

Observed ^{3}He groups are displayed in Table 15.9 of (1981AJ01). Comparisons of the angular distributions obtained in this reaction at E(^{6}Li) $= 60.1$ MeV and in the (^{6}Li, t) reaction shows analog correspondence for the following pairs of levels: $5.27 - 5.24$, $7.16 - 6.86$, $7.57 - 7.28$, $8.57 - 8.28$, $10.80 - 10.48$, 13.15(u)–12.84, 15.49(u)–15.05 [first listed is $E_{\rm x}$ in ^{15}N, second in ^{15}O]. [$E_{\rm x}$ are nominal; u $=$ unresolved.] For γ-decay measurements see Table 15.5. See also (1976AJ04) and (1983PI03; theor.).

19. ^{12}C(^{7}Li, α)^{15}N $\qquad Q_{\rm m} = 12.3804$

Observed α-groups are shown in Table 15.10. Angular distributions have been measured to E(^{7}Li) $= 48$ MeV. Comparison of spectra from this reaction (E(^{7}Li) $= 34.9$ MeV) with those from ^{13}C(^{6}Li, α) (reaction 27) lead to configurations of (d)^{3} for ^{15}N*(10.7, 12.57, 13.20, 15.42) and suggest that ^{15}N*(12.57, 13.20) have lower J than ^{15}N*(10.7, 15.5), probably $J \leq \frac{7}{2}$. ^{15}N*(13.02) is shown to be p(d)^{2} in agreement with $J^\pi = \frac{11}{2}^-$: see (1981AJ01).

^{15}N*(9.155) [$J^\pi = \frac{5}{2}$] decays to ^{15}N*(5.30)[$J^\pi = \frac{1}{2}^+$] by an E2 transition; therefore its parity is positive. It has a large triton cluster parentage. This is not true of ^{15}N*(9.152): see (1981AJ01). For γ-decay measurements see Table 15.5. For $\tau_{\rm m}$ measurements see Table 15.6. See also (1983PI03; theor.).

Table 15.10: States of ^{15}N from ^{12}C(^{7}Li, α)

E_x (MeV $\pm$ keV)		E_x (MeV $\pm$ keV)	
(1973TS02) [a]	(1980ZE02) [b]	(1973TS02) [a]	(1980ZE02) [b]
0		12.923	
5.295	5.284	13.004 [a]	13.001
6.332	6.323	13.173 [a]	13.178
7.163	7.157	13.614	
7.310	7.299	14.087	14.097
7.566	7.574	14.720	14.693
8.320			14.874
8.580 [a]	8.574	15.021	15.024
9.163 [a]	9.159	15.373	15.379
9.828 [a]	9.809	15.782	15.778
9.932	9.921	16.026	16.032
10.072	10.075	16.190	16.210
10.524	10.518		17.735
10.700 [a]	10.714		17.949 [b]
10.808			18.272
	11.274		18.698 [b]
11.430	11.456		19.27 ± 40
11.951	11.936		19.68 ± 50 [b,d]
12.320 [a]	12.328		20.93 ± 50 [b,d]
12.559 [a,c]	12.551		24.75 ± 150 [b,d]

[a] $E(^7\text{Li}) = 35$ MeV; angular distributions have been measured for the states labelled by this footnote; $E_x \pm 10$ keV.

[b] $E(^7\text{Li}) = 48$ MeV; angular distributions have been measured for the states labelled by this footnote; $E_x \pm 20$ keV unless otherwise shown.

[c] (1973TS02) suggests that this state is not the $T = \frac{3}{2}$ state at 12.52 MeV.

[d] Wide or unresolved.

20. (a) ^{12}C(^{10}B, ^{7}Be)^{15}N $\quad Q_{\rm m} = -3.8194$

(b) ^{12}C(^{11}B, ^{8}Be)^{15}N $\quad Q_{\rm m} = 3.6248$

See (1981AJ01). See also (1983DEZW).

21. ^{13}C(d, γ)^{15}N $\quad Q_{\rm m} = 16.1593$

The $90° - 95°$ yields of γ_0 have been measured for $E_{\rm d} = 1$ to 10 MeV: observed resonances are displayed in Table 15.11. The γ-ray angular distributions are consistent with the emission of predominantly E1 radiation except for evidence of M1/E2 transitions in the region $E_{\rm x} = 20 - 21.5$ MeV: see (1981AJ01).

22. (a) ^{13}C(d, n)^{14}N $\quad Q_{\rm m} = 5.3260 \quad E_{\rm b} = 16.1593$

(b) ^{13}C(d, p)^{14}C $\quad Q_{\rm m} = 5.9519$

Observed resonances are displayed in Table 15.11. Polarization measurements have been carried out at $E_{\vec{\rm d}} = 12.3$ MeV (1983LIZW) for reaction (a) and at $E_{\vec{\rm d}} = 13$ MeV [see (1981AJ01)] and 56 MeV (1984HA26; $\rm p_0$) for reaction (b).

23. ^{13}C(d, d)^{13}C $\quad E_{\rm b} = 16.1593$

Excitation functions for elastically scattered deuterons have been measured in the range $E_{\rm d} = 0.4$ to 5.7 MeV: see (1976AJ04). Polarization studies are reported for $E_{\rm d} = 12.5$ to 15 MeV [see (1981AJ01)] and at $E_{\vec{\rm d}} = 56$ MeV (1984HA26; $\rm d_0$). See also (1980BO31; 3.1 GeV).

24. (a) ^{13}C(d, t)^{12}C $\quad Q_{\rm m} = 1.3109 \quad E_{\rm b} = 16.1593$

(b) ^{13}C(d, ^{3}He)^{12}B $\quad Q_{\rm m} = -12.040$

(c) ^{13}C(d, α)^{11}B $\quad Q_{\rm m} = 5.1679$

Observed resonances are listed in Table 15.11. For polarization measurements to $E_{\vec{\rm d}} = 29$ MeV [reactions (a, b)] see (1981AJ01).

25. ^{13}C(^{3}He, p)^{15}N $\quad Q_{\rm m} = 10.6658$

Table 15.11: Resonances in ^{13}C + d [a]

E_d (MeV)	Particles out	Γ_{lab} (keV)	^{15}N* (MeV)
0.37	p		16.48
0.64	n, p_0, t_0	≈ 100	16.71
0.85	n, p_0	≈ 400	16.90
1.10	α_0	broad	17.11
1.24 ± 0.04	t_0, (α_0)	≈ 200	17.23
1.40 ± 0.04	p_0, t_0, α_0	≈ 400	17.37
1.64 ± 0.04	t_0	≈ 200	17.58
1.74 ± 0.04	γ_0, n, α_0	≈ 600	17.67 [b]
1.80 ± 0.01	(p_0), t_0, α_1	55 ± 10	17.72
2.20 ± 0.01	(n), α_0, α_1	22 ± 4	18.06
2.23 ± 0.02	(n), p_0, t	≈ 50	18.09
2.45 ± 0.03	n, p_0, α_0	270 ± 70	18.28
3.46 ± 0.03	n	≈ 150	19.16
5.1	n_1, p_0	≈ 50	20.6
6.65	γ_0	≈ 700	21.92
8.8	γ_0	broad	23.8

[a] See references listed in Tables 15.10 (1976AJ04, 1981AJ01).
[b] $J^\pi = \frac{1}{2}^-$ or $\frac{3}{2}^+$; $T = \frac{1}{2}$.

Observed proton groups and γ-rays are listed in Table 15.11 of (1981AJ01). Gamma-ray branching ratios are displayed in Table 15.5 and τ_m in Table 15.6. Angular distributions have been reported for $E(^3\text{He}) = 4.37$ to 20 MeV: see (1981AJ01). The g-factor for ^{15}N*(5.27)[$J^\pi = \frac{5}{2}^+$] is $+(0.9 \pm 0.3)$. See also ^{16}O in (1982AJ01) and (1976AJ04).

26. ^{13}C(α, d)^{15}N $\qquad Q_m = -7.6874$

At $E_\alpha = 34.9$ MeV a ZRDWBA analysis has been made of the angular distributions to ^{15}N*(5.27, 5.30, 7.16, 7.30, 7.56, 8.31, 8.57, 9.05, 9.15, 10.07, 10.53, 10.69, 11.43, 11.94, 12.10, 12.33, 12.49, 12.56, 13.00, 13.83, 14.08). $L = 0$ for the group(s) to ^{15}N*(9.15, 10.69); $L = 2$ for ^{15}N*(12.56); $L = 3$ for ^{15}N*(5.27, 7.16, 7.56); $L = 4$ for ^{15}N*(11.94, 13.00); $L = 1$ fopr the remaining transitions (1984YA03). See also Table 15.11 of (1976AJ04).

27. ^{13}C(^{6}Li, α)^{15}N $\qquad Q_m = 14.6842$

Angular distributions have been measured at $E(^{6}\text{Li}) = 32$ MeV to ^{15}N*(0, 5.30, 6.32, 7.16, 7.30, 7.57, 8.31, 8.57, 9.15, 9.23, 9.83, 10.07, 10.70, 11.94, 13.00): the results are consistent with the previously known J^{π}, with (odd) parity for ^{15}N*(9.83) and with $J^{\pi} = \frac{9}{2}^{-}$ for ^{15}N*(11.94): see (1981AJ01).

28. (a) ^{13}C(^{10}B, ^{8}Be)^{15}N $\qquad Q_m = 10.1326$
(b) ^{13}C(^{11}B, ^{9}Be)^{15}N $\qquad Q_m = 0.3438$

For reaction (a) see (1983DEZW). At $E(^{11}\text{B}) = 114$ MeV the dominant group is ^{15}N*(13.00): see (1981AJ01).

29. ^{13}C(^{17}O, ^{15}N)^{15}N $\qquad Q_m = 2.1127$

See (1981AJ01).

30. ^{14}C(p, γ)^{15}N $\qquad Q_m = 10.2074$

Observed resonances are displayed in Table 15.12; the branching ratios are shown in Table 15.5. Narrow anomalies (in the γ_0 yield for $E_p = 2.8$ to 30 MeV) are reported at $E_p = 10.0$, 11.0, 12.35, 13.6, 16.4 MeV. A good fit to the total cross section ($E_{\vec{p}} = 7.5$ to 19 MeV) is obtained with the GDR split into peaks at $E_x = 21.0$ and 25.5 MeV with $\Gamma = 6$ and 2 MeV, respectively. The integrated E2 cross section for $E_x = 19.5$ to 27.0 MeV is (6.8 ± 1.4)% of the isoscalar sum rule. The reaction thus shows no sign of a collective E2 resonance in that E_x region. [Another study shows no appreciable E2 strength concentration for $E_x = 14.3$ to 23.3 MeV.] Above the GDR region the $90°$ γ_0 cross section decreases smoothly with energy except for a small peak which would correspond to ^{15}N*(37.). See (1981AJ01) for the references. See also (1984WA07) and (1980WE1D, 1982WE01).

31. (a) ^{14}C(p, n)^{14}N $\qquad Q_m = -0.6259 \qquad E_b = 10.2074$
(b) ^{14}C(p, p)^{14}C
(c) ^{14}C(p, α)^{11}B $\qquad Q_m = -0.7840$

Table 15.12: Resonances in ^{14}C + p [a]

E_p (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	Γ_n (keV)	Γ_p (keV)	Γ_α (keV)	Γ_γ (eV)	J^π	E_x (MeV ± keV)
0.261 ± 0.6	< 0.5		$(0.08 \pm 0.01) \times 10^{-6}$		> 21 meV	$\frac{5}{2}^-$	10.4497 ± 0.3 [d]
0.352 ± 1					$(3.4 \pm 0.4) \times 10^{-2}$ [b]	$\frac{5}{2}^+$	10.5333 ± 0.5 [d]
0.519 ± 1			$(0.49 \pm 0.10) \times 10^{-6}$		> 40 meV	$\frac{9}{2}^+$	10.6932 ± 0.3 [d]
0.527 ± 1			0.2		0.37 ± 0.07	$\frac{3}{2}^-$	10.7019 ± 0.3 [d]
0.634 ± 1			$(0.22 \pm 0.10) \times 10^{-3}$		0.27 ± 0.14	$\frac{3}{2}^{(+)}$	10.804 ± 2 [d]
1.162 ± 2	7.9 ± 3	2.3	5.6	< 0.3	0.29 [c]	$\frac{1}{2}^-$	11.291
1.3188 ± 0.5	41.4 ± 1.1	34.6 ± 0.9	6.8 ± 0.5	< 0.3	4.2 ± 0.7 [c]	$\frac{1}{2}^+$	11.4376
1.509 ± 4	404.9 ± 6.3	4.0 ± 0.2	400.9 ± 6.3	< 0.3	19.2 ± 0.4 [c]	$\frac{1}{2}^+; T = \frac{3}{2}$	11.615
1.688 ± 3	37	36.5	0.5	< 0.3		$\frac{3}{2}^+$	11.782
1.788 ± 3	24.5	24.5	0.03	< 0.3		$\frac{3}{2}^-, (\frac{5}{2}^-)$	11.875
1.884 ± 3	21.5	21.2	0.3	< 0.3		$\frac{1}{2}^-$	11.965
2.025 ± 4	14 ± 5	12.0	1.7	0.6		$\frac{5}{2}^+$	12.096
2.077 ± 3	47 ± 7	30.2	16.6	2.2		$\frac{3}{2}^-$	12.145
2.272 ± 4	22	21.7	0.3	< 0.3		$\frac{5}{2}^{(+)}$	12.327
2.450 ± 4	44 ± 3	28	0.3	5.5		$\frac{5}{2}^+; T = \frac{1}{2}$	12.493
2.482 ± 8	58 ± 4				4.6 ± 0.7	$\frac{5}{2}^+; T = \frac{3}{2}$	12.523
2.908 ± 4	70	25	9.0	15		$\frac{3}{2}^-$	12.920
2.93 ± 10	81	n.r.	0.5	80		$\frac{5}{2}^+$	12.940
3.19	5.5	r.					13.18
3.38 ± 10	24	6	6.0	12		$\frac{3}{2}^-$	13.360
3.421 ± 10	57	20.6	35	5.5	3.0 ± 0.9	$\frac{3}{2}^+$	13.390
3.57 ± 10	124	≈ 75	8.0	≈ 40		$\frac{3}{2}^-$	13.537

Table 15.12: Resonances in ^{14}C + p [a] (continued)

$E_{\rm p}$ (MeV ± keV)	$\Gamma_{\rm c.m.}$ (keV)	$\Gamma_{\rm n}$ (keV)	$\Gamma_{\rm p}$ (keV)	Γ_{α} (keV)	Γ_{γ} (eV)	J^{π}	$E_{\rm x}$ (MeV ± keV)
3.65 ± 10	88	≈ 16	12.0	≈ 60		$\frac{1}{2}^+$	13.612
3.71		r.					13.67
4.0	930		500		r.	$\frac{1}{2}^+$	13.9
4.1 ± 100	98 ± 10		25	r.		$\frac{5}{2}^+$	14.0
4.2 ± 100				r.		$(\frac{3}{2})$	14.1
4.6 ± 150	74 ± 7		20	r.	(r.)	$\frac{3}{2}^-$	14.5
4.8	149 ± 18		39	r.	(r.)	$\frac{3}{2}^+$	14.7
4.83	750				r.		14.71
5.08	158 ± 19		20		r.	$\frac{3}{2}^+$	14.95
5.16 ± 130	28 ± 3		9.0	r.		$\frac{3}{2}^+$	15.0
5.54 ± 130	39 ± 5		12	r.	(r.)	$\frac{3}{2}^-$	15.4
5.62	750				r.		15.45
6.4 ± 150	130 ± 14		19	r.		$\frac{3}{2}^+$	16.2
6.70	560				r.		16.46
6.925	90 ± 10			r.	r.	$(\frac{3}{2}^+; \frac{1}{2})$	16.67
7.18 ± 180	110 ± 50			r.		$\frac{5}{2}$	16.9
≈ 9					r.	$\frac{1}{2}^+; \frac{1}{2}$	19
10.0	sharp		(1000)		r.	$\frac{3}{2}^+; (T = \frac{3}{2})$	19.5 [e]
11.0	sharp				r.	$\frac{3}{2}^+$	20.5
12.35					r.		21.72
13.65					r.		22.94
16.4					r.	$(T = \frac{3}{2})$	25.5 [e]

Table 15.12: Resonances in ^{14}C + p [a] (continued)

E_p (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	Γ_n (keV)	Γ_p (keV)	Γ_α (keV)	Γ_γ (eV)	J^π	E_x (MeV ± keV)
≈ 29					r.		≈ 37

r. = resonant.

n.r. = non-resonant.

[a] See Tables 15.5 in (1959AJ76), 15.11 in (1970AJ04) and 15.12 in (1981AJ01) for references and additional comments.

[b] $\omega\gamma$ (in eV).

[c] Γ_{γ_0}. I am indebted to P.M. Endt for this correction.

[d] E_x measured directly: see (1981AJ01).

[e] Analog not observed in ^{14}N(p, γ)^{15}O.

Observed resonances and anomalies are displayed in Table 15.12. Polarization measurements for reaction (a) have been reported for $E_p = 1.79$ to 13.3 MeV [see (1981AJ01)] and at $E_{\vec{p}} = 120$ and 160 MeV (1981GO1D, 1982MAZZ) and for reaction (b) at $E_p = 3.2$ to 5.7 MeV [see (1981AJ01)] and at $E_{\vec{p}} = 25$ and 35 MeV (1984BAZZ, 1985BAZZ). See also (1984TA02) and ^{14}C, ^{14}N.

32. ^{14}C(d, n)^{15}N $\qquad Q_m = 7.9829$

Angular distributions have been measured for $E_d = 1.3$ to 6.5 MeV: see (1976AJ04). See also (1983CR1A).

33. ^{14}C(^{3}He, d)^{15}N $\qquad Q_m = 4.7139$

Angular distributions have been studied at $E(^3\text{He}) = 23$ MeV to ^{15}N*(0, $5.27 + 5.30$, 6.32, 7.16, 7.30): see (1981AJ01). See also (1976AJ04).

34. ^{14}C(^{16}O, ^{15}N)^{15}N $\qquad Q_m = -1.9201$

Angular distributions to $^{15}\text{N}_{\text{g.s.}}$ have been studied at $E(^{16}\text{O}) = 20$, 25 and 30 MeV: see (1976AJ04). See also (1981KO07; yields).

35. ^{14}N(n, γ)^{15}N $\qquad Q_m = 10.8333$

$Q_0 = 10833.343 \pm 0.009$ keV (1983KE11). [However values of E_γ obtained by (1983KE11) [see Table 15.13] are based on $Q_0 = 10833.302$ keV: see (1983CO09).]

The thermal cross section is 77.2 ± 2.1 mb (1981IS07). See also (1981MUZQ). This large cross section is not understood in terms of the level structure in ^{15}N: see (1959AJ76).

Observed γ-rays are displayed in Table 15.13. See also Tables 15.5 and 15.6. The $90°$ γ_0 yield and angular distributions have been measured for $E_n = 5.6$ to 15.3 MeV. The cross section shows two prominent dips at $E_x = 16.7$ and 18.1 MeV [compare with ^{14}N(p, γ); reaction 11 in ^{15}O] and broad structures at $E_x \approx 17$ and 19 MeV. The angular distribution data are consistent with essentially pure E1 radiation in the region $E_x = 17$ to 24 MeV (1982WE01). See also (1980WE1D).

36. ^{14}N(n, n)^{14}N $\qquad E_b = 10.8333$

The scattering amplitude (bound) $a = 9.37 \pm 0.03$ fm, $\sigma_{\text{free}} = 10.05 \pm 0.12$ b, $\sigma_{\text{inc}}^{\text{spin}}$(bound nucleus) $= 0.49 \pm 0.11$ b (1979KO26). See also (1981MUZQ).

Table 15.13: Gamma radiation from ^{14}N(n, γ) [a]

Transition in ^{15}N	E_γ [b] (keV)	E_x [b] (keV)	I_γ [c]
C → 0	10829.10 (2)	10833.30 (1.4)	13.8 (7)
C → 5.27	5562.04 (2)		10.7 (1.4)
C → 5.30	5533.40 (2)		20.0 (2.6)
C → 6.32	4508.71 (3)		16.6 (2.6)
C → 7.16	3677.73 (2)		14.9 (2.7)
C → 7.30	3532.00 (3)		9.72 (19)
C → 8.31	2520.47 (2)		6.16 (24)
C → 9.05			[a]
C → 9.152	1681.12 (6)		[a]
C → 9.155	1678.24 (3)		[a]
C → 9.76		9757.5 (30) [a]	[a]
C → 9.93			[a]
5.27 → 0	5269.14 (2)	5270.15 (2)	30.1 (4.1)
5.30 → 0	5297.79 (2)	5298.80 (2)	21.1 (3)
6.32 → 0	6322.47 (3)	6323.89 (2)	18.8 (3)
7.16 → 0		7155.11 (2)	
7.16 → 5.27	1884.85 (2)		19.7 (10) [e]
7.16 → 5.30			0.8 (2) [e]
7.30 → 0	7298.98 (4)	7300.86 (2)	9.59 (19)
7.30 → 5.30			[a]
8.31 → 0	8310.14 (4)	8312.60 (2)	4.20 (12)
8.31 → 6.32	1989 (2) [e]		1.5 (3) [e]
8.57 → 0	8570 (4) [e]		0.2 (0.3) [e]
9.05 → 0	9047 (4) [e]		0.2 (0.3) [e]
9.152 → 0		9152.14 (6)	
	9149.18 (3)		1.67 (7)
9.155 → 0		9155.00 (4)	
9.155 → 5.27	3884.28 (7) [d]		0.8 (1) [e]
9.155 → 5.30	3855.60 (7) [d]		1.0 (1) [e]
9.155 → 6.32	2830.75 (9) [d]		2.03 (9)
9.155 → 7.16	1999.73 (10) [d]		4.6 (2) [e]

Table 15.13: Gamma radiation from ^{14}N(n, γ) [a] (continued)

Transition in ^{15}N	E_γ [b] (keV)	E_x [b] (keV)	I_γ [c]
$9.155 \rightarrow 7.30$			a

C = capturing state.

[a] See also Table 15.13 in (1981AJ01).

[b] Weighted mean of values from (1980GR12, 1983KE11); uncertainties are rounded off. 12 eV has been added in quadrature to the uncertainties of (1983KE11). I am very grateful to T.J. Kennett for his comments. See also (1981KE02).

[c] In units of photons/100 captures. based on earlier values of (1967TH05) but recalculated by (1980KE1K).

[d] (1980GR12).

[e] (1967TH05).

Observed resonances are shown in Table 15.14: for a discussion of the evidence leading to J^π assignments see (1959AJ76). Cross sections for production of γ-rays die to the decay of excited states of ^{14}N have been measured in the range $E_n = 2$ to 20 MeV: see (1976AJ04, 1981AJ01). Analyzing powers for the n_0 group have been measured for $E_{\vec{n}} = 5 \rightarrow 17$ MeV (1985ANZX). See also (1984TEZZ), (1982HA1A) and (1982DI1E; applied).

37. ^{14}N(n, 2n)^{13}N $\qquad Q_m = -10.5535 \qquad E_b = 10.8333$

Cross sections have been measured for $E_n = 10$ to 37 MeV: see (1970AJ04, 1981AJ01). See also (1983CSZX).

38. (a) ^{14}N(n, p)^{14}C $\qquad Q_m = 0.6259 \qquad E_b = 10.8333$

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

(c) ^{14}N(n, t)^{12}C $\qquad Q_m = -4.0151$

(d) ^{14}N(n, α)^{11}B $\qquad Q_m = -0.1581$

The thermal cross section for reaction (a) is 1.83 ± 0.03 b (1981MUZQ). Reported resonances for reactions (a) and (d) are displayed in Table 15.14. For a listing of cross-section measurements see (1981AJ01). See also (1981HAZJ, 1985BO1D).

39. ^{14}N(d, p)^{15}N $\qquad Q_m = 8.6087$

Table 15.14: Resonances in ^{14}N + n [a]

$E_{\rm res}$ (MeV $\pm$ keV)	$\Gamma_{\rm lab}$ (keV)	$\Gamma_{\rm n}$ (keV)	$\Gamma_{\rm p}$ (keV)	Γ_{α} (keV)	J^{π}	^{15}N* (MeV)
0.430 ± 5	3.5	< 3	< 0.01		$\geq \frac{3}{2}$	11.235
0.4926 ± 0.65	7.5	< 3	< 10		$\frac{1}{2}^{-}$	11.2928
0.639 ± 5	43	34	9		$\frac{1}{2}^{+}$	11.429
0.998 ± 5	46	45	0.8		$\frac{3}{2}^{+}$	11.764
1.120 ± 6	19	19	0.20		$\frac{3}{2}^{-}$	11.878
1.188 ± 6	≤ 3.2	< 2	< 0.1		$\geq \frac{3}{2}$	11.942
1.211 ± 7	13	12	0.4		$\frac{1}{2}^{-}$	11.963
1.350 ± 7	21	20	0.9	0.4	$\frac{5}{2}^{(+)}$	12.093
1.401 ± 8	54	41	11	1.8	$\frac{5}{2}^{(+)}$	12.140
1.595 ± 8	22	21	0.2	< 0.1	$\frac{5}{2}^{(-)}$	12.321
1.779 ± 10	47	37	0.5	9.0	$(\frac{5}{2}^{+})$	12.493
2.23	65	39	7.8	18	$\frac{3}{2}^{-}$	12.91
2.47	< 3			r.		13.14
2.52	≈ 7	r.		r.		13.18
2.71	40			r.	$\frac{3}{2}^{-}$	13.36
2.74	95		r.		$\frac{5}{2}^{+}$	13.39
2.95	20	16	1.1	3.2	$\frac{5}{2}^{+}$	13.39
3.09	60		r.	r.		13.72
3.21	85	r.	r.	r.	$\frac{3}{2}^{+}$	13.83
3.51	≈ 20	r.	r.	r.		14.11
3.57	30	r.	r.	r.	$\frac{3}{2}^{(+)}$	14.16
≈ 3.8	≈ 2000	≈ 1000	200	≈ 1000		14.4
4.09	50	r.	r.	r.		14.65
≈ 4.2	≈ 300	r.	r.	r.		14.8
4.38	40			r.		14.92
4.60		r.		r.		15.12
5.03				r.		15.52
5.60	100			r.		16.06
5.94				r.		16.37
6.16	75			r.		16.58
6.26	100	r.		r.		16.67

Table 15.14: Resonances in ^{14}N + n [a] (continued)

E_{res} (MeV ± keV)	Γ_{lab} (keV)	Γ_n (keV)	Γ_p (keV)	Γ_α (keV)	J^π	^{15}N* (MeV)
6.55	170	r.		r.		16.94
6.94	200	r.		r.		17.31
7.16				r.		17.51
7.34	120			r.		17.68
7.48	180	r.		r.		17.81
7.92	170	r.		r.		18.22
8.00	120			r.		18.29

r. = resonant.

[a] See references in Tables 15.14 in (1970AJ04, 1976AJ04).

Proton groups (and γ-rays) from this reaction are displayed in Table 15.15 of (1981AJ01). The results include $E_x = 7567.1 \pm 1.0$ keV for ^{15}N*(7.57). Angular distributions have been measured for $E_d = 0.32$ to 52 MeV and lead to l_n, J^π and spectroscopic factors: see Table 15.15 in (1981AJ01). Branching ratios and multipolarities are shown in Table 15.5; τ_m in Table 15.6. See also (1982BE1R; applied), (1978GR16; theor.) and ^{16}O in (1982AJ01).

40. (a) ^{14}N(t, d)^{15}N $Q_m = 4.5760$
(b) ^{14}N(^{3}He, 2p)^{15}N $Q_m = 3.1152$

See (1981AJ01) for reaction (a). For reaction (b) see (1985HA01) and ^{16}O in (1986AJ04).

41. ^{14}N(α, ^{3}He)^{15}N $Q_m = -9.7445$

See (1981AJ01).

42. (a) ^{14}N(^{11}B, ^{10}B)^{15}N $Q_m = -0.6208$
(b) ^{14}N(^{13}C, ^{12}C)^{15}N $Q_m = 5.8870$

At $E(^{11}\text{B}) = 115$ MeV and at $E(^{13}\text{C}) = 105$ MeV (1980PR09) have studied the transitions to ^{15}N*(0, 7.16, 7.57). See also (1981AJ01).

Table 15.15: Beta decay of ^{15}C [a]

Decay to ^{15}N* (keV)	J^{π}	Branch (%)	log ft
g.s.	$\frac{1}{2}^-$	36.8 ± 0.8 [c]	5.99 ± 0.03 [c]
5298.87 ± 0.15 [b]	$\frac{1}{2}^+$	63.2 ± 0.8 [c]	4.11 ± 0.01
6323.3 ± 0.6	$\frac{3}{2}^-$	$\leq 0.4 \times 10^{-2}$	≥ 7.8
7301.1 ± 0.5	$\frac{3}{2}^+$	$(0.74 \pm 0.08) \times 10^{-2}$	6.89 ± 0.05
8312.9 ± 0.5	$\frac{1}{2}^+$	$(4.1 \pm 0.5) \times 10^{-2}$	5.18 ± 0.05
8571.4 ± 1.0	$\frac{3}{2}^+$	$(1.3 \pm 0.2) \times 10^{-2}$	5.34 ± 0.07
9050.0 ± 0.7	$\frac{1}{2}^+$	$(3.4 \pm 0.3) \times 10^{-2}$	4.05 ± 0.04

[a] (1979AL23).
[b] (1976AL16). 5297.794 ± 0.035 keV: see (1981WA06).
[c] (1984WA07).

43. ^{14}N(^{14}N, ^{13}N)^{15}N $\qquad Q_m = 0.2799$

See (1981AJ01).

44. ^{15}C(β^-)^{15}N $\qquad Q_m = 9.7717$

See reaction 1 in ^{15}C and Table 15.15.

45. (a) ^{15}N(γ, n)^{14}N $\qquad Q_m = -10.8333$
(b) ^{15}N(γ, p)^{14}C $\qquad Q_m = -10.2074$
(c) ^{15}N(e, ep$_0$)^{14}C $\qquad Q_m = -10.2074$
(d) ^{15}N(γ, d)^{13}C $\qquad Q_m = -16.1593$
(e) ^{15}N(γ, t)^{12}C $\qquad Q_m = -14.8484$

The total photoneutron cross section from threshold to 38 MeV shows a very broad GDR which extends from ≈ 16 to 30 MeV with a maximum $\sigma \approx 11$ mb at 23.5 MeV. Most of the strength in the GDR goes via transitions to excited states of ^{14}N (1982JU03: monoenergetic photons). The (γ, n$_0$) cross section for $E_x = 13$ to 24 MeV shows a broad structure centered at $E_x \approx 14.5$ MeV and a resonance at $E_x = 17.3 \pm 0.1$ MeV. A large fraction of the photoabsorption strength leading to ^{14}N$_{\rm g.s.}$ is due to the formation of $\frac{3}{2}^+$, $T = \frac{1}{2}$ states in ^{15}N which decay by d-wave emission.

The absorption is essentially pure E1 (1983WA03). The total integrated cross section up to 35 MeV for transitions to excited states [^{14}N*(2.31, 3.95, $5.11+5.83$, 7.03), ^{14}C*($6.09+6.59+6.90$, 7.01), ^{12}C*(4.4)] is 44 MeV $\cdot$ mb. The nature of the transitions is such as to indicate a very strong $(1p_{3/2})^0(1p_{1/2})^3$ component in $^{15}N_{g.s.}$. The presence of $T=\frac{1}{2}$ in the main giant resonance region is indiacted by strong population of ^{14}N*(7.03): see (1981AJ01).

A study at $E_e = 18.8$, 20.8, 25.7 and 29.7 MeV (reaction (c)) shows a "pigmy" resonance at $E_x = 14.8$ MeV, a shoulder at 15.6 MeV, a peak at 16.7 MeV [probably $\frac{1}{2}^+$ but $\frac{3}{2}^+$ is not ruled out], and the giant dipole resonance, which exhibits a great deal of structure, centered at 22 MeV. The data on the pigmy resonance are consistent with an admixture of $\approx 1\%$ $\frac{3}{2}^-$(E2) or $\frac{1}{2}^-$(M1) to a predominantly $\frac{1}{2}^+$(E1) state. The experiment shows that for $14 < E_x < 28$ MeV the reaction goes predominantly via $\frac{1}{2}^+$ or $\frac{3}{2}^+$(E1) states in ^{15}N; the $T=\frac{3}{2}$ strength is concentrated above 18 MeV.

The cross section for d_0 [reaction (d)] is reported at 90° for $E_\gamma \approx 20.5$ to 28.5 MeV: a resonance is observed at $E_x \approx 21.9$ MeV. The (γ, t_0) cross section (reaction (e)) at 90° decreases from a value of 30 μb/sr at 20 MeV to 5 μb/sr at 22 MeV and remains flat out to 25 MeV. Comparison of this cross section, and those of the other photonuclear reactions, suggests an isospin splitting of ≈ 6 MeV with the $T=\frac{1}{2}$ strength concentrated between 16 and 21 MeV and the $T=\frac{3}{2}$ strength between 21 and 28 MeV. ^{15}N*(21.9) is not observed. See (1981AJ01) for references.

46. ^{15}N(γ, γ)^{15}N

See Table 15.16 (1981MO09) and (1981AJ01).

47. ^{15}N(e, e)^{15}N

The rms radius of ^{15}N is 2.580 ± 0.026 fm. Inelastic groups are displayed in Table 15.16. The transverse form factors for the transitions to ^{15}N*(0, 6.32) have been measured at $E_e = 70.4$ to 326.7 MeV (1983SI11).

The giant resonance is split into two main peaks at $E_x = 22$ and 25.5 MeV with some structure around 20 MeV. Γ_{γ_0}(C1) $= (1.1 \pm 0.3) \times 10^3$ eV (14–18.5 MeV), Γ_{γ_0}(C2) $= (12.5 \pm 2.0)$ eV assuming the states responsible are $\frac{3}{2}^+$ and $\frac{3}{2}^-$, respectively. For $E_x = 18.5$ to 30 MeV, Γ_{γ_0}(C1) $= (1.96 \pm 0.04) \times 10^4$ eV while $\Gamma_{\gamma_0} < 0.1$ eV for any C2 strength. See (1981AJ01) for references. See also (1984DO20) and (1981SU03, 1981SU08, 1982LIZW; theor.).

48. ^{15}N($\pi^\pm$, $\pi^\pm$)^{15}N

At $E_{\pi^\pm} = 164$ MeV angular distributions have been studied to states at $E_x = 10.68 \pm 0.03$, 12.52 ± 0.02, 14.04 ± 0.03 and 17.19 ± 0.03 MeV: $J^\pi = \frac{9}{2}^+$, $\frac{9}{2}^+$, $(\frac{9}{2}^+, \frac{7}{2}^+)$ and $(\frac{9}{2}^+, \frac{7}{2}^+)$, respectively, as well as to the $^{15}N_{g.s.}$. Additional π^+ cross sections were measured at 120 and 260

MeV: peaks were observed at $E_x = 20.11 \pm 0.06$ and 23.19 ± 0.06 MeV [both are probably $T = \frac{3}{2}$ states]. ^{15}N*(5.27, 6.32, 7.57) were also populated (1985SE06). See also (1984SAZU), (1982OS01; theor.) and the "GENERAL" section here.

Table 15.16: Radiative widths [a] from ^{15}N(γ, γ') and ^{15}N(e, e′)

E_x (MeV ± keV)	J^π	Mult.	Γ_{γ_0} (eV)
5.27	$\frac{5}{2}^+$	C3	$(4.2 \pm 0.3) \times 10^{-6}$
		M2	$(1.2 \pm 0.7) \times 10^{-4}$
5.30	$\frac{1}{2}^+$	C1	2.2 ± 2.3
6.323 ± 1 [b]	$\frac{3}{2}^-$	C2	0.050 ± 0.004
		M1	1.9 ± 0.4 [c]
		M1 + E2	3.12 ± 0.18 [b,d,e]
7.16	$\frac{5}{2}^+$	C3	$(0.86 \pm 0.10) \times 10^{-5}$
7.301 ± 1 [b]	$\frac{3}{2}^+$	C1	2.6 ± 1.0
		M2	$(0.3 \pm 0.2) \times 10^{-5}$
		E1 + M2	1.08 ± 0.08 [b]
7.57	$\frac{7}{2}^+$	C3	$(1.84 \pm 0.16) \times 10^{-5}$
8.310 ± 4 [b]	$\frac{1}{2}^+$	E1	0.3 ± 0.2 [b]
8.575 ± 4 [b]	$\frac{3}{2}^+$	E1 + M2	0.3 ± 0.3 [b]
9.048 ± 1 [b]	$\frac{1}{2}^+$	E1	1.2 ± 0.2 [b]
9.150 ± 1 [b]	$\frac{3}{2}^-$	C2	0.095 ± 0.005 [f]
		M1	0.2 ± 0.8
		M1 + E2	0.47 ± 0.12 [b,g]
9.760 ± 1 [b]	$\frac{5}{2}^-$	C2	0.20 ± 0.05
		E2	0.21 ± 0.07 [b]
9.924 ± 1 [b]	$\frac{3}{2}^-$	M1	1.6 ± 0.2 [b]
10.064 ± 1 [b]	$\frac{3}{2}^+$	E1	6.3 ± 0.4 [b]
10.8	$\frac{3}{2}^+$	M2	$(1.8 \pm 0.8) \times 10^{-2}$
11.88	$\frac{3}{2}^-$	C2	0.44 ± 0.10
		M1	4.4 ± 3.8
12.5	$\frac{5}{2}^+$	M2	$(5.2 \pm 2.0) \times 10^{-2}$
(13.98)			
14.7	$\frac{5}{2}^-$	C2	1.8 ± 0.2
20.10			

Table 15.16: Radiative widths [a] from ^{15}N(γ, γ') and ^{15}N(e, e′) (continued)

E_x (MeV ± keV)	J^π	Mult.	Γ_{γ_0} (eV)
23.25			

[a] For references and $B(\lambda)\uparrow$ see Table 15.17 in (1981AJ01). See also Tables 15.5 and 15.6 here.
[b] (1981MO09): (γ, γ).
[c] See note added in proof in (1975MO28).
[d] δ(E2/M1) $= 0.137 \pm 0.005$. See, however, Table 15.5.
[e] Using δ(E2/M1) $= 0.132 \pm 0.004$ [see Table 15.5] $\Gamma_{\gamma_0} = 3.07 \pm 0.18$ eV (M1) and $(5.34 \pm 0.44) \times 10^{-2}$ eV (E2) (D.J. Millener, private communication).
[f] δ(E2/M1) > 0.3.
[g] Mixing ratio is very small [see Table 15.5] and the transition is almost purely M1 (D.J. Millener, private communication).

49. ^{15}N(n, n)^{15}N

See ^{16}N in (1982AJ01).

50. ^{15}N(p, p)^{15}N

Angular distributions of elastically scattered protons have been measured at E_p to 44.2 MeV [see (1981AJ01)] and at $E_{\vec{p}} = 2.8$ to 7.0 MeV (1984DA18). See also ^{16}O in (1982AJ01, 1986AJ04).

51. (a) ^{15}N(d, d)^{15}N
(b) ^{15}N(^{3}He, ^{3}He)^{15}N

Angular distributions of elastically scattered deuterons have been measured at $E_d = 5 - 6$ MeV. Elastic and inelastic ^{3}He distributions have been studied for $E(^3\text{He}) = 11$ to 39.8 MeV: see (1976AJ04).

52. ^{15}N(α, α)^{15}N

At $E_{\alpha} = 40.5$ MeV, a number of particle groups have been observed and angular distributions have been measured: see Table 15.17 of (1976AJ04). See also (1981AJ01) for additional information.

53. ^{15}N(^{7}Li, ^{7}Li)^{15}N

The elastic scattering angular distribution has been measured at $E(^{7}\mathrm{Li}) = 28.8$ MeV (1982WO09).

54. (a) ^{15}N(^{12}C, ^{12}C)^{15}N
(b) ^{15}N(^{13}C, ^{13}C)^{15}N

Angular distributions of elastic scattering have been measured at $E(^{15}\mathrm{N}) = 31.5$ to 47 MeV for reaction (a) [see (1981AJ01)] and at $E(^{13}\mathrm{C}) = 105$ MeV (1980PR09). The SFP (to ^{12}C*(4.4)) has been studied at $E(^{15}\mathrm{N}) = 94$ MeV by (1981TA21). For fusion cross sections see (1981AJ01) and (1982NO12). See also (1983BI1A, 1983DU13, 1984FR1A, 1984HA53) and (1982LO13, 1983CI08, 1983GO13; theor.).

55. (a) ^{15}N(^{16}O, ^{16}O)^{15}N
(b) ^{15}N(^{17}O, ^{17}O)^{15}N
(c) ^{15}N(^{18}O, ^{18}O)^{15}N
(d) ^{15}N(^{19}F, ^{19}F)^{15}N

Elastic angular distributions (reaction (a)) have been measured at $E(^{16}\mathrm{O}) = 35.1$ and 42.6 MeV (1983SR01). For fusion cross sections see (1981VO01). See also (1976AJ04). For reaction (d) see (1976AJ04). See also (1983DU13) and (1981AB1A, 1982LO13, 1982OH05, 1982OK02, 1983CI08; theor.).

56. (a) ^{15}N(^{27}Al, ^{27}Al)^{15}N
(b) ^{15}N(^{28}Si, ^{28}Si)^{15}N
(c) ^{15}N(^{40}Ca, ^{40}Ca)^{15}N

Elastic distributions (reaction (a)) have been measured in the range $E(^{15}\mathrm{N}) = 32.8$ to 69.8 MeV (1980PR06; see also for fusion cross sections). An elastic distribution (reaction (b)) is reported at $E(^{15}\mathrm{N}) = 44$ MeV: see (1981AJ01). See also (1983BI1A, 1983DU13 [also scattering on ^{22}Ne, ^{26}Mg, ^{30}Si, ^{36}S], 1984FR1A, 1984HA53).

57. ^{15}O(β^+)^{15}N $Q_m = 2.7540$

See ^{15}O.

58. (a) ^{16}O(γ, p)^{15}N $Q_m = -12.1276$
(b) ^{16}O(e, ep)^{15}N $Q_m = -12.1276$

Over the giant resonance region in ^{16}O, the decay takes place to the odd parity states ^{15}N*(0, 6.32) and less strongly o the even parity states ^{15}N*(5.27, 5.30, 8.31, 9.05) and to ^{15}N*(9.23): see (1970AJ04, 1976AJ04). At $E_e = 500$ MeV most of the 1p hole strength is concentrated in the groups to ^{15}N*(0, 6.32). The 1s state shows up as a very wide asymmetric structure centered at $E_x \approx 41$ MeV: see (1981AJ01). In the range $E_\gamma = 101.5$ to 382 MeV differential cross sections are reported for the p_0, (p_{1+2}) and p_3 groups at $\theta = 45°$, $90°$ and $135°$ (1985LE07).

Forward differential cross sections have been measured at $E_\gamma = 80$ MeV (1980SC27; p_0) and at $E_\gamma = 200$ MeV angular distributions have been studied by (1984AD1D, 1984TUZZ; p to ^{15}N*(5.3, 6.3); prelim.). ^{15}N*(0, 6.3) are populated at $E_e = 128$ MeV (1983VO1F; prelim.) and 500 MeV (1982BE02; also ^{15}N*(10.8)). See also (1980KH1C), (1980GO13, 1981GA1M, 1981WI1E, 1983TR1J, 1984WA1J) and (1981BO14, 1982BO28, 1983MA2B, 1985CO01; theor.).

59. ^{16}O(μ^-, νn)^{15}N $Q_m = 92.7495$

Gamma rays from the decay of one of the states at 5.3 MeV and from ^{15}N*(6.3) are reported by (1983VA1E).

60. ^{16}O(n, d)^{15}N $Q_m = -9.9030$

Angular distributions of the d_0 group have been reported at $E_n = 14$ and 14.4 MeV: see (1976AJ04).

61. (a) ^{16}O($\pi^\pm$, $\pi^\pm$p)^{15}N $Q_m = -12.1276$
(b) ^{16}O(p, 2p)^{15}N $Q_m = -12.1276$

At $E_{\pi^\pm} = 240$ MeV, the spectra are dominated by ^{15}N*(0, ≈ 6.5). The π^+/π^- ratio has been measured for the ground state transitions (1984KY01). At $E_{\pi^+} = 2.0$ GeV/c differential cross sections have been determined for the transition to ^{15}N*(6.3) (1983KI01).

At $E_p = 460$ MeV, the summed proton spectrum shows two peaks corresponding to the knock-out of $p_{1/2}$ and $p_{3/2}$ protons with binding energies of 12.4 and 19.0 MeV, respectively [^{15}N*(0, 6.32)]: see (1976AJ04). See also (1980MA28; theor.).

62. ^{16}O(d, ^{3}He)^{15}N $\quad Q_m = -6.6340$

Angular distributions of ^{3}He groups have been measured for $E_d = 20$ to 82 MeV: see (1976AJ04, 1981AJ01). The spectra are dominated by the transitions to ^{15}N*(0, 6.32). A ZRDWBA analysis leads to $C^2S = 2.25$ and 3.25 for these two states [and to 2.37 and 3.31 for the analog states in ^{15}O studied with the (d, t) reaction]. $J^\pi = \frac{3}{2}^-$ for both ^{15}N*(9.94, 10.71): see (1981AJ01). See also (1981MA14).

63. ^{16}O(t, α)^{15}N $\quad Q_m = 7.6865$

See (1970AJ04).

64. (a) ^{16}O(^{7}Li, ^{8}Be)^{15}N $\quad Q_m = 5.1265$
(b) ^{16}O(^{9}Be, ^{10}B)^{15}N $\quad Q_m = -5.5416$
(c) ^{16}O(^{10}B, ^{11}C)^{15}N $\quad Q_m = -3.438$
(d) ^{16}O(^{11}B, ^{12}C)^{15}N $\quad Q_m = 3.8295$

For reaction (a) see (1983DEZW). For reaction (b) see (1985WI18). The ground-state angular distribution has been studied at $E(^{10}\text{B}) = 100$ MeV. At $E(^{11}\text{B}) = 115$ MeV ^{15}N*(0, 6.32) are populated: see (1981AJ01).

65. (a) ^{16}O(^{14}N, ^{15}O)^{15}N $\quad Q_m = -4.8306$
(b) ^{16}O(^{16}O, ^{17}F)^{15}N $\quad Q_m = -11.5271$
(c) ^{16}O(^{19}F, ^{20}Ne)^{15}N $\quad Q_m = 0.7203$

See (1981AJ01). See also (1983OS08, 1984CL09; theor.).

66. ^{17}O(p, ^{3}He)^{15}N $\quad Q_m = -8.5531$

At $E_p = 39.8$ MeV angular distributions of the groups to ^{15}N*(0, 6.32) have been compared with those to the analog states in ^{15}O reached in the (p, t) reaction: see (1976AJ04).

67. ^{18}O(γ, t)^{15}N $\qquad Q_m = -15.8336$

The cross section to $^{15}N_{g.s.}$ has been determined in the GDR region (1982BA03): see ^{18}O in (1983AJ01).

68. ^{18}O(p, α)^{15}N $\qquad Q_m = 3.9804$

Angular distributions of α_0 have been measured for $E_p = 0.125$ to 42.2 MeV: see (1976AJ04, 1981AJ01) and ^{19}F in (1983AJ01). $\tau_m = 2.49 \pm 0.24$ psec, $|g| = 0.94 \pm 0.07$ for ^{15}N*(5.27) (1983BI10). See also (1983LI1T; applied).

69. (a) ^{19}F(γ, α)^{15}N $\qquad Q_m = -4.0138$
(b) ^{19}F(p, pα)^{15}N $\qquad Q_m = -4.0138$
(c) ^{19}F(α, 2α)^{15}N $\qquad Q_m = -4.0138$

See ^{19}F in (1983AJ01) and (1981AJ01).

70. ^{19}F(d, ^{6}Li)^{15}N $\qquad Q_m = -2.5387$

Angular distributions involving ^{15}N*(0, 5.3, 6.3) have been measured in the range $E_d = 9.0$ to 28 MeV [see (1976AJ04, 1981AJ01)]. See also (1984GO1H; 50 MeV) and (1984NE1A).

71. ^{19}F(^{3}He, ^{7}Be)^{15}N $\qquad Q_m = -2.4263$

See (1976AJ04).

^{15}O

(Figs. 12 and 13)

GENERAL: (See also (1981AJ01).)

Nuclear models: (1982WA1Q, 1982YA1D, 1983SH38).

Special states: (1979GO27, 1980GO1Q, 1980HI1C, 1984ST1E).

Electromagentic transitions: (1980KO1L, 1980MI1G, 1980RI06, 1982AW02, 1983TO08, 1984CA02).

Astrophysical questions: (1980BA1P, 1981WA1Q, 1983LI01, 1985GI1C).

Complex reactions involving ^{15}O: (1981HU1D, 1981SC1P, 1983DE26, 1983FR1A, 1983JA05, 1983OL1A, 1983WI1A, 1984FI1N, 1984GR08, 1984HI1A, 1984HO23, 1985MO08).

Applied work: (1982BO1N, 1982HI1H, 1982PI1H, 1982YA1C, 1983KO1Q, 1984HA1F, 1984HI1D, 1984NI1C).

Pion and other mesons capture and reactions (See also reactions 10, 20 and 24): (1980BA1Y, 1980SC1E, 1981OS04, 1981RE04, 1982VI05, 1983KA19, 1983KI01, 1983TR1J, 1984MA63, 1985RE1D).

Hypernuclei: (1981WA1J, 1982KA1D, 1983SH38, 1983SH1E, 1984AS1D).

Other topics: (1980GO1Q, 1980HI1C, 1981SH17, 1982AW02, 1982CA12, 1982NG01, 1983KH1D, 1983MA38, 1983SH1T, 1983TO08).

Ground-state properties of ^{15}O: (1979GO27, 1980HI1C, 1981NO1F, 1982CA12, 1982NG01, 1983BU07, 1983DE1X, 1983MA38, 1983TO08, 1984KA25, 1984ST1E, 1985AR11, 1985HA18, 1985FA01).

$$\mu = 0.7189\ (8)\ \text{nm (1978LEZA)}.$$

1. ^{15}O(β^+)^{15}N $\qquad Q_\mathrm{m} = 2.7540$

The half-life of ^{15}O is 122.24 ± 0.16 sec: see (1981AJ01); $\log f_0t = 3.637$. The K/β^+ ratio is $(10.7\pm0.6)\times10^{-4}$: see (1976AJ04). See also (1982OS1C, 1983GO2C), (1981BA2G, 1982CO1D, 1983LI01, 1984BO1C, 1984DA1H, 1984HA1M, 1985KL1A; astrophys.), (1982KA1C; applied) and (1980AF1A, 1981ME1H, 1982OS1C; theor.).

2. ^{10}B(^{14}N, ^{9}Be)^{15}O $\qquad Q_\mathrm{m} = 0.7110$

Table 15.17: Energy levels of ^{15}O [a]

E_x in ^{15}O (MeV ± keV)	$J^\pi; T$	τ or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
0	$\frac{1}{2}^-; \frac{1}{2}$	$\tau_{1/2} = 122.24 \pm 0.16$ sec	β^+	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30
5.183 ± 1	$\frac{1}{2}^+$	$\tau_m = 8.2 \pm 1.0$ fsec	γ	2, 6, 9, 11, 16, 17, 22, 23, 25, 26, 27
5.2409 ± 0.3	$\frac{5}{2}^+$	3.25 ± 0.30 psec $g = +0.248 \pm 0.026$	γ	2, 5, 6, 9, 11, 16, 17, 21, 22, 23, 25, 26, 27
6.1763 ± 1.7	$\frac{3}{2}^-$	< 2.5 fsec	γ	6, 9, 11, 16, 17, 21, 22, 23, 24, 25, 26, 27, 29
6.7931 ± 1.7	$\frac{3}{2}^+$	< 28 fsec	γ	2, 6, 9, 11, 16, 17, 22, 27
6.8594 ± 0.9	$\frac{5}{2}^+$	16.0 ± 2.5 fsec	γ	2, 5, 6, 9, 11, 16, 17, 19, 22, 23, 27
7.2759 ± 0.6	$\frac{7}{2}^+$	0.70 ± 0.15 psec	γ	5, 6, 7, 8, 9, 10, 16, 17, 19, 22, 25, 27
7.5564 ± 0.5	$\frac{1}{2}^+$	$\Gamma = 1.2 \pm 0.2$ keV	γ, p	9, 11, 16, 17, 22, 25, 27
8.2839 ± 0.6	$\frac{3}{2}^+$	3.6 ± 0.7	γ, p	6, 9, 11, 16, 17, 27
8.743 ± 6	$\frac{1}{2}^+$	32	γ, p	9, 11, 27
8.922 ± 2	$\frac{5}{2}^+$	3.3 ± 0.3	γ, p	5, 6, 11, 13, 25, 27
8.922 ± 2	$\frac{1}{2}^+$	7.5	γ, p	6, 11, 13, 25, 27
8.9821 ± 1.7	$(\frac{1}{2})^-$	3.9 ± 0.4	γ, p	6, 9, 11, 27
9.488 ± 3	$\frac{5}{2}^-$	10.1 ± 0.5	γ, p	6, 9, 11, 27
9.527 ± 17	$(\frac{3}{2})^+$	280 ± 25	γ, p	9, 11, 13, 27
9.609 ± 2	$\frac{3}{2}^-$	8.8 ± 0.5	γ, p	6, 9, 11, 21, 27
9.662 ± 3	$(\frac{7}{2}, \frac{9}{2})^-$	2 ± 1	p	6, 9, 13, 27
10.29 [b]	$(\frac{5}{2}^-)$	3 ± 1	p	6, 9, 13, 27
10.30 [b]	$\frac{5}{2}^+$	11 ± 2	p	6, 9, 13, 27
10.461 ± 5	$(\frac{9}{2}^+)$	< 2	γ, p	6, 11, 27
10.48	$(\frac{3}{2}^-)$	25 ± 5	γ, p	7, 9, 11, 13, 26
(10.506)	$(\frac{3}{2})^+$	140 ± 40	γ, p	11, 13

Table 15.17: Energy levels of ^{15}O [a] (continued)

E_x in ^{15}O (MeV ± keV)	$J^\pi; T$	τ or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
10.917 ± 12	$\frac{7}{2}^+$	90	p	13, 27
10.938 ± 3	$\frac{1}{2}^+$	99 ± 5	γ, p	11, 13, 27
11.025 ± 3	$\frac{1}{2}^-$	25 ± 2	γ, p	11, 13, 27
11.151 ± 7		< 10	p	6, 13, 27
11.218 ± 3	$\frac{3}{2}^+$	40 ± 4	γ, p	11, 13, 27
11.565 ± 15		< 10	p	6, 13, 27
11.569 ± 15	$\frac{5}{2}^-$	20 ± 15	γ, p	6, 11, 13
11.616 ± 15	$(\frac{3}{2}, \frac{1}{2})^-$	80 ± 50	γ, p	11, 13
11.719 ± 8		< 10	p	5, 6, 13, 27
11.748 ± 3	$\frac{5}{2}^+$	99 ± 5	γ, p	11, 13
11.846 ± 3	$\frac{5}{2}^-$	65 ± 3	γ, p	11, 13
11.980 ± 10	$\frac{5}{2}^-$	20 ± 5	p	6, 13, 27
12.129 ± 15	$\frac{5}{2}^+$	200 ± 50	p	13
12.222 ± 20		100 ± 50	p	13
12.255 ± 13	$\frac{5}{2}^+; \frac{3}{2}$	135 ± 15	p	29
12.295 ± 10				6
12.471 ± 3	$\frac{5}{2}^-, (\frac{3}{2}^-)$	77 ± 4	p	13
12.60 ± 10				6
12.80		≈ 250	γ, p	11
12.835 ± 3	$(\frac{1}{2}^-)$	16 ± 1	p	5, 6, 7, 8, 13
13.008 ± 3		215 ± 3	p	13
13.025 ± 3		40 ± 30	p, (^{3}He)	4, 13
13.45	$(\frac{1}{2}, \frac{3}{2})^+$	≈ 1000	γ, p, (α)	5, 11, 13, 15
(13.49)	$(\frac{3}{2}^+)$		(p)	13
13.60	$\frac{5}{2}^+$		p, α	15
13.70	$\frac{3}{2}^-$		p	5, 13
13.79	$\frac{3}{2}^-$		n, p, ^{3}He, α	4, 13, 15
13.87		≈ 150	γ, p	11
14.03 ± 40	$(\frac{1}{2}^-, \frac{3}{2}^-)$	160 ± 20	n, p, ^{3}He	4
14.17	$\frac{5}{2}^-$		p, α	15

Table 15.17: Energy levels of ^{15}O [a] (continued)

E_x in ^{15}O (MeV $\pm$ keV)	$J^\pi; T$	τ or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
14.27 ± 10	$\frac{1}{2}^+$	340 ± 30	n, p, ^{3}He, α	4, 5, 6, 12, 13, 14, 15
14.34	$\frac{5}{2}^+$	(240)	p, (^{3}He), α	4, 15
14.465 ± 10	$\frac{3}{2}^+, \frac{5}{2}^+$	100 ± 10	n, p, ^{3}He, α	4
14.70 ± 40		170 ± 35	n, p, ^{3}He	4
14.95 ± 40		400 ± 25	n, p, ^{3}He, α	4
15.05 ± 10	$((\frac{13}{2}^+))$			6, 7, 8
15.1	$(\frac{1}{2}, \frac{3}{2})^+$	≈ 1000	γ, p	11
15.45 ± 30		70 ± 20	p, ^{3}He, α	4, 6
15.54 ± 10			(p, ^{3}He, α)	4, 6
15.60 ± 10			(p, ^{3}He, α)	6
15.65 ± 10				6
15.80 ± 10			n, ^{3}He	4, 6
15.90 ± 15	$\frac{1}{2}^-, \frac{3}{2}^-$	350	^{3}He, α	4
16.05 ± 20		≈ 185	n, p, ^{3}He, α	4
16.10 ± 20			(n) ^{3}He, α	4
16.21 ± 20		≈ 140	(n), p, ^{3}He, α	4
16.43 ± 75	$\frac{1}{2}^+$	560 ± 100	^{3}He, α	4
16.75 ± 50			n, ^{3}He	4, 27
17.05 ± 60	$(\frac{1}{2}, \frac{3}{2})^+; \frac{1}{2}$	700 ± 70	γ, p, ^{3}He	4
17.46 ± 20				6
17.51 ± 20	$\frac{1}{2}^-, \frac{3}{2}^-$	600	n, ^{3}He, α	4, 6
17.99 ± 50	$\frac{1}{2}^-, \frac{3}{2}^-$	200	^{3}He	4
18.23 ± 50			n, p, ^{3}He	4
18.67 ± 60	$(\frac{1}{2}, \frac{3}{2})^+; \frac{1}{2}$	520 ± 110	γ, ^{3}He	4
19.03 ± 50			n, ^{3}He	4
19.57 ± 80	$(\frac{1}{2}, \frac{3}{2})^+; \frac{1}{2}$	780 ± 270	γ, ^{3}He	4
19.91 ± 50			n, ^{3}He	4
20.42 ± 70	$(\frac{3}{2}, \frac{1}{2})^+; \frac{1}{2}$	970 ± 240	γ, p, ^{3}He	4
21.56 ± 70	$(\frac{3}{2}, \frac{1}{2})^+; \frac{1}{2}$	730 ± 120	γ, p, ^{3}He	4
(26.0)	$(\frac{13}{2}^-)$	≈ 600	^{3}He	4

Table 15.17: Energy levels of ^{15}O [a] (continued)

E_x in ^{15}O (MeV ± keV)	$J^\pi; T$	τ or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
(28.0)	$(\frac{9}{2}^-, \frac{11}{2}^-)$	≈ 2500	^{3}He	4
(29.0)		≈ 2500	^{3}He	4

[a] See also Table 15.18.

[b] It is possible that these two are in fact a single state: see (1976AJ04).

Angular distributions have been measured at $E(^{14}\text{N}) = 73.9$ and 100 MeV: see (1981AJ01).

3. ^{11}B(^{14}N, ^{10}Be)^{15}O $\qquad Q_m = -3.9311$

Elastic angular distributions have been studied at $E(^{14}\text{N}) = 41$, 77 and 113 MeV: see (1976AJ04). See also (1984CL09; theor.).

Table 15.18: Radiative decays in ^{15}O [a]

E_i (MeV)	J_i^π	E_f (MeV)	J_f^π	Branch (%)	δ [b]
5.24	$\frac{5}{2}^+$	0	$\frac{1}{2}^-$	100	$+0.10 \pm 0.04$ (E3/M2)
6.18 [c]	$\frac{3}{2}^-$	0	$\frac{1}{2}^-$	100	-0.125 ± 0.007 (E2/M1) [k]
6.79 [d]	$\frac{3}{2}^+$	0	$\frac{1}{2}^-$	100	-0.02 ± 0.02 (M2/E1)
6.86 [e]	$\frac{5}{2}^+$	5.24	$\frac{5}{2}^+$	100	$+0.04 \pm 0.03$ (E2/M1)
7.28 [f]	$\frac{7}{2}^+$	0	$\frac{1}{2}^-$	3.8 ± 1.2	
		5.24	$\frac{5}{2}^+$	96.2 ± 1.2	
7.56 [g]	$\frac{1}{2}^+$	0	$\frac{1}{2}^-$	3.5 ± 0.5	
		5.18	$\frac{1}{2}^+$	15.8 ± 0.6	
		6.18	$\frac{3}{2}^-$	57.5 ± 0.4	
		6.79	$\frac{3}{2}^+$	23.2 ± 0.6	
		6.86	$\frac{5}{2}^+$	[l]	
					Γ (eV)
8.28	$\frac{3}{2}^+$	0	$\frac{1}{2}^-$	53.8 ± 0.25	0.531 [m]
		5.24	$\frac{5}{2}^+$	42.7 ± 0.5	0.405
		6.18	$\frac{3}{2}^-$	2.2 ± 0.6	0.021
		6.86	$\frac{5}{2}^+$	1.2 ± 0.3	0.011

Table 15.18: Radiative decays in ^{15}O [a] (continued)

E_i (MeV)	J^π_i	E_f (MeV)	J^π_f	Branch (%)	δ [b]
8.74	$\frac{1}{2}^+$	5.18	$\frac{1}{2}^+$	67	0.32
		6.18	$\frac{3}{2}^-$	33	0.16
8.922 [h]	$\frac{5}{2}^+$	0	$\frac{1}{2}^-$	9 ± 4	
		5.18	$\frac{1}{2}^+$	39 ± 3	
		6.18	$\frac{3}{2}^-$	24 ± 3	
		6.86	$\frac{5}{2}^+$	28 ± 3	
8.922 [h]	$\frac{1}{2}^-$	0	$\frac{1}{2}^-$	50 ± 25	
		5.18	$\frac{1}{2}^+$	20 ± 10	
		6.18	$\frac{3}{2}^-$	20 ± 10	
		6.86	$\frac{5}{2}^+$	(10 ± 10)	
8.982 [i]	$(\frac{3}{2})^-$	0	$\frac{1}{2}^-$	94 ± 1	
		5.18	$\frac{1}{2}^+$	6 ± 1	
9.49	$\frac{5}{2}^-$	0	$\frac{1}{2}^-$	86	2.1
		5.24	$\frac{5}{2}^+$	6.5	0.15
		6.18	$\frac{3}{2}^-$	0.7	0.22
		6.86	$\frac{5}{2}^+$	3.4	0.08
		7.28	$\frac{7}{2}^+$	5.1	0.11
9.50 [j]	$\frac{3}{2}^+(\frac{1}{2}^+)$	0	$\frac{1}{2}^-$	≈ 100	
9.61	$\frac{3}{2}^-$	0	$\frac{1}{2}^-$	79	4.0
		5.24	$\frac{5}{2}^+$	19	1.0
		6.18	$\frac{3}{2}^-$	2	0.1
10.46	$(\frac{9}{2}^+)$	5.24	$\frac{5}{2}^+$	62 ± 6	18 ± 6 [n]
		6.86	$\frac{5}{2}^+$	< 4	< 1.5
		7.28	$\frac{7}{2}^+$	38 ± 6	11 ± 4 [n]
10.48	$(\frac{3}{2})^-$	0	$\frac{1}{2}^-$	60 ± 8	0.21 ± 0.07 [n]
		5.24	$\frac{5}{2}^+$	40 ± 6	0.14 ± 0.01 [n]
		6.18	$\frac{3}{2}^-$	< 4	< 0.02
		9.79	$\frac{3}{2}^+$	< 4	< 0.02
10.94	$\frac{1}{2}^+$	0	$\frac{1}{2}^-$	44 ± 8	14 ± 4
		5.18	$\frac{1}{2}^+$	34 ± 3	11 ± 2
		6.18	$\frac{3}{2}^-$	22 ± 8	7 ± 2

Table 15.18: Radiative decays in ^{15}O [a] (continued)

E_i (MeV)	J^{π}_{i}	E_f (MeV)	J^{π}_{f}	Branch (%)	δ [b]
		6.79	$\frac{3}{2}^+$	< 8	< 3
11.03 [a]	$\frac{1}{2}^-$	0	$\frac{1}{2}^-$	100	1.4 ± 0.4
11.22	$\frac{3}{2}^+$	0	$\frac{1}{2}^-$	74 ± 5	5.5 ± 0.5
		5.18	$\frac{1}{2}^+$	14 ± 5	1.0 ± 0.2
		5.24	$\frac{5}{2}^+$	12 ± 5	0.9 ± 0.2
		6.79	$\frac{3}{2}^+$	< 4	< 0.4
11.57	$\frac{5}{2}^-$	0	$\frac{1}{2}^-$	18 ± 9	0.3 ± 0.2
		5.24	$\frac{5}{2}^+$	63 ± 9	1.2 ± 0.1
		6.18	$\frac{3}{2}^-$	20 ± 9	0.4 ± 0.2
		6.79	$\frac{3}{2}^+$	< 3	< 0.1
11.75 [a]	$\frac{5}{2}^+$	5.24	$\frac{5}{2}^+$	47 ± 7	5 ± 1
		6.18	$\frac{3}{2}^-$	53 ± 7	5 ± 1
11.85 [a]	$\frac{5}{2}^-$	5.24	$\frac{5}{2}^+$	100	1.4 ± 0.6

[a] For references and other comments see Table 15.19 in (1981AJ01).

[b] δ = multipole mixing ratio.

[c] Branches to ^{15}O*(5.18, 5.24) are $< 2.5\%$ each.

[d] Branches to ^{15}O*(5.18, 5.24, 6.18) are $< 3\%$, $< 3\%$ and $< 7\%$, respectively.

[e] Branches to ^{15}O*(0, 5.18, 6.18) are $< 10\%$, $< 4\%$ and $< 0.4\%$, respectively.

[f] Branches to ^{15}O*(5.18, 6.18) are $< 4\%$ and $< 2\%$, respectively.

[g] Branchings shown to ^{15}O*(5.18, 6.18, 6.79) are weighted means of values shown in Table 15.19 of (1981AJ01), recalculated to sum to 100% for all the transitions.

[h] See, however, the comments in reaction 14 of (1981AJ01).

[i] Branchings to ^{15}O*(6.18, 6.86) are $< 1\%$ each.

[j] Unresolved doublet: see Table 15.21, and Table 15.23 in (1981AJ01).

[k] Weighted mean of values shown in Table 15.19 of (1981AJ01).

[l] Intensity $< 25\%$ of transition to ^{15}O*(6.79).

[m] Sum is 0.97 eV, but see Table 15.21 [$\Gamma_\gamma = 1.4$ eV].

[n] Γ_γ values assume J-values in column 2.

4. (a) ^{12}C(^{3}He, γ)^{15}O $\quad Q_m = 12.0758$

   (b) ^{12}C(^{3}He, n)^{14}O $\quad Q_m = -1.1466 \quad E_b = 12.0758$

   (c) ^{12}C(^{3}He, p)^{14}N $\quad Q_m = 4.7789$

(d) ^{12}C(^{3}He, d)^{13}N $\quad Q_{\rm m} = -3.5500$

(e) ^{12}C(^{3}He, t)^{12}N $\quad Q_{\rm m} = -17.357$

(f) ^{12}C(^{3}He, ^{3}He)^{12}C

(g) ^{12}C(^{3}He, α)^{11}C $\quad Q_{\rm m} = 1.8563$

Excitation functions and polarization measurements for these reactions have been measured over a wide range of energies: see Tables 15.20 in (1970AJ04, 1976AJ04), (1981AJ01) and the text below. Observed resonances are displayed in Table 15.19 here.

The $90°$ yield and angular distributions of γ_0, measured from $E(^3\text{He}) = 5.24$ to 13.95 MeV show five resonances attributed to E1 transitions from $J^\pi = \frac{1}{2}^+$ or $\frac{3}{2}^+$, $T = \frac{1}{2}$ states in the GDR characterized by a considerable 3p4h admixture (1978DE33 [also for ω_γ], 1984DE09). See also (1983MAZZ, 1984MAZP). The yield of n_0 (reaction (b)) shows resonances for $E(^3\text{He}) < 10$ MeV and little structure above, to 30.6 MeV: see (1981AJ01) [n_1 and n_{2+3+4} yields are also reported]. See also (1984SH04; Xn).

The yield of protons (reaction (d)) shows some clear resonances below $E(^3\text{He}) = 4.5$ MeV and some uncorrelated structures at higher energies (to $E(^3\text{He}) = 12$ MeV) with the possible exception of states at $E_{\rm res} = 7.8$, 9.2–9.6 and (10.5) MeV. For $E(^3\text{He}) = 16$ to 30.6 MeV no appreciable structure is observed in the p_0, p_1 and p_2 yields: see (1976AJ04). At $E(^3\text{He}) = 33$ MeV A_y is measured for ^{14}N*(0, 2.31, 3.95) (1983LE17, 1983RO22). For reaction (d) see (1981AJ01) and (1983DR06; $E(^3\vec{\text{He}}) = 33$ MeV; g.s.; also dp). See also (1984AB1G; Xd). For reaction (e) see (1976AJ04).

The elastic scattering (reaction (f)) shows some resonant structure near 3, 5 and 6 MeV and some largely uncorrelated structures in the range $E(^3\text{He}) = 16.5$ to 24 MeV. There is some suggestion, however, of two resonances at $E(^3\text{He}) = 17$ and 20 MeV: see (1976AJ04). Resonance-like behavior is also reported for $E(^3\vec{\text{He}}) = 29$ MeV. Polarization measurments are also reported for $E(^3\vec{\text{He}}) = 20.5$ to 32.6 MeV: see (1981AJ01). Recently the elastic yield has been measured for $E(^3\text{He}) = 1.0$ to 2.7 MeV (1980VO1C). See also (1981AS04; n ^{3}He cross section at 910 MeV). The yield of α-particles displays resonance structure below 8 MeV, and broad fluctuations for $E(^3\text{He}) = 12$ to 18.6 MeV: see (1976AJ04). Polarization measurements are reported for $E(^3\vec{\text{He}}) = 33.3$ MeV for the α_0 and α_1 groups: see (1981AJ01). For total cross sections see (1980DE28, 1981PE01). For a fragmentation study at 10.78 GeV/c see (1985AB1H). See also (1983CA07, 1984AA01), (1980TR02, 1981RO1H, 1985BL1B) and (1981LE01, 1984NA06; theor.).

5. ^{12}C(α, n)^{15}O $\quad Q_{\rm m} = -8.5019$

Angular distributions of the n_0 group have been measured for $E_\alpha = 18.4$ to 23.1 MeV: see (1976AJ04). At $E_\alpha = 41$ MeV angular distributions are reported to ^{15}O*(5.24, $6.89 + 7.26$, 9.63, 10.48, 11.71, 12.85, 15.05). ^{15}O*(0, 8.91, 11.1, 12.3, 13.45, 13.72, 14.27, 15.65) are also

Table 15.19: Resonances in $^{12}C + {}^{3}He$ [a]

$E(^3He)$ (MeV ± keV)	Resonant for	$\Gamma_{c.m.}$	J^π	E_x (MeV)
1.21	p_0, p_2		$(\frac{5}{2})^-$	13.04
1.3	$p_0 \rightarrow p_3$			13.1
2.15	n, p_0		$(> \frac{5}{2})$	13.79
2.45 ± 40	$n_0, p_0 \rightarrow p_3$	160 ± 20	$(\frac{1}{2}^-, \frac{3}{2}^-)$	14.03
2.75 ± 40	$n_0, p_1, p_2, {}^3He, \alpha_0$	340 ± 30	$\frac{1}{2}^+$	14.27
(2.87)	p_0, p_2	240		(14.37)
2.990 ± 10	$n_0, p_0, p_1, p_2, p_4, p_5, p_8, {}^3He, \alpha_0$	100 ± 10	$\frac{3}{2}^+, \frac{5}{2}^+$	14.465
3.28 ± 40	$p_0, (p_1, p_2)$	180 ± 40		14.70
3.60 ± 40	p_0, p_1, p_2	400 ± 25		14.95
4.20 ± 10	p_5, p_6, α_0	65 ± 15		15.43
4.37 ± 40	$p_0, p_1, p_2, p_4, p_7, p_8, \alpha_0$	80 ± 25		15.57
4.65 ± 50	n_0			15.79
4.78 ± 50	$^3He, \alpha_0$	350	$\frac{1}{2}^-, \frac{3}{2}^-$	15.90
4.97 ± 20	α_0			16.05
5.03 ± 20	$n_0, {}^3He, \alpha_0$			16.10
5.15 ± 20	$n_0, {}^3He, \alpha_0$			16.19
5.45 ± 50	$^3He, \alpha_0$	170	$\frac{1}{2}^+$	16.43
5.85 ± 50	$n_0, {}^3He$			16.75
6.23 ± 70	γ_0	700 ± 70	$(\frac{1}{2}, \frac{3}{2})^+$	17.05 ± 0.06 [b]
6.80 ± 50	$n_0, {}^3He, \alpha_0$	600	$\frac{1}{2}^-, \frac{3}{2}^-$	17.51
7.40 ± 50	^3He	200	$\frac{1}{2}^-, \frac{3}{2}^-$	17.99
7.70 ± 50	n_0, p_0			18.23
8.25 ± 70	γ_0	520 ± 110	$(\frac{1}{2}, \frac{3}{2})^+$	18.67 ± 0.06 [b]
8.70 ± 50	n_0			19.03
9.38 ± 100	γ_0	780 ± 270	$(\frac{1}{2}, \frac{3}{2})^+$	19.57 ± 0.08
9.80 ± 50	n_0			19.91
10.45 ± 90	$\gamma_0, (p_0)$	970 ± 240	$(\frac{3}{2}, \frac{1}{2})^+$	20.42 ± 0.07 [b]
11.87 ± 80	γ_0	730 ± 120	$(\frac{3}{2}, \frac{1}{2})^+$	21.56 ± 0.07 [b]
(17.0) [c]	^3He	≈ 600	$(\frac{13}{2}^-)$	(26.0)
(20.0) [c]	^3He	≈ 2500	$(\frac{9}{2}^-, \frac{11}{2}^-)$	(28.0)
(21.5)	^3He to $^{12}C^*(15.1)$	≈ 2500		(29.0)

[a] For references see Table 15.21 in (1976AJ04).
[b] (1978DE33, 1984DE09 [see p. 290]); $T = \frac{1}{2}$; $\Gamma_{^3He}/\Gamma_p = 0.17 \pm 0.07$ and 0.09 ± 0.04 for $^{15}O^*(17.05, 18.67)$.
[c] $\Gamma_p = 0.06$ and ≥ 0.1 MeV for $^{15}O^*(26, 28)$.

populated (1981OV01 [uncertainties in E_x are not shown; unresolved states are a problem]). See also (1981HA1J, 1983KO1A, 1984GO03) and ^{16}O in (1986AJ04).

6. ^{12}C(^{6}Li, t)^{15}O $\quad Q_m = -3.7198$

States observed in this reaction are displayed in Table 15.20 (1975BI06: $E(^{6}\text{Li}) = 59.8$ MeV). Comparisons of angular distributions of the triton groups in this reaction and of the ^{3}He groups to analog states in ^{15}N have been made: analog correspondence is established for $(10.48 - 10.70)$, $(12.84 - 13.15$(u)) and $(15.05 - 15.49$(u)) [E_x in ^{15}O, E_x in ^{15}N; u = unresolved] (1975BI06). See also (1976AJ04) for the earlier work, ^{18}F in (1987AJ02) and (1980KR1F).

7. (a) ^{12}C(^{10}B, ^{7}Li)^{15}O $\quad Q_m = -5.712$
(b) ^{12}C(^{11}B, ^{8}Li)^{15}O $\quad Q_m = -15.133$

See (1981AJ01).

8. ^{12}C(^{12}C, ^{9}Be)^{15}O $\quad Q_m = -14.2032$

At $E(^{12}\text{C}) = 187$ MeV, $\theta_{\text{lab}} = 8°$ the spectrum is dominated by ^{15}O*(12.84, 15.05) [assumed $J^\pi = \frac{1}{2}^-, \frac{13}{2}^+$, respectively]. ^{15}O*(7.28) [$J^\pi = \frac{7}{2}^+$] is populated but ^{15}O*(0, 6.79) are not observed. The situation is similar at $E(^{12}\text{C}) = 114$ MeV but at $E(^{12}\text{C}) = 72$ MeV ($\theta_{\text{lab}} = 11°$) ^{15}O*(0, 5.2, 7.28) are populated with comparable intensities: see (1976AJ04).

9. ^{13}C(^{3}He, n)^{15}O $\quad Q_m = 7.1295$

Observed groups are displayed in Table 15.22 of (1981AJ01).

10. ^{14}C(p, π^-)^{15}O $\quad Q_m = -132.1139$

At $E_{\vec{p}} = 183$ MeV differenatial cross sections and A_y are reported for the transitions to ^{15}O*(0, 7.3), the two states strongly excited in the reaction (1982JA05, 1982VI05). See also (1982GR1K, 1984JA1F), (1984BEZZ; theor.) and the "GENERAL" section here.

Table 15.20: Levels of ^{15}O from ^{12}C(^{6}Li, t)^{15}O [a]

E_x (MeV ± keV)	L	E_x (MeV ± keV)	L
5.180 ± 5		11.72 ± 10	[c]
5.242 ± 5	[b]	11.98 ± 10	
6.179 ± 5		12.295 ± 10	[c]
6.790 ± 5		12.60 ± 10	
6.865 ± 5	[b]	12.835 ± 10 [e]	3
7.275 ± 5	[b]	13.55 ± 10	[c,d]
8.285 ± 5	[b]	13.75 ± 10	[c,d]
8.918 ± 5	[c]	14.27 ± 10	[c]
8.978 ± 5		15.05 ± 10 [e]	3
9.485 ± 5		15.48 ± 10	
9.610 ± 5	[c,d]	15.54 ± 10	
9.658 ± 5	[c,d]	15.60 ± 10	[c,d]
9.76 ± 5		15.65 ± 10	
10.27 ± 5		15.80 ± 10	
10.45 ± 5 [e]	3	17.46 ± 20	
11.145 ± 10		17.51 ± 20	
11.56 ± 10			

[a] (1975BI06): $E(^{6}\mathrm{Li}) = 59.8$ MeV.

[b] Angular distributions measured and compared with those of the (^{6}Li, ^{3}He) reaction to analog states in ^{15}N.

[c] Angular distributions measured: analog states in ^{15}N not known.

[d] Unresolved in angular distribution.

[e] $\Gamma_{\gamma}/\Gamma < 0.13$.

11. ^{14}N(p, γ)^{15}O $\qquad Q_m = 7.2970$

Observed resonances in the yield of γ-rays are listed in Table 15.21. Branching ratios are displayed in Table 15.18.

The cross section increases from $(8.5 \pm 3.7) \times 10^{-12}$ b at 100 keV to $(140 \pm 30) \times 10^{-12}$ b at 135 keV. Extrapolation from the $E_p = 0.28$ MeV resonance gives $S(0) = 2.75 \pm 0.50$ keV · b, with zero slope to $E_p = 0.05$ MeV. Measurements of E_γ lead to $E_x = 5183 \pm 1$, 5240.9 ± 0.4, 6175 ± 2, 6794 ± 2, 6858 ± 2, 8284.1 ± 0.8, 8922 ± 2 and 8978 ± 2 keV.

The 90° yield γ_0 curve has been measured for $E_p = 2.2$ to 19.0 MeV: resonances are observed over most of the range in the γ_0 yield. The $(\gamma_1 + \gamma_2)$ yield is relatively weak. For $E_p = 18$ to 28 MeV the excitation function for γ_0 decreases smoothly with energy: there is no evidence for structures. $\tau_m = 8.2 \pm 1.0$, > 3000, < 2.5, 16.0 ± 2.5 and 750 ± 200 fsec for ^{15}O*(5.18, 5.24, 6.18, 6.86, 7.28), respectively. For references and additional discussions see (1976AJ04, 1981AJ01). See also (1982KR05, BL84E), (1980WE1D, 1982WE01) and (1980BA2M, 1982BA80, 1984BO1Q, 1984MA2J, 1984TR1C; astrophys.).

Table 15.21: Resonances in ^{14}N + p [a]

E_p (keV)	Γ_{lab} (keV)	$\omega\Gamma_\gamma$ (eV)	Particles out	J^π	E_x (MeV)
278.1 ± 0.4	1.3 ± 0.2	0.014 [b]	γ	$\frac{1}{2}^+$	7.5564
1058.0 ± 0.5	3.9 ± 0.7	0.95	γ	$\frac{3}{2}^+$	8.2839
1550 ± 6	34	0.16	γ	$\frac{1}{2}^+$	8.743
1742 ± 2 [c]	3.5 ± 0.3	0.16	γ, p_0	$\frac{5}{2}^+$	8.922
1742 ± 2 [c]	8	0.06	γ, p_0	$\frac{1}{2}^+$	8.922
1806.4 ± 1.5	4.2 ± 0.4	0.52	γ	$(\frac{3}{2})^-$	8.9821
2348 ± 3	10.8 ± 0.5	2.4	γ	$\frac{5}{2}^-$	9.488
2368 ± 32	300 ± 26		γ, p_0	$(\frac{3}{2}^+)$	9.506
2479 ± 1.7	9.4 ± 0.5	3.3	γ	$\frac{3}{2}^-$	9.609
2537 ± 4	2 ± 1		p_0	$(\frac{7}{2}, \frac{9}{2})^-$	9.664
3209	3 ± 1		p_0	$(\frac{5}{2}^-)$	10.291
3215	12 ± 2		p_0	$\frac{5}{2}^+$	10.296
3392 ± 5	< 2	0.029 ± 0.010	γ_2, γ_6	$(\frac{9}{2}^+)$	10.461
3410	27 ± 5		γ_0, γ_2, p_0	$(\frac{3}{2})^-$	10.478
3440	150 ± 45		γ, p_0	$(\frac{3}{2})^+$	10.506
3880 ± 15	97		p_0	$\frac{7}{2}^+$	10.916
		Γ_{γ_0} (eV)			
3903 ± 3	106 ± 5	14 ± 3	γ, p_0, p_1	$\frac{1}{2}^+$	10.938

Table 15.21: Resonances in ^{14}N + p [a] (continued)

E_p (keV)	Γ_{lab} (keV)	$\omega\Gamma_\gamma$ (eV)	Particles out	J^π	E_x (MeV)
3996 ± 3	27 ± 2	1.4 ± 0.4	γ, p_0, p_1	$\frac{1}{2}^-$	11.025
4130 ± 15	< 10		p_0		11.150
4203 ± 3	43 ± 4	5.2 ± 0.4	γ, p_0	$\frac{3}{2}^+$	11.218
4575 ± 15	< 10		p_0		11.565
4580 ± 15	21 ± 15	0.7 ± 0.2	γ, p_0	$\frac{5}{2}^-$	11.569
4580	150		γ		11.57
4630 ± 15	86 ± 50		γ, p_0	$(\frac{3}{2}, \frac{1}{2})^-$	11.616
4740 ± 15	< 10		p_0		11.718
4772 ± 3	106 ± 5		γ, p_0, p_1	$\frac{5}{2}^+$	11.748
4877 ± 3	70 ± 3		γ, p_0, p_1	$\frac{5}{2}^-$	11.846
5025 ± 15	21 ± 5		p_0, p_1	$\frac{5}{2}^-$	11.984
5180 ± 15	214 ± 50		p_0, p_1	$\frac{5}{2}^+$	12.129
5280 ± 20	106 ± 50		p_1 [d]		12.222
5547 ± 3	82 ± 4		p_1, p_2	$\frac{5}{2}^-(\frac{3}{2}^-)$	12.471
5900	≈ 250		γ		12.80
5937 ± 3	17 ± 1		p_2 [e]		12.835
(6100)	30		$p_0 \rightarrow p_2$, α_0	$\frac{5}{2}^+$	(12.99)
6123 ± 3	230 ± 30		p_2 [e]		13.008
6141 ± 3	43 ± 30		p_2 [e]		13.025
6600	≈ 1000		γ, (p_2, α_0)	$(\frac{1}{2}, \frac{3}{2})^+$	13.45
6640			(p_0), (p_2)	$(\frac{3}{2}^+)$	13.49
6760			α_0	$\frac{5}{2}^+$	13.60
6870			p_2	$\frac{3}{2}^-$	13.70
6960			p_1, p_2, p_4, α_0	$\frac{3}{2}^-$	13.79
7050	≈ 150		γ		13.87
7370			α_0	$\frac{5}{2}^-$	14.17
7500	≈ 500		n, $p_0 \rightarrow p_2$, ^{3}He, α		14.29
7550			α_0	$\frac{5}{2}^+$	14.34
7700			n, p_0, α_0		14.48
7950	170 ± 50		n		14.71
8200			n, $p_2 \rightarrow p_6$, ^{3}He, α_0, α_1		14.94

Table 15.21: Resonances in $^{14}N + p$ [a] (continued)

E_p (keV)	Γ_{lab} (keV)	$\omega\Gamma_\gamma$ (eV)	Particles out	J^π	E_x (MeV)
8400	≈ 1000		γ	$(\frac{1}{2}, \frac{3}{2})^+$	15.1
9050			n		15.74
[f]					
9370 ± 20	≈ 200		n, p_2, p_8, α_1		16.04
9580 ± 20	≈ 150		p_0, p_1, $p_3 \rightarrow p_7$, p_9, ^3He, α_1		16.23
9850 ± 50	600 ± 100		n, ^3He		16.48
10300	≈ 1000		γ	$(\frac{1}{2}, \frac{3}{2})^+$	16.9
10600			$p_4 \rightarrow p_9$, α_0, α_1		17.2
11900	≈ 1000		γ	$(\frac{1}{2}, \frac{3}{2})^+$	18.4
14200	≈ 2000		γ	$(\frac{1}{2}, \frac{3}{2})^+$	20.5
15800	≈ 2000		γ	$(\frac{1}{2}, \frac{3}{2})^+$	22.0

[a] For references see (1970AJ04, 1976AJ04, 1981AJ01). See also Table 15.18 here.
[b] ± 0.001 (1982BE29).
[c] Separated by 0.5 ± 0.5 keV: see, however, reaction 14 in (1981AJ01).
[d] Weak.
[e] Strong.
[f] See footnote [e] in Table 15.23 of (1981AJ01).

12. $^{14}N(p, n)^{14}O$ $\quad Q_m = -5.9255$ $\quad E_b = 7.2970$

The excitation function has been measured for $E_p = 6.3$ to 12 MeV: see (1970AJ04). Observed resonances are displayed in Table 15.21. The cross section [obtained by measuring the 2.31 MeV γ-rays from the $^{14}O(\beta^+)$ decay] is reported at 12 energies in the range $E_p = 7$ to 22 MeV (1981DY03). The ratio of the cross section to $^{14}O_{g.s.}$ to that for the analog state $^{14}N^*(2.31)$ [from the (p, p′) reaction] has been determined at $E_p = 35$ MeV (1984TA02). See also ^{14}O.

13. (a) $^{14}N(p, p)^{14}N$ $\quad E_b = 7.2970$

(b) $^{14}N(p, d)^{13}N$ $\quad Q_m = -8.3289$

The yields of elastic and inelastic protons, and of 2.31 MeV γ-rays, have been studied at many energies: see (1959AJ76, 1970AJ04, 1976AJ04). Observed resonances are displayed in Table

15.21. At higher energies excitation functions have been measured for the p_0, p_1 and p_2 groups for $E_p = 17$ to 26.5 MeV: there is no evidence for resonant behavior but the p_1 yield shows a large increase between $E_p = 20$ and 23 MeV. Total cross sections for the $p_0 \rightarrow p_9$ groups have been measured at $E_p = 8.6$, 10.6, 12.6 and 14.6 MeV. See (1981AJ01) and ^{14}N.

Polarization measurements have been reported for $E_p = 3.0$ to 155 MeV: see Table 15.25 in (1970AJ04), and (1976AJ04). A_y measurements have also been reported at $E_{\vec{p}} = 21$ MeV (1982AO05; to ^{14}N*(0, 2.31, 3.95) and ^{13}N*(0, 3.51)) and at 159.4 MeV (1983TA12; p_0, p_1, p_2). See also (1980LE28), (1981DY03, 1984RE14) and (1984AN1M; theor.).

14. ^{14}N(p, ^{3}He)^{12}C $\quad Q_m = -4.7789 \quad E_b = 7.2970$

Excitation functions for the ground-state group have been measured at $E_p = 7$ to 11 MeV: some resonant structure is indicated [see Table 15.21]. See also (1976AJ04).

15. ^{14}N(p, α)^{11}C $\quad Q_m = -2.9226 \quad E_b = 7.2970$

Excitation functions and total cross-section measurements have been carried out for the α_0 group for $E_p = 3.8$ to 45 MeV: see (1976AJ04). Fairly sharp structures persist until $E_p = 15$ MeV: see Table 15.21 here and footnote [e] in Table 15.23 of (1981AJ01).

16. ^{14}N(d, n)^{15}O $\quad Q_m = 5.0724$

Angular distributions have been studied at many energies in the range $E_d = 0.9$ to 11.8 MeV: see Table 15.27 in (1970AJ04), and (1976AJ04). $\tau_m = 3.2 \pm 0.5$ psec, < 28 fsec, 0.70 ± 0.15 psec, respectively for ^{15}O*(5.24, 6.79, 7.28): see (1970AJ04). $K_y^{y'}(0°)$ have been measured for $E_{\vec{d}} \approx 7.5$ to ≈ 14 MeV for the $\vec{n}$ to an unresolved group involving at least ^{15}O*(6.79, 7.55) (1981LI23). See also Table 15.22, (1983MU13; theor.) and ^{16}O in (1986AJ04).

17. ^{14}N(^{3}He, d)^{15}O $\quad E_m = 1.8034$

See Table 15.22 and (1976AJ04). See also (1985HA01) and ^{16}F in (1986AJ04).

18. ^{14}N(α, t)^{15}O $\quad Q_m = -12.5171$

See (1976AJ04).

Table 15.22: Levels of ^{15}O from ^{14}N(d, n) and ^{14}N(^{3}He, d)

E_x in ^{15}O [a] (MeV $\pm$ keV)	l_p	S [c]	J^π
0	1 [d]	0.87	$\frac{1}{2}^-$
5.18	(0) [e]	0	$\frac{1}{2}^+$
5.2410 ± 0.5 [b]	2 [d]	(0.03)	$\frac{5}{2}^+$
6.180 ± 4 [b]	1 [d]	0.04	$\frac{3}{2}^-$
6.79	0 [d]	≤ 0.3	$\frac{3}{2}^+$
6.8598 ± 1.0 [b]	2 [d]	0.4	$\frac{5}{2}^+$
7.2762 ± 0.6 [b]	2 [d]	0.42	$\frac{7}{2}^+$
7.56	0 [d]	≤ 0.4	$\frac{1}{2}^+$
8.28	0 [e]		$\frac{3}{2}^+$

[a] Nominal energies if uncertainty is not indicated.
[b] From γ-ray measurements: see Table 15.26 in (1976AJ04) for references for these and other measurements displayed in this table.
[c] See (1971BO35: (d, n)) also for a review of spectroscopic factors derived from other work.
[d] From both (d, n) and (^{3}He, d) work: see (1976AJ04).
[e] From (^{3}He, d).

19. (a) ^{14}N(^{11}B, ^{10}Be)^{15}O $\qquad Q_m = -3.9319$
(b) ^{14}N(^{13}C, ^{12}B)^{15}O $\qquad Q_m = -10.237$

Differential cross sections are reported for ^{15}O*(0, 6.86, 7.28) at $E(^{11}\text{B}) = 115$ MeV and for $^{15}\text{O}_{\text{g.s.}}$ at $E(^{13}\text{C}) = 105$ MeV (1980PR09).

20. ^{15}N(π^+, π^0)^{15}O $\qquad Q_m = 1.850$

Angular distributions to $^{15}\text{O}_{\text{g.s.}}$ have been studied at $E_{\pi^+} = 48$ MeV (1984CO04) and 165 MeV (1982DO10). At 48 MeV a deep forward-angle minimum is observed. It appears to reflect the analogous minimum in the free-nucleon cross section which is caused by cancellation between the s- and p-wave π-nucleon amplitudes (1984CO04).

21. ^{15}N(p, n)^{15}O $\qquad Q_m = -3.5363$

Angular distributions have been measured for the n_0 group at $E_p = 3.95$ to 18.5 MeV [and for the n_2 group at $E_p = 5.5$ MeV]: see (1981AJ01) for the earlier work, (1981MU01: $E_p = 5.5$ to 9.3 MeV) and (1981BY01; 9.1 to 15.6 MeV). At $E_p = 160$ MeV transitions are observed to ^{15}O*(0, 6.2, (9.6)): the transition to ^{15}O*(6.2) [$\frac{3}{2}^-$] is significantly more quenched than the $\frac{1}{2} \rightarrow \frac{1}{2}$ transition, as is also the case in ^{13}C(p, n) (1985GO02). At $E_p = 135$ MeV ^{15}O*(10.5) is weakly populated (1985PAZV). See also (1981BY1B, 1981WA1F, 1984TAZS, 1985KI1L), and (1983BY03) in ^{16}O (1986AJ04).

22. ^{15}N(^{3}He, t)^{15}O $\qquad Q_m = -2.7726$

Angular distributions for the t_0, t_{1+2}, t_3, t_{4+5}, t_6 and t_7 groups have been studied for $E(^3\text{He}) = 16.5$ to 44.6 MeV: see (1976AJ04).

23. ^{16}O(γ, n)^{15}O $\qquad Q_m = -15.6639$

The spectrum of photoneutrons has been investigated at many energies. Measurements over the giant dipole resonance region show the predominant strength is to the $J^\pi = \frac{1}{2}^-$ and $\frac{3}{2}^-$ states $E_x = 0$ and 6.18 MeV, consistent with the basic validity of the single-particle, single-hole theory of photoexcitation in ^{16}O. However, the positive-parity states at $E_x = 5.18$, 5.24, 6.86 MeV are also populated suggesting some more complicated excitations in ^{16}O: see (1970AJ04, 1976AJ04). Differential cross sections for the n_0 group have been measured from threshold to $E_\gamma = 28$ MeV [see (1976AJ04)] and at $E_\gamma = 60$ to 160 MeV (1980GO13, 1982GO09, 1982SC02 [also ^{15}O*(6.18); no appreciable strength in the 5.2 MeV doublet]). In the energy range $E_\gamma = 30 - 35$ MeV, $\approx 4\%$ of the isovector energy-weighted sum rule is found in the (γ, n_0) channel (1984KU21). See also (1981AJ01), ^{16}O in (1986AJ04) and (1981GA1M, 1982LO1B).

24. (a) ^{16}O(π^+, p)^{15}O $\qquad Q_m = 124.6857$

(b) ^{16}O(π^+, π^+n)^{15}O $\qquad Q_m = -15.6639$

For reaction (a) see (1982DO01). At $E_{\pi^+} = 2.0$ GeV/c differential cross sections have been determined for the transition to ^{15}N*(6.2) (1983KI01). See also (1982LO1B).

25. ^{16}O(p, d)^{15}O $\qquad Q_m = -13.4393$

Angular distributions have been reported at many energies for $E_p = 18.5$ to 155.6 MeV [see Table 15.30 in (1970AJ04), and (1976AJ04)] and at $E_{\vec{p}} = 65$ MeV (1980HO18; d_0). At those energies ^{15}O*(0, 6.18) are primarily populated. At $E_p = 800$ MeV (1984SM04) report the population of ^{15}O*(0, $5.18+5.24$, 6.18, $7.28+7.56$, $8.84+0.15$, 10.42 ± 0.15, 10.87 ± 0.15, 12.21 ± 0.15, 13.59 ± 0.15, 19.0 ± 0.2, 21.1 ± 0.2) [the last states have $\Gamma \geq 0.8$ MeV]. See also (1981LI1B), (1982LO1B) and ^{17}F in (1986AJ04).

26. ^{16}O(d, t)^{15}O $\quad Q_m = -9.4066$

Angular distributions have been reported at a number of energies in the range $E_d = 20$ to 52 MeV: see (1981AJ01) and reaction 62 in ^{15}N here. See also ^{18}F in (1983AJ01).

27. (a) ^{16}O(^{3}He, α)^{15}O $\quad Q_m = 4.9139$
(b) ^{16}O(^{3}He, tp)^{15}O $\quad Q_m = -14.9002$

The $p_{1/2}$ and $p_{3/2}$ hole states ^{15}O*(0, 6.18) are strongly populated. Information on these and other states are displayed in Table 15.25 of (1981AJ01). Angular distributions have been measured at energies up to $E(^3\text{He}) = 217$ MeV: see (1981AJ01). Branching ratios and multipole mixing ratios are displayed in Table 15.18. (1978BE73) report τ_m of ^{15}O*(5.24) $= 3.25 \pm 0.30$ psec, $|g| = 0.260 \pm 0.028$. (1983BI10) determine g $= +0.17 \pm 0.07$. For reaction (b) see (1984ST10; $E(^3\text{He}) = 81$ MeV) and ^{16}O. See also ^{19}Ne in (1983AJ01), (1982AB04), (1983GO2D; applied) and (1982LO1B).

28. (a) ^{16}O(^{10}B, ^{11}B)^{15}O $\quad Q_m = -4.2098$
(b) ^{16}O(^{12}C, ^{13}C)^{15}O $\quad Q_m = -10.7176$

Angular distributions involving ^{15}O$_{\text{g.s.}}$ have been investigated at $E(^{10}\text{B}) = 100$ MeV: see (1981AJ01). See also (1983OS08; theor.). For reaction (b) see (1984FL1B; theor.).

29. ^{17}O(p, t)^{15}O $\quad Q_m = -11.3257$

At $E_p = 39.8$ MeV angular distributions of t_0 and t_3 groups have been compared to those of the ^{3}He groups to the analog states in ^{15}N. At $E_p = 45$ MeV a state, assumed to be the $J^\pi = \frac{5}{2}^+$, $T = \frac{3}{2}$ analog of ^{15}C*(0.74), is observed at $E_x = 12.255 \pm 0.013$ MeV, $\Gamma_{\text{c.m.}} = 135 \pm 15$ keV. The state decays by proton emission to the $T = 1, 0^+$ state ^{14}N*(2.31) [the population of some $T = \frac{1}{2}$ states is also reported]: see (1981AJ01). See also (1984VOZY).

30. ^{19}F(^{3}He, ^{7}Li)^{15}O $\qquad Q_{\rm m} = -4.318$

See (1976AJ04).

^{15}F
(Fig. 13)

GENERAL: (See also (1981AJ01).)

See (1982AW02, 1983ANZQ; theor.). See the latter also for discussions of higher Z, $A = 15$ nuclei.

Mass of ^{15}F: The atomic mass excess of ^{15}F is 16.77 ± 0.13 MeV. ^{15}F is unstable with respect to breakup into ^{14}O + p by 1.47 MeV: see (1981AJ01).

1. ^{12}C(^{3}He, π^-)^{15}F $\qquad Q_{\rm m} = -141.41$

This reaction is not observed at $E(^3{\rm He}) = 235$ MeV, $\theta_{\rm lab} = 20°$: the differential cross section (c.m.) is $\leq 4 \times 10^{-11}$ b (1984BI08).

Table 15.23: Energy levels of ^{15}F

$E_{\rm x}$ in ^{15}F (MeV)	$J^\pi; T$	$\Gamma_{\rm c.m.}$ (MeV)	Decay	Reaction
g.s.	$(\frac{1}{2}^+); \frac{3}{2}$	1.0 ± 0.2	p	2
1.3 ± 0.1	$(\frac{5}{2}^+); \frac{3}{2}$	0.24 ± 0.03	p	2

2. ^{20}Ne(^{3}He, ^{8}Li)^{15}F $\qquad Q_{\rm m} = -29.83$

This reaction has been studied at $E(^3{\rm He}) = 74.5$ MeV (1978BE26) and 75.4 and 87.8 MeV (1978KE06). Two groups are observed: the ground state [$\Gamma_{\rm c.m.} = 0.8 \pm 0.3$ MeV (1978KE06), 1.2 ± 0.3 MeV (1978BE26)] and a relatively strongly populated state, presumed to be the mirror of ^{15}C*(0.74) [$J^\pi = \frac{5}{2}^+$], with $E_{\rm x} = 1.3 \pm 0.1$ MeV (1978KE06), 1.2 ± 0.2 MeV (1978BE26) and $\Gamma_{\rm c.m.} = 0.5 \pm 0.2$ MeV (1978KE06), 0.24 ± 0.03 MeV (1978BE26). The differential cross section for populating ^{15}F*(1.3) is 250 ± 20 nb/sr at $10°$ and $E(^3{\rm He}) = 74.5$ MeV (1978BE26) and 80 ± 25 nb/sr at $9°$, 87.8 MeV (1978KE06). At $E(^3{\rm He}) = 75.4$ MeV, $\theta = 9°$, the ground state is populated with 8 ± 4 nb/sr (1978KE06).

References

(Closed 01 June 1985)

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

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

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

1971BO35 J. Bommer, H. Fuchs, K. Grabisch, U. Janetzki and G. Roschert, Nucl. Phys. A172 (1971) 618

1973TS02 I. Tserruya, B. Rosner and K. Bethge, Nucl. Phys. A213 (1973) 22

1975BI06 H.G. Bingham, M.L. Halbert, D.C. Hensley, E. Newman, K.W. Kemper and L.A. Charlton, Phys. Rev. C11 (1975) 1913

1975MO28 R. Moreh and O. Shahal, Nucl. Phys. A252 (1975) 429

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

1976AL16 D.E. Alburger, Nucl. Instrum. Meth.136 (1976) 323

1976BE1B Beukens, Unpublished Ph.D. Thesis, Univ. Toronto (1976)

1978BE26 W. Benenson, E. Kashy, A.G. Ledebuhr, R.C. Pardo, R.G.H. Robertson and L.W. Robinson, Phys. Rev. C17 (1978) 1939

1978BE73 F.A. Beck, T. Byrski, G.J. Costa, W.L. Randolph and J.P. Vivien, Hyperfine Interactions 4 (1978) 181

1978DE23 A. Degre, M. Schaeffer, G. Bonneaud and I. Linck, Nucl. Phys. A306 (1978) 77

1978DE33 W. Del Bianco, J.C. Kim and G. Kajrys, Can. J. Phys. 56 (1978) 1054

1978GR16 K.A. Gridnev, V.M. Semenov and E.F. Hefter, Izv. Akad. Nauk SSSR, Ser. Fiz. 42 (1978) 1540; Bull. Acad. Sci. USSR, Phys. Ser. 42 (1978) 164

1978KE06 G.J. KeKelis, M.S. Zisman, D.K. Scott, R. Jahn, D.J. Vieira, J. Cerny and F. Ajzenberg-Selove, Phys. Rev. C17 (1978) 1929.

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

1978WU07 P. Wust, W. von Oertzen, H. Ossenbrink, H. Lettau, H.G. Bohlen, W. Saathoff, K. Wannebo and C.A. Wiedner, S. Afr. J. Phys. 1 (1978) 226

1979AL23 D.E. Alburger and D.J. Millener, Phys. Rev. C20 (1979) 1891

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

1979GO27 A.M. Gorbatov, Yu.N. Krylov and A.B. Solovei, Yad. Fiz. (USSR) 30 (1979) 1487; Sov. J. Nucl. Phys. 30 (1979) 770

1979HA38 L.H. Harwood and K.W. Kemper, Phys. Rev. C20 (1979) 1383

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

1979ZA07 J.G. Zabolitzk and, W. Ey, Nucl. Phys. A328 (1979) 507

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

1980AL1F Alburger, Transactions of the N.Y. Acad. of Sci. 40 (1980) 1

1980AS01 J. Asher, D.W. Bennett, B.A. Brown, H.A. Doubt and M.A. Grace, J. Phys. G6 (1980) 251

1980AU1D Audouze, Chieze and Vangioni-Flam, Astron. Astrophys. 91 (1980) 49

1980BA1P J.N. Bahcall, S.H. Lubow, W.F. Huebner, N.H. Magee, A.L. Merts, M.F. Argo, P.D. Parker, B. Rozsnyai and R.K. Ulrich, Phys. Rev. Lett. 45 (1980) 945

1980BA1Y Balashov, Barz, Rotter and Wunsch, Proc. Int. Conf. on Nucl. Phys. (Berkeley) (1980) 143

1980BA2M Bahcall, Proc. Int. School in Nucl. Phys., Progress in Particle and Nucl. Phys., Erice, Italy, Vol. 6 (1980) 111

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

1980DE28 R.M. DeVries and J.C. Peng, Phys. Rev. C22 (1980) 1055

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

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

1980GO1Q Gorbatov, Krylov and Solovei, Yad. Fiz. 32 (1980) 636

1980GR12 R.C. Greenwood and R.E. Chrien, Nucl. Instrum. Meth. Phys. Res. 175 (1980) 515

1980HI1C Hirsekorn, Z. Phys. A297 (1980) 141

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

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

1980KE1K Kennet, Prestwich, Islam and Kerr, Nucl. Instrum. Meth. Phys. Res. 174 (1980) 539

1980KH1C Khodyachikh, Vatset, Dogyust and Kirichenko, Ukr. Fiz. Zh. 25 (1980) 229; Phys. Abs. 47465 (1980)

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

1980KR1F Kraus and Linck, Proc. Int. Conf. on Nucl. Phys. (Berkeley) (1980) 555

1980LE28 A.A. Levkovsky and E.F. Dreiman, Yad. Fiz. 31 (1980) 569; Sov. J. Nucl. Phys. 31 (1980) 295

1980MA28 Th.A.J. Maris, M.R. Teodoro and E.A. Veit, Phys. Lett. B94 (1980) 6

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

1980PR06 F.W. Prosser, Jr., R.A. Racca, K. Daneshvar, D.F. Geesaman, W. Henning, D.G. Kovar, K.E. Rehm and S.L. Tabor, Phys. Rev. C21 (1980) 1819

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

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

1980SC1E Schoch and Goringer, Proc. Int. Conf. on Nucl. Phys. (Berkeley) (1980) 682

1980SC27 B. Schoch, H. Goringer, P. Jennewein, F. Klein, G. Luhrs and F. Zettl, Phys. Rev. C22 (1980) 2630

1980SE1E Sellschop, Bull. Amer. Phys. Soc. 25 (1980) 800

1980TR02 H.-J. Trost, A. Schwarz, U. Feindt, F.H. Heimlich, S. Heinzel, J. Hintze, F. Korber, R. Lekebusch, P. Lezoch, G. Mock et al., Nucl. Phys. A337 (1980) 377

1980VO1C Voigts and Friedland, S. African J. Phys. 3 (1980) 61

1980VO1D von Oertzen, Nukleonika 25 (1980) 939

1980WA1M Wannier, Ann. Rev. Astro. Astrophys. 18 (1980) 399

1980WE1D Weller and Roberson, Rev. Mod. Phys. 52 (1980) 699

1980ZE02 A.F. Zeller, K.W. Kemper, T.R. Ophel and A. Johnston, Nucl. Phys. A344 (1980) 307

1981AB1A Abe, RIFP-421 (1981) 428

1981AD1F Adams and Smith, Astrophys. J. 247 (198) L123

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

1981AS04 E. Aslanides, P. Fassnacht, G. Dellacasa, M. Gallio and J.W.N. Tuyn, Phys. Rev. C23 (1981) 1826

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

1981BA1P Bauer et al., Proc. Versailles Conf. (19801) p. 321

1981BA2G Bahcall, Prog. Part. Nucl. Phys. 6 (1981) 111

1981BE19 T.L. Belyaeva, N.S. Zelenskaya, L.Z. Ismail, V.M. Lebedev, A.V. Spassky and I.B. Teplov, Yad. Fiz. 33 (1981) 294; Sov. J. Nucl. Phys. 33 (1981) 153

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

1981BY01 R.C. Byrd, C.E. Floyd, K. Murphy, P.P. Guss, R.L. Walter and S.R. Cotanch, Nucl. Phys. A351 (1981) 189

1981BY1B Byrd and Walter, Santa Fe 1980, AIP Conf. Proc. 69 (1981) 1475

1981DE1W Deutch, Lu and Tang, Hyperfine Interactions 9 (1981) 169

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

1981FR23 R.M. Freeman, C. Beck, F. Haas, B. Heusch, H. Bohn, U. Kaufl, K.A. Eberhard, H. Puchta, T. Senftleben and W. Trautmann, Phys. Rev. C24 (1981) 2390

1981GA1M Gari and Hebach, Phys. Rept. 72 (1981) 1

1981GO1D Goulding et al., Bull. Amer. Phys. Soc. 26 (1981) 623

1981GR08 K. Grotowski, P. Belery, Th. Delbar, Y. El Masri, Gh. Gregoire, R. Janssens, J. Vervier, G. Paic, M. Albinska, J. Albinski et al., Phys. Rev. C23 (1981) 2513

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

1981HA1J Hamill et al., Bull. Amer. Phys. Soc. 26 (1981) 579

1981HAZJ R.C. Haight and S.M. Grimes, Bull. Amer. Phys. Soc. 26 (1981) 1138, CE1

1981HU01 M.S. Hussein, K.W. McVoy and D. Saloner, Phys. Lett. B98 (1981) 162

1981HU1D J. Hufner and M.C. Nemes, Phys. Rev. C23 (1981) 2538

1981IS07 M.A. Islam, W.V. Prestwich and T.J. Kennett, Nucl. Instrum. Meth. 188 (1981) 243

1981IS11 B.S. Ishkhanov, I.M. Kapitonov, V.G. Neudachin and R.A. Eramzhyan, Fiz. Elem. Chastits At. Yadra 12 (1981) 905; Sov. J. Part. Nucl. 12 (1981) 362

1981KA04 C. Kalbach and F.M. Mann, Phys. Rev. C23 (1981) 112

1981KE02 T.J. Kennett, M.A. Islam and W.V. Prestwich, Can. J. Phys. 59 (1981) 93

1981KO07 J.J. Kolata, C. Beck, R.M. Freeman, F. Haas and B. Heusch, Phys. Rev. C23 (1981) 1056

1981LE01 P. Lezoch, H.J. Trost, Md.A. Rahman and U. Strohbusch, Phys. Lett. B98 (1981) 158

1981LE06 E. Levin and J.M. Eisenberg, Nucl. Phys. A355 (1981) 277

1981LI19 R.A. Lindgren, M.A. Plum, W.J. Gerace, R.S. Hicks, B. Parker, G.A. Peterson, R. Singhal, C.F. Williamson, X.K. Maruyama and F. Petrovich, Phys. Rev. Lett. 47 (1981) 1266

1981LI1B Liljestrand et al., Proc. Versailles Conf. (1981) 544

1981LI23 P.W. Lisowski, R.C. Byrd, G. Mack, W. Tornow, R.L. Walter, T.B. Clegg and F.D. Santos, Phys. Rev. C24 (1981) 1852

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

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

1981ME1H Meyer-ter-Vehn, Phys. Rept. 74 (1981) 323

1981MO09 R. Moreh, W.C. Sellyey and R. Vodhanel, Phys. Rev. C23 (1981) 988; Erratum Phys. Rev. C24 (1981) 2394

1981MU01 K. Murphy, R.C. Byrd, P.P. Guss, C.E. Floyd and R.L. Walter, Nucl. Phys. A355 (1981) 1

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

1981NO1F J.V. Noble, Nucl. Phys. A368 (1981) 477

1981OS04 E. Oset and D. Strottman, Nucl. Phys. A355 (1981) 437

1981OS05 E. Oset, Nucl. Phys. A356 (1981) 413

1981OV01 D.J. Overway and W.C. Parkinson, Nucl. Phys. A363 (1981) 93

1981PE01 J.C. Peng, R.M. DeVries and N.J. DiGiacomo, Phys. Lett. B98 (1981) 244

1981RE04 G.W. Reynaud and F. Tabakin, Phys. Rev. C23 (1981) 2652

1981RO1H Roman, Santa Fe 1980, AIP Conf. Proc.69 (1981) 282

1981SC1P Scott, MSUCL-359 (1981)

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

1981SH17 V.R. Shaginyan, Yad. Fiz. 33 (1981) 1473; Sov. J. Nucl. Phys. 33 (1981) 790

1981SU03 T. Suzuki, H. Hyuga, A. Arima and K. Yazaki, Nucl. Phys. A358 (1981) 421c

1981SU08 T. Suzuki, H. Hyuga, A. Arima and K. Yazaki, Phys. Lett. B106 (1981) 19

1981TA21 M. Tanaka, J. Kawa, T. Fukuda, T. Shimoda, K. Katori, S. Nakayama, I. Miura and H. Ogata, Phys. Lett. B106 (1981) 293

1981VA1D van Driel et al., Kernfysisch Versneller Inst. (KVI) 235 (1980) 1

1981VO01 C. Volant and S. Gary, J. Phys. (Paris) 42 (1981) 27

1981VO06 W. von Oertzen, E.R. Flynn, J.C. Peng, J.W. Sunier and R.E. Brown, Z. Phys. A301 (1981) 365

1981WA06 E.K. Warburton and D.E. Alburger, Phys. Rev. C23 (1981) 1234

1981WA1F Walter et al., Santa Fe 1980 AIP Conf. proc. 69 (1981) 1326

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

1981WA1K Wada, Shibata and Torii, Nature 292 (1981) 327

1981WA1N Wannier, Linke and Penzias, Astrophys. J. 247 (1981) 522; Erratum Astrophys. J. 254 (1982) 419

1981WA1Q R.K. Wallace and S.E. Woosley, Astrophys. J. Suppl. 45 (1981) 389

1981WI1E Wienhard et al., Santa Fe 1980, AIP Conf. Proc. 69 (1981) 747

1982AB04 M.S. Abdel-Wahab, L. Potvin, R. Roy, P. Bricault, R. Larue, D. Pouliot, C. Rioux and R.J. Slobodrian, Can. J. Phys. 60 (1982) 1595

1982AJ01 F. Ajzenberg-Selove, Nucl. Phys. A375 (1982) 1

1982AM02 L.L. Ames, Phys. Rev. C25 (1982) 729

1982AO05 Y. Aoki, S. Kunori, K. Nagano, Y. Toba and K. Yagi, Nucl. Phys. A382 (1982) 269

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

1982BA03 K. Bangert, U.E.P. Berg, G. Junghans, R. Stock and K. Wienhard, Nucl. Phys. A376 (1982) 15

1982BA80 J.N. Bahcall, W.F. Huebner, S.H. Lubow, P.D. Parker and R.K. Ulrich, Rev. Mod. Phys. 54 (1982) 767

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

1982BE1R Berti and Drigo, Nucl. Instrum. Meth. Phys. Res. 201 (1982) 473

1982BE29 H.W. Becker, W.E. Kieser, C. Rolfs, H.P. Trautvetter and M. Wiescher, Z. Phys. A305 (1982) 319

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

1982BO28 S. Boffi, C. Giusti and F.D. Pacati, Nucl. Phys. A386 (1982) 599

1982CA12 E. Caurier and A. Poves, Nucl. Phys. A385 (1982) 407

1982CO1D Cowan and Haxton, Science 216 (1982) 51

1982DI1E Dimbylow, Phys. Med. Biol. 27 (1982) 989

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

1982DO10 A. Doron, J. Alster, A. Erell, M.A. Moinester, R.A. Anderson, H.W. Baer, J.D. Bowman, M.D. Cooper, F.H. Cverna, C.M. Hoffman et al., Phys. Rev. C26 (1982) 189

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

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

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

1982GO09 H. Goringer, B. Schoch and G. Luhrs, Nucl. Phys. A384 (1982) 414

1982GR1K Green, in "Pion Production and Absorption in Nuclei-Indiana 1981", AIP Conf. Proc. 79 (1982) 131

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

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

1982HA1A Haight, Proc. 4th Int. Symp. Grenoble 1981 (IOP 1982) 510

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

1982HO10 H. Homeyer, M. Burgel, M. Clover, Ch. Egelhaaf, H. Fuchs, A. Gamp, D. Kovar and W. Rauch, Phys. Rev. C26 (1982) 1335

1982JA05 W.W. Jacobs, T.G. Throwe, S.E. Vigdor, M.C. Green, J.R. Hall, H.O. Meyer, W.K. Pitts and M. Dillig, Phys. Rev. Lett. 49 (1982) 855

1982JU03 J.W. Jury, B.L. Berman, J.G. Woodworth, M.N. Thompson, R.E. Pywell and K.G. McNeill, Phys. Rev. C26 (1982) 777

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

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

1982KE1B Kerridge, Nature 295 (1982) 643

1982KR05 H. Krawinkel, H.W. Becker, L. Buchmann, J. Gorres, K.U. Kettner, W.E. Kieser, R. Santo, P. Schmalbrock, H.P. Trautvetter, A. Vlieks et al., Z. Phys. A304 (1982) 307

1982LE1N R. Legrain, Nucl. Phys. A387 (1982) 219

1982LIZW C.K. Lin and L. Zamick, Bull. Amer. Phys. Soc. 27 (1982) 530, GE10

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

1982LO1B Londergain, ”Pion Production and Absorption in Nuclei-Indiana 1981”, AIP Conf. Proc. 79 (1982) 339

1982LU02 F.Q. Lu, J.Y. Tang and B.I. Deutch, Phys. Rev. C25 (1982) 1476

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

1982MA1R Matsumoto et al., Nucl. Instrum. Meth. Phys. Res. 196 (1982) 565

1982MAZZ T.G. Masterson, C.A. Goulding, J. Rapaport, T.N. Taddeucci, C.D. Goodman, C. Foster, E. Sugarbaker, C. Gaarde, J. Larsen and D. Horen, Bull. Amer. Phys. Soc. 27 (1982) 26, DF8

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

1982NO12 R. Novotny, D. Shapira, Y.-d. Chan, D.E. DiGregorio, J.L.C. Ford, Jr., J. Gomez del Campo, M.E. Ortiz and F. Pougheon, Phys. Rev. C26 (1982) 2664

1982OH05 S. Ohkubo, Phys. Rev. C25 (1982) 2498

1982OK02 S. Okabe, Prog. Theor. Phys. 68 (1982) 1790

1982OS01 E. Oset and D. Strottman, Nucl.. Phys. A377 (1982) 297

1982OS1C Oset, Toki and Weise, Phys. Rept. (1982) 281

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

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

1982SC02 B. Schoch and H. Goringer, Phys. Lett. B109 (1982) 11

1982VI05 S.E. Vigdor, T.G. Throwe, M.C. Green, W.W. Jacobs, R.D. Bent, J.J. Kehayias, W.K. Pitts and T.E. Ward, Phys. Rev. Lett. 49 (1982) 1314

1982WA1Q Wang et al., Phys. Energ. Fortis Phys. Nucl. 6 (1982) 525

1982WE01 S.A. Wender, H.R. Weller, N.R. Roberson, D.R. Tilley and R.G. Seyler, Phys. Rev. C25 (1982) 89

1982WO09 C.L. Woods, B.A. Brown and N.A. Jelley, J. Phys. G8 (1982) 1699

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

1982YA1D Yang, Jing, Wang and Wu, Phys. Energ. Fortis Phys. Nucl. 6 (1982) 480

1982ZA1D Zabolitzky, Proc. Conf. on Hypernuclear and Kaon Phys., Heidelberg, June 1982 (1982) p. 175

1983AJ01 F. Ajzenberg-Selove, Nucl. Phys. A392 (1983) 1; Erratum Nucl. Phys. A413 (1984) 168

1983AL1M Almeida and Kappeler, Astrophys. J. 265 (1983) 417

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

1983AM1D G. Amsel and B. Maurel, Nucl. Instrum. Meth. Phys. Res. 218 (1983) 183

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

1983BA2R Baltz, Dover and Sainio, in Florence (1983) p. 388

1983BA33 M. Bawin, C.A. Hughes and G.L. Strobel, Phys. Rev. C28 (1983) 456

1983BE02 E. Betak and V.D. Toneev, J. Phys. G9 (1983) L47

1983BI10 J. Billowes, J. Burde, J.A.G. De Raedt, M.A. Grace, W.R. Kolbl and A. Pakou, J. Phys. G9 (1983) 1407

1983BI1A J.R. Birkelund and J.R. Juizenga, Ann. Rev. Nucl. Part. Sci. 33 (1983) 265

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

1983BY03 R.C. Byrd, W. Tornow, P.W. Lisowski, K. Murphy and R.l. Walter, Nucl. Phys. A410 (1983) 29

1983CA07 G. Calvi, M. Lattuada, C. Spitaleri, F. Riggi, D. Vinciguerra, C.M. Sutera and A. Pantaleo, Lett. Nuovo Cim. 36 (1983) 475

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

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

1983CI08 O. Civitarese, B.V. Carlson, M.S. Hussein and A. Szanto de Toledo, Phys. Lett. B125 (1983) 22

1983CO09 E.R. Cohen and A.H. Wapstra, Nucl. Instrum. Meth. 211 (1983) 153

1983CR1A Craig et al., Bull. Amer. Phys. Soc. 28 (1983) 733

1983CSZX J. Csikai, Proc. Int. Conf. Nucl. Physics, Florence,1 (1983) 451

1983DE1X Desplanques, in Florence (1983) p. 218

1983DE26 P.A. De Young, J.J. Kolata, L.J. Satkowiak and M.A. Xapsos, Phys. Rev. C28 (1983) 692

1983DEZW L.C. Dennis, A.D. Frawley and J.F. Mateja, Bull. Amer. Phys. Soc. 28 (1983) 669, BF1

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

1983DR06 P.V. Drumm, J.B.A. England, O. Karban, J.M. Nelson, J.M. Barnwell and N.E. Sanderson, Phys. Lett. B126 (1983) 155

1983DR13 D.M. Drake, N.R. Roberson, S.A. Wender and H.R. Weller, Nucl. Phys. A410 (1983) 429

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

1983EL01 M.A. El-Shabshiry, J. Phys. G9 (1983) 205

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

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

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

1983GA17 A. Gal, Phys. Rev. C28 (1983) 2186

1983GM1A M. Gmitro, H.R. Kissener, P. Truol and R.A. Eramzhyan, Fiz. Elem. Chastits At. Yadra 14 (1983) 773; Sov. J. Part. Nucl. 14 (1983) 323

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

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

1983GO2C Goodman, in Florence (1983) p. 165

1983GO2D Gossett, Nucl. Instrum. Meth. Phys. Res. 218 (1983) 149

1983HA32 J.J. Hamill, R.J. Peterson and M. Yasue, Nucl. Phys. A408 (1983) 21

1983HO08 M.A.C. Hotchkis, L.K. Fifield, J.R. Leigh, T.R. Ophel, G.D. Putt and D.C. Weisser, Nucl. Phys. A398 (1983) 130

1983JA05 U. Jahnke, G. Ingold, H. Homeyer, M. Burgel, Ch. Egelhaaf, H. Fuchs and D. Hilscher, Phys. Rev. Lett. 50 (1983) 1246

1983KA19 W.B. Kaufmann and W.R. Gibbs, Phys. Rev. C28 (1983) 1286

1983KE11 T.J. Kennett, W.V. Prestwich, R.J. Tervo and J.S. Tsai, Nucl. Instrum. Meth. Phys. Res. 215 (1983) 159

1983KH1D Khanna and Towner, AIP Conf. Proc. 97 (1983) 406

1983KI01 I.V. Kirpichnikov, V.A. Kuznetsov, A.S. Starostin, E.F. Kislyakov, V.L. Korotkikh and D.E. Lanskoy, Nucl. Phys. A392 (1983) 352

1983KO1A Kondratiev et al., in Moscow (1983) 326

1983KO1D Koutroulos, in Florence (1983) 689

1983KO1Q Koh et al., Bull. Amer. Phys. Soc. 28 (1983) 131

1983KO1V Kolesnikov, Zakharov, Kolesov and Tarasov, in Moscow (1983) 240

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

1983LI01 K.F. Liu and F. Gabbard, Phys. Rev. C27 (1983) 93

1983LI1T C.-D. Lien, L. Wielunski and M.-A. Nicolet, Nucl. Instrum. Meth. Phys. Res. 213 (1983) 463

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

1983MA06 S. Marsh, Phys. Lett. B121 (1983) 238

1983MA1Q Mariotti, Nature 303 (1983) 685

1983MA2B Mahaux, in Symm. in Nucl. Struct., Abrahams, Allaart and Dieperink Eds., (Plenum Press 1983) 151

1983MA35 F.J. Margetan and J.P. Vary, Phys. Rev. C28 (1983) 907

1983MA38 H.A. Mavromatis and M.A. Jadid, Nucl. Phys. A403 (1983) 77

1983MA83 B. Maurel and G. Amsel, Nucl. Instrum. Meth. Phys. Res. 218 (1983) 159

1983MAZZ D. Marchlenski, S.L. Blatt, H.J. Hausman, T.R. Donoghue, T. Rackers, M. Wiescher, M.A. Kovash, A.D. Bacher and C.C. Foster, Bull. Amer. Phys. Soc. 28 (1983) 650, AG5

1983MU13 A.M. Mukhamedzhanov, R. Yarmukhamedov and P.O. Dzhamalov, Yad. Fiz. 37 (1983) 1405; Sov. J. Nucl. Phys. 37 (1983) 838

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

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

1983PI03 A.A. Pilt, Nuovo Cim. A74 (1983) 185

1983PL1A F. Plasil, Nucl. Phys. A400 (1983) 417

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

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

1983SC43 D.M. Scott and B.M. Paine, Nucl. Instrum. Meth. Phys. Res. 218 (1983) 154

1983SH1E Y.-J. Shi and F. Zhuang, Phys. Energ. Fortis Phys. Nucl. 7 (1983) 605

1983SH1T Shaginian, in Moscow (1983) 172

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

1983SI11 R.P. Singhal, J. Dubach, R.S. Hicks, R.A. Lindgren, B. Parker and G.A. Peterson, Phys. Rev. C28 (1983) 513

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

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

1983SK1B Skakun, Svetashov, Storizhko and Strashinsky, Radiat. Eff. Lett. 68 (1983) 169

1983SN03 K.A. Snover, E.G. Adelberger, P.G. Ikossi and B.A. Brown, Phys. Rev. C27 (1983) 1837

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

1983ST04 U. Straumann, M. Lebrun, C.J. Martoff, P. Truol, H.R. Kissener, J.P. Perroud, C. Joseph, W. Dahme and K.M. Crowe, Phys. Rev. C27 (1983) 2771

1983TA12 T.N. Taddeucci, J. Rapaport, C.C. Foster and J.R. Comfort, Phys. Rev. C28 (1983) 969

1983TO08 I.S. Towner and F.C. Khanna, Nucl. Phys. A399 (1983) 334

1983TO17 G. Toker and F. Tabakin, Phys. Rev. C28 (1983) 1725

1983TR12 S. Truong and H.T. Fortune, Phys. Rev. C28 (1983) 977

1983TR1J Truol, in Florence (1983) 247

1983VA1E A. Van Der Schaaf, E.A. Hermes, R.J. Powers, F.W. Schleputz, R.G. Winter, A. Zglinski, T. Kozlowski, W. Bertl, L. Felawka, W. H.A. Hesselink et al., Nucl. Phys. A408 (1983) 573

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

1983VO04 W. von Oertzen, E.R. Flynn, J.C. Peng, J.W. Sunier and R.E. Brown, Z. Phys. A310 (1983) 275

1983VO1F Voitsekhovski et al., in Moscow (1983) 340

1983WA03 J.D. Watson, J.W. Jury, P.C.-K. Kuo, W.F. Davidson, N.K. Sherman and K.G. McNeill, Phys. Rev. C27 (1983) 506

1983WI1A Wilczynski, in Florence (1983) 305

1984AA01 E.H.L. Aarts, R.A.R.L. Malfliet, R.J. De Meijer and S.Y. Van Der Werf, Nucl. Phys. A425 (1984) 23

1984AB1G Ableev et al., in Panic (1984) J25

1984AD1D Adams et al., in Panic (1984) A7

1984AN1M Anisovich, Braun and Shabelski, in Panic (1984) J5

1984AR1D Arima, Prog. Part. Nucl. Phys. 11 (1984) 53

1984AS1D F. Asai, H. Bando and M. Sano, Phys. Lett. B145 (1984) 19

1984BAZZ N.L. Back, F.S. Dietrich, J.G. Woodworth, I.D. Proctor, C.H. Poppe, H.E. Conzett and C. Rioux, Bull. Amer. Phys. Soc. 29 (1984) 640, AK8

1984BEZZ R. Bent, J. Conte and M. Dillig, Bull. Amer. Phys. Soc. 29 (1984) 627, AF9

1984BI08 L. Bimbot, T. Hennino, J.C. Jourdain, Y. Le Bornec, F. Reide, N. Willis and J.F. Germond, Phys. Rev. C30 (1984) 739

1984BO11 A. Bouyssy, S. Marcos and J.F. Mathiot, Nucl. Phys. A415 (1984) 497

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

1984BO1Q Boyd, Newsom, Collins and Wiescher, Science 225 (1984) 508

1984CA02 J.A. Cameron, Can. J. Phys. 62 (1984) 115

1984CH1G H.Z. Chen, F. Zhuang, X.J. Shi and X.N. Jin, Chin. J. Nucl. Phys. 6 (1984) 303

1984CL09 N.M. Clarke, J. Phys. G10 (1984) 1219

1984CO04 M.D. Cooper, H.W. Baer, R. Bolton, J.D. Bowman, F. Cverna, N.S.P. King, M. Leitch, J. Alster, A. Doron, A. Erell et al., Phys. Rev. Lett. 52 (1984) 1100

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

1984DA18 S.E. Darden, S. Sen, G. Murillo, M. Fernandez, J. Ramirez, A. Galindo, P.L. Jolivette and B.P. Hichwa, Nucl. Phys. A429 (1984) 218

1984DA1H R. Davis, Jr., B.T. Cleveland and J.K. Rowley, AIP Conf. Proc. 123 (1984) 1037

1984DE09 W. Del Bianco, G. Kajrys, J. Kim, S. Kundu, S. Landsberger, R. Lecomte and S. Monaro, Can. J. Phys. 62 (1984) 288

1984DE53 P. De Bievre, M. Gallet, N.E. Holden and I.L. Barnes, J. Phys. Chem. Ref. Data 13 (1984) 809

1984DO20 T.W. Donnelly and I. Sick, Rev. Mod. Phys. 56 (1984) 461

1984DU15 J.P. Dufour, S. Beraud-Sudreau, R. Del Moral, H. Emmermann, A. Fleury, F. Hubert, C. Poinot, M. Pravikoff, J. Frehaut, M. Beau et al., Z. Phys. A319 (1984) 237.

1984FI01 D. Fick, R.E. Brown, W. Gruebler, R.A. Hardekopf and J.S. Hanspal, Phys. Rev. C29 (1984) 324

1984FI1N Fifield et al., ANU-P/898 (1984)

1984FL1B M.F. Flynn, J.W. Clark, R.M. Panoff, O. Bohigas and S. Stringari, Nucl. Phys. A427 (1984) 253

1984FR13 H. Friedrich, Phys. Lett. B146 (1984) 135

1984FR1A P. Frobrich, Phys. Rept. 116 (1984) 337

1984GA11 C. Gaarde, J.S. Larsen, H. Sagawa, N. Ohtsuka, J. Rapaport, T.N. Taddeucci, C.D. Goodman, C.C. Foster, C.A. Goulding, D. Horen et al., Nucl. Phys. A422 (1984) 189

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

1984GO1H Gorionov et al, in Alma Ata (1984) 335

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

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

1984GR27 S.J. Greene, C.J. Harvey, P.A. Seidl, R. Gilman, E.R. Siciliano and M.B. Johnson, Phys. Rev. C30 (1984) 2003

1984HA1F Haight, Bull. Amer. Phys. Soc. 29 (1984) 1086

1984HA1M W.C. Haxton, AIP Conf. Proc. 123 (1984) 1026

1984HA1Q Hannien and raisanen, Nucl. Instrum. Meth. Phys. Res. B233 (1984) 34

1984HA26 K. Hatanaka, N. Matsuoka, T. Saito, K. Hosono, M. Kondo, S. Kato, T. Higo, S. Matsuki, Y. Kadota and K. Ogino, Nucl. Phys. A419 (1984) 530

1984HA53 Q. Haider and F.B. Malik, At. Data Nucl. Data Tables 31 (1984) 185

1984HAZV A.L. Hallin, H.W. Baer, J.D. Bowman, F. Irom, M.J. Leitch, J.-C. Peng, J.R. Comfort and J.N. Knudson, Bull. Amer. Phys. Soc. 29 (1984) 670, DE2

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

1984HI1D R.D. Hichwa, Bull. Amer. Phys. Soc. 29 (1984) 1072

1984HO23 H. Homeyer, M. Burgel, Ch. Egelhaaf, H. Fuchs and G. Thoma, Z. Phys. A319 (1984) 143

1984HUZZ C.A. Hughes, G.L. Strobel and M. Bawin, Bull. Amer. Phys. Soc. 29 (1984) 130, DC1

1984JA1F Jacobs, AIP Conf. Proc. 123 (1984) 1090

1984KA25 G. Karl, G.A. Miller and J. Rafelski, Phys. Lett. B143 (1984) 326

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

1984KU21 P.C.-K. Kuo, J.W. Jury, N.K. Sherman and W.F. Davidson, Phys. Rev. C30 (1984) 1789

1984KY01 G.S. Kyle, P.-A. Amaudruz, Th.S. Bauer, J.J. Domingo, C.H.Q. Ingram, J. Jansen, D. Renker, J. Zichy, R. Stamminger and F.Vogler, Phys. Rev. Lett. 52 (1984) 974

1984LEZX M.J. Leitch, F. Irom, J. Comfort, M.D. Cooper, H.W. Baer, J.D. Bowman, E. Piasetzky, U. Sennhauser, H. Ziock, J. Alster et al., Bull. Amer. Phys. Soc. 29 (1984) 675, DH7

1984MA2H Mariotti, Nature 311 (1984) 251

1984MA2J Mathews and Dietrich, Astrophys. J. 287 (1984) 969

1984MA63 U.N.L. Mathur and Y.R. Waghmare, Pramana 22 (1984) 457

1984MAZP D.G. Marchlenski, S.L. Blatt, H.J. Hausman, T.R. Donoghue, T.W. Rackers, P. Schmalbrock, V. Wijekumar, W. Kim, S.M. Jensen, A.D. Bacher et al., Bull. Amer. Phys. Soc. 29 (1984) 1051, DD6

1984MU27 J.A. Musser and J.D. Stevenson, Phys. Rev. Lett. 53 (1984) 847

1984NA06 T. Nakamura and Y. Uwamino, Phys. Rev. C29 (1984) 1317; Erratum Phys. Rev. C30 (1984) 413

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

1984NI1C R.J. Nickles, Bull. Amer. Phys. Soc. 29 (1984) 1072

1984PO11 D.N. Poenaru and M. Ivascu, J. Phys. (Paris) 45 (1984) 1099

1984RE14 S.M. Read and V.E. Viola, Jr., At. Data Nucl. Data Tables 31 (1984) 359

1984SAZP D.P. Sanderson, A.W. Carpenter and K.W. Kemper, Bull. Amer. Phys. Soc. 29 (1984) 1040, CB4

1984SAZU D.P. Saunders, R.R. Kiziah, P.A. Seidl, C.F. Moore, D. Dehnhard, S.J. Seestrom-Morris, C.L. Morris, L.C. Bland and R. Gilman, Bull. Amer. Phys. Soc. 29 (1984) 677, DH18

1984SH04 K. Shin, K. Hibi, M. Fujii, Y. Uwamino and T. Nakamura, Phys. Rev. C29 (1984) 1307

1984SH1J M. Shoeb and M.Z. Khan, J. Phys. (London) G10 (1984) 1047

1984SL04 R.J. Slobodrian, Phys. Rev. C29 (1984) 2353

1984SM04 G.R. Smith, J.R. Shepard, R.L. Boudrie, R.J. Peterson, G.S. Adams, T.S. Bauer, G.J. Igo, G. Pauletta, C.A. Whitten, Jr., A. Wriekat et al., Phys. Rev. C30 (1984) 593.

1984ST10 W.A. Sterrenburg, S. Brandenburg, J.H. Van Dijk, A.G. Drentje, M.B. Greenfield, M.N. Harakeh, H. Riezebos, H. Sakai, W. Segeth, S.Y. Van Der Werf et al., Nucl. Phys. A420 (1984) 257

1984ST1E Stone, Moszkowski, Mathews and Bloom, Bull. Amer. Phys. Soc. 29 (1984) 630

1984TA02 T.N. Taddeucci, R.R. Doering, A. Galonsky and S.M. Austin, Phys. Rev. C29 (1984) 764

1984TAZS T.N. Taddeucci, Bull. Amer. Phys. Soc. 29 (1984) 1032, BA4

1984TEZZ J.A. Templon, J.H. Dave, C.R. Gould, L.W. Seagondollar, C.S. Whisnant, G.M. Honore and S.S. Singkarat, Bull. Amer. Phys. Soc. 29 (1984) 131, DC9

1984TR1C J.W. Truran, Ann. Rev. Nucl. Part. Sci. 34 (1984) 53

1984TUZZ R.S. Turley, G.S. Adams, E.R. Kinney, J.L. Matthews, W.W. Sapp, R.A. Schumacher, S.A. Wood and R.O. Owens, Bull. Amer. Phys. Soc. 29 (1984) 708, FI7

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

1984VOZY K.F. Von Reden, W.W. Daehnick, S. Dytman, R.D. Rosa, J. Brown, C.C. Foster, W.W. Jacobs and J.R. Comfort, Bull. Amer. Phys. Soc. 29 (1984) 716, GG3

1984WA07 E.K. Warburton, D.E. Alburger and D.J. Millener, Phys. Rev. C29 (1984) 2281

1984WA1J J.D. Walecka, AIP Conf. Proc. 123 (1984) 1

1984WE04 E. Wesolowski, J. Phys. (London) G10 (1984) 321

1984YA03 M. Yasue, J.J. Hamill, H.C. Bhang, M.A. Rumore and R.J. Peterson, Phys. Rev. C30 (1984) 770

1984ZW1A Zwarts, Unpublished Ph.D. Thesis, Utrecht (1984)

1985AB1H Ableev et al., in Visby (1985) p. 156

1985AH1A I. Ahmad, M. Mian and M.Z. Rahman Khan, Phys. Rev. C31 (1985) 1590

1985AL1N Altabet and Deuser, Nature 315 (1985) 218

1985ANZX Anli Li, C.R. Howell, R.K. Murphy, H.G. Pfutzner, M.L. Roberts and R.L. Walter, Bull. Amer. Phys. Soc. 30 (1985) 797, IG11

1985AR11 A. Arima, T. Cheon and K. Shimizu, Hyperfine Interactions 21 (1985) 79

1985BAZZ N.L. Back, F.S. Dietrich, J.G. Woodworth, I.D. Proctor, C.H. Poppe, H.E. Conzett and C. Rioux, Bull. Amer. Phys. Soc. 30 (1985) 702

1985BL1B S.L. Blatt, AIP Conf. Proc. 125 (1985) 570

1985BO1D Body and Mihaly, INDC (HUN)-22/L (1985)

1985CO01 G. Co and S. Krewald, Nucl. Phys. A433 (1985) 392

1985DR1A Drossart, Encrenaz and Combes, Astron. Astrophys. 146 (1985) 181

1985FA01 F. Wang and C.W. Wong, Nucl. Phys. A432 (1985) 619

1985GA06 A.O. Gattone, B. Goulard and W-Y.P. Hwang, Phys. Rev. C31 (1985) 1430

1985GI1C R.L. Gilliland, Astrophys. J. 290 (1985) 344

1985GO02 C.D. Goodman, R.C. Byrd, I.J. Van Heerden, T.A. Carey, D.J. Horen, J.S. Larsen, C. Gaarde, J. Rapaport, T.P. Welch, E. Sugarbaker et al., Phys. Rev. Lett. 54 (1985) 877; Erratum Phys. Rev. Lett. 54 (1985) 2060

1985GU1A Guzik et al., Bull. Amer. Phys. Soc. 30 (1985) 762

1985HA01 N.H. Hamann. Nucl. Phys. A433 (1985) 198

1985HA18 S.S. Hanna and J.W. Hugg, Hyperfine Interactions 21 (1985) 59

1985HA1J H.J. Hauser, T. Rohwer, F. Hoyler, G. Staudt, S. Abd el-Kariem, P. Grasshoff, H.V. Klapdor, A. Korber, W. Leitner, V. Rapp et al., AIP Conf. Proc. 125 (1985) 701

1985KI1L King et al., Bull. Amer. Phys. Soc. 30 (1985) 36

1985KL1A H.V. Klapdor, Fortschr. Phys. 33 (1985) 1

1985KO04 D. Konnerth, W. Trombik, K.G. Bernhardt, K.A. Eberhard, R. Singh, A. Strzalkowski and W. Trautmann, Nucl. Phys. A436 (1985) 538

1985LE07 M.J. Leitch, J.L. Matthews, W.W. Sapp, C.P. Sargent, S.A. Wood, D.J.S. Findlay, R.O. Owens and B.L. Roberts, Phys. Rev. C31 (1985) 1633

1985MO08 M. Morjean, J.L. Charvet, J.L. Uzureau, Y. Patin, A. Peghaire, Y. Pranal, L. Sinopoli, A. Billerey, A. Chevarier, N. Chevarier et al., Nucl. Phys. A438 (1985) 547

1985PAZV W. Pairsuwan, J.W. Watson, B.D. Anderson, B.S. Flanders, R. Madey, C.C. Foster, B.A. Brown and B.H. Wildenthal, Bull. Amer. Phys. Soc. 30 (1985) 784, GH9

1985RE1D R.P. Redwine, Nucl. Phys. A434 (1985) 239

1985SE06 S.J. Seestrom-Morris, D. Dehnhard, C.L. Morris, L.C. Bland, R. Gilman, H.T. Fortune, D.J. Millener, D.P. Saunders, P.A. Seidl, R.R. Kiziah et al., Phys. Rev. C31 (1985) 923

1985WA02 A.H. Wapstra and G. Audi, Nucl. Phys. A432 (1985) 1

1985WA1R M. Wahlen and T. Yoshinari, Nature 313 (1985) 780

1985WI18 J.S. Winfield, N.A. Jelley, W.D.M. Rae and C.L. Woods, Nucl. Phys. A437 (1985) 65

1986AJ04 F. Ajzenberg-Selove, Nucl. Phys. A460 (1986) 1

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

BL84E Unknown source