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Energy Levels of Light Nuclei
$A = 14$

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Abstract: An evaluation of $A = 13$–15 was published in *Nuclear Physics A*449 (1986), p. 1. This version of $A = 14$ 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)

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^{14}He

(Not illustrated)

^{14}He has not been observed. See also (1983ANZQ; theor.).

^{14}Li

(Not illustrated)

^{14}Li has not been observed. The calculated mass excess is 72.29 MeV: see (1981AJ01). ^{14}Li is then particle unstable with respect to decay into ^{13}Li + n and ^{12}Li + 2n by 3.88 and 3.22 MeV, respectively.

^{14}Be

(Figs. 5 and 9)

^{14}Be has been observed in the 4.8 GeV proton bombardment of uranium [see (1976AJ04)], in the bombardment of ^{232}Th by 145 MeV ^{15}N ions (1982OG02; forward differential cross section is 4×10^{-5} mb/sr) and in the ^{14}C(π^-, π^+)^{14}Be reaction (1984GI09; $E_{\pi^-} = 164$ MeV, $\theta = 5°$). It has not been observed in the ^{48}Ca(^{14}C, ^{14}Be)^{48}Ti reaction ($E(^{14}\text{C}) = 87.4$ MeV, $\theta = 4° - 8°$) (1981NAZQ). A group in the (π^-, π^+) reaction is observed at $Q = -37.08 \pm 0.13$ MeV [(Value quoted by (1984GI09) + $2m_ec^2$.)] with a cross section of 0.73 ± 0.19 μb/sr (1984GI09). If this is the ground-state group, the atomic mass excess is 40.10 ± 0.13 MeV. ^{14}Be is then bound by 2.97 and 1.12 MeV, respectively, with respect to decay into ^{13}Be + n and ^{12}Be + 2n. See also (1984EP1A) and (1981KI04, 1981SE06, 1983ANZQ, 1985WI1B; theor.).

^{14}B

(Figs. 5 and 9)

GENERAL: (See also (1981AJ01).)

Nuclear models: (1981SE06, 1984VA06).

Complex reactions involving ^{14}B: (1983WI1A, 1984HI1A).

Pion capture and reactions: (1983TR1J).

Hypernuclei: (1981WA1J, 1982KA1D, 1983FE07).

Other topics: (1984PO11).

Ground state of ^{14}B: (1983ANZQ).

Mass of ^{14}B: We adopt the Wapstra atomic mass excess for ^{14}B: 23664 ± 21 keV. See also (1981NAZQ).

Table 14.1: Energy levels of ^{14}B

E_x (MeV ± keV)	$J^\pi; T$	$\tau_{1/2}$ (msec) or Γ (MeV)	Decay	Reactions
g.s.	$2^-; 2$	$\tau_{1/2} = 16.1 \pm 1.2$	β^-	1, 3, 4
0.74 ± 40	$(1^-); 2$			3
1.38 ± 30	$(3^-); 2$			3
1.86 ± 70	$2^-; 2$	$\Gamma = 1.0 \pm 0.5$		2, 3
2.08 ± 50	$(4^-); 2$			3
(2.32 ± 40)				3
2.97 ± 40				3
[a]				

[a] See reaction 2.

1. ^{14}B(β^-)^{14}C $\qquad Q_m = 20.64$

^{14}B has a half-life of 16.1 ± 1.2 msec. The β^- decay is primarily to ^{14}C*(6.09, 6.73): see Table 14.2. The nature of the decay fixes the J^π of ^{14}B to be 2^-.

2. ^{14}C(π^-, γ)^{14}B $\qquad Q_m = 118.92$

A single strong transition is observed in this pion capture cross section to a state in ^{14}B at $E_x = 2.15 \pm 0.17$ MeV, $\Gamma = 1.0 \pm 0.5$ MeV, with $J^\pi = 2^-$. The relative branching ratio of the ground state [2^-] to this second 2^- state is < 0.1. The data are also suggestive of the population of 2^- and 1^- states in the $E_x = 5 - 7$ MeV region (1983BA36).

3. ^{14}C(^{7}Li, ^{7}Be)^{14}B $\qquad Q_m = -21.51$

^{14}B states with $0 < E_x < 3$ MeV have been populated in this reaction at $E(^7\text{Li}) = 52$ MeV: see Table 14.1. Similarities in the relative intensities of ^{14}B*(0, 0.74, 1.38, 1.82, 2.08) and of ^{12}B*(1.67, 2.62, 3.39, 4.30, 4.52) [populated in ^{12}C(^{7}Li, ^{7}Be)^{12}B], and the similarity in the ΔE_x of these ^{12}B states with the E_x of the ^{14}B states suggest that they have the same J^π (1973BA34). See also (1982AL1G, 1984GL1G).

Table 14.2: Beta decay of ^{14}B [a]

Decay to ^{14}C* (MeV)	J^{π}	Branch (%)	log ft
0	0^+	(5 ± 3) [c]	
6.09 [b]	1^-	81 ± 9	4.22 ± 0.05
6.73	3^-	$8.6^{+1.7}_{-4.0}$	$5.10^{+0.30}_{-0.08}$
7.34	2^-	< 11 [d]	> 4.9

[a] (1974AL11).
[b] E_{β^-}(max) $= 14.0 \pm 0.7$ MeV to this state.
[c] This branch has not been observed. It is assumed to be $(5 \pm 3)\%$ in the calculation of the branching ratios to ^{14}C*(6.09, 6.73).
[d] This branch has not been observed: the upper limit is shown. In the calculations of the branching ratios to ^{14}C*6.09, 6.73) a value $(5 \pm 5)\%$ was used.

4. ^{14}C(^{14}C, ^{14}N)^{14}B $\qquad Q_{\rm m} = -20.49$

At $E(^{14}\text{C}) = 87.4$ MeV the ground state of ^{14}B is observed: the atomic mass excess is 23.67 ± 0.03 MeV. The differential cross section ($\theta = 4° - 8°$) is 7 μb/sr. The previously reported excited state at 0.74 MeV is not observed (1981NAZQ).

^{14}C

(Figs. 6 and 9)

GENERAL: (See also (1981AJ01).)

Nuclear models: (1982SA1U, 1983SH38, 1983VA31, 1984AS07, 1984SA37, 1984VA06).

Special states: (1983GO1R, 1983GO1B, 1983VA31, 1984AS07, 1984GO1M, 1984SA37, 1984VA06, 1985WE02).

Electromagnetic transitions and giant resonances: (1980RI06, 1982RI04, 1984AS07, 1984KU07, 1985WE02).

Astrophysical questions: (1981GU1D, 1983RE1B).

Applied work: (1979PE1B, 1979TA1B, 1980EL1B, 1980EL1C, 1980SH1Q, 1981FA1E, 1981LI1K, 1981SC1D, 1982ZA1C, 1983BR1Q, 1983DO1H, 1983DO1K, 1983FA1B, 1983FA1H, 1983GI1E, 1983JU1B, 1983KR1B, 1983KU1C, 1983LI1A, 1983NE1A, 1983RE1B, 1983SC1B, 1983SU1C, 1983TU1C, 1984AN1P, 1984AN1Q, 1984BE1H, 1984BI1E, 1984BO1T, 1984CU1A, 1984DO1B, 1984EL1B, 1984EL1C, 1984FA1G, 1984GI1K, 1984GI1L, 1984GI1M, 1984HE1G, 1984HE1B, 1984KA1R, 1984KL1E, 1984LI1R, 1984MO1T, 1984NA1R, 1984NE1C, 1984NE1E, 1984PO1L, 1984PO1C, 1984RU1C, 1984SP1B, 1984SU1B, 1984SU1J, 1984TA1P, 1984VA1D, 1984VO1J).

Complex reactions involving ^{14}C: (1981ME13, 1981OL1C, 1981VO06, 1982LY1A, 1983CH23, 1983EN04, 1983FR17, 1983FR1A, 1983MA06, 1983OL1A, 1983SA06, 1983WI1A, 1984AL34, 1984BA1H, 1984GA38, 1984GR08, 1984HI1A, 1984HO23, 1984KU1K, 1985PR01, 1985PR1G, 1985SA02, 1985SH01, 1985SH07).

Muon and neutrino capture and reactions (See also reaction 32): (1981GI08, 1981PH1C, 1982SC11, 1983GM1A, 1984KO1U).

Pion and kaon capture and reactions (See also reactions 15, 25, 33 and 34.): (1980GO1M, 1981HAZU, 1981SEZR, 1981SI09, 1981WH01, 1982DE1K, 1982IN1A, 1982KA16, 1982MU09, 1982RE1M, 1982THZZ, 1983AS01, 1983GM1A, 1983KRZZ, 1983LI1G, 1983MA63, 1983PE14, 1983SE16, 1983TR1J, 1984AS05, 1984CO1V, 1984GR27, 1984MI15, 1984SE14, 1985ALZX, 1985DY1C, 1985GI1J, 1985LE05).

Hypernuclei: (1981WA1J, 1982KA1D, 1982RA1L, 1983CH1T, 1983FE07, 1983MA63, 1984AS1D, 1984CH1G, 1984SH1J, 1985AH1A).

Other topics: (1982NG01, 1983GO1R, 1984PO11, 1985BO1D).

Ground state of ^{14}C: (1980WH03, 1981AV02, 1982NG01, 1983ANZQ, 1983VA31, 1984FR13, 1984WE04, 1985WE02).

$$\langle r^2\rangle^{1/2} = 2.4962\ (19)\ \text{fm}$$ (1982SC11).

Table 14.3: Energy levels of ^{14}C [a]

E_x in ^{14}C (MeV ± keV)	$J^\pi; T$	τ or $\Gamma_{c.m.}$	Decay	Reactions
g.s.	$0^+; 1$	$\tau_{1/2} = 5730 \pm 40$ y	β^-	1, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43
6.0938 ± 0.2	1^-	$\tau_m < 10$ fsec	γ	3, 4, 8, 9, 13, 15, 16, 17, 22, 24, 25, 26, 28, 38, 41
6.5894 ± 0.2	0^+	4.3 ± 0.6 psec	γ	3, 4, 9, 13, 16, 26
6.7282 ± 1.3	3^-	96 ± 11psec $\|g\| = 0.272 \pm 0.007$	γ	3, 4, 8, 9, 10, 11, 12, 15, 16, 17, 19, 22, 24, 25, 26, 28, 30, 38, 41
6.9026 ± 0.2	0^-	36 ± 4 fsec	γ	3, 4, 8, 9, 10, 13, 15, 16, 17, 24, 25, 26, 34
7.0120 ± 4.2	2^+	13 ± 2 fsec	γ	3, 4, 8, 9, 15, 16, 17, 24, 25, 26, 28, 32, 34, 38, 39
7.3414 ± 3.1	2^-	160 ± 60 fsec	γ	3, 4, 8, 9, 15, 16, 17, 19, 24, 26, 28, 38
8.3179 ± 0.8	2^+	$\Gamma = 3.4 \pm 0.6$ keV	γ, n	3, 4, 8, 9, 10, 13, 14, 15, 16, 24, 25, 26, 28, 34, 35, 38, 39
9.746 ± 7	0^+			9
9.801 ± 6	3^-	45 ± 12	γ, n	3, 9, 14, 16, 24, 28, 38
10.425 ± 5	2^+		n	9, 14, 16, 28, 38
10.449 ± 7	≥ 1		n	3, 8, 9, 14, 38
10.498 ± 4	(3^-)	26 ± 8	n	3, 8, 9, 14, 16
10.736 ± 5	4^+	20 ± 7		3, 8, 9, 10, 11, 12, 16, 28
11.306 ± 15	1^+	46 ± 12	γ, n	3, 14, 23, 24, 28, 38
11.395 ± 8	1^-	22 ± 7	n	3, 8, 9, 14, 16

Table 14.3: Energy levels of ^{14}C [a] (continued)

E_x in ^{14}C (MeV ± keV)	$J^\pi; T$	τ or $\Gamma_{c.m.}$	Decay	Reactions
11.666 ± 10	4^-	20 ± 7	γ	3, 8, 9, 10, 16, 24, 25, 28, 38
11.730 ± 9	(5^-)			3, 8, 9
11.9 ± 300		950 ± 300		16
12.583 ± 10	3^-	95 ± 15	n	3, 8, 9, 14, 16, 24, 28, 38
12.863 ± 8		30 ± 10	n	3, 8, 9, 14, 16
12.963 ± 9	(3^-)	30 ± 10	n	3, 8, 9, 14, 16, 28
13.58	1^-	(≈ 1300)	(n)	14, 28
14.667 ± 20	2^+, 3, 4, 5, 6^+	57 ± 15		3, 8
14.868 ± 20	$(6^+, 5^-)$			3, 8, 10, 38
15.20 ± 23	4^-			3, 8, 24, 25
(15.37 ± 30)				3
15.44 ± 40				3, 35
(16.02 ± 50)				3
16.43 ± 16				3, 8
(16.57 ± 40)				3
16.715 ± 30	(1^+)	≈ 200	γ, n	3, 13
17.30 ± 30	4^-		γ	3, 8, 24, 25
(17.5)	(1^+)	≈ 200	γ, n	13
17.95 ± 40				3
18.10 ± 40				3
20.4		wide		35
22.1			γ	24
24.3	$4^-; (T = 2)$	< 300	γ	24, 25
24.5		wide		25

[a] See also Tables 14.4 and 14.5, and Table 14.3 in (1981AJ01).

1. ^{14}C(β^-)^{14}N $\qquad Q_m = 0.1565$

Table 14.4: Lifetimes of bound excited states of ^{14}C [a]

^{14}C* (MeV)	τ_m	Reaction	Refs.
6.09	< 10 fsec	^{9}Be(^{13}C, ^{8}Be)	(1975SE04)
6.59	3.7 ± 0.9 psec	^{7}Li(^{9}Be, np)	(1981KO08)
	4.6 ± 0.7 psec	^{2}H(^{13}C, p)	(1980TO05)
	4.3 ± 0.6 psec		mean
6.73	97 ± 15 psec	^{12}C(t, p)	(1968AL12)
	96 ± 15 psec	^{7}Li(^{9}Be, np)	(1981KO08)
	96 ± 11 psec		mean
6.90	36 ± 4 fsec	^{9}Be(^{13}C, ^{8}Be)	(1975SE04)
7.01	13 ± 2 fsec	^{14}C(e, e)	(1972CRZN)
7.34	160 ± 60 fsec	^{11}B(α, p)	(1976GR02)

[a] See also Table 14.10 in (1976AJ04).

The adopted value of the half-life is 5730 ± 40 y: see (1976AJ04). See also (1981KHZY). Using Q_m, $\log ft = 9.04$ (1971GO40). For discussions of the lifetime of ^{14}C see (1959AJ76, 1970AJ04, 1976AJ04). See also (1981MA1P, 1983GO2C) and (1981PR1G, 1984HUZY; theor.).

2. (a) ^{7}Li(^{7}Li, n)^{13}C $\quad Q_m = 18.617 \quad E_b = 26.794$
   (b) ^{7}Li(^{7}Li, p)^{13}B $\quad Q_m = 5.963$
   (c) ^{7}Li(^{7}Li, d)^{12}B $\quad Q_m = 3.309$
   (d) ^{7}Li(^{7}Li, t)^{11}B $\quad Q_m = 6.196$
   (e) ^{7}Li(^{7}Li, α)^{10}Be $\quad Q_m = 14.782$
   (f) ^{7}Li(^{7}Li, ^{7}Li)^{7}Li
   (g) ^{7}Li(^{7}Li, ^{8}Be)^{6}He $\quad Q_m = 7.280$

These reactions have been studied with $E(^7\text{Li})$ to 6.5 MeV: see (1970AJ04) for the early references. For $E(^7\text{Li}) = 2.3$ to 5.8 MeV, the cross section for emission of α_0, α_1 and α_{2+3+4} is found to increase monotonically with energy. There is a report of several broad structures in the 0° yield of α_0 and α_1 for $E(^7\text{Li}) = 2$ to 20 MeV: it is suggested that they are due to a forward-direction cluster transfer process: see (1976AJ04) for references. The elastic scattering has been studied for $E(^7\text{Li}) = 2.0$ to 5.5 MeV by (1983NO08). See also (1983KAZF).

3. ^{9}Be(^{6}Li, p)^{14}C $\quad Q_m = 15.1244$

Table 14.5: Branching ratios of γ-rays in ^{14}C [a]

E_i (MeV)	J_i^π	E_f (MeV)	Branch (%)
6.09	1^-	0	100
6.59	0^+	0	1.1 ± 0.1 [b]
		6.09	98.9 ± 0.1 [c]
6.73	3^-	0	96.4 ± 1.2
		6.09	3.6 ± 1.2
6.90	0^-	6.09	100 [d]
7.01	2^+	0	98.6 ± 0.7
		6.09	1.4 ± 0.7
7.34	2^-	0	16.7 ± 3.5
		6.09	49.0 ± 3.1 [e,f]
		6.73	34.3 ± 3.5 [e]

[a] For references see Table 14.5 in (1981AJ01).
[b] Internal pairs. $\Gamma_\pi/\Gamma = (1.1 \pm 0.1) \times 10^{-2}$, $\langle M \rangle_\pi = 0.36 \pm 0.06$ fm^2.
[c] $E_\gamma = 495.35 \pm 0.10$ keV (1981KO08).
[d] $E_\gamma = 808.7 \pm 1.0$ keV.
[e] δ(M2/E1) $= -0.04 \pm 0.09$ and $+0.07 \pm 0.30$, respectively.
[f] $E_\gamma = 1248 \pm 3$ keV.

Observed proton groups are displayed in Table 14.6. See also ^{15}N.

4. ^{9}Be(^{7}Li, d)^{14}C $\qquad Q_m = 10.099$

Angular distributions have been measured at $E(^7\text{Li}) = 5.6$ to 6.2 MeV for the deuterons to ^{14}C*(0, 6.09, $6.59 + 6.73$, $6.90 + 7.01$, 7.34, 8.32). Gamma rays with $E_\gamma = 6094.5 \pm 3.2$, 6728.1 ± 1.4 and 7011.7 ± 5.2 keV have been reported. For τ_m and E_γ measurements see Table 14.4 and 14.5 (1981KO08) [see this reference for an extensive study of electromagnetic transitions in ^{14}C and ^{14}N].

5. ^{9}Be(^{9}Be, α)^{14}C $\qquad Q_m = 17.2506$

See (1981AJ01).

Table 14.6: Levels of ^{14}C from $^{9}Be(^{6}Li, p)^{14}C$ [a]

E_x (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	$2J_f + 1$ [b]	J^{π} [c]
6.089 ± 10		2.5 [3]	
6.588 ± 10		1.0 [1]	
6.726 ± 10		7.6 [7]	
6.899 ± 10		1.1 [1]	
7.016 ± 10		4.5 [5]	
7.341 ± 10		5.2 [5]	
8.318 ± 10	22 ± 6	5.1	2^+
9.796 ± 10	45 ± 12	7.7	3
10.441 ± 15		10.8	2^+, 3
10.512 ± 15	26 ± 8	9.1	4
10.743 ± 15	20 ± 7	15.4	
11.306 ± 15	46 ± 12	2.4	1^-
11.397 ± 15	22 ± 7	6.2	2^+, 3
11.667 ± 15	20 ± 7	12.4	5^-
11.74 ± 20			
12.57 ± 25	80 ± 20	15.1	
12.867 ± 20	30 ± 10	10.4	4, 5
12.970 ± 20	30 ± 10	7.8	3, 4
14.667 ± 20	57 ± 15		2^+, 3, 4, 5, 6^+
14.867 ± 25			
15.19 ± 30			
(15.37 ± 30)			
15.44 ± 40			
(16.02 ± 50)			
16.411 ± 20			
(16.57 ± 40)			
16.715 ± 30			
(17.28 ± 40)			
17.95 ± 40			
18.10 ± 40			

[a] (1973AJ01): $E(^6\text{Li}) = 20$ MeV. See Table 14.6 in (1981AJ01) for additional information on cross sections and reduced widths.
[b] The first number gives $2J_\text{f} + 1$ based on a best fit to the experimentally determined values for the cross section of the states with known spins. These $2J_\text{f} + 1$ values are determined to $\pm 10\%$, except for the last six values which are determined to $\pm 20\%$. The second number, in bracktes, gives $2J_\text{f} + 1$ derived from the J_f assignments shown in Table 14.3.
[c] Suggested from the $2J_\text{f} + 1$ rule and comparison of predicted neutron width with observed $\Gamma_\text{c.m.}$ assuming $0.01 < \theta^2_\text{n} < 1.0$.

6. (a) ^{11}B(t, n)^{13}C $\quad Q_\text{m} = 12.4215 \quad E_\text{b} = 20.5980$
(b) ^{11}B(t, α)^{10}Be $\quad Q_\text{m} = 8.5860$

For possible resonant structure in (a) see (1976AJ04). For reaction (b) see (1981AJ01) and see also (1983CE01).

7. ^{11}B(α, p)^{14}C $\quad Q_\text{m} = 0.7840$

Angular distributions of p_0 have been measured at $E_\alpha = 1.43$ to 25.1 MeV: see (1976AJ04, 1981AJ01) and at 31.2 MeV (1984KO1Q). See also ^{15}N.

8. (a) ^{11}B(^{6}Li, ^{3}He)^{14}C $\quad Q_\text{m} = 4.8024$
(b) ^{11}B(^{7}Li, α)^{14}C $\quad Q_\text{m} = 18.130$

Below $E_\text{x} = 10.4$ MeV, ^{14}C*(6.09, 6.73, 6.90 + 7.01, 7.34, 8.32, 9.78) are observed in both reactions at $E(\text{Li}) = 34$ MeV (1984CL08): the states observed at higher excitation energies are displayed in Table 14.7. The intensities of the ^{3}He and α groups in the two reactions are significantly different. Comparison of the angular distributions in reaction (a) and in the analog reaction ^{11}B(^{6}Li, t)^{14}N, as well as other data, leads to the assignment of analog pairs: see reaction 10 in ^{14}N. It is suggested that ^{14}C*(11.73) and not ^{14}C*(11.67) is populated in the inelastic pion scattering (1984CL08). For earlier work on reaction (b) see (1976AJ04).

9. ^{12}C(t, p)^{14}C $\quad Q_\text{m} = 4.6410$

Table 14.7: States in ^{14}C from ^{11}B(^{6}Li, ^{3}He) and ^{11}B(^{7}Li, α) [a]

E_x (MeV ± keV) [b]	$d\sigma/d\Omega_{c.m.}$ (μb/sr) [c]		E_x (MeV ± keV) [b]	$d\sigma/d\Omega_{c.m.}$ (μb/sr) [c]	
	A	B		A	B
10.47 ± 15 [d]	127	130	14.67 ± 30	127 }	489
10.74 ± 15	365	57	14.87 ± 30	430 }	
11.40 ± 20	38	112	15.21 ± 30	188	291
11.66 ± 15	75	90	16.45 ± 25	633	1285
11.73 ± 15	120	80	17.32 ± 40	76	293
12.58 ± 30	106	123			
12.86 ± 30 }	276	275			
12.96 ± 30 }					

A: ^{11}B(^{6}Li, ^{3}He).

B: ^{11}B(^{7}Li, α).

[a] (1984CL08): E(Li) $= 34$ MeV. See for angular distributions and for discussion of analog states in ^{14}N. See also reaction 10 in ^{14}N.

[b] States below $E_x = 10.4$ MeV are not displayed here.

[c] At $\theta_{lab} = 10°$. Uncertainties in the differential cross sections are approximately ±20%.

[d] Unresolved.

Observed proton groups are displayed in Table 14.8. Angular distributions have been measured at $E_t = 5.5$ to 23 MeV. The (t, p) strength to the positive parity states of ^{14}C are well accounted for by a model of (sd)^2 two-neutron states coupled to an inert ^{12}C core: see (1981AJ01). The amplitude of sd-shell excitation in ^{14}C$_{g.s.}$ is 0.35 ± 0.02 (1982FO01). The nuclear gyromagnetic ratio for ^{14}C*(6.73) is $|g| = 0.272 \pm 0.007$ showing that the state is not of a pure $(p_{1/2}^{-3} d_{5/2})$ configuration (1974AL07). For τ_m see Table 14.4. See also ^{15}N.

10. ^{12}C(α, 2p)^{14}C $\qquad Q_m = -15.1731$

At $E_\alpha = 65$ MeV angular distributions have been measured to ^{14}C*(0, 6.73 ± 0.02(u), 8.40 ± 0.14, 10.69 ± 0.05, 11.69 ± 0.06(u), 14.84 ± 0.4) [groups known to be unresolved are labelled (u)]. The two most strongly populated states (or groups of states) are ^{14}C*(6.73, 10.69). $J^\pi = 1^-$ and $(6^+, 5^-)$ are favored for ^{14}C*(11.69, 14.84). For the latter 4^+ is considered to be very unlikely (1980VA17). See also (1981AJ01) for the earlier work.

Table 14.8: ^{14}C states from ^{12}C(t, p)^{14}C [a]

E_x [b] (MeV ± keV)	E_x [c] (MeV ± keV)	L [b,c]	J^π
-0.006 ± 10	0	0	0^+
6.087 ± 10	6.099 ± 10	1	1^-
6.577 ± 10	6.589 ± 10	0	0^+
6.725 ± 10	6.731 ± 10	3	3^-
6.895 ± 10	6.899 ± 10	weak	
$\equiv 7.012$	7.017 ± 10	2	2^+
7.336 ± 10	7.342 ± 10	weak	
8.307 ± 12	8.315 ± 10	2	2^+
9.746 ± 7 [d]		0	0^+
09.809 ± 10 [d]	9.80 ± 20 [e]	(1)	(1^-)
10.425 ± 6 [d]	10.419 ± 20	2	2^+
10.448 ± 10			
10.498 ± 4 [d]	10.492 ± 20	(3)	(3^-) [f]
10.736 ± 5 [d]	10.730 ± 20	4	4^+
11.398 ± 10	11.377 ± 20	1	1^-
11.665 ± 13	11.647 ± 30	(1)	(1^-)
11.727 ± 10	[e]	(5)	(5^-)
12.580 ± 12		(2, 3)	$(2^+, 3^-)$
12.867 ± 10	12.849 ± 20	2, 3	$2^+, 3^-$
12.963 ± 10	12.945 ± 30	(1)	(1^-)

[a] See also Tables 14.5 in (1976AJ04) and 14.7 in (1981AJ01), and (1982FO01).

[b] $E_t = 18$ MeV (1978MO07, 1978MO08).

[c] $E_t = 23$ MeV (1978AJ02).

[d] The widths for ^{14}C*(9.75, 9.81, 10.43, 10.50, 10.74) are, respectively 18, 40, 14, 18 and 15 keV (1978MO07, 1978MO08).

[e] Very weak at all angles.

[f] See also the note added in proof on p. 476 of (1978MO08).

11. ^{12}C(^{10}B, ^{8}B)^{14}C $\qquad$ $Q_m = -13.889$

At $E(^{10}\text{B}) = 100$ MeV ^{14}C*(6.72, 10.74) are strongly populated and the angular distributions to these states are reported. ^{14}C*(15.0) is also observed (1978HA10).

12. ^{12}C(^{16}O, ^{14}O)^{14}C $\qquad$ $Q_m = -15.7635$

At $E(^{16}\text{O}) = 128$ MeV angular distributions have been measured to ^{14}C*(0, 6.73, 10.74) [$J^\pi = 0^+, 3^-, 4^+$] (1979PR07). See also (1981AJ01).

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

$Q_0 = 8176.483 \pm 0.015$ keV [see (1983CO09)].

The thermal capture cross section is 1.37 ± 0.04 mb (1982MU14). The decay is primarily to ^{14}C*(0, 6.59) [$(84.0\pm2.3)\%$, $(8.5\pm0.5)\%$] with weaker branches to ^{14}C*(6.09, 6.90) [$(2.5\pm0.5)\%$, $(4.9\pm1)\%$]. Gamma rays with $E_\gamma = 8173.92$, 6092.4 ± 0.2, 2082.6 ± 0.3, 1586.8 ± 0.2, 1273.9 ± 0.2, 808.9 ± 0.2 and 495.4 ± 0.3 keV have been observed: $E_x = 6093.8\pm0.2$, 6589.4 ± 0.2 and 6902.6 ± 0.2 keV are reported for ^{14}C*(6.09, 6.59, 6.90). A (d, p) spectroscopic factor of 0.060 ± 0.004 was deduced for ^{14}C*(6.59) (1982MU14). The neutron capture yield for $E_n = 95$ to 235 keV shows a resonance at $E_n = 152\pm1$ keV, $\Gamma_{lab} = 5\pm1$ keV, $\Gamma_\gamma = 4.0\pm1.6$ eV: see Table 14.8 in (1981AJ01). Angular distributions of cross sections and A_y and the 90° γ_0 cross sections have been measured in the range $E_{\vec{n}} = 5.6$ to 17 MeV. M1 resonances are indicated at $E_n \approx 9.2$ and 10.1 MeV ($\Gamma \approx 200$ keV) [$E_x = 16.7$ and 17.5 MeV]. σ(E2) is less than 2% of the total capture cross section for $E_n = 5.6$ to 17 MeV (1985WR01). See also (1984SE16).

14. ^{13}C(n, n)^{13}C $\qquad$ $E_b = 8.1765$

The coherent scattering length (thermal, bound) is 6.19 ± 0.09 fm, $\sigma_{scatt} = 4.16\pm0.13$ b (1979KO26). [However F.C. Barker, private communication, has recalculated this value and finds $\sigma_{scatt} = 4.84$ b.] The difference in the bound-state scattering lengths, $b^+ - b^- = -1.2\pm0.2$ fm (1979GL12). The free coherent scattering length $a_+ = 5.47\pm0.09$ fm (1982MU14). See also (1981MUZQ). The total cross section has been measured for $E_n = 0.10$ to 23 MeV: see (1981AJ01). Elastic differential cross sections have been measured for $E_n = 1.25$ to 6.5 MeV (1981LA05), 4.55 to 8.25 MeV (1982REZY, 1982REZX; also $n_{1\to3}$) and 10 to 18 MeV (1982DA05, 1983DA22). See also ^{13}C, (1983GO1H) and (1985WE02; theor.).

The results of an R-matrix analysis based on σ_T and $\sigma(\theta)$ (elastic) measurements (1981LA05) are summarized in Table 14.9.

Table 14.9: R-matrix analysis of ^{13}C(n, n) [a]

E_n (keV)	E_x (MeV)	$\Gamma_{n,lab}$ [b] (keV)	J^π
152.9 ± 1.4	8.3184	3.7 ± 0.7	
1736	9.79	15	3^-
1754	9.80	41	1^-
2426	10.43	10	$3^{(-)}$
2445	10.45	7	$(1^+, 2)$
2504	10.50	$\ll 5$	≥ 1
3350	11.3	≈ 180	1^+
3466	11.39	$\lesssim 7$	≥ 2 [d]
3510	11.4		1^-
3710	11.6		2^-
4350	12.2		1^-
4770	12.6	130	3^- [e]
5050 [b,c]	12.86		
5162 [b,c]	12.97		
5900	13.7	≈ 1300	$(1, 2)^-$

[a] (1981LA05): based on an analysis of σ_T and $\sigma(\theta)$ elastic measurements, except for the 153 keV resonances. See also Table 14.8 in (1981AJ01).

[b] Quoted by (1981LA05) from work by (1979AU07), except for first value.

[c] Not included in R-matrix fit.

[d] See, however, Table 14.8.

[e] (1982REZY).

15. ^{13}C(p, π^+)^{14}C $\qquad Q_{\rm m} = -132.1732$

At $E_{\rm p} = 185$ MeV (1973DA37) and 200 MeV (1980HO20) the angular distributions of π^+ and π^- to the ground states of ^{14}C and ^{14}O are very different. The population of ^{14}C*(6.09, $6.73 + 6.90 + 7.01$, 7.34, 8.32) is also reported; that to the first excited state is very strong (1980SO05). See also (1981AJ01), the "GENERAL" section here, (1982GRZY, 1983THZZ, 1984KOZU) and (1979ME2A, 1981AU1C).

16. ^{13}C(d, p)^{14}C $\qquad Q_{\rm m} = 5.9519$

Observed proton groups are displayed in Table 14.10. Angular distributions have been measured at a number of energies up to $E_{\rm d} = 14.8$ MeV [see (1981AJ01)] and at $E_{\rm d} = 17.7$ MeV (1984PE24; DWBA, CCBA; see Table 14.10) and at $E_{\rm d} = 56$ MeV (1984HA26; p_0; $A_{\rm y}$).

Gamma rays are exhibited in Table 14.5: studies of these, of the angular distributions analyzed by DWBA, and of pγ correlations lead to the following J^π assignments [see reaction 14 in (1970AJ04) for a full discussion of the evidence and a listing of the relevant references]. ^{14}*C(6.09)* is 1^- (decay is E1); ^{14}*C*(6.59)* is 0^+ (internal pairs only); ^{14}*C*(6.73)* is 3^- (γ_0 is E3; $l_{\rm n} = 2$); ^{14}*C*(6.90)* is 0^- (no γ_0; 0.81 MeV cascade via 6.09 is predominantly dipole; $\gamma_{0.8} + \gamma_{6.1}$ correlation is only consistent with $J = 0$, and plane polarization leads to negative parity); ^{14}*C*(7.34)* is 2^- (strength of cascade decay and angular correlation results). See also ^{15}N.

17. ^{13}C(^{7}Li, ^{6}Li)^{14}C $\qquad Q_{\rm m} = 0.926$

At $E(^7{\rm Li}) = 34$ MeV the angular distribution to ^{14}C$_{\rm g.s.}$ has been measured: see (1976AJ04). ^{14}C*(6.09, 6.73, 6.90, 7.01, 7.34, 10.47) are also populated at that energy (1984CL08).

18. ^{13}C(^{9}Be, ^{8}Be)^{14}C $\qquad Q_{\rm m} = 6.511$

At $E(^9{\rm Be}) = 28.8$ MeV the angular distribution to ^{14}C$_{\rm g.s.}$ has been measured (1980BO21). See also (1984DA17).

19. ^{13}C(^{11}B, ^{10}B)^{14}C $\qquad Q_{\rm m} = -3.2777$

At $E(^{11}{\rm B}) = 114$ MeV ^{14}C$_{\rm g.s.}$ is weakly excited but ^{14}C*(6.73, 7.34) [$J^\pi = 3^-$ and 2^-] are strongly populated: see (1976AJ04).

Table 14.10: Proton groups from $^{13}C(d, p)^{14}C$ [a]

E_x [b] (MeV)	J^{π} [c]	j trans. [d]	S [d]
0	0^+		
6.09	1^-	$\frac{1}{2}^+$	0.75
6.59	0^+	$(\frac{1}{2}^-)$	(0.14)
6.73	3^-	$\frac{5}{2}^+$	0.65
6.90	0^-	$\frac{1}{2}^+$	1.02
7.01	2^+	$\frac{3}{2}^-$	0.065
7.34	2^-	$\frac{5}{2}^+$	0.72
8.32	2^+	$\frac{3}{2}^-$	0.065
9.80	3^-	$\frac{5}{2}^+$	0.07
10.43	2^+		
10.50	(3^-)		
10.74	4^+	$(\frac{7}{2}^-)$	(0.06)
11.5	$(1^-, 2^-)$	$\frac{3}{2}^+$	≈ 1
11.67	4^-		
11.9 [e]			
12.58 [f]			
12.86			
12.96	(1^-)		

[a] See also Table 14.9 in (1981AJ01).

[b] Nominal values: see Table 14.3.

[c] See Table 14.3 and text.

[d] (1984PE24).

[e] ± 300 keV, $\Gamma_{lab} = 1.10 \pm 0.30$ MeV.

[f] $\Gamma_{lab} = 0.13 \pm 0.02$ MeV.

20. ^{13}C(^{13}C, ^{12}C)^{14}C $\qquad Q_m = 3.2301$

Elastic angular distributions have been studied at $E(^{13}\text{C}) = 16$ to 50 MeV (1983KO15). For yield measurements see (1983KO15, 1984BA31). See also (1981BR1P) and (1983KO16; theor.).

21. (a) ^{13}C(^{17}O, ^{16}O)^{14}C $\qquad Q_m = 4.0328$
(b) ^{13}C(^{18}O, ^{17}O)^{14}C $\qquad Q_m = 0.132$

Angular distributions have been measured at $E(^{17}\text{O}) = 29.8$ and 32.3 MeV and $E(^{18}\text{O}) = 31.0$ MeV: see (1981AJ01). See also (1984AB1A; theor.).

22. ^{14}B(β^-)^{14}C $\qquad Q_m = 20.64$

^{14}B decays primarily to ^{14}C*(6.09, 6.73): see Table 14.2. The half-life is 16.1 ± 1.2 msec.

23. ^{14}C(γ, n)^{13}C $\qquad Q_m = -8.1765$

A narrow resonance is observed in the (γ, n_0) reaction at $E_x = 11.3$ MeV with an integrated cross section of 1.65 ± 0.12 MeV · mb of which 0.62 ± 0.06 MeV · mb is due to the GDR tail. Nearly 100% of the photoneutron reaction proceeds to $^{13}\text{C}_{\text{g.s.}}$ below $E_x \approx 13$ MeV. Above this energy (and below 28 MeV) about one-half of the $T_<$ GDR is in the g.s. channel. There are strong indications of E1-M1 interference at 11.3 MeV [for which $J^\pi = 1^+$ is suggested]. There is no evidence for E2 excitation for $15 < E_x < 20$ MeV (1985KU01).

24. ^{14}C(e, e)^{14}C

The charge radius of ^{14}C, $r_{\text{rms}} = 2.56 \pm 0.05$ fm (1973KL12). At $E_e = 37-60$ MeV ($\theta = 180°$) inelastic groups are reported to ^{14}C*(7.01, 7.34, 8.32, 9.80, 10.5, 11.31 ± 0.02, 12.96, 14.67) with the 11.3 MeV state [1^+, $\Gamma = 207 \pm 13$ keV, $\Gamma_{\gamma_0} = 6.8 \pm 1.4$ eV] dominant (1977CR02). At $E_e = 196.3$ MeV ($\theta = 180°$) (1984PL02) find the dominant strength to be to 4^- states at 11.7, 17.3 and 24.3 MeV [± 0.1 MeV]. The first two of these are $T = 1$ states reported in the (π, π) reaction below, the third is suggested to have $T = 2$. The M4 form factors account for 41% and 37% of the $T = 1$ and $T = 2$ single-particle (e, e$'$) cross section, respectively. The observed transitions to the $T = 1$ states exhaust $33 - 45\%$ of the total isovector transition strength and $1 - 15\%$ of the isoscalar transition strength. Magnetic electron scattering is most sensitive to isovector transitions. ^{14}C*(6.09, 6.7, 7.0, 8.32, 9.8, 10.5, 22.1) are also populated (1984PL02). See also (1983TR1J, 1984LI25) and (1983GM1A, 1984GO1J; theor.).

25. ^{14}C($\pi^{\pm}$, $\pi^{\pm}$)^{14}C

Elastic angular distributions have been measured at $E_{\pi^{\pm}} = 50$ MeV (1983MIZY, 1984MI1M) and 65 and 80 MeV (1983BL11). At $E_{\pi^{\pm}} = 164$ MeV π^{+} and π^{-} spectra have been studied: angular distributions have been obtained to states at $E_{\rm x} = 6.7 \pm 0.1$, 11.7 ± 0.1, 15.2 ± 0.1, 17.3 ± 0.1 MeV with $J^{\pi} = 3^{-}, 4^{-}, 4^{-}, 4^{-}$ (1985HO07). In addition a braod structure ($\Gamma \approx 1.7$ MeV) is observed near 24.5 MeV. It may include a narrower peak at 24.4 MeV. ^{14}C*(7.01, 8.32) are also populated (1985HO07). ^{14}C*(6.1, 10.4, 12.6, 15.1) are also observed (1981HO14). See also reaction 8.

26. (a) ^{14}C(n, n)^{14}C
(b) ^{14}C(p, p)^{14}C
(c) ^{14}C(d, d)^{14}C

Elastic angular distributions have been studied for $E_{\rm p} = 19$ to 27 MeV (1984BAZZ). See also ^{15}N. Angular distributions have also been studied at $E_{\rm d} = 19$ to 27 MeV to ^{14}C*(6.09, 6.59, 6.73, 6.90, 7.01, 7.34, 8.32) (1985BAZZ). See also (1981AJ01) and (1985DI1B; theor.).

27. ^{14}C(^{3}He, ^{3}He)^{14}C

Elastic angular distributions have been measured at $E(^{3}{\rm He}) = 4.5$ to 18 MeV: see (1976AJ04).

28. ^{14}C(α, α)^{14}C

Elastic angular distributions have been studied at $E_{\alpha} = 22$, 24 and 28 MeV [see (1976AJ04)] and at $E_{\alpha} = 35.5$ MeV (1984PE24). At the latter energy many inelastic groups have also been studied: see Table 14.11 and reaction 16 (1984PE24). See also (1984RA17), ^{18}O in (1987AJ02) and (1983WI12, 1984LA01; theor.).

29. ^{14}C(^{6}Li, αd)^{14}C $\qquad Q_{\rm m} = -1.4751$

See (1983AR11, 1983CU03) and ^{18}O in (1987AJ02).

Table 14.11: States of ^{14}C from ^{14}C(α, α') [a]

E_x (MeV) [b]	L [c]	J^π	β^2 [d]
6.09	1	1^-	0.050
6.73	3	3^-	0.158
7.01 [e]	2	2^+	0.086
7.34		2^-	
8.32 [e]	2	2^+	0.049
9.80	3	3^-	0.068
10.44 ± 0.06 [e]	2	2^+	0.038
10.74	4	4^+	0.018
11.32 ± 0.06	2	2^+	0.014
11.62 ± 0.08		4^-	
12.58	3	3^-	0.041
12.96	(3)	(3^-)	0.033
13.58	1	1^-	0.068
14.82	3	3^-	0.079
15.66	3	3^-	0.096

[a] (1984PE24): $E_\alpha = 35$ MeV.

[b] Excitation energies without uncertainties are from Table 14.3, except for the last three values.

[c] Microscopic DWBA analysis.

[d] Collective deformations.

[e] Isoscalar transition rates $B(02)$ are 168, 96 and 74 fm^4 for ^{14}C*(7.01, 8.32, 10.44).

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

The elastic scattering for reaction (a) has been studied at E(C) $=$ 12, 15, 18 and 20 MeV, and at 15 MeV for reaction (b) [see (1976AJ04)] and at $E(^{14}$C) $= 31$ to 56 MeV for reaction (a) (1985KO04) and for reaction (c) at $E(^{14}$C) $= 31.4$, 35.4, 38.9, 47.9 and 55.9 MeV (1981DR01) and 31 to 56 MeV (1980KO23, 1985KO04). For yield and fusion studies see (1981HE08, 1985KO04, 1985RI1C) for reaction (a) and (1980KO23, 1981DR01, 1981FR23, 1985KO04) for reaction (c). (1981FR23, 1985KO04) have studied the yields of γ-rays from ^{14}C*(6.73) [$J^{\pi} = 3^{-}$] for $E(^{14}$C) $= 25$ to 70 MeV. See also (1981BR1P, 1981HA1V, 1982CI1C, 1982FR1U, 1983BI13) and (1981AB1A, 1981HA18, 1981TA20, 1982AB1F, 1983BA38, 1983FR23; theor.).

31. (a) ^{14}C(^{16}O, ^{16}O)^{14}C
(b) ^{14}C(^{17}O, ^{17}O)^{14}C

The elastic scattering angular distributions have been measured at $E(^{16}$O) $= 20$, 25 and 30 MeV: see (1981AJ01). For excitation functions see (1981KO07, 1982HE07, 1983VO1B). See also (1981HA1V, 1982FR1U) and (1981HA18, 1983DU13, 1983FR23, 1984AB1F; theor.).

32. ^{14}N(μ^{-}, ν)^{14}C $\qquad Q_{\rm m} = 105.5030$

Observation of the γ-transition has led to the determination of the capture rate to ^{14}C*(7.01) [$J^{\pi} = 2^{+}$]: the experimental value is four times smaller than that predicted by theory (1981GI08). See also the "GENERAL" section here.

33. ^{14}N(γ, π^{+})^{14}C $\qquad Q_{\rm m} = -139.7238$

The π^{+} production has been studied at $E_{\gamma} = 173$ MeV to ^{14}C$_{\rm g.s.}$: the Cohen-Kurath wave functions overestimate the data as much as a factor of 4 (1985RO05). See also (1984COZW) and the "GENERAL" section here.

34. ^{14}N(π^{-}, γ)^{14}C $\qquad Q_{\rm m} = 139.4108$

Branching ratios have been measured for the capture of stopped pions to ^{14}C*(0, 7.0 ± 0.1, 8.3, 11.3, 20.0 ± 1.0). The total radiative capture branching is $(2.1 \pm 0.2)\%$ [see (1981AJ01)]. See also the "GENERAL" section here.

35. ^{14}N(n, p)^{14}C $Q_{\rm m} = 0.6259$

The p_0 angular distribution has been measured at $E_{\rm n} = 14$ MeV: see (1981AJ01). At $E_{\rm n} = 60$ MeV the strongest transitions are to ^{14}C*($7.0 + 8.3$, 11.3, 15.4) and to the giant resonance peak, centered at ≈ 20.4 MeV, and angular distributions have been studied to these groups (1982NE04). See also (1984TU1D; search for supermassive Cahn-Glashow particles), (1981BR1L), (1983FI1L, 1983KH1F; applied) and (1983GM1A; theor.).

36. ^{15}N(γ, p)^{14}C $Q_{\rm m} = -10.2074$

See (1981AJ01).

37. ^{15}N(n, d)^{14}C $Q_{\rm m} = -7.9829$

Ground-state angular distributions have been measured for $E_{\rm n} = 14.1 - 14.8$ MeV: see (1976AJ04, 1981AJ01).

38. ^{15}N(d, ^{3}He)^{14}C $Q_{\rm m} = -4.7139$

^{14}C states populated in this reaction are displayed in Table 14.9 of (1976AJ04), together with l and C^2S values.

39. ^{16}O(^{6}Li, ^{8}B)^{14}C $Q_{\rm m} = -16.592$

At $E(^{6}{\rm Li}) = 93$ MeV ^{14}C*(0, 7.01, 8.32, 10.45) are populated, the first two of these strongly: see (1981AJ01).

40. ^{16}O(^{18}O, ^{20}Ne)^{14}C $Q_{\rm m} = -1.493$

Angular distributions are reported at $E(^{18}O) = 28$, 32 and 36.1 MeV: see (1981AJ01).

41. $^{18}O(\gamma, \alpha)^{14}C$ $Q_m = -6.2270$

The ground-state reaction has been studied at $E_{bs} = 24$ and 32 MeV (1982BA03): see ^{18}O in (1983AJ01). See also (1981AJ01).

42. $^{18}O(d, ^{6}Li)^{14}C$ $Q_m = -4.7519$

See (1984NE1A).

43. $^{19}F(d, ^{7}Be)^{14}C$ $Q_m = -7.1402$

The ground-state angular distribution has been measured at $E_d = 13.6$ MeV by (1980GA27). See also (1984NE1A).

^{14}N
(Figs. 7 and 9)

GENERAL: (See also (1981AJ01).)

Nuclear models: (1983KA1K, 1983SH38, 1983VA31, 1984AS07, 1984VA06, 1984ZW1A).

Special states: (1980GO1Q, 1980KA28, 1980RI06, 1983AD1B, 1983AD1D, 1983GO1R, 1983VA31, 1984AD1E, 1984AS07, 1984GO1M, 1984VA06, 1984ZW1A, 1985HA1J).

Electromagnetic transitions and giant resonances: (1980RI06, 1980SP1E, 1981KN06, 1982RI04, 1983GO1B, 1984AS07, 1984BI10, 1984KU07, 1984MA67).

Astrophysical questions: (1980CO1R, 1980SC1L, 1981AD1F, 1981BE2K, 1981DE2C, 1981GA1C, 1981GA1H, 1981GU1D, 1981IB1A, 1981LA1L, 1981WA1N, 1981WA1Q, 1982IB1B, 1983AL23, 1983BO1F, 1983SI1B, 1984CO1H, 1984TR1C, 1985DR1A, 1985GU1A).

Complex reactions involving ^{14}N: (1980CE1B, 1980GR10, 1980RI06, 1981BH02, 1981CI03, 1981EG02, 1981ME13, 1981TA16, 1982BO1M, 1982LE1N, 1982LY1A, 1982TA02, 1983BH09, 1983CH23, 1983DE26, 1983FR1A, 1983JA05, 1983OL1A, 1983PAZT, 1983PL1A, 1983SA06, 1983SO08, 1983WI1A, 1984BA1H, 1984BE22, 1984FI17, 1984GR08, 1984HI1A, 1984HO23, 1984KA1J, 1984NA12, 1984SI15, 1984TS03, 1985AG1A, 1985BH02, 1985GU1A, 1985JA18, 1985LI1B, 1985MC03, 1985MO08, 1985ST1J).

Applied work: (1980MC1H, 1980SE1E, 1982BE64, 1983AM1A, 1983DU1D, 1983FI1L, 1983FI1C, 1983KU1C, 1984CA1D, 1984HA1Q, 1984MA2H, 1985WA1R).

Muon and neutrino capture and reactions: (1980SC18, 1981GI08, 1981MU1E, 1982NA01, 1983GM1A, 1983VA1E, 1984KE1D, 1984KO1U).

Pion caPture and reactions (See also reactions 36 and 43.): (1980BE24, 1980BE56, 1980ST25, 1981BE63, 1981BE2P, 1981DU1H, 1981FE2A, 1981FR1F, 1981GI1E, 1981GI15, 1981RO14, 1981SI1D, 1981TA08, 1981WH1D, 1982BI08, 1982KA16, 1982LI15, 1982MA22, 1982MU09, 1982RA28, 1982RI1A, 1982WH1A, 1983AZ1B, 1983GE12, 1983GM1A, 1983RI1C, 1983RO07, 1983SP06, 1983TO17, 1983TR1J, 1984CO1V, 1984MI1L, 1985ALZX, 1985DY1C, 1985RO05).

Kaon capture and reactions: (1981BA1H, 1981MA27, 1982BA1R, 1982ER1E, 1982KA1U, 1983AN05, 1983FE07, 1983GA17, 1983MA63).

Antiproton reactions: (1983SU04, 1983SU07, 1984SU07).

Hypernuclei: (1980IW1A, 1981MA27, 1981WA1J, 1982BA1R, 1982ER1E, 1982KA1U, 1982KA1D, 1982ZO1B, 1983AU1A, 1983FE07, 1983MA63, 1983SH38, 1983SH1E, 1984AS1D, 1984BA1N, 1984DA03, 1984ER1A).

Other topics: (1980GO1Q, 1981BL1K, 1982BA2G, 1982DE1N, 1982NG01, 1982VE02, 1983AD1B, 1983GO1R, 1983MA35, 1984BU1Q).

Table 14.12: Energy levels of ^{14}N [a]

E_x in ^{14}N [b] (MeV $\pm$ keV)	$J^\pi; T$	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
g.s.	$1^+; 0$	stable	–	1, 6, 7, 8, 9, 18, 19, 20, 21, 24, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67
2.312798 ± 0.011	$0^+; 1$	$\tau_m = 92 \pm 10$ fsec	γ	1, 9, 18, 19, 21, 24, 30, 31, 32, 33, 36, 37, 38, 39, 44, 45, 46, 47, 48, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66
3.94810 ± 0.20	$1^+; 0$	8.0 ± 1.0 fsec	γ	1, 6, 7, 9, 18, 19, 20, 21, 24, 30, 31, 32, 33, 37, 38, 39, 43, 44, 45, 46, 47, 48, 57, 58, 59, 60, 62, 63, 64, 65, 66
4.9151 ± 1.4	$0^-; 0$	7.6 ± 1.4 fsec	γ	1, 6, 7, 18, 19, 20, 21, 24, 30, 31, 32, 38, 43, 44, 45, 46, 47, 48, 59, 60, 65
5.10589 ± 0.10	$2^-; 0$	6.27 ± 0.07 psec $\lvert g\rvert = 0.66 \pm 0.04$	γ	1, 6, 7, 18, 19, 20, 21, 24, 30, 31, 32, 33, 38, 39, 43, 44, 45, 46, 47, 48, 58, 59, 60, 62, 64, 65
5.69144 ± 0.13	$1^-; 0$	16 ± 8 fsec	γ	6, 7, 18, 19, 20, 21, 24, 30, 31, 33, 38, 43, 44, 45, 46, 47, 48, 59, 60, 65

Table 14.12: Energy levels of ^{14}N [a] (continued)

E_x in ^{14}N [b] (MeV ± keV)	$J^\pi; T$	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
5.83425 ± 0.14	$3^-; 0$	11.98 ± 0.23 psec	γ	1, 6, 7, 11, 18, 19, 20, 21, 23, 30, 31, 33, 38, 39, 43, 44, 45, 46, 47, 48, 58, 59, 60, 62, 65
6.2035 ± 0.6	$1^+; 0$	160 ± 20 fsec	γ	1, 6, 7, 18, 19, 20, 21, 24, 30, 31, 38, 39, 45, 46, 47, 48, 59, 60, 65
6.44617 ± 0.10	$3^+; 0$	620 ± 60 fsec	γ	1, 6, 7, 18, 19, 20, 21, 24, 30, 31, 38, 44, 45, 46, 48, 59, 60, 65
7.02912 ± 0.12	$2^+; 0$	5.4 ± 0.5 fsec	γ	6, 7, 18, 19, 20, 21, 24, 30, 31, 33, 38, 39, 43, 44, 45, 46, 47, 48, 58, 59, 60, 64, 65
7.9669 ± 0.5	$2^-; 0$	$\Gamma = (2.5 \pm 0.7) \times 10^{-3}$	γ, p	6, 7, 18, 19, 20, 21, 24, 30, 31, 45, 48, 59, 64, 65
8.062 ± 1.0	$1^-; 1$	30 ± 1	γ, p	18, 19, 24, 25, 30, 31, 41, 45, 59, 60
8.4899 ± 1.2	$4^-; 0$	$\tau_m = 19 \pm 3$ fsec	γ, p	6, 7, 18, 19, 20, 21, 24, 30, 31, 39, 43, 45, 48, 65
8.6197 ± 1.4	$0^+; 1$	$\Gamma = 3.8 \pm 0.3$	γ, p	18, 19, 24, 25, 30, 31, 45, 59, 60, 65
8.776 ± 7	$0^-; 1$	410 ± 20	γ, p	24, 25, 31
8.9118 ± 2.0	$3^-; 1$	16 ± 2	γ, p	19, 24, 25, 30, 31, 33, 42, 45, 59, 60
8.9638 ± 1.2	$5^+; 0$	$\tau_m = 105 \pm 17$ fsec	γ, p	7, 11, 19, 20, 21, 22, 23, 24, 52, 59
8.9804 ± 2.4	$2^+; (0)$	$\Gamma = 8 \pm 2$	γ, p	6, 7, 19, 24, 25, 30, 31, 59

Table 14.12: Energy levels of ^{14}N [a] (continued)

E_x in ^{14}N [b] (MeV $\pm$ keV)	$J^\pi; T$	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
9.1289 ± 0.5 [c]	$3^+; 0$	$\tau_m = 13 \pm 5$ fsec	γ, p	6, 7, 19, 20, 24, 30, 31, 48
9.17250 ± 0.28	$2^+; 1$	$\Gamma = 0.135 \pm 0.008$	γ, p	19, 24, 30, 31, 41, 42, 45, 59, 60, 64
9.3893 ± 1.4	$2^-; 0$	13 ± 3	p	6, 7, 19, 20, 21, 25, 30, 31, 45, 48, 59, 60, 65
9.509 ± 3	$2^-; 1$	41 ± 2	γ, p	19, 24, 25, 30, 31, 45, 59, 60, 65
9.703 ± 4	$1^+; 0$	15 ± 3	p	6, 19, 20, 21, 25, 30, 31, 45, 60, 65
10.079 ± 10	(3^+)	< 10		6, 7, 10, 19, 21, 31
10.101 ± 15	$2^+, 1^+; 0$	12 ± 3	γ, p	19, 20, 21, 24, 25, 31, 45, 65
10.226 ± 8	$1^{(-)}; 0$	80 ± 15	γ, p	19, 21, 24, 25, 31, 65
10.432 ± 7	$2^+; 1$	33 ± 3	γ, p	10, 19, 24, 25, 38, 42, 59, 65
10.534 ± 20	(1^-)	140	p	19, 25, 31
10.812 ± 15	$5^+; 0$	$(0.39 \pm 0.16) \times 10^{-3}$	γ	6, 7, 10, 19, 20, 21, 31, 59, 65
11.00 ± 30		165 ± 30	γ, p	24, 48
11.050 ± 5	3^+	1.2 ± 0.4	γ, p	6, 7, 10, 19, 21, 24, 31, 59, 64
11.07	$1^+; 0$	100	n, p, d	7, 13, 20, 25, 26, 65
11.21 ± 30	$T = 1$	220 ± 30	γ, p, d	13, 24, 31, 65
11.24 ± 15	$3^-; 0$	11	γ, n, p	10, 19, 23, 25, 26, 31, 42, 45, 46, 47, 48
11.27 ± 15	$2^-; 0$	180	n, p, d	6, 13, 14, 20, 21, 25, 31

Table 14.12: Energy levels of ^{14}N [a] (continued)

E_x in ^{14}N [b] (MeV ± keV)	$J^\pi; T$	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
11.357 ± 15	$1^+; 0$	30	n, p, d	13, 14, 19, 20, 25, 26, 65
11.5135 ± 1.5	$2^+, 3^+$	7.0 ± 0.5	p, d	6, 7, 10, 13, 14, 19, 20, 21, 31, 65
11.676 ± 18	$1^-, 2^-$	150 ± 20	n, p, d	13, 14, 26, 31
11.741 ± 6	$1^-, 2^-$	40 ± 9	(γ), p, d	13, 24
11.761 ± 6	$3^-, 4^-$	78 ± 6	(γ), p, d	13, 24
11.807 ± 7	$2^-, (1^+)$	119 ± 9	n, p, d	6, 13, 14
11.874 ± 6	$2^-, (1^-)$	101 ± 9	n, p, d	13, 26
12.20 ± 19	$1^-, 2^-$	300 ± 30	n, p, d	13, 14, 20, 26, 59
12.408 ± 3	(4^-)	34 ± 3	n, p, d, α	3, 4, 6, 7, 10, 13, 14, 19, 20, 21
12.418 ± 3	$3^-, 4^-$	41 ± 4	p, d	6, 7, 10, 13, 19, 21
12.495 ± 9		39 ± 5	γ, n, p, d, α	3, 13, 19, 24, 38, 42, 59, 64
12.594 ± 3	3^+	48 ± 2	(n), p, d, α	3, 13, 14, 19, 20, 59
12.690 ± 5	3^-	18 ± 5	n, p, d, α	2, 3, 4, 5, 6, 10, 13, 14, 19, 20, 21, 26, 48
(12.708 ± 9)		(43 ± 15)	p, d	13
12.789 ± 5	4^+	16 ± 3	n, p, d, α	2, 3, 4, 5, 7, 10, 13, 14, 19, 59
12.813 ± 4	4^-	5 ± 2	γ, p, d, α	3, 4, 6, 7, 13, 19, 42, 43, 45, 46, 47, 48, 59
12.826 ± 6		11 ± 3	n, p, d	7, 13, 14
12.857 ± 6		78 ± 10	n, p, d	13, 21, 26
12.883 ± 8		134 ± 11	p, d	13, 19
12.922 ± 5	4^+	22 ± 4	p, d, α	3, 4, 10, 13, 14, 19, 22

Table 14.12: Energy levels of ^{14}N [a] (continued)

E_x in ^{14}N [b] (MeV ± keV)	$J^\pi; T$	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
13.007 ± 17		120 ± 30	γ, p	6, 7, 24
13.167 ± 5	1^+	15 ± 5	γ, n, p, d, α	2, 3, 4, 5, 13, 14, 19, 42, 59
13.192 ± 9	3^+	65 ± 10	α	5, 6, 10, 59
13.243 ± 10	2^-	92 ± 5	γ, n, p, α	2, 3, 26, 42, 48, 59
13.30 ± 40	(2^-); 1	1000 ± 150	γ, p	24
13.656 ± 5	$(2^+, 3^+)$	≈ 90	n, p, d, α	2, 3, 5, 13, 14
13.714 ± 5	$2^-, 3^+$	105 ± 25	γ, n, p, d, α	2, 3, 4, 6, 10, 42, 59
13.74 ± 10	1^+; 1	180 ± 20	(γ), n, p, d, α	2, 3, 5, 13, 14, 24, 26, 38, 59
13.77 ± 10	(1^+)	120	p, α	3
14.04 ± 30		100	n, p, d, α	2, 3, 13, 14, 26
14.16 ± 30		230	n, p, d, α	2, 3, 13, 14
14.25 ± 50	3^+	420 ± 100	p, α	3, 5
14.30 ± 20		150	p, α	3
14.56 ± 20		100	n, p, α	2, 3, 6, 10
14.59 ± 30		50	n, p, α	2, 3, 6, 10
14.66 ± 10	5^-; 0	100 ± 20	α	5, 43
14.73 ± 25	$(2^-; 1)$	125	γ, n, p, α	2, 3, 42
14.86 ± 30		140	n, p, d, α	2, 3, 6, 10, 13, 14, 16, 19, 21, 26
14.92 ± 30		43 ± 8	n, p, α	2, 3, 10, 19, 26
15.02 ± 20	$3^-, 4^-$; 1	≈ 60	γ, n, p, α	2, 6, 26, 42, 43
15.24 ± 20		100	p, d, α	3, 6, 7, 10, 13, 14
15.43 ± 20		100	n, p, d, α	2, 3, 13, 16, 21, 48
15.70 ± 50		350	γ, n, p, d, α	6, 13, 14, 16, 19, 21, 26, 42
16.21 ± 20		125	n, p, α	2, 3, 21, 26, 42

Table 14.12: Energy levels of ^{14}N [a] (continued)

E_x in ^{14}N [b] (MeV ± keV)	$J^\pi; T$	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
16.40 ± 20		150	p, d, α	3, 16
16.65 ± 25 [d]	$4^+; 0+1$	240 ± 25	d, α	16
16.91 ± 20	$5^-; 1$	170 ± 25	γ	42
16.91 ± 30	$4^+; 0+1$	290 ± 30	p, d, α	3, 10, 16
16.92 ± 20 [e]	$2^+; 0+1$	830 ± 170	d, α	16
17.03 ± 50	$3^-; 0+1$	245 ± 50	d, α	16
17.17 ± 30	$1^-; 0+1$	300 ± 30	γ, p, d, α	3, 10, 16, 20, 21, 42
17.31 ± 30	$4^+; 0+1$	275 ± 30	d, α	16, 19
17.40 ± 25	$4^+; 0+1$	245 ± 25	d, α	16, 19
17.46	$5^-; 0$			43
17.85 ± 50 [e]	$4^+; 0+1$	475 ± 50	d, α	16
17.85 ± 50 [e]	$3^-; 0+1$	440 ± 50	d, α	16
17.93 ± 70 [e]	$2^+; 0+1$	340 ± 70	d, α	16
18.02 ± 60	$3^-; 0+1$	570 ± 60	d, α	16
18.14 ± 50	$4^+; 0+1$	480 ± 50	d, α	16, 43
18.35 ± 60	$1^-; 0+1$	560 ± 60	d, α	16, 43
18.43 ± 65	$4^+; 0+1$	315 ± 65	d, α	16, 43
18.50 ± 10	$5^-; 0+1$	62 ± 10	d, α	16, 42
18.53 ± 80	$2^+; 0+1$	410 ± 80	d, α	16
18.53 ± 60	$3^-; 0+1$	310 ± 60	d, α	16
18.64 ± 70	$3^-; 0+1$	675 ± 70	d, α	16, 43
18.78 ± 35	$1^-; 0+1$	315 ± 35	d, α	16
18.88 ± 50	$4^+; 0+1$	475 ± 50	d, α	16
18.93 ± 50	$2^+, 3^-; 0+1$	450 ± 50	d, α	16
19.10 ± 90	$3^-; 0+1$	870 ± 90	d, α	16
19.90 ± 60	$2^+; 0+1$	575 ± 60	d, α	16
19.99 ± 50	$1^-; 0+1$	510 ± 50	d, α	16
(20.11 ± 20)	$3^-, 4^-; 0+1$	120 ± 20	γ	42, 43
20.63 ± 110	$4^+; 0+1$	1100 ± 110	d, α	16

Table 14.12: Energy levels of ^{14}N [a] (continued)

E_x in ^{14}N [b] (MeV $\pm$ keV)	$J^{\pi}; T$	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
20.65 ± 60	$5^-; 0+1$	610 ± 60	d, α	16
21.24 ± 50	$4^+; 0+1$	415 ± 50	d, α	16
21.51 ± 25	$3^-; 0+1$	235 ± 25	d, α	16
21.53 ± 75	$5^-; 0+1$	360 ± 75	d, α	16
21.68 ± 40	$4^+; 0+1$	360 ± 40	d, α	16
21.8	$4^+; 0+1$	650	γ, ^{3}He	8
22.26 ± 15	$4^+; 0+1$	65 ± 15	d, α	16
22.31 ± 60	$5^-; 0+1$	570 ± 60	d, α	16
22.5	$2^-; T=1$		γ, p	24, 40
23.0	$2^-; T=1$	≈ 3000	γ, n, p	24, 40
23.40 ± 70	$5^-; 0+1$	640 ± 70	d, α	16
24.0		≈ 1000	n, ^{3}He, α	8

[a] See also Tables 14.13 and 14.14.

[b] I am indebted to E.K. Warburton for sending me a reanalysis of the E_x of many of the states in ^{14}N with $E_x < 9.4$ MeV: see e.g. footnote [b] in Table 14.18.

[c] The present evidence (E.K. Warburton, to be published) only supports the presence of one state at $E_x \approx 9.13$ MeV, with $J^{\pi} = 3^+$. The only remaining evidence for a doublet is the ^{12}C(^{3}He, p′)^{14}N(p)^{13}C$_{g.s.}$ work by (1974NO01).

[d] With the exception of ^{14}N*(16.9, 17.5, 21.8, 22.5, 23.0, 24.0), this state and all the higher states were derived from an S-matrix analysis of the ^{12}C(d, α_1) reaction by (1981JO02).

[e] See, however, Tables 14.22 and 14.23. I am indebted to F.C. Barker for his comments.

Ground state of ^{14}N: (1981AV02, 1982BA2G, 1982LO13, 1982NG01, 1983ANZQ, 1983VA31, 1984AN1B, 1984BR25, 1984WE04, 1985HA18).

$\mu = +0.4037607\ (2)$ nm (1978LEZA),

$Q = +0.0156$ b (1978LEZA),

$\langle r^2 \rangle^{1/2} = 2.560\ (11)$ fm (1980SC18). See also (1984BR25).

Natural abundance: $(99.634 \pm 0.009)\%$ (1984DE53).

Table 14.13: Radiative decays in ^{14}N [a]

E_i (MeV)	$J^\pi_i; T$	E_f (MeV)	$J^\pi_f; T$	Branch (%)	Γ_γ (eV)
2.31	$0^+; 1$	0	$1^+; 0$	100	$(7.2 \pm 0.8) \times 10^{-3}$
3.95	$1^+; 0$	0	$1^+; 0$	3.9 ± 0.2	(M1)$(3.6 \pm 0.7) \times 10^{-4}$
					(E2)$(2.8 \pm 0.2) \times 10^{-3}$
		2.31	$0^+; 1$	96.1 ± 0.2	0.079 ± 0.010
4.92	$0^-; 0$	0	$1^+; 0$	97 ± 3	$(8.4 \pm 1.6) \times 10^{-2}$
		2.31	$0^+; 1$	< 1	
		3.95	$1^+; 0$	[b]	
5.11	$2^-; 0$	0	$1^+; 0$	79.9 ± 1.0	(E1)$(8.00 \pm 0.18) \times 10^{-5}$ [c]
					(M2)$(2.05 \pm 0.51) \times 10^{-6}$ [c,d]
					(E3)$(1.80 \pm 0.51) \times 10^{-6}$ [c,d]
		2.31	$0^+; 1$	19.4 ± 1.2	$(2.04 \pm 0.13) \times 10^{-5}$ [c]
		3.95	$1^+; 0$	(0.7 ± 0.4)	$(7.4 \pm 4.2) \times 10^{-7}$ [c]
5.69	$1^-; 0$	0	$1^+; 0$	36.1 ± 1.2 [e]	$(0.9 \pm 0.5) \times 10^{-2}$
		2.31	$0^+; 1$	63.9 ± 1.2 [e]	$(1.7 \pm 0.8) \times 10^{-2}$
5.83	$3^-; 0$	0	$1^+; 0$	21.3 ± 1.3 [f]	(M2)$(4.8 \pm 1.4) \times 10^{-6}$ [c]
					(E3)$(6.9 \pm 1.5) \times 10^{-6}$ [c]
		5.11	$2^-; 0$	78.7 ± 1.3 [f]	(M1)$(4.32 \pm 0.11) \times 10^{-5}$ [c]
					(E2)$(7^{+8}_{-5}) \times 10^{-8}$ [c]
6.20	$1^+; 0$	0	$1^+; 0$	23.1 ± 1.9 [e]	$(0.9 \pm 0.1) \times 10^{-3}$
		2.31	$0^+; 1$	76.9 ± 2.0 [e]	$(3.2 \pm 0.4) \times 10^{-3}$
6.45	$3^+; 0$	0	$1^+; 0$	70.1 ± 1.5 [e]	$(7.4 \pm 0.7) \times 10^{-4}$ [g]
		3.95	$1^+; 0$	19.7 ± 1.0 [e]	$(2.1 \pm 0.3) \times 10^{-4}$
		5.11	$2^-; 0$	6.5 ± 0.6 [e]	$(0.7 \pm 0.1) \times 10^{-4}$
		5.83	$3^-; 0$	3.7 ± 0.6 [e]	$(0.4 \pm 0.1) \times 10^{-4}$
7.03	$2^+; 0$	0	$1^+; 0$	98.6 ± 0.3	(M1)$(7.8 \pm 1.1) \times 10^{-2}$ [h]
					(E2)$(4.3 \pm 1.0) \times 10^{-2}$
		2.31	$0^+; 1$	0.5 ± 0.1	(E2)$(6.2 \pm 1.4) \times 10^{-4}$
		3.95	$1^+; 0$	0.9 ± 0.25	$< (11 \pm 3) \times 10^{-4}$
7.97 [i]	$2^-; 0$	0	$1^+; 0$	55 ± 3	0.010
		3.95	$1^+; 0$	45 ± 3	0.008
8.06 [f]	$1^-; 1$	0	$1^+; 0$	80.3 ± 0.6	9.9 ± 2.5

Table 14.13: Radiative decays in ^{14}N [a] (continued)

$E_{\rm i}$ (MeV)	$J^{\pi}_{\rm i}; T$	$E_{\rm f}$ (MeV)	$J^{\pi}_{\rm f}; T$	Branch (%)	Γ_{γ} (eV)
		2.31	$0^+; 1$	1.40 ± 0.14	0.17 ± 0.05
		3.95	$1^+; 0$	12.7 ± 0.4	1.56 ± 0.40
		4.92	$0^-; 0$	1.86 ± 0.14	0.23 ± 0.06
		5.11	$2^-; 0$	0.25 ± 0.14	0.03 ± 0.02
		5.69	$1^-; 0$	3.5 ± 0.4	0.43 ± 0.12
8.49 [f]	$4^-; 0$	5.11	$2^-; 0$	83 ± 3	$(6.1 \pm 1.5) \times 10^{-3}$ [j]
		5.83	$3^-; 0$	17 ± 3	$(1.3 \pm 0.4) \times 10^{-3}$ [j]
8.62	$0^+; 1$	0	$1^+; 0$	23	1.20
		3.95	$1^+; 0$	24	1.26
		5.69	$1^-; 0$	13	0.69
		6.20	$1^+; 0$	40	
8.79 [f]	$0^-; 1$	0	$1^+; 0$	90 ± 10	46 ± 12
8.91 [f]	$3^-; 1$	0	$1^+; 0$	1.6 ± 0.5	$(6.6 \pm 2.2) \times 10^{-3}$
		5.11	$2^-; 0$	5.4 ± 2.5	$(2.3 \pm 1.2) \times 10^{-2}$
		5.83	$3^-; 0$	89 ± 3	0.37 ± 0.10
		6.45	$3^+; 0$	3 ± 1	0.012 ± 0.006
		7.03	$2^+; 0$	1.4 ± 0.8	0.006 ± 0.004
8.96	$5^+; 0$	0	$1^+; 0$	< 1	
		6.45	$3^+; 0$	100	$(1.2 \pm 0.2) \times 10^{-3}$ [k]
9.13	$3^+; 0$	0	$1^+; 0$	82 ± 3	$(8.5 \pm 1.0) \times 10^{-3}$ [l]
		5.83	$3^-; 0$	9 ± 3	$(0.9 \pm 0.3) \times 10^{-3}$ [l]
		6.45	$3^+; 0$	9 ± 3	$(0.9 \pm 0.3) \times 10^{-3}$ [l]
9.17 [m]	$2^+; 1$	0	$1^+; 0$	85.9 ± 1.0 [e]	6.2 ± 0.3
		2.31	$0^+; 1$	0.86 ± 0.08 [e]	$(6.2 \pm 0.7) \times 10^{-2}$
		5.69	$1^-; 0$	0.50 ± 0.10 [e]	$(3.6 \pm 0.8) \times 10^{-2}$
		5.83	$3^-; 0$	0.62 ± 0.08 [e]	$(4.5 \pm 0.7) \times 10^{-2}$
		6.45	$3^+; 0$	8.9 ± 0.8 [e]	0.64 ± 0.07
		7.03	$2^+; 0$	3.2 ± 0.3 [e]	0.23 ± 0.03
9.51 [f]	$2^-; 1$	0	$1^+; 0$	< 0.16	< 0.008
		3.95	$1^+; 0$	6 ± 1	0.30 ± 0.09
		5.11	$2^-; 0$	78 ± 3	3.84 ± 0.97

Table 14.13: Radiative decays in ^{14}N [a] (continued)

E_i (MeV)	$J^\pi_i; T$	E_f (MeV)	$J^\pi_f; T$	Branch (%)	Γ_γ (eV)
		5.83	$3^-; 0$	16 ± 2	0.79 ± 0.22
10.23	$1^{(-)}; 0$	2.31	$0^+; 1$	≈ 100	4 ± 1.3
10.43 [n]	$2^+; 1$	0	$1^+; 0$	81.4	10.21 ± 0.65
		5.11	$2^-; 0$	2.2	0.28 ± 0.04
		5.69	$1^-; 0$	1.9	0.24 ± 0.04
		6.45	$3^+; 0$	7.4	0.93 ± 0.12
		7.03	$2^+; 0$	7.0	0.88 ± 0.12
10.81	$5^+; 0$	6.45	$3^+; 0$	100	$(1.6 \pm 0.7) \times 10^{-2}$ [o]
11.05	3^+	0	$1^+; 0$		0.12 ± 0.02
		3.95	$1^+; 0$		0.09 ± 0.02

[a] See Table 14.11 in (1981AJ01) for the earlier references and for additional comments. See also Table 14.14 here and (1981KO08) for additional discussions.

[b] Two values have been reported: $(1.3 \pm 1.0)\%$ and $\leq 0.5\%$.

[c] (1982BH06).

[d] δ(M2/E1) $= -0.16 \pm 0.02$, δ(E3/E1) $= -0.15 \pm 0.025$: see (1981KO08).

[e] Recalculated to sum to 100%: see Table 14.11 in (1981AJ01).

[f] (1981KO08).

[g] δ(M3/E2) $= -0.004 \pm 0.010$.

[h] δ(E2/M1) $= 0.74 \pm 0.09$; and E.K. Warburton, private communication.

[i] $\Gamma_\gamma/\Gamma = (0.7 \pm 0.2)\%$; $(2J+1)\Gamma_p = 12.6 \pm 3.6$ eV; $\Gamma = 2.5 \pm 0.7$ eV.

[j] $\Gamma = (3.5 \pm 0.5) \times 10^{-2}$ eV from Table 14.14; $\Gamma_p/\Gamma = 3.7 \pm 1.1$ [see (1981AJ01)] leads to $\Gamma_\gamma = 7.4 \pm 2.5$ meV.

[k] $\Gamma = 6.3 \pm 1.0$ meV from Table 14.14; $\Gamma_p/\Gamma_\gamma = 4.1 \pm 0.5$.

[l] $\Gamma_p = 43^{-15}_{+31}$ meV; δ(M3/E2) $= -0.03 \pm 0.02$.

[m] $\Gamma_\gamma = 7.2 \pm 0.4$ eV (1981BI17) [from ^{14}N(γ, γ)].

[n] See (1983PR1B; preliminary work). Branching ratios from Γ_γ. See also (1981AJ01).

[o] $\Gamma_\gamma/\Gamma = (4.1 \pm 0.8)\%$; $\Gamma = 0.39 \pm 0.16$ eV.

1. ^{9}Be(^{7}Li, 2n)^{14}N $\qquad Q_m = 7.248$

The energy of the $5.83 \rightarrow 5.11$ γ-transition is $E_\gamma = 728.34 \pm 0.10$ keV. When corrected for the nuclear recoil and added to $E_x = 5105.87 \pm 0.18$ keV, $E_x = 5834.23 \pm 0.21$ keV for ^{14}N*(5.83) (1981KO08). For branching ratios and τ_m see Tables 14.13 and 14.14 (1981KO08).

Table 14.14: Lifetimes of some ^{14}N states [a]

E_x (MeV)	τ_m (fsec)	Reaction	Refs.
2.31	75 ± 19	^{13}C(p, γ)	(1972RE10)
	105 ± 15	^{13}C(p, γ)	(1977BI07)
	79 ± 7	^{13}C(p, γ)	(1980AN1E)
	106 ± 10	^{14}N(γ, γ)	(1975RA22)
	92 ± 10 [A]		
3.95	8.4 ± 0.4	^{13}C(p, γ)	(1977BI07)
	5.7 ± 0.7	^{13}C(p, γ)	(1980AN1E)
	8.7 ± 0.9	^{14}N(e, e)	see reaction 45 in (1981AJ01)
	8.0 ± 1.0 [A]		
4.92	7.6 ± 1.4 [A]		[b]
5.11	(6.2 ± 0.4) psec [c]	^{12}C(^{3}He, p)	(1978MO27)
	(6.27 ± 0.07) psec [A]	^{11}B(α, n)	(1982BH06)
5.69	16 ± 8 [A]	^{13}C(p, γ)	(1977BI07)
5.83	(13.7 ± 1.1) psec	^{12}C(^{3}He, p)	(1978MO27)
	(12.9 ± 1.9) psec	^{9}Be(^{7}Li, 2n)	(1981KO08)
	(11.88 ± 0.24) psec	^{11}B(α, n)	(1982BH06)
	(11.98 ± 0.23) psec		mean
6.20	185 ± 15	^{13}C(p, γ)	(1977BI07)
	132 ± 8	^{13}C(p, γ)	(1980AN1E)
	160 ± 20 [A]		[e]
6.45	620 ± 60 [A]		[e]
7.03	5.4 ± 0.5	^{14}N(γ, γ)	(1966SW01)
8.49 [d]	19 ± 3	^{13}C(p, γ)	(1978KE03) [e]
8.96	105 ± 17	^{13}C(p, γ)	(1978KE03) [e]
9.13	13 ± 5	^{13}C(p, γ)	(1978KE03)

A = adopted.

[a] See also Tables 14.13 in (1976AJ04), 14.12 in (1981AJ01) and 14.22 here.

[b] Based on unpublished measurements: see (1976AJ04).

[c] $|g| = 0.66 \pm 0.04$ (1978MO27).

[d] See also (1981KO08).

[e] I am indebted to P.M. Endt for his suggestions.

See (1981KO08) also for a general discussion of electromagnetic transitions in ^{14}C and ^{14}N, and comparison with theory.

2. ^{10}B(α, n)^{13}N $\quad Q_{\rm m} = 1.0589 \quad E_{\rm b} = 111.6123$

Observed resonances are displayed in Table 14.15. See also (1979BA48).

3. ^{10}B(α, p)^{13}C $\quad Q_{\rm m} = 4.0616 \quad E_{\rm b} = 11.6123$

Excitation functions have been measured to $E_\alpha = 26$ MeV. Observed resonances are displayed in Table 14.15. (1975WI04) has expanded the angular distributions of the $p_0 \rightarrow p_3$ groups into Legendre polynominals and fitted the coefficients at resonances corresponding to ^{14}N*(13.16, 13.24, 13.67, 13.76) obtaining $J^\pi = 1^+$, 2^-, 2 or 3^+, and 1, respectively, for these states. However an R-matrix aanalysis by (1983CS03) suggests $J^\pi = 2^-$, 3^+, 1^+ for ^{14}N*(13.69, 13.74, 13.77). (1975WI04) finds that a surprising proportion of states have a higher cross section for neutron than for proton emission: the fluctuations of $\sigma_{\rm n}/\sigma_{\rm p}$ at low E_α suggest sizable isospin impurities in the ^{14}N states.

4. ^{10}B(α, d)^{12}C $\quad Q_{\rm m} = 1.3399 \quad E_{\rm b} = 11.6123$

Excitation curves have been measured at E_α up to 27 MeV [see (1970AJ04, 1976AJ04, 1981AJ01)]. The low energy resonances are exhibited in Table 14.15. At the higher energies the yield curves are fairly smooth although broad resonances in the d_1 and d_0 yields corresponding to ^{14}N*(23, 25), respectively, have been reported as has a sharp rise in the 15.1 MeV γ yield ≈ 1 MeV above the ^{12}C*(15.1) + p + n threshold, a channel which is not isospin forbidden: see (1981AJ01).

5. ^{10}B(α, α)^{10}B $\quad E_{\rm b} = 11.6123$

The yield of α-particles [and of 0.7 MeV γ-rays for $E_\alpha = 2.1$ to 3 MeV] has been measured for E_α to 50.6 MeV: see (1981AJ01). Observed resonances are displayed in Table 14.15. In addition to two strong resonances in the α_0 yields at $E_\alpha = 2.21$ and 4.26 MeV (^{14}N*(13.19, 14.66)), two other states (^{14}N*(13.72, 14.25)) are required to fit the data: an R-matrix calculation leads to $J^\pi = 3^+$, 1^+ [see, however, (1975WI04)], 3^+ and 2^- for ^{14}N*(13.19, 13.72, 14.25, 14.66): see (1981AJ01).

6. ^{10}B(^{6}Li, d)^{14}N $\quad Q_{\rm m} = 10.1371$

Table 14.15: Resonances in $^{10}B + \alpha$ [a]

E_α (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	Outgoing particle (x) [b]	$^{14}N^*$ (MeV)	J^π
0.95		p_0	12.29	
1.13 ± 5	30 ± 5	$p_0 \rightarrow p_3$, d	12.42	4^-
1.20 ± 5	≈ 20	p_0, (p_2), p_3	12.47	
1.23 ± 5	35 ± 5	p_0, p_3	12.49	
1.40 ± 5	46 ± 4	p_1, p_2, (p_3)	12.61	3^+
1.507 ± 5	18 ± 5	n_0, p_0, p_1, p_2, p_3, d, α [c]	12.690	3^-
1.645 ± 5	16 ± 3	n_0, p_0, p_1, p_2, p_3, d, α [d]	12.789	4^+
1.68 ± 5	5 ± 2	p_1, p_2, p_3, d	12.814	4^-
1.83 ± 5	22 ± 4	$p_0 \rightarrow p_3$, d	12.921	4^+
2.174 ± 5	15 ± 5	n_0, $p_0 \rightarrow p_3$, d, α_1	13.166	1^+
2.21 ± 10	65 ± 10	α_0	13.192	3^+
2.281 ± 10	92 ± 5	n_0, $p_0 \rightarrow p_3$	13.243	2^-
2.86 ± 5	≈ 90	n_0, p_1, p_2, α_1	13.656	
2.94 ± 5 [e]	105 ± 25	n_0, $p_0 \rightarrow p_3$, d	13.714	2^-, 3^+
2.98 ± 10 [e]	180 ± 20	n_0, p_0, p_1, (p_2), α_0	13.74	3^+, $1^{(+)}$
3.02 ± 10 [e]	120	p_1, p_3	13.77	(1^+)
3.40 ± 30	100	n_0, p_1	14.04	
3.56 ± 30	230	n_0, (p_0), p_3	14.16	
3.69 ± 50	420 ± 100	p, α_0	14.25	3^+
3.76 ± 20	150	p_1	14.30	
3.98 ± 20	100	n_0, p_0, p_2	14.56	
4.16 ± 30	50	n_0, p_0, p_3	14.59	
4.26 ± 10	100 ± 20	α_0	14.66	2^-
4.36 ± 30	125	n_0, p_0, p_1, (p_2)	14.73	
4.54 ± 30	140	n_0, p_2, p_3	14.86	
4.633 ± 30	43 ± 8	n_0, n_{2+3}, p_0	14.92	
4.77 ± 20	≈ 60	n_0, n_1	15.02	
5.08 ± 20	100	p_3	15.24	
5.35 ± 20	100	n_1, p_2, p_3	15.43	
6.44 ± 20	125	n_0, p_0, p_2	16.21	
6.70 ± 20	150	p_2	16.40	
7.42 ± 20		p_0	16.91	
7.78 ± 20	50	p_3	17.17	

[a] See references in Table 14.13 in (1981AJ01) as well as in (1970AJ04, 1976AJ04). See also Table 1 in (1975WI04).
[b] n_0, n_1, n_{2+3} correspond to ^{13}N*(0, 2.37, 3.51 + 3.55); p_0, p_1, p_2, p_3 correspond to ^{13}C*(0, 3.09, 3.68, 3.85) and the corresponding γ-rays; α_1 corresponds to the transition to ^{10}B*(0.7). For θ_x^2 see Table 14.8 in (1970AJ04).
[c] $\Gamma_x = 4.3, 0.62, 0.17, 0.70, 5.6, 0.93, 1.7$ keV for n_0, p_0, p_1, p_2, p_3, d, α.
[d] $\Gamma_x = \leq 0.6, 0.18, 0.085, 0.44, 9.6, 2.0, 1.0$ keV for n_0, p_0, p_1, p_2, p_3, d, α.
[e] See (1983CS03).

States with $E_x > 10$ MeV studied in this reaction at $E(^6\text{Li}) = 34$ MeV are displayed in Table 14.16 (1984CL08). In addition most of the lower-lying $T = 0$ states have been populated: see (1970AJ04).

7. ^{10}B(^{7}Li, t)^{14}N $\qquad Q_m = 9.144$

At $E(^7\text{Li}) = 24$ MeV angular distributions of the tritons to ^{14}N*(3.95, 5.83, 6.45, 8.96, 9.13, 10.06, 10.81, 12.79 + 12.83, 13.03, 15.26) have been studied. ^{14}N*(4.91, 5.11, 5.69, 6.20, 7.03, 7.97, 8.49, 8.98, 9.39, 11.05, 11.51, 12.42) are also populated: see (1981AJ01).

8. (a) ^{11}B(^{3}He, γ)^{14}N	$Q_m = 20.7359$	
(b) ^{11}B(^{3}He, n)^{13}N	$Q_m = 10.1824$	$E_b = 20.7359$
(c) ^{11}B(^{3}He, p)^{13}C	$Q_m = 13.1853$	
(d) ^{11}B(^{3}He, d)^{12}C	$Q_m = 10.4635$	
(e) ^{11}B(^{3}He, t)^{11}C	$Q_m = -2.001$	
(f) ^{11}B(^{3}He, ^{3}He)^{11}B		
(g) ^{11}B(^{3}He, α)^{10}B	$Q_m = 9.1236$	
(h) ^{11}B(^{3}He, ^{6}Li)^{8}Be	$Q_m = 4.5720$	

The capture γ-rays [reaction (a)] have been studied at $E(^3\text{He}) = 0.9$ to 2.6 MeV ($\theta = 0°$, 90°). When the barrier penetration factor has been removed a single resonance is observed at $E(^3\text{He}) \approx 1.4$ MeV [^{14}N*(21.8)], $\Gamma_{\text{c.m.}} = 0.65$ MeV.

The excitation function for reaction (b) has been measured for $E(^3\text{He}) = 1.5$ to 18 MeV [see (1981AJ01)]. A broad peak at $E(^3\text{He}) = 4.15$ MeV may indicate the existence of ^{14}N*(24), $\Gamma \approx 1$ MeV.

Yield curves for protons [reaction (c)] have been measured for $E(^3\text{He}) = 3.0$ to 5.5 MeV (p_0, p_1, $p_1 + p_2 + p_3$): they are rather featureless. This is also true for the ground-state deuterons of reaction (d) in the same energy interval. Yield curves for reaction (e) have been measured for $E(^3\text{He}) = 6$ to 30 MeV: see (1976AJ04). A_y measurements for t_0 and t_1 are reported at $E(^3\vec{\text{He}}) = 33$ MeV by (1981BA1G). See also ^{13}C and ^{13}N, and ^{11}B, ^{11}C, ^{12}C in (1985AJ01).

Table 14.16: States in ^{14}N from ^{10}B(^{6}Li, d), ^{11}B(^{6}Li, t), ^{12}C(^{6}Li, α) [a]

[b] E_x (MeV ± keV)	$d\sigma/d\Omega_{c.m.}$ (μb/sr) [c]		
	A	B	C
10.07 ± 15	266	262	290
10.43 ± 15		88	
10.81 ± 15	234	164	
11.05 ± 15	82	64	770
11.24 ± 15		118	
11.27 ± 15	74		1510
11.51 ± 20	102	65	1170
11.79 ± 20	55		
12.42 ± 15	68	305	2702
12.66 ± 30	82	286	1175
12.79 ± 15		434	
12.81 ± 15	149		
12.85 ± 30			4960
12.92 ± 20		324	
13.00 ± 30	138		
13.19 ± 20	80	234	
13.71 ± 20	34	202	
14.57 ± 20	183	217	
14.81 ± 25		332	
14.85 ± 30	189		2325
14.95 ± 30		515	
15.00 ± 30	157		
15.24 ± 20	141	540	
15.40 ± 50			1653
15.70 ± 50	51		3530
16.20 ± 50			1830
16.80 ± 40		246	
16.91 ± 30		297	
17.17 ± 30		712	4860

A: ^{10}B(^{6}Li, d); $E(^{6}\text{Li}) = 34$ MeV.
B: ^{11}B(^{6}Li, t); $E(^{6}\text{Li}) = 34$ MeV.
C: ^{12}C(^{6}Li, α); $E(^{6}\text{Li}) = 32$ MeV.
[a] (1984CL08): see for angular distributions and for discussion of analog states in ^{14}C.
[b] States below $E_x = 10$ MeV are not displayed here.
[c] At $\theta_{lab} = 10°$. Uncertainties in the differential cross sections are approximately ±20%.

The excitation functions for α-particle groups [reaction (g)] have been measured for $E(^3\text{He}) = 0.9$ to 5.5 MeV: see (1976AJ04). No significant resonance behavior is seen except for the α_2 group which, in the $15°$ excitation function, exhibits a resonance at $E(^3\text{He}) = 4$ MeV, $\Gamma \approx 1$ MeV. See also ^{10}B in (1984AJ01).

The excitation function for reaction (h) to $^6\text{Li}_{\text{g.s.}} + {}^8\text{Be}_{\text{g.s.}}$ has been measured for $E(^3\text{He}) = 1.4$ to 5.8 MeV: no pronounced structure is observed. At $E(^3\text{He}) = 25.20$ to 26.25 MeV the excitation functions for the transitions to ^{8}Be*(0, 16.63, 16.91, 17.64) are smooth, indicating a predominantly direct reaction mechanism: see (1976AJ04).

9. ^{11}B(α, n)^{14}N $\qquad Q_{\text{m}} = 0.1581$

For angular distributions to $E_\alpha = 13.9$ MeV see (1981AJ01). For radiative transitions and τ_{m} see (1982BH06) in Tables 14.13 and 14.14. See also ^{15}N.

10. ^{11}B(^{6}Li, t)^{14}N $\qquad Q_{\text{m}} = 4.9403$

States with $E_{\text{x}} > 10$ MeV studied in this reaction at $E(^6\text{Li}) = 34$ MeV are displayed in Table 14.16 (1984CL08).

11. ^{11}B(^{11}B, ^{8}Li)^{14}N $\qquad Q_{\text{m}} = -6.473$

At $E(^{11}\text{B}) = 114$ MeV the relatively strongly populated states are ^{14}N*(5.83, 8.96, 12.8) [$J^\pi = 3^-, 5^+, 4^+$]: see (1976AJ04).

12. ^{12}C(d, γ)^{14}N $\qquad Q_{\text{m}} = 10.27239$

At 1.5 MeV the capture cross section is < 1 μb: see (1970AJ04).

13. (a) ^{12}C(d, n)^{13}N $\qquad Q_{\text{m}} = -0.2811 \qquad E_{\text{b}} = 10.27239$

(b) ^{12}C(d, p)^{13}C $\qquad Q_{\text{m}} = 2.7218$

Resonances in the yields of neutrons and protons are displayed in Table 14.17. Earlier measurements of the yields of neutrons (to $E_{\text{d}} = 17$ MeV) and of protons (to $E_{\text{d}} = 14.7$ MeV) are listed in Tables 14.11 (1970AJ04) and 14.16 (1976AJ04). The $0°$ yield of neutrons has also been reported by (1981LI23: n_0, 5.5 to 13.5 MeV; n_1, 6 to 14 MeV): broad structures are observed at $E_d \approx 7.2$ and 11.5 MeV [n_0] and 8 and (10.8) MeV [n_1] as well as a sharper structure at $E_d \approx 9.5$ MeV [n_0]. The 25° excitation functions for n_0, n_1 and n_{2+3} are reported for $E_d = 10.6$ to 13 MeV (1984SC04). See also (1981SH22). Excitation functions for proton groups ($p_0 \rightarrow p_3$) are also reported for $E_d = 0.5$ to 2.5 MeV (1980HA1X, 1983JI04, 1983JI1B).

The VAP and the 0° transverse vector polarization transfer coefficient $K_y^{y'}(0°)$ have been measured for $E_d = 5.7$ to 9.7 MeV [n_0, n_1]. The values of $K_y^{y'}$ are large, close to the maximum value of $\frac{2}{3}$, consistent with a model of the neutron as a simple spectator in the reaction (1976TE03). $K_y^{y'}(0°)$ has also been measured in the range $E_{\vec{d}} = 5 \rightarrow 12$ MeV by (1981LI23; n_0, n_1). Polarization measurements are alsoi reported at $E_{\vec{d}} = 10$ MeV (1981DR1D; n_0) and 12.3 MeV (1981BR1E; n_0, n_1, n_{2+3}), and for reaction (b) at $E_{\vec{d}} = 10$ MeV (1981DR1D; p_0), 11.35 MeV (1982BU03; p_0) and 56 MeV (1984HA26; $p_0 \rightarrow p_3$). For earlier polarization studies see Tables 14.12 (1970AJ04), 14.17 (1976AJ04) and (1981AJ01).

Table 14.17: Resonances in $^{12}C + d$ [a]

E_d (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	Particles out	$^{14}N^*$ (MeV)	$J^\pi; T$
0.92	95	n, p_0, p_1	11.06	$1^+; 0$
1.13		p_0, p_1	11.24	$T = 1$
1.19	190	n, p_0, p_1, d	11.29	$2^-; 0$
1.23		p_0	11.33	(3^+)
1.30	30	n, p_0, p_1, d	11.39	$1^+; 0$
1.39		p_0	11.46	(2^-)
1.4495 ± 1.5	7.0 ± 0.5	p_0, p_1, d	11.5135	$2^+, 3^+$
1.55		p_0	11.60	(2^-)
1.640 ± 20	150 ± 20	n, p_1, d_0	11.68	$1^-, 2^-$
1.715 ± 6	40 ± 9	p_2	11.741	$1^-, 2^-$
1.738 ± 6 [b]	78 ± 6	p_1	11.761	$3^-, 4^-, (2^-)$
1.792 ± 7	119 ± 9	n, p_0, p_1, p_2, d_0	11.807	$2^-, (1^+)$
1.870 ± 6	101 ± 9	p_0, p_1, p_2	11.874	$2^-, (1^-)$
2.250 ± 19	300 ± 30	n, $p_0 \rightarrow p_3$, d_0	12.20	$1^-, 2^-$
2.494 ± 3 [c]	37 ± 4	n, $p_0 \rightarrow p_3$, d_0	12.408	$3^+, (3^-, 4^-)$
2.506 ± 3	41 ± 4	p_1	12.418	$3^-, 4^-, (2^+, 3^+)$
2.610 ± 20	30 ± 20	n, p_1, p_2, p_3	12.507	
2.712 ± 3	48 ± 2	(n), $p_0 \rightarrow p_3$, d_0	12.594	3^+
(2.817 ± 7)	27 ± 6	n, p_1, p_2, p_3, d_0	(12.684)	
2.844 ± 9	43 ± 15	p_2, p_3	12.708	

Table 14.17: Resonances in ^{12}C + d [a] (continued)

E_d (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	Particles out	^{14}N* (MeV)	$J^\pi; T$
2.940 ± 10	30 ± 10	p_2, p_3, d	12.790	
2.967 ± 5	37 ± 6	p_1	12.813	
2.982 ± 6	11 ± 3	n, p_3, d	12.826	
3.018 ± 6	78 ± 10	n, p_0, p_1	12.857	
3.049 ± 8	134 ± 11	p_1	12.883	
3.100 ± 10	20 ± 14	p_1, p_2, p_3, d	12.927	$(3^-, 4^-)$
3.39 ± 12	47 ± 15	n, p_2, p_3, d	13.17	$(0^-, 1^-)$
3.97 ± 30	< 200	p_0, p_2, p_3, (d)	13.67	$(2^+, 3^+)$
4.02^{+20}_{-10}	≈ 235	n, (p), d	13.71	(1^+)
4.40		$p_0 \rightarrow p_3$, d	14.04	
4.55		n, p_2, d	14.17	
4.80		p_0, p_2, d	14.38	
5.17		d	14.70	
5.34	≈ 100	$p_0 \rightarrow p_3$, d, α	14.84	
5.65		d	15.11	
5.83		p_1, p_3, d	15.26	
6.07		p_1, p_2, α	15.47	
6.3		p_0, p_3, d, α	15.7	
7.2		α	16.4	
7.448 [d]	240	α_2	16.65 [d]	4^+
7.760 [e]	828	α_2	16.92	2^+
7.784	293	α_2	16.94	4^+
7.887	246	α_2	17.03	3^-
8.034	307	α_2	17.15	1^-
8.217	275	α_2	17.31	4^+
8.327	244	α_2	17.40	4^+
8.851	473	α_2	17.85	4^+
8.852	437	α_2	17.85	3^-
8.942 [e]	336	α_2	17.93	2^+
9.051	567	α_2	18.02	3^-
9.186	481	α_2	18.14	4^+

Table 14.17: Resonances in ^{12}C + d [a] (continued)

E_d (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	Particles out	^{14}N* (MeV)	$J^\pi; T$
9.433	558	α_2	18.35	1^-
9.530 [e]	313	α_2	18.43	4^+
9.610	62	α_2	18.50	5^-
9.637 [e]	410	α_2	18.53	2^+
9.647 [e]	312	α_2	18.53	3^-
9.768	673	α_2	18.64	3^-
9.939	314	α_2	18.78	1^-
10.057	475	α_2	18.88	4^+
10.112	452	α_2	18.93	$2^+, 3^-$
10.306	872	α_2	19.10	3^-
11.237	575	α_2	19.90	2^+
11.348	506	α_2	19.99	1^-
12.094	1071	α_2, α_3	20.63	4^+
12.122	612	α_2	20.65	5^-
12.809	414	α_2	21.24	4^+
13.124	233	α_2	21.51	3^-
13.148 [e]	362	α_2	21.53	5^-
13.323	357	α_2	21.68	4^+
14.002 [e]	65	α_2	22.26	4^+
14.054	568	α_2	22.31	5^-
15.334	640	α_2	23.40	5^-

[a] For references see Table 14.15 in (1976AJ04).

[b] See also (1983JI04, 1983JI1B).

[c] A study of this resonance shows that either f-shell components are present in the wave function or that the coupling is very strong or that both effects are present.

[d] S-matrix analysis of α_2 by (1981JO02) leads to the resonance parameters for the states shown below, all of which are isospin-mixed. See also Table 14.14 in (1981AJ01) and Table 1 in (1981JO02). Uncertainties in $\Gamma_{c.m.}$ and E_x are about 10% of $\Gamma_{c.m.}$.

[e] Uncertainties in $\Gamma_{c.m.}$ and E_x are about 20% of $\Gamma_{c.m.}$.

For continuum cross sections [reaction (b)] see (1980MA32; E_d = 56 MeV). For neutron production cross sections see (1984SH04). For total cross sections see (1980DE28, 1981PE01, 1983IM1A). For pion emission see (1981AL1K, 1984AL1L). For fragmentation studies see

(1980BO31, 1983AB01). See also (1980HA1N, 1983LIZW) and (1981NO1B, 1984NA06, 1985MA1L; theor.).

14. ^{12}C(d, d)^{12}C $E_{\rm b} = 10.27239$

Reported resonances are displayed in Table 14.17. Yield measurements of d_0 up to $E_{\rm d} = 26.5$ MeV are listed in Table 14.16 of (1976AJ04). A recent measurement at $E_{\rm d} = 0.5$ to 2.5 MeV is reported by (1980HA1X). See also (1981AJ01). For polarization measurements to $E_{\rm d} = 52$ MeV see Table 14.17 in (1976AJ04), (1981AJ01) and (1984HA26: $E_{\vec{\rm d}} = 56$ MeV; d_0). For polarization transfer in the deuteron breakup at $E_{\vec{\rm d}} = 56$ MeV see (1985SA16). See also (1981DA1B, 1983JI04, 1983JI1B) and (1980HA56, 1980ST1K, 1982TA19, 1983BA1V; theor.).

15. (a) ^{12}C(d, t)^{11}C $Q_{\rm m} = -12.4642$ $E_{\rm b} = 10.27239$

(b) ^{12}C(d, ^{3}He)^{11}B $Q_{\rm m} = -10.4635$

At $E_{\vec{\rm d}} = 29$ MeV, polarizations of the groups to $^{11}{\rm B}_{\rm g.s.}$ and $^{11}{\rm C}_{\rm g.s.}$ have been studied by (1978CO13). VAP measurements to $^{11}{\rm B}_{\rm g.s.}$ are reported at $E_{\vec{\rm d}} = 52$ MeV by (1981MA14).

16. ^{12}C(d, α)^{10}B $Q_{\rm m} = -1.3399$ $E_{\rm b} = 10.27239$

Reported resonances are displayed in Table 14.17. Listing of the measurements of the yields of α-groups to $E_{\rm d} = 29.5$ MeV are given in Tables 14.16 (1976AJ04) and 14.11 (1970AJ04).

The major interest in this reaction has been the study of the yield of the α_2 group to the $J^\pi = 0^+$, isospin "forbidden" $T = 1$ state. In particular, the work of (1971RI15, 1972SM07) has shown that while the α_0, α_1 and α_3 yields show only weak fluctuations, the α_2 "forbidden" yield shows narrow resonances which implies that the source of the isospin mixing (at least in the region which they, and the subsequent work of (1974JO01) studied: $E_{\rm d} = 7.2$ to 16 MeV) is due to states in the ^{14}N compund nucleus. The ratio of the $\sigma_{\rm t}$ for the α_2 group compared to the $\sigma_{\rm t}$ for the "allowed" groups is $\approx 1\%$, an order of magnitude greater than predicted by direct of multistep processes (1972SM07). An S-matrix analysis leads to the resonance parameters shown in Table 14.17 (1981JO02). See also (1972SM07, 1974JO01).

Polarization measurements have been reported at $E_{\vec{\rm d}} = 11$ to 29 MeV [see (1981AJ01)] and at 52 MeV (1982MA25; α_0, α_1, $\alpha_{3\to5}$).

17. ^{12}C(d, ^{6}Li)^{8}Be $Q_{\rm m} = -5.8915$ $E_{\rm b} = 10.27239$

For polarization measurements see (1981AJ01) and (1983TA1Q, 1983YA1D; $E_{\vec{d}} = 51.7$ MeV).

18. ^{12}C(t, n)^{14}N $\qquad Q_m = 4.01511$

Angular distributions have been measured to states below 8.7 MeV at $E_t = 1.12$ to 1.68 MeV and at 8 MeV: see (1976AJ04).

19. ^{12}C(^{3}He, p)^{14}N $\qquad Q_m = 4.7789$

Observed proton groups are displayed in Table 14.18. Angular distributions have been measured for $E(^3$He) to 25.3 MeV [see (1970AJ04, 1976AJ04)] and at $E(^3\vec{\mathrm{He}}) = 33$ MeV (1983RO22, 1983LE17; p_0, p_1, p_2). See also ^{15}O. For τ_m and $|g|$ measurements see Table 14.14. For inclusive proton measurements see (1984AA01; $E(^3\mathrm{He}) = 52$ MeV). See also (1983CA07) and (1983GO2D; applied).

20. ^{12}C(α, d)^{14}N $\qquad Q_m = -13.57434$

Angular distributions of deuterons corresponding to $T = 0$ states in ^{14}N have been measured at $E_\alpha = 42$ and 55 MeV: see Table 14.19 in (1976AJ04), and (1981AJ01). At $E_\alpha = 34.5$ MeV a ZRDWBA analysis has been made of the angular distributions to ^{14}N*(4.92, 5.11, 5.69, 5.83, 7.97, 8.49, 8.96, 9.13, 9.39, 10.81). Spectroscopic information on the 2^- states ^{14}N*(5.11, 7.97, 9.13, 9.39) [but see Table 14.12] is also reported (1984YA03). At the higher energies the deuteron spectrum is dominated by very strong groups corresponding to the $(d_{5/2})^2$, $J^\pi = 5^+$ state at 8.96 MeV, and to a state at 15.1 MeV: see (1976AJ04).

21. ^{12}C(^{6}Li, α)^{14}N $\qquad Q_m = 8.7972$

At $E(^6\mathrm{Li}) = 20$ MeV [see Table 14.9 in (1976AJ04)] and 32 MeV (1984CL08: see Table 14.16 here) many of the α-groups corresponding to $T = 0$ states with $E_x < 17.2$ MeV are observed. The spectrum is dominated by the α-group corresponding to the 5^+ state at 9.0 MeV: see (1970AJ04). Angular distributions have been measured for $E(^6\mathrm{Li}) = 2$ to 33 MeV [see (1981AJ01)] and at $E(^6\mathrm{Li}) = 3.2$ to 8.0 MeV (1981SC13; $\alpha_0 \rightarrow \alpha_2$). See also ^{18}F in (1983AJ01) and (1981MA26, 1983OS03; theor.).

Table 14.18: States of ^{14}N from ^{12}C(^{3}He, p)^{14}N [a]

E_x (MeV ± keV)	L	$J^\pi; T$	E_x (MeV ± keV)	L	$J^\pi; T$
0	2		10.063 ± 15 [e]		$3^+, \geq 4$
2.319 ± 15	0		10.101 ± 15		$1^+, 2^+$
3.9502 ± 1.5 [b]	0		10.23		1
4.9153 ± 1.4 [b]	1		10.441 ± 15	[g]	$(2^+; 1)$ [h]
≡ 5.10587 ± 0.18	1		10.53		1, 2
5.6888 ± 1.4 [b]	1		10.812 ± 15		$5^+; 0$
5.8324 ± 1.4 [b]	3		11.053 ± 15		
6.2025 ± 1.4 [b]	0		11.249 ± 15		
6.4449 ± 1.4 [b]	2		11.357 ± 15		
7.0279 ± 1.4 [b]	2		11.517 ± 15		
7.9649 ± 1.4 [b]	3		[f]		
8.072 ± 15	1		12.29 ± 15		
8.4864 ± 1.5 [b,c]	3	$4^-; 0$	12.425 ± 15		
8.6174 ± 4 [b]	0	$(0^+; 1)$ [h]	12.506 ± 15		
8.9099 ± 1.9 [b,d]		$(3^-; 1)$ [h]	12.608 ± 15		
8.9598 ± 1.4 [b]			12.69 ± 15		
8.9773 ± 4 [b]		$(2^+; 0)$ [h]	12.80 ± 15		
9.1241 ± 1.5 [b]			12.90 ± 25 [f]		
9.1674 ± 1.4 [b]	[g]	$(2^+; 1)$ [h]	13.15 ± 40		
9.3854 ± 1.6 [b,d]		$2^-; 0$ [i]	14.91 ± 60		
9.51		$(2^-; 1)$ [h]	15.8 ± 200		
9.703 ± 15		$(1^+; 0)$ [h]	17.4 ± 200		

[a] See Tables 14.14 in (1970AJ04), 14.18 in (1976AJ04) and 14.15 in (1981AJ01) for references.
[b] A re-evaluation by E.K. Warburton (private communication) [based on an overall comparison with γ-ray values) of the E_x obtained by (1971DU03) leads to E_x = 3949.1 ± 1.5, 4915.1 ± 1.4, 5689.4 ± 1.4, 5833.1 ± 1.4, 6203.6 ± 1.4, 6446.2 ± 1.4, 7029.8 ± 1.4, 7967.8 ± 1.4, 8489.8 ± 1.5, 8620.9 ± 4.0, 8913.7 ± 1.9, 8963.7 ± 1.4, 8981.2 ± 4.0, 9128.1 ± 1.5, 9171.5 ± 1.4 and 9389.7 ± 1.6 keV.
[c] $\Gamma_p/\Gamma = 0.73 \pm 0.10$.
[d] The widths of ^{14}N*(8.91, 9.39) are, respectively, 19.7 ± 1.9 and 15.6 ± 2.0 keV.
[e] $\Gamma < 10$ keV (J.W. Noe, private communication).
[f] See Table 14.15 in (1981AJ01).
[g] $\theta_p^2(l = 3) = (2.3 \pm 1.1) \times 10^{-3}$ and $< 1.6 \times 10^{-3}$ for ^{14}N*(9.17, 10.43).
[h] Known from other data; consistent with the results in this reaction.
[i] Or $J^\pi = 3^-$.

22. ^{12}C(^{11}B, ^{9}Be)^{14}N $\qquad Q_m = -5.5431$

At $E(^{11}B) = 114$ MeV the spectrum is dominated by groups to the 5^+ state at $E_x = 8.96$ MeV and to one or more of states at 12.9 MeV, presumably the 4^+ one: see (1981AJ01).

23. ^{12}C(^{12}C, ^{10}B)^{14}N $\qquad Q_m = -14.9142$

This reaction has been studied at $E(^{12}C) = 114$ MeV: the spectrum is dominated by ^{14}N*(8.96)[$J^\pi = 5^+$] but there is substantial population also of ^{14}N*(5.83)[3^-] and of a state at $E_x = 11.2$ MeV. Angualr distributions are reported at $E(^{12}C) = 58$ to 64.5 MeV, at 93.8 MeV [see (1981AJ01)] and at $E(^{12}C) = 49.0$ to 75.5 MeV (1980CO10; involving also ^{10}B*(0, 0.7); see also for excitation functions).

24. (a) ^{13}C(p, γ)^{14}N $\qquad Q_m = 7.55062$
(b) ^{13}C(p, p$'\gamma$)^{13}C $\qquad E_b = 7.55062$

Observed resonances are displayed in Table 14.19. Radiative decay and τ_m measurements are exhibited in Tables 14.13 and 14.14.

The low-energy capture cross section yields an extrapolated S-factor at $E_p = 25$ keV (c.m.), $S_0 = 6.0 \pm 0.8$ kev · b. The capture cross section rises from $(7.7 \pm 1.8) \times 10^{-10}$ b at $E_p = 100$ keV to $(9.8 \pm 1.2) \times 10^{-9}$ b at $E_p = 140$ keV: see (1970AJ04).

Following is a summary of the reasons for the assignments of $J^\pi; T$ to some of the lower resonances displayed in Table 14.19: for a fuller discussion and complete references see (1970AJ04, 1976AJ04, 1981AJ01). ^{14}*N*(7.97)*: angular distribution of the γ-rays is consistent with $J^\pi = 2^-$. ^{14}*N*(8.06)*: width of resonance, isotropy of γ-rays show $l_p = 0$: $J^\pi = 1^-$ from ^{13}C(p, p); E1 transition to g.s. is uninhibited e.g. $T = 1$ [but 1.4% $8.06 \rightarrow 2.31$ transition [$E_x = 2312.6 \pm 0.3$ keV] shows $T = 0$ admixture: $\alpha_2 = 0.046$]. The strong transition $8.06 \rightarrow 5.69$ [3.5%] permits either E1 or M1, $\Delta T = 1$. Since $5.69 \rightarrow 2.31$ is seen ^{14}*N*(5.69)* cannot have $J^\pi = 0^+$, and 2^+ is excluded by the strength of the $8.62 \rightarrow 5.69$ transition. It is then $J^\pi = 1^-; T = 0$ [the isospin mixing $\alpha_2 = 0.09$]; $E_x = 5690.5 \pm 1.5$ keV. ^{14}*N*(8.49, 8.96, 9.13)* correspond to anomalies in the cross section. The nature of their γ-decays [see Table 14.13] and the angular distribution leads to $J^\pi; T = 4^-$; 0, 5^+; 0, 3^+; 0, respectively.

^{14}*N*(8.62)* [$J^\pi = 0^+$ from ^{13}C(p, p)] shows strong transitions to ^{14}N*(0, 3.95, 5.69): $T = 1$. The strength of the $8.62 \rightarrow 3.95$ decay shows it is dipole and therefore $J = 1$ for ^{14}N*(3.95)[$E_x = 3947.6 \pm 0.4$ keV]. The strength of the transition $8.62 \rightarrow 6.20$ and the angular correlation $8.62 \rightarrow 6.20 \rightarrow$ g.s. is consistent with $J^\pi = 1^+$, $T = 0$ for ^{14}*N*(6.20)*[$E_x = 6203.7 \pm 0.6$ keV]. ^{14}*N*(8.79)*[$J^\pi = 0^-$ from ^{13}C(p, p)] has a large Γ_γ consistent with E1 and $T = 1$. ^{14}*N*(9.17)*: angular correlation and angular distribution measurements indicate $J^\pi = 2^+$ for that state, 3^- for

^{14}*N*(6.45)* [see however Table 14.12] and $J = 2$ for ^{14}*N*(7.03)*. For a recent study of ^{14}*N*(9.17)* see (1981BI17): $E_x = 9172.5 \pm 0.3$ keV from E_γ, $\Gamma_{\gamma 0}/\Gamma_\gamma = (79 \pm 4)\%$, Γ [from (p, p)] $= 135 \pm 8$ eV [135 ± 11 eV in (γ, γ)]. Other E_x determined by (1981BI17) are 2312.90 ± 0.03, 3948.2 ± 0.2, 5105.9 ± 0.3, 5691.55 ± 0.13 and 6446.3 ± 0.2 keV. See also Table 14.13.

Table 14.19: Levels of ^{14}N from ^{13}C(p, γ)^{14}N and ^{13}C(p, p)^{13}C [a]

E_p (MeV $\pm$ keV)	$\Gamma_{c.m.}$ (keV)	l_p	$\omega\Gamma_\gamma$ (eV)	J^π; T	^{14}N* (MeV)
0.4485 ± 0.5	< 0.37	2	0.022	2^-	7.9669
0.551 ± 1	30 ± 1	0	9.2	1^-; 1	8.062
1.012 ± 2	≤ 0.2	4	≈ 0.01	(4^-); 0	8.490
1.152 ± 1.4 [b]	3.8 ± 0.3	1	1.3	0^+; 1	8.620
1.320 ± 7 [b]	410 ± 20	0	12.8	0^-; 1	8.776
1.462 ± 3	16 ± 2	2	0.72	3^-; 1	8.907
1.523 ± 2	< 1		≈ 0.003	5^+; 0	8.964
1.540 ± 3	8 ± 2	1, (3)	0.13	2^+	8.980
1.7005 ± 1	< 1			3^+; 0	9.1287
1.7476 ± 0.9 [c]	135 ± 8 eV		[c]	2^+; 1	9.1724
1.980 ± 3	13 ± 3	2		3^-, 2^-	9.388
2.110 ± 3	41 ± 2	2	6.2	2^-; 1	9.509
2.319 ± 4	15 ± 3	1		1^+	9.703
2.743 [d]	12 ± 3	1	[j]	1^+, (2^+)	10.096
2.885 ± 10 [d]	80 ± 15	0, 2		$1^{(-)}$; 0	10.228
3.105 ± 7 [d,e]	33 ± 3	1	17	2^+; 1	10.432
3.20 [d]	140	0, 2		1^-	10.52
3.72 ± 30 [f]	165 ± 30				11.00
3.771 ± 5	1.2 ± 0.4		[k]	3^+	11.050
3.79	100			1^+	11.07
3.94 ± 30	220 ± 30				11.21
3.98 [d]	11	2		3^-	11.24
4.04 [d]	175	2		2^-	11.30
4.14 [d]	28	1		1^+	11.39
4.525 ± 15 [g]	115 ± 10		[l]	1^+	11.750
5.325 ± 10	48 ± 7		[m]		12.492
5.88 ± 20 [f]	120 ± 30				13.01

Table 14.19: Levels of ^{14}N from ^{13}C(p, γ)^{14}N and ^{13}C((p, p)^{13}C [a] (continued)

E_p (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	l_p	$\omega\Gamma_\gamma$ (eV)	$J^\pi; T$	^{14}N* (MeV)
6.20 ± 100 [h]	1000 ± 150		[n]	$(2^-); 1$	13.30
6.62 ± 20 [f]					13.69
[i]					
16.1				$2^-; 1$	22.5
16.7				$2^-; 1$	23.0

[a] See references in Tables 14.16 in (1970AJ04), 14.20 in (1976AJ04) and 14.16 in (1981AJ01).
[b] (1985FEZY). See also (1984AD04).
[c] See (1981BI17): $E_x = 9172.5 \pm 0.3$ keV from γ-ray measurements. See also Table 14.13, $\Gamma_{\gamma_0}/\Gamma_\gamma = (79 \pm 4)\%$; Γ_{γ_0} (from reaction 41) $= 7.2 \pm 0.4$ eV; $\Gamma_{c.m.}$ from ^{13}C(p, p).
[d] Reduced width for proton emission is of the order of 1% of the Wigner limit.
[e] $\Gamma_{\gamma_0} = 11.2 \pm 1.4$ eV (1983PR1B; prelim.).
[f] Weak resonance.
[g] In the $\gamma_{3.09}$ channel the peak occurs 55 keV higher: interference effects may be present.
[h] Part of the giant dipole resonance.
[i] Some broad structures appear in the γ_0, $\gamma_{3.68}$ and $\gamma_{3.85}$ yields. See also reaction 25.
[j] $(2J+1)\Gamma_\gamma = 0.5 \pm 0.2$ eV.
[k] $\Gamma_\gamma = 1.2 \pm 0.4$ keV; $\Gamma_p = 0.5\%$ of single-particle unit. J^π based on angular distribution of γ_0. For nature of γ-decay see Table 14.13.
[l] $(2J+1)\Gamma_\gamma = (18.5 \pm 4.2)\Gamma/\Gamma_p$ eV; if $J = 1$, $\Gamma_\gamma \geq 6$ eV.
[m] $(2J+1)\Gamma_{\gamma_0} = 2.3\Gamma/\Gamma_p$ eV; if $\Gamma = 38$ eV is assumed.
[n] $(2J+1)\Gamma_{\gamma_0} \geq 200$ eV: thus the transition is dipole and $T = 1$. The resonance is asymmetric and it is suggested that two states are involved, one with $J^\pi = 1^-$ at $E_x = 12.7$ and the other one with 2^- at $E_x = 13.3$ MeV.

The angular distribution of the γ-rays from $10.23 \rightarrow 2.31$ is consistent with $J^\pi = 1^+$ for ^{14}*N*(10.23)*: $T = 0$ from M^2(M1) [see, however, Table 14.12]. The γ_0 angular distribution is consistent with $J = 2$ for ^{14}*N*(10.43)*: the similar decay characteristics of this state and of ^{14}*N*(9.17)* suggest that they are both $J^\pi = 2^+$, $T = 1$.

Below $E_p = 5.5$ MeV only γ_0 can be observed in the capture radiation. A number of resonances in the γ_0 yield and in the yield of the ground-state γ-rays from ^{13}C*(3.09, 3.68, 3.85) have been observed: these are shown in Table 14.19 in the range $E_p = 3.7$ to 6.6 MeV. Angular distributions and measurements of Γ_{γ_0} lead to the J^π values shown. Above $E_p = 7$ MeV the γ_0 yield shows broad structure and the giant dipole resonance at $E_x = 22.5$ and 23.0 MeV. Measurements of the γ_0 and γ_1, 90° yields $E_x = 23$ to 33 MeV find that the $T = 2$ resonances reported earlier at $E_x = 23.7$ and 24.2 MeV do not exist and that there is no evidence for the $T = 2$ GDR between $E_x = 25$ and 29 MeV. The 90° yields of γ-rays to $T = 0$ states ($4.9 < E_x < 5.9$ MeV) and to $T = 1$

states ($8.0 < E_x < 9.5$ MeV) have been measured from $E_x = 23$ and 26 MeV, respectively, to $E_x = 33$ MeV. A study of the 90° yield of γ_0 and γ_1 [and of analyzing powers] has been reported for $E_{\vec{p}} = 6.25$ to 17.0 MeV. The γ_0 results are in good agreement with those in the inverse reaction [^{14}N(γ, p)^{13}C]. Broad structures are observed at $E_p \approx 8$, 13, 14, 15 and 16.5 MeV. The γ_1 results indicate that the $T = 0$ strength is spread out fairly uniformly between $E_x = 13$ and 23 MeV. At $E_p = 25$ MeV strong transitions are observed to two groups of states centered near $E_x = 5.8$ and 8.9 MeV.

See also (1980WE1D, 1981WE1A, 1984SE16), (1981BA2F, 1982BA80, 1984BO1Q, 1984TR1C; astrophys.) and (1980SO1D, 1981AB1E, 1983GO1B; theor.).

25. ^{13}C(p, p)^{13}C $E_b = 7.55062$

The elastic scattering has been studied for $E_p = 0.14$ MeV to 1 GeV: see (1981AJ01) and ^{13}C here. For observed resonances see Table 14.19. A study of the $0^+ - 0^-$ doublet at $E_x \approx 8.7$ MeV is presented by (1984AD04). A phase-shift analysis implies the existence of resonances with $J^\pi = 1^-$, 2^- and 3^+ in the vicinity of $E_p \approx 15$ MeV. The 1^- and 2^- resonances have widths of $\approx 3 - 4$ MeV and have a total Γ_p/Γ value of 0.1. The correlation between these resonances and the GDR is not clear (1978WE13). A_y measurements are reported at $E_{\vec{p}} = 200$ MeV (1981ME02) and 547 MeV (1984SE12; $p_0 \rightarrow p_4$ and to ^{13}C*(7.55, 8.86, 9.5)). See also (1976AJ04) and (1981CO1D; theor.).

26. ^{13}C(p, n)^{13}N $Q_m = -3.0028$ $E_b = 7.55062$

The yield of neutrons has been measured from threshold to $E_p = 13.7$ MeV: see (1970AJ04). Observed resonances are displayed in Table 14.20. The n_0 excitation function is also reported for $E_p = 10.1$ to 16.8 MeV (1981BY01; n_0). The ratio of the reaction cross section at $E_p = 22.8$ MeV to the n_0 yield is 1.06 ± 0.07: thus there is little competition of γ-rays from the excited states of ^{13}N with neutron emission making this a convenient fast neutron calibration source. A_y measurements are reported for $E_{\vec{p}} = 6.88$ to 17.0 MeV (1981MU1C, 1981MU1D; n_0; prelim.) and 160 MeV (1981GOZX; ^{13}N*(0, 3.5)). For the earlier work see (1981AJ01). See also ^{13}N and (1981BY1C, 1984HE20).

27. ^{13}C(p, d)^{12}C $Q_m = -2.7218$ $E_b = 7.55062$

Excitation functions have been reported recently for $E_p = 16$ to 21 MeV (1982MA1H) and 200 to 500 MeV (1980KA01; d_0, d_1). A_y measurements have been made at $E_{\vec{p}} = 13.6$ to 14.4 MeV (1982BU03; d_0), 65 MeV (1980HO18; for d to ^{12}C*(0, 12.71, 15.1, 16.1)), (1982KA01; for d to ^{12}C*(16.11)), 200 and 400 MeV (1981LI06; d_0, d_1) and 530 MeV (1984OH06; d_0). See also ^{12}C in (1985AJ01), (1981IR1A) and (1982YA1A).

Table 14.20: Resonances in ^{13}C(p, n)^{13}N (1961DA09) [a]

E_p (MeV)	Γ (keV)	^{14}N* (MeV)	E_p (MeV)	Γ (keV)	^{14}N* (MeV)
3.76 ± 0.05	100	11.04	6.67 ± 0.13	250	13.74
3.98 ± 0.02	30	11.24	7.0 ± 0.1	150	14.0
4.05		11.31	7.3		14.3
4.15 ± 0.02	40	11.40	7.85 ± 0.08	150	14.83
4.5 ± 0.1	100	11.7	7.93 ± 0.03	50	14.91
4.7 ± 0.1	150	11.9	8.03 ± 0.03	50	15.00
5.03 [b]		12.22	8.7 ± 0.2	350	15.6
(5.44 ± 0.03)	(60)	(12.60)	9.3 ± 0.1	150	16.2
5.53 ± 0.03	50	12.68	10.2 ± 0.2	400	17.0
5.72 ± 0.03	60	12.86	11.4 ± 0.3	600	18.1
6.20 ± 0.04	70	13.30			

[a] See also Table 14.9 in (1959AJ76).
[b] (1959GI47).

28. (a) ^{13}C(p, t)^{11}C $\quad Q_m = -15.186 \quad E_b = 7.55062$
(b) ^{13}C(p, ^{3}He)^{11}B $\quad Q_m = -13.1853$

At $E_p = 49.6$ MeV polarization measurements have been carried out for the tritons and ^{3}He ions to the mirror groups ^{11}B*(0, 2.12, 4.45, 5.02, 6.74, 12.91) and ^{11}C*(0, 2.00, 4.32, 4.80, 6.48, 12.50) (1974MA12). A_y measurements are reported at $E_{\vec{p}} = 65$ MeV for the triton and ^{3}He groups to ^{11}B*(0, 2.12) and ^{11}C*(0, 2.00) (1982KA01).

29. ^{13}C(p, α)^{10}B $\quad Q_m = -4.0616 \quad E_b = 7.55062$

Excitation functions have been measured from $E_p = 5.5$ (α_0), 6.0 (α_1), 7.0 (α_2), 8.0 (α_3), 10 (α_4), 11 (α to ^{10}B*(5.11)) to 18 MeV. Total cross sections have also been obtained for the production of ^{6}Li, ^{9}Be and ^{10}B: the latter shows a great deal of structure. The analyzing power for the α_0 group has been measured at $E_{\vec{p}} = 65$ MeV: see (1981AJ01).

30. ^{13}C(d, n)^{14}N $\quad Q_m = 5.3260$

Table 14.21: ^{14}N levels from ^{13}C(d, n) and ^{13}C(^{3}He, d) [a]

^{14}N* [b] (MeV ± keV)	$J^{\pi}; T$ [b]	l_p [c]	l_j [d]	$(2J_f + 1)C^2S$ [d]
0	$1^+; 0$	1	$p_{1/2}$	2.27
2.31	$0^+; 1$	1	$p_{1/2}$	0.92
3.95	$1^+; 0$	1	$p_{3/2}$	1.10
4.92	$0^-; 0$	0	$s_{1/2}$	0.29
5.11	$2^-; 0$	2	$d_{5/2}$	1.79
5.69	$1^-; 0$	0	$s_{1/2}$	0.91
			$d_{3/2}$	0.29
5.83	$3^-; 0$	2	$d_{5/2}$	2.19
6.20	$1^+; 0$	1	$p_{1/2}$	0.032
6.45	$3^+; 0$	1	$f_{7/2}$	(0.1)
7.03	$2^+; 0$	1	$p_{3/2}$	0.31
7.97	$2^-; 0$		$d_{5/2}$	0.051
8.06	$1^-; 1$	0	$s_{1/2}$	0.10
			$d_{3/2}$	< 0.006
8.49	$4^-; 0$	4 [h,i]		
8.62	$0^+; 1$	1 [j]	$p_{1/2}$	0.021
8.79	$0^-; 1$		$s_{1/2}$	< 0.009
8.91	$3^-; 1$	2 [k]	$d_{5/2}$	3.32
8.98	$2^+; (0)$	(1, 2, 3)	$p_{3/2}$	< 0.2
9.12	$(2^-; 0)$ [g]	2	$d_{5/2}$	0.14
9.17	$2^+; 1$	(1, 3)	$p_{3/2}$	< 0.08
9.39	$2^-; 0$	2	$d_{5/2}$	0.62
9.51	$2^-; 1$	2	$d_{5/2}$	1.31
9.70	$1^+; 0$	1	$p_{1/2}$	0.039
10.085 ± 12	$(1-3)^-$ [e]		$d_{5/2}$	0.054
10.222 ± 12	$(0-2)^+$ [e]		$p_{1/2}$	0.16
10.534 ± 20	$(0-2)^+$ [e,f]		$p_{1/2}$	0.34
10.81	$5^+; 0$ [f]			
11.05	(3^+) [e,f]			
11.26 ± 50	$(0-2)^+$ [e,f]		$p_{1/2}$	0.22
11.49 ± 40	$(0-2)^+$ [e,f]		$p_{3/2}$	0.040

Table 14.21: ^{14}N levels from ^{13}C(d, n) and ^{13}C(^{3}He, d) [a] (continued)

^{14}N* [b] (MeV ± keV)	$J^\pi; T$ [b]	l_p [c]	l_j [d]	$(2J_f+1)C^2S$ [d]
11.66 ± 40	$(0-2)^{+}$ [e,f]		$p_{1/2}$	0.092

[a] See also Table 14.18 in (1981AJ01) and 14.23 in (1976AJ04).
[b] From Table 14.12.
[c] ^{13}C(d, n)^{14}N: $E_d = 4.5$ to 6.5 MeV.
[d] ^{13}C(^{3}He, d)^{14}N: $E(^3He) = 43.6$ MeV (1981PE07); DWBA.
[e] From (1981PE07).
[f] $\Gamma \approx 200$, 50, 50, 80, 80 and 100 keV for ^{14}N*(10.53, 10.81, 11.06, 11.26, 11.51, 11.66).
[g] See, however, Table 14.12.
[h] Observed in (d, n) and (^{3}He, d).
[i] $\Gamma_p < 9.9 \times 10^{-2}$ eV.
[j] $\Gamma_p < 18$ keV.
[k] $\Gamma_p = 12.1$ keV.

Observed neutron groups are displayed in Table 14.21. Angular distributions have been reported at many energies up to $E_d = 12$ MeV: see (1970AJ04). Comparisons of relative spectroscopic factors obtained in this reaction and in reaction 31 are shown in Table 14.23 of (1976AJ04): it appears that S_{rel} for ^{14}N*(2.31) [$T = 1$] is smaller in this reaction than in the (^{3}He, d) reaction although simple DWBA calculations would suggest that the factors would be the same in both proton pickup reactions. The $\tau \cdot \mathbf{T}$ term appear to be energy dependednt: see Table 14.23 (1976AJ04). See also ^{15}N.

31. ^{13}C(^{3}He, d)^{14}N $\qquad Q_m = 2.5071$

Angular distributions have been studied at $E(^3He) = 13$ to 17 MeV [see (1976AJ04)] and at 43.6 MeV (1981PE07): see Table 14.21 for the states observed in this reaction. See also (1981AJ01).

32. ^{13}C(α, t)^{14}N $\qquad Q_m = -12.2634$

Angular distributions have been measured at $E_\alpha = 27$ MeV for the α groups to ^{14}N*(0, 2.31, 3.95, 4.92, 5.11). See also (1981AJ01).

33. ^{13}C(^{7}Li, ^{6}He)^{14}N $\qquad Q_m = -2.424$

Table 14.22: ^{14}N states from ^{14}N(γ, γ') and ^{14}N(e, e′) [a]

E_x (MeV ± keV)	Mult.	$J^\pi; T$	Γ_{γ_0} (eV)	Γ (keV)
8.06	E1	$1^-; 1$	10.5 ± 6	
8.91	M2	$3^-; 1$	$(6.6 \pm 2.2) \times 10^{-3}$	
9.17	M1	$2^+; 1$	7.2 ± 0.4 [b]	
			6.3 ± 0.3 [c]	
10.43 [d]	M1	$2^+; 1$	9.6 ± 1.9 [e]	
11.24 [f]	C3	(3^-)		
12.54 ± 100 [e]	(M1, C2)	$J = 0 \to 3$	$\frac{14.7 \pm 3.2}{2J+1}$	
12.81 [f]	C3	4^-		
13.27 ± 100 [e]	(M1, M2, C2)	$J = 0 \to 3$		
13.76 ± 100 [e]	(M1, C1)	$J = 0 \to 2$	$(4 \pm 1) \times 10^{-3}$ [g]	
14.72 ± 30 [f]	M2	$(2^-; 1)$		≈ 100
15.01 ± 30 [f]	M4	$3^-, 4^-; \approx 1$		≈ 100
16.11 ± 100 [e]	(M2)	$J = 0 \to 3$		
16.91 ± 20 [f]	M4	$5^-; \approx 1$		170 ± 20
18.48 ± 40 [f]	M4	$5^-; \approx 1$		
20.11 ± 20 [f]	M4	$3^-, 4^-; \approx 1$		120 ± 20

[a] See Table 14.19 in (1981AJ01) for references and additional information. See also Tables 14.13 and 14.14 here.
[b] (1981BI17).
[c] A. Richter and G. Kuehner, private communication.
[d] $\Gamma = 44$ keV, $\Gamma_{\gamma_0} = 8.8$ eV (A. Richter and G. Kuehner, private communication).
[e] (1979EN01).
[f] (1984BE13).
[g] And $\Gamma = 105 \pm 20$ keV (A. Richter and G. Kuehner, private communication).

At $E(^7\text{Li}) = 34$ MeV ^{14}N*(0, 2.31, 3.95, 5.11, 5.69, 5.83, 7.03, 8.91) are populated: the ground state is dominant (1984CL08). See also (1981AJ01) and reaction 17 in ^{14}C.

34. ^{13}C(^{13}C, ^{12}C)^{14}C $\qquad Q_{\text{m}} = 3.3866$

For fusion cross sections [and population of a 6.73 MeV γ-ray] see (1982CH05).

35. ^{14}C(β^-)^{14}N $\qquad Q_{\text{m}} = 0.15647$

See ^{14}C.

36. ^{14}C(π^+, π^0)^{14}N $\qquad Q_{\text{m}} = 4.761$

Forward-angle differential cross sections for the isobaric-analog state have been measured at $E_{\pi^+} = 100$, 165, 230 and 295 MeV (1983IR04). See also (1984KNZY, 1985KNZZ; $E_{\pi^+} = 35 - 100$ MeV) and (1985KA04).

37. ^{14}C(p, n)^{14}N $\qquad Q_{\text{m}} = -0.6259$

Angular distributions, generally for the n_0, n_1 and n_2 groups, have been measured in the range $E_{\text{p}} = 2.45$ to 35 MeV [see (1981AJ01)] and at 25.7, 35 and 45 MeV (1984TA02). (1984TA07) have measured the transverse spin-transfer coefficients [$D_{\text{NN}}(0°)$] at 160 MeV for the groups to ^{14}N*(0, 2.31 [$D_{\text{NN}} = 1$], 3.95, 13.72). The main GT strength lies in the three 1^+ states and their D_{NN} values, which are consistent with $\frac{1}{3}$, are those expected for pure $L = 0$ transitions (1984TA07). See also (1982MAZZ, 1983OR1D, 1985OR1G, 1985OR1H), (1981GO1H, 1982GO1C, 1982TA03, 1982YA1A, 1983TA1F, 1984TAZS, 1985TA1T) and (1982TO1C, 1983BO24, 1984HA58; theor.).

38. ^{14}C(^{3}He, t)^{14}N $\qquad Q_{\text{m}} = 0.1379$

At $E(^3\text{He}) = 44.8$ MeV, triton groups are observed corresponding to all known levels of ^{14}N with $E_{\text{x}} < 7.1$ MeV. Triton groups were also seen to unresolved states with $E_{\text{x}} = 8.0 \rightarrow 9.5$ MeV, to ^{14}N*(10.43) and to excited states with $E_{\text{x}} = 12.49 \pm 0.04$, 12.83 ± 0.05 and 13.70 ± 0.04 MeV. Angular distributions were obtained for nine of the triton groups and analyzed using a local two-body interaction with an arbitrary spin-isospin exchange mixture. Dominant $L = 0$ transitions are found to ^{14}N*(2.31, 3.95, 13.7), $L = 1$ to ^{14}N*(5.11), $L = 2$ to ^{14}N*(0, 7.03, 10.43) and $L = 3$ to ^{14}N*(5.83) (1969BA06).

39. (a) ^{14}C(^{6}Li, ^{6}He)^{14}N $\quad Q_{\rm m} = -3.350$
(b) ^{14}C(^{7}Li, ^{7}He)^{14}N $\quad Q_{\rm m} = -11.05$

Angular distributions have been studied at $E(^{6}\text{Li}) = 34$ MeV (1981CU02; to ^{14}N*(0, 3.95, 5.11)), at 62 MeV (1980WH03; to ^{14}N*(0, 2.31, 3.95, 5.11, 5.83, 6.20, 7.03, 8.49)), and at 210 MeV (1985AN1H; to ^{14}N*(3.95); prelim.). At $E(^{6}\text{Li}) = 93$ MeV and $E(^{7}\text{Li}) = 78$ MeV (1984GL06) report the population of a number of states: the most intense groups are to ^{14}N*(0, 3.95, 5.0, 7.0, 8.5). (1980WH03) have measured the total GT strength up to $E_{\rm x} \approx 12$ MeV. See also (1981AJ01), (1982AL1F, 1983AL1L) and (1983GA12; theor.).

40. (a) ^{14}N(γ, n)^{13}N $\quad Q_{\rm m} = -10.5535$
(b) ^{14}N(γ, p)^{13}C $\quad Q_{\rm m} = -7.55062$
(c) ^{14}N(γ, d)^{12}C $\quad Q_{\rm m} = -10.27239$

The total absorption over the range $E_\gamma = 9$ to 31 MeV is dominated by a single peak at 22.5 MeV [estimated $\sigma \approx 29$ mb, $\Gamma \approx 2 - 3$ MeV] and appreciable strength extending beyond 30 MeV. The cross section cannot be accounted for solely by the (γ, n) and (γ, p$_0$) processes: particle unstable excited states of ^{13}C, ^{13}N are involved. The combined (γ, n) and (γ, pn) cross section begins to rise rapidly above 18 MeV, reaches its maximum value of 15 mb at 23.3 MeV and exhibits structure at about 19, 20.5 and 26 MeV. The main peak ($\Gamma \approx 3.5$ MeV: see (1970AJ04)) at 23.3 MeV appears to be split into two absorption levels: see (1981AJ01). Maxima reported in other experiments and "breaks" in the (γ, n) activation curve are listed in (1970AJ04). Most of the photon absorption in the giant resonance region forms $J^\pi = 2^-$ states in ^{14}N which decay by d-wave neutron emission to ^{13}N g.s. Some evidence is found for the existence of $J^\pi = 0^-$ strength at the peak of the giant resonance and for a small amount of isospin $T = 0$ mixing near 22.5 MeV: see (1981AJ01).

The (γ, p$_0$) and (γ, p$_2$) cross sections and angular distributions have been measured in the giant resonance region. The giant dipole states [$(\text{p}_{3/2})^{-1}$(2s1d)] which decay by p$_0$ emission to ^{13}C*(3.68) appear to carry $\approx 90\%$ of the E1 strength and do not contribute substantially to the (γ, p$_0$) process which is populated by $(\text{p}_{1/2})^{-1}$(2s1d) giant dipole states. Above $E_\gamma = 22$ MeV d-wave emission from 2^- states appears to dominate the (γ, p$_0$) cross section: see (1976AJ04) and (1983VA1K).

For reaction (c) see (1980IS10) and reaction 42. See also (1982JU03) and (1982VI07; applied).

41. ^{14}N(γ, γ)^{14}N

See (1981BI17) and Table 14.12. See also (1985SM1G) and (1983ZH1D; theor.).

42. (a) ^{14}N(e, e′)^{14}N

(b) ^{14}N(e, d)^{12}C $\qquad Q_{\rm m} = -10.27239$

Form factors have been determined at many energies in the range $E_{\rm e} = 60.7$ to 300 MeV: see (1981AJ01) for the earlier references and (1984HU07; $q = 0.80$ fm^{-1} to 3.33 fm^{-1}; to ^{14}N*(0, 2.31)) and (1984BE13; see Table 14.22 and below). In addition to the states above $E_{\rm x} = 11$ MeV reported in Table 14.22, (1984BE13) have populated ^{14}N*(12.50, 13.17, 13.71, 15.43, 15.7, 17.2, 17.8) but not the 5^- states at $E_{\rm x} = 14.66$ and 17.46 MeV which are thus presumably $T = 0$. (1984BE13) report that within the triplet of 5^- states at 14.66, 16.91, 17.46 MeV, they can account for $\approx 60\%$ of the isovector 5^- strength but only 35% of the isoscalar strength. There is no other significant M4 strength up to $E_{\rm x} \approx 28$ MeV (1984BE13). See (1981AJ01) for the earlier work.

For reaction (b) see (1980TA15) and reaction 40. See also (1984DO20, 1984LI25, 1985HI04) and (1981DE1T, 1981IS11, 1981KE15, 1983AL04, 1983DE13, 1983GM1A, 1984VO1G, 1984VOZW; theor.).

43. ^{14}N($\pi^{\pm}$, $\pi^{\pm}$)^{14}N

Angular distributions at $E_{\pi^{\pm}} = 162$ MeV have been studied to the states listed in Table 14.23 (1983GE03). See the the “GENERAL” section here.

44. ^{14}N(n, n′)^{14}N*

Angular distributions of elastically and inelastically scattered neutrons are displayed in Table 14.23 of (1970AJ04). See also (1984TEZZ; n$_0$; 11, 14, 17 MeV). Observed γ-rays are shown in Table 14.25 of (1976AJ04).

45. (a) ^{14}N(p, p′)^{14}N*

(b) ^{14}N(p, pα)^{10}B $\qquad Q_{\rm m} = -11.6123$

Angular distributions of elastically and inelastically scattered protons have been studied at many energies up to $E_{\rm p} = 155$ MeV [see (1981AJ01)] and at $E_{\vec{\rm p}} = 21$ MeV (1982AO05; p$_0$, p$_1$, p$_2$) and 159.4 MeV (1983TA12; p$_0$, p$_1$, p$_2$), as well as at $E_{\rm p} = 800$ MeV (1982BL08; p$_0$, p$_2$ and p to ^{14}N*(5.83, 7.03, 7.97, 8.49): see Table 14.24. The spin-flip probability has been measured at $E_{\vec{\rm p}} = 32$ MeV to ^{14}N*(2.31) by (1981CO08). For reaction (b) see (1984VDZZ; $E_{\rm p} = 50$ MeV). See also (1981AJ01), ^{15}O, (1983BEYW, 1984DE1F), (1983SC1G), (1984HA1Q; applied), (1984BO1Q; astrophys.) and (1981FE04, 1981IS11, 1983GO10, 1983IK1B, 1984HUZY; theor.).

Table 14.23: States of ^{14}N from ^{14}N($\pi^{\pm}$, $\pi^{\pm}$) (1983GE03)

E_x (MeV)	$J^\pi; T$	Mult.	$B(E\lambda)\uparrow$ ($e^2 \cdot fm^{2\lambda}$)
0			
3.95		E2	2.8 ± 0.4
4.92			
5.11		E3	74 ± 10
5.69			
5.83		E3	117 ± 18
7.03		E2	3.95 ± 0.7
8.49			
11.24		E3	110 ± 12
12.79		E3	151 ± 17
13.14		E3	31 ± 8 [b]
14.66	$5^-; 0+1$		
15.10			
15.57	$2, 3, 4^-; 0$	E3	$10(2J+1)$
16.06	$3^-; 0$		
16.86	$5^-; 1+0$		
17.46	$5^-; 0+1$		
17.89	$2^- + 4^-; 0$		
[a]			
18.70	$(3^-); 0+1$		
20.10	$(3^-); 0+1$		

[a] States at $E_x = 18.2$ and 18.4 MeV are also populated.

[a] $J^\pi = 2^-$ assumed.

Table 14.24: ^{14}N levels from ^{14}N(p, p′), (d, d′), (^{3}He, ^{3}He′) and (α, α') [a]

^{14}N* (MeV ± keV)				L	Dominant config.	$J^\pi; T$
(p, p′) [b]	(d, d′)	(^{3}He, ^{3}He′)	(α, α')			
2.31 [c]	see text	[e]	see text		$(p_{1/2})^2$	$0^+; 1$
3.95	[e]	[e]	[e]	2	$(p_{1/2})^2$ + c.e. [i]	$1^+; 0$
4.92	[e]	[e]	[e,h]	1	$p_{1/2}s_{1/2}$	$0^-; 0$
5.11	[e]	[e]	[e,h]	3	$p_{1/2}d_{5/2}$	$2^-; 0$
5.69	[e]	[e]	[e,h]	1	$p_{1/2}s_{1/2}$	$1^-; 0$
5.83	[e]	[e]	[e,h]	3	$p_{1/2}d_{5/2}$	$3^-; 0$
6.20 [d]	[e]	[e]	[e,f]		$(s_{1/2})^2$	$1^+; 0$
6.45 [d]	[e]		[e,f]		$s_{1/2}d_{5/2}$	$3^+; 0$
7.03	[e]	[e]	[e]	2	c.e. [i]	$2^+; 0$
7.97			[e,h]	1	$p_{1/2}d_{3/2}$	$2^-; 0$
8.06 [c]		$8.0 \to 11.0$ [g]			$p_{1/2}s_{1/2}$	$1^-; 1$
8.49			[e,h]	3		$4^-; 1$
8.62					$(s_{1/2})^2$	$0^+; 1$
8.91					$p_{1/2}d_{5/2}$	$3^-; 0$
			9.12 [h]	3		$2^-; 0$ [j]
9.17					c.e. [i]	$2^+; 1$
9.39			[e,h]	3		$2^-, 3^-; 0$
9.51					$p_{1/2}d_{5/2}$	$1^+; 0$
9.70					$(p_{1/2})^2$	$1^+; 0$
10.1					$s_{1/2}d_{5/2}$	$2^+, 1^+; 0$
			10.98 [h]	3		
11.2 ± 200	[f]	11.22 ± 50	11.21 [h]	3		(3^-)
			12.59 [h]	3		3^-
12.8 ± 400	[f]	12.77 ± 50	12.78 [h]	3		4^-
			13.13 [h]	3		2^-
			15.41 [h]	3		$\pi = -$
17						
21.5						

[a] For references see Tables 14.20 in (1981AJ01) and 14.27 in (1976AJ04). Most of the L-values shown here are from the (α, α') work of (1982PE05).

[b] See text of reaction 47 in (1981AJ01) and reactions 45 here.

[c] Not observed at $E_p = 800$ MeV (1982BL08).

[d] Weakly populated at $E_p = 800$ MeV (1982BL08).

[e] Observed.

[f] Relatively low cross section due to two-nucleon transition.

[g] Unresolved structure.

[h] (1982PE05): $E_\alpha = 34.85$ MeV.

[i] c.e. = compound elastic.

[j] See, however, Table 14.12.

46. ^{14}N(d, d′)^{14}N*

Angular distributions of elastically and inelastically scattered deuterons have been studied to $E_d = 52$ MeV: see (1981AJ01) and Table 14.24 for the listing of the observed states. The deuteron group to the 0^+, $T = 1$ state ^{14}N*(2.31) is isospin forbidden: its cross section is $1 - 2$ orders of magnitude less than that to ^{14}N*(3.95) [$J^\pi; T = 1^+; 0$]. It is summarized for $E_d = 6$ to 20 MeV by (1979AO01) who find that the observed isospin violation is well accounted for by a direct multistep reaction mechansim which assumes that there is isospin mixing in the intermediate channels.

47. ^{14}N(^{3}He, ^{3}He′)^{14}N*

Angular distributions of elastically and inelastically scattered ^{3}He ions have been measured at $E(^3\text{He})$ up to 44.6 MeV: see Table 14.23 in (1970AJ04) and (1976AJ04).

At $E(^3\text{He}) = 44.6$ MeV, twelve ^{3}He groups are reported corresponding to states in ^{14}N: see Table 14.24. The angular distributions were analyzed using a local two-body interaction with an arbitrary spin-isospin exchange mixture. A comparison of the cross sections of the reactions ^{14}N(^{3}He, t)^{14}O(g.s.), ^{14}N(^{3}He, ^{3}He)^{14}N*(2.31) and ^{14}C(^{3}He, t)^{14}N(0) [which all correspond to transitions between identical initial and final states] shows that they are roughly equal, as would be expected from charge independence, once detailed-balance, isospin-coupling and phase-space corrections have been applied: see (1976AJ04).

48. ^{14}N(α, α')^{14}N*

Angular distributions of elastically and inelastically scattered α-particles have been measured for $E_\alpha = 7.6$ to 104 MeV: see Table 14.23 in (1970AJ04) and (1976AJ04, 1981AJ01), as well as (1982PE05; $E_\alpha = 34.85$ MeV) in Table 14.24 here. Generally the intensity of the α_1 group is weak: see also ^{18}F in (1983AJ01). See also (1983SA07) and (1980SP1E, 1982BU1D, 1983GO27; theor.).

49. (a) ^{14}N(^{6}Li, ^{6}Li)^{14}N
(b) ^{14}N(^{7}Li, ^{7}Li)^{14}N
(c) ^{14}N(^{6}Li, αd)^{14}N $\qquad Q_m = -1.4751$

Elastic angular distributions have been measured at $E(^6\text{Li}) = 19.5$ and 32 MeV [see (1981AJ01)] and at 36 MeV (1983ET02) as well as at $E(^7\text{Li}) = 36$ MeV: see (1981AJ01). See also (1979KN1A). For reaction (c) see ^{18}F in (1987AJ02), (1983ET02).

50. ^{14}N(^{9}Be, ^{9}Be)^{14}N

For fusion cross sections see (1984MA28).

51. (a) ^{14}N(^{10}B, ^{10}B)^{14}N
(b) ^{14}N(^{11}B, ^{11}B)^{14}N

Elastic angular distributions have been measured for reaction (a) at $E(^{10}\text{B}) = 100$ MeV and $E(^{14}\text{N}) = 73.9$ and 93.6 MeV [see (1981AJ01)] as well as at 86 MeV (1982OR02). Those for reaction (b) have been studied at $E(^{14}\text{N}) = 41$, 77 and 113 MeV: see (1981AJ01). For fusion and other yield measurements see (1980PA19, 1982BE54, 1982OR02) for (a) and (1983DA10) for (b). See also (1981AJ01), (1982HO1F), (1983BI13, 1984FR1A, 1984HA53) and (1981AB1A, 1983GO13, 1984HA43, 1984IN03; theor.).

52. ^{14}N(^{12}C, ^{12}C)^{14}N

Elastic and inelastic angular distributions have been studied in the range $E(^{14}\text{N}) = 21.3$ to 155 MeV: see (1981AJ01). For fusion cross-section measurements and for yield measurements see (1981AJ01) and (1981CO11, 1984GO05, 1985CA01). For evaporation studies see (1982BO1M, 1983QU02). See also (1981DIZW, 1983CA1N, 1983DA10), (1981ST1P, 1983BI13, 1983DU13, 1984FR1A, 1984HA53) and (1981CH23, 1981CU06, 1981DE13, 1981VA1E, 1981VA1H, 1982BL12, 1982HA42, 1982HA56, 1982HU1G, 1982LO13, 1983CI08, 1983GO13, 1984HA43, 1984MAZT; theor.).

53. ^{14}N(^{13}C, ^{13}C)^{14}N

Elastic angular distributions have been measured at $E(^{14}\text{N}) = 19.3$ MeV [see (1981AJ01)] and 28 and 35 MeV (1983SR01) as well as at $E(^{13}\text{C}) = 105$ MeV (1980PR09). For fusion studies see (1980WI09, 1982DI13). See also (1983BI13, 1984FR1A, 1984HA53) and (1983GO13; theor.).

54. ^{14}N(^{14}N, ^{14}N)^{14}N

Elastic angular distributions have been studied for $E(^{14}\text{N}) = 4.99$ to 20.22 MeV: see (1981AJ01). For fusion and reaction cross-section measurements see (1981AJ01) and (1982DE39, 1982TR1C). See also (1983DA10), (1981ST1P, 1983BI13, 1984FR1A, 1984HA53) and (1981AB1A, 1982HA42, 1982LO13, 1984HA43, 1984IN03; theor.).

55. ^{14}N(^{16}O, ^{16}O)^{14}N

Elastic angular distributions have been studied for $E(^{14}\text{N}) = 8.08$ to 155 MeV: see (1981AJ01). For fusion cross-section measurements see (1981AJ01) and (1981VO01). See also (1982FI1G, 1983DA10), (1981ST1P, 1983BI13, 1983DU13, 1984FR1A) and (1982HA42, 1982LO13, 1983CI08, 1984HA43, 1984IN03; theor.).

56. For other heavy-ion reactions see (1981AJ01).

(a) ^{14}N(^{24}Mg, ^{24}Mg)^{14}N
(b) ^{14}N(^{27}Al, ^{27}Al)^{14}N
(c) ^{14}N(^{28}Si, ^{28}Si)^{14}N
(d) ^{14}N(^{29}Si, ^{29}Si)^{14}N

Elastic angular distributions are reported at $E(^{14}\text{N}) = 53.03$ MeV for reaction (a), 52.29 MeV for (b) and 53.40 MeV for (c) (1981MA02) and at $E(^{14}\text{N}) = 40$, 46 and 56 MeV for reactions (b, c, d) (1983CR1B; prelim.). For fusion and fragmentation studies see (1981BI10, 1981TA22, 1983CR1B, 1984GU05, 1985GU1M). See also (1981AJ01) and (1982DM1A, 1984SHZY), (1983BI13) and (1980BI13, 1982FR1Q, 1983CE1C, 1985BE09, 1985BL09; theor.).

57. ^{14}O(β^+)^{14}N $\qquad Q_{\text{m}} = 5.1431$

$^{14}O_{g.s.}$ decays predominantly to its analog state $^{14}N^*(2.31)$: $E_x = 2312.798 \pm 0.011$ keV (1982WA16): see reaction 1 in ^{14}O.

58. $^{15}N(\gamma, n)^{14}N$ $\quad Q_m = -10.8333$

For cross sections see (1982JU03, 1983WA03) in ^{15}N. See also (1981AJ01).

59. $^{15}N(p, d)^{14}N$ $\quad Q_m = -8.6087$

Angular distributions have been obtained for the deuterons corresponding to $^{14}N^*(0 \rightarrow 8.06$, 8.62, 8.91, $8.96 + 8.98$, $9.17 \rightarrow 10.43$, 10.81, 11.05, $11.24 + 11.29$, $11.36 \rightarrow 11.66$, 11.75, 11.95, 12.20, 12.50, 12.61, $12.79 + 12.82$, $13.17 + 13.24$, $13.71 + 13.72$). Spectroscopic factors were extracted by DWBA analysis of the $l_n = 1$ pickup angular distributions (1969SN04).

60. $^{15}N(^3He, \alpha)^{14}N$ $\quad Q_m = 9.7445$

Observed states in ^{14}N are displayed in Table 14.28 of (1976AJ04) together with the derived spectroscopic factors.

61. $^{15}N(^{13}C, ^{14}C)^{14}N$ $\quad Q_m = -2.6568$

At $E(^{15}N) = 30$, 32 and 45 MeV the angular distributions involving $^{14}N^*(0, 2.31)$ have been studied: they are symmetric about $90°$ for the transition to the $T = 1$ analog state $^{14}N^*(2.31)$: see (1981AJ01).

62. (a) $^{16}O(\pi^+, 2p)^{14}N$ $\quad Q_m = 117.3888$
(b) $^{16}O(\pi^-, 2n)^{14}N$ $\quad Q_m = 115.8241$

At $E_{\pi^+} = 59.6$ MeV $^{14}N^*(0, 2.31, 3.95, \approx 7, \approx 11)$ are populated (1985WH01): the $^{14}N_{g.s.}$ form factor shows a large $L = 0$ component. For reaction (b) see (1980BA31) and (1981AJ01).

63. (a) $^{16}O(\gamma, d)^{14}N$ $\quad Q_m = -20.7363$
(b) $^{16}O(p, pd)^{14}N$ $\quad Q_m = -20.7363$

For reaction (a) see ^{16}O in (1982AJ01). At $E_p = 75$ MeV, angular distributions to ^{14}N*(0, 3.95) have been studied by (1977GR04); ^{14}N*(2.31) is also populated.

64. ^{16}O(p, ^{3}He)^{14}N $\qquad Q_m = -15.2428$

Angular distributions have been measured in the range $E_p = 27$ to 54.1 MeV: see (1981AJ01). Comparisons have been made of the ratio of (p, ^{3}He) to the $T = 1$ state at 2.31 MeV and of (p, t) to the analog ^{14}O$_{g.s.}$: see ^{17}F in (1982AJ01).

65. ^{16}O(d, α)^{14}N $\qquad Q_m = 3.1104$

Angular distributions have been measured at many energies up to $E_d = 40$ MeV: see (1981AJ01). The yield of the isospin-forbidden α_1 group [to ^{14}N*(2.31)] has been studied for $E_d = 2$ to 15 MeV: the intensity of the isospin group is strongly dependent on E_d and on the angle of observation. The α_1 reaction appears to proceed almost exclusively by a compound-nuclear process and its study leads to the determination of a large number of ^{18}F states: the average isospin impurity in ^{18}F for $10 \leq E_x \leq 20$ MeV is $3-10\%$. At $E_d = 50$ MeV, the intensity of ^{14}N*(2.31) is $0.1-0.2\%$ that of ^{14}N$_{g.s.}$. See also (1981KA21, 1982AOZZ) and ^{18}F in (1983AJ01). See also (1983GO2D, 1983LI1T; applied).

66. ^{16}O(α, ^{6}Li)^{14}N $\qquad Q_m = -19.2611$

At $E_\alpha = 42$ MeV the transitions involving (^{14}N$_{g.s.}$ and ^{6}Li*(0, 3.56)), (^{14}N*(2.31) + ^{6}Li$_{g.s.}$) and (^{14}N*(3.95) + ^{6}Li$_{g.s.}$) have been studied: see (1976AJ04).

67. ^{19}F(d, ^{7}Li)^{14}N $\qquad Q_m = -6.1218$

The ground-state angular distribution (involving ^{7}Li*(0, 0.48)) has been measured at $E_d = 13.6$ MeV by (1980GA27). See also (1984NE1A).

^{14}O

(Figs. 8 and 9)

GENERAL: (See also (1981AJ01).)

Nulcear models: (1982SA1U, 1983SH38, 1984SA37).

Electromagentic transitions: (1982LA26, 1982RI04, 1984MA67, 1985LA06).

Astrophysical questions: (1981GU1D, 1981WA1Q, 1984MA67, 1985LA06).

Applied work: (1982HI1H).

Complex reactions involving ^{14}*C:* (1985WO1B).

Reactions involving pions (See also reactions 5, 7 and 10.): (1979ME2A, 1980BE35, 1981AU1C, 1981DU1H, 1981SI09, 1982COZV, 1982GR1K, 1982MU09, 1983SH31, 1983TR1J, 1983VI01, 1984CO1V, 1984JA1F, 1984MI15, 1985ALZX).

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

Other topics: (1982NG01, 1983FR1A, 1983OL1A, 1984BA1H).

Ground state of ^{14}*O:* (1982NG01, 1983ANZQ).

1. ^{14}O(β^+)^{14}N $\quad Q_{\rm m} = 5.1431$

The best value of $\tau_{1/2} = 70.606 \pm 0.018$ sec: see (1978WI04). See also (1976AJ04). ^{14}O decays predominantly to its analog state ^{14}N*(2.31) [J^π; $T = 0^+$; 1; $E_{\rm x} = 2312.798$ (11) keV, $E_\gamma = 2312.593$ (11) keV (1982WA16)]. The branching ratio to the state is (99.336 ± 0.010)%. This value is obtained by adopting (0.61 ± 0.01)% (1966SI05) and (0.054 ± 0.002)% [the weighted mean of the values of (1980WI13, 1981HE19)] for the branching ratios to ^{14}N*(0, 3.95) [both 1^+; 0 states]. Log $f^{\rm R}t = 3.4892$ (2) for the $0^+ \rightarrow 0^+$ transition (1981WH03), using the Wapstra masses for the atomic mass excess of ^{14}N, ^{1}H and n; $E_{\rm thresh.}$ for the ^{14}N(p, n) threshold (1981WH03) and $E_{\rm x}$ shown above for ^{14}N*(2.31) (1982WA16). See (1983WA09) for other calculations of $\log f^{\rm R}t$. For the transitions to ^{14}N*(0, 3.95) $\log ft = 7.266 \pm 0.009$ (1980WI13) and 3.15 ± 0.02, respectively. See also (1982KO28), (1980WI1N, 1982SZ1A, 1983KO2A, 1985HA1T), (1982RA1M, 1984BO1Q; astrophys.) and (1981SZ01, 1983SZ01, 1984BO03, 1984HA58, 1984HO1L, 1984SZ04; theor.).

2. ^{12}C(^{3}He, n)^{14}O $\quad Q_{\rm m} = -1.1466$

Observed neutron groups are displayed in Table 14.26. Angular distributions have been measured at $E(^3{\rm He}) = 15$, 18, 20, and 25.4 MeV: see (1981AJ01) and ^{15}O. See also (1984SUZZ).

Table 14.25: Energy levels of ^{14}O

E_x (MeV ± keV)	$J^\pi; T$	$\tau_{1/2}$ or $\Gamma_{c.m.}$ (sec) (keV)	Decay	Reactions
g.s.	$0^+; 1$	$\tau_{1/2} = 70.606 \pm 0.018$ sec	β^+	1, 2, 4, 5, 7, 8, 9, 10, 11
5.173 ± 10	$1^-; 1$	$\Gamma = 38.1 \pm 1.8$ keV		2, 4, 6, 9, 11
5.920 ± 10	$0^+; 1$	≤ 50	p	2, 4, 9, 11
6.272 ± 10	$3^-; 1$	103 ± 6	p	2, 3, 4, 9, 11
6.590 ± 10	$2^+; 1$	≤ 60	p	2, 9, 11
(6.79 ± 30)	$\pi = -$			9
7.768 ± 10	$2^+; 1$	76 ± 10	p	2, 8, 9, 11
(8.72 ± 40)				4, 9, 11
9.715 ± 20	$(2^+); 1$			2, 4, 9, 11
9.915 ± 20	$4^+; 1$	100 ± 50		2, 3, 4
10.89 ± 50				9
11.24 ± 50				9
11.97 [a]				9
12.84 ± 50				9
13.01 ± 50				9
14.15 ± 40				9
14.64 ± 60				9
17.40 ± 60				9

[a] Possibly more than one level.

Table 14.26: Levels of ^{14}O from ^{12}C(^{3}He, n)^{14}O [a]

E_x (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	L [b]	J^π [b]
0		0	0^+
5.173 ± 10		1	1^-
5.930 ± 15 [c]	≤ 47	0	0^+
6.272 ± 10	103 ± 6	3	3^-
6.596 ± 10 [d]	≤ 56	(2)	2^+ [e]
7.768 ± 10	76 ± 10	2	2^+
9.705 ± 25		(2)	(2^+)
9.915 ± 20 [b]	100 ± 50	4	4^+

[a] For references see Table 14.22 in (1981AJ01).

[b] See Table 14.30 in (1976AJ04).

[c] $E_x = 5905 \pm 12$ keV has also been reported.

[d] 6585 ± 5 keV has also been reported.

[e] $J = 2$ follows from an np coincidence study. The J shown for ^{14}O*(5.92, 6.27, 7.77) are in accord with this work.

3. (a) ^{12}C(^{10}B, ^{8}Li)^{14}O $\quad Q_m = -16.901$
   (b) ^{12}C(^{11}B, ^{9}Li)^{14}O $\quad Q_m = -24.292$

At $E(^{10}\mathrm{B}) = 100$ MeV angular distributions have been studied to ^{14}O*(6.27, 9.92), the states preferentially excited. At $E(^{11}\mathrm{B}) = 114$ MeV these two states [$J^\pi = 3^-, 4^+$] are also dominant: see (1981AJ01).

4. (a) ^{12}C(^{12}C, ^{10}Be)^{14}O $\quad Q_m = -20.6136$
   (b) ^{12}C(^{14}N, ^{12}B)^{14}O $\quad Q_m = -18.513$

At $E(^{12}\mathrm{C}) = 114$ MeV [reaction (a)], the population of ^{14}O*(0, 6.27, 9.9) is reported: it is suggested that ^{14}O*(9.9) has a $(d_{5/2})^2_{4^+;1}$ configuration. $^{14}\mathrm{O}_{g.s.}$ is weakly populated: see (1976AJ04). At $E(^{14}\mathrm{N}) = 118$ MeV, the population of ^{14}O*(6.27, 9.9) is reported. At $E(^{14}\mathrm{N}) = 155$ MeV there is some evidence for the excitation of ^{14}O*(5.17, 5.92, 8.72, 9.72): see (1981AJ01).

5. ^{13}C(p, π^-)^{14}O $\quad Q_m = -137.1598$

At $E_p = 200$ MeV the angular distributions of π^- and π^+ to the ground states of ^{14}O and ^{14}C are very different (1980HO20). At $E_{\vec{p}} = 183$ to 205 MeV cross sections and analyzing powers for the ground-state transition have been studied by (1982JA05). An angular distribution is also reported by (1982VI05) to the states centered at $E_x \approx 6.5$ MeV. See also (1983THZZ, 1984KOZU) and the "GENERAL" section in ^{14}N here.

6. ^{13}N(p, γ)^{14}O $\qquad Q_m = 4.6280$

This reaction is important in the hot-CNO cycle when its rate is dominated by $l = 0$ capture through ^{14}O*(5.17). For $\Gamma_{c.m.}$ see reaction 9 (1985CH06). Calculations have recently been reported: $\Gamma_{c.m.} = 34.7$ keV, $\Gamma_\gamma = 2.4$ eV (1984MA67); $\Gamma_{c.m.} = 40.1$ keV, $\Gamma_\gamma = 1.9$ eV (1985LA06). See also (1983FO1D).

7. ^{14}C(π^+, π^-)^{14}O $\qquad Q_m = -4.9867$

Angular distributions for the transition to ^{14}O$_{g.s.}$ have been measured at $E_{\pi^+} = 164$ and 292 MeV [also to the unresolved structure at $E_x \approx 5.9$ MeV at 164 MeV] (1984SE14) as well as at $E_{\pi^+} = 50$ MeV (1985LE05) and 140 and 200 MeV (1984MOZU). See also (1985SEZZ). At the lower energy the differential cross sections for the DIAS transition are larger than expected from an extrapolation of the higher-energy data (1985LE05). For other cross-section measurements see (1984NA01, 1984SE14). See also (1985KA04; theor.).

8. ^{14}N(p, n)^{14}O $\qquad Q_m = -5.9255$

$E_{thresh.} = 6353.04 \pm 0.08$ keV (1981WH03).

Ground-state angular distributions have been measured at $E_p = 144$ MeV (1980MO10; and to ^{14}O*(7.77)) as well as at $E_p = 35.2$ MeV (1984TA02). See also (1980DU16; theor.).

9. ^{14}N(^{3}He, t)^{14}O $\qquad Q_m = -5.1617$

Triton groups have been observed at $E(^3\text{He}) = 44.6$ MeV to the first six states shown in Table 14.25 and to levels with $E_x = 6.79 \pm 0.03$, 8.74 ± 0.06, 9.74 ± 0.03, 10.89 ± 0.05, 11.24 ± 0.05, 11.97 (unresolved), 12.84 ± 0.05, 13.01 ± 0.05, 14.15 ± 0.04, 14.64 ± 0.06 and 17.40 ± 0.06 MeV (1967BA13, 1969BA06). See also reaction 47 in ^{14}N. [The states at 6.79 and 8.74 MeV reported in this reaction are relatively weakly excited and are not observed in reaction 2.] $\Gamma_{c.m.}$ of ^{14}O*(5.17) $= 38.1 \pm 1.8$ keV (1985CH06). See also (1982HAZM, 1982KO28).

10. ^{16}O(π^+, d)^{14}O $\qquad Q_m = 113.6879$

See (1982DO01).

11. ^{16}O(p, t)^{14}O $\qquad Q_m = -20.4045$

Angular distributions of ground-state tritons have been studied to $E_p = 54.1$ MeV: see (1981AJ01). For comparison with the (p, ^{3}He) results see reaction 64 in ^{14}N.

Triton groups have also been observed to states with $E_x = 5.21 \pm 0.04$, 5.92 ± 0.06, 6.28 ± 0.05, 6.59, 7.77, 8.69 ± 0.06 [weak, not observed in reaction 2], and 9.65 ± 0.06 MeV. Angular distributions have been studied with polarized protons at $E_p = 43.8$ MeV to ^{14}O*(0, 5.17, 6.27, 6.59, 7.77, 9.72): see (1976AJ04).

^{14}F
(Not illustrated)

^{14}F has not been observed: its atomic mass excess is predicted to be 32.98 MeV which would make it unstable with respect to decay into ^{13}O + p by 2.58 MeV: see (1981AJ01). See also (1985WA02) and (1983ANZQ); theor.).

^{14}Ne, ^{14}Na, ^{14}Mg
(Not illustrated)

^{14}Ne, ^{14}Na and ^{14}Mg have not been observed. See (1983ANZQ; theor.).

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