

Energy Levels of Light Nuclei $A = 14$

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Abstract: An evaluation of $A = 13-15$ was published in *Nuclear Physics A360* (1981), 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. Also, [Reference](#) key numbers have been changed to the NNDC/TUNL format.

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¹⁴Li
(Not illustrated)

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

¹⁴Be
(Figs. 5 and 9)

¹⁴Be has been observed in the 4.8 GeV proton bombardment of uranium; it is particle stable: see (1976AJ04). Its atomic mass excess is calculated to be 40.69 MeV. ¹⁴Be is then bound by 2.73 and 0.55 MeV, respectively, with respect to decay into $^{13}\text{Be} + \text{n}$ and $^{12}\text{Be} + 2\text{n}$ (1974TH01). [See (1980AJ01) for a discussion of the mass of ¹²Be]. See also (1976BE1G, 1976BE1V, 1977SE1D, 1979BO22; theor.).

¹⁴B
(Figs. 5 and 9)

GENERAL: (See also (1976AJ04).)

See (1975FE1A, 1977AR06, 1979KI11).

Mass of ¹⁴B: The atomic mass excess of ¹⁴B is 23.644 ± 0.027 MeV, based on the mean of the values reported by (1973BA34) and (1980NA14).

$T = 2$ states of $A = 14$. On the basis of the mass of ¹⁴B, the lowest $T = 2$ states in ¹⁴C, ¹⁴N and ¹⁴O are estimated to lie at $E_x = 22.5, 24.8$ and 22.5 MeV (1973BA34).

1. $^{14}\text{B}(\beta^-)^{14}\text{C}$ $Q_m = 20.62$

¹⁴B has a half-life of 16.1 ± 1.2 msec. The β -decay is primarily to $^{14}\text{C}^*(6.09)$ [$J^\pi = 1^-$] 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 ¹⁴B to be 2^- (1974AL11).

2. $^{10}\text{Be}(^6\text{Li}, 2\text{p})^{14}\text{B}$ $Q_m = -11.53$

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

Table 14.1: Energy levels of ^{14}B

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

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

Decay to $^{14}\text{C}^*$ (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 $E_{\beta^-}(\text{max}) = 14.0 \pm 0.7$ 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 $(5 \pm 3)\%$ in the calculation of the branching ratios to $^{14}\text{C}^*(6.09, 6.73)$. However, (1975MI12; theor.) suggest that the branch may be as small as $\approx 0.3\%$. 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 $^{14}\text{C}^*(6.09, 6.73)$ a value $(5 \pm 5)\%$ was used.

3. $^{14}\text{C}(^7\text{Li}, ^7\text{Be})^{14}\text{B}$ $Q_m = -21.49$

^{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 $^{14}\text{B}^*(0, 0.74, 1.38, 1.82, 2.08)$ and of $^{12}\text{B}^*(1.67, 2.62, 3.39, 4.37, 4.52)$ [populated in $^{12}\text{C}(^7\text{Li}, ^7\text{Be})^{12}\text{B}$], and the similarity in the ΔE_x of these ^{12}B states with the E_x of the ^{14}B states suggest that they have the same J^π (1973BA34).

4. $^{14}\text{C}(^{14}\text{C}, ^{14}\text{N})^{14}\text{B}$ $Q_m = -20.47$

At $E(^{14}\text{C}) = 87.4$ MeV, the ground state of ^{14}B is observed: the atomic mass excess is 23.59 ± 0.06 MeV. The first excited state is not populated (1980NA14).

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

GENERAL: (See also (1976AJ04).)

Nuclear models: (1976VO1C).

Special levels: (1978AL1T, 1979HO1J).

Special reactions involving ^{14}C : (1976AB04, 1976BU16, 1976LE1F, 1977AR06, 1978AB08, 1978GE1C, 1978HE1C, 1978KA23, 1978KO01, 1978LE15, 1978TU06, 1979AL22, 1979BO22).

Giant resonance: (1979DO17, 1979KI11).

Astrophysical questions: (1976DE1G, 1976LI1K, 1977BR1N, 1977CO1U, 1977HA1L, 1977KU1J, 1978BU1B, 1979DE1V, 1979OL1B, 1980ST1C).

Muon and neutrino capture and reactions: (1977GO13, 1978DE15, 1979GO1M, 1980LO07, 1980MU1B).

Pion and kaon capture and reactions (See also reactions 19, 36 and 44.): (1976DI11, 1976DI10, 1976EN02, FI76F, 1977DO06, 1977RI1H, 1978DA1A, 1978SH16, 1979KI11, 1980ER01, 1980FI05).

Applied work: (1976LI1K, 1977ME1D, 1977MU1B, 1977RY1A, 1978AI1A, 1978BE2D, 1978DO1G, 1978HE1M, 1978MU1E, 1978MU1B, 1979BE2J, 1979GO1L, 1979LI1C, 1979ST1P, 1979TA1N, 1980GO1B).

Other topics: (1976ST13, 1978DA1A, 1978GA1C, 1978PO1A, 1978SO1A, 1979KA13).

Ground state of ^{14}C : (1976BE1G, 1977AN21, 1978AN07, 1978HE1D, 1978NA07, 1978SM02, 1978TA09).

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

The adopted value of the half-life is 5730 ± 40 y: see (1976AJ04). Using Q_m , $\log ft = 9.04$ (1971GO40). For discussions of the lifetime of ^{14}C see (1959AJ76, 1970AJ04, 1976AJ04). See also (1978MA1P), (1976BE1E), (1980RO1D; applied) and (1977GO13, 1977IK1B, 1977RI08, 1979DE15, 1979FE1E, 1979PR1D, 1980LO07; theor.).

2. (a) $^7\text{Li}(^7\text{Li}, n)^{13}\text{C}$	$Q_m = 18.620$	$E_b = 26.796$
(b) $^7\text{Li}(^7\text{Li}, p)^{13}\text{B}$	$Q_m = 5.965$	
(c) $^7\text{Li}(^7\text{Li}, d)^{12}\text{B}$	$Q_m = 3.311$	
(d) $^7\text{Li}(^7\text{Li}, t)^{11}\text{B}$	$Q_m = 6.199$	

(e) ${}^7\text{Li}({}^7\text{Li}, \alpha){}^{10}\text{Be}$ $Q_m = 14.784$

(f) ${}^7\text{Li}({}^7\text{Li}, {}^7\text{Li}){}^7\text{Li}$

(g) ${}^7\text{Li}({}^7\text{Li}, {}^8\text{Be}){}^6\text{He}$ $Q_m = 7.281$

Table 14.3: Energy levels of ${}^{14}\text{C}$ ^a

E_x in ${}^{14}\text{C}$ (MeV \pm keV)	$J^\pi; T$	τ or $\Gamma_{\text{c.m.}}$	Decay	Reactions
g.s.	$0^+; 1$	$\tau_{1/2} = 5730 \pm 40$ y	β^-	1, 3, 4, 5, 9, 10, 11, 12, 15, 16, 19, 20, 22, 23, 24, 25, 26, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 50, 51
6.0942 ± 1.6	1^-	$\tau_m < 10$ fsec	γ	3, 4, 5, 6, 10, 11, 19, 20, 22, 27, 37, 40, 42, 49
6.5898 ± 1.6	0^+	4.3 ± 0.6 psec	γ	3, 4, 5, 10, 11, 20, 40
6.7282 ± 1.3	3^-	96 ± 11 psec $ g = 0.272 \pm 0.007$	γ	3, 4, 5, 6, 10, 11, 12, 13, 14, 15, 20, 22, 23, 27, 30, 33, 37, 40, 42, 44, 49
6.9023 ± 1.8	0^-	36 ± 4 fsec	γ	3, 4, 5, 6, 10, 11, 20, 40, 44
7.0120 ± 4.2	2^+	13 ± 2 fsec	γ	3, 4, 5, 9, 10, 11, 20, 29, 30, 36, 40, 42, 45
7.3414 ± 3.1	2^-	160 ± 60 fsec	γ	3, 4, 5, 9, 10, 11, 20, 23, 29, 42
8.3179 ± 0.8	2^+	$\Gamma = 3.4 \pm 0.6$ keV	γ, n	3, 4, 5, 10, 11, 16, 17, 19, 20, 29, 36, 42, 45
9.746 ± 7	0^+	18		11
9.801 ± 6	(1^-)	45 ± 12	n	3, 5, 10, 11, 17, 20, 29, 42
10.425 ± 5	2^+	15	n	10, 11, 17, 20, 42, 45
10.449 ± 7	≥ 1	9	n	3, 10, 11, 17, 20, 42, 45
10.498 ± 4	(3^-)	26 ± 8		3, 10, 11, 20, 29

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

E_x in ^{14}C (MeV \pm keV)	$J^\pi; T$	τ or $\Gamma_{\text{c.m.}}$	Decay	Reactions
10.736 ± 5	4^+	20 ± 7		3, 10, 11, 12, 13, 15, 36, 40
11.306 ± 15 ^b	1^+	46 ± 12	γ	3, 10, 29, 42
11.395 ± 8	1^-	22 ± 7		3, 10, 11
11.666 ± 10	(5^-)	20 ± 7		3, 10, 11, 42
11.730 ± 10	(5^-)			3, 11
11.9 ± 300		950 ± 300	n	11, 20
12.583 ± 10		95 ± 15		3, 11, 20, 42
12.863 ± 8		30 ± 10		3, 11, 20
12.963 ± 9	(1^-)	30 ± 10		3, 11, 20, 29
14.667 ± 20	$2^+, 3, 4, 5, 6^+$	57 ± 15		3, 29
14.867 ± 25				3, 12, 19, 42
15.19 ± 30				3
(15.37 ± 30)				3
15.44 ± 40				3
(16.02 ± 50)				3
16.411 ± 20				3
(16.57 ± 40)				3
16.715 ± 30			γ, \mathbf{n}	3
(17.28 ± 40)			γ	3
17.95 ± 40				3
18.10 ± 40				4

^a See also Tables 14.4 and 14.5.

^b (1977CR02) [see reaction 29] identify a state with $E_x = 11.31 \pm 0.02$ MeV, $J^\pi = 1^+$, $\Gamma = 207 \pm 13$ keV, $\Gamma_{\gamma_0} = 6.8 \pm 1.4$ keV. It is difficult to understand the large Γ difference with that reported in reaction 3. 1^+ is consistent with the state not being reported in $^{12}\text{C}(t, p)$.

These reactions have been studied with $E(^7\text{Li})$ to 6.5 MeV: see (1970AJ04) for the early references. For $E(^7\text{Li}) = 2.3$ to 5.8 MeV, the cross section for emission of α_0 , α_1 and α_{2+3+4} is found to increase monotonically with energy (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

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

$^{14}\text{C}^*$ (MeV)	τ_m	Reaction	Refs.
6.09	< 10 fsec	$^9\text{Be}(^{13}\text{C}, ^8\text{Be})$	(1975SE04)
6.59	3.7 ± 0.9 psec	$^7\text{Li}(^9\text{Be}, \text{np})$	(1979KO1W) ^b
	4.6 ± 0.7 psec	$^2\text{H}(^{13}\text{C}, \text{p})$	(1980TO05)
	4.3 ± 0.6 psec		mean
6.73	97 ± 15 psec ^c	$^{12}\text{C}(\text{t}, \text{p})$	(1968AL12)
6.90	36 ± 4 fsec	$^9\text{Be}(^{13}\text{C}, ^8\text{Be})$	(1975SE04)
7.01	13 ± 2 fsec ^A	$^{14}\text{C}(\text{e}, \text{e})$	(1972CR1A)
	< 7 fsec	$^{11}\text{B}(\alpha, \text{p})$	(1976GR02)
7.34	160 ± 60 fsec	$^{11}\text{B}(\alpha, \text{p})$	(1976GR02)

A = adopted value.

^a See also Table 14.10 in (1976AJ04).

^b And E.K. Warburton, private communication.

^c (1981KO08) find 96 ± 15 psec leading to a weighted mean of 96 ± 11 psec (E.K. Warburton, private communication).

due to a forward-direction cluster transfer process (1971WY01). For reaction (f) see (1978NO1F: 2.0 \rightarrow 5.5 MeV).

$$3. \ ^9\text{Be}(^6\text{Li}, \text{p})^{14}\text{C} \quad Q_m = 15.126$$

Observed proton groups are displayed in Table 14.6 (1973AJ01). See also (1976AJ04) and ^{15}N .

$$4. \ ^9\text{Be}(^7\text{Li}, \text{d})^{14}\text{C} \quad Q_m = 10.100$$

Angular distributions of the deuterons to $^{14}\text{C}^*(0, 6.09, 6.59 + 6.73, 6.90 + 7.01, 7.34, 8.32)$ have been measured at $E(^7\text{Li}) = 5.6, 5.8, 6.0$ and 6.2 MeV (1969SN02). (1969TH01) report $E_\gamma = 6094.5 \pm 3.2, 6728.1 \pm 1.4$ and 7011.7 ± 5.2 keV for the ground state transitions of these states. See also (1976AJ04).

$$5. \ ^9\text{Be}(^9\text{Be}, \alpha)^{14}\text{C} \quad Q_m = 17.2511$$

At $E(^9\text{Be}) = 5 \text{ MeV}$ $^{14}\text{C}^*(0, 6.09, 6.6, 6.9, 7.34, 8.32, 9.80)$ are populated. The α_0 angular distributions have been measured at 5 and 12 MeV ([1977YO02](#)).

$$6. \text{}^9\text{Be}(^{13}\text{C}, \text{}^8\text{Be})^{14}\text{C} \quad Q_m = 6.5114$$

τ_m for $^{14}\text{C}^*(6.09, 6.73, 6.90)$ are $< 10, > 5 \times 10^4$ and 36 ± 4 fsec, respectively ([1975SE04](#)): see Table [14.4](#).

$$7. \text{}^{10}\text{Be}(\alpha, \text{p})^{13}\text{B} \quad Q_m = -8.818 \quad E_b = 12.0126$$

A preliminary report of a resonance corresponding to a $T = 2$ state has not been published: see ([1976AJ04](#)).

$$8. \text{(a) } ^{11}\text{B}(\text{t}, \text{n})^{13}\text{C} \quad Q_m = 12.4214 \quad E_b = 20.5979$$

$$\text{(b) } ^{11}\text{B}(\text{t}, \alpha)^{10}\text{Be} \quad Q_m = 8.585$$

For possible resonant structure in (a) see ([1976AJ04](#)). For reaction (b) see ([1977CI1A](#)).

$$9. \text{}^{11}\text{B}(\alpha, \text{p})^{14}\text{C} \quad Q_m = 0.7839$$

Angular distributions of p_0 have been measured at $E_\alpha = 1.43$ to 25.1 MeV [see ([1976AJ04](#))] and at $E_\alpha = 1.43$ to 2.94 MeV ([1976DA06](#)) and 4.4 to 6.7 MeV ([1978HO08](#)). See also Table [14.4](#), ^{15}N and ([1976EP1A](#), [1980DO1C](#); astrophys.).

$$10. \text{}^{11}\text{B}(^7\text{Li}, \alpha)^{14}\text{C} \quad Q_m = 18.131$$

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

$$11. \text{}^{12}\text{C}(\text{t}, \text{p})^{14}\text{C} \quad Q_m = 4.6410$$

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

E_i (MeV)	J_i^π	E_f (MeV)	Branch (%)	
			A	B
6.09	1^-	0		
6.59	0^+	0	1.1 ± 0.1^c	
		6.09	98.9 ± 0.1^d	
6.73	3^-	0	93 ± 2	97.3 ± 1
		6.09	7 ± 2	2.7 ± 1
6.90	0^-	6.09	$100^{a,e,g}$	
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): $^{13}\text{C}(d, p)^{14}\text{C}$.

B: (1968BE30): $^{12}\text{C}(t, p)^{14}\text{C}$.

^a (1958WA02).

^b $\delta(M2/E1) = -0.04 \pm 0.09$ and $+0.07 \pm 0.30$, respectively (1968BE30).

^c Internal pairs. $\Gamma_\pi/\Gamma = (1.1 \pm 0.1) \times 10^{-2}$, $\langle M \rangle_\pi = 0.36 \pm 0.06 \text{ fm}^2$ (1980TO05).

^d $E_\gamma = 495.35 \pm 0.10 \text{ keV}$ (1981KO08) and E.K. Warburton (private communication).

^e $E_\gamma = 808.7 \pm 1.0 \text{ keV}$ (1966AL10).

^f $E_\gamma = 1248 \pm 3 \text{ keV}$ (1966AL10).

^g The ground state branch via pair emission is $< 1.1 \times 10^{-4}$ (1978AL19).

Observed proton groups are displayed in Table 14.7. Angular distributions have been measured at $E_t = 5.5$ to 23 MeV: see (1976AJ04) and Table 14.6 (1978AJ02, 1978MO07, 1978MO08, 1979PI01). (1978FO06) report that a calculation which treats the positive parity states of ^{14}C as $(sd)^2$ two-neutron states coupled to an inert ^{12}C core gives good agreement with the (t, p) strengths and the experimental E_x . τ_m of $^{14}\text{C}^*(6.73)$ is $97 \pm 15 \text{ psec}$ (1968AL12); the nuclear gyromagnetic ratio is $|g| = 0.272 \pm 0.007$ showing that the state is not of a pure $(p_{1/2}^{-3}d_{5/2})$ configuration (1974AL07). See also (1977FO1E) and ^{15}N .

12. $^{12}\text{C}(\alpha, 2p)^{14}\text{C}$

$$Q_m = -15.1731$$

At $E_\alpha = 65 \text{ MeV}$ $^{14}\text{C}^*(6.73, 10.74)$ are strongly populated. Angular distributions are measured to $^{14}\text{C}^*(0, 6.73, 10.74, 14.9 \pm 0.1)$: the distribution to $^{14}\text{C}^*(10.74)$ is consistent with $L = 4$

(1976JA13, 1978JA10). See also (1976CE1E).

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

E_x (MeV \pm keV)	$\Gamma_{\text{c.m.}}$ (keV)	σ^{b} (μb)	$2J_f + 1^{\text{c}}$	J^π^{d}	$\theta_n^2^{\text{e}}$
6.089 \pm 10		71	2.5 [3]		
6.588 \pm 10		30	1.0 [1]		
6.726 \pm 10		220	7.6 [7]		
6.899 \pm 10		31	1.1 [1]		
7.016 \pm 10		130	4.5 [5]		
7.341 \pm 10		151	5.2 [5]		
8.318 \pm 10	22 \pm 6	146	5.1	2 ⁺	0.08 \pm 0.02
9.796 \pm 10	45 \pm 12	223	7.7	3	0.4 \pm 0.1 if $\pi = +$ 0.04 \pm 0.01 if $\pi = -$
10.441 \pm 15		312	10.8	2 ⁺ , 3	
10.512 \pm 15	26 \pm 8	262	9.1	4	0.08 \pm 0.02 if $\pi = +$ 1.3 \pm 0.4 if $\pi = -$
10.743 \pm 15	20 \pm 7	444	15.4		
11.306 \pm 15	46 \pm 12	70	2.4	1 ⁻	0.012 \pm 0.003
11.397 \pm 15	22 \pm 7	179	6.2	2 ⁺ , 3	
11.667 \pm 15	20 \pm 7	358	12.4	5 ⁻	0.20 \pm 0.07
11.74 \pm 20					
12.57 \pm 25	80 \pm 20	435	15.1		
12.867 \pm 20	30 \pm 10	300	10.4	4, 5	
12.970 \pm 20	30 \pm 10	225	7.8	3, 4	
14.667 \pm 20	57 \pm 15			2 ⁺ , 3, 4, 5, 6 ⁺	
14.867 \pm 25					
15.19 \pm 30					
(15.37 \pm 30)					
15.44 \pm 40					
(16.02 \pm 50)					
16.411 \pm 20					
(16.57 \pm 40)					
16.715 \pm 30					

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

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

^a (1973AJ01): $E(^6\text{Li}) = 20$ MeV.

^b Total cross section for formation of this state; absolute value: $\pm 20\%$ except for the last six values, $\pm 30\%$.

^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 $\pm 10\%$, except for the last six values which are determined to $\pm 20\%$. 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 $\Gamma_{\text{c.m.}}$ 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 .

13. $^{12}\text{C}(^{10}\text{B}, ^8\text{B})^{14}\text{C}$ $Q_m = -13.890$

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

14. $^{12}\text{C}(^{12}\text{C}, ^{10}\text{C})^{14}\text{C}$ $Q_m = -18.7228$

At $E(^{12}\text{C}) = 114$ MeV $^{14}\text{C}^*(6.73, 10.25)$ [3^- and 4^+ , respectively] are populated (1972SC21, 1974AN36).

15. (a) $^{12}\text{C}(^{14}\text{N}, ^{12}\text{N})^{14}\text{C}$ $Q_m = -17.494$
 (b) $^{12}\text{C}(^{16}\text{O}, ^{14}\text{O})^{14}\text{C}$ $Q_m = -15.7652$
 (c) $^{12}\text{C}(^{18}\text{O}, ^{16}\text{O})^{14}\text{C}$ $Q_m = 0.9341$

For reaction (a) see (1976AJ04). At $E(^{16}\text{O}) = 128$ MeV angular distributions are reported to $^{14}\text{C}^*(0, 6.73, 10.74)$ [$J^\pi = 0^+, 3^-, 4^+$] (1979PR07). For reaction (c) see (1976WE05) and (1976AJ04). See also (1976KA04; theor.).

Table 14.7: ^{14}C states from $^{12}\text{C}(t, p)^{14}\text{C}$ ^a

E_x ^b (MeV \pm keV)	E_x ^c (MeV \pm keV)	L ^b	L ^c	Γ (keV) ^b	J^π
-0.006 ± 10	0	0	0		0^+
6.087 ± 10	6.099 ± 10	1	1		1^-
6.577 ± 10	6.589 ± 10	0	0		0^+
6.725 ± 10	6.731 ± 10	3 ^e	3		3^-
6.895 ± 10	6.899 ± 10	weak			
$\equiv 7.012$	7.017 ± 10	2 ^e	2		2^+
7.336 ± 10	7.342 ± 10	weak			
8.307 ± 12	8.315 ± 10	2	2		2^+
9.746 ± 7		0		18	0^+
9.809 ± 10	9.80 ± 20 ^d	(1)		40	(1^-)
10.425 ± 6	10.419 ± 20	2		14	2^+
10.448 ± 10					
10.498 ± 4	10.492 ± 20	(3)		18	(3^-) ^f
10.736 ± 5	10.730 ± 20	4		15	4^+
11.398 ± 10	11.377 ± 20	1			1^-
11.665 ± 13	11.647 ± 30	(1)			(1^-)
11.727 ± 10	^d	(5)			(5^-)
12.580 ± 12		(2, 3)			$(2^+, 3^-)$
12.867 ± 10	12.849 ± 20	2, 3			$2^+, 3^-$
12.963 ± 10	12.945 ± 30	(1)			(1^-)

^a See also Table 14.5 in (1976AJ04).

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

^c $E_t = 23$ MeV (1978AJ02).

^d Very weak at all angles.

^e See also (1979PI01; $E_t = 15$ MeV).

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

Table 14.8: Resonances in $^{13}\text{C}(n, \gamma)$ and (n, n)

E_{res} (keV)	E_x (MeV \pm keV)	Γ_{lab} (keV)	Γ_{γ} (eV)	σ^a (b)	l_n	J^{π}
152 ± 1^b	8.3184 ± 0.9	5 ± 1	4.0 ± 1.6^f			
152.9 ± 1.4^c		3.7 ± 0.7^f		21 ± 2	1	2^+
1751 ± 8^d	9.801 ± 8	20		$[\approx 1.3]$	> 0	1
2432 ± 10^d	10.433 ± 10	17		$[\approx 1.3]$		2
2454 ± 10^d	10.454 ± 10	10		$[\approx 0.7]$		≥ 1
3800 ^e	11.7					

^a Corrected peak cross section above background.

^b (1971AL09): (n, γ) .

^c (1975HE02).

^d (1961CO05).

^e Broad resonance structure. See, however, the structures observed by (1979AU07).

^f Recommended by (1973MU14). I am indebted to S.F. Mughabghab for a very useful discussion.

16. $^{13}\text{C}(n, \gamma)^{14}\text{C}$

$$Q_m = 8.1765$$

$$Q_0 = 8176.477 \pm 0.047 \text{ keV (1979GR1J; prelim.)}$$

The thermal capture cross section is 0.9 ± 0.2 mb (1973MU14, 1974SH1E). The neutron capture yield has been measured from $E_n = 95$ to 235 keV: see Table 14.8. The (n, γ_0) cross section has also been measured for $E_n = 5.6$ to 14.0 MeV (1980JE1A). ^{13}C is probably not significantly involved as a neutron poison in s-process nucleosynthesis: see (1976AJ04). Two γ -rays are observed in thermal neutron capture with $E_{\gamma} = 8174 \pm 2$ and 6093 ± 2 keV [$E_x = 6094 \pm 2$ keV], with intensities of 87 ± 5 and $13 \pm 1\%$. Intensities of transitions via other ^{14}C states are $< 2\%$ (1967TH05). [(1979GR1J; prelim.) find $E_{\gamma} = 8173.92 \pm 0.05$ keV].

17. $^{13}\text{C}(n, n)^{13}\text{C}$

$$E_b = 8.1765$$

The coherent scattering length (thermal, bound) is 6.19 ± 0.09 fm, $\sigma_{\text{scatt}} = 4.16 \pm 0.13$ b (1979KO26). 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 14.8. High resolution σ_t measurements by (1979AU07) for $E_n = 1.2$ to 13.9 MeV are displayed in Fig. 6 of that paper but an analysis in terms of resonances has not been reported. See also (1978LA1H) and (1976GAYV).

18. (a) $^{13}\text{C}(\text{n}, \text{t})^{11}\text{B}$ $Q_{\text{m}} = -14.403$ $E_{\text{b}} = 8.1765$
 (b) $^{13}\text{C}(\text{n}, \alpha)^{10}\text{Be}$ $Q_{\text{m}} = -3.836$

For reaction (a) see (1973BI1B). For reaction (b) see (1970AJ04).

19. $^{13}\text{C}(\text{p}, \pi^+)^{14}\text{C}$ $Q_{\text{m}} = -132.173$

At $E_{\text{p}} = 185$ MeV (1973DA37) and 200 MeV (1979HO1F) the angular distributions of π^+ and π^- to the ground states of ^{14}C and ^{14}O are very different. The population of $^{14}\text{C}^*(6.09, 8.32, 14.9 \pm 0.2)$ is also reported (1973DA37). For cross-section measurements near threshold see (1979MA38, 1979MA39). See also (1976BO2C, 1979SO1C) and (1976NO1D; theor.).

20. $^{13}\text{C}(\text{d}, \text{p})^{14}\text{C}$ $Q_{\text{m}} = 5.9519$

Observed proton groups are displayed in Table 14.9. Angular distributions have been measured at a number of energies up to $E_{\text{d}} = 14.8$ MeV [see (1976AJ04)] and at $E_{\text{d}} = 13$ MeV (1978DA17; to $^{14}\text{C}^*(0, 6.09, 7.34)$). For listings of θ_{n}^2 see Table 14.5 in (1970AJ04).

Gamma rays are exhibited in Table 14.5: studies of these, of the angular distributions analyzed by DWBA, and of $\text{p}\gamma$ 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]. $^{14}\text{C}^*(6.09)$ is 1^- (decay is E1); $^{14}\text{C}^*(6.59)$ is 0^+ (internal pairs only); $^{14}\text{C}^*(6.73)$ is 3^- (γ_0 is E3; $l_{\text{n}} = 2$); $^{14}\text{C}^*(6.90)$ is 0^- (no γ_0 ; 0.81 MeV cascade via 6.09 is predominantly dipole; $\gamma_{0.8} + \gamma_{6.1}$ correlation is only consistent with $J = 0$, and plane polarization leads to negative parity); $^{14}\text{C}^*(7.34)$ is 2^- (strength of cascade decay and angular correlation results). See also (1974FI1D) and ^{15}N .

21. $^{13}\text{C}(\text{t}, \text{d})^{14}\text{C}$ $Q_{\text{m}} = 1.9192$

See (1976AJ04).

22. $^{13}\text{C}(^7\text{Li}, ^6\text{Li})^{14}\text{C}$ $Q_{\text{m}} = 0.926$

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

23. $^{13}\text{C}(^{11}\text{B}, ^{10}\text{B})^{14}\text{C}$ $Q_{\text{m}} = -3.2787$

Table 14.9: Proton groups from $^{13}\text{C}(\text{d}, \text{p})^{14}\text{C}$

E_x (MeV \pm keV)	(1954SP01, 1955MC75)		(1958WA02, 1959WA04)
	l_n^a	J^π	J^π
0	1	$0^+, 1^+, 2^+$	0^+
6.091 ± 10^b	0	$0^-, 1^-$	1^-
6.589 ± 20	1, 2, 3 ^f	($1^-, 2, 3^-$)	
$6.723 \pm 10^{b,c}$	2	$1^-, 2^-, 3^-$	$3^-(2^-)$
$6.894 \pm 10^{b,c}$	0, 1 ^f	$0, 1, 2^+$	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^d			
12.601 ± 20^e			
12.854 ± 20			
12.958 ± 20			

^a See also (1959AJ76).

^b (1979SO01) report $E_x = 6.094, 6.733$ and 6.904 MeV [± 4 keV].

^c The spacing of these two levels is 171 ± 3 keV (1954SP01).

^d $\Gamma_{\text{lab}} = 1.10 \pm 0.30$ MeV.

^e $\Gamma_{\text{lab}} = 0.130 \pm 0.020$ MeV.

^f See footnotes 18 and 31 in (1958WA02).

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

24. $^{13}\text{C}(^{13}\text{C}, ^{12}\text{C})^{14}\text{C}$ $Q_m = 3.2302$

See (1979KO1R).

25. (a) $^{13}\text{C}(^{14}\text{N}, ^{13}\text{N})^{14}\text{C}$ $Q_m = -2.377$

(b) $^{13}\text{C}(^{15}\text{N}, ^{14}\text{N})^{14}\text{C}$ $Q_m = -2.6568$

See (1976GA37) and (1976AJ04). See also (1978OS06; theor.).

26. (a) $^{13}\text{C}(^{17}\text{O}, ^{16}\text{O})^{14}\text{C}$ $Q_m = 4.032$
(b) $^{13}\text{C}(^{18}\text{O}, ^{17}\text{O})^{14}\text{C}$ $Q_m = 0.132$

Angular distributions have been measured at $E(^{17}\text{O}) = 29.8$ and 32.3 MeV (1977CH22, 1978CH16) and $E(^{18}\text{O}) = 31.0$ MeV (1978CH16).

27. $^{14}\text{B}(\beta^-)^{14}\text{C}$ $Q_m = 20.62$

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

28. $^{14}\text{C}(\gamma, n)^{13}\text{C}$ $Q_m = -8.1765$

See (1976AJ04) and (1979KI11; theor.).

29. $^{14}\text{C}(e, e)^{14}\text{C}$

The charge radius of ^{14}C , $r_{\text{rms}} = 2.56 \pm 0.05$ fm (1973KL12). At $E_e = 37, 50$ and 60 MeV ($\theta = 180^\circ$), inelastic groups are observed to $^{14}\text{C}^*(7.01, 7.34, 8.32, 9.80, 10.5, 11.31 \pm 0.02, 12.96, 14.67)$ with $J^\pi = 2^+, 2^-, 2^+, (1), -, 1^+$ and $(3, 4)$, respectively, for the states with $7.0 < E_x < 13.0$ MeV. $^{14}\text{C}^*(11.31)$ dominates the spectrum: this 1^+ state has $\Gamma = 207 \pm 13$ keV and $\Gamma_{\gamma_0} = 6.8 \pm 1.4$ eV (1977CR02). There is no evidence of sharp structure in the region $E_x = 19$ to 24 MeV where the $T = 2$ analog state of $^{14}\text{B}_{\text{g.s.}}$ would be expected (1974KL12: $E_e = 61.5$ and 80.7 MeV). See also (1976AJ04) and (1979KI11, 1980ER01; theor.).

30. (a) $^{14}\text{C}(p, p)^{14}\text{C}$
(b) $^{14}\text{C}(d, d)^{14}\text{C}$

For reaction (a) see (1976AJ04). Angular distributions have also been studied at $E_d = 17$ MeV to $^{14}\text{C}^*(0, 6.73, 7.01)$ (1975CE04). See also (1976AJ04).

31. $^{14}\text{C}(^3\text{He}, ^3\text{He})^{14}\text{C}$

Elastic angular distributions have been measured at $E(^3\text{He}) = 4.5, 5.1$ and 5.8 MeV (1972KE08) and $10, 12, 15$ and 18 MeV (1970DU07).

32. $^{14}\text{C}(\alpha, \alpha)^{14}\text{C}$

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

33. (a) $^{14}\text{C}(^{12}\text{C}, ^{12}\text{C})^{14}\text{C}$

(b) $^{14}\text{C}(^{13}\text{C}, ^{13}\text{C})^{14}\text{C}$

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). Yields of γ -rays from $^{14}\text{C}^*(6.73)$ for $E(^{14}\text{C}) = 40$ to 57 MeV are reported by (1980FR03).

34. $^{14}\text{C}(^{14}\text{N}, ^{14}\text{N})^{14}\text{C}$

See (1976AJ04).

35. $^{14}\text{C}(^{16}\text{O}, ^{16}\text{O})^{14}\text{C}$

The elastic scattering angular distributions have been measured at $E(^{16}\text{O}) = 20, 25$ and 30 MeV (1975SC35). See also (1978BE2C) and (1979HE02; theor.).

36. $^{14}\text{N}(\pi^-, \gamma)^{14}\text{C}$

$$Q_m = 139.410$$

Branching ratios have been measured for the capture of stopped pions to $^{14}\text{C}^*(0, 7.0 \pm 0.1, 8.3, 11.3, 20.0 \pm 1.0)$ (1975BA52): the total radiative capture branching is $2.1 \pm 0.2\%$. The preliminary results of (1979AL1M) are in general agreement, but it is suggested that the E_x of the fourth group is 10.7 MeV. See also (1977RI1H, 1979PE1C) and the "GENERAL" section here.

37. $^{14}\text{N}(n, p)^{14}\text{C}$ $Q_m = 0.6259$

The p_0 angular distribution has been measured at $E_n = 14$ MeV (1971CO32). See also ^{15}N , (1976KI1D, 1978NE1B, 1978NE1A), (1977CO1U: astrophys.) and (1976AJ04).

38. $^{14}\text{N}(t, ^3\text{He})^{14}\text{C}$ $Q_m = -0.1379$

See (1970AJ04).

39. $^{14}\text{N}(^7\text{Li}, ^7\text{Be})^{14}\text{C}$ $Q_m = -1.018$

See (1976AJ04).

40. (a) $^{15}\text{N}(\gamma, p)^{14}\text{C}$ $Q_m = -10.2074$

(b) $^{15}\text{N}(e, e'p)^{14}\text{C}$ $Q_m = -10.2074$

For $E_{\text{bs}} = 19.6$ to 38.3 MeV, $^{14}\text{C}^*(0, 6.1 + 6.6 + 6.9, 7.0, 10.7)$ are preferentially excited (1972DE1D, 1976PA22). See also ^{15}N . For reaction (b) see (1975MU07).

41. $^{15}\text{N}(n, d)^{14}\text{C}$ $Q_m = -7.9828$

Ground state angular distributions have been measured for $E_n = 14.1 - 14.8$ MeV: see (1976AJ04) and (1978BA1M). See also ^{16}N in (1982AJ01).

42. $^{15}\text{N}(d, ^3\text{He})^{14}\text{C}$ $Q_m = -4.7139$

^{14}C states populated in this reaction are displayed in Table 14.9 of (1976AJ04), together with l and C^2S values (1971KA35: $E_d = 52$ MeV).

43. $^{15}\text{N}(t, \alpha)^{14}\text{C}$ $Q_m = 9.6066$

See (1976AJ04).

44. $^{16}\text{O}(\pi^-, np)^{14}\text{C}$ $Q_m = 116.449$

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

45. $^{16}\text{O}(^6\text{Li}, ^8\text{B})^{14}\text{C}$ $Q_m = -16.592$

At $E(^6\text{Li}) = 93$ MeV $^{14}\text{C}^*(0, 7.01, 8.32, 10.45)$ are populated, the first two of these strongly (1976WE09, 1977WE1B).

46. $^{16}\text{O}(^{11}\text{B}, ^{13}\text{N})^{14}\text{C}$ $Q_m = -4.435$

See (1976AJ04).

47. $^{16}\text{O}(^{18}\text{O}, ^{20}\text{Ne})^{14}\text{C}$ $Q_m = -1.4970$

Angular distributions are reported at $E(^{18}\text{O}) = 28$ and 32 MeV (1971BA68) and 36.1 MeV (1977KA26).

48. $^{17}\text{O}(n, \alpha)^{14}\text{C}$ $Q_m = 1.8167$

See ^{18}O in (1978AJ03).

49. $^{18}\text{O}(\gamma, \alpha)^{14}\text{C}$ $Q_m = -6.2279$

At $E_{\text{bs}} = 23.5$ and 28 MeV $^{14}\text{C}^*(6.09, 6.73)$ are excited (1976BA41). See also ^{18}O in (1978AJ03).

50. $^{18}\text{O}(d, ^6\text{Li})^{14}\text{C}$ $Q_m = -4.7544$

See (1978BE1H) and (1976AJ04).

51. $^{19}\text{F}(d, ^7\text{Be})^{14}\text{C}$ $Q_m = -7.142$

See (1976AJ04).

¹⁴N
(Figs. 7 and 9)

GENERAL: (See also (1976AJ04).)

Model calculations: (1976CO1R, 1978FU13).

Special states: (1977GO1H, 1977RI08, 1979KI10).

Electromagnetic transitions: (1977DO06, 1977KO1N, 1977YO1D, 1978FU13, 1978KI08).

Giant resonances: (1979DO17, 1979KI11).

Astrophysical questions: (1976AU1B, 1976BO1M, 1976DI1F, 1976DW1A, 1976EP1A, 1976FI1E, 1976GI1C, 1976ME1H, 1976NO1C, 1976OS1E, 1976QU1A, 1976RO1J, 1976SI1D, 1976VA1D, 1976VI1B, 1977AU1B, 1977AU1E, 1977AU1F, 1977AU1J, 1977BE2J, 1977CA1N, 1977CA1J, 1977CA1K, 1977CL1E, 1977CL1C, 1977CO1W, 1977DE1N, 1977HA1L, 1977JO1D, 1977KI1M, 1977LA1G, 1977MA1T, 1977PR1E, 1977ST1J, 1977ST1H, 1977TR1D, 1977WA1P, 1978BO1M, 1978BU1H, 1978BU1B, 1978CL1F, 1978DE1R, 1978DI1D, 1978DW1B, 1978EN1C, 1978GL1E, 1978IB1A, 1978KA1R, 1978LA1K, 1978LU1C, 1978ME1D, 1978OR1A, 1978PO1B, 1978SN1A, 1978ST1C, 1978TO1C, 1978TR1C, 1979GU1D, 1979KA1T, 1979LA1H, 1979NO1F, 1979PE1E, 1979RA1C, 1979SA1M, 1979SW1B, 1979WE1F, 1980CA1C, 1980FR1G, 1980ME1B, 1980PE1F, 1980SP1B).

Special reactions involving ¹⁴N: (1975KO1F, 1976AB04, 1976BA08, 1976BU16, 1976CH28, 1976EG02, 1976HI05, 1976NA11, 1977AR06, 1977CO14, 1977GE08, 1977GO07, 1977KU1D, 1977NA03, 1977PR05, 1977ST1J, 1977ST1G, 1977TO1G, 1978AB08, 1978BH03, 1978BI03, 1978CR1B, 1978GE1C, 1978GR1F, 1978HE1J, 1978HE1C, 1978KO01, 1979DY01, 1979GA04, 1979GE1A, 1979GO11, 1979HA1Q, 1979HE1D, 1979KO1M, 1979SA27, 1979SA26, 1979SC08, 1979ST1D, 1980MI01).

Applied work: (1975SE1J, 1976CH1N, 1976CH1P, 1976EA1A, 1976EC1B, 1976LE1Q, 1976RA1J, 1976SI1G, 1976ST1H, 1976SU1E, 1977LE1J, 1977LO1J, 1977MA1F, 1978MU1E, 1978OX1A, 1978VA1H, 1979AN1L, 1979EN1D, 1979GR1E, 1979VA1D, 1979WI1C, 1979WI1L).

Muon and neutrino capture and reactions: (1975BA40, 1975GE1E, 1977BA1P, 1977DO06, 1977GO13, 1977GO1H, 1977MU1A, 1978DE15, 1978GO1Q, 1979DE01, 1979DO1E, 1979GO1M, 1980LO07, 1980MU1B).

Pion capture and reactions: (1975BA1W, 1975KA1G, 1975KO25, 1975MA1M, 1976AS1B, 1976BA54, 1976BO2C, 1976EN02, 1976LI26, 1976RO14, 1977DO06, 1977GI14, 1977KO25, 1977MA1M, 1977MA35, 1977MA1F, 1977RI1H, 1977ST09, 1977VI1A, 1977WA1H, 1978BE27, 1978BO25, 1978GI05, 1978KI08, 1978KI13, 1978KW1A, 1978SH12, 1978SH16, 1978WE1H, 1979AM1B, 1979BA16, 1979BA2J, 1979DO17, 1979KI1K, 1979KL07, 1979MA2H, 1979PR1D, 1979SP1C, 1979UL1A, 1980DE10, 1980ER01, 1980FI05, 1980SI07).

Kaon capture and scattering: (1977JU1C, 1978AT01, 1978DA1A, 1979RA18).

Table 14.10: Energy levels of ^{14}N ^a

E_x in ^{14}N (MeV \pm keV)	$J^\pi; T$	τ_m or $\Gamma_{\text{c.m.}}$ (keV)	Decay	Reactions
g.s.	$1^+; 0$	stable		1, 7, 9, 10, 19, 20, 21, 22, 28, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 63, 64, 65, 67, 68, 69, 70, 71, 75
2.31287 ± 0.07	$0^+; 1$	$\tau_m = 92 \pm 10$ fsec	γ	1, 10, 19, 20, 22, 28, 34, 35, 36, 37, 40, 41, 45, 46, 47, 48, 50, 51, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71
3.9478 ± 0.4	$1^+; 0$	8.0 ± 1.0 fsec	γ	1, 7, 8, 10, 19, 20, 21, 22, 28, 34, 35, 36, 37, 40, 41, 42, 45, 46, 47, 48, 50, 51, 62, 63, 64, 66, 67, 68, 69, 70, 71
4.9150 ± 1.3	$0^-; 0$	7.6 ± 1.4 fsec	γ	1, 7, 8, 19, 20, 21, 22, 34, 35, 36, 41, 45, 46, 47, 48, 50, 51, 63, 64, 69
5.10587 ± 0.18	$2^-; 0$	6.2 ± 0.4 psec $ g = 0.66 \pm 0.04$	γ	7, 8, 19, 20, 21, 22, 34, 35, 36, 41, 45, 46, 47, 48, 50, 51, 62, 63, 64, 66, 68, 69
5.6896 ± 1.1	$1^-; 0$	16 ± 8 fsec	γ	7, 8, 19, 20, 21, 22, 28, 34, 35, 41, 45, 46, 47, 48, 50, 51, 63, 64, 69
5.83423 ± 0.21	$3^-; 0$	13.5 ± 1.0 psec	γ	7, 8, 12, 19, 20, 21, 22, 25, 34, 35, 41, 45, 46, 47, 48, 50, 51, 62, 63, 64, 66, 69
6.2035 ± 0.6	$1^+; 0$	160 ± 20 fsec	γ	1, 7, 8, 19, 20, 21, 22, 28, 34, 35, 41, 42, 47, 48, 50, 51, 63, 64, 69
6.4444 ± 1.1	$3^+; 0$	627 ± 33 fsec	γ	1, 7, 8, 19, 20, 21, 22, 28, 34, 35, 41, 46, 47, 48, 51, 63, 64, 69
7.0279 ± 1.4	$2^+; 0$	5.4 ± 0.5 fsec	γ	7, 8, 19, 20, 21, 22, 28, 34, 35, 41, 42, 46, 47, 48, 50, 51, 62, 63, 64, 68, 69
7.9666 ± 0.6	$2^-; 0$	$\Gamma = (2.5 \pm 0.7) \times 10^{-3}$	γ, p	7, 8, 19, 20, 21, 22, 28, 34, 35, 47, 63, 64, 69
8.062 ± 1.0	$1^-; 1$	30 ± 1	γ, p	19, 20, 28, 29, 34, 44, 47, 63, 64
8.4877 ± 1.2	$4^-; 0$	$\tau_m = 18.8 \pm 1$ fsec	γ, p	7, 8, 19, 20, 21, 22, 28, 34, 35, 47, 69
8.618 ± 2	$0^+; 1$	$\Gamma = 7 \pm 1$	γ, p	19, 20, 28, 29, 34, 35, 47, 63, 64, 69

Table 14.10: Energy levels of ^{14}N ^a (continued)

E_x in ^{14}N (MeV \pm keV)	$J^\pi; T$	τ_m or $\Gamma_{\text{c.m.}}$ (keV)	Decay	Reactions
8.79 \pm 50	0 ⁻ ; 1	\approx 460	γ, p	28, 29
8.9091 \pm 1.6	3 ⁻ ; 1	19.7 \pm 1.9	γ, p	20, 28, 29, 34, 35, 45, 47, 63, 64
8.9612 \pm 1.3	5 ⁺ ; 0	$\tau_m = 105 \pm 5$ fsec	γ, p	8, 12, 20, 21, 22, 24, 25, 28, 55, 63
8.979 \pm 3	2 ⁺ ; (0)	$\Gamma = 8 \pm 2$	γ, p	7, 8, 20, 28, 29, 34, 63
9.1241 \pm 1.5	3 ⁺	$\tau_m = 13 \pm 5$ fsec	γ, p	7, 8, 20, 28
9.1287 \pm 1.0	2 ⁻ ; 0			7, 8, 34
9.1707 \pm 1.6	2 ⁺ ; 1	$\Gamma = 0.078 \pm 0.016$	γ, p	20, 28, 34, 45, 47, 64, 68
9.3860 \pm 1.4	2 ⁻ ; 3 ⁻ ; 0	15.6 \pm 2.0	p	7, 8, 20, 21, 22, 29, 34, 35, 47, 64, 69
9.509 \pm 3	2 ⁻ ; 1	41 \pm 2	γ, p	20, 28, 29, 34, 35, 47, 64, 69
9.703 \pm 4	1 ⁺ ; 0	15 \pm 3	p	7, 20, 21, 22, 29, 34, 47, 64, 69
10.063 \pm 15	3 ⁺ , \geq 4	$<$ 10	p	8, 20
10.101 \pm 15	2 ⁺ , 1 ⁺ ; 0	5	γ, p	7, 20, 21, 22, 28, 29, 47, 69
10.228 \pm 10	1 ⁽⁻⁾ ; 0	80 \pm 15	γ, p	20, 22, 28, 29, 69
10.434 \pm 6	2 ⁺ ; 1	33 \pm 3	γ, p	7, 20, 28, 29, 41, 45, 47, 64, 69
(10.54)	(1)	(140)	p	20, 29
10.811 \pm 7	5 ⁺ ; 0	$(0.39 \pm 0.16) \times 10^{-3}$		8, 20, 21, 22, 63, 69
11.00 \pm 30		165 \pm 30	γ, p	8, 28
11.050 \pm 5	3 ⁺	1.2 \pm 0.4	γ, p	7, 8, 20, 28, 63, 68
11.07	1 ⁺ ; 0	100	n, p, d	8, 14, 21, 29, 30, 69
11.24 \pm 20	$T = 1$	220 \pm 30	γ, p, d	14, 20, 28, 69
11.24 \pm 20	(3 ⁻)	\approx 20	n, p	29, 30
11.29	2 ⁻ ; 0	180	n, p, d	14, 15, 21, 29, 30
11.357 \pm 15	1 ⁺ ; 0	30	n, p, d	14, 15, 20, 21, 29, 30, 69
11.5135 \pm 1.5	2 ⁺ , 3 ⁺	7.0 \pm 0.5	p, d	8, 14, 15, 20, 21, 69
11.68 \pm 20	1 ⁻ , 2 ⁻	150 \pm 20	n, p, d	14, 15, 20
11.741 \pm 6	1 ⁻ , 2 ⁻	40 \pm 9	(γ), p, d	14, 28
11.761 \pm 6	3 ⁻ , 4 ⁻	78 \pm 6	(γ), p, d	8, 14, 20, 28
11.807 \pm 7	(2 ⁻)	119 \pm 9	n, p, d	8, 14, 15, 17
11.874 \pm 6	(2 ⁻)	101 \pm 9	p, d	8, 14
12.20 \pm 20	1 ⁻ , 2 ⁻	300 \pm 30	n, p, d	14, 15, 21, 30, 63
(12.29 \pm 15)				20
12.408 \pm 3	(3 ⁺)	37 \pm 4	n, p, d	14, 15, 20, 21
12.418 \pm 3	(4 ⁻)	41 \pm 4	p, d, α	4, 5, 14, 20

Table 14.10: 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
(12.47 \pm 5)		≈ 20	p, α	4
12.497 \pm 4		35 \pm 10	γ , n, p, d, α	4, 14, 20, 28, 41, 63, 68
12.594 \pm 3	3 ⁺	48 \pm 2	n, p, d, α	4, 14, 15, 20, 21, 30, 63
12.688 \pm 4	3 ⁻	22 \pm 4	n, p, d, α	3, 4, 5, 6, 14, 15, 20, 21, 30
(12.708 \pm 9)		(43 \pm 15)	p, d	14
12.792 \pm 4	4 ⁺	18 \pm 3	n, p, d, α	4, 5, 6, 12, 14, 15, 20, 24
(12.813 \pm 5)		37 \pm 6	p, d	14
12.819 \pm 4	4 ⁻	8 \pm 3	n, p, d, α	4, 5, 14, 15
12.857 \pm 6		78 \pm 10	n, p, d	14, 30
12.923 \pm 5	(4 ⁺)	25 \pm 3	p, d, α	4, 5, 14, 15, 20
13.03 \pm 15		≈ 100	γ , p	8, 21, 28
13.166 \pm 5	(1 ⁺)	15 \pm 5	n, p, d, α	3, 4, 5, 6, 14, 15, 20
13.192 \pm 10	3 ⁺	65 \pm 10	α	6, 20
13.243 \pm 10	2 ⁻	92 \pm 5	n, p, α	3, 4, 30
13.30 \pm 40	(2 ⁻); 1	1000 \pm 150	γ , p	28
13.656 \pm 5	(2 ⁺ , 3 ⁺)	≈ 90	n, p, d, α	3, 4, 6, 14
13.714 \pm 5	2, 3 ⁺	105 \pm 25	n, p, d, α	3, 4, 5
13.71 \pm 30	1 ⁺ ; 1	180 \pm 25	(γ), n, p, d, α	3, 4, 6, 14, 15, 28, 64
13.72 \pm 20		110	p, α	4
14.04 \pm 30		100	n, p, d, α	3, 4, 14, 15, 30
14.16 \pm 30		230	n, p, d, α	3, 4, 14, 15
14.25 \pm 50	3 ⁺	420 \pm 100	p, α	4, 6
14.30 \pm 20		150	p, α	4
14.56 \pm 20		100	n, p, α	3, 4
14.59 \pm 30		50	n, p, α	3, 4
14.66 \pm 10	2 ⁻	100 \pm 20	α	6
14.73 \pm 30		125	n, p, α	3, 4
14.86 \pm 30		140	n, p, d, α	3, 4, 14, 15, 17, 30
14.92 \pm 25		43 \pm 8	n, p, α	3, 4, 20, 30
15.015 \pm 15		≈ 60	n, α	3, 30
15.24 \pm 20		100	p, d, α	4, 8, 14, 15
15.43 \pm 20		100	n, p, d, α	3, 4, 14, 17, 21
15.7 \pm 150		≈ 300	n, p, d, α	14, 15, 17, 20, 30
16.21 \pm 20		125	(γ), n, p, α	3, 4, 30, 45
16.40 \pm 20		150	p, d, α	4, 17
16.8	4 ⁺ ; $T = 0 + 1$	≈ 300	d, α	17
16.91 \pm 20	(5 ⁻); 0 + 1	≈ 100	p, d, α	4, 17

Table 14.10: 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
17.17 \pm 20	$4^+; 0+1$	≈ 300	n, p, d, α	4, 14, 15, 17, 21, 30
18.1	$(1^-, 2^+); 0+1$	(≈ 300)	d, α	17
18.1	$4^+; 0+1$	≈ 600	d, α	17, 30
18.2	$3^-; 0+1$	(≈ 400)	d, α	17
18.4	$3^-; 0+1$	(≈ 300)	d, α	17
18.50	$5^-; 0+1$	≈ 60	d, α	17
18.8	$4^+; 0+1$	(≈ 400)	d, α	17
20.1	$1^-; 0+1$	(≈ 500)	d, α	17
20.8	$5^-; 0+1$	≈ 600	d, α	17
20.8	$(3^-, 4^+); 0+1$	(≈ 500)	d, α	17
21.3	$4^+; 0+1$	(≈ 1000)	d, α	17
21.5	$3^-; 0+1$	(≈ 500)	d, α	17
21.7	$5^-; 0+1$	≈ 200	d, α	17
21.8		650	$\gamma, ^3\text{He}$	9
22.5 \pm 100	$5^-; 0+1$	610 \pm 100	d, α	17
22.5	$(2^-); 1$		γ, p	28
23.0	$(0, 1, 2)^-; 1$	≈ 3000	γ, n	43
23.0	$2^-; 1$		γ, p	28
23.3 \pm 100	$5^-; 0+1$	500 \pm 100	d, α	17
24.0		≈ 1000	n, $^3\text{He}, \alpha$	9

^a See also Tables 14.11 and 14.12.

Reactions involving antiprotons: (1977WE1E, 1978PO02).

Other topics: (1976CO1R, 1978DA1A, 1978GA1C, 1978KW1A, 1978SO1A, 1979GA1D, 1979HE1F, 1979KA13, 1979KO1V).

Ground state of ^{14}N : (1977AN21, 1977GO1H, 1977MA35, 1978AN07, 1978HE1D, 1978ZA1D, 1979BU12, 1979SA27).

$$\mu = +0.4037607 (2) \text{ nm (1978LEZA)}.$$

$$Q = +0.0156 \text{ b (1978LEZA)}.$$

1. (a) $^9\text{Be}(^6\text{Li}, n)^{14}\text{N}$ $Q_m = 14.500$

(b) $^9\text{Be}(^7\text{Li}, 2n)^{14}\text{N}$ $Q_m = 7.250$

A recent measurement of the (5.83 \rightarrow 5.11) γ -ray in reaction (b), $E_\gamma = 728.34 \pm 0.10$ keV, leads to $E_x = 5834.23 \pm 0.21$ keV (1981KO08) and E.K. Warburton, private communication. See also (1976AJ04).

Table 14.11: Radiative decays in $^{14}\text{N}^a$

E_i (MeV)	$J_i^\pi; T$	E_f (MeV)	$J_f^\pi; T$	Branch (%)	Γ_γ (eV)	Refs.
2.31	$0^+; 1$	0	$1^+; 0$	100	$(7.2 \pm 0.8) \times 10^{-3}$	Table 14.12
3.95	$1^+; 0$	0	$1^+; 0$	$^A 3.9 \pm 0.2^b$	(M1) $(4.1 \pm 1.2) \times 10^{-4}$	(1967OL02, 1968RO1C, Table 14.12)
		2.31	$0^+; 1$	$^A 96.1 \pm 0.3^b$	(E2) $(3.2 \pm 0.4) \times 10^{-3}$ 0.079 \pm 0.010	(1967OL02, 1968RO1C, Table 14.12)
4.92	$0^-; 0$	0	$1^+; 0$	97 ± 3	$(8.4 \pm 1.6) \times 10^{-2}$	(1972RE10, Table 14.12)
		2.31	$0^+; 1$	< 1		(1966GO15)
		3.95	$1^+; 0$	1.3 ± 1.0		(1965NE06)
				≤ 0.5		(1966GO15)
5.11	$2^-; 0$	0	$1^+; 0$	$^A 79.9 \pm 1.0^b$	$(8.5 \pm 0.6) \times 10^{-5}^r$	(1966GO15, 1968AL12, Table 14.12)
		2.31	$0^+; 1$	$^A 19.4 \pm 1.2^b$		
		3.95	$1^+; 0$	(0.7 ± 0.4)		(1966GO15)
5.69 ^c	$1^-; 0$	0	$1^+; 0$	$^A 35.6 \pm 1.2$		mean
		2.31	$0^+; 1$	$^A 63.1 \pm 1.2$	$(2.6 \pm 1.3) \times 10^{-2}$	mean; Table 14.12
5.83 ^d	$3^-; 0$	0	$1^+; 0$	$^A 26.5 \pm 2.5$		mean
		5.11 ^e	$2^-; 0$	$^A 73 \pm 3$	$(3.6 \pm 0.3) \times 10^{-5}$	mean; Table 14.12
6.20 ^f	$1^+; 0$	0	$1^+; 0$	$^A 23.0 \pm 1.9$		mean
		2.31	$0^+; 1$	$^A 76.7 \pm 2.0$	$(3.2 \pm 0.4) \times 10^{-3}$	mean; Table 14.12
6.44 ^h	$3^+; 0$	0	$1^+; 0$	69.6 ± 1.5	$(7.3 \pm 0.4) \times 10^{-4}^g$	(1976SI07); Table 14.12
		3.95	$1^+; 0$	19.6 ± 1.0		(1976SI07)
		5.11	$2^-; 0$	6.4 ± 0.6		(1976SI07)
		5.83	$3^-; 0$	3.7 ± 0.6		(1976SI07)
7.03	$2^+; 0$	0	$1^+; 0$	$^A 98.6 \pm 0.3$	(M1) $(9.1 \pm 1.3) \times 10^{-2}^i$	(1967OL02, 1968RO1C)
					(E2) $(5.0 \pm 1.2) \times 10^{-2}$	
		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	$< (11 \pm 0.3) \times 10^{-4}$	(1967OL02, 1968RO1C)
		other states		≤ 0.4		(1967OL02)
7.97 ^o	$2^-; 0$	0	$1^+; 0$	55 ± 3	0.010	(1960HE14)
		3.95	$1^+; 0$	45 ± 3	0.008	(1960HE14)
		other states		≤ 3		(1960HE14)
8.06	$1^-; 1$	0	$1^+; 0$	80.3 ± 0.6	9.9 ± 2.5^q	(1972RE10); Table 14.19
		2.31	$0^+; 1$	1.40 ± 0.14	0.17 ± 0.05^q	(1972RE10)

Table 14.11: Radiative decays in $^{14}\text{N}^a$ (continued)

E_i (MeV)	$J_i^\pi; T$	E_f (MeV)	$J_f^\pi; T$	Branch (%)	Γ_γ (eV)	Refs.
8.49	$4^-; 0$	3.95	$1^+; 0$	12.7 ± 0.4	1.56 ± 0.40^q	(1972RE10)
		4.92	$0^-; 0$	1.86 ± 0.14	0.23 ± 0.06^q	(1972RE10)
		5.11	$2^-; 0$	0.25 ± 0.14	0.03 ± 0.02^q	(1972RE10)
		5.69	$1^-; 0$	3.5 ± 0.4	0.43 ± 0.12^q	(1972RE10)
		5.11	$2^-; 0$	83 ± 3	$(6.1 \pm 1.5) \times 10^{-3}$	^p
8.62	$0^+; 1$	5.83	$3^-; 0$	17 ± 3	$(1.3 \pm 0.4) \times 10^{-3}$	^p
		0	$1^+; 0$	23	1.20	(1959WA16)
		3.95	$1^+; 0$	24	1.26	(1959WA16)
		5.69	$1^-; 0$	13	0.69	(1959WA16) ^a
8.79	$0^-; 1$	6.20	$1^+; 0$	40		(1957WI27)
		0	$1^+; 0$	90 ± 10^s	46 ± 12^s	(1953WO41)
		8.91	$3^-; 1$	0	1.6 ± 0.5^q	$(6.6 \pm 2.2) \times 10^{-3}$
8.96	$5^+; 0$	5.11	$2^-; 0$	5.4 ± 2.5^q	$(2.3 \pm 1.2) \times 10^{-2}^q$	(1959WA04)
		5.83	$3^-; 0$	89 ± 3^q	0.37 ± 0.10^q	(1959WA04)
		6.44	$3^+; 0$	3 ± 1	0.012 ± 0.006^q	(1959WA04)
		7.03	$2^+; 0$	1.4 ± 0.8	0.006 ± 0.004^q	(1959WA04)
		0 ^a	$1^+; 0$	< 1		
		6.44 ^a	$3^+; 0$	100	$\Gamma_\gamma = (1.2 \pm 0.2) \times 10^{-3}$	Table 14.12
					$\Gamma_p/\Gamma_\gamma = 4.1 \pm 0.5$	
9.13	$3^+; 0$	0	$1^+; 0$	82 ± 3	$\Gamma_\gamma = (8.5 \pm 1.0) \times 10^{-3}^j$	(1978KE01, 1978KE03)
		3.95	$1^+; 0$	≤ 2		(1978KE01)
		5.83	$3^-; 0$	9 ± 3		(1978KE01)
		6.44	$3^+; 0$	9 ± 3		(1978KE01)
		9.17 ^l	$2^+; 1$	0	$1^+; 0$	85.1 ± 1.0
2.31	$0^+; 1$	0.85 ± 0.08			(1976SI07)	
5.69	$1^-; 0$	0.49 ± 0.10			(1976SI07)	
5.83	$3^-; 0$	0.61 ± 0.08			(1976SI07)	
6.44	$3^+; 0$	8.8 ± 0.8			(1976SI07)	
9.51	$2^-; 1$	7.03	$2^+; 0$	3.2 ± 0.3		(1976SI07)
		0	$1^+; 0$	< 0.16^q	< 0.08^q	
		3.95	$1^+; 0$	6 ± 1	0.30 ± 0.09^q	(1959WA04)
		5.11	$2^-; 0$	78 ± 3	3.84 ± 0.97^q	(1959WA04)
		5.83	$3^-; 0$	16 ± 2	0.79 ± 0.22^q	(1959WA04)
10.23	$1^{(-)}; 0$	2.31	$0^+; 1$	≈ 100	4 ± 1.3	(1963RO17)
10.43 ^m	$2^+; 1$	0	$1^+; 0$	82 ± 6	9.6 ± 1.9	(1964RO03); Table 14.19
		5.11	$2^-; 0$	2 ± 1	0.2 ± 0.1	(1964RO03)
		6.44	$3^+; 0$	8 ± 1	0.9 ± 0.2	(1964RO03)

Table 14.11: 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.
10.81 ⁿ	5 ⁺ ; 0	7.03	2 ⁺ ; 0	6 ± 1	0.7 ± 0.2	(1964RO03)
11.05	3 ⁺	6.44	3 ⁺ ; 0	100	$\Gamma_\gamma/\Gamma = 4.1 \pm 0.8\%$	(1972NO08)
		0	1 ⁺ ; 0		$\Gamma_\gamma = 0.12 \pm 0.02$	(1980RA06)
		3.95	1 ⁺ ; 0		= 0.09 ± 0.02	(1980RA06)

A = adopted. See also Table 14.12 in (1976AJ04).

^a See also Table 14.9 in (1970AJ04), Table 14.12 in (1976AJ04) and Tables 14.12 and 14.16 here.

^b Means of branching ratios quoted in Table 14.9 (1970AJ04).

^c Transitions to $^{14}\text{N}^*(3.95, 4.92)$ are ≤ 0.4 and $\leq 0.3\%$ (1972RE10).

^d Transitions to $^{14}\text{N}^*(2.31, 3.95, 4.92)$ are < 3 , < 1 and < 1 percent (1966GO15).

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

^f Transitions to $^{14}\text{N}^*(3.95, 5.11)$ are $< 1\%$ (1966GO15).

^g $\delta(\text{M3/E2}) = -0.004 \pm 0.010$ (1976SI07).

^h Transitions to $^{14}\text{N}^*(4.92, 5.69)$ are < 0.4 and $< 0.3\%$ (1976SI07).

ⁱ $\delta(\text{E2/M1}) = 0.74 \pm 0.09$ (1976SI07).

^j $\Gamma_p = 43_{-31}^{-15}$ meV (1978KE03); $\delta(\text{M3/E2}) = -0.03 \pm 0.02$ (1978KE01).

^k $\delta(\text{E2/M1}) = -0.003 \pm 0.003$, 0.031 ± 0.006 and -0.037 ± 0.015 for the transitions to $^{14}\text{N}^*(0, 6.44, 7.03)$ (1976SI07).

^l Transitions to $^{14}\text{N}^*(3.95, 4.91, 5.11, 6.20)$ are $< 0.2\%$; transitions to $^{14}\text{N}^*(7.97, 8.06, 8.49, 8.62)$ are $< 0.03\%$ (1976SI07).

^m Transitions to $^{14}\text{N}^*(2.31, 3.95, 5.69, 5.83)$ are < 1 , < 2 , < 3 and $< 1\%$ (1964RO03).

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

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

^p $\Gamma = (3.5 \pm 0.5) \times 10^{-2}$ eV from Table 14.12; $\Gamma_p/\Gamma = 3.7 \pm 1.1$ (1967GA12) leads to $\Gamma_\gamma = 7.4 \pm 2.5$ meV. I am indebted to P.M. Endt and E.K. Warburton for their comments.

^q E.K. Warburton (private communication). See also (1981KO08).

^r $\delta(\text{M2/E1}) = -0.16 \pm 0.02$, $\delta(\text{E3/E1}) = -0.15 \pm 0.025$; see (1981KO08).

^s E.K. Warburton (private communication).

$$2. \text{}^9\text{Be}(\text{}^{10}\text{B}, \alpha\text{n})\text{}^{14}\text{N} \quad Q_m = 10.040$$

See (1979CH22).

$$3. \text{}^{10}\text{B}(\alpha, \text{n})\text{}^{13}\text{N} \quad Q_m = 1.060 \quad E_b = 11.6133$$

Table 14.12: Lifetimes of some ^{14}N states ^a

E_x (MeV)	τ_m (fsec)	Reaction	Refs.
2.31	75 ± 19	$^{13}\text{C}(p, \gamma)$	(1972RE10)
	105 ± 15	$^{13}\text{C}(p, \gamma)$	(1977BI07)
	79 ± 7	$^{13}\text{C}(p, \gamma)$	(1980AN1E)
	106 ± 10	$^{14}\text{N}(\gamma, \gamma)$	(1975RA22)
3.95	92 ± 10		adopted value
	8.4 ± 0.4	$^{13}\text{C}(p, \gamma)$	(1977BI07)
	5.7 ± 0.7	$^{13}\text{C}(p, \gamma)$	(1980AN1E)
4.92	8.7 ± 0.9	$^{14}\text{N}(e, e)$	see reaction 45
	8.0 ± 1.0		adopted value
	7.6 ± 1.4^A		^b
5.11	(6.2 ± 0.4) psec ^c	$^{12}\text{C}(^3\text{He}, p)$	(1978MO27)
5.69	$16 \pm 8^{d,A}$	$^{13}\text{C}(p, \gamma)$	(1977BI07)
	≤ 5.5	$^{13}\text{C}(p, \gamma)$	(1980AN1E)
5.83	(13.7 ± 1.1) psec	$^{12}\text{C}(^3\text{He}, p)$	(1978MO27)
	(12.9 ± 1.9) psec	$^9\text{Be}(^7\text{Li}, 2n)$	(1981KO08)
6.20 ^a	(13.5 ± 1.0) psec		mean: see (1981KO08) ^g
	185 ± 15	$^{13}\text{C}(p, \gamma)$	(1977BI07)
	132 ± 8	$^{13}\text{C}(p, \gamma)$	(1980AN1E)
6.44	160 ± 20		adopted value ^f
	620 ± 60^A		adopted value ^f
7.03	5.4 ± 0.5	$^{14}\text{N}(\gamma, \gamma)$	(1966SW01)
8.49	19 ± 3	$^{13}\text{C}(p, \gamma)$	(1978KE03) ^f
8.96	105 ± 17	$^{13}\text{C}(p, \gamma)$	(1978KE03) ^f
9.13	13 ± 5	$^{13}\text{C}(p, \gamma)$	(1978KE03)

A = adopted.

^a See also Table 14.13 in (1976AJ04) and Table 14.19 here.

^b Based on unpublished measurements: see Table 14.13 (1976AJ04).

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

^d Previous value [see (1976AJ04)] is unpublished.

^e See also (1977FR1M, 1979EN01).

^f I am indebted to P.M. Endt for his suggestions.

^g See also (1980TO05).

Observed resonances are displayed in Table 14.13. See also (1976AJ04).

Table 14.13: Resonances in $^{10}\text{B} + \alpha$ ^a

E_α (MeV \pm keV)	$\Gamma_{\text{c.m.}}$ (keV)	Outgoing particle ^b (x)	Γ_x ^c (keV)	$^{14}\text{N}^*$ (MeV)	J^π	Refs.
0.95		p_0		12.29		A
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		A
1.23 ± 5	35 ± 5	p_0, p_3		12.49		A
1.40 ± 5	46 ± 4	$p_1, p_2, (p_3)$		12.61	3^+	A
1.507 ± 5	18 ± 5	n_0	4.3	12.690	3^-	A
		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
		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	$n_0, p_0 \rightarrow p_3, d, \alpha_1$		13.166	1^+	A, (1975WI04)
2.21 ± 10	65 ± 10	α_0		13.192	3^+	A
2.281 ± 10	92 ± 5	$n_0, p_0 \rightarrow p_3$		13.243	2^-	A, (1975WI04)
2.86 ± 5	≈ 90	n_0, p_1, p_2, α_1		13.656		A
2.94 ± 5	105 ± 25	$n_0, p_0 \rightarrow p_3, d$		13.714	$2, 3^+$	A, (1975WI04)

Table 14.13: Resonances in $^{10}\text{B} + \alpha$ ^a (continued)

E_α (MeV \pm keV)	$\Gamma_{\text{c.m.}}$ (keV)	Outgoing particle ^b (x)	Γ_x ^c (keV)	$^{14}\text{N}^*$ (MeV)	J^π	Refs.
2.95 \pm 50	180 \pm 20	$n_0, p_0, (p_2), \alpha_0$		13.72	1 ⁽⁺⁾	A, (1975WI04) ^d
2.95 \pm 20	110	p_1, p_3		13.72		A, (1975WI04) ^d
3.40 \pm 30	100	n_0, p_1		14.04		A, (1975WI04)
3.56 \pm 30	230	$n_0, (p_0), p_3$		14.16		A, (1975WI04)
3.69 \pm 50	420 \pm 100	p, α_0		14.25	3 ⁺	A
3.76 \pm 20	150	p_1		14.30		(1975WI04)
3.98 \pm 20	100	n_0, p_0, p_2		14.56		A, (1975WI04)
4.16 \pm 30	50	n_0, p_0, p_3		14.59		A, (1975WI04)
4.26 \pm 10	100 \pm 20	α_0		14.66	2 ⁻	A
4.36 \pm 30	125	$n_0, p_0, p_1, (p_2)$		14.73		A, (1975WI04)
4.54 \pm 30	140	n_0, p_2, p_3		14.86		A, (1975WI04)
4.633 \pm 30	43 \pm 8	n_0, n_{2+3}, p_0		14.923		A, (1975WI04)
4.77 \pm 20	\approx 60	n_0, n_1		15.02		A
^e 5.08 \pm 20	100	p_3		15.24		(1975WI04)
5.35 \pm 20	100	n_1, p_2, p_3		15.43		A, (1975WI04)
6.44 \pm 20	125	n_0, p_0, p_2		16.21		(1975WI04)
6.70 \pm 20	150	p_2		16.40		(1975WI04)
7.42 \pm 20		p_0		16.91		(1975WI04)
7.78 \pm 20	50	p_3		17.17		(1975WI04)

A: See references quoted for this state in (1970AJ04, 1976AJ04).

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

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

^c For θ_x^2 see Table 14.8 in (1970AJ04).

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

^e See text of reaction 6.

4. $^{10}\text{B}(\alpha, \text{p})^{13}\text{C}$

$$Q_m = 4.0626$$

$$E_b = 11.6133$$

Excitation functions have been measured to $E_\alpha = 26$ MeV. Observed resonances are displayed in Table 14.13. (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 $^{14}\text{N}^*(13.16, 13.24, 13.67, 13.76)$ 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. See also (1970AJ04, 1976AJ04).

5. $^{10}\text{B}(\alpha, \text{d})^{12}\text{C}$

$$Q_m = 1.3408$$

$$E_b = 11.6133$$

Excitation curves have been measured at E_α up to 27 MeV [see (1970AJ04, 1976AJ04)] and (1975VA19: $E_\alpha = 15$ to 25 MeV; d_0, d_1). The low energy resonances are exhibited in Table 14.13. At the higher energies the yield curves are fairly smooth although (1975VA19) show broad resonances in the d_1 and d_0 yields corresponding to $^{14}\text{N}^*(23, 25)$ respectively, and at $\theta = 170^\circ$ (1975SP04) report a sharp rise in the 15.1 MeV γ yield ≈ 1 MeV above the $^{12}\text{C}^*(15.1) + \text{p} + \text{n}$ threshold, a channel which is not isospin forbidden. See also (1976LE1K).

6. $^{10}\text{B}(\alpha, \alpha)^{10}\text{B}$

$$E_b = 11.6133$$

The yield of α -particles [and of 0.7 MeV γ -rays for $E_\alpha = 2.1$ to 3 MeV] has been measured for E_α to 30 MeV [see (1976AJ04)] and for $E_\alpha = 30$ to 50.6 MeV by (1976BE1M; α_0). Observed resonances are displayed in Table 14.13. In addition to two strong resonances in the α_0 yields at $E_\alpha = 2.21$ and 4.26 MeV ($^{14}\text{N}^*(13.19, 14.66)$), two other states ($^{14}\text{N}^*(13.72, 14.25)$) are required to fit the data: an R -matrix calculation leads to $J^\pi = 3^+, 1^+$ [see, however, (1975WI04)], 3^+ and 2^- for $^{14}\text{N}^*(13.19, 13.72, 14.25, 14.66)$ (1973MO15). A strong resonance at $E_\alpha = 5.0 \pm 0.1$ MeV is reported in the reaction cross section for $E_\alpha = 4.0$ to 9.0 MeV (1976GR1F; abstract): it is suggested that $J^\pi = 6^+$.

7. $^{10}\text{B}(^6\text{Li}, \text{d})^{14}\text{N}$ $Q_{\text{m}} = 10.140$

At $E(^6\text{Li}) = 5$ MeV $^{14}\text{N}^*(0, 3.95, 4.92, 5.11, 5.69, 5.83, 6.20, 6.44, 7.03, 7.97, 8.49, 8.98, 9.12, 9.39, 9.70, 10.10, 10.43$ ($T = 1$, weakly populated), 11.06) are populated ((1966MC05), and private communication). (1975FO01) have examined $^{14}\text{N}^*(9.13)$ in detail and conclude that it is a closely spaced doublet of which one member is populated in $^{13}\text{C}(\text{p}, \gamma)$ 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 $E(^6\text{Li}) = 16.5$ and 21.0 MeV which shows the contributions of several L values and, in particular, $L = 0$. For γ branching ratios see Table 14.12 of (1976AJ04). See also reaction 22.

8. $^{10}\text{B}(^7\text{Li}, \text{t})^{14}\text{N}$ $Q_{\text{m}} = 9.147$

At $E(^7\text{Li}) = 24$ MeV angular distributions of the tritons to $^{14}\text{N}^*(3.95, 5.83, 6.44, 8.96, 9.13, 10.06, 10.81, 12.79 + 12.83, 13.03, 15.26)$ have been studied by (1977KO27). $^{14}\text{N}^*(4.91, 5.11, 5.69, 6.20, 7.03, 7.97, 8.49, 8.98, 9.39, 11.04, 11.05, 11.52, 12.41)$ are also populated (1977KO27).

9. (a) $^{11}\text{B}(^3\text{He}, \gamma)^{14}\text{N}$	$Q_{\text{m}} = 20.7358$	$E_{\text{b}} = 20.7358$
(b) $^{11}\text{B}(^3\text{He}, \text{n})^{13}\text{N}$	$Q_{\text{m}} = 10.182$	
(c) $^{11}\text{B}(^3\text{He}, \text{p})^{13}\text{C}$	$Q_{\text{m}} = 13.1851$	
(d) $^{11}\text{B}(^3\text{He}, \text{d})^{12}\text{C}$	$Q_{\text{m}} = 10.4634$	
(e) $^{11}\text{B}(^3\text{He}, \text{t})^{11}\text{C}$	$Q_{\text{m}} = -2.001$	
(f) $^{11}\text{B}(^3\text{He}, ^3\text{He})^{11}\text{B}$		
(g) $^{11}\text{B}(^3\text{He}, \alpha)^{10}\text{B}$	$Q_{\text{m}} = 9.1226$	
(h) $^{11}\text{B}(^3\text{He}, ^6\text{Li})^8\text{Be}$	$Q_{\text{m}} = 4.5702$	

The capture γ -rays [reaction (a)] have been studied at $E(^3\text{He}) = 0.9$ to 2.6 MeV (1970BL10; γ_0 ; $\theta = 0^\circ$ and 90°). When the barrier penetration factor has been removed a single resonance is observed at $E(^3\text{He}) \approx 1.4$ MeV [$^{14}\text{N}^*(21.8)$], $\Gamma_{\text{c.m.}} = 0.65$ MeV. The higher energy work quoted in (1976AJ04) has not been published.

The excitation function for reaction (b) has been measured for $E(^3\text{He}) = 1.5$ to 18 MeV [see (1976AJ04)] and 5.0 to 11.5 MeV (1977DA18; n_0). A broad peak at $E(^3\text{He}) = 4.15$ MeV may indicate the existence of $^{14}\text{N}^*(24)$, $\Gamma \approx 1$ MeV (1966DI04).

Yield curves for protons [reaction (c)] have been measured for $E(^3\text{He}) = 3.0$ to 5.5 MeV ($p_0, p_1, p_1 + p_2 + p_3$): they are rather featureless (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 $E(^3\text{He}) = 6$ to 30 MeV: see (1976AJ04). See also ^{13}C and ^{13}N , and ^{11}B , ^{11}C , ^{12}C in (1980AJ01).

The excitation functions for α -particle groups [reaction (g)] have been measured for $E(^3\text{He}) = 0.9$ to 5.5 MeV: see (1976AJ04). No significant resonance behavior is seen except for the α_2 group which, in the 15° excitation function, exhibits a resonance at $E(^3\text{He}) = 4$ MeV, $\Gamma \approx 1$ MeV (1965FO06). See also ^{10}B in (1979AJ01).

The excitation function for reaction (h) to $^6\text{Li}_{\text{g.s.}} + ^8\text{Be}_{\text{g.s.}}$ has been measured for $E(^3\text{He}) = 1.4$ to 5.8 MeV: no pronounced structure is observed (1967YO02). At $E(^3\text{He}) = 25.20$ to 26.25 MeV the excitation functions for the transitions to $^8\text{Be}^*(0, 16.63, 16.91, 17.64)$ are smooth, indicating a predominantly direct reaction mechanism (1974DE25).

$$10. \text{}^{11}\text{B}(\alpha, \text{n})^{14}\text{N} \quad Q_{\text{m}} = 0.1580$$

Angular distributions have been measured for E_α to 13.9 MeV [see (1970AJ04, 1976AJ04)] and at $E_\alpha = 2.05$ MeV (1977NI03). See also ^{15}N and (1976EP1A, 1980DO1C; astrophys.).

$$11. \text{}^{11}\text{B}(^6\text{Li}, \text{t})^{14}\text{N} \quad Q_{\text{m}} = 4.9418$$

See (1970AJ04).

$$12. \text{}^{11}\text{B}(^{11}\text{B}, ^8\text{Li})^{14}\text{N} \quad Q_{\text{m}} = -6.475$$

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

$$13. \text{}^{12}\text{C}(\text{d}, \gamma)^{14}\text{N} \quad Q_{\text{m}} = 10.27240$$

At $E_{\text{d}} = 1.5$ MeV the capture cross section is $< 1\mu\text{b}$ (1955AL16). [The other work quoted in (1976AJ04) has not been published.]

$$14. \text{(a) } ^{12}\text{C}(\text{d}, \text{n})^{13}\text{N} \quad Q_{\text{m}} = -0.2812 \quad E_{\text{b}} = 10.27240$$

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

Resonances in the yields of neutrons and protons are displayed in Table 14.14. Measurements of the yields of neutrons (to $E_{\text{d}} = 17$ MeV) and of protons (to $E_{\text{d}} = 14.7$ MeV) are listed in Tables 14.11 (1970AJ04) and 14.16 (1976AJ04). The yield of n_0 has also been measured by (1976WA1L: $E_{\text{d}} = 5.5$ to 12.5 MeV). This preliminary work is characterized by a broad bump at $E_{\text{d}} \approx 7$ MeV and by a somewhat sharper one at $E_{\text{d}} \approx 9$ MeV (1976WA1L). For angular distributions see ^{13}C , ^{13}N . For spallation measurements see (1978AZ1E, 1978DU1B).

Table 14.14: Resonances in $^{12}\text{C} + \text{d}$ ^a

E_d (MeV \pm keV)	$\Gamma_{\text{c.m.}}$ (keV)	Particles out	$^{14}\text{N}^*$ (MeV)	$J^\pi; T$
0.92	95	n, p ₀ , p ₁	11.06	1 ⁺ ; 0
1.13		p ₀ , p ₁	11.24	T = 1
1.19	190	n, p ₀ , p ₁ , d	11.29	2 ⁻ ; 0
1.23		p ₀	11.33	(3 ⁺)
1.30	30	n, p ₀ , p ₁ , d	11.39	1 ⁺ ; 0
1.39		p ₀	11.46	(2 ⁻)
1.4495 \pm 1.5	7.0 \pm 0.5	p ₀ , p ₁ , d	11.5135	2 ⁺ , 3 ⁺
1.55		p ₀	11.60	(2 ⁻)
1.640 \pm 20	150 \pm 20	n, p ₁ , d ₀	11.68	1 ⁻ , 2 ⁻ ^b
1.715 \pm 6	40 \pm 9	p ₂	11.741	1 ⁻ , 2 ⁻
1.738 \pm 6	78 \pm 6	p ₁	11.761	3 ⁻ , 4 ⁻ , (2 ⁻)
1.792 \pm 7	119 \pm 9	n, p ₀ , p ₁ , p ₂ , d ₀	11.807	2 ⁻ , (1 ⁺) ^b
1.870 \pm 6	101 \pm 9	p ₀ , p ₁ , p ₂	11.874 ^c	2 ⁻ , (1 ⁻)
2.250 \pm 19	300 \pm 30	n, p ₀ \rightarrow p ₃ , d ₀	12.20	1 ⁻ , 2 ⁻ ^b
2.494 \pm 3 ^d	37 \pm 4	n, p ₀ \rightarrow p ₃ , d ₀	12.408	3 ⁺ , (3 ⁻ , 4 ⁻) ^b
2.506 \pm 3	41 \pm 4	p ₁	12.418	3 ⁻ , 4 ⁻ , (2 ⁺ , 3 ⁺)
2.610 \pm 20	30 \pm 20	n, p ₁ , p ₂ , p ₃	12.507	(b)
2.712 \pm 3	48 \pm 2	(n), p ₀ \rightarrow p ₃ , d ₀	12.594	3 ⁺ ^b
(2.817 \pm 7)	27 \pm 6	n, p ₁ , p ₂ , p ₃ , d ₀	(12.684)	(b)
2.844 \pm 9	43 \pm 15	p ₂ , p ₃	12.708	
2.940 \pm 10	30 \pm 10	p ₂ , p ₃ , d	12.790	
2.967 \pm 5	37 \pm 6	p ₁	12.813	
2.982 \pm 6	11 \pm 3	n, p ₃ , d	12.826	
3.018 \pm 6	78 \pm 10	n, p ₀ , p ₁	12.857	
3.049 \pm 8	134 \pm 11	p ₁	12.883	
3.100 \pm 10	20 \pm 14	p ₁ , p ₂ , p ₃ , d	12.927	(3 ⁻ , 4 ⁻)
3.39 \pm 12	47 \pm 15	n, p ₂ , p ₃ , d	13.17	(0 ⁻ , 1 ⁻)
3.97 \pm 30	< 200	p ₀ , p ₂ , p ₃ , (d)	13.67	(2 ⁺ , 3 ⁺)
4.02 ⁺²⁰ ₋₁₀	\approx 235	n, (p), d	13.71	(1 ⁺)
4.40		p ₀ \rightarrow p ₃ , d	14.04	

Table 14.14: Resonances in $^{12}\text{C} + \text{d}$ ^a (continued)

E_{d} (MeV \pm keV)	$\Gamma_{\text{c.m.}}$ (keV)	Particles out	$^{14}\text{N}^*$ (MeV)	$J^\pi; T$
4.55		n, p ₂ , d	14.17	
4.80		p ₀ , p ₂ , d	14.38	
5.17		d	14.70	
5.34	≈ 100	p ₀ \rightarrow p ₃ , d, α	14.84	
5.65		d	15.11	
5.83		p ₁ , p ₃ , d	15.26	
6.07		p ₁ , p ₂ , α	15.47	
6.3		p ₀ , p ₃ , d, α	15.7	
7.2		α	16.4	
7.6 ^e	≈ 300	α_2	16.8	4 ⁺ ^f
7.8	≈ 100	α_2	16.9	(5 ⁻)
8.1	≈ 300	p ₀ , p ₂ , d, α_2	17.2	4 ⁺
9.1	(≈ 300)	α_2	18.1	(1 ⁻ , 2 ⁺)
9.2	≈ 600	α_2	18.1	4 ⁺
9.3	(≈ 400)	α_2	18.2	3 ⁻
9.5	(≈ 300)	α_2	18.4	3 ⁻
9.61	≈ 60	α_2	18.50	5 ⁻
10.0 ^g	(≈ 400)	α_2	18.8	4 ⁺
11.5	(≈ 500)	α_2, α_3	20.1	1 ⁻
12.3	≈ 600	α_2	20.8	5 ⁻
12.3	(≈ 500)	α_2	20.8	(3 ⁻ , 4 ⁺)
12.9	(≈ 1000)	α_2	21.3	4 ⁺
13.1	(≈ 500)	α_2	21.5	3 ⁻
13.4	≈ 200	α_2	21.7	5 ⁻
14.29 \pm 100	610 \pm 100	α_2	22.5	5 ⁻ ^h
15.28 \pm 100	500 \pm 100	α_2	23.3	5 ⁻ ^h

^a For the references for each of the resonances, see Table 14.15 in (1976AJ04).

^b See also (1976BO1Q; prelim.)

^c (1974GM01) also report a state at 12.05 MeV with $\Gamma = 190$ keV seen as a structure 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 $^{14}\text{N}^*(17.2, 19.6, 20.4)$.

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

The vector analyzing power and the 0° transverse vector polarization transfer coefficient, $K_y^{y'}(0^\circ)$ have been measured for $E_{\bar{d}} = 5.7$ to 9.7 MeV [n_0, n_1]. The values of $K_y^{y'}$ are large, close to the maximum value of $\frac{2}{3}$, consistent with a model of the neutron as a simple spectator in the reaction (1976TE03). $K_y^{y'}(0^\circ)$ has also been measured for $5 < E_{\bar{d}} < 12$ MeV (1976WA1L; prelim.; n_0, n_1). Other recent measurements are those of the tensor polarization power for $E_{\bar{d}} = 9$ to 11 MeV (1977DR1F; p; prelim.) and the vector analyzing power at $E_{\bar{d}} = 11$ MeV (1976KR1B; n_0, n_1 ; prelim.). See also (1979SI07). For the earlier polarization measurements of neutrons (to $E_{\bar{d}} = 51.5$ MeV) and of protons (to $E_{\bar{d}} = 51$ MeV) see the listings in Table 14.12 (1970AJ04) and 14.17 (1976AJ04).

See also (1974LO1B, 1977HA1P, 1977SE1C, 1977SE09), (1977YO1F, 1977YO1G; applications) and (1975BO58, 1976SA04, 1978HA1Q, 1979SE04; theor.).

15. $^{12}\text{C}(d, d)^{12}\text{C}$

$$E_b = 10.27240$$

Reported resonances are displayed in Table 14.14. Yield measurements of d_0 up to $E_d = 26.5$ MeV are listed in Table 14.16 of (1976AJ04). See also (1976BO1Q: $E_d = 1.6$ to 3.0 MeV). For total cross-section measurements at $E_d = 1.55$ and 2.89 GeV/ c see (1978JA16). See also (1979DE1P).

Polarization measurements to $E_d = 51$ MeV are displayed in Table 14.17 of (1976AJ04). Recent work has been carried out at $E_d = 12.6$ MeV (1976ZA1B; d_0 ; VAP), $E_{\bar{d}} = 29.5$ MeV (1977PE07; d_0 ; VAP, TAP) and 52 MeV (1980MA10, 1976BE1U; to $^{12}\text{C}^*(0, 4.4, 9.6)$). The (d, np) processes are discussed in reaction 50 of ^{12}C in (1980AJ01), reaction 36 in ^{13}C and reaction 19 in ^{13}N . See also (1976GE20). See also (1975BO58, 1977FR12, 1978HA1Q; theor.).

16. (a) $^{12}\text{C}(\text{d}, \text{t})^{11}\text{C}$ $Q_{\text{m}} = -12.464$ $E_{\text{b}} = 10.27240$
 (b) $^{12}\text{C}(\text{d}, ^3\text{He})^{11}\text{B}$ $Q_{\text{m}} = -10.4634$

At $E_{\bar{\text{d}}} = 29$ MeV, polarizations to the ground states of ^{11}B and ^{11}C have been studied by (1978CO13). See also (1976AJ04).

17. $^{12}\text{C}(\text{d}, \alpha)^{10}\text{B}$ $Q_{\text{m}} = -1.3408$ $E_{\text{b}} = 10.27240$

Reported resonances are displayed in Table 14.14. Listings of measurements of the yields of α -groups to $E_{\bar{\text{d}}}$ to 29.5 MeV are given in Tables 14.16 (1976AJ04) and 14.11 (1970AJ04).

The major interest in this reaction has been the study of the yield of the α_2 group to the $J^{\pi} = 0^+$, isospin “forbidden” $T = 1$ state. In particular, the work of (1972SM07, 1971RI15) 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: $E_{\bar{\text{d}}} = 7.2$ 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 14.14 (1972SM07, 1974JO01). See also (1970AJ04).

Polarization measurements are reported for the $\alpha_0 \rightarrow \alpha_4$ groups at $E_{\bar{\text{d}}} = 11$ to 14 MeV (1976PE08) and 20.7 and 29 MeV (1977CO17). See also (1976KU1D), (1974LO1B) and (1977TO1E, 1978IZ02, 1979SE04; theor.).

18. (a) $^{12}\text{C}(\text{d}, ^6\text{Li})^8\text{Be}$ $Q_{\text{m}} = -5.893$ $E_{\text{b}} = 10.27240$
 (b) $^{12}\text{C}(\text{d}, ^7\text{Li})^7\text{Be}$ $Q_{\text{m}} = -17.542$

Vector analyzing power measurements have been carried out at $E_{\bar{\text{d}}} = 16$ MeV for the group to $^8\text{Be}_{\text{g.s.}}$ (1976JA1G). See also (1976JA1H) and ^7Be and ^8Be in (1979AJ01).

19. $^{12}\text{C}(\text{t}, \text{n})^{14}\text{N}$ $Q_{\text{m}} = 4.01507$

Angular distributions have been measured at $E_{\text{t}} = 1.12$ to 1.68 MeV (1971MA46: n_0, n_1, n_2) and at 8 MeV (1972CO01: to ^{14}N states with $E_{\text{x}} < 8.7$ MeV).

20. $^{12}\text{C}(^3\text{He}, \text{p})^{14}\text{N}$ $Q_{\text{m}} = 4.7788$

Observed proton groups are displayed in Table 14.15. Angular distributions have been measured for $E(^3\text{He})$ to 25.3 MeV: see (1970AJ04, 1976AJ04).

Table 14.15: Excited states of ^{14}N from $^{12}\text{C}(^3\text{He}, \text{p})^{14}\text{N}^{\text{a}}$

E_x (MeV \pm keV)		L^i	$J^\pi; T$
(1971DU03)	(1969HO23)		
	0	2	
	2.319 ± 15	0	
3.9502 ± 1.5	3.952 ± 15	0	
4.9153 ± 1.4	4.927 ± 15	1	
$\equiv 5.10587 \pm 0.18^{\text{b}}$	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	0	
6.4449 ± 1.4	6.468 ± 15	2	
7.0279 ± 1.4	7.036 ± 15	2	
7.9649 ± 1.4	7.974 ± 15	3	
	8.072 ± 15	1	
$8.4864 \pm 1.5^{\text{c}}$	8.493 ± 15	3	$4^-; 0^{\text{e,i}}$
8.6174 ± 4	8.625 ± 15	0	$(0^+; 1)^{\text{k}}$
$8.9099 \pm 1.9^{\text{d}}$	8.912 ± 15		$(3^-; 1)^{\text{k}}$
8.9598 ± 1.4			
	8.97 ± 15		
8.9773 ± 4			$(2^+; 0)^{\text{k}}$
9.1241 ± 1.5	9.126 ± 15		n
9.1674 ± 1.4	9.176 ± 15	j	$(2^+; 1)^{\text{k}}$
$9.3854 \pm 1.6^{\text{d}}$	9.389 ± 15		$2^-; 0^{\text{i,l}}$
	9.51^{e}		$(2^-; 1)^{\text{k}}$
	9.703 ± 15		$(1^+; 0)^{\text{k}}$
	$10.063 \pm 15^{\text{f}}$		$3^+, \geq 4^{\text{e}}$
	10.101 ± 15		$1^+; 2^+^{\text{e}}$
	10.23^{e}		1^{e}
	10.441 ± 15	j	$(2^+; 1)^{\text{k}}$
	10.56^{e}		$1, 2^{\text{e}}$
	10.812 ± 15		$5^+; 0^{\text{e,m}}$
	11.053 ± 15		
	11.249 ± 15		
	11.357 ± 15		

Table 14.15: Excited states of ^{14}N from $^{12}\text{C}(^3\text{He}, \text{p})^{14}\text{N}$ ^a (continued)

E_x (MeV \pm keV)		L ⁱ	$J^\pi; T$
(1971DU03)	(1969HO23)		
	11.517 \pm 15		
	g		
	12.29 \pm 15		
	12.425 \pm 15		
	12.506 \pm 15		
	12.608 \pm 15		
	12.69 \pm 15		
	12.80 \pm 15		
	12.90 \pm 25 ^h		
	13.15 \pm 40		
	14.91 \pm 60		
	15.8 \pm 200		
	17.4 \pm 200		

^a See also Tables 14.14 in (1970AJ04) and 14.18 in (1976AJ04).

^b All E_x shown by (1971DU03) are measured relative to this energy obtained by (1967CH19) from E_γ .

^c $\Gamma_p/\Gamma = 0.73 \pm 0.10$ (1974NO01).

^d The widths of $^{14}\text{N}^*(8.91, 9.39)$ are, respectively, 19.7 ± 1.9 and 15.6 ± 2.0 keV.

^e (1974NO01): from a study of decay proton correlation ($^{12}\text{C}(^3\text{He}, \text{p}')^{14}\text{N}^*(\text{p})^{13}\text{C}_{\text{g.s.}}$) with the relevant p' group.

^f $\Gamma < 10$ keV (J.W. Noe, private communication).

^g Three states at 11.66 ± 0.04 , 11.79 ± 0.11 , 11.95 ± 0.03 MeV are reported by (1968MA29).

^h This state and the states below are from (1968MA29).

ⁱ (1968MA29).

^j $\theta_p^2(l = 3) = (2.3 \pm 1.1) \times 10^{-3}$ and $< 1.6 \times 10^{-3}$ for $^{14}\text{N}^*(9.17, 10.43)$ (1974NO01).

^k Known from other data: consistent with results of (1974NO01).

^l The results of (1974NO01) are consistent with either $J^\pi = 2^-$ or 3^- for this state.

^m (1972NO08): from study of angular correlations. See also (1968MA29).

ⁿ Unresolved doublet; see reactions 22 and 27.

Extensive studies of $\text{p}'\gamma$ and $\text{p}'\text{p}$ correlations (the latter from $^{12}\text{C}(^3\text{He}, \text{p}')^{14}\text{N}^*(\text{p})^{13}\text{C}_{\text{g.s.}}$) have led to the confirmation and determination of J^π of many of the unbound states: see Tables 14.15

and 14.11: see (1970AJ04, 1976AJ04) for a fuller discussion and a listing of the relevant references. Recently (1977HE04: $E(^3\text{He}) = 11$ to 20 MeV) have studied $p'\gamma$ angular correlations involving $^{14}\text{N}^*(3.95, 5.10, 5.69, 6.21, 7.03)$. (1978MO27) find $|g| = 0.66 \pm 0.04$ for $^{14}\text{N}^*(5.11)$: τ_m for $^{14}\text{N}^*(5.11, 5.83)$ are displayed in Table 14.12. See also (1978MO1N). See also ^{15}O , (1966YO1A, 1979HA1M), (1974LO1B) and (1976EP1A; astrophys.).

$$21. \ ^{12}\text{C}(\alpha, d)^{14}\text{N} \quad Q_m = -13.57434$$

Angular distributions of deuterons corresponding to $T = 0$ states in ^{14}N have been measured at $E_\alpha = 42$ MeV: see Table 14.19 in (1976AJ04), and (1970AJ04) for a listing of the references. At $E_\alpha = 55$ MeV, d_0 and d_1 angular distributions have been studied by (1976VA07). The deuteron spectrum is dominated by very strong groups corresponding to the $(d_{5/2})^2$, $J^\pi = 5^+$ state at 8.96 MeV, and to a state at 15.1 MeV: see (1976AJ04). See also (1976BU21).

$$22. \ ^{12}\text{C}(^6\text{Li}, \alpha)^{14}\text{N} \quad Q_m = 8.7989$$

At $E(^6\text{Li}) = 20$ MeV, α groups corresponding to most of the $T = 0$ states with $E_x < 12.7$ MeV are reported: see Table 14.19 in (1976AJ04). The spectrum is dominated by the α -group corresponding to the 5^+ state at 9.0 MeV (1968ME10). Angular distributions have also been measured for $E(^6\text{Li}) = 2$ to 33 MeV [see (1970AJ04, 1976AJ04)] and at $E(^6\text{Li}) = 10.5$ to 13.75 and 20 MeV (1975SO1E, 1978SO01: $\alpha_0, \alpha_1, \alpha_2$) and $E(^6\text{Li}) = 20$ MeV (1978MA13, 1979MA1T: analyzing power, all known $T = 0$ states with $E_x < 10.9$ MeV). For the yield of the isospin “forbidden” group, α_1 , see ^{18}F in (1978AJ03, 1983AJ01). See also (1978AR01) and (1977WE08, 1978ME20; theor.).

$$23. \ ^{12}\text{C}(^9\text{Be}, ^7\text{Li})^{14}\text{N} \quad Q_m = -6.424$$

See (1976AJ04).

$$24. \ ^{12}\text{C}(^{11}\text{B}, ^9\text{Be})^{14}\text{N} \quad Q_m = -5.544$$

At $E(^{11}\text{B}) = 114$ 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 (1976AJ04).

$$25. \ ^{12}\text{C}(^{12}\text{C}, ^{10}\text{B})^{14}\text{N} \quad Q_m = -14.915$$

This reaction has been studied at $E(^{12}\text{C}) = 114$ MeV: the spectrum is dominated by $^{14}\text{N}^*(8.96)$ [$J^\pi = 5^+$] but there is substantial population also of $^{14}\text{N}^*(5.83)$ [3^-] and of a state at $E_x = 11.2$ MeV (1974AN36). Angular distributions are reported at $E(^{12}\text{C}) = 58$ to 64.5 MeV (1979CL06) and at 93.8 MeV (1979FU04).

$$26. \ ^{12}\text{C}(^{18}\text{F}, ^{16}\text{O})^{14}\text{N} \quad Q_m = 2.746$$

See (1976AJ04).

$$27. \ ^{12}\text{C}(^{20}\text{Ne}, ^{18}\text{F})^{14}\text{N} \quad Q_m = -10.779$$

See (1979ME1F).

$$28. \ (a) \ ^{13}\text{C}(p, \gamma)^{14}\text{N} \quad Q_m = 7.55063$$

$$(b) \ ^{13}\text{C}(p, p'\gamma)^{13}\text{C} \quad E_b = 7.55063$$

Observed resonances are displayed in Table 14.16. The decay schemes of various levels of ^{14}N , as derived from the γ -spectra in this and other reactions, are exhibited in Table 14.11. For τ_m see Table 14.12 and (1977BI07, 1980AN1E).

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 \cdot b (1960HE14). See also (1970AJ04). 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^π ; T to some of the lower resonances displayed in Table 14.16: for a fuller discussion and complete references see (1970AJ04, 1976AJ04) and see Table 14.11. $^{14}\text{N}^*(7.97)$: angular distribution of the γ -rays is consistent with $J^\pi = 2^-$. $^{14}\text{N}^*(8.06)$: width of resonance, isotropy of γ -rays show $l_p = 0$: $J^\pi = 1^-$ from $^{13}\text{C}(p, p)$; E1 transition to g.s. is uninhibited, e.g., $T = 1$ [but 1.4% $8.06 \rightarrow 2.3$ transition [$E_x = 2312.6 \pm 0.3$ keV] shows $T = 0$ admixture: $\alpha^2 = 0.046$]. The strong transition $8.06 \rightarrow 5.69$ [3.5%] permits either E1 or M1, $\Delta T = 1$. Since $5.69 \rightarrow 2.31$ is seen $^{14}\text{N}^*(5.69)$ cannot have $J^\pi = 0^+$, and 2^+ is excluded by the strength of the $8.62 \rightarrow 5.69$ transition. It is then $J^\pi = 1^-$; $T = 0$ [the isospin mixing $\alpha^2 = 0.09$]; $E_x = 5690.5 \pm 1.5$ keV. $^{14}\text{N}^*(8.49, 8.96, 9.12)$ correspond to anomalies in the cross section. The nature of their γ -decays [see Table 14.11] and the angular distribution leads to J^π ; $T = 4^-$; $0, 5^+$; $0, 3^+$; 0 , respectively [see (1978KE01) for a recent study of $^{14}\text{N}^*(9.13)$].

$^{14}\text{N}^*(8.62)$ [$J^\pi = 0^+$ from $^{13}\text{C}(p, p)$] shows strong transitions to $^{14}\text{N}^*(0, 3.95, 5.69)$: $T = 1$. The strength of the $8.62 \rightarrow 3.95$ decay shows it is dipole and therefore $J = 1$ for $^{14}\text{N}^*(3.95)$ [$E_x = 3947.6 \pm 0.4$ keV]. The strength of the transition $8.62 \rightarrow 6.21$ and the angular correlation $8.62 \rightarrow 6.21 \rightarrow$ g.s. is consistent with $J^\pi = 1^+$, $T = 0$ for $^{14}\text{N}^*(6.20)$ [$E_x = 6203.7 \pm 0.6$ keV]. $^{14}\text{N}^*(8.79)$ [$J^\pi = 0^-$ from $^{13}\text{C}(p, p)$] has a large Γ_γ consistent with E1 and $T = 1$. $^{14}\text{N}^*(9.17)$: angular correlation and angular distribution measurements indicate $J^\pi = 2^+$ for that state, 3^- for $^{14}\text{N}^*(6.44)$ [see, however, Table 14.10] and $J = 2$ for $^{14}\text{N}^*(7.03)$.

Table 14.16: Levels of ^{14}N from $^{13}\text{C}(p, \gamma)^{14}\text{N}$ and $^{13}\text{C}(p, p)^{13}\text{C}$ ^a

E_p (MeV \pm keV)	$\Gamma_{\text{c.m.}}$ (keV)	l_p	$\omega\Gamma_\gamma$ (eV)	$J^\pi; T$	$^{14}\text{N}^*$ (MeV)	Refs.
0.4485 \pm 0.5	< 0.37	2	0.022	2 ⁻	7.9669	A
0.551 \pm 1	30 \pm 1	0	9.2	1 ⁻ ; 1	8.062	A
1.012 \pm 2	\leq 0.2	4	\approx 0.01	(4 ⁻); 0	8.490	A, (1978KE03)
1.150 \pm 2	7 \pm 1	1	1.3	0 ⁺ ; 1	8.618	A
1.34 \pm 50	\approx 460	0	12.8	0 ⁻ ; 1	8.79	A
1.462 \pm 3	16 \pm 2	2	0.72	3 ⁻ ; 1	8.907	A
1.523 \pm 2	< 1		\approx 0.003	5 ⁺ ; 0	8.964	A, (1978KE03)
1.540 \pm 3	8 \pm 2	1, (3)	0.13	2 ⁺	8.980	A
1.7005 \pm 1	< 1		^a	3 ⁺ ; 0	9.1287	A, (1978KE01, 1978KE03)
1.7476 \pm 0.9	0.07 \pm 0.05		14.8	2 ⁺ ; 1	9.1724	A, (1976SI07)
1.980 \pm 3	13 \pm 3	2		3 ⁻ , 2 ⁻	9.388	A
2.110 \pm 3	41 \pm 2	2	6.2	2 ⁻ ; 1	9.509	A
2.319 \pm 4	15 \pm 3	1		1 ⁺	9.703	A
2.743 ^b	5	1	^c	1 ⁺ , (2 ⁺)	10.096	A
2.885 \pm 10 ^b	80 \pm 15	0, 2		1 ⁽⁻⁾ ; 0	10.228	A
3.105 \pm 7 ^b	33 \pm 3	1	17	2 ⁺ ; 1	10.432	A
3.20 ^b	140	0, 2		1 ⁻	10.52	(1961KA04)
3.72 \pm 30 ^d	165 \pm 30				11.00	(1971RI13)
3.771 \pm 5	1.2 \pm 0.4		ⁱ	3 ⁺	11.050	(1971RI13, 1980RA06)
3.79	100			1 ⁺	11.07	A
3.94 \pm 30 ^e	220 \pm 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 \pm 15 ^f	115 \pm 10		^j	1 ⁺	11.750	A, (1971RI13)
5.325 \pm 10	48 \pm 7		^k		12.492	(1971RI13)
5.88 \pm 20 ^d	120 \pm 30				13.01	(1971RI13)
6.20 \pm 100 ^g	1000 \pm 150		^l	(2 ⁻); 1	13.30	(1971RI13)
6.62 \pm 20 ^d					13.69	(1971RI13)
^h						

Table 14.16: Levels of ^{14}N from $^{13}\text{C}(p, \gamma)^{14}\text{N}$ and $^{13}\text{C}(p, p)^{13}\text{C}$ ^a (continued)

E_p (MeV \pm keV)	$\Gamma_{\text{c.m.}}$ (keV)	l_p	$\omega\Gamma_\gamma$ (eV)	$J^\pi; T$	$^{14}\text{N}^*$ (MeV)	Refs.
16.1				$2^-; 1$	22.5	(1971RI13, 1980TU01)
16.7				$2^-; 1$	23.0	(1971RI13, 1980TU01)

A: See references for this state quoted in Table 14.16 in (1970AJ04) and 14.20 in (1976AJ04).

^a See also Table 14.11.

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

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

^d Weak resonance.

^e See also Table 14.16 in (1970AJ04).

^f In the $\gamma_{3.09}$ channel the peak occurs 55 keV higher (1971RI13); interference effects may be present.

^g Part of the giant dipole resonance.

^h Some broad structures are evident in the γ_0 , $\gamma_{3.68}$ and $\gamma_{3.85}$ yields (1971RI13) and in the γ_0 yield (1980TU01).

See also reaction 31.

ⁱ $\Gamma_\gamma = 1.2 \pm 0.4$ keV (1980RA06); $\Gamma_p = 0.5\%$ of single particle unit. J^π based on angular distribution of γ_0 .

For nature of γ -decay see Table 14.11.

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

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

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

The angular distribution of the γ -rays from $10.23 \rightarrow 2.31$ is consistent with $J^\pi = 1^+$ for $^{14}\text{N}^*(10.23)$: $T = 0$ from $M^2(M1)$ [see, however, Table 14.10]. The γ_0 angular distribution is consistent with $J = 2$ for $^{14}\text{N}^*(10.43)$: the similar decay characteristics of this state and of $^{14}\text{N}^*(9.17)$ suggest that they are both $J^\pi = 2^+$, $T = 1$.

Below $E_p = 5.5$ MeV only γ_0 can be observed in the capture radiation. (1971RI13) have observed a number of resonances in the γ_0 yield and in the yield of the ground state γ -rays from $^{13}\text{C}^*(3.09, 3.68, 3.85)$: these are shown in Table 14.16 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 find 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 from $E_x = 23$ and 26 MeV, respectively, to $E_x = 33$ MeV (1975PA18). A recent study of the 90° yield of γ_0 and γ_1

[and of analyzing powers] has been reported for $E_{\bar{p}} = 6.25$ to 17.0 MeV by (1980TU01). The γ_0 results are in good agreement with those of (1974BA37) in the inverse reaction [$^{14}\text{N}(\gamma, \text{p})^{13}\text{C}$]. Broad structures are observed at $E_{\text{p}} \approx 8, 13, 14, 15$ and 16.5 MeV. The γ_1 results indicate that the $T = 0$ strength is spread out fairly uniformly between $E_{\text{x}} = 13$ and 23 MeV (1980TU01). At $E_{\text{p}} = 25$ MeV strong transitions are observed to two groups of states centered near $E_{\text{x}} = 5.8$ and 8.9 MeV (1980MA1E).

See also (1966YO1A, 1976KR1A, 1979TR1G) and (1975ZI1A, 1976BR1H; astrophys.).

29. $^{13}\text{C}(\text{p}, \text{p})^{13}\text{C}$

$E_{\text{b}} = 7.55063$

The elastic scattering has been studied for $E_{\text{p}} = 0.14$ MeV to 11 MeV: see (1970AJ04, 1976AJ04). For observed resonances see Table 14.16; for angular distributions see ^{13}C . The yields of p_0 at eight angles (and the analyzing power) have been measured for $E_{\bar{p}} = 9.1$ to 18.4 MeV. A phase shift analysis implies the existence of resonances with $J^{\pi} = 1^{-}, 2^{-}$ and 3^{+} in the vicinity of $E_{\text{p}} \approx 15$ MeV. The 1^{-} and 2^{-} resonances have widths of $\approx 3 - 4$ MeV and have a total Γ_{p}/Γ value of 0.1 . The correlation between these resonances and the GDR is not clear. There is no indication of the $T = 2$ states previously reported in reaction 30 (1978WE13). For other polarization measurements see (1976AJ04) and (1976TR1C). See also (1978DW1A; astrophys.).

30. $^{13}\text{C}(\text{p}, \text{n})^{13}\text{N}$

$Q_{\text{m}} = -3.0030$

$E_{\text{b}} = 7.55063$

The yield of neutrons has been measured from threshold to $E_{\text{p}} = 13.7$ MeV: see (1970AJ04). Observed resonances are displayed in Table 14.17. The ratio of the reaction cross section at $E_{\text{p}} = 22.8$ 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). The 0° polarization transfer coefficients have been measured for $E_{\bar{p}} = 7.9$ to 14.6 MeV (1976LI08). For other polarization measurements see (1965WA02; n_0 ; $E_{\text{p}} = 6.9$ to 12.3 MeV) and (1979CL1C; 6 MeV). See also (1979BY1C), (1974LO1B, 1976WA1B, 1979BY1B) and ^{13}N .

31. $^{13}\text{C}(\text{p}, \text{d})^{12}\text{C}$

$Q_{\text{m}} = -2.7218$

$E_{\text{b}} = 7.55063$

Analyzing power measurements for $^{12}\text{C}^*(0, 12.71, 15.11, 16.11)$ have been measured at $E_{\bar{p}} = 65$ MeV (1979HO1H) and those for $^{12}\text{C}^*(0, 4.4)$ are reported at $E_{\bar{p}} = 200$ MeV (1979CA1A). See also (1976AJ04), ^{12}C in (1980AJ01) and (1980MC1C, 1980WH1A).

Table 14.17: Resonances in $^{13}\text{C}(p, n)^{13}\text{N}$
(1961DA09)^a

E_p (MeV)	Γ (keV)	$^{14}\text{N}^*$ (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).

32. (a) $^{13}\text{C}(\text{p}, \text{t})^{11}\text{C}$ $Q_{\text{m}} = -15.186$ $E_{\text{b}} = 7.55063$
 (b) $^{13}\text{C}(\text{p}, ^3\text{He})^{11}\text{B}$ $Q_{\text{m}} = -13.1851$

At $E_{\text{p}} = 49.6$ MeV polarization measurements have been carried out for the tritons and ^3He ions to the mirror groups $^{11}\text{B}^*(0, 2.12, 4.45, 5.02, 6.74, 12.91)$ and $^{11}\text{C}^*(0, 2.00, 4.32, 4.80, 6.48, 12.50)$ (1974MA12). See also (1976AJ04) and ^{11}B , ^{11}C in (1980AJ01).

33. $^{13}\text{C}(\text{p}, \alpha)^{10}\text{B}$ $Q_{\text{m}} = -4.0626$ $E_{\text{b}} = 7.55063$

Excitation functions have been measured from $E_{\text{p}} = 5.5$ (α_0), 6.0 (α_1), 7.0 (α_2), 8.0 (α_3), 10 (α_4), 11 (α to $^{10}\text{B}^*(5.11)$) to 18 MeV. Total cross sections have also been obtained for the production of ^6Li , ^9Be and ^{10}B : the latter shows a great deal of structure. The consequences for astrophysical problems are discussed by (1975OB01). The analyzing power for the α_0 group has been measured at $E_{\text{p}} = 65$ MeV by (1980KA03). See also ^{10}B in (1979AJ01).

34. $^{13}\text{C}(\text{d}, \text{n})^{14}\text{N}$ $Q_{\text{m}} = 5.3260$

Observed neutron groups are displayed in Table 14.18. Angular distributions have been reported at many energies up to $E_{\text{d}} = 12$ MeV: see (1970AJ04) and Table 14.18. Comparisons of relative spectroscopic factors obtained in this reaction and in reaction 35 are shown in Table 14.23 of (1976AJ04): it appears that S_{rel} for $^{14}\text{N}^*(2.31)$ [$T = 1$] is smaller in this reaction than in the (^3He , 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 appear to be energy dependent: see Table 14.23 (1976AJ04). See also ^{15}N and (1976FOZW).

35. $^{13}\text{C}(^3\text{He}, \text{d})^{14}\text{N}$ $Q_{\text{m}} = 2.0571$

Angular distributions have been studied at $E(^3\text{He}) = 13$ to 17 MeV [see (1976AJ04) and Table 14.18]. At $E(^3\text{He}) = 13$ MeV the angular distributions of deuterons and singlet deuterons to $^{14}\text{N}^*(0, 2.31, 3.95)$ have been investigated by (1976JA14): the relative spectroscopic factors for these three states are 1.0, 1.50, 0.43 for deuterons and 1.0, 1.57, 0.41 for singlet deuterons. Spectroscopic factors for these and other states of ^{14}N observed in this reaction and in reaction 34 are displayed in Table 14.23 of (1976AJ04). At $E(^3\text{He}) = 43.6$ MeV $^{14}\text{N}^*(8.91, 9.51)$ are strongly populated while $^{14}\text{N}^*(8.49, 9.13, 9.39)$ are weakly excited. The $d_{5/2}$ transfer to $T = 0$ states is concentrated in the transitions to $^{14}\text{N}^*(5.11, 5.83)$ (1980HA1E). See also (1979MA2K; theor.).

Table 14.18: ^{14}N levels from $^{13}\text{C}(\text{d}, \text{n})^{14}\text{N}$ and $^{13}\text{C}(\text{}^3\text{He}, \text{d})^{14}\text{N}$

$^{14}\text{N}^*$ (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
8.06	$1^-; 1$	0 ^e	
8.49	$4^-; 0$	(3, 4) ^b	4 ^h
8.62	$0^+; 1$	0 ^f , 1 ^k	1 ⁱ
8.91	$3^-; 1$	2 ^{c,k}	2 ^j
8.98	$2^+; (0)$	(1, 2, 3)	
9.13	$2^-; 0$	2 ^k	1
9.17	$2^+; 1$	(1, 3) ^k	
9.39	$2^-, 3^-; 0$	2 ^k	1
9.51	$2^-; 1$	2 ^k	1
9.70	$1^+; 0$	1 ^k	

^a $^{13}\text{C}(\text{d}, \text{n})^{14}\text{N}$: $E_d = 5.5$ and 6 MeV (1966FU10), 4.5 , 5.0 and 5.5 MeV (1973BO10), 6.5 MeV (1975BO35).

^b $^{13}\text{C}(\text{}^3\text{He}, \text{d})^{14}\text{N}$: $E(\text{}^3\text{He}) = 15$ 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 The width obtained for this state in $^{13}\text{C}(\text{p}, \gamma)$: $(2J + 1)\Gamma_p = 12.6 \pm 3.6$ eV implies $l_p = 2$ and therefore odd parity: Γ_p is then 2.5 ± 0.07 eV, based on $J = 2$ (1972BA56).

^h $\Gamma_p < 9.9 \times 10^{-2}$ eV (1971FO05).

ⁱ $\Gamma_p < 18$ keV (1971FO05).

^j $\Gamma_p = 12.1$ keV (1971FO05).

^k (1975BO35).

^l Observed (1980HA1E).

36. $^{13}\text{C}(\alpha, t)^{14}\text{N}$ $Q_m = -12.2634$

Angular distributions have been measured at $E_\alpha = 27$ MeV for the α groups to $^{14}\text{N}^*(0, 2.31, 3.95, 4.92, 5.11)$. See also (1976AJ04), (1976LE1K) and (1978ZE03, 1980ZE05; theor.).

37. $^{13}\text{C}(^7\text{Li}, ^6\text{He})^{14}\text{N}$ $Q_m = -2.424$

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

38. $^{13}\text{C}(^{11}\text{B}, ^{10}\text{Be})^{14}\text{N}$ $Q_m = -3.678$

See (1976AJ04).

39. $^{14}\text{C}(\beta^-)^{14}\text{N}$ $Q_m = 0.15648$

See ^{14}C .

40. $^{14}\text{C}(p, n)^{14}\text{N}$ $Q_m = -0.6259$

Angular distributions have been obtained for the n_0, n_1 and n_2 groups in the range $E_p = 6$ to 14 MeV [see (1976AJ04)] and at $E_p = 2.45$ MeV (1977NI03; n_0) and 35 MeV (1979DO14; n_0, n_2). DWBA analysis of the latter results favors the inclusion of an isovector tensor interaction in the transition to $^{14}\text{N}_{g.s.}$ (1979DO14). See also ^{15}N .

41. $^{14}\text{C}(^3\text{He}, t)^{14}\text{N}$ $Q_m = 0.1379$

At $E(^3\text{He}) = 44.8$ MeV, triton groups are observed corresponding to all known levels of ^{14}N with $E_x < 7.1$ MeV. Triton groups were also seen to unresolved states with $E_x = 8.0 \rightarrow 9.5$ MeV, to $^{14}\text{N}^*(10.43)$ and to excited states with $E_x = 12.49 \pm 0.04, 12.83 \pm 0.05$ 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 $^{14}\text{N}^*(2.31, 3.95, 13.7)$, $L = 1$ to $^{14}\text{N}^*(5.11)$, $L = 2$ to $^{14}\text{N}^*(0, 7.03, 10.43)$ and $L = 3$ to $^{14}\text{N}^*(5.83)$ (1969BA06). See also reaction 50.

42. (a) $^{14}\text{C}(^6\text{Li}, ^6\text{He})^{14}\text{N}$ $Q_m = -3.350$
 (b) $^{14}\text{C}(^{14}\text{C}, ^{14}\text{B})^{14}\text{N}$ $Q_m = -20.47$
 (c) $^{14}\text{C}(^{18}\text{O}, ^{18}\text{N})^{14}\text{N}$ $Q_m = -13.90$

Angular distributions have been studied at $E(^6\text{Li}) = 62$ MeV for the transitions to $^{14}\text{N}^*(0, 3.95, 6.20, 7.03)$: the $L = 0$ transition to $^{14}\text{N}^*(3.95)$ carries at least 90% of the GT strength (1976GO25). For reactions (b) and (c) see (1980NA14).

43. (a) $^{14}\text{N}(\gamma, n)^{13}\text{N}$ $Q_m = -10.554$
 (b) $^{14}\text{N}(\gamma, p)^{13}\text{C}$ $Q_m = -7.55063$
 (c) $^{14}\text{N}(\gamma, d)^{12}\text{C}$ $Q_m = -10.27240$
 (d) $^{14}\text{N}(\gamma, 2n)^{12}\text{N}$ $Q_m = -30.617$

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, 1976BE1H: monoenergetic photons) and (1980JU02). Maxima reported in other experiments and “breaks” in the (γ, n) activation curve are listed in (1970AJ04). Most of the photon absorption in the giant resonance region forms $J^\pi = 2^-$ states in ^{14}N which decay by d-wave neutron emission to $^{13}\text{N}_{\text{g.s.}}$. Some evidence is found for the existence of $J^\pi = 0^-$ strength at the peak of the giant resonance. Some evidence exists for a small amount of isospin $T = 0$ mixing near 22.5 MeV (1980JU02).

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 $^{13}\text{C}^*(3.68)$ carry $\approx 90\%$ 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). See also reaction 30.

For reaction (c) see (1977TA1B); for reaction (d) see (1979WI1A). For spallation reactions see (1970AJ04) and (1976TU05, 1978DI1A). See also (1974BU1A, 1977DA1B) and (1979ME1E, 1980ME12; theor.).

44. $^{14}\text{N}(\gamma, \gamma)^{14}\text{N}$

Table 14.19: Gamma widths ^a of some unbound levels of ¹⁴N from ¹⁴N(γ , γ') and ¹⁴N(e, e')

E_x (MeV)	$J^\pi; T$	Γ_{γ_0} (eV)	Mult.	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	$2^+; 1$	7.7 ± 0.9	M1	(e, e)	(1968CL05)
		6.6 ± 1.3^A		(e, e)	(1979EN01)
10.43	$2^+; 1$	12.1 ± 1.5	M1	(e, e)	(1968CL05)
		9.6 ± 1.9^A			(1979EN01)
12.54 ± 0.1	$J = 0, 1, 2, 3$	$\frac{14.7 \pm 3.2}{2J+1}$	(M1, E2)	(e, e)	(1979EN01)
13.27 ± 0.1	$J = 0, 1, 2, 3$		(M1, M2, E2)	(e, e)	(1979EN01)
13.76 ± 0.1	$J = 0, 1, 2$	^b	(M1, E1)	(e, e)	(1979EN01)
16.11 ± 0.1	$J = 0, 1, 2, 3$		(M2)	(e, e)	(1979EN01)

A = Adopted.

^a See also Tables 14.11, 14.12 and 14.16, and Table 14.24 in (1976AJ04).

^b See also (1977FR1M).

See (1976AJ04) and Table 14.19.

45. (a) ¹⁴N(e, e')¹⁴N

(b) ¹⁴N(e, ep)¹³C $Q_m = -7.55063$

The r.m.s. radius of ¹⁴N is 2.54 ± 0.02 fm: see (1976AJ04). Form factors have been determined at $E_e = 60.7$ to 122.0 MeV for ¹⁴N*(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). E.K. Warburton (private communication) calculates 8.7 ± 0.9 fsec for the τ_m of ¹⁴N*(3.95), on the basis of (1974EN01), the branching ratios of Table 14.11, and the $\delta(E2/M1)$ of (1967OL02). Inelastic scattering (at $\theta = 180^\circ$) gives evidence for the excitation of states with $E_x = 8.91$ to 16.11 MeV: see Table 14.19. See also Table 14.11.

See also (1977FR1M, 1978VO12), (1977RI1H) and (1976BH1B, 1978FU13, 1979DO1P, 1979DO17, 1979KI1K, 1980ER01; theor.). For reaction (b) see (1978DE32).

46. ¹⁴N(n, n')¹⁴N*

Angular distributions of elastically and inelastically scattered neutrons are displayed in Table 14.23 of (1970AJ04). See also (1975BE1Y, 1978BE2B). Observed γ -rays are shown in Table 14.25 of (1976AJ04). See also (1979SO1B; applied).

47. (a) $^{14}\text{N}(p, p')^{14}\text{N}^*$
 (b) $^{14}\text{N}(p, 2p)^{13}\text{C}$ $Q_m = -7.55063$
 (c) $^{14}\text{N}(p, pd)^{12}\text{C}$ $Q_m = -10.27240$

Angular distributions of elastically and inelastically scattered protons have been studied at a number of energies up to $E_p = 155$ MeV: see Tables 14.23 in (1970AJ04) and 14.26 in (1976AJ04) and (1977SA1B; p_0 ; $E_p = 5.85$ MeV), (1979AO02; p_0, p_1 ; 21 MeV; pol.), (1980FO05; p_0, p_1, p_2 and see Table 14.20; 29.8, 36.6 and 40.0 MeV), (1980FA07; p_0 ; 35.2 MeV), (1980CO05; p_0, p_1, p_2 ; 122 MeV) and (1980MO01; p_0 ; 144 MeV).

(1980FO05) have analyzed angular distributions to $^{14}\text{N}^*(2.31)$ with a microscopic model DWA which included contributions from the knock-on exchange amplitude and from central, tensor and spin-orbit forces. The first were fairly satisfactory. The extracted strengths of the tensor force were 20 – 75% larger than estimates based on the one-pion-exchange potential (1980FO05). See also (1976AJ04).

Observed inelastic groups are exhibited in Table 14.20. At $E_p = 800$ MeV, the spectra are dominated by the groups to $^{14}\text{N}^*(9.17, 10.43)$ [$J^\pi = 2^+$] (1979MO1E; prelim.).

For reaction (b) see (1976AJ04). For reaction (c) see (1970AJ04). See also (1977BA85), (1979RA1C; astrophys.), (1976DO12, 1977GA22, 1978GO1L, 1978MA34, 1979KI10, 1979MA20; theor.) and ^{15}O .

48. $^{14}\text{N}(d, d')^{14}\text{N}^*$

Angular distributions of elastically and inelastically scattered deuterons have been studied for $E_d = 52$ MeV: see Table 14.23 in (1970AJ04), (1976AJ04), (1980KR01; d_0 ; $E_{\bar{d}} = 10$ MeV), and (1976AO01, 1979AO01; d_0, d_1, d_2 ; $E_d = 10.0, 11.7, 14.8, 17.9$ MeV). Inelastic groups are displayed in Table 14.20. The deuteron group to the $0^+, T = 1$ state $^{14}\text{N}^*(2.31)$ is isospin forbidden: its cross section is 1 – 2 orders of magnitude less than that to $^{14}\text{N}^*(3.95)$ [$J^\pi; T = 1^+; 0$]. It is summarized for $E_d = 6$ to 20 MeV by (1979AO01) who find that the observed isospin violation is well accounted for by a direct multistep reaction mechanism which assumes that there is isospin mixing in the intermediate channels. See also (1976AJ04), ^{16}O in (1977AJ02, 1982AJ01) and (1977IZ01, 1977IZ1B, 1978MA34; theor.).

49. $^{14}\text{N}(t, t)^{14}\text{N}$

Table 14.20: ^{14}N levels from $^{14}\text{N}(p, p')$, (d, d') , $(^3\text{He}, ^3\text{He}')$ and (α, α')

$^{14}\text{N}^*(\text{MeV} \pm \text{keV})$				L^e	Dominant config. ⁿ	$J^\pi; T$
(p, p') ^a	(d, d')	$(^3\text{He}, ^3\text{He}')$	(α, α')			
2.31	see text	c	see text		$(p_{\frac{1}{2}})^2$	$0^+; 1$
3.95	b	c	e	2	$(p_{\frac{1}{2}})^2 + \text{c.e.}^h$	$1^+; 0$
4.91	b	c	e	1, 3	$p_{\frac{1}{2}}s_{\frac{1}{2}}$	$0^-; 0$
5.11	b	c	e	1, 3	$p_{\frac{1}{2}}d_{\frac{5}{2}}$	$2^-; 0$
5.69	b	c	e	1, 3	$p_{\frac{1}{2}}s_{\frac{1}{2}}$	$1^-; 0$
5.83	b	c	e	1, 3	$p_{\frac{1}{2}}d_{\frac{5}{2}}$	$3^-; 0$
6.20	b	c	e,f		$(s_{\frac{1}{2}})^2$	$1^+; 0$
6.44	b		e,f		$s_{\frac{1}{2}}d_{\frac{5}{2}}$	$3^+; 0$
7.03	b	c	e	2	c.e. ^h	$2^+; 0$
7.97					$p_{\frac{1}{2}}d_{\frac{3}{2}}$	$2^-; 0$
8.06		8.0 \rightarrow 11.0 ^d			$p_{\frac{1}{2}}s_{\frac{1}{2}}$	$1^-; 1$
8.49						$4^-; 1$
8.62					$(s_{\frac{1}{2}})^2$	$0^+; 1$
8.91					$p_{\frac{1}{2}}d_{\frac{5}{2}}$	$3^-; 0$
9.17					c.e. ^h	$2^+; 1$
9.39						$2^-, 3^-; 0$
9.51					$p_{\frac{1}{2}}d_{\frac{5}{2}}$	$1^+; 0$
9.70					$(p_{\frac{1}{2}})^2$	$1^+; 0$
10.1					$s_{\frac{1}{2}}d_{\frac{5}{2}}$	$2^+, 1^+; 0$
11.2 ± 200	f,g	11.22 ± 50^c				
12.8 ± 400	f,g	12.77 ± 50^c				
17						
21.5						

^a For references see Table 14.27 in (1976AJ04). Angular distributions are reported at $E_p = 29.8$ MeV to all the states with $E_x \leq 8.49$ MeV (1980FO05).

^b Observed: see (1970AJ04).

^c Observed: see (1969BA06).

^d Unresolved structure.

^e (1966HA19).

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

^g (1971CU01): pp' .

^h c.e. = compound elastic.

See (1976AJ04).

50. $^{14}\text{N}(^3\text{He}, ^3\text{He}')^{14}\text{N}^*$

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

At $E(^3\text{He}) = 44.6$ MeV, twelve ^3He groups are reported corresponding to states in ^{14}N : see Table 14.20 (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 $^{14}\text{N}(^3\text{He}, t)^{14}\text{O}_{\text{g.s.}}$, $^{14}\text{N}(^3\text{He}, ^3\text{He}')^{14}\text{N}^*(2.31)$ and $^{14}\text{C}(^3\text{He}, t)^{14}\text{N}(0)$ [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).

51. (a) $^{14}\text{N}(\alpha, \alpha')^{14}\text{N}^*$

(b) $^{14}\text{N}(\alpha, ^8\text{Be})^{10}\text{B}$ $Q_{\text{m}} = -11.7051$

Angular distributions of elastically and inelastically scattered α -particles have been measured for $E_{\alpha} = 7.6$ to 104 MeV: see Table 14.23 in (1970AJ04) and (1976AJ04), (1974CH1T, 1976CH24; α_1 ; $E_{\alpha} = 7.6$ to 16.9 MeV), (1977EN01; α_0 ; 19.8 to 23.1 MeV) and (1976FE12; α_0 , $\alpha_{2 \rightarrow 4}$, α_{5+6} , α_{7+8} , α_9 , α_{10} ; 23.7 MeV). Table 14.20 displays the observed α -groups. Generally the intensity of the α_1 group is weak: see (1976CH24) and ^{18}F in (1978AJ03, 1983AJ01). See also (1976YO02). (1976WO11) find $S_{\alpha} = 0.75$ for $^{14}\text{N}_{\text{g.s.}}$. See also (1977KN1E), (1976HA1Q, 1977MA2E, 1979KN1F), (1979RA1C; astrophys.) and (1977DM1A; theor.).

52. (a) $^{14}\text{N}(^6\text{Li}, ^6\text{Li})^{14}\text{N}$

(b) $^{14}\text{N}(^7\text{Li}, ^7\text{Li})^{14}\text{N}$

Elastic angular distributions have been measured at $E(^6\text{Li}) = 19.5$ MeV (1977KU06) and 32 MeV (1971GR44) and at $E(^7\text{Li}) = 36$ MeV (1976CO23).

53. $^{14}\text{N}(^9\text{Be}, ^9\text{Be})^{14}\text{N}$

See ^9Be in (1974AJ01).

54. (a) $^{14}\text{N}(^{10}\text{B}, ^{10}\text{B})^{14}\text{N}$
 (b) $^{14}\text{N}(^{11}\text{B}, ^{11}\text{B})^{14}\text{N}$

Elastic angular distributions (reaction (a)) have been measured at $E(^{10}\text{B}) = 100$ MeV (1975NA15) and $E(^{14}\text{N}) = 73.9$ and 93.6 MeV (1977MO1A, 1979MO14). The elastic distributions (reaction (b)) have been studied at $E(^{14}\text{N}) = 41, 77$ and 113 MeV (1971LI11). For fusion cross sections see (1977HI01, 1978KO1J, 1978WU1C, 1980OR1C). See also (1978TA1B).

55. $^{14}\text{N}(^{12}\text{C}, ^{12}\text{C})^{14}\text{N}$

Elastic angular distributions have been measured in the range $E(^{14}\text{N}) = 21.3$ to 155 MeV: see (1976AJ04). More recently studies are reported at $E(^{14}\text{N}) = 37, 47$ and 58.3 MeV (1978CO20), 53 MeV (1976ZE04) and 78.8 MeV (1977MO1A, 1979MO14). At $E(^{14}\text{N}) = 155$ MeV the selective population of certain ^{14}N states is observed and angular distributions are reported for the transitions to $^{14}\text{N}^*(0, 8.96, 12.7)$ (1975NA11).

For fusion cross section measurements see (1976ST12, 1977SW02, 1979GO09, 1979GO11, 1979KO20, 1980WI09) and (1976AJ04). See also (1978DA1E, 1978HA1F), (1976LE1F, 1978TS04, 1979GO1R, 1979NA1G, 1980TA1B), (1978RO1D; astrophys.) and (1976AM01, 1977BA3E, 1977MA11, 1978AV1A, 1978CU1C, 1978CU1E, 1978CU06, 1978FR1N, 1978HO13, 1978KA14, 1978VA1A, 1979MO1J, 1979NA03, 1980LE11, 1980LO02, 1980VA03; theor.).

56. (a) $^{14}\text{N}(^{13}\text{C}, ^{13}\text{C})^{14}\text{N}$
 (b) $^{14}\text{N}(^{14}\text{C}, ^{14}\text{C})^{14}\text{N}$

The elastic angular distribution (reaction (a)) has been measured at $E(^{14}\text{N}) = 19.3$ MeV (1971VO01). For a fusion study see (1980WI09). For reaction (b) see (1976AJ04).

57. $^{14}\text{N}(^{14}\text{N}, ^{14}\text{N})^{14}\text{N}$

Elastic angular distributions have been studied for $E(^{14}\text{N}) = 4.99$ to 20.22 MeV (1969JA15). For fusion cross section measurements see (1976ST12, 1976SW02). See also (1976AJ04), (1978RO1D; astrophys.) and (1976RU1B, 1978AV1A, 1979HU1B; theor.).

58. $^{14}\text{N}(^{16}\text{O}, ^{16}\text{O})^{14}\text{N}$

Elastic angular distributions have been measured for $E(^{14}\text{N}) = 8.08$ to 155 MeV: see (1976AJ04). Recent work is reported at $E(^{14}\text{N}) = 76.2$ MeV (1979MO14, 1977MO1A) and 155 MeV (1977TO02: see also ^{16}O in (1982AJ01)). For fusion cross section measurements see (1976ST12, 1977SW02, 1977VO08). See also (1976AJ04) and (1978AV1A, 1978VA1A; theor.).

59. $^{14}\text{N}(^{19}\text{F}, ^{19}\text{F})^{14}\text{N}$

The elastic scattering has been studied at $E(^{14}\text{N}) = 19.5$ MeV (1977KU06).

60. (a) $^{14}\text{N}(^{24}\text{Mg}, ^{24}\text{Mg})^{14}\text{N}$

(b) $^{14}\text{N}(^{27}\text{Al}, ^{27}\text{Al})^{14}\text{N}$

(c) $^{14}\text{N}(^{28}\text{Si}, ^{28}\text{Si})^{14}\text{N}$

(d) $^{14}\text{N}(^{29}\text{Si}, ^{29}\text{Si})^{14}\text{N}$

For reactions (a, b, c) see (1977TH1G). For reactions (b, c) see (1971KO11: $E(^{14}\text{N}) = 65, 84$ and 88 MeV). For reaction (c) see (1977EC04: $E(^{14}\text{N}) = 27, 30$ and 33 MeV). For reaction (d) see (1978PE13: $E(^{14}\text{N}) = 39$ MeV). See also (1977SC1G, 1980TA1B) and (1979KA27; theor.).

61. (a) $^{14}\text{N}(^{39}\text{K}, ^{39}\text{K})^{14}\text{N}$

(b) $^{14}\text{N}(^{40}\text{Ca}, ^{40}\text{Ca})^{14}\text{N}$

(c) $^{14}\text{N}(^{48}\text{Ca}, ^{48}\text{Ca})^{14}\text{N}$

For reaction (a) see (1978BA26; theor.). For reaction (b) see (1978BU10), (1978HO1C) and (1979SA27; theor.). For reaction (c) see (1978HO1C).

62. $^{15}\text{N}(\gamma, n)^{14}\text{N}$ $Q_m = -10.8334$

Cross sections (integrated to 35 MeV) have been measured for the transitions to $^{14}\text{N}^*(2.31, 3.95, 5.11 + 5.83, 7.03)$ (1976PA22). See also ^{15}N .

63. $^{15}\text{N}(p, d)^{14}\text{N}$ $Q_m = -8.6087$

Angular distributions have been obtained for the deuterons corresponding to $^{14}\text{N}^*(0 \rightarrow 8.06, 8.62, 8.91, 8.96 + 8.98, 9.17 \rightarrow 10.43, 10.81, 11.05, 11.24 + 11.29, 11.36 \rightarrow 11.66, 11.75, 11.95, 12.20, 12.50, 12.61, 12.79 + 12.82, 13.17 + 13.24, 13.71 + 13.72)$ (1969SN04: $E_p = 39.8$ MeV). Spectroscopic factors were extracted by DWBA analysis of the $l_n = 1$ pickup angular distributions (1969SN04). See also (1976AJ04).

$$64. \ ^{15}\text{N}(^3\text{He}, \alpha)^{14}\text{N} \quad Q_m = 9.7445$$

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

$$65. \ ^{15}\text{N}(^{13}\text{C}, ^{14}\text{C})^{14}\text{N} \quad Q_m = -2.6568$$

At $E(^{15}\text{N}) = 30, 32$ and 45 MeV the angular distributions involving $^{14}\text{N}^*(0, 2.31)$ have been studied: they are symmetric about 90° for the transition to the $T = 1$ analog state $^{14}\text{N}^*(2.31)$ (1975GA17, 1976GA37).

$$66. \ ^{16}\text{O}(\pi^-, 2n)^{14}\text{N} \quad Q_m = 155.824$$

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

$$67. \ (a) \ ^{16}\text{O}(\gamma, d)^{14}\text{N} \quad Q_m = -20.7363$$

$$(b) \ ^{16}\text{O}(p, pd)^{14}\text{N} \quad Q_m = -20.7363$$

For reaction (a) see (1979WIZW) and ^{16}O in (1982AJ01). At $E_p = 75$ MeV, angular distributions to $^{14}\text{N}^*(0, 3.95)$ have been studied by (1977GR04); $^{14}\text{N}^*(2.31)$ is also populated. See also (1976GO1E).

$$68. \ ^{16}\text{O}(p, ^3\text{He})^{14}\text{N} \quad Q_m = -15.2428$$

Angular distributions have been measured in the range $E_p = 27$ to 54.1 MeV: see (1976AJ04) and at $E_p = 27.0$ to 30.7 MeV (1978GO04; to $^{14}\text{N}^*(2.31)$). A number of comparisons have been made of the ratio of (p, ^3He) to the $T = 1$ state at 2.31 MeV and of (p, t) to the analog ground state of ^{14}O : see e.g. (1978GO04). See also ^{17}F in (1982AJ01) and (1976DA1K).

69. $^{16}\text{O}(\text{d}, \alpha)^{14}\text{N}$

$$Q_m = 3.1104$$

Angular distributions have been measured at many energies up to $E_d = 40$ MeV: see Table 14.25 in (1970AJ04), (1976AJ04) and (1973CA30; α_0 ; 0.98 \rightarrow 1.97 MeV), (1976LU1A; α_0 , α_2 ; 16 MeV) and (1976VA07: α to $^{14}\text{N}^*(0, 3.95, 7.03, 11.04; 40$ MeV). Analysis with a one-step ZRDWBA is reported by (1976VA07) And S values are derived: $^{14}\text{N}^*(11.04)$ probably has $J^\pi = 3^+$.

The yield of the isospin forbidden α_1 group [to $^{14}\text{N}^*(2.31)$] 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). At $E_d = 50$ MeV, the intensity of $^{14}\text{N}^*(2.31)$ is 0.1 – 0.2% that of $^{14}\text{N}_{\text{g.s.}}$ (1975FA06). See also ^{18}F in (1978AJ03, 1983AJ01) and (1976PE08, 1978RI05).

Measurements on the absolute cross sections of this reaction [$E_d = 3.6$ to 5.3 MeV] and its inverse [$^{14}\text{N}(\alpha, \text{d})^{16}\text{O}$] 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 (1978HI1E, 1978PI1D; applications).

70. $^{16}\text{O}(\alpha, ^6\text{Li})^{14}\text{N}$

$$Q_m = -19.2628$$

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

71. $^{16}\text{O}(^{10}\text{B}, 3\alpha)^{14}\text{N}$

$$Q_m = -2.8236$$

See (1978BE1G).

72. $^{16}\text{O}(^{11}\text{B}, ^{13}\text{C})^{14}\text{N}$

$$Q_m = -2.0576$$

See (1976AJ04).

73. $^{16}\text{O}(^{16}\text{O}, ^{18}\text{F})^{14}\text{N}$

$$Q_m = -13.2100$$

See (1974RO04).

74. $^{17}\text{O}(\text{p}, \alpha)^{14}\text{N}$ $Q_{\text{m}} = 1.191$

See (1978SE08) and ^{18}F in (1978AJ03, 1983AJ01).

75. $^{19}\text{F}(\text{d}, ^7\text{Li})^{14}\text{N}$ $Q_{\text{m}} = -6.1232$

See (1967DE03).

¹⁴O
(Figs. 8 and 9)

GENERAL: (See also (1976AJ04).)

Special reactions involving ¹⁴O: (1976AB04, 1978AB08).

Astrophysical questions: (1977JO1D, 1977SI1D).

Applied topics: (1978HI1D).

Reactions involving pions: (1976DI10, 1976DI11, 1977HO1B, 1978SH12, 1979LI1H, 1980DE10, 1980SI07).

Other topics: (1976IR1B, 1976ST13, 1976VO1C, 1979KA13).

Mass of ¹⁴O: The recent ¹⁴N(p, n)¹⁴O threshold measurement by (1977WH01) leads to an atomic mass excess of 8007.1 ± 0.4 keV for ¹⁴O. See also (1980BA1M). A preliminary measurement of the ¹⁶O(p, t) *Q*-value (P.A. Barker and J.A. Nolen, private communication) leads to 8008.65 ± 0.51 keV, in excellent agreement with the value adopted by (1977WA08) [8008.3 ± 0.5 keV] which we continue to adopt. See also (1980NO1A).

1. ¹⁴O(β^+)¹⁴N $Q_m = 5.1449$

A recent measurement of the half-life of ¹⁴O is 70.613 ± 0.025 sec (1978WI04); [for earlier measurements see (1976AJ04)]. The “best” value of $\tau_{1/2} = 70.606 \pm 0.018$ sec (1978WI04). ¹⁴O [$J^\pi = 0^+$; $T = 1$] decays predominantly to the analog state ¹⁴N*(2.31): the branching ratio to that state is $(99.332 \pm 0.011)\%$. This value is obtained by adopting $(0.61 \pm 0.01)\%$ (1966SI05) and $(0.058 \pm 0.004)\%$ (1980WI1H)† for the branching ratios to ¹⁴N*(0, 3.95) [both 1^+ ; 0 states]. The *ft*-value for the $0^+ \rightarrow 0^+$ transition to ¹⁴N*(2.31) is 3086.5 ± 2.7 sec (1978WI04): [$\log ft = 3.4895 \pm 0.0004$]. For the transition to ¹⁴N*(0, 3.95) $\log ft = 7.266 \pm 0.009$ (1980WI1H) and 3.112 ± 0.034 (1980WI1H), respectively. See also the discussion in (1976AJ04).

See also (1977BA2L, 1977WH01), (1976BE1E, 1978WE1J), (1978DA1H, 1978TA1U; astro-phys.) and (1976LO01, 1976WI15, 1977GO13, 1977RI08, 1977RY1B, 1977SZ03, 1977TO11, 1977WI04, 1978SZ03, 1978TO02, 1978VA14, 1978WE1J, 1979DE15, 1979FE02, 1979KI1G, 1979SZ07, 1980LO07; theor.).

2. ¹²C(³He, n)¹⁴O $Q_m = -1.1484$

Observed neutron groups are displayed in Table 14.22. Angular distributions have been measured at $E(^3\text{He}) = 25.4$ MeV [see (1976AJ04, 1970AJ04)] and at 15, 18 and 20 MeV (1978FE03: n_0, n_1, n_{2+3+4}). See also (1976WA1B) and ¹⁵O.

† Note added in proof: Sum of ϵ_K and β -decay in ratio 6/4 (R.W. Kavanagh, private communication).

Table 14.21: Energy levels of ^{14}O

E_x (MeV \pm keV)	$J^\pi; T$	$\tau_{1/2}$ (sec) or $\Gamma_{\text{c.m.}}$ (keV)	Decay	Reactions
g.s.	$0^+; 1$	$\tau_{1/2} = 70.606 \pm 0.018$ sec	β^+	1, 2, 5, 8, 9, 10, 11, 13
5.173 ± 10	$1^-; 1$			2, 6, 11, 13
5.920 ± 10	$0^+; 1$	$\Gamma \leq 50$ keV	p	2, 6, 11, 13
6.272 ± 10	$3^-; 1$	103 ± 6	p	2, 3, 4, 5, 6, 11, 13
6.590 ± 10	$2^+; 1$	≤ 60	p	2, 11, 13
(6.79 ± 30)	$\pi = -$			11
7.768 ± 10	$2^+; 1$	76 ± 10	p	2, 10, 11, 13
(8.72 ± 40)				6, 11, 13
9.715 ± 20	$(2^+); 1$			2, 6, 11, 13
9.915 ± 20	$4^+; 1$	100 ± 50		2, 3, 4, 5, 6
10.89 ± 50				11
11.24 ± 50				11
11.97^a				11
12.84 ± 50				11
13.01 ± 50				11
14.15 ± 40				11
14.64 ± 60				11
17.40 ± 60				11

^a Possibly more than one level.

Table 14.22: Levels of ^{14}O from $^{12}\text{C}(^3\text{He}, \text{n})^{14}\text{O}$

E_x (MeV \pm keV) (1972GR39)	$\Gamma_{\text{c.m.}}$ (keV) (1973PR08)	L ^d	J^π ^d
0		0	0^+
5.173 ± 10		1	1^-
5.930 ± 15 ^a	≤ 47	0	0^+
6.272 ± 10	103 ± 6	3	3^-
6.596 ± 10 ^b	≤ 56	(2)	2^+ ^e
7.768 ± 10	76 ± 10	2	2^+
9.705 ± 25		(2)	(2^+)
9.915 ± 20 ^c	100 ± 50 ^c	4	4^+

^a (1961TO03, 1968TO09) report $E_x = 5.905 \pm 0.012$ MeV.

^b (1970AD01) report $E_x = 6.585 \pm 0.005$ MeV.

^c (1972BR60) report $E_x = 9.95 \pm 0.043$ MeV; $J^\pi = 3^-$.

^d See Table 14.30 in (1976AJ04).

^e $J = 2$ follows from the np coincidence study of (1973PR08).

The J shown for $^{14}\text{O}^*(5.92, 6.27, 7.77)$ are in accord with this work.

3. $^{12}\text{C}(^{10}\text{B}, ^8\text{Li})^{14}\text{O}$ $Q_m = -16.904$

At $E(^{10}\text{B}) = 100$ MeV the angular distributions of the transitions to $^{14}\text{O}^*(6.27, 9.92)$ [$J^\pi = 3^-, 4^+$], the states preferentially excited, have been studied by (1978HA10).

4. $^{12}\text{C}(^{11}\text{B}, ^9\text{Li})^{14}\text{O}$ $Q_m = -24.296$

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

5. $^{12}\text{C}(^{12}\text{C}, ^{10}\text{Be})^{14}\text{O}$ $Q_m = -20.6159$

At $E(^{12}\text{C}) = 114$ MeV, the population of $^{14}\text{O}^*(0, 6.27, 9.9)$ is reported: it is suggested that $^{14}\text{O}^*(9.9)$ has a $(d_{5/2})_{4^+;1}^2$ configuration (1972SC21, 1974AN36). $^{14}\text{O}_{\text{g.s.}}$ is weakly populated (1974AN36).

6. $^{12}\text{C}(^{14}\text{N}, ^{12}\text{B})^{14}\text{O}$ $Q_m = -18.514$

At $E(^{14}\text{N}) = 118$ MeV, the population of $^{14}\text{O}^*(6.27, 9.9)$ is reported ([1974AN36](#)). At $E(^{14}\text{N}) = 155$ MeV there is some evidence for the excitation of $^{14}\text{O}^*(5.17, 5.92, 6.27, 8.72, 9.72)$ ([1975NA11](#)). See also ([1979NA1G](#)).

7. $^{12}\text{C}(^{16}\text{O}, ^{14}\text{C})^{14}\text{O}$ $Q_m = -15.7652$

See ^{14}C ([1979PR07](#)).

8. $^{12}\text{C}(^{20}\text{Ne}, ^{18}\text{O})^{14}\text{O}$ $Q_m = -14.2683$

See ([1979OR01](#)): $E(^{20}\text{Ne}) = 150$ to 294 MeV).

9. $^{13}\text{C}(\text{p}, \pi^-)^{14}\text{O}$ $Q_m = -137.161$

At $E_p = 200$ MeV the angular distributions of π^- and π^+ to the ground states of ^{14}O and ^{14}C are very different ([1979HO1F](#)). See also ([1979JO1C](#)) and ([1976NO1D](#), [1976PO1D](#); theor.).

10. $^{14}\text{N}(\text{p}, \text{n})^{14}\text{O}$ $Q_m = -5.9273$

$$\begin{aligned} E_{\text{thresh.}} &= 6355.6 \pm 1.6 \text{ keV ([1976FR1D](#));} \\ E_{\text{thresh.}} &= 6353.6 \pm 0.4 \text{ keV ([1977WH01](#))}^\ddagger; \\ E_{\text{thresh.}} &= 6353.99 \pm 0.1 \text{ keV ([1980BA1M](#); prelim.).} \end{aligned}$$

Ground state angular distributions have been measured at $E_p = 35$ MeV ([1979TA1M](#)) and 144 MeV (([1980MO10](#)) and to $^{14}\text{O}^*(7.77)$). See also ([1976AJ04](#)).

11. $^{14}\text{N}(^3\text{He}, \text{t})^{14}\text{O}$ $Q_m = -5.1635$

[‡] See also the “*Mass of ^{14}O* ” section in ^{14}O here.

Triton groups have been observed at $E(^3\text{He}) = 44.6$ MeV to the first six states shown in Table 14.21 and to levels with $E_x = 6.79 \pm 0.03, 8.74 \pm 0.06, 9.74 \pm 0.03, 10.89 \pm 0.05, 11.24 \pm 0.05, 11.97$ (unresolved), $12.84 \pm 0.05, 13.01 \pm 0.05, 14.15 \pm 0.04, 14.64 \pm 0.06$ and 17.40 ± 0.06 MeV (1967BA13, 1969BA06). See also reaction 50 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.]

$$12. \text{}^{16}\text{O}(\gamma, 2\text{n})^{14}\text{O} \quad Q_m = -28.8882$$

See (1977JO02).

$$13. \text{}^{16}\text{O}(\text{p}, \text{t})^{14}\text{O} \quad Q_m = -20.4062$$

Angular distributions of ground state tritons have been studied to $E_p = 54.1$ MeV [see (1976AJ04)] and at 28.9, 29.8 and 30.7 MeV (1978GO04). For comparison with the (p, ^3He) results see reaction 68 in ^{14}N .

Triton groups have also been observed to states with $E_x = 5.21 \pm 0.04, 5.92 \pm 0.06, 6.28 \pm 0.05, 6.59, 7.77, 8.69 \pm 0.06$ [weak, not observed in reaction 2], and 9.65 ± 0.06 MeV (1971FL04). Angular distributions have been studied with polarized protons at $E_p = 43.8$ MeV to $^{14}\text{O}^*(0, 5.17, 6.27, 6.59, 7.77, 9.72)$ (1974MA12). See also (1977BA2L, 1979NO1B), (1976DA1K) and (1978PI1B, 1978PI10; theor.).

$$14. \text{}^{16}\text{O}(\alpha, \text{}^6\text{He})^{14}\text{O} \quad Q_m = -27.914$$

See (1975VA01, 1975VA1F).

$$15. \text{}^{18}\text{O}(\alpha, \text{}^8\text{He})^{14}\text{O} \quad Q_m = -37.962$$

See (1975JA10).

^{14}F

(Not illustrated)

^{14}F has not been observed: its atomic mass excess is predicted to be 32.98 MeV (1978GU10) which would make it unstable with respect to decay into $^{13}\text{O} + \text{p}$ by 2.58 MeV. See also (1976AJ04).

^{14}Ne

(Not illustrated)

^{14}Ne has not been observed. See (1976BE1V; theor.).

References

(Closed 01 August 1980)

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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