Energy Levels of Light Nuclei
$A = 14$

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Abstract: An evaluation of $A = 13$–15 was published in *Nuclear Physics A*268 (1976), 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 January 31, 1976)

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^{14}Li

(Not illustrated)

^{14}Li has not been observed: it is calculated to be particle unstable with a binding energy of -2.66 MeV for decay into ^{13}Li + n and of -3.23 MeV for decay into ^{12}Li + 2n. The calculated mass excess is 72.29 MeV (1974TH01).

^{14}Be

(Figs. 5 and 9)

^{14}Be has been observed with a production cross section of ≈ 10 μb in the 4.8 GeV proton bombardment of uranium (1973BO30, 1974BO05). It is particle stable: its atomic mass excess is calculated to be 40.69 MeV. ^{14}Be is then bound by 2.73 and 0.41 MeV, respectively, with respect to decay into ^{13}Be + n and ^{12}Be + 2n (1974TH01). See, however, (1975JE02). ^{14}Be had not been observed in the bombardment of ^{232}Th with 145 MeV ^{15}N ions (1970AR27). See also (1971AR1P, 1973VO1D), (1973KO1D, 1973TA30) and (1972ST1C, 1972TH13, 1975BE31; theor.).

^{14}B

(Figs. 5 and 9)

GENERAL: (See also (1970AJ04).)

See (1970AR1D, 1970AR27, 1971AR02), (1973KO1D, 1973TO16) and (1972TH13, 1973WI15, 1974TH01, 1975JE02, 1975BE31, 1975MI12; theor.).

Mass of ^{14}B: From the Q-value of the ^{14}C(^{7}Li, ^{7}Be)^{14}B reaction the atomic mass excess of ^{14}B is 23.657 ± 0.030 MeV. ^{14}B is then stable with respect to breakup into ^{13}B + n and ^{12}B + 2n by 0.98 and 5.86 MeV, respectively (1973BA34). The lowest $T = 2$ states in ^{14}C, ^{14}N and ^{14}O are estimated to lie at $E_{\rm x} = 22.5$, 24.8 and 22.5 MeV. These states would then be stable against allowed neutron decay by ≈ 0.7 MeV and unstable to proton decay by < 3.0 MeV (1973BA34).

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

^{14}B has a half-life of 16.1 ± 1.2 msec. The β-decay is primarily to ^{14}C*(6.09) [$J^\pi = 1^-$] and (6.73) [$J^\pi = 3^-$]: see Table 14.2. The measured γ-ray intensity ratios are $I_{6.09}/I_{6.73}/I_{7.34} = 100/(10.0 \pm 2.0)/< 2.2$. The nature of the decay fixes the J^π of ^{14}B to be 2^- (1974AL11). See also (1975MI12; theor.).

2. ^{10}Be(^{6}Li, 2p)^{14}B $\qquad Q_{\rm m} = -11.54$

Table 14.1: Energy levels of ^{14}B

E_x (MeV $\pm$ keV)	J^π; T	$\tau_{1/2}$ (msec)	Decay	Reactions
g.s.	2^-; 2	16.1 ± 1.2 msec	β^-	1, 2, 3, 4
0.74 ± 40	(1^-); 2			4
1.38 ± 30	(3^-); 2			4
1.82 ± 60	(2^-); 2			4
2.08 ± 50	(4^-); 2			4
(2.32 ± 40)				4
2.97 ± 40	$T = 2$			4

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

Decay to ^{14}C* (MeV)	J^π	Branch (%)	log ft
0	0^+	(5 ± 3) [d]	
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 [e]	> 4.9
[c]			

[a] (1974AL11).

[b] E_{β^-}(max) $= 14.0 \pm 0.7$ MeV to this state.

[c] A search for possible delayed neutrons following the population of higher states has not yet been carried out.

[d] This branch has not been observed. It is assumed to be 5 ± 3% in the calculation of the branching ratios to ^{14}C*(6.09, 6.73). However, (1975MI12; theor.) suggest that the branch may be as small as ≈ 0.3%. The errors shown for the branching ratios reflect this uncertainty (1974AL11).

[e] 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 ± 5% was used.

^{14}B has been populated in this reaction at $E(^6\text{Li}) = 31$ MeV (1974AL11).

3. ^{10}Be(^{9}Be, αp)^{14}B $\qquad Q_m = -9.41$

See (1974AL11).

4. ^{14}C(^{7}Li, ^{7}Be)^{14}B $\qquad Q_m = -21.50$

$Q_0 = -21.499 \pm 0.030$ (1973BA34).

^{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, 4.37, 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. The differential cross section for producing ^{14}B$_{\text{g.s.}}$ at $\theta = 15°$ is ≈ 4 μb/sr (1973BA34).

^{14}C
(Figs. 6 and 9)

GENERAL: (See also (1970AJ04).)

Nuclear models: (1970FR13, 1970FR1C, 1970KH01, 1971BA2Y, 1972LI06, 1973KU03, 1973SA30, 1975MI12, 1975VE01).

Special reactions involving ^{14}C: (1969GA18, 1969KR21, 1971AR02, 1972VO06, 1973KO1D, 1973KU03, 1973VO1G, 1973WI15, 1974BE16, 1974KO25, 1975HU14, 1975KU01, 1975UD01).

Reactions involving muons: (1970DM01, 1970VA24, 1973BE16, 1973KI12, 1973MU05, 1973MU11, 1973MU1B, 1974FU1B).

Reactions involving pions (See also reactions 17, 33, 41.): (1970DO04, 1971KO23, 1973DA37, 1973KA1D, 1974LI15, 1975EI1B, 1975HU1D, 1975RE01).

Other topics: (1970FO1B, 1970GU13, 1970KH01, 1970SU1B, 1971BA2Y, 1971JA14, 1972AN05, 1972CA37, 1972ST1C, 1973AL1B, 1973GO1H, 1973HO32, 1973KI05, 1973KU03, 1973MA48, 1973PA1F, 1974CA1H, 1974DZ03, 1974HA1C, 1975KU01, 1975MO1M, 1975VE01, 1976MA04).

Ground state: (1974DE1E, 1975BE31).

Mass of ^{14}C: 14.003241983 (12) amu (1975SM02).

1. ^{14}C(β^-)^{14}N $\qquad Q_{\rm m} = 0.1561$

Measured $\tau_{1/2}$ are 5745 ± 50 y (1961MA32, 1964HU09), 5780 ± 65 y (1961WA16), 5680 ± 40 y (1962OL04), 5660 ± 30 y (1968BE47), 5736 ± 56 y (1972EM01): the recommended value of $\tau_{1/2} = 5730 \pm 40$ y [†]. Using $Q_{\rm m}$, $\log ft = 9.02$ (1969KA1B). The spectrum does not deviate from the allowed shape down to 3 keV (1954MO84). The large $\log ft$ difference between this and the mirror transition in ^{14}O(β^+) cannot be accounted for by the differences in the binding energies of ^{14}C and ^{14}O (1972WI05). For other discussions of the long lifetime of ^{14}C see (1959AJ76, 1970AJ04) and (1976GO1U). See also (1970SO08) and (1969EL1A, 1970FR13, 1971HU10, 1973HA49, 1973KU1J, 1974ZA1G; theor.).

2. (a) ^{7}Li(^{7}Li, 2n)^{12}C $\qquad Q_{\rm m} = 13.674 \qquad E_{\rm b} = 26.797$
(b) ^{7}Li(^{7}Li, n)^{13}C $\qquad Q_{\rm m} = 18.620$
(c) ^{7}Li(^{7}Li, p)^{13}B $\qquad Q_{\rm m} = 5.966$
(d) ^{7}Li(^{7}Li, d)^{12}B $\qquad Q_{\rm m} = 3.311$

† W. Mann, private communication.

(e) ^{7}Li(^{7}Li, t)^{11}B $\quad Q_{\mathrm{m}} = 6.199$

(f) ^{7}Li(^{7}Li, α)^{10}Be $\quad Q_{\mathrm{m}} = 14.784$

(g) ^{7}Li(^{7}Li, ^{8}Be)^{6}He $\quad Q_{\mathrm{m}} = 7.278$

(h) ^{7}Li(^{7}Li, ^{7}Li)^{7}Li

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

E_{x} in ^{14}C (MeV $\pm$ keV)	$J^{\pi}; T$	τ or $\Gamma_{\mathrm{c.m.}}$	Decay	Reactions
g.s.	$0^{+}; 1$	$\tau_{1/2} = 5730 \pm 40$ y	β^{-}	1, 2, 3, 4, 8, 9, 10, 12, 13, 17, 18, 19, 20, 21, 22, 23, 25, 26, 27, 28, 29, 30, 31, 32, 33, 35, 36, 37, 38, 39, 40, 42, 44, 45, 46, 47
6.0942 ± 1.6	1^{-}	$\tau_{\mathrm{m}} < 10$ fsec	γ	2, 3, 4, 5, 9, 10, 13, 17, 18, 20, 24, 27, 34, 39
6.5898 ± 1.6	0^{+}	> 0.6 psec	γ	2, 3, 4, 9, 10, 17, 18, 27
6.7282 ± 1.3	3^{-}	97 ± 15 psec $\lvert g\rvert = 0.272 \pm 0.007$	γ	2, 3, 4, 5, 9, 10, 11, 18, 20, 21, 24, 27, 34, 39, 41
6.9023 ± 1.8	0^{-}	36 ± 4 fsec	γ	2, 3, 4, 5, 10, 18, 41
7.0120 ± 4.2	2^{+}	13 ± 2 fsec	γ	3, 4, 9, 10, 26, 27, 33, 39
7.3414 ± 3.1	2^{-}		γ	3, 4, 9, 10, 18, 21, 27, 39
8.3183 ± 0.9	2^{+}	$\Gamma_{\mathrm{c.m.}} = 3.4 \pm 0.6$	γ, n	3, 4, 9, 10, 13, 14, 17, 18, 26, 27, 33, 39
9.799 ± 7	(3, 1)	45 ± 12	n	3, 9, 14, 18, 26, 27, 39
10.437 ± 9	(2^{+}, 3)	16	n	3, 9, 14, 18, 39
10.509 ± 13	(4^{+})	26 ± 8	n	3, 9, 12, 14, 18, 27
10.743 ± 5		20 ± 7		3, 9, 10
11.306 ± 15	$1^{(-)}$	46 ± 12		3, 26, 33, 39
11.397 ± 15	(2^{+}, 3)	22 ± 7		3
11.667 ± 15	(5^{-})	20 ± 7		3, 9, 39
11.740 ± 20				3
11.9 ± 300		950 ± 300	n	14, 18
12.589 ± 16		105 ± 15		3, 18, 39
12.860 ± 14	(4, 5)	30 ± 10		3, 18

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
12.964 ± 14	(3, 4)	30 ± 10		3, 18
14.667 ± 20	(2^+, 3, 4, 5, 6^+)	57 ± 15		3, 9
14.867 ± 25				3, 39
15.19 ± 30				3, 9
(15.37 ± 30)				3
15.44 ± 40				3
(16.02 ± 50)				3
16.411 ± 20				3
(16.57 ± 40)				3
16.72 ± 30				3
(17.28 ± 40)				3
17.95 ± 40				3
18.10 ± 40				3
b				
23.624 ± 36	$(T = 2)$	120^{+120}_{-60}		6

[a] See also Tables 14.6 and 14.10.

[b] See also reactions 7 and 33.

These reactions have been studied with $E(^7\text{Li})$ to 6.5 MeV: see (1970AJ04) for the earlier 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 (1964DZ1A, 1969CA1A). However, (1971WY01) reports 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 these are neither compound nucleus resonances nor Ericson-type fluctuations but that they are due to a forward-direction cluster transfer process (1971WY01).

3. ^{9}Be(^{6}Li, p)^{14}C $\qquad Q_m = 15.127$

Observed proton groups are displayed in Table 14.4 (1973AJ01). Angular distributions have been measured at $E(^6\text{Li}) = 1.9$ MeV (1969KO1A: p_0, p_1, $p_{2+3+4+5}$, p_6, p_7, p_8) and at 20 MeV ((1973AJ01) and unpublished results: to most states shown in Table 14.4). See also ^{15}N.

Table 14.4: Levels of ^{14}C from ^{9}Be(^{6}Li, p)^{14}C [a]

E_x (MeV $\pm$ keV)	$\Gamma_{c.m.}$ (keV)	σ [b] (μb)	$2J_f+1$ [c]	J^π [d]	θ_n^2 [e]
6.089 ± 10		71	2.5 [2]		
6.588 ± 10		30	1.0 [1]		
6.726 ± 10		220	7.6 [7]		
6.899 ± 10		31	1.1 [1]		
7.016 ± 10		130	4.5 [5]		
7.341 ± 10		151	5.2 [5]		
8.318 ± 10	22 ± 6	146	5.1	2^+	0.08 ± 0.02
9.796 ± 10	45 ± 12	223	7.7	3	0.4 ± 0.1 if $\pi = +$ 0.04 ± 0.01 if $\pi = -$
10.441 ± 15		312	10.8	2^+, 3	
10.512 ± 15	26 ± 8	262	9.1	4	0.08 ± 0.02 if $\pi = +$ 1.3 ± 0.4 if $\pi = -$
10.743 ± 15	20 ± 7	444	15.4		
11.306 ± 15	46 ± 12	70	2.4	1^-	0.012 ± 0.003
11.397 ± 15	22 ± 7	179	6.2	2^+, 3	
11.667 ± 15	20 ± 7	358	12.4	5^-	0.20 ± 0.07
11.74 ± 20					
12.57 ± 25	80 ± 20	435	15.1		
12.867 ± 20	30 ± 10	300	10.4	4, 5	
12.970 ± 20	30 ± 10	225	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)					

Table 14.4: Levels of ^{14}C from ^{9}Be(^{6}Li, p)^{14}C [a] (continued)

E_x (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	σ [b] (μb)	$2J_f + 1$ [c]	J^π [d]	θ_n^2 [e]
17.95 ± 40					
18.10 ± 40					

[a] (1973AJ01): $E(^6\text{Li}) = 20$ MeV.
[b] Total cross section for formation of this state; absolute value: ±20% except for the last six values, ±30%.
[c] The first number gives $2J_f + 1$, based on a best fit to the experimentally determined values for the cross section of the states with known spins. These $2J_f + 1$ values are determined to ±10%, except for the last six values which are determined to ±20%. The second number, in brackets, gives $2J_f + 1$ derived from the J_f assignments shown in Table 14.3.
[d] Suggested from the $2J_f + 1$ rule and comparison of predicted neutron width with observed $\Gamma_{c.m.}$ assuming $0.01 < \theta_n^2 < 1.0$.
[e] Calculated from neutron penetration of the centrifugal barrier, assuming that the total width is the neutron decay width Γ_n.

4. ^{9}Be(^{7}Li, d)^{14}C $\quad Q_m = 10.101$

Angular distributions of the deuterons to ^{14}C*(0, 6.09, $6.59 + 6.73$, $6.90 + 7.01$, 7.34, 8.32) have been measured at $E(^7\text{Li}) = 5.6$, 5.8, 6.0 and 6.2 MeV (1969SN02). Angular distributions for the d_0 group have also been measured at $E(^7\text{Li}) = 1.7$ to 1.9 MeV (1969KA1C). The γ-decay of six bound excited states has been studied by (1966CA07). (1969TH01) report $E_\gamma = 6094.5 \pm 3.2$, 6728.1 ± 1.4 and 7011.7 ± 5.2 keV for the ground state transitions of these states and $\tau_m < 120$ fsec for ^{14}C*(7.01).

5. ^{9}Be(^{13}C, ^{8}Be)^{14}C $\quad Q_m = 6.512$

At $E(^{13}\text{C}) = 9$ MeV ^{14}C*(6.09, 6.73, 6.90) have been populated: $\tau_m < 10$, $> 5 \times 10^4$ and 36 ± 4 fsec, respectively (1975SE04). See also (1975SE03).

6. ^{10}Be(α, p)^{13}B $\quad Q_m = -8.818 \quad E_b = 12.013$

Table 14.5: ^{14}C levels from ^{12}C(t, p)^{14}C

E_x [a] (MeV ± keV)	(1964MI05) [b] L	(1960JA17) [c] L
0	0	0
6.090 ± 10	(2)	1
6.582 ± 10	1	1
6.725 ± 10	(2)	3
6.893 ± 10	[e]	[e]
7.009 ± 10	(2)	0
7.335 ± 10	[e]	[e]
8.32 [a]	2	
10.74 ± 20 [d]		

[a] The excitation energies of the first six excited states have been determined by (1960JA17); the seventh comes from the ^{13}C(n, n)^{13}C work of (1961CO05); the eighth has been determined by (1964MI05).
[b] $E_t = 11$ MeV; except ground state $E_t = 8$ to 13 MeV.
[c] $E_t = 5.5$ MeV.
[d] $\Gamma < 15$ keV. No states are observed between this level and the broad state at 11.9 MeV (1964MI05).
[e] Weak group.

The yield of 3.7 MeV γ-rays coincident with $E_\beta > 4$ MeV (from the ^{13}B decay) has been measured for $E_\alpha = 13.6$ to 17 MeV: a strong interference anomaly is observed which appears to correspond to $E_x = 23.624 \pm 0.036$ MeV, $\Gamma_{c.m.} = 120^{+120}_{-60}$ keV. It is suggested that it is a $T = 2$ state whose analog is either ^{14}B*(0.74) or (1.38) (1974GO1T).

7. ^{11}B(t, n)^{13}C $Q_m = 12.4214$ $E_b = 20.5984$

Resonant structure has been reported in the yield of neutrons with $E_t = 1.20$ to 2.32 MeV: these are thought to correspond to ten excited states in ^{14}C in the range $21.54 < E_x < 22.42$ MeV (1965VA13).

8. ^{11}B(α, p)^{14}C $Q_m = 0.7837$

Angular distributions of p_0 have been measured at $E_\alpha = 1.43$ to 2.94 MeV (1976DA1U), 2.5 to 5.0 MeV (1963MA28) and 10.8 to 25.1 MeV (1969SP02). See also (1967SP09), (1971BU1K; theor.) and ^{15}N.

9. ^{11}B(^{7}Li, α)^{14}C $\quad Q_m = 18.132$

At $E(^7\text{Li}) = 5$ MeV, α-particle groups are observed to the known states of ^{14}C with $E_x < 10$ MeV except ^{14}C*(6.90), and to the unresolved $10.4 - 10.5$ MeV states. There is some indication also of ^{14}C states at (10.71), 11.35, 11.66, (14.15), (14.73) and (15.07) MeV ($\pm$ approx. 50 keV). Angular distributions have been obtained for the α-particles to ^{14}C*(0, 6.09, 8.32) (1966MC05).

10. ^{12}C(t, p)^{14}C $\quad Q_m = 4.6412$

Observed proton groups are displayed in Table 14.5. Angular distributions have been measured at $E_t = 5.5$ MeV (1960JA17), 8 to 13 MeV (1964MI05) [see Table 14.5] and at 16 and 20 MeV (1972KE02: p_0). Particle-gamma correlations have been studied by (1968BE30): see Table 14.6. The lifetime of ^{14}C*(6.73) is 97 ± 15 psec; the $(6.73 \to 0)$ E3 transition is enhanced by 3.3 ± 0.8 W.u. (1968AL12). 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 $(p^{-3}_{1/2}d_{5/2})$ configuration (1974AL07).

See also (1969AR1B), (1974BA65; theor.) and ^{15}N.

11. ^{12}C(^{12}C, ^{10}C)^{14}C $\quad Q_m = -18.723$

At $E(^{12}\text{C}) = 114$ MeV ^{14}C*(6.73, 10.25) [$J^\pi = 3^-$ and 4^+, respectively] are populated (1972SC21, 1974AN36). See also (1971SC1F, 1972MO1E, 1973SC1J).

12. (a) ^{12}C(^{14}N, ^{12}N)^{14}C $\quad Q_m = -17.500$
(b) ^{12}C(^{18}O, ^{16}O)^{14}C $\quad Q_m = 0.934$

For reaction (b) see (1970BA1J, 1974CH1Q). See also (1970AJ04), (1974GO1L) and (1970AN1D, 1971AL1D, 1971RO1G, 1972RO35, 1975TA02; theor.). For reaction (a) see (1975NA11).

13. ^{13}C(n, γ)^{14}C $\quad Q_m = 8177.0$
$Q_0 = 8176.575 \pm 0.030$ keV (1975SM02).

Table 14.6: Branching ratios of γ-rays in ^{14}C

$E_{\rm i}$ (MeV)	$J^\pi_{\rm i}$	$E_{\rm f}$ (MeV)	Branch (%)	
			A	B
6.09	1^-	0		
6.59	0^+	0	1.0 ± 0.4 [c]	
		6.09	99.0 ± 0.4 [d]	
6.73	3^-	0	97.3 ± 1	93 ± 1
		6.09	7 ± 2	2.7 ± 1
6.90	0^-	6.09	100 [a,e]	
7.01	2^+	0		98.6 ± 0.7
		6.09		1.4 ± 0.7
7.34	2^-	0	18 ± 4	14 ± 4
		6.09	47 ± 4 [f]	52 ± 5 [b]
		6.73	35 ± 7	34 ± 4 [b]

A: (1966AL10): ^{13}C(d, p)^{14}C.
B: (1968BE30): ^{12}C(t, p)^{14}C.
[a] (1958WA02).
[b] δ(M2/E1) $= -0.04 \pm 0.09$ and $+0.07 \pm 0.30$, respectively (1968BE30).
[c] Internal pairs.
[d] $E_\gamma = 495.8 \pm 0.4$ keV (1966AL10).
[e] $E_\gamma = 808.7 \pm 1.0$ keV (1966AL10).
[f] $E_\gamma = 1248 \pm 3$ keV (1966AL10).

The thermal capture cross section is 0.9 ± 0.2 mb (1973MU14). The neutron capture yield has been measured for $E_{\rm n} = 95$ to 235 keV. The parameters for ^{14}C*(8.32) are $E_{\rm n} = 152 \pm 1$ keV, $\Gamma_{\rm n} = 5 \pm 1$ keV, $\Gamma_\gamma = 4.0 \pm 1.6$ eV [see Table 14.7]. The calculated cross section for $kT = 30$ keV is 0.12 ± 0.04 mb suggesting that ^{13}C is not significantly involved as a neutron poison in s-process nucleosynthesis (1971AL09). See also (1970CL1C, 1973CL1E; astrophys. questions). Two γ-rays are observed with $E_\gamma = 8.174 \pm 0.002$ and 6.093 ± 0.002 MeV [$E_{\rm x} = 6.094 \pm 0.002$ MeV], with intensities of 87 ± 5 and 13 ± 1%. Intensities of transitions via other ^{14}C states are < 2% (1967TH05).

14. ^{13}C(n, n)^{13}C $\qquad E_{\rm b} = 8.170$

Table 14.7: Resonances in ^{13}C(n, γ) and (n, n)

E_{res} (keV)	E_x (MeV $\pm$ keV)	Γ_{lab} (keV)	Γ_γ (eV)	σ [a] (bn)	l_n	J^π
152 ± 1 [b]		5 ± 1	4.0 ± 1.6 [f]			
	8.3183 ± 0.9					
152.9 ± 1.4 [c]		3.7 ± 0.7 [f]		21 ± 2	1	2^+
1751 ± 8 [d]	9.802 ± 8	20		[≈ 1.3]	> 0	1
2432 ± 10 [d]	10.434 ± 10	17		[≈ 1.3]		2
2454 ± 10 [d]	10.454 ± 10	10		[≈ 0.7]		≥ 1
3800 [e]	11.7					

[a] Corrected peak cross section above background.
[b] (1971AL09): (n, γ).
[c] (1975HE02).
[d] (1961CO05).
[e] Broad resonance structure.
[f] Recommended by (1973MU14). I am indebted to S.F. Mughabghab for a very useful discussion.

The coherent scattering length (thermal, bound) is 6.0 ± 0.2 fm (1973MU14). The total cross section has been measured for $E_n = 0.10$ to 9 MeV and 16 to 23 MeV: observed resonances are displayed in Table 14.7 (1961CO05, 1975HE02). See also (1973MU14).

15. ^{13}C(n, t)^{11}B $\quad Q_m = -12.4214 \quad E_b = 8.1770$

See (1973BI1B).

16. ^{13}C(n, α)^{10}Be $\quad Q_m = -3.836 \quad E_b = 8.1770$

See (1970AJ04).

17. ^{13}C(p, π^+)^{14}C $\quad Q_m = -132.174$

At $E_p = 185$ MeV, an angular distribution has been measured for the transition to $^{14}C_{g.s.}$: it is forward peaked and goes through a minimum at $90°$ [while the π^- to $^{14}O_{g.s.}$ show a flat distribution: see reaction 6 in ^{14}O]. There is evidence also for the population of ^{14}C*(6.09, 8.32, 14.9 ± 0.2) as well as some other structure (1973DA37). See also (1970DO04).

Table 14.8: Proton groups from ^{13}C(d, p)^{14}C

E_x (MeV ± keV)	(1954SP01, 1955MC75) l_n [d]	J^π	(1958WA02, 1959WA04) J^π
0	1	$0^+, 1^+, 2^+$	0^+
6.091 ± 10	0	$0^-, 1^-$	1^-
6.589 ± 20	1, 2, 3 [e]	$(1^-, 2, 3^-)$	
6.723 ± 10 [a]	2	$1^-, 2^-, 3^-$	$3^-(2^-)$
6.894 ± 10 [a]	0, 1 [e]	$0, 1, 2^+$	0^-
7.346 ± 20	2	$1^-, 2^-, 3^-$	$2^-, 3^-$
8.321 ± 20			
9.800 ± 20			
10.433 ± 20			
10.505 ± 20			
11.9 ± 300 [b]			
12.601 ± 20 [c]			
12.854 ± 20			
12.958 ± 20			

[a] The spacing of these two levels is 171 ± 3 keV (1954SP01).

[b] $\Gamma_{\rm lab} = 1.10 \pm 0.30$ MeV.

[c] $\Gamma_{\rm lab} = 0.130 \pm 0.020$ MeV.

[d] See also (1959AJ76).

[e] See footnotes 18 and 31 in (1958WA02).

18. ^{13}C(d, p)^{14}C $\qquad Q_m = 5.9524$

Observed proton groups are displayed in Table 14.8. Angular distributions have been measured at a number of energies up to $E_d = 14.8$ MeV: recent measurements have been carried out for the p_0 group at $E_p = 0.41$ to 0.81 MeV (1971PU01) and 12.1 to 14.0 MeV (1969GU1C; prelim. results). See also (1970LI1E, 1971LI1K, 1975ZA06). For listings of θ^2_n see Table 14.5 in (1970AJ04).

Gamma rays are exhibited in Table 14.6: 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 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; $l_n = 2$); ^{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 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, in particular, (1958WA02, 1965LA09, 1966AL10, 1966RI02, 1966WA1C). $\tau_{\rm m} < 15$ fsec (1974RU1B), < 40 fsec (1973RE1E, 1973RE1F; prelim. results) for ^{14}C*(6.09). See also (1967SP09) and ^{15}N.

19. ^{13}C(t, d)^{14}C $\qquad$ $Q_{\rm m} = 1.9194$

See (1961BA10).

20. ^{13}C(^{7}Li, ^{6}Li)^{14}C $\qquad$ $Q_{\rm m} = 0.926$

At $E(^{7}{\rm Li}) = 34$ MeV the angular distribution has been measured for the ground state transition. ^{14}C*(6.09, 6.73) and possibly other states are also populated (1973SC26).

21. ^{13}C(^{11}B, ^{10}B)^{14}C $\qquad$ $Q_{\rm m} = -3.279$

At $E(^{11}{\rm B}) = 114$ MeV $^{14}{\rm C}_{\rm g.s.}$ is weakly excited but ^{14}C*(6.73, 7.34) [$J^{\pi} = 3^{-}$ and 2^{-}, respectively] are strongly populated (1974AN36). See also (1972MO1E, 1973SC1J).

22. (a) ^{13}C(^{14}N, ^{13}N)^{14}C $\qquad$ $Q_{\rm m} = -2.377$
(b) ^{13}C(^{15}N, ^{14}N)^{14}C $\qquad$ $Q_{\rm m} = -2.657$

See (1971GA05) and (1973TO05; theor.) for reaction (a). For reaction (b) see ^{14}N, reaction 60 (1975GA17).

23. (a) ^{13}C(^{17}O, ^{16}O)^{14}C $\qquad$ $Q_{\rm m} = 4.035$
(b) ^{13}C(^{18}O, ^{17}O)^{14}C $\qquad$ $Q_{\rm m} = 0.130$

See (1974CH1Q).

24. ^{14}B(β^{-})^{14}C $\qquad$ $Q_{\rm m} = 20.64$

^{14}B decays primarily to ^{14}C*(6.09, 6.73): see Table 14.2. $\tau_{1/2} = 16.1 \pm 1.2$ msec (1974AL11).

25. ^{14}C(γ, n)^{13}C $\qquad Q_m = -8.1770$

See (1973KI05; theor.).

26. ^{14}C(e, e)^{14}C

The elastic scattering has been studied at $E_e = 374.6$ MeV: the charge radius $r_{rms} = 2.56 \pm 0.05$ fm (1973KL12). At $E_e = 101.2$ MeV, ^{14}C*(7.01, 8.32) [both $J^\pi = 2^+$] are excited strongly: $\Gamma_\gamma = 50.8 \pm 7.1$ and 4.1 ± 1.7 meV (1972CR1A; prelim. results). There is some evidence also for excitation of other states of ^{14}C including ^{14}C*(9.8, 11.3) (1973CR1B; prelim. results; see also (1975FA1A)), however, there is no evidence of sharp structure in the region $E_x = 19$ to 24 MeV where the $T = 2$ analog state of ^{14}B$_{g.s.}$ would be expected (1974KL12: $E_e = 61.5$ and 80.7 MeV). See also (1973FA1K, 1974DE1E).

27. (a) ^{14}C(p, p)^{14}C
(b) ^{14}C(d, d$'$)^{14}C*

The elastic angular distribution has been measured by (1971CU01) at $E_p = 14.5$ MeV (reaction (a)) and by (1967NE06) at $E_d = 3.4$ MeV (reaction (b)). The population of ^{14}C*(6.09, 6.58, 6.72, 7.01 ± 0.02, 7.34, 8.32, 9.80, 10.5) has been reported by (1959AR1A) at $E_d = 14.9$ MeV. Angular distributions have also been studied at $E_d = 17$ MeV to ^{14}C*(0, 6.73, 7.01) (1975CE04).

28. ^{14}C(^{3}He, ^{3}He)^{14}C

The elastic angular distribution has been measured at $E(^3\text{He}) = 10$, 12, 15 and 18 MeV (1970DU07). See also (1971CO14).

29. ^{14}C(α, α)^{14}C

Elastic angular distributions have been studied at $E_\alpha = 22$, 24 and 28 MeV (1972OE01, 1973OE01).

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

The elastic scattering for reaction (a) has been studied at $E(^{12}\text{C}) = 12$, 15, 18 and 20 MeV and for reaction (b) at 15 MeV (1972BO68). See also (1973FE03), (1974GO1L) and (1973MC1J, 1973VO04, 1975DE09, 1975VO1B; theor.).

31. ^{14}C(^{14}N, ^{14}N)^{14}C

See (1971BO1U) and (1971VO1D, 1975DE09, 1975VO1B; theor.).

32. ^{14}C(^{16}O, ^{16}O)^{14}C

The elastic scattering angular distributions have been measured at $E(^{16}\text{O}) = 20$, 25 and 30 MeV (1974KO1P).

33. ^{14}N(π^-, γ)^{14}C $\qquad Q_\text{m} = 139.413$

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) (1975BA52): the total radiative capture branching is 2.1 ± 0.2%.

34. ^{14}N(n, p)^{14}C $\qquad Q_\text{m} = 0.6263$

^{14}C*(6.09) decays with $E_\gamma = 6098 \pm 5$ keV, $\tau_\text{m} < 0.1$ psec (1972NY02), and $E_\gamma = 6732 \pm 5$ keV from the decay of ^{14}C*(6.73) (1971NY03). The p_0 angular distribution has been measured at $E_\text{n} = 14$ MeV (1971CO32). See also (1970AJ04), (1970DI1A), (1973CL1E; astrophys. questions) and ^{15}N.

35. ^{14}N(t, ^{3}He)^{14}C $\qquad Q_\text{m} = -0.1375$

See (1970AJ04).

36. ^{14}N(^{7}Li, ^{7}Be)^{14}C $\qquad Q_\text{m} = -1.018$

See (1971BAWQ).

Table 14.9: Levels of ^{14}C from the ^{15}N(d, ^{3}He) reaction [a]

E_x (MeV)	l	J^π [a]	C^2S
g.s.	1		1.10
6.12 ± 0.04	[b]		[d]
6.73 ± 0.04	[b]		(< 0.11)
7.02 ± 0.03	1		1.13
7.34 ± 0.04	[b]		(< 0.04)
8.32	1	2^+	0.86
9.78 ± 0.04	[b]		
10.44 ± 0.03		$((0), 1, 2)^+$	0.39
11.29 ± 0.04	1	1^+	1.23
11.67 ± 0.05	[b]		
12.08 ± 0.10	[b]		
12.60 ± 0.08	[b]		
14.81 ± 0.08			
[c]			

[a] (1971KA18).
[b] Dominant non-stripping reaction mechanism.
[c] Several other weak transitions occur up to $E_x \approx 18$ MeV.
[d] C^2S for ^{14}C*(6.59) < 0.01.

37. (a) ^{15}N(γ, p)^{14}C $\qquad Q_m = -10.2073$
(b) ^{15}N(e, e′p)^{14}C $\qquad Q_m = -10.2073$

For $E_{bs} = 19.6$ to 38.3 MeV ^{14}C is reported to be formed preferentially in the ground state and in excited states with $E_x = 7.0 \pm 0.2$ and 10.7 MeV (1972DE1D). See also (1973DE30) and ^{15}N. For reaction (b) see (1975MU07).

38. ^{15}N(n, d)^{14}C $\qquad Q_m = -7.9827$

The angular distributions of n_0 have been measured at $E_n = 14.1$ and 14.8 MeV (1967FE06, 1971MI12).

39. ^{15}N(d, ^{3}He)^{14}C $Q_{\rm m} = -4.7136$

^{14}C states populated in this reaction at $E_{\rm d} = 52$ MeV are displayed in Table 14.9. The table also shows the l-values obtained from the analysis of the angular distributions (1971KA35).

40. ^{15}N(t, α)^{14}C $Q_{\rm m} = 9.6073$

Angular distributions of the α_0 group have been measured at $E_{\rm t} = 0.82$ to 1.62 MeV (1973AB1E). See also ^{18}O in (1978AJ03).

41. ^{16}O(π^-, np)^{14}C $Q_{\rm m} = 121.188$

At $E_{\pi^-} = 230$ MeV, γ-rays from the population of ^{14}C*(6.73, 6.90) are observed (1974LI15). See also (1971KO23).

42. ^{16}O(^{6}Li, ^{8}B)^{14}C $Q_{\rm m} = -16.591$

See (1973CE1B).

43. ^{16}O(^{11}B, ^{13}N)^{14}C $Q_{\rm m} = -4.434$

See (1972KU1H; theor.).

44. ^{16}O(^{18}O, ^{20}Ne)^{14}C $Q_{\rm m} = -1.497$

Angular distributions are reported at $E(^{18}{\rm O}) = 28$ and 32 MeV (1971BA68).

45. ^{17}O(n, α)^{14}C $Q_{\rm m} = 1.819$

See ^{18}O in (1978AJ03) and (1973CL1E; astrophys. relevance).

46. ^{18}O(d, ^{6}Li)^{14}C $Q_{\rm m} = -4.754$

Table 14.10: Lifetimes of bound excited states of ^{14}C

^{14}C*	τ_m	Reaction	Refs.
6.09 [a]	< 15 fsec	^{13}C(d, p)	(1974RU1B)
	< 10 fsec [A]	^{9}Be(^{13}C, ^{8}Be)	(1975SE04)
6.59	> 0.6 psec	^{13}C(d, p)	(1966AL10)
6.73	> 50 psec	^{9}Be(^{13}C, ^{8}Be)	(1975SE04)
	97 ± 15 psec [A]	^{12}C(t, p)	(1968AL12)
6.90	36 ± 4 fsec [A]	^{9}Be(^{13}C, ^{8}Be)	(1975SE04)
7.01	< 120 fsec	^{9}Be(^{7}Li, d)	(1969TH01)
	13 ± 2 fsec [A]	^{14}C(e, e)	(1972CR1A)

A = adopted value.
[a] See also (1972NY02).

See (1975BE01), (1970AJ04) and (1974DO03; theor.).

47. ^{19}F(d, ^{7}Be)^{14}C $\qquad Q_m = -7.140$

See (1967DE03).

48. ^{22}Ne(α, ^{12}C)^{14}C $\qquad Q_m = -8.6201$

Not observed: see (1962LA15).

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

GENERAL: (See also (1970AJ04).)

Shell model: (1970CO1H, 1970FR13, 1970HS02, 1970UL01, 1971NO02, 1972LE1L, 1972LI06, 1973IG02, 1973KU03, 1973SA30, 1974KI1B, 1975DI04, 1975MI12, 1975VE01).

Collective and deformed models: (1972LA12).

Cluster model: (1969BA1J, 1969KU1B, 1970KO26, 1971NO02, 1972LE1L, 1973KU03, 1975CH1V).

Special levels: (1969HA1F, 1971HS05, 1971JA13, 1971MC15, 1971NO02, 1972LA12, 1972LI06, 1973SA30, 1974BO22, 1974NI1A, 1974VA24, 1975CH1V, 1975DI04, 1975MI12).

Giant resonance: (1971JA14, 1973KI05, 1974FA1A, 1974HA1C, 1974MU13, 1974VE10, 1975VE01).

Electromagnetic transitions: (1969HA1F, 1969WA1C, 1970HS02, 1971JA13, 1972BE1E, 1972LI06, 1972LO1D, 1972TA21, 1973HA49, 1973SA30, 1974HA1C, 1974MU13, 1974PI1C, 1974VE10, 1975VE01).

Special reactions: (1969GA18, 1971AR02, 1971HE24, 1973KU03, 1973WI15, 1974KO25, 1975AR14, 1975HU14, 1975KA07, 1975KU01, 1975ME1F, 1975RE08, 1976YO1A).

Astrophysical questions: (1972CL1A, 1973AR1E, 1973AU1B, 1973AU1D, 1973AU1C, 1973BO1R, 1973CA1B, 1973CO1B, 1973IB1B, 1973MI1D, 1973RA1D, 1973SA1J, 1973SC1T, 1973SM1A, 1973TA1E, 1973TA1D, 1973TR1B, 1974BE1R, 1974SN1B, 1974WI1F, 1975AU1D, 1975CO1Q, 1975DW1A, 1975EN1A, 1975GO1Y, 1975IB1A, 1975JA1F, 1975KA1L, 1975KE1A, 1975NO1D, 1975PE1E, 1975PR1B, 1975RA1M, 1975RY1A, 1975SC1H, 1975SH1N, 1975SN1A, 1975TR1A, 1975UL1A).

Muon and neutrino capture and reactions: (1970BU1D, 1970DM01, 1970VA24, 1972BA1X, 1972BU29, 1973BA68, 1973KI12, 1973MU05, 1973MU11, 1973MU1B, 1974DU02, 1974EN10, 1974FU1B, 1975CA1H, 1975CH22).

Pion capture and reactions (See also reaction 60.): (1969BA1L, 1969GO1C, 1969MA1C, 1970BA44, 1970BA1E, 1970DO04, 1970KO26, 1970NE1F, 1971AM1A, 1971FA09, 1971KO23, 1971MA38, 1971MA1T, 1971MA2A, 1972AG01, 1972FA14, 1972HU1A, 1972KO31, 1972SW1A, 1972YO1C, 1973AG05, 1973AG06, 1973AR1B, 1973BA2G, 1973BU1B, 1973CH20, 1973EI01, 1973GR1F, 1973KA19, 1973KA1D, 1973NY04, 1973ST1K, 1974HU14, 1974KO07, 1974LE25, 1974LI15, 1974NE18, 1974ST1G, 1974TA18, 1974ZA05, 1975AR02, 1975BA52, 1975DE1D, 1975EI1B, 1975VE05, 1976JA04).

Kaon capture: (1969KU1B, 1971MA1T, 1972WA1F, 1974CA1H).

Applied work: (1975BE1U, 1975OL1A).

Table 14.11: Energy levels of ^{14}N [a]

E_x in ^{14}N (MeV $\pm$ keV)	$J^\pi; T$	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
g.s.	$1^+; 0$	stable		1, 6, 7, 9, 10, 18, 19, 20, 21, 32, 33, 34, 35, 36, 37, 38, 39, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 57, 59, 60, 61, 63, 64, 65, 66, 67, 68, 70, 71, 72
2.31287 ± 0.07	$0^+; 1$	$\tau_m = 87 \pm 6$ fsec	γ	1, 9, 10, 18, 19, 21, 26, 32, 33, 34, 35, 38, 39, 41, 42, 43, 44, 47, 56, 57, 59, 60, 61, 64, 65, 66
3.9478 ± 0.4	$1^+; 0$	4.5 ± 0.4 fsec	γ	1, 6, 7, 9, 10, 18, 19, 20, 21, 26, 32, 33, 34, 35, 38, 39, 42, 43, 44, 45, 47, 48, 57, 59, 61, 64, 65, 66
4.9150 ± 1.3	$0^-; 0$	7.6 ± 1.4 fsec	γ	1, 6, 7, 18, 19, 20, 21, 32, 33, 34, 39, 41, 42, 43, 44, 45, 47, 48, 57, 59, 65
5.10587 ± 0.18	$2^-; 0$	(12.4 ± 1.4) psec	γ	6, 7, 18, 19, 20, 21, 26, 32, 33, 34, 39, 42, 43, 44, 45, 47, 48, 57, 59, 61, 64, 65
5.6896 ± 1.1	$1^-; 0$	10.0 ± 2.0 fsec	γ	6, 7, 18, 19, 20, 21, 32, 33, 39, 42, 43, 44, 45, 47, 48, 57, 59, 65
5.8324 ± 1.4	$3^-; 0$	18 ± 2 psec	γ	6, 7, 11, 18, 19, 20, 21, 24, 32, 33, 39, 42, 43, 44, 45, 47, 48, 57, 59, 61, 65
6.2035 ± 0.6	$1^+; 0$	124 ± 15 fsec	γ	1, 6, 7, 18, 19, 20, 21, 26, 32, 33, 39, 44, 45, 47, 48, 57, 59, 65
6.4444 ± 1.1	$3^+; 0$	627 ± 33 fsec	γ	1, 6, 7, 18, 19, 20, 21, 32, 33, 39, 43, 44, 45, 48, 57, 59, 65
7.0279 ± 1.4	$2^+; 0$	5.4 ± 0.5 fsec	γ	6, 7, 18, 19, 20, 21, 32, 33, 39, 41, 43, 44, 45, 47, 48, 57, 59, 64, 65
7.9666 ± 0.6	$2^-; 0$	$\Gamma = (2.5 \pm 0.7) \times 10^{-3}$	γ, p	6, 7, 18, 19, 20, 21, 26, 32, 33, 44, 48, 57, 59, 65

Table 14.11: Energy levels of ^{14}N [a] (continued)

E_x in ^{14}N (MeV $\pm$ keV)	$J^\pi; T$	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
8.062 ± 1.0	$1^-; 1$	30 ± 1	γ, p	18, 19, 26, 27, 32, 41, 44, 57, 59
8.4877 ± 1.2	$4^-; 0$	27×10^{-6}	γ, p	6, 7, 18, 19, 20, 21, 26, 32, 33, 44, 65
8.618 ± 2	$0^+; 1$	7 ± 1	γ, p	18, 19, 26, 27, 32, 33, 44, 57, 59, 65
8.79 ± 50	$0^-; 1$	≈ 460	γ, p	26, 27
8.9091 ± 1.6	$3^-; 1$	19.7 ± 1.9	γ, p	19, 26, 27, 32, 33, 42, 44, 57, 59
8.9612 ± 1.3	$5^+; 0$	7×10^{-6}	γ, p	11, 19, 20, 21, 23, 24, 26, 52, 57
8.979 ± 3	2^+; (0)	8 ± 2	γ, p	6, 19, 26, 27, 32, 57
9.1241 ± 1.5	3^+			6, 19
9.129 ± 1.0	$2^-; 0$	< 1	γ, p	26, 32
9.1708 ± 1.6	$2^+; 1$	0.074 ± 0.008	γ, p	19, 21, 26, 32, 41, 42, 44, 57, 59, 64
9.3860 ± 1.4	$2^-, 3^-; 0$	15.6 ± 2.0	γ, p	6, 19, 20, 21, 26, 27, 32, 44, 57, 59, 65
9.509 ± 3	$2^-; 1$	41 ± 2	γ, p	19, 26, 27, 32, 44, 57, 59, 65
9.703 ± 4	$1^+; 0$	15 ± 3	p	6, 19, 20, 21, 27, 32, 44, 57, 59, 65
10.063 ± 15	$3^+, \geq 4$	< 10	p	19, 57
10.101 ± 15	$2^+, 1^+; 0$	5	γ, p	6, 19, 20, 21, 26, 27, 44, 57, 65
10.228 ± 10	$1^{(-)}; 0$	80 ± 15	γ, p	19, 26, 27, 57, 65
10.434 ± 6	$2^+; 1$	33 ± 3	γ, p	6, 19, 26, 27, 39, 42, 57, 59, 64, 65
(10.54)	(1)	(140)	p	19, 27
10.811 ± 7	$5^+; 0$	$(0.39 \pm 0.16) \times 10^{-3}$	γ, p	19, 20, 21, 26, 57, 65
11.00 ± 30		165 ± 30	γ, p	26, 42
11.050 ± 5	$(2, 3)^+$	≤ 2	γ, p	6, 19, 26, 42, 57
11.07	$1^+; 0$	100	n, p, d	6, 13, 20, 21, 26, 28, 64, 65
11.24 ± 20	; 1	220 ± 30	γ, p, d	13, 19, 24, 26, 44, 45, 47, 57, 65

Table 14.11: Energy levels of ^{14}N [a] (continued)

E_x in ^{14}N (MeV $\pm$ keV)	$J^\pi; T$	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
11.24	(3^-)	≈ 20	n, p	27, 28, 57
11.29	$2^-; 0$	180	n, p, d	13, 14, 21, 27, 28, 57
11.357 ± 15	$1^+; 0$	30	γ, n, p, d	13, 14, 19, 20, 21, 27, 28, 57, 65
11.5136 ± 1.5	$2^+, 3^+$	7.0 ± 0.5	p, d	13, 14, 19, 21, 57, 65
11.68 ± 20	$1^-, 2^-$	150 ± 20	n, p, d	13, 19, 57
11.741 ± 6	$1^-, 2^-$	40 ± 9	(γ, n), p, d	13, 19, 26, 27, 28, 57
11.761 ± 6	$3^-, 4^-$	78 ± 6	(γ, n), p, d	13, 19, 26, 27, 28, 57
11.807 ± 7	(2^-)	119 ± 9	n, p, d	13, 14, 19
11.874 ± 6	(2^-)	101 ± 9	p, d	13, 19, 28
12.20 ± 20	$1^-, 2^-$	300 ± 30	n, p, d	13, 21, 28, 57
(12.29 ± 15)				19
12.408 ± 3	(3^+)	37 ± 4	n, p, d	13, 14, 19, 21
12.418 ± 3	(4^-)	41 ± 4	p, d	3, 4, 13, 19
(12.47 ± 5)		≈ 20	p, α	3
12.497 ± 4		35 ± 10	γ, n, p, d, α	3, 13, 19, 26, 39, 57, 64
12.594 ± 3	3^+	48 ± 2	n, p, d, α	3, 13, 14, 19, 21, 28, 57
12.688 ± 4	3^-	22 ± 4	n, p, d, α	2, 3, 4, 5, 13, 14, 19, 20, 21, 28
(12.708 ± 9)		43 ± 15	p, d	13
12.792 ± 4	4^+	18 ± 3	p, d, α	3, 4, 5, 11, 13, 14, 19, 23, 44, 45, 47, 57
(12.813 ± 5)		37 ± 6	p, d	13
12.819 ± 4	4^-	8 ± 3	n, p, d, α	3, 4, 13, 14, 57
12.857 ± 6		78 ± 10	n, p, d	13, 28
12.923 ± 5	(4^+)	25 ± 3	p, d, α	3, 4, 13, 14, 19
13.03 ± 15		≈ 100	γ, p	20, 26
13.166 ± 5	(1^+)	15 ± 5	n, p, d, α	2, 3, 4, 5, 13, 14, 19, 57
13.192 ± 10	3^+	65 ± 10	α	5, 9, 57
13.243 ± 10	2^-	92 ± 5	n, p, α	2, 3, 28, 57
13.30 ± 40	$(2^-); 1$	1000 ± 150	γ, p	26
13.656 ± 5	$(2^+, 3^+)$	≈ 90	n, p, d, α	2, 3, 5, 13
13.714 ± 5	$2, 3^+$	105 ± 25	n, p, d, α	2, 3, 4, 28, 57

Table 14.11: Energy levels of ^{14}N [a] (continued)

E_x in ^{14}N (MeV $\pm$ keV)	$J^\pi; T$	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
13.71 ± 30	$1^+; 1$	180 ± 20	γ, n, p, α	2, 3, 5, 13, 14, 26, 28, 39, 57, 59
13.72 ± 20		110	p, α	3
14.04 ± 30		100	n, p, d, α	2, 3, 13, 14, 28
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, d, α	3, 13, 14
14.56 ± 20		100	n, p, α	2, 3
14.59 ± 30		50	n, p, α	2, 3
14.66 ± 10	2^-	100 ± 20	α	5
14.73 ± 30		125	n, p, α	2, 3
14.86 ± 30		140	n, p, d, α	2, 3, 13, 14, 16, 19, 28
14.92 ± 25		43 ± 8	n, p, α	2, 3, 19, 28
15.015 ± 15		≈ 60	n, d, α	2, 14, 20, 28
15.24 ± 20		100	p, d, α	3, 13, 14, 23
15.43 ± 20		100	n, p, d, α	2, 3, 13, 16, 20
15.7 ± 150		350	n, p, d, α	13, 14, 16, 19, 20, 28
16.21 ± 20		125	n, p, α	2, 3, 20, 23, 28
16.40 ± 20		150	p, α	3, 16, 20, 23
16.8	$4^+; 0+1$	≈ 300	d, α	16
16.91 ± 20	$(5^-); 0+1$	≈ 100	p, d, α	3, 16
17.17 ± 20	$4^+; 0+1$	≈ 300	n, p, d, α	3, 13, 14, 16, 19, 20, 23, 28
17.7				20, 23
18.1	$(1^-, 2^+); 0+1$	(≈ 300)	d, α	16
18.1	$4^+; 0+1$	≈ 600	d, α	16, 28
18.2	$3^-; 0+1$	(≈ 400)	d, α	16
18.4	$3^-; 0+1$	(≈ 300)	d, α	16
18.50	$5^-; 0+1$	≈ 60	d, α	16
18.8	$4^+; 0+1$	(≈ 400)	d, α	16
20.1	$1^-; 0+1$	(≈ 500)	d, α	16
20.6		500 ± 100	γ, d	12
20.8	$5^-; 0+1$	≈ 600	d, α	16

Table 14.11: Energy levels of ^{14}N [a] (continued)

E_x in ^{14}N (MeV ± keV)	$J^\pi; T$	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
20.8	$(3^-, 4^+); 0+1$	(≈ 500)	d, α	16
21.3	$4^+; 0+1$	$(\approx 1$ MeV)	d, α	16
21.5	$3^-; 0+1$	(≈ 500)	d, α	16, 44
21.7	$5^-; 0+1$	≈ 200	d, α	16
21.8		650	γ, ^{3}He	8
22.5 ± 100	$5^-; 0+1$	610 ± 100	d, α	16
22.5	$(2^-); 1$		γ, p	26
23.0	$(0, 1, 2)^-; 1$	≈ 3 MeV	γ, n	40
23.0	$2^-; 1$		γ, p	26
23.3 ± 100	$5^-; 0+1$	500 ± 100	d, α	16
24.0		≈ 1000	n, ^{3}He, α	8

[a] See also Table 14.7 in (1970AJ04) and Tables 14.12 and 14.13 here.

Other topics: (1968JO1C, 1970BO1M, 1970CO1H, 1970FO1B, 1970FR13, 1971BO1F, 1971HS05, 1971JA13, 1971MC15, 1972CA37, 1972LA12, 1972LE1L, 1972WA1F, 1973CL09, 1973CO16, 1973GO1H, 1973IG02, 1973KE1C, 1973KU03, 1973MA48, 1973PA1F, 1973PO1D, 1973RO1R, 1973RO1Q, 1973SH14, 1973SI21, 1974BO22, 1974CA1H, 1974DU11, 1974FA1A, 1974MU13, 1974SI04, 1974VA24, 1974ZU1A, 1975CA1N, 1975KU01, 1976MA04, 1976PA03).

Ground state: (1969LE1B, 1971SC29, 1971SH26, 1971TA1A, 1972LE1L, 1972VA36, 1973CH38, 1973HO32, 1973SU1B, 1974AD1C, 1974DE1E, 1974DU02, 1974EN10, 1974MU13, 1975AL19, 1975BE31, 1975CA1N, 1976PA03).

$$\mu = +0.403562 \pm 0.000010 \text{ nm (1964BA11); see also (1969FU11);}$$
$$= +0.40376077 \pm 0.00000006 \text{ (1974SHYR);}$$
$$Q = +10 \text{ mb (1969FU11); see also (1968OK1C, 1969BO1D, 1974SHYR);}$$
$$r_{rms} = 2.55 \pm 0.03 \text{ fm (1974DU02).}$$

Mass of ^{14}N: 14.003 074 001 (11) amu (1975SM02).

See also (1971KE01, 1971SM01, 1972WA1G).

1. (a) ^{9}Be(^{6}Li, n)^{14}N $\quad Q_m = 14.500$
   (b) ^{9}Be(^{7}Li, 2n)^{14}N $\quad Q_m = 7.250$

Table 14.12: Radiative decays in ^{14}N [a]

E_i (MeV)	$J^\pi_i; T$	E_f (MeV)	$J^\pi_f; T$	Branch (%)	Γ_γ (eV)	Refs.
2.31	$0^+; 1$	0	$1^+; 0$	100	$(7.6 \pm 0.5) \times 10^{-3}$	Table 14.13
3.95	$1^+; 0$	0	$1^+; 0$	[A] 3.9 ± 0.2 [b]	(M1)$(5.8 \pm 1.2) \times 10^{-4}$	(1967OL02, 1968RO1C)
					(E2)$(4.81 \pm 0.33) \times 10^{-3}$	
				4.2 ± 1.4		(1972RE10)
		2.31	$0^+; 1$	[A] 96.1 ± 0.3 [b]	0.140 ± 0.013	(1967OL02, 1968RO1C)
				95.8 ± 1.4		(1972RE10)
4.92	$0^-; 0$	0	$1^+; 0$	97 ± 3	$(8.4 \pm 1.6) \times 10^{-2}$	(1972RE10), Table 14.13)
		2.31	$0^+; 1$	0.4 ± 0.7		(1965NE06; see also 1966GO15)
				≤ 2		(1972RE10)
		3.95	$1^+; 0$	1.3 ± 1.0		(1965NE06)
				≤ 2		(1972RE10)
				≤ 0.5		(1966GO15)
5.11	$2^-; 0$	0	$1^+; 0$	[A] 79.9 ± 1.0 [b]	$(4.0 \pm 0.5) \times 10^{-5}$ [d]	(1966GO15, 1968AL12)
		2.31	$0^+; 1$	[A] 19.7 ± 1.2 [b]		
		3.95	$1^+; 0$	(0.7 ± 0.4)		(1966GO15)
5.69	$1^-; 0$	0	$1^+; 0$	37 ± 2		(1963AL21)
				40 ± 3		(1964WA09)
				40 ± 4		(1966CA07)
				36 ± 4		(1966GO15)
				31.6 ± 1.9		(1972RE10)
				35.6 ± 1.2		mean
		2.31	$0^+; 1$	63 ± 2	$(4.2 \pm 0.8) \times 10^{-2}$ [d]	(1963AL21); Table 14.13

Table 14.12: Radiative decays in ^{14}N [a] (continued)

E_{i} (MeV)	J^{π}_{i}; T	E_{f} (MeV)	J^{π}_{f}; T	Branch (%)	Γ_{γ} (eV)	Refs.
				60 ± 3		(1964WA09)
				60 ± 5		(1966CA07)
				64 ± 4		(1966GO15)
				64.7 ± 1.9		(1972RE10)
				63.1 ± 1.2		mean
		3.95	1^+; 0	≤ 0.4 [e]		(1972RE10)
		4.92	0^-; 0	≤ 0.3 [e]		(1972RE10)
5.83	3^-; 0	0	1^+; 0	25 ± 5		(1965WA06)
				25 ± 4		(1966CA07)
				29 ± 4		(1966GO15)
				26.5 ± 2.5		mean
		2.31	0^+; 1	< 3		(1966GO15)
		3.95	1^+; 0	< 1		(1966GO15)
		4.92	0^-; 0	< 1		(1966GO15)
		5.11 [f]	2^-; 0	75 ± 5	$(2.7 \pm 0.3) \times 10^{-5}$ [d]	(1965WA06, 1966CA07)
				71 ± 4		(1966GO15, 1968AL12)
				73 ± 3		mean
6.20	1^+; 0	0	1^+; 0	24 ± 3		(1964WA09)
				25 ± 4		(1966CA07)
				21 ± 3		(1966GO15)
				23.0 ± 1.9		mean
		2.31	0^+; 1	76 ± 3	$(4.1 \pm 0.5) \times 10^{-3}$ [d]	(1964WA09); Table 14.13

Table 14.12: 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)	Refs.
				72 ± 5		(1966CA07)
				79 ± 3		(1966GO15)
				76.7 ± 2.0		mean
		3.95	$1^+; 0$	< 1		(1966GO15)
		5.11	$2^-; 0$	< 1		(1966GO15)
6.44	$3^+; 0$	0	$1^+; 0$	65 ± 3	$(7.3 \pm 0.4) \times 10^{-4}$ [d]	(1964WA09)
				73 ± 5		(1959RO54, 1966CA07)
				74 ± 4		(1966GO15)
				69.4 ± 2.2		mean
		3.95	$1^+; 0$	21 ± 2		(1964WA09)
				20 ± 4		(1966CA07)
				19 ± 4		(1966GO15)
				20.5 ± 1.6		mean
		5.11 [g]	$2^-; 0$	7 ± 3		(1966CA07)
				[A] 7 ± 2		(1966GO15)
		5.83	$3^-; 0$	< 2		(1966GO15)
7.03	$2^+; 0$	0	$1^+; 0$	91 ± 4		(1965WA06)
				[A] 98.6 ± 0.3	(M1)$(9.1 \pm 1.3) \times 10^{-2}$	(1967OL02, 1968RO1C)
					(E2)$(3.3 \pm 0.9) \times 10^{-2}$	
		2.31	$0^+; 1$	0.5 ± 0.1	(E2)$(6.2 \pm 1.4) \times 10^{-4}$	(1967OL02, 1968RO1C)
		3.95	$1^+; 0$	0.9 ± 0.25	$< (11 \pm 3) \times 10^{-4}$	(1967OL02, 1968RO1C)
		other states		≤ 0.4		(1967OL02)

Table 14.12: 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)	Refs.
7.97 [h]	$2^-; 0$	0	$1^+; 0$	55 ± 3	$\omega\Gamma_p\Gamma_\gamma/\Gamma = 0.012$	(1960HE14)
		3.95	$1^+; 0$	45 ± 3	$= 0.010$	(1960HE14)
		other states		≤ 3		(1960HE14)
8.06	$1^-; 1$	0	$1^+; 0$	80.3 ± 0.6	10.3	(1972RE10); Table 14.24
		2.31	$0^+; 1$	1.40 ± 0.14	0.2	(1972RE10)
		3.95	$1^+; 0$	12.7 ± 0.4	1.6	(1972RE10)
		4.92	$0^-; 0$	1.86 ± 0.14	0.3	(1972RE10)
		5.11	$2^-; 0$	0.25 ± 0.14	0.03	(1972RE10)
		5.69	$1^-; 0$	3.5 ± 0.4	0.5	(1972RE10)
8.49 [j]	$4^-; 0$	5.11	$2^-; 0$	100	$(5.61 \pm 2.0) \times 10^{-3}$	(1965DE19, 1966CA07, 1967GA12)
8.62	$0^+; 1$	0	$1^+; 0$	23	1.20	(1959WA16)
		3.95	$1^+; 0$	24	1.26	(1959WA16)
		5.69	$1^-; 0$	13	0.69	(1956LE28, 1957WI27, 1959WA16)
		6.20	$1^+; 0$	40		(1957WI27)
8.79	$0^-; 1$	0	$1^+; 0$		43 ± 9	(1960WA12)
		3.95	$1^+; 0$		0.9 ± 0.3	(1960WA12)
8.91	$3^-; 1$	0	$1^+; 0$		$(6.6 \pm 2.2) \times 10^{-3}$	(1968CL05)
		5.11	$2^-; 0$	5.5 ± 2.5	$\omega\Gamma_\gamma = 0.040$	(1959WA04)
		5.83	$3^-; 0$	89 ± 3	$= 0.65$	(1959WA04)
		6.44	$3^+; 0$	3 ± 1	$= 0.022$	(1959WA04)
		7.03	$2^+; 0$	1.4 ± 0.8	$= 0.010$	(1959WA04)
8.96 [j]	$5^+; 0$	0	$1^+; 0$	< 1		(1967BL22, 1967GA12)

Table 14.12: 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)	Refs.
		6.44	$3^+; 0$	100	$\begin{cases} \Gamma_p/\Gamma_\gamma = 4.1 \pm 0.5 \\ \Gamma_\gamma = (1.36 \pm 0.21) \times 10^{-3} \end{cases}$	(1965DE19, 1966CA07, 1967GA12)
9.13	$2^-; 0$	0	$1^+; 0$	> 80	$\omega\Gamma_\gamma \approx 0.03$	(1965DE19)
9.17	$2^+; 1$	0	$1^+; 0$	79 ± 4	7.7 ± 0.9	(1959HA11, 1960RO13, 1963PR03, 1967GA12, 1968CL05)
		2.31	$0^+; 1$	1.1 ± 0.4	0.11 ± 0.4	(1963PR03, 1968CL05)
		5.11	$2^-; 0$	< 1		(1960RO13)
		5.69	$1^-; 0$	< 6	0.3 ± 0.25	(1960RO13, 1968CL05)
		5.83	$3^-; 0$	3 ± 2	0.33	(1960RO13)
		6.44	$3^+; 0$	8 ± 2	0.78 ± 0.35	(1960RO13, 1968CL05)
				6.3 ± 0.5	0.85 ± 0.15	(1963PR03)
		7.03	$2^+; 0$	3 ± 1	0.3 ± 0.15	(1960RO13, 1968CL05)
				3.5 ± 0.5	0.34 ± 0.05	(1963PR03)
9.39	$2^-; 3^-; 0$	[i]				(1975NO1F)
9.51	$2^-; 1$	3.95	$1^+; 0$	6 ± 1	0.37	(1959WA04)
		5.11	$2^-; 0$	78 ± 3	4.8	(1959WA04)
		5.83	$3^-; 0$	16 ± 2	1.0	(1959WA04)
10.23	$1^{(-)}; 0$	2.31	$0^+; 1$		4 ± 1.3	(1963RO17)
10.43	$2^+; 1$	0	$1^+; 0$	82 ± 6	12.1 ± 1.5	(1960RO13, 1968CL05)
		2.31	$0^+; 1$	< 1		(1964RO03)
		3.95	$1^+; 0$	< 2		(1964RO03)
		5.11	$2^-; 0$	2 ± 1	0.3 ± 0.2	(1960RO13, 1968CL05)

Table 14.12: Radiative decays in ^{14}N [a] (continued)

E_i (MeV)	$J_i^\pi; T$	E_f (MeV)	$J_f^\pi; T$	Branch (%)	Γ_γ (eV)	Refs.
		5.69	$1^-; 0$	< 3		(1964RO03)
		5.83	$3^-; 0$	< 1		(1964RO03)
		6.44	$3^+; 0$	8 ± 1	1.2 ± 0.4	(1960RO13, 1968CL05)
		7.03	$2^+; 0$	6 ± 1	0.88 ± 0.31	(1960RO13, 1968CL05)
10.81 [k]	$5^+; 0$	6.44	$3^+; 0$	100	$\Gamma_\gamma/\Gamma = 4.1 \pm 0.8$%	(1972NO08)

A = Adopted.

[a] See also Table 14.9 in (1970AJ04) and Tables 14.13 and 14.20 here.

[b] Means of branching ratio values quoted in Table 14.9 (1970AJ04).

[c] See also (1972NY02, 1974RAZD).

[d] Corrected for branching: see Table 14.13.

[e] See also (1966GO15).

[f] $5.83 \rightarrow 5.11$: $E_\gamma = 728.3 \pm 1.0$ keV (1966AL10): the plane polarization of the γ-rays leads to odd parity for ^{14}N*(5.83) (1962RO21).

[g] See also (1964WA09).

[h] $\Gamma_\gamma/\Gamma = 0.7 \pm 0.2$%; $(2J+1)\Gamma_p = 12.6 \pm 3.6$ eV (1972BA56); $\Gamma = 2.5 \pm 0.7$ eV (J.W. Noe, private communication).

[i] Decays predominantly to ^{14}N*(5.11, 5.83, 8.9): ≈ 5 meV each (1975NO1F).

[j] $\Gamma = 27 \times 10^{-3}$ and 7×10^{-3} eV, respectively for ^{14}N*(8.49, 8.96) (J.W. Noe, private communication).

[k] $\Gamma = 0.39 \pm 0.16$ eV (J.W. Noe, private communication).

Table 14.13: Lifetimes of some ^{14}N states [a]

E_x (MeV)	τ_m (fsec)	Reaction	Refs.
2.31 [b]	83 ± 19	^{12}C(^{3}He, p)	(1966LI07)
	83 ± 30	^{12}C(^{3}He, p)	(1965LO07)
	114 ± 30	^{12}C(^{3}He, p)	(1973HA40)
	70 ± 10	^{13}C(p, γ)	(1971BI03)
	75 ± 19	^{13}C(p, γ)	(1972RE10)
	106 ± 10	^{14}N(γ, γ)	(1975RA22)
	87 ± 6		mean
3.95 [c]	10.5 ± 3.5	^{13}C(p, γ)	(1971BI03)
	4.5 ± 0.4 [A]	^{14}N(e, e)	(1964BI09, 1967OL02)
4.92 [d]	7.05 ± 1.5	^{13}C(d, n)	(1974RU1B)
	10 ± 3	^{14}N(γ, γ)	(1974RAZD)
	7.6 ± 1.4		mean
5.11 [e]	(12.4 ± 1.4) psec [A]	^{12}C(t, n)	(1968AL12)
5.69	< 21 fsec	^{12}C(^{3}He, p)	(1973HA40)
	< 15 fsec	^{13}C(p, γ)	(1971BI03, 1972RE10)
	10.0 ± 2.0 [A]	^{13}C(d, n)	(1974RU1B)
5.83	18 ± 2 psec [A]	^{12}C(t, n)	(1968AL12)
6.20 [f]	200 ± 45	^{12}C(^{3}He, p)	(1973HA40)
	118 ± 13	^{13}C(p, γ)	(1971BI03)
	124 ± 15		mean
6.44	630 ± 80	reactions 1, 6, 21	(1969TH01)
	590 ± 120	^{12}C(^{3}He, p)	(1964BE12)
	630 ± 100	^{12}C(^{3}He, p)	(1973HA40)
	630 ± 40	^{12}C(^{3}He, p)	(1970GA09)
	627 ± 33		mean
7.03	5.4 ± 0.5	^{14}N(γ, γ)	(1966SW01)

A = adopted.

[a] See also Table 14.12, and also Table 14.13 in (1970AJ04).

[b] See also (1974RU1B).

[c] See also (1974RU1B, 1973HA40).

[d] See also (1973HA40).

[e] See also Table 14.13 in (1970AJ04) and (1974RU1B).

[f] See also (1970GA09).

Table 14.14: Resonances in $^{10}B + \alpha$ [a]

E_α (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	Outgoing particle [b] (x)	Γ_x [c] (keV)	$^{14}N^*$ (MeV)	J^π	Refs.
0.95		p_0		12.29		(1953MA42)
1.13 ± 5	30 ± 5	$p_0 \rightarrow p_3$, d		12.42	4^-	A
1.20 ± 5	≈ 20	p_0, (p_2), p_3		12.47		(1953MA42, 1969GA01)
1.23 ± 5	35 ± 5	p_0, p_3		12.49		(1953SH64, 1969GA01)
1.40 ± 5	46 ± 4	p_1, p_2, (p_3)		12.61	3^+	(1953SH64, 1969GA01)
1.507 ± 5	18 ± 5	n_0	4.3	12.690	3^-	A, (1973VA25)
		p_0	0.62			
		p_1	0.17			
		p_2	0.70			
		p_3	5.6			
		d	0.93			
		α	1.7			
1.645 ± 5	16 ± 3	n_0	≤ 0.6	12.789	4^+	A, (1973VA25)
		p_0	0.18			
		p_1	0.085			
		p_2	0.44			
		p_3	9.6			
		d	2.0			
		α	1.0			
1.68 ± 5	5 ± 2	p_1, p_2, p_3, d		12.814	4^-	A
1.83 ± 5	22 ± 4	$p_0 \rightarrow p_3$, d		12.921	4^+	A
2.174 ± 5	15 ± 5	n_0, $p_0 \rightarrow p_3$, d, α_1		13.166	1^+	A, (1973VA25, 1975WI04)

Table 14.14: Resonances in ^{10}B + α [a] (continued)

E_α (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	Outgoing particle [b] (x)	Γ_x [c] (keV)	^{14}N* (MeV)	J^π	Refs.
2.21 ± 10	65 ± 10	α_0		13.192	3^+	(1973MO15)
2.281 ± 10	92 ± 5	n_0, $p_0 \rightarrow p_3$		13.243	2^-	A, (1973VA25, 1975WI04)
2.86 ± 5	≈ 90	n_0, p_1, p_2, α_1		13.656		(1969GA01, 1973VA25)
2.94 ± 5	105 ± 25	n_0, $p_0 \rightarrow p_3$, d		13.714	2, 3^+	A, (1973VA25, 1975WI04)
2.95 ± 50	180 ± 20	n_0, p_0, (p_2), α_0		13.72	$1^{(+)}$	(1973MO15, 1973VA25, 1975WI04) [d]
2.95 ± 20	110	p_1, p_3		13.72		(1969GA01, 1975WI04) [d]
3.40 ± 30	100	n_0, p_1		14.04		(1973VA25, 1975WI04)
3.56 ± 30	230	n_0, (p_0), p_3		14.16		(1973VA25, 1975WI04)
3.69 ± 50	420 ± 100	$p\gamma$, α_0		14.25	3^+	(1956BO61, 1959GI47, 1973MO15)
3.76 ± 20	150	p_1		14.30		(1975WI04)
3.98 ± 20	100	n_0, p_0, p_2		14.56		(1956BO61, 1973VA25, 1975WI04)
4.16 ± 30	50	n_0, p_0, p_3		14.59		(1973VA25, 1975WI04)
4.26 ± 10	100 ± 20	α_0		14.66	2^-	(1973MO15)
4.36 ± 30	125	n_0, p_0, p_1, (p_2)		14.73		(1973VA25, 1975WI04)
4.54 ± 30	140	n_0, p_2, p_3		14.86		(1956BO61, 1959GI47, 1973VA25, 1975WI04)
4.633 ± 30	43 ± 8	n_0, n_{2+3}, p_0		14.923		(1973VA25, 1975WI04)
4.77 ± 20	≈ 60	n_0, n_1		15.02		(1973VA25)
5.08 ± 20	100	p_3		15.24		(1975WI04)
5.35 ± 20	100	n_1, p_2, p_3		15.43		(1956BO61, 1975WI04)
6.44 ± 20	125	n_0, p_0, p_2		16.21		(1975WI04)
6.70 ± 20	150	p_2		16.40		(1975WI04)
7.42 ± 20		p_0		16.91		(1975WI04)

Table 14.14: Resonances in $^{10}B + \alpha$ [a] (continued)

E_α (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	Outgoing particle [b] (x)	Γ_x [c] (keV)	$^{14}N^*$ (MeV)	J^π	Refs.
7.78 ± 20	50	p_3		17.17		(1975WI04)

A: See references quoted for this state in (1970AJ04).

[a] See Table 1 in (1975WI04) for a display of the resonance data obtained both in $^{12}C + d$, $^{13}C + p$ and $^{10}B + \alpha$.

[b] n_0, n_1, n_{2+3} correspond to the g.s. and $^{13}N^*(2.37, 3.51 + 3.55)$; p_0, p_1, p_2, p_3 correspond to the g.s. and $^{13}C^*(3.09, 3.68, 3.85)$ and the corresponding γ-rays; α_1 corresponds to the transition to $^{10}B^*(0.7)$.

[c] For θ^2_x see Table 14.8 in (1970AJ04).

[d] See reference [f] to Table 1 of (1975WI04).

In reaction (a) $E_\gamma = 1631.3 \pm 1.3$ [$3.95 \rightarrow 2.31$], 4913.8 ± 3.0 [$4.92 \rightarrow$ g.s.], 3883.0 ± 1.9 [$6.20 \rightarrow 2.31$] and 6443.7 ± 1.8 keV [$6.44 \rightarrow$ g.s.] have been observed [transitions shown in brackets]. The τ_m of ^{14}N*(6.44) is 620 ± 80 fsec [see also Table 14.13] (1969TH01). For reaction (b) see (1957NO17).

2. ^{10}B(α, n)^{13}N $\qquad Q_m = 1.060 \qquad E_b = 11.6134$

Recent measurements have been carried out at $E_\alpha = 1.0$ to 5.0 MeV (1973VA25: n_0, n_1, n_{2+3}) and at 2.0 to 7.0 MeV (1975WI04: n_0). Observed resonances in these and in previous experiments are displayed in Table 14.14. See also reaction 3.

3. ^{10}B(α, p)^{13}C $\qquad Q_m = 4.0627 \qquad E_b = 11.6134$

Excitation functions have been measured to $E_\alpha = 26$ MeV: see (1970AJ04) for a listing of the earlier references and (1975WI04: $E_\alpha = 2.0$ to 10.7 MeV (p_0), to 7.5 MeV (p_1) and to 8 MeV (p_2, p_3); see also reaction 2). Observed resonances are displayed in Table 14.14. (1975WI04) has expanded the angular distributions of the $p_0 \rightarrow p_3$ groups into Legendre polynomials and fitted the coefficients at the 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. (1975WI04) also finds that a surprising proportion of states have a higher cross section for neutron than for proton emission: the fluctuations of σ_n/σ_p at low E_α suggest sizable isospin impurities in the ^{14}N states (1975WI04).

4. ^{10}B(α, d)^{12}C $\qquad Q_m = 1.3409 \qquad E_b = 11.6134$

Excitation curves have been measured for E_α up to 27 MeV: see (1970AJ04) for the earlier references and (1975SP04: $E_\alpha = 18$ to 27 MeV; yields of 12.7 and 15.1 MeV γ). The low-energy resonances ($E_d < 2.2$ MeV) are exhibited in Table 14.14. At the higher energies the yield curves are fairly smooth (see (1968AL1C, 1975SP04)), although (1975SP04) report a sharp rise in the 15.1 MeV γ-yield ≈ 1 MeV above the ^{12}C*(15.1)$+$p$+$n threshold, a reaction which is not isospin forbidden.

5. (a) ^{10}B(α, α)^{10}B $\qquad E_b = 11.6134$
(b) ^{10}B(α, ^{6}Li)^{8}Be $\qquad Q_m = -4.552$

The yield of 0.72 MeV γ-rays has been measured for $E_\alpha = 2.1$ to 3.5 MeV by (1969GA01). Excitation functions for elastically scattered α-particles have been measured for $E_\alpha = 2.0$ to 4.3

MeV (1973MO15) and for 5 to 30 MeV (1972DA04). 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^-, respectively for ^{14}N*(13.19, 13.72, 14.25, 14.66) (1973MO15). For reaction (b) see (1974JE1A).

6. ^{10}B(^{6}Li, d)^{14}N $\qquad Q_{\rm m} = 10.140$

At $E(^6{\rm Li}) = 5$ MeV ^{14}N*(0, 3.95, 4.92, 5.11, 5.69, 5.83, 6.20, 6.44, 7.03, 7.97, 8.49, 8.98, 9.12, 9.39, 9.70, 10.10, 10.43 ($T = 1$, weakly populated), 11.06) are populated ((1966MC05), and private communication). (1975FO01) have examined ^{14}N*(9.13) in detail and conclude that it is a closely spaced doublet of which one member is populated in ^{13}C(p, γ) and has been assigned $J^\pi = 2^-$, and the other member, populated here, has $J^\pi = 3^+$. This assignment is based on a DWBA analysis of the angular distributions at $E(^6{\rm Li}) = 16.5$ and 21.0 MeV which shows the contributions of several L values and, in particular, $L = 0$. See also reaction 19. Branching ratios for the γ-decay of ^{14}N states are displayed in Table 14.12 (1966CA07). See also reaction 1 (1969TH01).

7. ^{10}B(^{7}Li, t)^{14}N $\qquad Q_{\rm m} = 9.147$

Triton groups corresponding to a number of ^{14}N states have been observed at $E(^7{\rm Li}) = 5$ MeV: see (1966MC05) and reaction 6. See also (1974KO1G).

8. (a) ^{11}B(^{3}He, γ)^{14}N	$Q_{\rm m} = 20.7359$	$E_{\rm b} = 20.7359$
(b) ^{11}B(^{3}He, n)^{13}N	$Q_{\rm m} = 10.182$	
(c) ^{11}B(^{3}He, p)^{13}C	$Q_{\rm m} = 13.1852$	
(d) ^{11}B(^{3}He, d)^{12}C	$Q_{\rm m} = 10.4634$	
(e) ^{11}B(^{3}He, t)^{11}C	$Q_{\rm m} = -2.001$	
(f) ^{11}B(^{3}He, ^{3}He)^{11}B		
(g) ^{11}B(^{3}He, α)^{10}B	$Q_{\rm m} = 9.1225$	
(h) ^{11}B(^{3}He, ^{6}Li)^{8}Be	$Q_{\rm m} = 4.570$	

The capture γ-rays (reaction (a)) have been studied at $E(^3{\rm He}) = 0.9$ to 2.6 MeV (1970BL10: γ_0; $\theta = 0°$ and $90°$) and 1.5 to 5.8 MeV (γ_0) and 2.0 to 5.8 MeV (γ_1) (1973MA1W: $90°$). When the barrier penetration factor has been removed the low-energy work shows a single resonance at $E(^3{\rm He}) \approx 1.4$ MeV (^{14}N*(21.8)), $\Gamma_{\rm c.m.} = 0.65$ MeV (1970BL10). (1973MA1W: prelim. results) report two broad resonances at $E_x = 23.4$ and 25.0 MeV in the γ_0 yield and at 24.0 MeV in the γ_1 yield.

The excitation function at $0°$ in the range $E(^3He) = 1.5$ to 5.6 MeV for n_0 (reaction (b)) shows a broad peak at $E(^3He) = 4.15$ MeV which may indicate the existence of a ^{14}N state at $E_x \approx 24.0$ MeV, $\Gamma \approx 1$ MeV (1966DI04). The excitation function for reaction (b) has also been measured for $E(^3He) = 6$ to 18 MeV (1967HA20).

Yield curves for protons (reaction (c)) have been measured for $E(^3He) = 3.0$ to 5.5 MeV (p_0, p_1, $p_1 + p_2 + p_3$): they are rather featureless (1959HO01). This is also true for the ground state deuterons of reaction (d) in the same energy interval (1959HO01). Yield curves for reaction (e) have been measured for $E(^3He) = 6$ to 18 MeV (1967HA20) and 10 to 30 MeV (1965BR1B). See also ^{13}C and ^{13}N. For reactions (d, e, f) see ^{12}C, ^{11}C and ^{11}B in (1975AJ02).

The excitation functions for α-particle groups (reaction (g)) have been measured for $E(^3He) = 0.9$ to 2.15 MeV (1966LO15: $\alpha_0 \rightarrow \alpha_4$) and 2.2 to 5.5 MeV (1965FO06: $\alpha_0 \rightarrow \alpha_3$). No significant resonance behavior is seen except for the α_2 group which, in the $15°$ excitation function, exhibits a resonance at $E(^3He) = 4$ MeV, $\Gamma \approx 1$ MeV (1965FO06). See also ^{10}B in (1974AJ01).

The excitation function for reaction (h) to $^6Li_{g.s.} + ^8Be_{g.s.}$ has been measured for $E(^3He) = 1.4$ to 5.8 MeV: no pronounced structure is observed (1967YO02). At $E(^3He) = 25.20$ 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 (1974DE25).

9. ^{11}B(α, n)^{14}N $\qquad Q_m = 0.1574$

Angular distributions have been measured for E_α to 13.9 MeV [see (1970AJ04) for the earlier references], $E_\alpha = 3.7$ to 7.9 MeV (1975VA06: n_0, n_1, n_2) and at $E_\alpha = 12.6$ to 14.8 MeV (1972CI01, 1973CI02: n_0).

10. ^{11}B(^{6}Li, t)^{14}N $\qquad Q_m = 4.9413$

See (1970AJ04).

11. ^{11}B(^{11}B, ^{8}Li)^{14}N $\qquad Q_m = -6.475$

At $E(^{11}B) = 114$ MeV the relatively strongly populated states are ^{14}N*(5.83, 8.96, 12.8) [$J^\pi = 3^-$, 5^+ and 4^+, respectively] (1974AN36).

12. ^{12}C(d, γ)^{14}N $\qquad Q_m = 10.2725$

Table 14.15: Resonances in ^{12}C + d

E_d (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	Particles out	^{14}N* [a] (MeV)	$J^\pi; T$	Refs. [b]
0.92	95	n, p_0, p_1	11.06	$1^+; 0$	A, (1972SE09, 1975SE07)
1.13		p_0, p_1	11.24	; 1	A
1.19	190	n, p_0, p_1, d	11.29	$2^-; 0$	A, (1972SE09, 1975SE07)
1.23		p_0	11.33	(3^+)	(1969BO32)
1.30	30	n, p_0, p_1, d	11.39	$1^+; 0$	A
1.39		p_0	11.46	(2^-)	(1969BO32)
1.4495 ± 1.5	7.0 ± 0.5	p_0, p_1, d	11.5136	$2^+, 3^+$	A, (1970AL26, 1973TR02, 1975TR07)
1.55		p_0	11.60	(2^-)	(1969BO32)
1.640 ± 20	150 ± 20	n, p_1	11.68	$1^-, 2^-$	(1969BO32, 1969JA06, 1975TR07)
1.715 ± 6	40 ± 9	p_2	11.741	$1^-, 2^-$	(1975TR07)
1.738 ± 6	78 ± 6	p_1	11.761	$3^-, 4^-, (2^-)$	(1975TR07)
1.792 ± 7	119 ± 9	n, p_0, p_1, p_2, d_0	11.807	$2^-, (1^+)$	A, (1970AL26, 1971ME18, 1975TR07)
1.870 ± 6	101 ± 9	p_0, p_1, p_2	11.874	$2^-, (1^-)$	(1969BO32, 1974GM01, 1975TR07)
			[c]		
2.250 ± 19	300 ± 30	n, $p_0 \rightarrow p_3$	12.20	$1^-, 2^-$	A, (1974GM01, 1975TR07)
2.494 ± 3 [d]	37 ± 4	n, $p_0 \rightarrow p_3$, d_0	12.408	$3^+, (3^-, 4^-)$	A, (1971ME18, 1974DA06, 1974ST05, 1975TR07)
2.506 ± 3	41 ± 4	p_1	12.418	$3^-, 4^-, (2^+, 3^+)$	(1975TR07)
2.610 ± 20	30 ± 20	n, p_1, p_2, p_3	12.507		A, (1975TR07)
2.712 ± 3	48 ± 2	(n), $p_0 \rightarrow p_3$, d	12.594	3^+	A, (1975TR07)
(2.817 ± 7)	27 ± 6	n, p_1, p_2, p_3, d	(12.684)		A
2.844 ± 9	43 ± 15	p_2, p_3	12.708		(1975TR07)
2.940 ± 10	30 ± 10	p_2, p_3, d	12.790		A, (1975TR07)

Table 14.15: Resonances in ^{12}C + d (continued)

E_d (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	Particles out	^{14}N* [a] (MeV)	$J^\pi; T$	Refs. [b]
2.967 ± 5	37 ± 6	p_1	12.813		(1975TR07)
2.982 ± 6	11 ± 3	n, p_3, d	12.826		A
3.018 ± 6	78 ± 10	n, p_0, p_1	12.857		A, (1975TR07)
3.049 ± 8	134 ± 11	p_1	12.883		(1975TR07)
3.100 ± 10	20 ± 14	p_1, p_2, p_3, d	12.927	$(3^-, 4^-)$	A, (1975TR07)
3.39 ± 12	47 ± 15	n, p_2, p_3, d	13.17	$(0^-, 1^-)$	A
3.97 ± 30	< 200	p_0, p_2, p_3, (d)	13.67	$(2^+, 3^+)$	A
4.02^{+20}_{-10}	≈ 235	n, (p), d	13.71	(1^+)	A
4.40		$p_0 \rightarrow p_3$, d	14.04		A
4.55		n, p_2, d	14.17		A
4.80		p_0, p_2, d	14.38		A
5.17		d	14.70		A
5.34	≈ 100	$p_0 \rightarrow p_3$, d, α	14.84		A
5.65		d	15.11		A
5.83		p_1, p_3, d	15.26		A
6.07		p_1, p_2, α	15.47		A
6.3		p_0, p_3, d, α	15.7		A
7.2		α	16.4		A
7.6 [e]	≈ 300	α_2	16.8	4^+ [f]	(1972SM07) [e]
7.8	≈ 100	α_2	16.9	(5^-)	(1972SM07)
8.1	≈ 300	p_0, p_2, d, α_2	17.2	4^+	A, (1972SM07)
9.1	(≈ 300)	α_2	18.1	$(1^-, 2^+)$	(1972SM07)

Table 14.15: Resonances in ^{12}C + d (continued)

E_d (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	Particles out	^{14}N* [a] (MeV)	$J^\pi; T$	Refs. [b]
9.2	≈ 600	α_2	18.1	4^+	(1972SM07)
9.3	(≈ 400)	α_2	18.2	3^-	(1972SM07)
9.5	(≈ 300)	α_2	18.4	3^-	(1972SM07)
9.61	≈ 60	α_2	18.50	5^-	(1972SM07)
10.0 [g]	(≈ 400)	α_2	18.8	4^+	(1972SM07)
11.5	(≈ 500)	α_2, α_3	20.1	1^-	(1972SM07)
12.3	≈ 600	α_2	20.8	5^-	(1972SM07)
12.3	(≈ 500)	α_2	20.8	$(3^-, 4^+)$	(1972SM07)
12.9	(≈ 1000)	α_2	21.3	4^+	A, (1972SM07)
13.1	(≈ 500)	α_2	21.5	3^-	(1972SM07)
13.4	≈ 200	α_2	21.7	5^-	(1972SM07)
14.29 ± 100	610 ± 100	α_2	22.5	5^- [h]	(1974JO01) [i]
15.28 ± 100	500 ± 100	α_2	23.3	5^- [h]	(1974JO01)

A: See references quoted for this state in (1970AJ04).

[a] (1963JE02) report 39 excited states of ^{14}N with $11.2 < E_x < 14.2$ MeV.

[b] See also (1959AJ76, 1970AJ04).

[c] (1974GM01) also report a state at 12.05 MeV with $\Gamma = 190$ keV in the p_0 yield.

[d] 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 (1974DA06).

[e] For all states reported by (1972SM07) see their discussion of the S-matrix analysis of their α_2 data: the resonances shown below correspond to one possible (albeit the most reasonable) solution. The α_2 channel is sensitive only to ^{14}N states that have natural parity and are isospin mixed.

[f] These, and all the states shown below, are isospin mixed. (1972SM07) notes that the average spacing of these states, as observed via the α_2 channel, $D \approx 400$ keV, as is the average width of the states, so $\Gamma \approx$ D.

[g] See also Table 14.10 in (1970AJ04) for states reported at ^{14}N*(17.2, 19.6, 20.4) by (1963OH02, 1965BA06, 1968KL06, 1969CO02).

[h] These states appear to be an isospin mixed pair with $\langle H_c \rangle \geq 40$ keV (1974JO01).

[i] See also (1968JA09).

Table 14.16: Recent ^{12}C + d yield curves [a]

E_d (MeV)	Yield of	Refs.
$3.6 - 12.0$	n_0	(1972DA02)
$12 - 17$	n_0	(1970GA07)
$0.4 - 1.35$	p_0	(1972HU13)
$0.80 - 2.20$	$p_1\gamma$	(1973TR02)
$1.4 - 2.3$	p_0, p_1	(1970AL26)
$1.4 - 3.2$	$p_1\gamma$, $p_2\gamma$, $p_3\gamma$	(1975TR07)
$1.82 - 2.50$	p_0	(1974GM01)
$2.61 - 2.82$	$p_0 \to p_3$	(1974DA06)
$3.3 - 3.7$	p_0	(1970LE20)
$12.3 - 14.7$	p_0, p_1	(1968HO23)
$1.5 - 2.0$	d_0	(1970AL26)
$2.61 - 2.82$	d_0	(1974DA06)
$7.19 - 13.99$	$\alpha_0 - \alpha_3$	(1971RI15, 1972SM07)
$13.8 - 16$	α_2	(1974JO01)
$16.0 - 17.0$	α_2	(1971VO04)
$26.2 - 29.5$	α_2	(1971JA04)

[a] See Table 14.11 in (1970AJ04) for a listing of the earlier measurements to $E_d = 13.8$ MeV for neutrons, to 14 MeV for protons, to 26.5 MeV for deuterons and to 29 MeV for α-particles. See also (1959AJ76).

At $E_d = 1.5$ MeV the capture cross section is < 1 μb (1955AL16). The yield of γ_0 is nearly flat from $E_d = 9$ to 11.7 MeV and then exhibits broad resonance structures at $E_d = 12.10$ and ≈ 12.8 MeV, with $\Gamma = 0.5 \pm 0.1$ and $1.5 - 2$ MeV, respectively [^{14}N*(20.6, 21.2)]. The γ_1 and γ_2 yields have also been measured [1972DI1B: prelim. results].

13. (a) ^{12}C(d, n)^{13}N $\quad Q_m = -0.281 \quad E_b = 10.2725$

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

Resonances in the yields of neutrons and protons are displayed in Table 14.15. Recent measurements of the yields of these particles are listed in Table 14.16. For angular distributions of neutrons see ^{13}N. See also (1971MU18, 1973BI1G), (1971DU1B; theor.) and (1972LU1B, 1973WE19, 1975LE1K; applied work). For angular distributions of protons see ^{13}C. See also (1971PU01,

Table 14.17: ^{12}C + d polarization studies [a]

E_d (MeV)	Groups	Refs.
2.71, 2.96	n_0	(1971JA17)
5.7 – 9.8	n_0, n_1	(1975TE1A)
6 – 14	n_0, n_1	(1974LI1K)
6.4	n_0, n_1	(1971BA1L)
8.5	n_0	(1971HI09)
1.13, 1.17	p_0	(1973LE26)
1.40 – 2.40	p_0	(1970BO20)
1.4 – 3.0	p_0, p_1	(1971BO44, 1972BO56, 1972MA77)
3.90 – 5.80	p_0	(1972BL04)
5 – 12	p_0	(1973ME22)
7.7 – 10	p_0, p_1	(1969CU10)
12.1, 12.3	p_0	(1971BR44, 1971GR20, 1973JO10)
12.4	p_0, p_1	(1971BU03)
13.6	p_0	(1967GO27)
15	$p_0 \rightarrow p_4$, $p_8 \rightarrow p_{11}$	(1973DA17)
51	p_0	(1971FE1D)
1.6 – 2.7	d_0	(1971ME18)
1.6 – 3.0	d_0	(1972BO1G)
9, 10, 11, 12	d_0	(1971WI02)
12.1	d_0	(1971GR20)
15.0	d_0	(1974BU06)
19.8 – 29.6	d_0	(1972PE09, 1972PE15, 1974AR16)
28.0	d_0, d_1	(1970BU08)
41, 46, 51	d_0	(1971SE06)

[a] See Table 14.12 in (1970AJ04) for a listing of previous studies with E_d to 51.5 MeV for neutron groups, 21 MeV for proton groups and 51 MeV for the d_0 group.

1973BE25) and (1971DU1B, 1974ST05, 1975GR12, 1975MO1L; theor.). For spallation measurements see (1971BA70, 1971JA02, 1975FU01).

Polarization measurements are summarized in Table 14.17 [and in Table 14.12 in (1970AJ04)]. The polarization transfer coefficient has been measured for $E_d = 6$ to 14 MeV for $\bar{n}_0$ and $\bar{n}_1$. The $\bar{n}_0$ dependence shows some influence from the compound nucleus (1974LI1K). See also (1975TE1A). For neutron polarization studies see also (1971TH1E, 1975KA26), (1971WA1D) and (1974BO51, 1974BO53, 1975BO1W; theor.). For proton polarization studies see also (1971GO1E, 1971HA1R) and (HA70P, 1970PE1B, 1972GO27, 1972KO30, 1972SE09, 1974BO52, 1974SA11, 1974SA20, 1975SE07; theor.).

14. ^{12}C(d, d)^{12}C $\qquad E_b = 10.2725$

Reported resonances are displayed in Table 14.15. Recent measurements of yields of d_0 are listed in Table 14.16. For a discussion of the relative yields of ^{12}C*(12.7, 15.1) see ^{12}C in (1975AJ02). See also (1970VE06, 1971PU01, 1971ZA04, 1975JA1A) and (1969IW1A, 1969KO1B, 1970SO11, 1974IN07, 1974ST05, 1975GU10; theor.). The (d, np) processes are discussed in reaction 38 of ^{13}C and in reaction 21 of ^{13}N.

15. ^{12}C(d, t)^{11}C $\qquad Q_m = -12.464 \qquad E_b = 10.2725$

The cross section rises from ≈ 0.1 mb at $E_d = 16$ MeV to ≈ 10 mb at 20 MeV (1955WI43).

16. ^{12}C(d, α)^{10}B $\qquad Q_m = -1.3409 \qquad E_b = 10.2725$

Reported resonances are displayed in Table 14.15. Recent measurements of the yields of α-groups are listed in Table 14.16 [see also Table 14.11 in (1970AJ04)]. For angular distributions see ^{10}B in (1974AJ01).

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: $E_d = 7.2$ to 16 MeV) is due to states in the ^{14}N compound nucleus. The ratio of the σ_t for the α_2 group compared to the σ_t for the "allowed" groups is $\approx 1\%$, an order of magnitude greater than predicted by direct or multistep processes (1972SM07). Partial wave analyses lead to the resonance parameters shown in Table 14.15 (1972SM07, 1974JO01). For an earlier discussion of these problems see (1970AJ04). See also (1970WE03).

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

E_x (MeV ± keV)			L [d]	$J^\pi; T$
(1971DU03)	(1969HO23)	(1968MA29)		
	0		2	
	2.319 ± 15		0	
3.9502 ± 1.5	3.952 ± 15		0	
4.9153 ± 1.4	4.927 ± 15		1	
≡ 5.10587 ± 0.18 [b]	5.117 ± 15		1	
5.6888 ± 1.4	5.713 ± 15		1	
5.8324 ± 1.4	5.885 ± 15		3	
6.2025 ± 1.4	6.224 ± 15	6.21 ± 20	0	
6.4449 ± 1.4	6.468 ± 15	6.46 ± 18	2	
7.0279 ± 1.4	7.036 ± 15	7.01 ± 42	2	
7.9649 ± 1.4	7.974 ± 15	7.95 ± 26	3	[l]
	8.072 ± 15	8.05 ± 35	1	
8.4864 ± 1.5 [g]	8.493 ± 15	8.47 ± 30	3	$4^-; 0$ [d,f]
8.6174 ± 4	8.625 ± 15	8.61 ± 34	0	$(0^+; 1)$ [h]
8.9099 ± 1.9 [c]	8.912 ± 15			$(3^-; 1)$ [h]
8.9598 ± 1.4				
	8.97 ± 15	8.96 ± 19		
8.9773 ± 4				$(2^+; 0)$ [h]
9.1241 ± 1.5	9.126 ± 15			[i]
		9.15 ± 18		
9.1674 ± 1.4	9.176 ± 15		[j]	$(2^+; 1)$ [h]
9.3854 ± 1.6 [c]	9.389 ± 15	9.39 ± 26		$2^-; 0$ [d,k]
		9.51 [f]		$(2^-; 1)$ [h]
	9.703 ± 15	9.70 ± 22		$(1^+; 0)$ [h]
	10.063 ± 15 [m]	10.08 ± 18		$3^+, \geq 4$ [f]
	10.101 ± 15			$1^+, 2^+$ [f]
		10.23 [f]		1 [f]
	10.441 ± 15	10.43 ± 20	[j]	$(2^+, 1)$ [h]
		10.56 [f]		1, 2 [f]
	10.812 ± 15	10.81 ± 23		$5^+, 0$ [e,f]

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

E_x (MeV ± keV)			L [d]	$J^{\pi}; T$
(1971DU03)	(1969HO23)	(1968MA29)		
	11.053 ± 15	11.06 ± 50		
	11.249 ± 15	11.27 ± 50		
	11.357 ± 15	11.39 ± 40		
	11.517 ± 15	11.51 ± 30		
		11.66 ± 40		
		11.79 ± 110		
		11.95 ± 30		
	12.29 ± 15			
	12.425 ± 15	12.40 ± 30		
	12.506 ± 15	12.50 ± 20		
	12.608 ± 15	12.63 ± 25		
	12.69 ± 15	12.74 ± 30		
	12.80 ± 15			
		12.90 ± 25		
		13.15 ± 40		
		14.91 ± 60		
		15.8 ± 200		
		17.4 ± 200		

[a] See also Table 14.14 in (1970AJ04).
[b] All E_x shown by (1971DU03) are measured relative to this energy obtained by (1967CH19) from E_{γ}.
[c] The widths of ^{14}N*(8.91, 9.39) are, respectively, 19.7 ± 1.9 and 15.6 ± 2.0 keV.
[d] (1968MA29).
[e] (1972NO08): from study of angular correlations. See also (1968MA29).
[f] (1974NO01): from a study of decay proton correlation (^{12}C(^{3}He, p′)^{14}N*(p)^{13}C$_{\mathrm{g.s.}}$) with the relevant p′ group.
[g] $\Gamma_{\mathrm{p}}/\Gamma = 0.73 \pm 0.10$ (1974NO01).
[h] Known from other data: consistent with results of (1974NO01).
[i] Unresolved doublet: see reactions 21 and 26.
[j] $\theta^2_{\mathrm{p}}(l = 3) = (2.3 \pm 1.1) \times 10^{-3}$ and $< 1.6 \times 10^{-3}$ for ^{14}N*(9.17, 10.43) (1974NO01).
[k] The results of (1974NO01) are consistent with either $J^{\pi} = 2^-$ or 3^- for this state.
[l] $\Gamma_{\gamma}/\Gamma = 0.7 \pm 0.2\%$; $(2J + 1)\ \Gamma_{\mathrm{p}} = 12.6 \pm 3.6$ eV: see Table 14.12 (1972BA56).
[m] $\Gamma < 10$ keV (J.W. Noe, private communication).

17. (a) ^{12}C(d, ^{6}Li)^{8}Be $Q_{\rm m} = -5.893$ $E_{\rm b} = 10.2725$

(b) ^{12}C(d, ^{7}Li)^{7}Be $Q_{\rm m} = -17.543$

For reaction (a) see (1970AN1E) and ^{8}Be in (1974AJ01). For reaction (b) see (1975FU01) and ^{7}Be in (1974AJ01).

18. ^{12}C(t, n)^{14}N $Q_{\rm m} = 4.0149$

Angular distributions have been measured at $E_{\rm t} = 1.12$ to 1.68 MeV (1971MA46: n_0, n_1, n_2) and at 8 MeV (1972CO01: to ^{14}N states with $E_{\rm x} < 8.7$ MeV). In the latter experiment L-assignments are suggested (1972CO01). For $\tau_{\rm m}$ measurements see Table 14.13 (1968AL12).

19. ^{12}C(^{3}He, p)^{14}N $Q_{\rm m} = 4.7787$

Many proton groups have been observed: see Table 14.18. Angular distributions have been measured at many energies up to $E(^{3}{\rm He}) = 25.3$ MeV: see (1970AJ04) for a listing of the earlier work and (1969SC1G: $2.22 - 3.60$ MeV; p_0, p_1, p_2), (1970CL1D: 3.0 to 4.05 MeV; p_0, p_1, p_2), (1971DU03: 11.95 MeV; to states shown in Table 14.18) and (1972BR60: 13.3 MeV; to states with $E_{\rm x} < 8.7$ MeV). The reaction mechanism involves the compound nucleus, at least for $E(^{3}{\rm He}) < 12$ MeV: see (1973HE09, 1973SO04) and ^{15}O.

Extensive studies of p$'\gamma$ and p$'$p correlations (the latter from ^{12}C(^{3}He, p$'$)^{14}N*(p)^{13}C$_{\rm g.s.}$) have led to the confirmation and determination of J^{π} of many of the unbound states [see Table 14.18 and (1972NO08, 1974NO01, 1974NO1G)] and of Γ_{γ}/Γ [see Table 14.12 and (1972BA56, 1972NO08)]. Table 14.12 also displays branching ratios and radiative widths studied earlier. These studies led to $J^{\pi} = 0^{-}$ or 1^{-} for ^{14}N*(4.92), $J^{\pi} = 2^{-}$ for ^{14}N*(5.11), odd parity for ^{14}N*(5.83), even parity for ^{14}N*(6.20, 6.44), $J = 2$ for ^{14}N*(7.03): see (1970AJ04) for a fuller discussion and a listing of the relevant references. For $\tau_{\rm m}$ measurements see Table 14.13 (1970AJ04, 1973HA40). (1973BEVW) find $0.5 \leq |g| \leq 0.85$ for the 3^{-} state ^{14}N*(5.83). See also (1970CA28), (1970AN1D) and (1970LK1A, 1973LI15, 1974GR39, 1974NE18; theor.).

20. ^{12}C(α, d)^{14}N $Q_{\rm m} = -13.5751$

Angular distributions of deuterons corresponding to $T = 0$ states in ^{14}N have been measured at $E_{\alpha} = 42$ to 55 MeV: see Table 14.19 and (1970AJ04) for a listing of the references. 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 (1962HA40, 1966RI04). See also (1974VA1M, 1975VA1H), (1970AN1D) and (1971BU1K; theor.).

Table 14.19: Energy levels of ^{14}N from ^{12}C(α, d)^{14}N and ^{12}C(^{6}Li, α)^{14}N

E_x [a] (MeV)	σ [a] (mb)	$\sigma/\sigma_{g.s.}$ [b]	Angular distribution [c]
0	5.8	1.00	d, α [i]
2.31 [d]	[d]		α
3.95	4.8	0.31	d, α [i]
4.92	4	0.16	α
5.11	5	1.32	d, α
5.69	4	0.11	α
5.83	6	0.97	d, α
6.20	7.0	0.24	α
6.44	13.0	1.15	d, α
7.03	4.0	0.18	d, α
7.97	5.0	0.16	d, α
8.49	8.3	0.53	d, α
9.00 ± 0.05 [e]	28.0	3.67	d, α
$9.12 + 9.13 + 9.17$	medium	(0.30)	
9.39	8.1	0.30	d, α
9.70	6.9	0.18	α
10.10	13.8	0.5	α
10.76 ± 0.02 [f]	medium	0.62	
11.06	weak	very weak [h]	
11.24	medium		
11.29	medium		
11.39	medium	very weak, broad	
11.51	weak		
11.95	weak		
12.24	weak		
		weak	
12.41	medium		
12.61	strong		
12.69	strong	strong, broad ($E_x = 12.76$)	
13.05 ± 0.02 [g]		very weak	

Table 14.19: Energy levels of ^{14}N from ^{12}C(α, d)^{14}N and ^{12}C(^{6}Li, α)^{14}N (continued)

E_x [a] (MeV)	σ [a] (mb)	$\sigma/\sigma_{\rm g.s.}$ [b]	Angular distribution [c]
14.7 [h]		weak, broad	
15.1 ± 0.1 [e]		strong, sharp	
15.5		weak	
16.0		weak	
16.3		medium	
17.1		medium	
17.7		medium	

[a] From ^{12}C(^{6}Li, α). E(^{6}Li) $= 20$ MeV (1968ME10).

[b] Cross section (relative to ground state) integrated for $0° - 90°$ (c.m.), from ^{12}C(α, d)^{14}N, $E_\alpha = 42$ MeV (1967ZA01). The $T = 1$ states at $E_x = 2.31, 8.06, 9.51, 10.43$ MeV were not observed: $\sigma/\sigma_{\rm g.s.} < 0.0027, 0.027, 0.018, 0.30, 0.03$, respectively. For absolute cross sections at $E_\alpha = 53$ MeV; see (1965PE03).

[c] d and α refer to angular distributions of the corresponding group from the ^{12}C(α, d)^{14}N and the ^{12}C(^{6}Li, α)^{14}N reactions: see text for E_α, E(^{6}Li) and references.

[d] The excitation of ^{14}N*(2.3) is inhibited by angular momentum and parity consideration as well as by isospin in the (α, d) reaction.

[e] (1966RI04).

[f] $E_x = 10.85 \pm 0.02$ MeV (1967ZA01).

[g] From ^{12}C(α, d)^{14}N (1967ZA01): $\Gamma < 70$ keV.

[h] Comments here and below are from (1965PE03).

[i] Angular distributions reported at $E_\alpha = 55$ MeV (1974VA1E).

21. ^{12}C(^{6}Li, α)^{14}N $\qquad Q_m = 8.7987$

At E(^{6}Li) $= 20$ MeV, α-groups corresponding to most of the $T = 0$ states with $E_x < 12.7$ MeV are reported: see Table 14.19. The spectrum is dominated by the α-group corresponding to the 5^+ state at 9.0 MeV (1968ME10). The α_1 group to the 0^+; $T = 1$ state at 2.31 MeV state has an intensity ($<$ 3% of α_0) which decreases sharply from E(^{6}Li) $= 4$ to 5.5 MeV, while the intensities of the α_0 and α_2 groups increase rapidly (1965CA06). Angular distributions of α-particles have been reported for E(^{6}Li) $= 2.0$ to 20 MeV: see (1970AJ04) for the earlier references, (1970JO09, 1970JO1D: 5.6 to 14.0 MeV; α_0, α_2, $\alpha_3 + \alpha_4$) and (1973WH03, 1975WH03: 33 MeV; α to ^{14}N*(0, 3.95, 4.92, 5.11, 5.69, 5.83, 6.20, 6.44)). At that energy the reaction proceeds primarily by direct interaction (1973WH03); multistep mechanisms may be very important (1975WH03). For τ_m measurements see Table 14.13. For angular correlation measurements see (1974NO1G). See also (1971LA1B) and (1970OG1A, 1973OG1A).

22. ^{12}C(^{9}Be, ^{7}Li)^{14}N $\qquad Q_m = -6.424$

See (1969RO1G, 1970LK1A; theor.).

23. ^{12}C(^{11}B, ^{9}Be)^{14}N $\qquad Q_m = -5.544$

At $E(^{11}\mathrm{B}) = 114$ MeV the spectrum is dominated by groups to the 5^+ state at $E_x = 8.96$ MeV and to one or more of the states at 12.8 MeV, presumably the 4^+ one (1974AN36, 1975PO10). See also (1972SC1L, 1973SC1J). The angular distribution of the group to ^{14}N*(8.96) is a smoothly varying, exponential function of angle (1975PO10): see the analyses by (1965SA07, 1975PO10). See also (1970AN1D, 1970LK1A; theor.).

24. ^{12}C(^{12}C, ^{10}B)^{14}N $\qquad Q_m = -14.916$

This reaction has been studied at $E(^{12}\mathrm{C}) = 114$ 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 (1974AN36). See also (1971SC1F, 1972SC1L, 1972SC21).

25. ^{12}C(^{18}F, ^{16}O)^{14}N $\qquad Q_m = 2.746$

See (1968RO1D; theor.).

26. (a) ^{13}C(p, γ)^{14}N $\qquad Q_m = 7.5507$
(b) ^{13}C(p, p$'\gamma$)^{13}C $\qquad E_b = 7.5507$

Observed resonances are displayed in Table 14.20. The decay schemes of various levels of ^{14}N, as derived from the γ-spectra in this and other reactions, are exhibited in Table 14.12 [see (1970AJ04) for the earlier references and see (1972RE10)]. For the τ_m of bound ^{14}N states see Table 14.13 (1971BI03, 1972RE10).

Table 14.20: Levels of ^{14}N from ^{13}C(p, γ)^{14}N and ^{13}C(p, p)^{13}C [a]

E_p (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	l_p	$\omega\Gamma_\gamma$ (eV)	$J^\pi; T$	^{14}N* (MeV)	Refs.
0.4485 ± 0.5	< 0.37	2	0.022	2^-	7.9669	A
0.551 ± 1	30 ± 1	0	9.2	$1^-; 1$	8.062	A, (1972RE10)
1.012 ± 2	≤ 0.2	4	≈ 0.01	$(4^-); 0$	8.490	A
1.150 ± 2	7 ± 1	1	1.3	$0^+; 1$	8.618	A, (1971BI03)
1.34 ± 50	≈ 460	0	12.8	$0^-; 1$	8.79	A
1.462 ± 3	16 ± 2	2	0.72	$3^-; 1$	8.907	A
1.523 ± 2	< 1		≈ 0.003	$5^+; 0$	8.964	A
1.540 ± 3	8 ± 2	1, (3)	0.13	2^+	8.980	A
1.701 ± 1	< 1	2	≈ 0.03	$(2^-; 0)$ [j]	9.129	A
1.7476 ± 0.9	0.07 ± 0.05		14.8	$2^+; 1$	9.1725	A
1.980 ± 3	13 ± 3	2	[c]	$3^-, 2^-$	9.388	A, (1975NO1F)
2.110 ± 3	41 ± 2	2	6.2	$2^-; 1$	9.509	A
2.319 ± 4	15 ± 3	1		1^+	9.703	A
2.743 [b]	5	1	[d]	$1^+, (2^+)$	10.096	A
2.885 ± 10 [b]	80 ± 15	0, 2		$1(^-); 0$	10.228	A
3.105 ± 7 [b]	33 ± 3	1	17	$2^+; 1$	10.432	A, (1971RI13)
3.20 [b]	140	0, 2		1^-	10.52	(1961KA04)
3.515 ± 6			[e]		10.812	(1975NO1F)
3.72 ± 30 [f]	165 ± 30				11.00	(1971RI13)
3.771 ± 5	≤ 2		[k]	$(2, 3)^+$	11.050	(1971RI13)
3.79	100			1^+	11.07	A
3.94 ± 30 [g]	220 ± 30				11.21	(1971RI13)
3.98 [b]	11	2		3^-	11.24	(1961KA04)
4.04 [b]	175	2		2^-	11.30	A
4.14 [b]	28	1		1^+	11.39	A
4.525 ± 15 [h]	115 ± 10		[l]	1^+	11.750	A, (1971RI13)
5.325 ± 10	48 ± 7		[m]		12.492	(1971RI13) [p]
5.88 ± 20 [f]	120 ± 30				13.01	(1971RI13)

Table 14.20: 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)	Refs.
6.20 ± 100 [i]	1000 ± 150		[n]	(2⁻); 1	13.30	(1971RI13)
6.62 ± 20 [f]					13.69	(1971RI13)
[o]						
16.1				2^-; 1	22.5	(1971RI13)
16.7				2^-; 1	23.0	(1971RI13)
					[q]	

A: See references for this state quoted in Table 14.16 in (1970AJ04).

[a] See also Table 14.12.

[b] Reduced width for proton emission is of the order of 1% of the Wigner limit (1961KA04).

[c] Gamma decays predominantly to ^{14}N*(5.11, 5.83, 8.9) (≈ 5 meV each) (1975NO1F).

[d] $(2J+1)\Gamma_\gamma = 0.5 \pm 0.2$ eV, $\Gamma = 12 \pm 3$ eV (1960RO23).

[e] Observed transitions 10.81 → 6.44 → g.s.: $\Gamma_\gamma = 15.8 \pm 5.9$ meV (1975NO1F). See also Tables 14.12 and 14.24.

[f] Weak resonance.

[g] See also Table 14.16 in (1970AJ04).

[h] In the $\gamma_{3.09}$ channel the leak occurs 55 keV higher (1971RI13); interference effects may be present.

[i] Part of the giant dipole resonance.

[j] See, however, (1975FO01) in reaction 6.

[k] $(2J+1)\Gamma_{\gamma_0} = (1.2 \pm 0.3)\ \Gamma/\Gamma_p$ eV (1971RI13).

[l] $(2J+1)\Gamma_\gamma = (18.5 \pm 4.2)\ \Gamma/\Gamma_p$ eV; if $J = 1$, $\Gamma_\gamma \geq 6$ eV (1971RI13).

[m] $(2J+1)\Gamma_{\gamma_0} = 2.3\ \Gamma/\Gamma_p$ eV; if $\Gamma = 38$ eV is assumed (1971RI13).

[n] $(2J+1)\Gamma_{\gamma_0} \geq 200$ eV (1971RI13): thus the transition is dipole and $T = 1$. The resonance is asymmetric and it is suggested that two states are invloved, one with $J^\pi = 1^-$ at $E_x = 12.7$ and the other one with 2^- at $E_x = 13.3$ MeV.

[o] Some broad structure is evident in the γ_0, $\gamma_{3.68}$ and $\gamma_{3.85}$ yields (1971RI13).

[p] See also (1974GM01).

[q] Two $T = 2$ states reported by (1971RI13) are not confirmed by (1975PA18).

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 (1960HE14). See also (1970AJ04) and (1971BA1A, 1972CA1N, 1973CL1E, 1973TR1E; astrophys. considerations). 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 (1961HE02).

Following is a summary of the reasons for the assignments of $J^\pi; T$ to some of the lower resonances displayed in Table 14.20: for a fuller discussion and complete references see (1970AJ04) and see Table 14.12. *^{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% $8.06 \to 2.3$ transition [$E_x = 2312.6 \pm 0.3$ keV (1971BI03)] shows $T = 0$ admixture: $\alpha^2 = 0.046$ (1972RE10)]. The strong transition $8.06 \to 5.69$ [3.5% (1972RE10)] permits either E1 or M1, $\Delta T = 1$. Since $5.69 \to 2.31$ is seen ^{14}*N*(5.69)* cannot have $J^\pi = 0^+$, and 2^+ is excluded by the strength of the $8.62 \to 5.69$ transition. It is then $J^\pi = 1^-$; $T = 0$ [the isospin mixing $\alpha^2 = 0.09$ (1972RE10)]; $E_x = 5690.5 \pm 1.5$ keV (1971BI03). ^{14}*N*(8.49, 8.96, 9.13)* correspond to anomalies in the cross section. The nature of their γ-decays [see Table 14.12] and the angular distribution leads to $J^\pi = 4^-$, 5^+ and 2^-; $T = 0$, 0 and 0, respectively (1965DE19). However, work by (1975FO01) in ^{10}B(^{6}Li, d) shows that ^{14}N*(9.13) is a doublet: the state populated in reaction 6 has $J^\pi = 3^+$. The structure at $E_p = 1.70$ MeV will therefore have to be reanalyzed.

^{14}*N*(8.62)* [$J^\pi = 0^+$ from ^{13}C(p, p)] shows strong transitions to ^{14}N*(0, 3.95, 5.69): $T = 1$ (1959WA16). The strength of the $8.62 \to 3.95$ decay shows it is dipole and therefore $J = 1$ for ^{14}*N*(3.95)* (1959WA04) [$E_x = 3947.6 \pm 0.4$ keV (1971BI03)]. The strength of the transition $8.62 \to 6.21$ and the angular correlation $8.62 \to 6.21 \to$ g.s. is consistent with $J^\pi = 1^+$; $T = 0$ for ^{14}*N*(6.20)* [$E_x = 6203.7 \pm 0.6$ keV (1971BI03)]. ^{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*(6.44)* [see, however, Table 14.11] and $J = 2$ for ^{14}*N*(7.03)*.

The angular distribution of the γ-rays from $10.23 \to 2.31$ is consistent with $J^\pi = 1^+$ for ^{14}*N*(10.23)*: $T = 0$ from M^2(M1) (1963RO17) [see, however, Table 14.11]. 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 $J^\pi = 2^+$; $T = 1$ (1964RO03).

Below $E_p = 5.5$ MeV only γ_0 can be observed in the capture radiation. (1971RI13) have observed 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): these are shown in Table 14.20 in the range $E_p = 3.7$ to 6.6 MeV [see reaction 25 in (1970AJ04) for the earlier work]. 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 (1971RI13). Measurements by (1975PA18) of the γ_0 and γ_1 $90°$ yields for $E_x = 23$ to 33 MeV show that the $J^\pi = 1^-$; $T = 0$ giant dipole resonance is concentrated between $E_x = 15$ and 23 MeV, that the $T = 2$ resonances reported by (1971RI13) 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 (1975PA18). 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 for $E_x = 23$ and 26 MeV, respectively, to $E_x = 33$ MeV; the former is quite constant at ≈ 4 μb/sr, the latter slowly rises to a value of ≈ 2 μb/sr: by comparison the γ_1 yield is ≈ 1 μb/sr (1975PA18). See also (1970SI1E, 1973BE1R), (1973SU1E) and (1975VE01; theor.).

27. ^{13}C(p, p)^{13}C $\qquad E_b = 7.5507$

The elastic scattering has been studied for $E_p = 0.14$ to 11 MeV (see (1970AJ04) for a listing of the older work) and at $E_p = 4.6$ to 5.3 MeV (1974GM01: also $p_1 \to p_3$). For observed resonances see Table 14.20; for angular distributions see ^{13}C. Polarization measurements for the p_0 group have been carried out at 7, 14.5 and 32.9 MeV (see (1970AJ04)) and at $E_p = 30.4$ MeV (1972GR02; also for p_1). For spallation measurements see (1973RA37).

28. ^{13}C(p, n)^{13}N $\qquad Q_m = -3.003 \qquad E_b = 7.5507$

The yield of neutrons has been measured from threshold to $E_p = 13.7$ MeV: see (1970AJ04). Observed resonances are displayed in Table 14.21 (1959GI47, 1961DA09). 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 excited states of ^{13}N with neutron emission making this a convenient fast neutron calibration source (1975LI11). Polarization measurements are reported for $E_p = 6.9$ to 12.3 MeV (1965WA02: n_0) and 7 to 15 MeV (1974LI1J). See also ^{13}N and (1971GE12; theor.).

29. ^{13}C(p, d)^{12}C $\qquad Q_m = -2.7218 \qquad E_b = 7.5507$

A polarization measurement has been reported at $E_p = 7$ MeV by (1969GU02). See also (1970AJ04) and ^{12}C in (1975AJ02).

30. (a) ^{13}C(p, t)^{11}C $\qquad Q_m = -15.1861 \qquad E_b = 7.5507$
(b) ^{13}C(p, ^{3}He)^{11}B $\qquad Q_m = -13.1852$

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). Integrated cross sections for populating the first four states in ^{11}B and ^{11}C have been measured at several energies in the range $E_p = 26.8$ to 43.1 MeV (1975MI01). See also ^{11}B and ^{11}C in (1975AJ02).

31. ^{13}C(p, α)^{10}B $\qquad Q_m = -4.0627 \qquad E_b = 7.5507$

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 consequences for astrophysical problems are discussed by (1975OB01).

Table 14.21: Resonances in $^{13}C(p, n)^{13}N$ (1961DA09) [a]

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

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

Table 14.22: ^{14}N levels from ^{13}C(d, n)^{14}N and ^{13}C(^{3}He, d)^{14}N

^{14}N* (MeV)	$J^\pi; T$	l_p [a]	l_p [b]
g.s.	1^+; 0	1	1
2.31	0^+; 1	1	1
3.95	1^+; 0	1	1
4.92	0^-; 0	0	0
5.11	2^-; 0	2	2
5.69	1^-; 0	0	0
5.83	3^-; 0	2	2
6.20	1^+; 0	isotropic [c]	1
6.44	3^+; 0	1 [c]	1
7.03	2^+; 0	1	1
7.97	2^-; 0	[d]	1, 2 [g,h]
8.06	1^-; 1	0 [e]	
8.49	4^-; 0	(3, 4) [l]	4 [i]
8.62	0^+; 1	0 [f], 1 [l]	1 [j]
8.91	3^-; 1	2 [c,l]	2 [g,k]
8.98	2^+; (0)	(1, 2, 3)	
9.13	2^-; 0	2 [l]	
9.17	2^+; 1	(1, 3) [l]	
9.39	2^-, 3^-; 0	2 [l]	
9.51	2^-; 1	2 [l]	
9.70	1^+; 0	1 [l]	

[a] ^{13}C(d, n)^{14}N: $E_d = 5.5$ and 6 MeV (1966FU10), 4.5, 5.0 and 5.5 MeV (1973BO10), 6.5 MeV (1975BO35).
[b] ^{13}C(^{3}He, d)^{14}N: $E(^3\text{He}) = 15$ MeV (1966HO15, 1971FO05).
[c] (1973BO10).
[d] Angular distributions not complete because groups partly masked by contaminant.
[e] (1973BO10) report $l = 1$ in their Table 1: this is a typographical error (see p. 367).
[f] Expected $l = 1$ (1973BO10).
[g] See also (1969HO23).
[h] The width obtained for this state in ^{13}C(p, γ): $(2J + 1)\Gamma_p = 12.6 \pm 3.6$ eV implies $l_p = 2$ and therefore odd parity: Γ_p is then 2.5 ± 0.07 eV, based on $J = 2$ (1972BA56).
[i] $\Gamma_p < 9.9 \times 10^{-2}$ eV (1971FO05).
[j] $\Gamma_p < 18$ keV (1971FO05).
[k] $\Gamma_p = 12.1$ keV (1971FO05).
[l] (1975BO35).

Table 14.23: Relative spectroscopic factors for ^{14}N states [a]

^{14}N* (MeV)	$J^{\pi}; T$	^{13}C(d, n)^{14}N $E_{\rm d}$ (MeV)				^{13}C(^{3}He, d)^{14}N $E(^{3}$He) (MeV)			Theory [j]
		$4.5-5.5$ [b]	6.0 [c]	6.5 [d]	$7.0-12.0$ [e]	13, 17 [g]	15 [h]	15 [i]	
g.s.	$1^+; 0$	1.00	1.00		1.00	1.00	1.00		1.00
2.31	$0^+; 1$	0.97	1.15		0.92 ± 0.05	1.77	1.53		1.24
3.95	$1^+; 0$	0.38	0.57		0.55 ± 0.03	0.51	0.39		0.29
4.92	$0^-; 0$	0.70	1.05		1.38 [f]		0.93		0.71
5.11	$2^-; 0$	0.67	1.26		1.10		0.78		0.68
5.69	$1^-; 0$	0.79	1.04		0.88		0.85		0.58
5.83	$3^-; 0$	0.87	1.03		0.94		0.51		0.59
6.20	$1^+; 0$				0.17		≈ 0.03		
6.44	$3^+; 0$						≈ 0.04		
7.03	$2^+; 0$	0.23	0.07		0.17		0.12		0.09
7.97	$2^-; 0$	0.12						0.04 [k]	
8.06	$1^-; 1$	0.74							
8.49	$4^-; 0$	0.18						< 0.07	
8.62	$0^+; 1$	0.10		0.03				< 0.22	
8.91	$3^-; 1$	0.60		0.03				0.67	
8.98	$2^+; (0)$			0.04, 0.02 [l]					
9.13	$2^-; 0$			0.04 [m]					
9.17	$2^+; 1$			0.013, 0.01 [l]					
9.39	$2^-, 3^-; 0$			0.09 [m]					
9.51	$2^-; 1$			0.12 [m]					
9.70	$1^+; 0$			0.02 [n]					

[a] See review in (1973BO10). See also Table 14.19 in (1970AJ04).
[b] (1973BO10).
[c] (1966FU10).
[d] (1975BO35).
[e] (1968CO24).
[f] This value and the ones below are at $E_{\rm d} = 7$ MeV (1968CO24): see (1973BO10).
[g] 13 and 17 MeV, energy averaged (1966SI02): see (1973BO10).
[h] (1966HO15).
[i] (1971FO05): see also (1973BO10).
[j] Negative parity states (1967CO32), positive parity states (1963SE19): see (1973BO10).
[k] Based on $l_{\rm p} = 2$: see Table 14.22 (1972BA56).
[l] If $l = 1$ or 3, respectively (1975BO35).
[m] Derived with $\rm d_{\frac{5}{2}}$ form factors (1975BO35).
[n] Derived with a $\rm p_{\frac{1}{2}}$ form factor (1975BO35).

32. $^{13}C(d, n)^{14}N$ $\quad Q_m = 5.3260$

Observed neutron groups are displayed in Table 14.22. Angular distributions have been reported at many energies up to $E_d = 12$ MeV: see (1970AJ04) for the earlier references and (1973BO10: $E_d = 4.5$, 5.0, 5.5 MeV; to states shown in Table 14.22), (1975BO35: $E_d = 6.5$ MeV; to states in Table 14.22). Comparison of relative spectroscopic factors obtained in this reaction and in reaction 32 are shown in Table 14.23: 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 $\tau \cdot \mathbf{T}$ terms appears to be energy dependent: see Table 14.23 (1968CO24).

Observed γ-rays attributed to transitions in ^{14}N are shown in Table 14.20 of (1970AJ04): see Table 14.12 here for a general review of radiative decays in ^{14}N. The angular correlation of internal pairs conclusively establish the parities of $^{14}N^*(4.92, 5.11, 5.69)$ as odd (1964WA05). For τ_m measurements see Table 14.13 (1974RU1B). See also (1972RE1C) and ^{15}N.

33. $^{13}C(^3He, d)^{14}N$ $\quad Q_m = 2.0569$

Angular distributions have been studied at $E(^3He) = 13$ and 17 MeV (1966SI02: d_0, d_1, d_2) and 15 MeV (1966HO15, 1969HO23, 1971FO05: see Table 14.22). Relative spectroscopic factors are displayed in Table 14.23 and compared with those from $^{13}C(d, n)^{14}N$. See also (1967SP09) and (1970BO1K, 1972DZ1A; theor.).

34. $^{13}C(\alpha, t)^{14}N$ $\quad Q_m = -12.2640$

Angular distributions have been measured at $E_\alpha = 27$ MeV for the α-groups to $^{14}N^*(0, 2.31, 3.95, 4.92, 5.11)$: relative spectroscopic factors are 1.0, 0.2, 0.3, 4.4, 5.5 (1974KE06). See also (1974DM01; 23.2, 23.7, 25.3 MeV; t_0). [The earlier work at $E_\alpha = 46$ MeV (see (1970AJ04)) has not been published.]

35. $^{13}C(^7Li, ^6He)^{14}N$ $\quad Q_m = -2.427$

At $E(^7Li) = 34$ MeV, angular distributions have been obtained for the transitions to $^{14}N^*(0, 2.31, 3.95)$ (1973SC26).

36. $^{13}C(^{11}B, ^{10}Be)^{14}N$ $\quad Q_m = -3.679$

This reaction has been studied at $E(^{11}\text{B}) = 113.5$ MeV (1967PO13) and 114 MeV (1974AN36). The relative population of the observed ^{14}N states in dependent upon whether $^{10}\text{Be}_{\text{g.s.}}$ or $^{10}\text{Be}^*_{3.37}$ is involved: in all cases the cross section is greater if the 2^+ state in ^{10}Be is populated. Difficulties are encountered in separating the two sets of ^{14}N states: see (1974AN36).

37. $^{14}\text{C}(\beta^-)^{14}\text{N}$ $\quad$ $Q_{\text{m}} = 0.1561$

See ^{14}C.

38. $^{14}\text{C(p, n)}^{14}\text{N}$ $\quad$ $Q_{\text{m}} = -0.6263$

$\text{E}_{\text{thresh.}} = 670.90 \pm 0.09$ keV (1974HI1C).

Neutron thresholds have been observed at $E_{\text{p}} = 671.5 \pm 0.5$ and 3149.6 ± 1.1 keV (1956SA06) and at $E_{\text{p}} = 4910 \pm 8$ keV (1960BA34) corresponding to the ground state of ^{14}N and to excited states at 2311.9 ± 1.2 keV and 3.952 ± 0.008 MeV. Angular distributions and polarizations of the neutrons corresponding to ^{14}N*(0, 2.31, 3.95) have been obtained at $E_{\text{p}} = 6$ to 14 MeV (1967WO05) and 7.2 to 13.3 MeV (1971WO03), respectively. The angular distributions for the ground state transition require a tensor interaction: the results are consistent with a tensor strength which is not energy dependent. The polarization measurements for the 1^+ states do not clearly favor a tensor component in the effective two-body force (1967WO05, 1971WO03). See also ^{15}N and (1969SC1H, 1972AU1A; theor.).

39. (a) $^{14}\text{C}(^{3}\text{He, t})^{14}\text{N}$ $\quad$ $Q_{\text{m}} = 0.1375$
(b) $^{14}\text{C}(^{6}\text{Li}, ^{6}\text{He})^{14}\text{N}$ $\quad$ $Q_{\text{m}} = -3.354$

At $E(^{3}\text{He}) = 44.8$ MeV, triton groups are observed corresponding to all the known levels of ^{14}N with $E_{\text{x}} < 7.1$ MeV. Triton groups were also seen to unresolved states with $E_{\text{x}} = 8.0 - 9.5$ 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). See also reaction 47 and (1969SC1H; theor.). Angular distributions have been studied for reaction (b) for the transitions to ^{14}N*(0, 3.95) [$L = 2$ and 0, respectively]: ^{14}N*(3.95) carries at least 95% of the GT strength (1976GO1U).

40. (a) ^{14}N(γ, n)^{13}N $\quad Q_{\rm m} = -10.554$
(b) ^{14}N(γ, p)^{13}C $\quad Q_{\rm m} = -7.5507$
(c) ^{14}N(γ, d)^{12}C $\quad Q_{\rm m} = -10.2725$
(d) ^{14}N(γ, pn)^{12}C $\quad Q_{\rm m} = -12.4971$
(e) ^{14}N(γ, α)^{10}B $\quad Q_{\rm m} = -11.6134$
(f) ^{14}N(γ, nα)^{9}B $\quad Q_{\rm m} = -20.049$
(g) ^{14}N(γ, pα)^{9}Be $\quad Q_{\rm m} = -18.199$

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 (1969BE92). 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 (1970BE54, 1975BE60, 1975BE1F: monoenergetic photons). Maxima reported in other experiments and "breaks" in the (γ, n) activation curve are listed in (1970AJ04). See also (1968KA1D, 1971FR11, 1971KA70).

The (γ, p$_0$) and (γ, p$_2$) cross sections and angular distributions have been measured in the giant resonance region by (1972CA34, 1974BA37). The authors infer that the giant dipole states [(p$_{3/2}$)$^{-1}$(2s1d)] which decay by p$_0$ emission to ^{13}C*(3.68) carry ≈ 90% of the E1 strength and do not contribute substantially to the (γ, p$_0$) process which is populated by (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 (1972CA34, 1974BA37). For reaction (d) see (1970SH06, 1972GE11) and ^{13}C. For reactions (d, e, f, g) see (1970AJ04). See also (1972BU1J, 1973DI1C, 1975BR1F) and (1969ER1A, 1971AN08, 1972GO23, 1973KI05; theor.).

41. ^{14}N(γ, γ)^{14}N

Absorption measurements have led to the determination of $\tau_{\rm m}$ (see Table 14.13) and of Γ_γ (see Tables 14.12 and 14.24): see the references in (1970AJ04) and the newer work by (1974RAZD, 1975RA22). (1966SW01) find $E_{\rm x} = 7029 \pm 6$ keV for ^{14}N*(7.03): the angular distribution of the γ-rays is consistent with $J = 2$.

42. ^{14}N(e, e′)^{14}N*

The r.m.s. radius of ^{14}N is given as 2.540 ± 0.020 fm (1973FE13, 1975SC18). See also (1971BE25: 2.493 ± 0.033 fm), (1970DA20: 2.64 fm), (1970AJ04) and (1969BE21, 1970BR1C,

Table 14.24: Gamma widths [a] of unbound levels from ^{14}N(γ, γ)^{14}N and ^{14}N(e, e)^{14}N

E_x (MeV)	$J^\pi; T$	Γ_γ to g.s. (eV)	Multipol.	Reaction	Refs.
8.06	$1^-; 1$	10.5 ± 6	E1	(γ, γ)	(1956GR17, 1958GR97)
8.91	$3^-; 1$	$(6.6 \pm 2.2) \times 10^{-3}$	M2	(e, e)	(1968CL05)
9.17 [b,c]	$2^+; 1$	7.7 ± 0.9	M1	(e, e)	(1968CL05)
		8.7 ± 1.5		(γ, γ)	(1959HA11)
		9 ± 3		(e, e)	(1962ED02)
10.43 [b]	$2^+; 1$	12.1 ± 1.5	M1	(e, e)	(1968CL05)
		20 ± 6		(e, e)	(1962ED02)

[a] See also Tables 14.12, 14.13 and 14.20.

[b] See also (1963BA19).

[c] $\Gamma = 72 \pm 10$ eV (1965LU05), 77 ± 12 eV (1959HA11).

1973TH1B). Form factors have been determined at $E_e = 60.7$ to 122.0 MeV for ^{14}N*(2.31, 3.95, 4.92, 5.11, 5.69, 5.83): the reduced transition probabilities for these states, in single-particle units, are, respectively, 0.065 ± 0.020, 1.70 ± 0.14, $(1.1 \pm 0.5) \times 10^{-7}$, 4.1 ± 1.0, $(3.8 \pm 2.1) \times 10^{-8}$ and 6.1 ± 1.3 (1974EN01). Inelastic scattering (at $\theta = 180°$) gives evidence for the excitation of ^{14}N*(8.91, 9.17, 10.43): the Γ_{γ_0} are given in Table 14.24 (1962ED02, 1963BA19, 1968CL05). In addition (1968CL05) report the excitation of a state with $E_x = 11.01 \pm 0.07$ MeV. Partial Γ_γ for cascade transitions of ^{14}N*(9.17, 10.43) are shown in Table 14.12 (1968CL05). See also (1970AJ04), (1970BR1E, 1972THZF, 1974DE1E) and (1971BA2T, 1973GA19, 1974PE08; theor.).

43. ^{14}N(n, n′)^{14}N*

Angular distributions of elastically and inelastically scattered neutrons are displayed in Table 14.23 of (1970AJ04). See also (1974HO1E) and (1971MI12; theor.). Observed γ-rays are shown in Table 14.25 (1969DI1B, 1971NY03, 1972NY02). See also (1970DI1A, 1972NI05).

44. (a) ^{14}N(p, p′)^{14}N*
(b) ^{14}N(p, 2p)^{13}C $\quad Q_m = -7.5507$
(c) ^{14}N(p, pd)^{12}C $\quad Q_m = -10.2725$

Angular distributions of elastically and inelastically scattered protons have been measured and analyzed at a number of energies up to $E_p = 155$ MeV: see Tables 14.26 here and 14.23 in (1970AJ04).

Table 14.25: Gamma rays from ^{14}N(n, n′)^{14}N*

E_γ [a] (keV)	E_γ [b] (keV)	Transition [e]
2310 ± 3	2312 ± 3 [c]	$2.31 \rightarrow$ g.s.
$\equiv 3945$		$3.95 \rightarrow$ g.s.
1632 ± 3	1634 ± 5 [c]	$3.95 \rightarrow 2.31$
4913 ± 3	4919 ± 10 [d]	$4.92 \rightarrow$ g.s.
$\equiv 5105$	5106 ± 3	$5.11 \rightarrow$ g.s.
2789 ± 2	2792 ± 3	$5.11 \rightarrow 2.31$
5686 ± 3		$5.69 \rightarrow$ g.s.
3378 ± 3		$5.69 \rightarrow 2.31$
5839 ± 2	5835 ± 5 [c]	$5.83 \rightarrow$ g.s.
729 ± 2	727 ± 3 [c]	$5.83 \rightarrow 5.11$
	6426 ± 10 [d]	$6.44 \rightarrow$ g.s.
	7021 ± 10 [d]	$7.03 \rightarrow$ g.s.

[a] (1972NY02): $E_{\rm n} = 6.9$ MeV.
[b] (1971NY03): $E_{\rm n} = 15$ MeV.
[c] $E_{\rm x}$ (3.95) is then 3947 ± 5 keV and $E_{\rm x}$ $(5.83) = 5833 \pm 3$ keV.
[d] These γ-ray energies have been corrected for Doppler shift.
[e] ((1969DI1B): $E_{\rm n} = 8.6$ MeV) also reports observation of the $6.44 \rightarrow 3.95$ and $6.20 \rightarrow 2.31$ transitions.

Compound nucleus effects are appreciable below $E_{\rm p} = 15$ MeV (1973HA54). The inclusion of a tensor term is necessary in the analysis of the distribution of the p_1 group (to ^{14}N*(2.31) $[J^\pi = 0^+; T = 1]$): see (1970CR03, 1973AU1E, 1973HA54). See also ^{15}O and (1971ES1A). Observed inelastic proton groups are shown in Table 14.27. See also (1969SC1H, 1970SA06, 1971MC15, 1972AU1A, 1973KA04, 1974OD01; theor.).

Reaction (b) at $E_{\rm p} = 19$ MeV proceeds at least in part through an intermediate state in ^{14}N at $E_{\rm x} \approx 11.2$ MeV (1965DE21). See also (1970WE09, 1970WE1J) in ^{13}C, (1972LO1F) and (1972JA1C; theor.). For reaction (c) see (1970AJ04).

45. ^{14}N(d, d′)^{14}N*

Angular distributions of elastically and inelastically scattered deuterons have been obtained for $E_{\rm d}$ up to 52 MeV: see Table 14.23 in (1970AJ04) and (1967FL10: $E_{\rm d} = 2.01$ to 5.50 MeV; d_0), (1970DU04: $E_{\rm d} = 5.47$ (d_1) and 6.37 (d_2) to 10.16 MeV), (1974JA25: $E_{\rm d} = 10.02$, 12.02 MeV:

Table 14.26: ^{14}N(p, p) angular distribution studies [a]

E_p (MeV)	Angular distribution of proton groups	Refs.
$7.53 - 10.54$	p_0, p_1, p_2	(1970ME30)
8.6	$p_0 \rightarrow p_6$	(1973HA54)
9.54, 10.54	$p_3 \rightarrow p_9$	(1970ME30)
10.6, 12.6, 14.6	$p_0 \rightarrow p_9$	(1973HA54)
$11.90 - 14.62$	$p_0 \rightarrow p_{10}$, p_{12} at $E_p = 14.6$ MeV, p to ^{14}N*(9.17)	(1971OD01)
$12.737 - 19.450$	p_0 [b]	(1974JA25)
14.5	p corresponding to $E_x < 10.1$ MeV: Table 14.27	(1971CU01)
17	p to $E_x < 8.5$ MeV	(1971RO1H, 1971RO1J)
$18 - 49.4$	p_0	(1974PI05)
24.8	p_1	(1970CR03)
29.8, 36.6, 40.0	p_0, p_1, p_2	(1971FO1K, 1973AU1E)
49.4	p_0	(1971RU04)
100	p_0	(1973CH06)

[a] See also Table 14.23 in (1970AJ04) for a listing of the earlier work to $E_p = 155$ MeV.

[b] Accurate differential cross sections, few angles.

d_0, very accurate, at a few angles) and (1974BU06: $E_d = 15$ MeV; d_0). Inelastic deuteron groups are discussed in Table 14.27. The deuteron group to the 0^+; $T = 1$ state ^{14}N*(2.31) is isospin forbidden: its intensity is $1 - 3\%$ of the deuteron group to ^{14}N*(3.95) for $E_d = 7.1$ to 10.2 MeV (1970DU04). The deuteron group to ^{14}N*(8.06) [$T = 1$] is not observed: see Table 14.27. See also (1970AJ04), ^{16}O in (1971AJ02, 1977AJ02), (1970PI1A) and (1970ME25, 1971SI24, 1972DM01, 1972FO07, 1973FA1J, 1975GU10; theor.).

46. ^{14}N(t, t)^{14}N

Elastic differential cross sections have been measured at four angles at $E_t = 20.03$ MeV (1974JA25). See also (1973FA1J; theor.).

Table 14.27: ^{14}N levels from ^{14}N(p, p′), (d, d′), (^{3}He, ^{3}He′) and (α, α')

^{14}N*(MeV ± keV)				L [k]	Dominant config. [n]	$J^\pi; T$
(p, p′)	(d, d′)	(^{3}He, ^{3}He′)	(α, α')			
2.313 ± 5 [a]	see text	[h]	see text		$(p_{\frac{1}{2}})^2$	0^+; 1
3.945 ± 5 [a]	[f]	[h]	[j]	2	$(p_{\frac{1}{2}})^2$+ c.e. [o]	1^+; 0
4.910 ± 10 [a]	[f]	[h]	[j]	1, 3	$p_{\frac{1}{2}}s_{\frac{1}{2}}$	0^-; 0
5.104 ± 10 [a]	[f]	[h]	[j]	1, 3	$p_{\frac{1}{2}}d_{\frac{5}{2}}$	2^-; 0
5.69 ± 30 [b]	[f]	[h]	[j]	1, 3	$p_{\frac{1}{2}}s_{\frac{1}{2}}$	1^-; 0
5.83 ± 30 [b]	[f]	[h]	[j]	1, 3	$p_{\frac{1}{2}}d_{\frac{5}{2}}$	3^-; 0
6.23 ± 20 [b]	[f]	[h]	[j,l]		$(s_{\frac{1}{2}})^2$	1^+; 0
6.46 ± 20 [b]	[f]		[j,l]		$s_{\frac{1}{2}}d_{\frac{5}{2}}$	3^+; 0
7.03 ± 20 [b]	[f]	[h]	[j]	2	c.e. [o]	2^+; 0
7.97 [c]			[m]		$p_{\frac{1}{2}}d_{\frac{3}{2}}$	2^-; 0
8.06 [c]		$8.0 \rightarrow 11.0$ [i]			$p_{\frac{1}{2}}s_{\frac{1}{2}}$	1^-; 1
8.49 [n]						(4^-); 1
8.62 [n]					$(s_{\frac{1}{2}})^2$	0^+; 1
8.91 [n]					$p_{\frac{1}{2}}d_{\frac{5}{2}}$	3^-; 0
9.17 [d,n]					c.e. [o]	2^+; 1
9.39 [n]						$2^-, 3^-$; 0
9.51 [n]					$p_{\frac{1}{2}}d_{\frac{5}{2}}$	1^+; 0
9.70 [n]					$(p_{\frac{1}{2}})^2$	1^+; 0
10.1 [n]					$s_{\frac{1}{2}}d_{\frac{5}{2}}$	$2^+, 1^+$; 0
11.2 ± 200 [e]	[f,g]	11.22 ± 50 [h]				
12.8 ± 400 [c]	[f,g]	12.77 ± 50 [h]				
17 [d]						
21.5 [d]						

[a] (1953BO70).
[b] (1956BU16). See also text, (1964EA04, 1971CU01), and Table 14.26.
[c] (1964EA04, 1971CU01).
[d] (1958TY46).
[e] (1965DE21).
[f] Observed: see (1970AJ04).
[g] $E_x = 11.3$ and 13 MeV (1968HI1B).
[h] (1969BA06).
[i] Unresolved structure (1969BA06).
[j] (1966HA19).
[k] From (α, α'): (1966HA19).
[l] Relatively low cross section due to two-nucleon transition (1966HA19).
[m] See also (1956MI17).
[n] (1971CU01): p, p′.
[o] c.e. = compound elastic.

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}He) up to 44.6 MeV: see Table 14.23 in (1970AJ04) and (1970KN01: 4.5, 7.0 MeV; elastic).

At $E(^3\text{He}) = 44.6$ MeV, twelve ^{3}He groups are reported corresponding to states in ^{14}N: see Table 14.27 (1969BA06). 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$_{\text{g.s.}}$, ^{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 (1969BA06). See also (1973FA1J; theor.).

48. (a) ^{14}N(α, α')^{14}N*

(b) ^{14}N(α, αp)^{13}C $Q_m = -7.5507$

(c) ^{14}N(α, αd)^{12}C $Q_m = -10.2725$

Angular distributions of elastically and inelastically scattered α-particles have been measured for $E_\alpha = 11$ to 104 MeV: see Table 14.23 in (1970AJ04) for the earlier references and (1969FE10, 1970AG08: $E_\alpha = 19.8 - 23.1$ MeV; α_0), (1970GA25, 1971GA44: 21.7 MeV; α_0, α_2, α_{3+4}, α_{5+6}, α_{7+8}, α_9), (1972KU19: 26.6 MeV; α_0), (1972LO08: 29.98 MeV; α_0) and (1970HA1G: 104 MeV; α_0). See also (1972OE01, 1974YO1B). See Table 14.27 for the observed α-groups. Generally the intensity of the α_1 group is weak, typically a few percent of the α_0 or α_2 groups: see (1959AJ76, 1966HA19). See also (1970CH1D).

Reduced transition probabilities are reported by (1966HA19): B(E2)↓$/e^2 = 6.5$ and 3.3 fm^4, respectively for ^{14}N*(3.95, 7.03); B(E3)↓$/e^2 = 40$ and 60 fm^6, respectively for ^{14}N*(5.11, 5.83). See also (1970AJ04) and ^{18}F in (1972AJ02, 1978AJ03). See also (1974HA1C) and (1971MU1H, 1972DM01, 1972RA34, 1973FA1J; theor.).

49. ^{14}N(^{6}Li, ^{6}Li)^{14}N

The angular distribution involving ^{6}Li$_{\rm g.s.}$ + ^{14}N$_{\rm g.s.}$ has been measured at E(^{6}Li) $= 32$ MeV by (1971GR44, 1971ZE1C). See also (1974FL1A).

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

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

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

The elastic angular distribution has been measured at E(^{10}B) $= 100$ MeV (1975NA15). For reaction (a) see also (1970IS1A). The elastic scattering angular distributions (reaction (b)) have been studied at E(^{14}N) $= 41$, 77 and 113 MeV (1971LI11).

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

Elastic angular distributions have been measured at E(^{14}N) $= 21.3$ MeV (1971VO01), 22.5 MeV (1969HE06), 65, 84 and 88 MeV (1971KO11, 1974KO38, 1975KO1E), 78 MeV (1970VO02: and ^{12}C*(4.4)), 118 MeV (1974AN36: and ^{12}C*(4.4)), and 155 MeV (1974BI1E, 1975NA11, 1975NA15: and various ^{12}C states). See also (1975ZE1C) and (1975MO23, 1975RA33, 1975VO1B; theor.). At E(^{14}N) $= 155$ MeV the selective population of certain ^{14}N states is observed and angular distributions are reported for the transitions to ^{14}N*(0, 8.96, 12.7) (1975NA11).

For yield measurements see (1974JO1J, 1974ST1N, 1975ZE1C), (1972SC1L), (1972MA74, 1974GA1L, 1975DE09; theor.) and ^{12}C in (1975AJ02).

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

The elastic angular distribution has been measured at $E(^{14}\text{N}) = 19.3$ MeV (1971VO01). See also (1973MC1J, 1973VO04, 1975DE09; theor.). For reaction (b) see (1971VO1D, 1975DE09, 1975VO1B; 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 (1969JA15). For yield measurements see (1969JA15, 1973GO01, 1973RE13, 1973ST1L, 1974ST1N). See also (1973ST1A) and (1972PA31, 1973KA46, 1973PA1L, 1973PA1M, 1973SC1K, 1974VE05; theor.).

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

Elastic angular distributions have been measured for $E(^{14}\text{N}) = 8.08$ to 18.05 MeV (1969JA15), 25 MeV (1971BO1U), 79 MeV (1976MO03) and 155 MeV (1975NA15). For yield measurements see (1969JA15, 1970SI09, 1973GO01, 1974ST1N). See also (1973KA46, 1974BA40, 1975MO23, 1975VO1B; theor.).

56. ^{14}O(β^+)^{14}N $\qquad Q_\text{m} = 5.1448$

The decay proceeds almost entirely to the $J^\pi = 0^+$; $T = 1$ state of ^{14}N at 2.31 MeV: see ^{14}O. Measurement of the γ-ray energy from the decay of ^{14}N*(2.31) leads to $E_\text{x} = 2312.87 \pm 0.10$ keV (1968FR08), 2312.89 ± 0.10 keV (1967CH19). See also reaction 1 in ^{14}O.

57. ^{15}N(p, d)^{14}N $\qquad Q_\text{m} = -8.6094$

Angular distributions have been obtained for the deuterons corresponding to ^{14}N*(0, 2.31, 3.95) (1961BE12: $E_\text{p} = 18.6$ MeV) and to ^{14}N*($0 - 8.06$, 8.62, 8.91, $8.96 + 8.98$, $9.17 - 10.43$, 10.81, 11.05, $11.24+11.29$, $11.36-11.66$, 11.75, 11.95, 12.20, 12.50, 12.61, $12.79+12.82$, $13.17+13.24$, $13.71 + 13.72$) (1969SN04, 1969SN1B: $E_\text{p} = 39.8$ MeV). Spectroscopic factors were extracted by DWBA analysis of the $l_\text{n} = 1$ pickup angular distributions. $\Gamma = 210 \pm 30$ keV for ^{14}N*(13.71). Weak deuteron groups to ^{14}N states at $E_\text{x} = 6.70$, 7.40 and 7.60 MeV are reported [see, however, Table 14.11] (1969SN04). See also (1972PA1A).

58. ^{15}N(d, t)^{14}N $\qquad Q_\text{m} = -4.5761$

Not reported.

59. ^{15}N(^{3}He, α)^{14}N $\qquad Q_{\rm m} = 9.7448$

Observed states in ^{14}N are displayed in Table 14.28 together with the derived spectroscopic factors (1966BA13, 1970BO21). See also (1962CL12, 1969HO23, 1974HO1M).

60. ^{15}N(^{13}C, ^{14}C)^{14}N $\qquad Q_{\rm m} = -2.657$

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) (1975GA17).

61. ^{16}O(π^-, 2n)^{14}N $\qquad Q_{\rm m} = 155.825$

At $E_{\pi^-} = 230$ MeV, γ-rays from the population of ^{14}N*(2.31, 3.95, 5.11, 5.83) are observed (1974LI15). See also (1971KO23).

62. ^{16}O(n, t)^{14}N $\qquad Q_{\rm m} = -14.4792$

Not reported.

63. ^{16}O(p, pd)^{14}N $\qquad Q_{\rm m} = -20.7368$

See (1972BO17) and (1974GO1G; theor.).

64. ^{16}O(p, ^{3}He)^{14}N $\qquad Q_{\rm m} = -15.2430$

Angular distributions have been measured at $E_{\rm p} = 27$ MeV (1973IN05: to ^{14}N*(2.31)), 32.2, 36.6, 43.5 MeV (1975MI01: to ^{14}N*(0, 2.31, 3.95)), 39.8 MeV (1973HO10: to ^{14}N*(0, 2.31, 3.95)); $L = 0 + 2$, 0, $0 + 2$, respectively), 43.7 and 54.1 MeV (1964CE02, 1970HA23, 1971FL04, 1974MA12: to ^{14}N*(0, 2.31, 3.95, 5.11, 7.03, 9.17, 11.05); some with pol. p [also observed ^{14}N*(10.43, 12.50)] and 49.5 MeV (1970NE1B, 1970NE17: pol. p to ^{14}N*(0, 2.31)). A number of 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 ground state of ^{14}O: see reaction 10 in ^{14}O. See also (1969SC1F, 1972HA1X, 1974AD1B), (1974ST16; theor.) and ^{17}F in (1977AJ02).

Table 14.28: States of ^{14}N from ^{15}N(^{3}He, α)^{14}N [a]

^{14}N* (MeV ± keV)	$J^{\pi}; T$	l [a]	S [b]	S [c]
0	$1^+; 0$	1	1.20	1.50
2.31	$0^+; 1$	1	1.50	2.00
3.95	$1^+; 0$	1	0.60	0.73
4.92 [d]	$0^-; 0$			
5.11	$2^-; 0$	2	0.06	
5.691 ± 8 [e]	$1^-; 0$	2	0.02	
5.83	$3^-; 0$	2	0.03	
6.20	$1^+; 0$	1	0.05	
6.44	$3^+; 0$	3	0.01	
7.032 ± 10 [e]	$2^+; 0$	1	1.03	1.00
7.97 [d]	$2^-; 0$			
8.06 [d]	$1^-; 1$			
8.62 [d]	$0^+; 1$			
8.91	$3^-; 1$	(4)	(5.5×10^{-2})	
9.17	$2^+; 1$	1	1.90	1.36
9.39 [d]	$2^-, 3^-; 0$			
9.51 [d]	$2^-, 1$			
9.70 [d]	$1^+, 1$			
10.43	$2^+; 1$	1	1.04	1.10
13.75 [f]	$1^+; 1$	1	(2.4 ± 1.0)	1.4

[a] See also (1962CL12, 1974HO1M).
[b] (1970BO21): $E(^{3}\mathrm{He}) = 11.0$ MeV; see also (1969HO23).
[c] (1966BA13): $E(^{3}\mathrm{He}) = 39.8$ MeV.
[d] (1969HO23).
[e] (1962CL12).
[f] 13.72 ± 0.04 MeV (1966BA13).

65. ^{16}O(d, α)^{14}N $\qquad Q_m = 3.1108$

Angular distributions of α-particles have been measured at many energies up to $E_d = 40$ MeV: see Table 14.25 in (1970AJ04) for the earlier measurements and (1971GR2B: $0.9 - 2.0$ MeV; α_0), (1970CA1C: $1.0 - 2.0$ MeV; α_0), (1973JO13: 2 to 14 MeV; α_0, α_1), (1971TH03: 4.405, 4.578, 4.710 MeV; α_0), (1970AL1F: 10.6 to 12.6 MeV; α_0), (1971JA04: 14.6, 15.0, 15.8 MeV; α_1) and (1974VA1M, 1975VA1H: 40 MeV; α_0, α_2). Alpha groups have been seen corresponding to most known states of ^{14}N with $E_x \leq 11.5$ MeV (1968JO07: $E_d = 5$ to 9 MeV) and (1974VA1M) observe ^{14}N*(11.05).

The yield of the isospin forbidden α_1 group [to ^{14}N*(2.31)] has been studied for $E_d = 2$ to 15 MeV by (1969JO09, 1973JO13): 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 $3 - 10\%$ (1973JO13). For further discussions see (1969DE29, 1971JA04) and (1970AJ04).

Measurements on the absolute cross sections of this reaction [$E_d = 3.6$ to 5.3 MeV] and its inverse [^{14}N(α, d)^{16}O] are consistent with the principle of detailed balance. An upper limit of 0.2% is assigned to the time-reversal non-invariant part of the reaction amplitudes (1971TH03).

See also (1967SP09), (1970FO1B; theor.) and ^{18}F in (1978AJ03).

66. ^{16}O(α, ^{6}Li)^{14}N $\qquad Q_m = -19.2631$

At $E_\alpha = 42$ MeV the transitions involving (^{14}N$_{\text{g.s.}}$ and ^{6}Li*(0, 3.56)), (^{14}N*(2.31) + ^{6}Li$_{\text{g.s.}}$) and (^{14}N*(3.95) + ^{6}Li$_{\text{g.s.}}$) have been studied by (1972RU03).

67. ^{16}O(^{6}Li, 2α)^{14}N $\qquad Q_m = 1.637$

See (1974MI1F).

68. ^{16}O(^{10}B, 3α)^{14}N $\qquad Q_m = -2.823$

See (1965SH10, 1966SH1B).

69. ^{16}O(^{11}B, ^{13}C)^{14}N $\qquad Q_m = -2.058$

See (1972KU1H; theor.).

70. $^{16}O(^{16}O, ^{18}F)^{14}N$ $\qquad Q_m = -13.210$

See (1974RO04).

71. $^{17}O(p, \alpha)^{14}N$ $\qquad Q_m = 1.193$

See (1973SE02) and (1975RO20; astrophys. questions) in ^{18}F (1978AJ03).

72. $^{19}F(d, ^{7}Li)^{14}N$ $\qquad Q_m = -6.122$

See (1967DE03).

^{14}O

(Figs. 8 and 9)

GENERAL: (See also (1970AJ04).)

Nuclear models: (1973SA30, 1974KU1F).

Special reactions involving ^{14}O: (1971AR02, 1973BA81, 1975BA1Q, 1975HU14).

Reactions involving pions: (1973CH20, 1973DA37, 1975HU1D, 1975RE01).

Other topics: (1970FO1B, 1972AN05, 1972CA37, 1972KU1C, 1973GO1H, 1973KA1H, 1973PA1F, 1973RO1R, 1973SP1A, 1974BO22, 1974KU1F, 1974SE1B, 1974VA24, 1975BU1M).

Ground state: (1975BE31).

1. ^{14}O(β^+)^{14}N $\qquad Q_m = 5.1448$

The adopted half-life of ^{14}O is 70.599 ± 0.022 sec (1975HA45). Recent measured values are $\tau_{1/2} = 70.588 \pm 0.028$ sec (1971CL07, 1973CL12), 70.48 ± 0.15 sec (1972AL01), 70.32 ± 0.12 sec (1972SI50), 70.43 ± 0.18 sec (1974AZ01). ^{14}O [$J^\pi = 0^+$; $T = 1$] decays predominantly to the analog state ^{14}N*(2.31): the branching ratio to that state is 99.328 ± 0.012%. This value is obtained by adopting 0.61 ± 0.01% (1966SI05) and 0.062 ± 0.007% (1969KA1B) for the branching ratios to ^{14}N*(0, 3.95) [both 1^+; 0 states]. The ft value for the $0^+ \rightarrow 0^+$ transition (to ^{14}N*(2.31)), based on the 99.328% branching ratio, the adopted $\tau_{1/2}$, a Q for the transition of 2831.83 ± 0.36 keV, is 3084.3 ± 3.6 sec (1975HA45). See also (1973CL12, 1973HA2E).

The question of how ft values for $0^+ \rightarrow 0^+$ transitions should be calculated has been studied by many other groups: see, e.g., (1972JA19, 1972WI05, 1973TO04, 1974RO21, 1974WI02; theor.). The importance of the question relates to the determination of the fundamental coupling constant G_v; see the discussion in (1975HA45). See also (1970AJ04). The ft values for the transitions to ^{14}N*(0, 3.95) are, respectively, $(1.9 \pm 0.2) \times 10^7$ (1969KA1B) and 1200 ± 150 (1969KA1B). For a summary of earlier values see Table 14.27 in (1970AJ04). See also (1975RA37), (1969BL1D, 1969LY1A, 1970HU08, 1970JA02, 1970LA1L, 1970PA23, 1971FA17, 1971HU10, 1971JA20, 1972AR20, 1972BE04, 1972WI28, 1972WI1C, 1973HA49, 1973WI1J, 1974AS07, 1974BO18, 1974KR09, 1975WI1K, 1975WI1E, 1976LO01; theor.).

2. ^{12}C(^{3}He, n)^{14}O $\qquad Q_m = -1.1486$

$E_{thresh.} = 1437.9 \pm 0.6$ keV (1970RO07).

[See also Table 14.28 in (1970AJ04).]

Table 14.29: Energy levels of ^{14}O

E_x (MeV ± keV)	$J^\pi; T$	$\tau_{1/2}$ (sec) or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
g.s.	$0^+; 1$	$\tau_{1/2} = 70.599 \pm 0.022$ sec	β^+	1, 2, 4, 6, 7, 8, 9, 10, 11, 12
5.173 ± 10	$1^-; 1$			2, 5, 8, 10
5.920 ± 10	$0^+; 1$	$\Gamma \leq 50$ keV	p	2, 5, 8, 10
6.272 ± 10	$3^-; 1$	103 ± 6	p	2, 3, 4, 5, 8, 10
6.590 ± 10	$2^+; 1$	≤ 60	p	2, 8, 10
(6.79 ± 30)	$\pi = -$			8
7.768 ± 10	$2^+; 1$	76 ± 10	p	2, 8, 10
(8.72 ± 40)				5, 8, 10
9.715 ± 20	$(2^+); 1$			2, 5, 8, 10
9.915 ± 20	$4^+; 1$	100 ± 50		2, 3, 4, 5
10.89 ± 50				8
11.24 ± 50				8
11.97 [a]				8
12.84 ± 50				8
13.01 ± 50				8
14.15 ± 40				8
14.64 ± 60				8
17.40 ± 60				8

[a] Possibly more than one level.

Observed neutron groups are displayed in Table 14.30. Angular distributions have been studied at many energies: among the recent measurements are those by (1970AD01, 1970AD02: $E(^3\text{He}) = 10$ to 15 MeV), (1972BR60: 13.3 and 18.2 MeV) and (1971GRYL, 1972GR39: 25.4 MeV). For earlier measurements see (1970AJ04). A study of n-p coincidences (^{14}O* $\rightarrow$ ^{13}N + p leads to J and Γ assignments for ^{14}O*(5.92, 6.27, 6.59, 7.77) (1973PR08): see Table 14.30. See also (1971KL1C, 1973JU1B, 1973RH1A, 1974AD11, 1974GO23), (1974GR39; theor.) and ^{15}O.

3. ^{12}C(^{11}B, ^{9}Li)^{14}O $\qquad Q_m = -24.307$

At $E(^{11}\text{B}) = 114$ MeV, ^{14}O*(6.27, 9.9) [$J^\pi = 3^-$ and 4^+, respectively] are populated: see (1973SC1J, 1974AN36).

Table 14.30: Levels of ^{14}O from ^{12}C(^{3}He, n)^{14}O

E_x (MeV ± keV)		$\Gamma_{c.m.}$ (keV)		L [c]	J^{π} [c]
(1961TO03, 1968TO09)	(1972GR39)	(1961TO03)	(1973PR08)		
0	0			0	0^+
5.17	5.173 ± 10			1	1^-
5.905 ± 12	5.930 ± 15	≤ 60	≤ 47	0	0^+
6.30 ± 30	6.272 ± 10	120	103 ± 6	3	3^-
6.586 ± 12 [a]	6.596 ± 10	≤ 60	≤ 56	(2)	2^+ [d]
	7.768 ± 10		76 ± 10	2	2^+
	9.705 ± 25			(2)	(2^+)
	9.915 ± 20 [b]	100 ± 50 [b]		4	4^+

[a] (1970AD01) report $E_x = 6.585 \pm 0.005$ MeV.
[b] (1972BR60) report $E_x = 9.95 \pm 0.043$ MeV; $J^{\pi} = 3^-$.
[c] See (1968TO09, 1970AD01, 1970AD02, 1972BR60, 1972GR39).
[d] $J = 2$ follows from the n-p coincidence study of (1973PR08). The J shown for ^{14}O*(5.91, 6.29, 7.78) are in accord with this work.

4. ^{12}C(^{12}C, ^{10}Be)^{14}O $\qquad Q_m = -20.617$

At $E(^{12}C) = 114$ MeV, 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 (1971SC1F, 1972SC21, 1974AN36). $^{14}O_{g.s.}$ is weakly populated (1974AN36).

5. ^{12}C(^{14}N, ^{12}B)^{14}O $\qquad Q_m = -18.515$

At $E(^{14}N) = 118$ MeV, the population of ^{14}O*(6.27, 9.9) is reported (1974AN36). At $E(^{14}N) = 155$ MeV there is some evidence for the excitation of ^{14}O*(5.17, 5.92, 6.27, 8.74, 9.72) (1975NA11).

6. ^{13}C(p, π^-)^{14}O $\qquad Q_m = -137.163$

At $E_p = 185$ MeV, an angular distribution has been obtained for the transition to $^{14}O_{g.s.}$: in the range $35° - 130°$ it shows no peaking (1973DA37).

7. ^{14}N(p, n)^{14}O $\qquad Q_{\rm m} = -5.9272$

See (1970AJ04) for the earlier work. See also (1970WI1B, 1971BE46, 1971TH1D) and (1970LO1B; theor.). [The earlier reported angular distributions have not been published.]

8. ^{14}N(^{3}He, t)^{14}O $\qquad Q_{\rm m} = -5.1634$

Triton groups have been observed at $E(^3\text{He}) = 44.6$ MeV to the first six states shown in Table 14.29 and to levels with $E_{\rm x} = 6.79 \pm 0.03$, 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 (1968BA1E) and 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.]

9. ^{16}O(γ, 2n)^{14}O $\qquad Q_{\rm m} = -28.889$

See (1970AJ04).

10. ^{16}O(p, t)^{14}O $\qquad Q_{\rm m} = -20.4064$

Angular distributions of ground state tritons have been studied at $E_{\rm p} = 27$ MeV (1973IN05), 32.2, 36.6 and 43.5 MeV (1975MI01), 43.7 and 54.1 MeV (1964CE02, 1971FL04), 43.8 MeV (1970HA23: pol. p) and 49.5 MeV (1970NE17, 1970NE1B: pol. p). Angular distributions have also been studied with polarized protons at $E_{\rm p} = 43.8$ MeV to ^{14}O*(0, 5.17, 6.27, 6.59, 7.77, 9.72) (1974MA12). The ratio of (p, ^{3}He) [to the analog state in ^{14}N at 2.31 MeV] to (p, t) [to $^{14}\text{O}_{\rm g.s.}$] is correctly predicted by DWBA calculations: see, e.g., (1974CR01).

Triton groups have also been observed to states with $E_{\rm x} = 5.21 \pm 0.04$, 5.92 ± 0.06, 6.28 ± 0.05, 6.59, 7.78, 8.69 ± 0.06 [weak, not observed in reaction 2], and 9.65 ± 0.06 MeV (1971FL04) and to ^{14}O*(6.59, 7.77, 9.71) (1970HA23). The J^π assignments derived from these two papers and from (1974MA12, 1975KU22) are in agreement with the values shown in Table 14.29. See also (1969SC1F, 1972HA1X, 1974AD1B), (1971KA04, 1974ST16; theor.) and ^{17}F in (1977AJ02).

11. ^{16}O(α, ^{6}He)^{14}O $\qquad Q_{\rm m} = -27.918$

At $E_\alpha = 58$ MeV the differential cross section for populating $^{14}\text{O}_{\rm g.s.} \lesssim 0.4$ μb at $\theta_{\rm lab} = 21°$ (1975VA01).

12. ^{18}O(α, ^{8}He)^{14}O $Q_{\rm m} = -38.016$

At $E_\alpha = 58$ MeV the differential cross section is 40 ± 15 nb/sr at $\theta_{\rm lab} = 8°$ (1975JA10).

^{14}F
(Not illustrated)

^{14}F has not been observed: its atomic mass excess is predicted to be 33.38 MeV which would make it unstable with respect to decay into ^{13}O + p by ≈ 3 MeV (1973BA34).

References

(Closed 31 January 1976)

References are arranged and designated by the year of publication followed by the first two letters of the first-mentioned author's name and then by two additional characters. Most of the references appear in the National Nuclear Data Center files (Nuclear Science References Database) and have NNDC key numbers. Otherwise, TUNL key numbers were assigned with the last two characters of the form 1A, 1B, etc. In response to many requests for more informative citations, we have, when possible, included up to ten authors per paper and added the authors' initials.

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