

# Energy Levels of Light Nuclei $A = 15$

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**Abstract:** An evaluation of  $A = 13-15$  was published in *Nuclear Physics A360* (1981), p. 1. This version of  $A = 15$  differs from the published version in that we have corrected some errors discovered after the article went to press. Figures and introductory tables have been omitted from this manuscript. Also, [Reference](#) key numbers have been changed to the NNDC/TUNL format.

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## Table of Contents for $A = 15$

*Below is a list of links for items found within the PDF document. Figures from this evaluation are not included in the PDF document but have been scanned in and are available on this website or via the link below.*

A. Nuclides:  [\$^{15}\text{Li}\$](#) ,  [\$^{15}\text{Be}\$](#) ,  [\$^{15}\text{B}\$](#) ,  [\$^{15}\text{C}\$](#) ,  [\$^{15}\text{N}\$](#) ,  [\$^{15}\text{O}\$](#) ,  [\$^{15}\text{F}\$](#)

B. Tables of Recommended Level Energies:

[Table 15.1](#): Energy levels of  $^{15}\text{C}$

[Table 15.3](#): Energy levels of  $^{15}\text{N}$

[Table 15.18](#): Energy levels of  $^{15}\text{O}$

[Table 15.26](#): Energy levels of  $^{15}\text{F}$

C. [References](#)

D. Figures:  [\$^{15}\text{C}\$](#) ,  [\$^{15}\text{N}\$](#) ,  [\$^{15}\text{O}\$](#) , [Isobar diagram](#)

E. Erratum to the Publication: [PS](#) or [PDF](#)

### <sup>15</sup>Li

(Not illustrated)

<sup>15</sup>Li has not been observed: its atomic mass excess is calculated to be 81.60 MeV. It is then unstable with respect to decay into <sup>14</sup>Li + n and <sup>13</sup>Li + 2n by 1.24 and 3.90 MeV, respectively (1974TH01). See also <sup>13</sup>Li.

### <sup>15</sup>Be

(Not illustrated)

<sup>15</sup>Be has not been observed. It is calculated to be particle unstable with respect to decay into <sup>14</sup>Be + n by 2.42 MeV. The binding energy of <sup>13</sup>Be + 2n is +0.31 MeV. The calculated mass excess is 51.18 MeV (1974TH01).

### <sup>15</sup>B

(Fig. 13)

The *Q*-value of the <sup>48</sup>Ca(<sup>18</sup>O, <sup>51</sup>V)<sup>15</sup>B reaction is  $-21.76 \pm 0.05$  MeV which leads to an atomic mass excess of  $28.96 \pm 0.05$  MeV for <sup>15</sup>B. At  $E(^{18}\text{O}) = 102$  MeV, this 3 proton transfer reaction has a 0° differential cross section of  $1.2 \mu\text{b/sr}$ . No excited states were observed (1978BH02). <sup>15</sup>B is then stable with respect to <sup>14</sup>B + n by 2.77 MeV. <sup>15</sup>B has neither been observed in the <sup>11</sup>B(<sup>18</sup>O, <sup>14</sup>O)<sup>15</sup>B reaction [ $E(^{18}\text{O}) = 96$  and  $103$  MeV;  $< 2$  nb/sr at  $\theta = 10 - 12^\circ$ ] (1977HI03) nor in the <sup>14</sup>C(<sup>9</sup>Be, <sup>8</sup>B)<sup>15</sup>B reaction [ $E(^9\text{Be}) = 121$  MeV;  $< 50$  nb/sr at  $\theta = 14^\circ$ ] (1975WI26). See also (1976AJ04) and (1975VO09, 1975WI26).

### <sup>15</sup>C

(Figs. 10 and 13)

GENERAL: (See also (1976AJ04).):

*Model calculations:* (1976LI16).

*Special levels:* (1976LI16).

*Astrophysical questions:* (1977LI1H, 1978SN1A).

*Special reactions involving <sup>15</sup>C:* (1975FE1A, 1975KO1J, 1977AR06, 1978GE1C, 1978HE1C, 1978KO01, 1979AL22).

*Muon and neutrino capture and reactions:* (1977BA1P).

*Pion capture and reactions:* (1977BA24).

*Other topics:* (1976LI16, 1978DA1A, 1979BE1H).

Table 15.1: Energy levels of  $^{15}\text{C}$ 

$E_x$ (MeV $\pm$ keV)	$J^\pi; T$	$\tau$ or $\Gamma_{\text{c.m.}}$ (keV)	Decay	Reactions
g.s.	$\frac{1}{2}^+; \frac{3}{2}$	$\tau_{1/2} = 2.449 \pm 0.005$ sec	$\beta^-$	1, 2, 3, 6
$0.7400 \pm 1.5$	$\frac{5}{2}^+; \frac{3}{2}$	$\tau_m = 3.76 \pm 0.10$ nsec	$\gamma$	2, 4, 6
$3.105 \pm 5$	$\frac{1}{2}^-; \frac{3}{2}$	$\Gamma_{\text{c.m.}} \leq 40$		2, 6
$4.221 \pm 3$	$(\frac{7}{2}^+, \frac{5}{2}^-)$	$< 14$		2, 6
$(4.55 \pm 30)$				2
$5.833 \pm 20$	$\leq \frac{3}{2}$			2
$5.858 \pm 20$	$\leq \frac{1}{2}$			2
$6.370 \pm 15$	$(\frac{5}{2}, \frac{7}{2}^+, \frac{9}{2}^+)$	$< 20$		2, 6
$6.429 \pm 7$	$(\frac{3}{2} \rightarrow \frac{7}{2})$	$\approx 50$		2, 6
$6.461 \pm 20$	$(\frac{9}{2}^-, \frac{11}{2})$	$< 14$		2, 6
$6.540 \pm 5$	<sup>a</sup>	$< 14$		2, 6
$6.639 \pm 15$	$(\frac{3}{2})$	$20 \pm 10$		2
$6.845 \pm 5$	$(\frac{13}{2}, \frac{11}{2})^+$	$< 14$		2, 6
$6.884 \pm 5$	$(\frac{9}{2})^a$	$< 20$		2, 6
$7.098 \pm 6$	$(\frac{3}{2})$	$< 15$		2, 6
$7.352 \pm 6$	$(\frac{9}{2}, \frac{11}{2})$	$20 \pm 10$		2, 4, 6
$7.414 \pm 20$				2
$7.75 \pm 30$ <sup>b</sup>				2, 6
$8.01 \pm 30$				2
$8.11 \pm 10$ <sup>b</sup>				2, 6
$8.47 \pm 15$	$(\frac{9}{2} \rightarrow \frac{13}{2})$	$40 \pm 15$		2, 6
$8.559 \pm 15$	$(\frac{7}{2} \rightarrow \frac{13}{2})$	$40 \pm 15$		2
$9.00 \pm 30$				2
$(9.73 \pm 30)$				2
$9.789 \pm 20$	$(\frac{9}{2} \rightarrow \frac{15}{2})$	$20 \pm 15$		2
$10.248 \pm 20$	$(\frac{5}{2} \rightarrow \frac{9}{2})$	$20 \pm 15$		2
$11.015 \pm 25$				2
$11.123 \pm 20$	$(\frac{11}{2} \rightarrow \frac{19}{2})$	$30 \pm 20$		2
$(11.68 \pm 30)$				2
$11.825 \pm 20$	$\geq \frac{13}{2}$	$70 \pm 30$		2

<sup>a</sup> See Table 15.2.

<sup>b</sup> Broad or unresolved states.

1.  $^{15}\text{C}(\beta^-)^{15}\text{N}$   $Q_m = 9.7717$

The half-life of  $^{15}\text{C}$  is  $2.449 \pm 0.005$  sec (1979AL23). Transitions have been observed to  $^{15}\text{N}_{\text{g.s.}}$  and to the upper of the 5.3 MeV states in  $^{15}\text{N}$  which has  $J^\pi = \frac{1}{2}^+$ . Therefore  $J^\pi(^{15}\text{C}_{\text{g.s.}}) = \frac{1}{2}^+$  or  $\frac{3}{2}^+$ . Weak transitions are observed to  $^{15}\text{N}^*(7.30, 8.31, 8.57, 9.05)$  (1979AL23): see Table 15.16. See also (1976AJ04) and (1977RI08, 1979AL23; theor.).

2.  $^9\text{Be}(^7\text{Li}, \text{p})^{15}\text{C}$   $Q_m = 9.094$

Observed proton groups are displayed in Table 15.2. Angular distributions have been reported for  $E(^7\text{Li}) = 1.7$  to 20 MeV: see (1976AJ04).

3.  $^{13}\text{C}(\text{t}, \text{p})^{15}\text{C}$   $Q_m = 0.9127$

$|g| = 0.703 \pm 0.012$  for  $^{15}\text{C}^*(0.74)$  (1980AS01). See also (1976AL16, 1979AL23).

4.  $^{13}\text{C}(\alpha, 2\text{p})^{15}\text{C}$   $Q_m = -18.9013$

At  $E_\alpha = 65$  MeV  $^{15}\text{C}^*(0.74, 6.74, 7.35)$  are strongly populated. The angular distribution to  $^{15}\text{C}^*(6.74 + 7.35)$  is consistent with  $L = 4$  leading to  $J^\pi = \frac{7}{2}^-$  and  $\frac{9}{2}^-$  for these two states on the basis of the  $(2J + 1)$  “rule” (1978JA10). See also (1976CE1E, 1976JA13). [However see Table 15.1 for the density of states, and compare with the resolution of (1978JA10).]

5. (a)  $^{14}\text{C}(\text{n}, \gamma)^{15}\text{C}$   $Q_m = 1.2182$   
 (b)  $^{14}\text{C}(\text{n}, \text{n})^{14}\text{C}$   $E_b = 1.2182$

$\sigma_\gamma < 1 \mu\text{b}$  (1973MU14). See also (1976AJ04).

6.  $^{14}\text{C}(\text{d}, \text{p})^{15}\text{C}$   $Q_m = -1.0065$

Observed proton groups are displayed in Table 15.2. See also (1976AJ04).

7.  $^{15}\text{N}(\text{n}, \text{p})^{15}\text{C}$   $Q_m = 8.9893$

See  $^{16}\text{N}$  in (1977AJ02).

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

(1974GA33) <sup>a</sup>			(1973GO28, 1975GO31) <sup>b</sup>		
$E_x$ (keV)	$\Gamma_{\text{c.m.}}$ (keV)	$J^\pi$ <sup>d</sup>	$E_x$ (keV)	$\Gamma_{\text{c.m.}}$ (keV)	$J^\pi$ <sup>h</sup>
g.s. $\equiv 740$ <sup>c</sup>	bound		g.s.	bound	$\frac{1}{2}^+$ <sup>j</sup>
	bound		$744.1 \pm 2$ <sup>n</sup>	bound	$\frac{5}{2}^+$ <sup>k</sup>
$3100 \pm 30$	$< 40$	$(\frac{1}{2}^-)$ <sup>e</sup>	$3105.3 \pm 5$	$\approx 42$	$(\frac{1}{2}^-)$
$4223 \pm 15$	$< 15$	$(\frac{5}{2}^-)$	$4221.1 \pm 3$	$< 14$	$(\frac{7}{2}^+, \frac{5}{2}^-)$
$(4550 \pm 30)$			f		
$5833 \pm 20$		1	f		
$5858 \pm 20$		1	f		
$6370 \pm 15$	$< 20$	$(\frac{5}{2})$	g	$< 14$ <sup>g</sup>	$(\frac{7}{2}, \frac{9}{2})^+$
$6436 \pm 20$			$6428.1 \pm 7$	$\approx 50$	$(\frac{3}{2}, \frac{5}{2}, \frac{7}{2})$
$6461 \pm 20$			g	$< 14$ <sup>g</sup>	$(\frac{9}{2}^-, \frac{11}{2})$
$6542 \pm 15$	$< 20$	$(\frac{3}{2})$	$6539.8 \pm 5$	$< 14$	$(\frac{9}{2}^-, \frac{11}{2})$
$6639 \pm 15$	$20 \pm 10$	$(\frac{3}{2})$			
$6847 \pm 15$	$< 20$	$(\frac{11}{2}, \frac{13}{2})$	$6844.9 \pm 5$	$< 14$	$(\frac{13}{2}, \frac{11}{2})^+$
$6894 \pm 15$	$< 20$	$(\frac{7}{2}, \frac{9}{2})$	$6882.4 \pm 5$		$((\frac{9}{2}^-, \frac{11}{2}^+, \frac{13}{2}^+))$
$7100 \pm 15$	$< 15$	$(\frac{3}{2})$	$7097.2 \pm 6$		
$7354 \pm 15$	$20 \pm 10$	$(\frac{9}{2}, \frac{11}{2})$	$7351.3 \pm 6$		
$7414 \pm 20$					
$7750 \pm 30$ <sup>i</sup>			$7.81 \pm 10$ <sup>m</sup>		
$8010 \pm 30$					
$8130 \pm 30$ <sup>i</sup>			$8.10 \pm 10$ <sup>m</sup>		
$8491 \pm 15$	$40 \pm 15$	$(\frac{9}{2}, \frac{11}{2}, \frac{13}{2})$	$8.46 \pm 10$ <sup>m</sup>		
$8559 \pm 15$	$40 \pm 15$	$(\frac{7}{2} \rightarrow \frac{13}{2})$			
$9000 \pm 30$					
$(9730 \pm 30)$					
$9789 \pm 20$	$20 \pm 15$	$(\frac{9}{2} \rightarrow \frac{15}{2})$			
$10248 \pm 20$	$20 \pm 15$	$(\frac{5}{2}, \frac{7}{2}, \frac{9}{2})$			
$11015 \pm 25$					
$11123 \pm 20$	$30 \pm 20$	$(\frac{11}{2} \rightarrow \frac{19}{2})$			
$(11680 \pm 30)$					
$11825 \pm 20$	$70 \pm 30$	$(\frac{13}{2} \rightarrow \frac{31}{2})$			

- <sup>a</sup>  ${}^9\text{Be}({}^7\text{Li}, \text{p})$ :  $E({}^7\text{Li}) = 20 \text{ MeV}$ .  $E_x$  based on 740 keV for first excited state.
- <sup>b</sup>  ${}^{14}\text{C}(\text{d}, \text{p})$ :  $E_d = 12 - 14 \text{ MeV}$ .
- <sup>c</sup>  $E_x = 739 \pm 1 \text{ keV}$  (1975HA42): from  $E_\gamma$ ;  $\tau_m = 3.77 \pm 0.11 \text{ nsec}$  (1968ME08).
- <sup>d</sup> Suggested  $J^\pi$  assignments based on angular distributions (and  $2J_f + 1$  dependence) and  $l_{\text{max}}$  from  $\Gamma_n$ : see (1974GA33).
- <sup>e</sup>  $\theta_n^2 = 0.0075 \pm 0.0015$  (1974GA33).
- <sup>f</sup> Not observed.
- <sup>g</sup> Observed in the later work of (1975GO31) but  $E_x$  not redetermined.
- <sup>h</sup> Analysis of the two bound states is done using DWUCK. For the unbound states DOXY was used. For values of  $\Gamma_n/\Gamma_{\text{s.p.}}$  under various assumptions see (1975GO31).
- <sup>i</sup> Broad or unresolved states.
- <sup>j</sup>  $S = 0.88$  (1975GO31).
- <sup>k</sup>  $S = 0.69$  or  $0.55$  (1975GO31). See also (1976AJ04).  $g = -0.77 \pm 0.06$  (1975HA42).
- <sup>l</sup> Sum of the  $J$  for these two states is 2 [based on  $(2J_f + 1)$  dependence of cross section] (1974GA33).
- <sup>m</sup> Observed by (1975CE04):  $E_d = 27 \text{ MeV}$  who also report proton groups to  ${}^{15}\text{C}^*(0, 0.74, 4.22, 6.43, 6.88, 7.35)$ .
- <sup>n</sup>  $\tau_m = 3.73 \pm 0.23 \text{ nsec}$  (1962LO02).

8.  ${}^{18}\text{O}(\text{n}, \alpha){}^{15}\text{C}$   $Q_m = -5.0097$

See (1976AJ04).

<sup>15</sup>N  
(Figs. 11 and 13)

GENERAL: (See also (1976AJ04).):

*Shell model:* (1976LI16, 1977EM01, 1977PO16, 1978BO31).

*Cluster and  $\alpha$ -particle models:* (1977FO1E, 1977SA19, 1978PI1E).

*Special states:* (1976LI16, 1977RI08, 1978BO31, 1978PI1E).

*Electromagnetic transitions:* (1976LI16, 1976SH04, 1977BR03, 1977HO04, 1978KR19, 1979SU1G).

*Astrophysical questions:* (1976BO1M, 1976EP1A, 1976FI1E, 1976ME1H, 1976NO1C, 1976SP1B, 1977AU1E, 1977AU1F, 1977CA1K, 1977CL1C, 1977CO1U, 1977CO1W, 1977HA1L, 1977JO1D, 1977PR1E, 1977ST1H, 1977TR1D, 1977WA1P, 1978BU1H, 1978BU1B, 1978CL1F, 1978DW1B, 1978EN1C, 1978PO1B, 1978SN1A, 1978ST1C, 1978ST1D, 1978YA1B, 1979GU1D, 1979JA1M, 1979LA1H, 1979OL1B, 1980CA1C, 1980PE1F).

*Special reactions involving <sup>15</sup>N:* (1976AB04, 1976BU16, 1976FU1J, 1976HE1H, 1976HI05, 1976LE1F, 1977AR06, 1977KO38, 1978AB08, 1978VO10, 1978CR1B, 1978GE1C, 1978HE1C, 1978KO01, 1978LE15, 1978TU06, 1978VO1A, 1979AL22, 1979GE1A, 1979HE1D, 1979SA27, 1979WU01, 1980MI01, 1980YO02).

*Muon and neutrino capture and reactions:* (1979ER07).

*Pion capture and pion reactions:* (1976EN02, 1978BA55, 1978ER04, 1978MO01, 1979BA2M, 1979ER07, 1979LI11, 1979OS1F, 1980LE02, 1980SA04, 1980WU01).

*Applied work:* (1977KE1B, 1978LA1N, 1978SH1L, 1979EN1D, 1979MA2M, 1980SA1C).

*Other topics:* (1976BI1A, 1976SA1H, 1977BA3P, 1977EM01, 1978DA1A, 1978PO1A, 1978SH1B, 1979BE1H, 1979HE1F, 1979KA13).

*Ground state properties of <sup>15</sup>N:* (1976FU06, 1976SA1H, 1977AN21, 1977BR03, 1977KO28, 1977PO16, 1977YO1D, 1978AN07, 1978AR1R, 1978HE1D, 1978SH1B, 1978SL1B, 1978ZA1D, 1979NO05, 1979SA27, 1979SU1G).

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

<sup>15</sup>N\*(6.33): see (1979WU01, 1979WU08).

1. (a) <sup>9</sup> Be( <sup>6</sup> Li, p) <sup>14</sup> C	$Q_m = 15.126$	$E_b = 25.334$
(b) <sup>9</sup> Be( <sup>6</sup> Li, t) <sup>12</sup> C	$Q_m = 10.485$	
(c) <sup>9</sup> Be( <sup>6</sup> Li, $\alpha$ ) <sup>11</sup> B	$Q_m = 14.342$	
(d) <sup>9</sup> Be( <sup>6</sup> Li, 2n) <sup>13</sup> N	$Q_m = 3.947$	



Table 15.3: Energy levels of  $^{15}\text{N}$  <sup>a</sup>

$E_x$ (MeV $\pm$ keV)	$J^\pi; T$	$\tau_m$ or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
0	$\frac{1}{2}^-; \frac{1}{2}$	—	stable	2, 3, 4, 5, 6, 15, 16, 17, 19, 20, 21, 22, 23, 24, 30, 31, 32, 33, 34, 35, 36, 40, 41, 42, 43, 44, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84
$5.27012 \pm 0.04$	$\frac{5}{2}^+$	$\tau_m = 2.6 \pm 0.2$ psec $g = +(0.9 \pm 0.3)$	$\gamma$	4, 5, 14, 20, 22, 31, 35, 40, 41, 44, 52, 61, 65, 66, 71, 74, 75, 82, 83
$5.29880 \pm 0.04$	$\frac{1}{2}^+$	$25 \pm 7$ fsec	$\gamma$	4, 5, 12, 13, 14, 17, 18, 19, 20, 22, 30, 32, 35, 40, 41, 44, 52, 58, 61, 71, 74, 75, 82, 83
$6.32391 \pm 0.06$	$\frac{3}{2}^-$	$0.23 \pm 0.02$ fsec	$\gamma$	3, 4, 5, 12, 13, 15, 17, 18, 19, 20, 30, 31, 32, 35, 40, 41, 44, 52, 60, 61, 65, 66, 71, 73, 74, 75, 76, 78, 83
$7.15506 \pm 0.06$	$\frac{5}{2}^+$	$18 \pm 8$ fsec	$\gamma$	4, 5, 19, 20, 30, 31, 32, 40, 44, 52, 61, 65, 66, 74
$7.30109 \pm 0.17$	$\frac{3}{2}^+$	$0.25 \pm 0.10$ fsec	$\gamma$	4, 5, 18, 19, 20, 30, 32, 40, 44, 52, 58, 61, 65, 66, 74
$7.5671 \pm 1.0$	$\frac{7}{2}^+$	$12_{-6}^{+11}$ fsec	$\gamma$	3, 4, 5, 12, 13, 17, 18, 19, 20, 30, 31, 32, 33, 40, 52, 55, 61, 65, 66, 74
$8.31279 \pm 0.14$	$\frac{1}{2}^+$	$< 16$ fsec	$\gamma$	3, 4, 5, 19, 30, 32, 40, 44, 52, 58, 65, 66, 71

Table 15.3: Energy levels of  $^{15}\text{N}$  <sup>a</sup> (continued)

$E_x$ (MeV $\pm$ keV)	$J^\pi; T$	$\tau_m$ or $\Gamma_{\text{c.m.}}$ (keV)	Decay	Reactions
$8.5714 \pm 1.0$	$\frac{3}{2}^+$	$11 \pm 7$ fsec	$\gamma$	3, 4, 5, 12, 13, 17, 18, 19, 30, 31, 32, 40, 52, 58, 65, 66
$9.0500 \pm 0.7$	$\frac{1}{2}^+$	$< 2$ fsec	$\gamma$	4, 5, 30, 40, 44, 52, 58, 71
$9.15161 \pm 0.23$	$\frac{3}{2}^-$	$< 40$ fsec	$\gamma$	4, 5, 12, 13, 17, 18, 19, 30, 32, 40, 44, 52, 61, 65, 66
$9.15492 \pm 0.07$	$\frac{5}{2}^+$	$7_{-3}^{+6}$ fsec	$\gamma$	4, 5, 17, 18, 19, 30, 32, 40, 44, 52, 65, 66
$9.225 \pm 3$	$\frac{1}{2}^-$	$< 130$ fsec	$\gamma$	30, 32, 40, 52, 71
$9.760 \pm 5$	$\frac{5}{2}^-$	12 fsec	$\gamma$	14, 30, 44, 52, 61
$9.829 \pm 3$	$\frac{7}{2}^-$	$17 \pm 7$ fsec	$\gamma$	4, 5, 12, 13, 18, 19, 20, 30, 31, 32, 33, 40, 52, 65, 66
$9.928 \pm 4$	$\frac{3}{2}^-$	$< 10$ fsec	$\gamma$	19, 30, 40, 44, 52, 74
$10.070 \pm 3$	$\frac{3}{2}^+$	$0.16 \pm 0.05$ fsec	$\gamma$	19, 30, 32, 52, 60, 65, 66
$10.4497 \pm 0.3$	$\frac{5}{2}^-$	$\Gamma < 0.5$ keV	$\gamma, \text{p}$	5, 12, 13, 20, 30, 31, 36, 40, 52
$10.5333 \pm 0.5$	$\frac{5}{2}^+$		$\gamma, \text{p}$	5, 13, 17, 18, 19, 31, 32, 36, 37
$10.6932 \pm 0.3$	$\frac{9}{2}^+$	$\tau_m = 18 \pm 9$ fsec	$\gamma, \text{p}$	5, 13, 17, 18, 19, 31, 32, 36, 37
$10.7019 \pm 0.3$	$\frac{3}{2}^-$	$\Gamma = 0.2$ keV	$\gamma, \text{p}$	12, 13, 30, 31, 32, 36, 37, 52, 65, 74
$10.804 \pm 2$	$\frac{3}{2}^+$	$< 1 \times 10^{-3}$	$\gamma, \text{p}$	4, 5, 12, 13, 19, 20, 30, 36, 52, 61
$11.235 \pm 5$	$\geq \frac{3}{2}$	3.3	<b>n</b>	40, 45
$11.2929 \pm 0.8$	$\frac{1}{2}^-$	$8 \pm 3$	$\gamma, \text{n}, \text{p}$	36, 37, 38, 40, 45, 65
$11.4376 \pm 0.7$	$\frac{1}{2}^+$	$41.4 \pm 1.1$	$\gamma, \text{n}, \text{p}, \alpha$	7, 12, 13, 19, 36, 37, 38, 40, 45, 46
$11.615 \pm 4$	$\frac{1}{2}^+; T = \frac{3}{2}$	$405 \pm 6$	$\gamma, \text{n}, \text{p}$	36, 37, 38
$11.778 \pm 5$	$\frac{3}{2}^+$	40	<b>n, p, <math>\alpha</math></b>	7, 37, 38, 45, 46

Table 15.3: Energy levels of  $^{15}\text{N}$  <sup>a</sup> (continued)

$E_x$ (MeV $\pm$ keV)	$J^\pi; T$	$\tau_m$ or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
$11.876 \pm 3$	$\frac{3}{2}^-$	25	$\gamma, n, p, \alpha$	7, 30, 37, 38, 45, 46, 61
$11.942 \pm 6$	$\frac{9}{2}^-$	$\leq 3.0$	$n, \alpha$	5, 7, 18, 19, 30, 31, 32, 33, 45, 65
$11.965 \pm 3$	$\frac{1}{2}^-$	17	$n, p$	5, 12, 13, 37, 38, 45, 46
$12.095 \pm 3$	$\frac{5}{2}^+$	$14 \pm 5$	$n, p, \alpha$	7, 8, 37, 38, 39, 40, 45, 46, 50
$12.145 \pm 3$	$\frac{3}{2}^-$	$41 \pm 5$	$n, p, \alpha$	7, 8, 12, 13, 37, 38, 39, 45, 46, 50
$12.327 \pm 4$	$\frac{5}{2}^{(+)}$	22	$n, p$	18, 19, 31, 37, 38, 45, 46
$12.493 \pm 4$	$\frac{5}{2}^+; \frac{1}{2}$	$40 \pm 5$	$n, p, \alpha$	7, 8, 37, 38, 39, 45, 46, 50, 65
$12.522 \pm 8$	$\frac{5}{2}^+; \frac{3}{2}$	$58 \pm 4$	$\gamma, p$	36, 61
$12.559 \pm 10$	$(\frac{9}{2})$			5, 13, 18, 19
$12.920 \pm 4$	$\frac{3}{2}^-$	$56 \pm 11$	$n, p, \alpha$	7, 8, 11, 19, 20, 37, 38, 39, 45, 46, 50
$12.940 \pm 10$	$\frac{5}{2}^+$	81	$p, \alpha$	8, 11, 37, 39
$13.004 \pm 10$	$\frac{11}{2}^-$			5, 12, 13, 14, 17, 19, 31, 32, 33
$13.149 \pm 10$		$7 \pm 3$	$n, p, \alpha$	7, 8, 20, 50
$13.174 \pm 7$	$(\frac{9}{2})$	$7 \pm 3$	$n, p, \alpha$	5, 7, 8, 13, 17, 18, 19, 38, 45, 50
$13.362 \pm 8$	$\frac{3}{2}^-$	$16 \pm 8$	$n, p, \alpha$	7, 8, 11, 37, 38, 39, 50
$13.390 \pm 10$	$\frac{3}{2}^+$	56	$\gamma, n, p, \alpha$	8, 11, 36, 37, 38, 39, 46
$13.537 \pm 10$	$\frac{3}{2}^-$	$85 \pm 30$	$n, p, \alpha$	7, 11, 37, 38, 39
$13.608 \pm 7$	$\frac{5}{2}^{(+)}$	$18 \pm 4$	$n, p, \alpha$	7, 8, 19, 37, 38, 39, 45, 46, 50
( $13.612 \pm 10$ )	$(\frac{1}{2}^+)$	90	$\alpha$	11
$13.713 \pm 10$		$26 \pm 8$	$n, p, \alpha$	7, 46, 50
$13.84 \pm 30$	$\frac{3}{2}^+$	75	$n, p, \alpha$	5, 7, 11, 13, 45, 46, 50

Table 15.3: Energy levels of  $^{15}\text{N}$  <sup>a</sup> (continued)

$E_x$ (MeV $\pm$ keV)	$J^\pi; T$	$\tau_m$ or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
13.9	$\frac{1}{2}^+$	930	$\gamma, p$	36, 37
13.99 $\pm$ 30	$\frac{5}{2}^+$	98 $\pm$ 10	n, p, $\alpha$	7, 13, 37, 39
14.090 $\pm$ 7		22 $\pm$ 6	n, p, $\alpha$	5, 7, 12, 13, 19, 45, 46, 50
14.10 $\pm$ 30	$\frac{3}{2}^+$	$\approx$ 100	n, $\alpha$	5, 7, 11, 65
14.162 $\pm$ 10	$\frac{3}{2}^{(+)}$	27 $\pm$ 6	n, $\alpha$	5, 7, 45, 46, 50
14.24 $\pm$ 40	$\frac{5}{2}^+$	150	$\alpha$	11, 12
14.38 $\pm$ 40	$\frac{7}{2}^+$	100	$\alpha$	11
14.4		$\approx$ 1900	n, p, $\alpha$	45, 46, 50
14.55 $\pm$ 20		200 $\pm$ 50	n, (p), $\alpha$	7, 37
14.647 $\pm$ 10		33 $\pm$ 6	n, p, $\alpha$	7, 45, 46, 50
14.71		750	$\gamma, p$	36
14.720 $\pm$ 10	$\frac{5}{2}^-$	110 $\pm$ 50	$\gamma, n, (p), \alpha$	7, 12, 13, 19, 37, 39, 61
14.86 $\pm$ 20		48 $\pm$ 11	n, $\alpha$	7, 11
14.920 $\pm$ 10		12 $\pm$ 3	n, $\alpha$	7, 12, 50
15.025 $\pm$ 10		13 $\pm$ 3	n, $\alpha$	7, 19
15.09 $\pm$ 20		80 $\pm$ 25	n, $\alpha$	7, 11, 45, 50, 65
15.288 $\pm$ 10		26 $\pm$ 6	n, $\alpha$	7, 11
15.373 $\pm$ 10	$\frac{13}{2}^+$			5, 12, 13, 17, 18, 19, 20
15.38 $\pm$ 20		75 $\pm$ 25	n, t, $\alpha$	7, 11, 16
15.43 $\pm$ 20		$\approx$ 100	n, ( $\alpha$ )	7, 11
15.45		750	$\gamma, p$	36
15.53 $\pm$ 20		$\approx$ 35	n, $\alpha$	7, 12, 13, 50
15.60 $\pm$ 20		95 $\pm$ 25	n, $\alpha$	7
15.782 $\pm$ 10			p, t, $\alpha$	16, 19, 20
15.93 $\pm$ 20		35 $\pm$ 5	n, t, $\alpha$	7, 16, 18
15.944 $\pm$ 15		21 $\pm$ 6	n, t, $\alpha$	7, 16
16.026 $\pm$ 10		62 $\pm$ 12	n, p, t, $\alpha$	7, 16, 19, 50
16.190 $\pm$ 10	$\frac{3}{2}^+$	450 $\pm$ 100	$\gamma, n, p, t, \alpha$	12, 16, 18, 19, 37, 39
16.26 $\pm$ 20		130 $\pm$ 14	n, t, $\alpha$	7, 11, 16, 20

Table 15.3: Energy levels of  $^{15}\text{N}$  <sup>a</sup> (continued)

$E_x$ (MeV $\pm$ keV)	$J^\pi; T$	$\tau_m$ or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
16.32 $\pm$ 20		$\approx 30$	n, p, t, $\alpha$	7, 11, 16
16.35 $\pm$ 20	$\frac{3}{2}^+$	270 $\pm$ 30	$\gamma$ , $\alpha$	6
16.39 $\pm$ 20		44 $\pm$ 11	n, p, t, $\alpha$	7, 16, 18, 50
16.46		560	$\gamma$ , p, d	26, 36
16.576 $\pm$ 15		27 $\pm$ 15	n, $\alpha$	7, 50
16.59 $\pm$ 25	$\frac{3}{2}^-$	490	$\gamma$ , n, p, t, $\alpha$	16
16.677 $\pm$ 15	$(\frac{3}{2}^+; \frac{1}{2})$	75 $\pm$ 5	$\gamma$ , n, p, d, t, $\alpha$	7, 16, 18, 25, 26, 28, 36, 39, 45, 50
16.73 $\pm$ 20	$(\frac{1}{2}^+, \frac{3}{2}^+)$	270 $\pm$ 30	$\gamma$ , n, t, $\alpha$	6, 14, 16
16.85 $\pm$ 30	$\frac{5}{2}$	110 $\pm$ 50	t, $\alpha$	16, 39
16.91		$\approx 350$	n, p, d, t, $\alpha$	16, 25, 26, 45, 50
(17.05)			p, t	16
17.11		broad	d, $\alpha$	29
17.15 $\pm$ 50	$(\frac{1}{2}^+, \frac{3}{2}^+)$	250 $\pm$ 60	$\gamma$ , t, $\alpha$	6, 16
17.23 $\pm$ 40		$\approx 175$	d, t, ( $\alpha$ )	28, 29
17.37 $\pm$ 40		$\approx 250$	p, d, t, $\alpha$	16, 26, 28, 29, 45, 50
17.58 $\pm$ 40	$\frac{3}{2}^+$	450 $\pm$ 120	$\gamma$ , d, t, $\alpha$	16, 28, 50
17.67 $\pm$ 40	$\frac{3}{2}^+; T = \frac{1}{2}$	600 $\pm$ 80	$\gamma$ , n, d, $\alpha$	6, 24, 25, 29
17.72 $\pm$ 10		48 $\pm$ 10	n, (p), d, t, $\alpha$	26, 28, 29, 50
17.81		167	n, $\alpha$	20, 45, 50
18.06 $\pm$ 10		19 $\pm$ 4	(n), d, $\alpha$	18, 25, 29
18.09 $\pm$ 20		$\approx 40$	(n), p, d, t	22, 26, 28
18.22		158	n, $\alpha$	45, 50
18.28 $\pm$ 30		235 $\pm$ 60	n, p, d, $\alpha$	25, 26, 29, 50
(18.76 $\pm$ 10)				18, 30
19.05 $\pm$ 50		$\approx 700$	$\gamma$ , $\alpha$	6
19.16	$(\frac{1}{2}^+; \frac{1}{2})$	$\approx 130$	n, d	25
19.5	$\frac{3}{2}^+; (\frac{3}{2})$	$\approx 400$	$\gamma$ , p	36, 37
19.77 $\pm$ 60				14, 18
20.5	$\frac{3}{2}^+$	$\approx 400$	$\gamma$ , n, p, d	25, 26, 36
21.26 $\pm$ 200		$\approx 1700$	$\gamma$ , $\alpha$	6

Table 15.3: Energy levels of  $^{15}\text{N}$  <sup>a</sup> (continued)

$E_x$ (MeV $\pm$ keV)	$J^\pi; T$	$\tau_m$ or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
21.82		$\approx 600$	$\gamma, p, d$	24, 36, 59, 61
22.92			$\gamma, p$	36
23.8		broad	$\gamma, d$	24
25.5	$\frac{3}{2}^-; (T = \frac{3}{2})$		$\gamma, p$	36, 61
(26.8)			t	16
$\approx 37$			$\gamma, p$	36

<sup>a</sup> See also Tables 15.4 and 15.5.

The yield of  $p_0$  and  $p_1$  (reaction (a)) for  $E(^6\text{Li}) = 3.84$  to  $6.40$  MeV shows some broad structure: analysis in terms of Ericson fluctuation theory gives a value of  $\approx 0.4$  MeV for the average level width at  $E_x = 28$  MeV in  $^{15}\text{N}$  (1967SE08). The excitation functions for  $t_0$  (reaction (b))  $\alpha_0$ ,  $\alpha_1$  and  $\alpha_2$  (reaction (c)) show broad structures for  $E(^6\text{Li}) = 4$  to  $14$  MeV (1971WY01). See also  $^{11}\text{B}$  and  $^{12}\text{C}$  in (1980AJ01) and  $^{14}\text{C}$ . See also (1976AJ04).



See (1978KA1T).



At  $E(^9\text{Be}) = 12$  MeV partial angular distributions are reported for the tritons to  $^{15}\text{N}^*(0, 6.32, 7.57, 8.31, 8.57)$  [also  $E(^9\text{Be}) = 5$  MeV for  $t_0, t_3$ ] (1977YO02). See also (1975VE10).



At  $E(^6\text{Li}) = 4.9$  MeV, thirty proton groups are observed corresponding to  $^{15}\text{N}$  states with  $E_x < 16.8$  MeV. Angular distributions have been measured for the proton groups corresponding to  $^{15}\text{N}^*(5.27 + 5.30, 6.32, 7.16 + 7.30, 7.57, 8.31, 8.57, 9.05 + 9.15)$  (1966MC05).



At  $E(^7\text{Li}) = 24$  MeV angular distributions have been studied to many of the  $^{15}\text{N}$  states with  $E_x < 15.5$  MeV: see reaction 13 (1976KO11). See also (1976AJ04).

Table 15.4: Radiative decays in  $^{15}\text{N}$  <sup>a</sup>

$E_i$ (MeV)	$J_i^\pi$	$E_f$ (MeV)	$J_f^\pi$	Branch (%)	Mult. mixing ratio $\delta$	Refs.
5.27	$\frac{5}{2}^+$	0	$\frac{1}{2}^-$	100	$-0.131 \pm 0.013$	(1975BE23, 1976BE1B)
5.30	$\frac{1}{2}^+$	0	$\frac{1}{2}^-$	100		
6.32	$\frac{3}{2}^-$	0	$\frac{1}{2}^-$	100	$+0.122 \pm 0.006^k$	(1975MO28, 1976BE1B)
		5.27	$\frac{5}{2}^+$	$< 1$		(1965WA16, 1975MO28)
		5.30	$\frac{1}{2}^+$	$< 0.5$		(1975MO28)
7.16	$\frac{5}{2}^+$	0	$\frac{1}{2}^-$	$< 0.1$		(1976BE1B)
		5.27	$\frac{5}{2}^+$	$100 \pm 0.4$	$-0.014^{+0.012}_{-0.015}$	(1976BE1B)
		5.30	$\frac{1}{2}^+$	$< 4$		(1966AL18, 1968GI11)
		6.32	$\frac{3}{2}^-$	$< 0.5$		(1965WA16)
7.30	$\frac{3}{2}^+$	0	$\frac{1}{2}^-$	$99.3 \pm 0.7$	$-0.017^{+0.005}_{-0.008}$	(1976BE1B)
		5.27	$\frac{5}{2}^+$	$0.6 \pm 0.1$	$+0.18 \pm 0.15$ , or $+2.5 \pm 1.0$	(1976BE1B)
		5.30	$\frac{1}{2}^+$	$0.2 \pm 0.1$	$-0.31 \pm 0.15$ , or $+4.6 \pm 3.4$	(1976BE1B)
		6.32	$\frac{3}{2}^-$	$< 0.25$		(1965WA16)
7.57	$\frac{7}{2}^+$	0	$\frac{1}{2}^-$	$1.3 \pm 0.6$		(1975BE23, 1976BE1B)
		5.27	$\frac{5}{2}^+$	$98.7 \pm 1.0$	$-0.028 \pm 0.012$	(1976BE1B)
		5.30	$\frac{1}{2}^+$	$< 4$		(1966AL18)
		6.32	$\frac{3}{2}^-$	$< 0.6$		(1965WA16)
8.31	$\frac{1}{2}^+$	0	$\frac{1}{2}^-$	$79 \pm 2$		(1965WA16, 1966WA08, 1967PH03)
		5.27	$\frac{5}{2}^+$	$< 3$		(1965WA16)
		5.30	$\frac{1}{2}^+$	$10 \pm 2$		(1965WA16)
		6.32	$\frac{3}{2}^-$	$7.8 \pm 2$		(1965WA16)
				$4.4 \pm 1.0^A$		(1967PH03)
		7.16	$\frac{5}{2}^+$	$1.2 \pm 0.6$		(1967PH03)
		7.30	$\frac{3}{2}^+$	$2.2 \pm 0.4$		(1965WA16)

Table 15.4: Radiative decays in  $^{15}\text{N}^a$  (continued)

$E_i$ (MeV)	$J_i^\pi$	$E_f$ (MeV)	$J_f^\pi$	Branch (%)	Mult. mixing ratio $\delta$	Refs.		
8.57 <sup>c</sup>	$\frac{3}{2}^+$	0	$\frac{1}{2}^-$	$4.4 \pm 0.7^A$ $33 \pm 2$	$-0.085^{+0.005}_{-0.009}$  $-0.091 \pm 0.007$	(1967PH03)		
		5.27	$\frac{5}{2}^+$	$65 \pm 3$		(1965WA16, 1966WA08, 1967PH03)		
		5.30	$\frac{1}{2}^+$	$< 12$		(1976BE1B)		
		6.32	$\frac{3}{2}^-$	$3 \pm 1$		(1966WA08)		
		7.16	$\frac{5}{2}^+$	$1.4 \pm 0.6^A$		(1976BE1B)		
		7.30	$\frac{3}{2}^+$	$3.6 \pm 0.5$		(1965WA16)		
		7.57	$\frac{7}{2}^+$	$< 0.7$		(1965WA16)		
		7.57	$\frac{7}{2}^+$	$< 3$		(1967PH03)		
		9.05	$\frac{1}{2}^+$	0		$\frac{1}{2}^-$	$92 \pm 3^A$	(1965WA16, 1966WA08)
		5.27		$\frac{5}{2}^+$		$91.6 \pm 00.9$ $3.5 \pm 1^A$	(1967PH03)	
6.32	$\frac{3}{2}^-$	$4.7 \pm 0.7$ $4.5 \pm 1^A$		(1966WA08)				
7.16	$\frac{5}{2}^+$	$3.7 \pm 0.5$		(1967PH03)				
7.30	$\frac{3}{2}^+$	$< 10$		(1965WA16)				
7.57	$\frac{7}{2}^+$	$1.2 \pm 0.4^A$		(1965WA16)				
8.31	$\frac{1}{2}^+$	$< 2$		(1965WA16)				
8.31	$\frac{1}{2}^-$	$< 0.5$		(1965WA16)				
9.152	$\frac{3}{2}^-$	0		$\frac{1}{2}^-$	$100 \pm 3$	(1969SI04, 1976BE1B)		
9.155 <sup>c,d</sup>	$\frac{5}{2}^+$	0		$\frac{1}{2}^-$	$< 2$	$+0.015^{+0.041}_{-0.034}$ (1976BE1B)		
					(1978HA39)			



Table 15.4: Radiative decays in  $^{15}\text{N}^a$  (continued)

$E_i$ (MeV)	$J_i^\pi$	$E_f$ (MeV)	$J_f^\pi$	Branch (%)	Mult. mixing ratio $\delta$	Refs.
9.23 <sup>e</sup>	$\frac{1}{2}^-$	5.27	$\frac{5}{2}^+$	$11 \pm 1$		(1978HA39)
		5.30	$\frac{1}{2}^+$	$10 \pm 1$		(1978HA39)
		6.32	$\frac{3}{2}^-$	$22 \pm 2$		(1978HA39)
		7.16	$\frac{5}{2}^+$	$57 \pm 3$		(1978HA39)
		0	$\frac{1}{2}^-$	$22 \pm 5$		(1979HA38)
		5.30	$\frac{1}{2}^+$	$42 \pm 8$		(1979HA38)
		6.32	$\frac{3}{2}^-$	$35 \pm 6$		(1979HA38)
		7.16	$\frac{5}{2}^+$	$< 30$		(1965WA16)
				$< 1$		(1967PH03)
		7.30	$\frac{3}{2}^+$	$< 30$		(1965WA16)
9.76 <sup>c</sup>	$\frac{5}{2}^-$	7.57	$\frac{7}{2}^+$	$2.6 \pm 0.7$		(1967PH03)
		8.31	$\frac{1}{2}^+$	$< 20$		(1965WA16)
		0	$\frac{1}{2}^-$	$< 5$		(1965WA16)
		5.27 + 5.30		$81.5 \pm 2.8$		(1967PH03)
		6.32	$\frac{3}{2}^-$	$7.5 \pm 1.5$		(1967PH03)
		7.16	$\frac{5}{2}^+$	$3.7 \pm 0.8$		(1967PH03)
		7.57	$\frac{7}{2}^+$	$2.3 \pm 0.5$		(1967PH03)
		8.31	$\frac{1}{2}^+$	$5.0 \pm 0.6$		(1967PH03)
		8.57	$\frac{3}{2}^+$	$< 1$		(1967PH03)
		0	$\frac{1}{2}^-$	$< 2$		(1965WA16, 1967PH03)
9.83 <sup>c</sup>	$\frac{7}{2}^-$	0	$\frac{1}{2}^-$	$< 4$		(1967PH03)
		5.27	$\frac{5}{2}^+$	$\approx 85$		(1965WA16, 1967PH03)
		5.30	$\frac{1}{2}^+$	$< 15$		(1965WA16)
		6.32	$\frac{3}{2}^-$	$2.2 \pm 0.9$		(1967PH03)
		7.16	$\frac{5}{2}^+$	$2.4 \pm 1.1$		(1967PH03)

Table 15.4: Radiative decays in  $^{15}\text{N}^a$  (continued)

$E_i$ (MeV)	$J_i^\pi$	$E_f$ (MeV)	$J_f^\pi$	Branch (%)	Mult. mixing ratio $\delta$	Refs.		
9.93	$\frac{3}{2}^-$	7.30	$\frac{3}{2}^+$	$3.7 \pm 0.9$		(1967PH03)		
		7.57	$\frac{7}{2}^+$	$7.3 \pm 1.0$		(1967PH03)		
		0	$\frac{1}{2}^-$	$77.6 \pm 1.9$		(1967PH03)		
		5.27 + 5.30		$15.4 \pm 1.5$		(1967PH03)		
		6.32	$\frac{3}{2}^-$	$4.9 \pm 1.2$		(1967PH03)		
		7.16	$\frac{5}{2}^+$	$< 1$		(1967PH03)		
		7.30	$\frac{3}{2}^+$	$2.1 \pm 0.8$		(1967PH03)		
		7.57	$\frac{7}{2}^+$	$< 1$		(1967PH03)		
		8.31	$\frac{1}{2}^+$	$< 1$		(1967PH03)		
		8.57	$\frac{3}{2}^+$	$< 1$		(1967PH03)		
10.07	$\frac{3}{2}^+$	0	$\frac{1}{2}^-$	$96.0 \pm 0.7$		(1967PH03)		
		5.27 + 5.30		$4.0 \pm 0.7$		(1967PH03)		
		6.32, 7.16, 7.30, 7.57		$< 2$		(1966WA08)		
		8.31	$\frac{1}{2}^+$	$< 2$		(1965WA16)		
		8.57	$\frac{3}{2}^+$	$< 3$		(1965WA16)		
10.45	$\frac{5}{2}^-$	0	$\frac{1}{2}^-$	$< 12$		(1976BE1B)		
		5.27	$\frac{5}{2}^+$	$55.0 \pm 0.8$	$+0.021 \pm 0.033$	(1976BE1B)		
		5.30	$\frac{1}{2}^+$	$< 2$		(1976BE1B)		
		6.32	$\frac{3}{2}^-$	$31.3 \pm 1.7$	$-0.59 \pm 0.13$	(1976BE1B)		
		7.16	$\frac{5}{2}^+$	$5.2 \pm 0.1$	$+0.13^{+0.03}_{-0.04}$	(1976BE1B)		
		8.57	$\frac{3}{2}^+$	$3.8 \pm 0.6$	$-0.3 \pm 0.4$	(1976BE1B)		
		9.152	$\frac{3}{2}^-$	$4.7 \pm 0.1$	$-0.32^{+0.09}_{-0.10}$	(1976BE1B)		
		9.83	$\frac{7}{2}^-$	$< 0.1$		(1976BE1B)		
		10.53	$\frac{5}{2}^+$	0	$\frac{1}{2}^-$	$< 0.1$		(1976BE1B)
				5.27	$\frac{5}{2}^+$	$38.7 \pm 0.2$	$-0.27 \pm 0.03$	(1976BE1B)

Table 15.4: Radiative decays in  $^{15}\text{N}^a$  (continued)

$E_i$ (MeV)	$J_i^\pi$	$E_f$ (MeV)	$J_f^\pi$	Branch (%)	Mult. mixing ratio $\delta$	Refs.		
10.69 <sup>c</sup>	$\frac{9}{2}^+$	6.32	$\frac{3}{2}^-$	$7.7 \pm 0.1$	$-0.028 \pm 0.004$	(1976BE1B)		
		7.16	$\frac{5}{2}^+$	$19.4 \pm 0.2$	$+0.007^{+0.010}_{-0.008}$	(1976BE1B)		
		7.30	$\frac{3}{2}^+$	$31.4 \pm 0.5$	$+0.066 \pm 0.005$	(1976BE1B)		
		8.57	$\frac{3}{2}^+$	$2.4 \pm 0.1$	$+0.012^{+0.006}_{-0.005}$	(1976BE1B)		
		9.152	$\frac{3}{2}^-$	$0.3 \pm 0.1$	$-0.20^{+0.03}_{-0.02}$	(1976BE1B)		
		5.27	$\frac{5}{2}^+$	$61.6 \pm 0.3$		(1975BE23, 1976BE1B)		
		7.16	$\frac{5}{2}^+$	$2.1 \pm 0.1$	$-0.03 \pm 0.07$	(1975BE23, 1976BE1B)		
10.70 <sup>f</sup>	$\frac{3}{2}^-$	7.57	$\frac{7}{2}^+$	$36.3 \pm 0.6$	$+0.118 \pm 0.008$	(1975BE23, 1976BE1B)		
		0	$\frac{1}{2}^-$	$52.6 \pm 0.8$	$+0.180^{+0.006}_{-0.002}$	(1976BE1B)		
		5.27	$\frac{5}{2}^+$	$37.4 \pm 0.6$	$-0.24^{+0.004}_{-0.008}$	(1976BE1B)		
		5.30	$\frac{1}{2}^+$	$0.8 \pm 0.1$	$-0.13 \pm 0.07$	(1976BE1B)		
		6.32	$\frac{3}{2}^-$	$3.8 \pm 0.1$	$+0.135 \pm 0.015$	(1976BE1B)		
		7.16	$\frac{5}{2}^+$	$0.4 \pm 0.1$	$0.3 \pm 0.3$	(1976BE1B)		
		7.30	$\frac{3}{2}^+$	$2.3 \pm 0.1$	$-0.027 \pm 0.023$	(1976BE1B)		
		8.31	$\frac{1}{2}^+$	$0.8 \pm 0.1$	$-0.017^{+0.018}_{-0.016}$	(1976BE1B)		
		9.05	$\frac{1}{2}^+$	$0.2 \pm 0.1$	$-0.007 \pm 0.12$	(1976BE1B)		
		9.152	$\frac{3}{2}^-$	$0.2 \pm 0.1$	$-0.11 \pm 0.03$	(1976BE1B)		
		9.23	$\frac{1}{2}^-$	$1.5 \pm 0.1$	$+0.049^{+0.006}_{-0.005}$	(1976BE1B)		
		10.80	$\frac{3}{2}^+ 1$	0	$\frac{1}{2}^-$	$51.5 \pm 0.4$	$-0.02 \pm 0.01^f$	(1976BE1B)
				5.27	$\frac{5}{2}^+$	$4.9 \pm 0.1$	$-0.63 \pm 0.04^f$	(1976BE1B)
5.30	$\frac{1}{2}^+$			$15.5 \pm 0.2$	$-0.55 \pm 0.02^f$	(1976BE1B)		
6.32	$\frac{3}{2}^-$			$5.4 \pm 0.2$	$-0.07 \pm 0.05^f$	(1976BE1B)		
7.16	$\frac{5}{2}^+$			$7.8 \pm 0.1$	$+0.14 \pm 0.03^f$	(1976BE1B)		
7.30	$\frac{3}{2}^+$			$5.8 \pm 0.1$	$-0.12 \pm 0.02^f$	(1976BE1B)		
8.31	$\frac{1}{2}^+$			$3.6 \pm 0.1$	$+0.12 \pm 0.03^f$	(1976BE1B)		

Table 15.4: Radiative decays in  $^{15}\text{N}^a$  (continued)

$E_i$ (MeV)	$J_i^\pi$	$E_f$ (MeV)	$J_f^\pi$	Branch (%)	Mult. mixing ratio $\delta$	Refs.
11.62 <sup>g</sup>	$\frac{1}{2}^+; T = \frac{3}{2}$	9.05	$\frac{1}{2}^+$	$0.3 \pm 0.1$		(1976BE1B)
		9.152	$\frac{3}{2}^3-$	$0.9 \pm 0.1$		(1976BE1B)
		9.155	$\frac{5}{2}^5-$	$4.2 \pm 0.1$		(1976BE1B)
		0	$\frac{1}{2}^-$	$90.7 \pm 3.0$		(1971KU01)
		5.27	$\frac{5}{2}^5+$	$< 1$		(1971KU01)
		5.30	$\frac{1}{2}^+$	$7.4 \pm 1.5$		(1971KU01)
		6.32	$\frac{3}{2}^3-$	$1.9 \pm 1.5$		(1971KU01)
12.52	$\frac{5}{2}^+; T = \frac{3}{2}$	0	$\frac{1}{2}^-$	$< 1$		(1971KU01)
		5.27	$\frac{5}{2}^5+$	$94.2 \pm 0.6^h$		(1971YO03)
		5.30	$\frac{1}{2}^+$	$< 1$		(1971KU01)
		6.32	$\frac{3}{2}^3-$	$5.8 \pm 0.6^i$		(1971YO03)
13.39 <sup>j</sup>	$\frac{3}{2}^+$	0	$\frac{1}{2}^-$	100		(1976KU01)

A = adopted.

<sup>a</sup> See also Tables 15.5 and 15.17.

<sup>b</sup> Please note that (1976BE1B) is an unpublished Ph.D. thesis.

<sup>c</sup> See also (1979HA38).

<sup>d</sup> See also Table 15.5 in (1976AJ04).

<sup>e</sup> See also (1967PH03).

<sup>f</sup> See (1969SI04).

<sup>g</sup>  $\Gamma_\gamma = 49 \pm 20, 4 \pm 2, 1.0 \pm 0.8$  eV for transitions to  $^{15}\text{N}^*(0, 5.30, 6.32)$  (1971KU01): see however Table 15.12.

<sup>h</sup>  $\Gamma_\gamma = 4.3 \pm 0.7$  eV (1971YO03);  $\delta = -0.02 \pm 0.04$  (E2/M1) (1971KU01).

<sup>i</sup>  $\Gamma_\gamma = 0.27 \pm 0.05$  eV (1971YO03);  $\delta = -0.02 \pm 0.04$  (E2/M1) (1971KU01).

<sup>j</sup>  $\Gamma_{\gamma_0} = 3.0 \pm 0.9$  eV,  $\Gamma_p \Gamma_{\gamma_0} / \Gamma = 1.70 \pm 0.5$  eV;  $\delta = 0.00 \pm 0.04$  (M2/E1);  $B(E1) = (1.2 \pm 0.4) \times 10^{-3} e^2 \cdot \text{fm}^2$ . Transitions to  $^{15}\text{N}^*(5.27, 5.30) < 8\%$  and to  $^{15}\text{N}^*(6.32, 7.16, 7.30) < 5\%$  (1976KU01).

<sup>k</sup> See also Table 15.17.

<sup>l</sup>  $\pi$  is + because if  $\pi$  were - the  $\Gamma_\gamma$  and  $\delta$  of the  $10.80 \rightarrow 5.30$  MeV transition would lead to an unacceptably high M2 value (33 W.u.) (P.M. Endt, private communication).

6.  $^{11}\text{B}(\alpha, \gamma)^{15}\text{N}$   $Q_m = 10.9913$

The  $90^\circ$  differential cross section for  $\gamma_0$  production has been measured for  $E_\alpha = 5.74$  to 17.80 MeV (1977DE04) and 6 to 11.5 MeV (1978DE23; also angular distributions). Observed resonances are displayed in Table 15.6.

7.  $^{11}\text{B}(\alpha, n)^{14}\text{N}$   $Q_m = 0.1580$   $E_b = 10.9913$

Reported resonances are displayed in Table 15.7. For angular distributions see  $^{14}\text{N}$ . For polarization measurements see (1977NI03:  $E_\alpha = 2.049$  MeV) and (1976AJ04). See also (1977LI19).

8.  $^{11}\text{B}(\alpha, p)^{14}\text{C}$   $Q_m = 0.7839$   $E_b = 10.9913$

Reported resonances are listed in Table 15.7. The yield curve for  $^{14}\text{C}$  is dominated by two strong resonances at  $E_\alpha = 1.57$  and 2.64 MeV (1976DA06; CTR implications). At higher energies (to 25 MeV) the  $p_0$  excitation functions show broad features: see (1978HO08:  $E_\alpha = 4.4$  to 6.7 MeV) and (1976AJ04).

9.  $^{11}\text{B}(\alpha, d)^{13}\text{C}$   $Q_m = -5.1680$   $E_b = 10.9913$

The yield of  $d_0$  has been measured for  $E_\alpha = 13.5$  to 25 MeV (1975VA19). See also (1976AJ04, 1976LE1K).

10.  $^{11}\text{B}(\alpha, t)^{12}\text{C}$   $Q_m = -3.8571$   $E_b = 10.9913$

Excitation functions for  $t_0$  and  $t_1$  (to 25 MeV) show strong uncorrelated structures: see (1976AJ04). See also (1976LE1K).

11.  $^{11}\text{B}(\alpha, \alpha)^{11}\text{B}$   $E_b = 10.9913$

Observed resonances for  $E_\alpha = 2.1$  to 7.9 MeV are shown in Table 15.7. See also (1976AJ04).

12.  $^{11}\text{B}(^6\text{Li}, d)^{15}\text{N}$   $Q_m = 9.5178$

Table 15.5: Lifetimes of some  $^{15}\text{N}$  states <sup>a</sup>

$E_x$ (MeV)	$\tau_m$	Reaction	Refs.
5.27	$2.6 \pm 0.2$ psec	mean	Table 15.6 in (1976AJ04)
5.30	$25 \pm 7$ fsec	mean	Table 15.6 in (1976AJ04)
6.32	$0.35 \pm 0.07$ fsec	$^{15}\text{N}(e, e)$	(1975KI08)
	$0.23 \pm 0.002$ fsec <sup>A</sup>	$^{15}\text{N}(\gamma, \gamma)$	(1976MO14)
7.16	$28 \pm 8$ fsec	$^{13}\text{C}(^{14}\text{N}, ^{12}\text{C})$	(1975SE04)
	$9 \pm 7$ fsec	$^{12}\text{C}(^7\text{Li}, \alpha)$	(1979HA38)
	$18 \pm 8$ fsec	mean	
7.30	$< 10$ fsec	$^{12}\text{C}(^7\text{Li}, \alpha)$	(1979HA38)
	$0.25 \pm 0.10$ fsec <sup>A</sup>	$^{15}\text{N}(e, e)$	(1975KI09)
7.57	$12_{-6}^{+11}$ fsec	$^{12}\text{C}(^7\text{Li}, \alpha)$	(1979HA38)
	$60 \pm 20$ fsec	$^{14}\text{N}(d, p)$	(1968GI11)
8.31	$< 16$ fsec	$^{12}\text{C}(^7\text{Li}, \alpha)$	(1979HA38)
8.57	$11 \pm 7$ fsec	$^{12}\text{C}(^7\text{Li}, \alpha)$	(1979HA38)
9.05	$< 2$ fsec	$^{12}\text{C}(^7\text{Li}, \alpha)$	(1979HA38)
9.152	$< 40$ fsec	$^{13}\text{C}(^3\text{He}, p)$	(1972ST22)
9.155	$7_{-3}^{+6}$ fsec	$^{12}\text{C}(^7\text{Li}, \alpha)$	(1978HA39)
9.23	$< 130$ fsec	$^{13}\text{C}(^3\text{He}, p)$	(1972ST22)
9.76	$< 12$ fsec	$^{12}\text{C}(^7\text{Li}, \alpha)$	(1979HA38)
9.83	$17 \pm 7$ fsec	$^{12}\text{C}(^7\text{Li}, \alpha)$	(1979HA38)
9.93	$< 10$ fsec	$^{12}\text{C}(^7\text{Li}, \alpha)$	(1979HA38)
10.07	$0.16 \pm 0.05$ fsec	$^{15}\text{N}(\gamma, \gamma)$	(1976PA22)
10.69	$18 \pm 9$ fsec	$^{12}\text{C}(^7\text{Li}, \alpha)$	(1979HA38)

A = adopted.

<sup>a</sup> See also Tables 15.12 and 15.17 for other states.

Table 15.6: Resonances in  $^{11}\text{B}(\alpha, \gamma_0)^{15}\text{N}$  <sup>a</sup>

$E_\alpha$ (MeV)	$E_x$ (MeV)	$\Gamma_{\text{c.m.}}$ (keV)	Multipol.	$\Gamma_\gamma$ (eV)	$J^\pi$
7.31	$16.35 \pm 0.02$	$270 \pm 30$	E1	$\geq 11$	$\frac{3}{2}^+$
7.83	$16.73 \pm 0.02$	$270 \pm 30$	(E1)	$\geq 11$	$(\frac{1}{2}^+, \frac{3}{2}^+)$
8.40	$17.15 \pm 0.05$	$250 \pm 60$	(E1)	$\geq 2$	$(\frac{1}{2}^+, \frac{3}{2}^+)$
9.11	$17.67 \pm 0.05$	$600 \pm 80$	E1	$\geq 7$	$\frac{3}{2}^+$
11.00	$19.05 \pm 0.05$	$\approx 700$ <sup>b</sup>			
14.0	$21.26 \pm 0.20$ <sup>b</sup>	$\approx 1700$ <sup>b</sup>			

<sup>a</sup> (1978DE23).

<sup>b</sup> (1977DE04).

At  $E(^6\text{Li}) = 34$  MeV angular distributions are reported to the states with  $5.3 < E_x < 16.3$  MeV: this reaction appears to be less than reaction 13. The most strongly populated states are  $^{15}\text{N}^*(9.2, 10.5, 10.7, 13.1, 14.8, 15.5)$  (1976NO01). See also (1976AJ04).

13.  $^{11}\text{B}(^7\text{Li}, \text{t})^{15}\text{N}$   $Q_m = 8.525$

At  $E(^7\text{Li}) = 24$  and  $34$  MeV, angular distributions to states with  $5.3 < E_x < 15.6$  MeV have been measured (1976KO11, 1976NO01):  $^{15}\text{N}^*(9.8, 10.5, 10.7, 15.4, 15.5)$  are particularly strongly populated at  $34$  MeV.  $J^\pi = \frac{9}{2}^+, \frac{9}{2}, \frac{11}{2}, \frac{9}{2}, \frac{11}{2}, \frac{13}{2}, \frac{15}{2}$  are suggested for  $^{15}\text{N}^*(10.69, 12.56, 13.03, 13.19, 13.84, 14.11, 15.37)$  (1976KO11). (1976NO01) find that only  $^{15}\text{N}^*(15.52)$  has a large cluster component corresponding to  $^{11}\text{B} + \alpha$ . The  $\gamma$ -decay of  $^{15}\text{N}$  states populated in this reaction has been studied by (1979HA38): see Tables 15.4 and 15.5. For earlier work see (1976AJ04).

14.  $^{11}\text{B}(^{11}\text{B}, ^7\text{Li})^{15}\text{N}$   $Q_m = 2.326$

At  $E(^{11}\text{B}) = 114$  MeV broad peaks are observed at  $^{15}\text{N}^*(5.3, 9.7, 13, 16.8, 20)$  (1974AN36).

15.  $^{11}\text{B}(^{16}\text{O}, ^{12}\text{C})^{15}\text{N}$   $Q_m = 3.8294$

Angular distributions have been measured at  $E(^{16}\text{O}) = 27, 30, 32.5, 35$  and  $60$  MeV involving  $^{15}\text{N}_{\text{g.s.}} + ^{12}\text{C}_{\text{g.s.}}$ ,  $^{15}\text{N}_{\text{g.s.}} + ^{12}\text{C}_{4.4}^*$ ,  $^{15}\text{N}_{6.32}^* + ^{12}\text{C}_{\text{g.s.}}$  and  $^{15}\text{N}_{\text{g.s.}} + ^{12}\text{C}_{9.6}^*$  (1972SC03, 1972SC17, 1975SC35): the reaction selectively populates the two proton-hole states of  $^{15}\text{N}$ :  $^{15}\text{N}^*(0, 6.32)$  [ $J^\pi = \frac{1}{2}^-, \frac{3}{2}^-$ ]. See also (1976AJ04) and (1976DE08, 1977WE1H; theor.).



Table 15.7: Resonances in  $^{11}\text{B} + \alpha$ 

$E_\alpha$ (MeV $\pm$ keV)	$\Gamma_{\text{c.m.}}$ (keV)	Particle out	$J^\pi$	$E_x$ (MeV)	Refs.
0.60		n		11.43	(1954BE08) <sup>a</sup>
1.03		n		11.75	(1954BE08)
1.18		n		11.86	(1954BE08)
1.30		n		11.94	(1954BE08)
1.51		n, p	$(\frac{5}{2}^+)$	12.10	(1955SH46, 1976DA06)
1.58	$41 \pm 5$	n, p	$(\frac{3}{2}^-)$	12.15	(1955SH46, 1976DA06)
$2.056 \pm 10$	$34 \pm 5$	$n_0, p_0$	$\frac{5}{2}^+$	12.499	A, (1975VA06, 1976DA06)
$2.610 \pm 13$	$56 \pm 11$	$n_0, p_0, \alpha$	$\frac{3}{2}^-$	12.905	A, (1972RA03, 1975VA06, 1976DA06)
$2.66 \pm 30$	81	$p_0, \alpha$	$\frac{5}{2}^+$	12.94	A, (1972RA03, 1976DA06)
$2.942 \pm 10$	$7 \pm 3$	$n_0, p_0$		13.149	A, (1975VA06)
$2.984 \pm 10$	$7 \pm 3$	$n_0, p_0$		13.180	A, (1975VA06)
$3.239 \pm 15$	$16 \pm 8$	$n_0, p, \alpha$	$\frac{3}{2}^-$	13.366	A, (1972RA03, 1975VA06)
$3.31 \pm 30$	61	$p, \alpha$	$\frac{3}{2}^+$	13.42	A, (1972RA03)
$3.46 \pm 30$	$85 \pm 30$	$n_0, \alpha$	$\frac{3}{2}^-$	13.53	(1972RA03, 1975VA06)
$3.560 \pm 10$	$18 \pm 4$	$n_0, p$	$(\frac{5}{2}, \frac{7}{2})^-$	13.602	A, (1975VA06)
$3.57 \pm 30$	94	$\alpha$	$\frac{1}{2}^+$	13.61	(1972RA03)
$3.712 \pm 10$	$26 \pm 8$	$n_0$		13.713	A, (1975VA06)
$(3.78 \pm 30)$	70	$\alpha$	$(\frac{1}{2}^+)$	(13.76)	(1972RA03)
$3.89 \pm 30$	$\approx 70$	$n_1, \alpha$	$(\frac{3}{2}^+)$	13.84	(1972RA03, 1975VA06)
$4.09 \pm 30$	$\approx 100$	$n_1$		13.99	(1975VA06)
$4.232 \pm 10$	$22 \pm 6$	$n_0$		14.094	(1975VA06)
$4.24 \pm 30$	$\approx 100$	$n_1, \alpha$	$\frac{3}{2}^+$	14.10	(1972OT04, 1975VA06)
$4.324 \pm 10$	$27 \pm 6$	$n_0$		14.162	A, (1975VA06)
$4.43 \pm 40$	150	$\alpha$	$\frac{5}{2}^+$	14.24	(1972OT04)
$4.62 \pm 40$	100	$\alpha$	$\frac{7}{2}^+$	14.38	(1972OT04)
$4.85 \pm 20$	$200 \pm 50$	$n_0$		14.55	(1975VA06)
$4.986 \pm 10$	$33 \pm 6$	$n_0$		14.647	(1975VA06)
$5.11 \pm 30$	$110 \pm 50$	$n_0$		14.74	(1975VA06)
$5.28 \pm 20$	$48 \pm 11$	$n_0, \alpha$		14.86	(1972OT04, 1975VA06)
$5.538 \pm 10$	$12 \pm 3$	$n_0$		14.920	(1975VA06)
$5.501 \pm 10$	$13 \pm 3$	$n_0$		15.025	(1975VA06)
$5.59 \pm 20$	$80 \pm 25$	$n_0, \alpha$		15.09	(1972OT04, 1975VA06)
$5.860 \pm 10$	$22 \pm 6$	$n_0, \alpha$		15.288	(1972OT04, 1975VA06)

Table 15.7: Resonances in  $^{11}\text{B} + \alpha$  (continued)

$E_\alpha$ (MeV $\pm$ keV)	$\Gamma_{\text{c.m.}}$ (keV)	Particle out	$J^\pi$	$E_x$ (MeV)	Refs.
$5.98 \pm 20$	$75 \pm 25$	$n_2, (\alpha)$		15.38	(1972OT04, 1975VA06)
$6.06 \pm 20$	$\approx 100$	$n_0, (\alpha)$		15.43	(1972OT04, 1975VA06)
$6.19 \pm 20$	$\approx 35$	$n_0$		15.53	(1975VA06)
$6.29 \pm 20$	$95 \pm 25$	$n_2$		15.60	(1975VA06)
(6.65 $\pm$ 40)		( $\alpha$ )		(15.87)	(1972OT04)
$6.73 \pm 20$	$35 \pm 10$	$n_0, n_2$		15.93	(1975VA06)
$6.755 \pm 15$	$21 \pm 6$	$n_1$		15.944	(1975VA06)
$6.83 \pm 20$	$60 \pm 20$	$n_2$		16.00	(1975VA06)
$6.884 \pm 15$	$62 \pm 12$	$n_0, \alpha$		16.039	(1972OT04, 1975VA06)
(6.98 $\pm$ 40)		( $\alpha$ )		(16.11)	(1972OT04)
$7.18 \pm 20$	$\approx 100$	$n_0, \alpha$		16.26	(1975VA06)
$7.27 \pm 20$	$\approx 30$	$n_0$		16.32	(1975VA06)
$7.37 \pm 20$	$44 \pm 11$	$n_2$		16.39	(1975VA06)
$7.616 \pm 15$	$27 \pm 15$	$n_0, (n_2)$		16.576	(1975VA06)
$7.754 \pm 15$	$60 \pm 10$	$n_0, (n_2)$		16.677	(1975VA06)

A: see references listed for this state in Table 15.5 (1970AJ04).

<sup>a</sup> And private communication.

16. (a) $^{12}\text{C}(t, \gamma)^{15}\text{N}$	$Q_m = 14.8484$	
(b) $^{12}\text{C}(t, n)^{14}\text{N}$	$Q_m = 4.01507$	$E_b = 14.8484$
(c) $^{12}\text{C}(t, p)^{14}\text{C}$	$Q_m = 4.6410$	
(d) $^{12}\text{C}(t, t)^{12}\text{C}$		
(e) $^{12}\text{C}(t, \alpha)^{11}\text{B}$	$Q_m = 3.8571$	

The  $90^\circ$  excitation function for  $\gamma_0$  (reaction (a)) in the range 1.0 to 3.4 MeV shows one very strong resonance (at peak,  $4.4 \pm 0.5 \mu\text{b}/\text{sr}$ ) corresponding to  $^{15}\text{N}^*(16.7)$ . The excitation function and the measured angular distributions were analyzed [ $S$ -matrix] (1977SC01): Table 15.8 shows the derived parameters. Table 15.8 also displays the structures observed in reactions (b)  $\rightarrow$  (e). Polarization studies of the elastic scattering are reported at  $E_{\bar{t}} = 15.0$  and 17.0 MeV by (1978SC02). See also  $^{11}\text{B}$  and  $^{12}\text{C}$  in (1980AJ01),  $^{14}\text{C}$  and  $^{14}\text{N}$  here, and (1976AJ04).

17. $^{12}\text{C}(\alpha, p)^{15}\text{N}$	$Q_m = -4.9656$
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Table 15.8: Resonances in  $^{12}\text{C} + t$ 

$E_t$ (MeV $\pm$ keV)	$E_x$ (MeV)	Particles out	$J^\pi$	$\Gamma$ (keV)	Refs. <sup>a</sup>
0.66	15.38	$\alpha_0$			
1.11	15.74	$p_0, t_0, \alpha_1$			
1.21	15.82	$t_0$			
$1.30 \pm 20$	15.89	$n, \alpha_0$			
$1.39 \pm 20$	15.96	$n, t_0, \alpha_0$			
1.46	16.02	$p_0$			
1.54	16.08	$n, \alpha_0, \alpha_1$			
$1.64 \pm 40$	16.16	$\gamma_0, n, \alpha_0$	$\frac{3}{2}^+$	$450 \pm 100$	(1977SC01) <sup>b</sup>
1.78	16.27	$\alpha_0$			
$1.85 \pm 20$	16.33	$n, p_0, \alpha_0, \alpha_1$			
$1.98 \pm 20$	16.43	$n, p_0$			
$2.05 \pm 30$	16.49	$p_0, t_0, \alpha_0$			
$2.18 \pm 25$	16.59	$\gamma_0, n, p_0, t_0, \alpha_0, \alpha_1$	$\frac{3}{2}^-$	490	(1977SC01) <sup>b</sup>
2.30	$16.69 \pm 0.01$	$\gamma_0, n, p_0, \alpha_0, \alpha_1$	$\frac{3}{2}^+$	$130 \pm 15$	(1977SC01) <sup>b</sup>
$2.39 \pm 30$	16.76	$n, t_0, \alpha_0, \alpha_1$			
$2.50 \pm 30$	16.85	$\alpha_0, \alpha_1$			
2.60	16.93	$\alpha_0$			
2.75	17.05	$p_0$			
2.82	17.10	$\gamma_0, t_0, \alpha_0, \alpha_1$	$\frac{3}{2}^-$		(1977SC01) <sup>b</sup>
$2.89 \pm 50$	17.16	$\alpha_0$			
3.14	17.36	$\alpha_1$			
3.30	$17.49 \pm 0.09$	$\gamma_0$	$\frac{3}{2}^+$	$450 \pm 120$	(1977SC01) <sup>b</sup>
15.0	26.8	$t_0$			

<sup>a</sup> See also references listed for each state in Table 15.8 of (1976AJ04).

<sup>b</sup>  $S$ -matrix analysis.

Angular distributions have been measured for  $E_\alpha = 13.4$  to 42 MeV [see (1976AJ04)] and at  $E_\alpha = 17.52$  to 18.64 MeV (1979MO03;  $p_0$ ), 24 to 33 MeV (1978BU27;  $p_3$ ), 40 MeV (1979VA08;  $p_{1+2}$  and  $p$  to  $^{15}\text{N}^*(10.7, 15.4)$ ) and at 96.8 MeV (1975FA07: see Table 15.9; reduced widths are calculated). At 97 MeV the spectrum at  $10.5^\circ$  is dominated by  $^{15}\text{N}^*(15.37)$  [ $J^\pi = \frac{13}{2}^+$ ]: DWBA calculations have been carried out using a semi-microscopic three-nucleon form factor and several different sets of wave functions (1975FA07). See also (1976BU21, 1979AMZU), (1977FO1E, 1978FA1H), (1980ZE05; theor.) and  $^{16}\text{O}$  in (1982AJ01).

$$18. \text{}^C({}^6\text{Li}, {}^3\text{He}){}^{15}\text{N} \quad Q_m = -0.9455$$

Observed  ${}^3\text{He}$  groups are displayed in Table 15.9. Comparisons of the angular distributions obtained in this reaction at  $E({}^6\text{Li}) = 60.1$  MeV and in the  $({}^6\text{Li}, t)$  reaction shows analog correspondence for the following pairs of levels: 5.27–5.24, 7.16–6.86, 7.57–7.28, 8.58–8.28, 10.80–10.48, 13.15(u)–12.84, 15.49(u)–15.05 [first listed is  $E_x$  in  $^{15}\text{N}$ ; second in  $^{15}\text{O}$ ] (1975BI06) [ $E_x$  are nominal; u = unresolved.]. For  $\gamma$ -decay measurements see Table 15.4 (1978HA39, 1979HA38). See also (1977MA2G), (1977FO1E) and the earlier work reported in (1976AJ04).

$$19. \text{}^{12}\text{C}({}^7\text{Li}, \alpha){}^{15}\text{N} \quad Q_m = 12.3817$$

Observed  $\alpha$  groups are shown in Table 15.9 (1973TS02). Angular distributions have been measured to  $E({}^7\text{Li}) = 35$  MeV: see (1976AJ04). Comparison of spectra from this reaction ( $E({}^7\text{Li}) = 34.9$  MeV) with those from  ${}^{13}\text{C}({}^6\text{Li}, \alpha)$  (reaction 32) lead to configurations of  $(d)^3$  for  $^{15}\text{N}^*(10.7, 12.57, 13.20, 15.42)$  and suggest that  $^{15}\text{N}^*(12.57, 13.20)$  have lower  $J$  than  $^{15}\text{N}^*(10.7, 15.5)$ , probably  $J \leq \frac{7}{2}$ .  $^{15}\text{N}^*(13.02)$  is shown to be  $p(d)^2$  in agreement with  $J^\pi = \frac{11}{2}^-$  (1976HA31).

$^{15}\text{N}^*(9.155)$  [ $J = \frac{5}{2}$ ] decays to  $^{15}\text{N}^*(5.30)$  [ $J^\pi = \frac{1}{2}^+$ ] by an E2 transition; therefore its parity is positive. It has a large triton cluster parentage. This is not true of  $^{15}\text{N}^*(9.152)$  (1978HA39). For  $\gamma$ -decay measurements see Table 15.4 (1978HA39, 1979HA38). For  $\tau_m$  measurements see Table 15.5.

$$20. \text{(a) } {}^{12}\text{C}({}^{10}\text{B}, {}^7\text{Be}){}^{15}\text{N} \quad Q_m = -3.820$$

$$\text{(b) } {}^{12}\text{C}({}^{11}\text{B}, {}^8\text{Be}){}^{15}\text{N} \quad Q_m = 3.6246$$

At  $E({}^{10}\text{B}) = 100$  MeV angular distributions have been measured for  $^{15}\text{N}^*(5.27, 7.57, 9.87, 10.87, 13.15, 15.72, 16.26, 17.83)$  and comparisons have been attempted with those to states in  $^{15}\text{O}$ , in the mirror reaction (1973NA09) [see however reaction 7 in  $^{15}\text{O}$  (1976AJ04)]. (1974AN36;  $E({}^{10}\text{B}) = 100$  MeV), on the other hand, report population of  $^{15}\text{N}^*(0, 5.24, 7.28, 9.64, 10.47, 12.89, 15.36, 15.88)$ .  $^{15}\text{N}^*(12.89, 15.36)$  are the most intense groups (1974AN36). For reaction (b) see (1978FR20, 1979FR05). See also (1977FO1E).

Table 15.9: States of  $^{15}\text{N}$  from  $^{12}\text{C}(\alpha, \text{p})^{15}\text{N}$ ,  $^{12}\text{C}({}^6\text{Li}, {}^3\text{He})^{15}\text{N}$  and  $^{12}\text{C}({}^7\text{Li}, \alpha)^{15}\text{N}$

$E_x$ (MeV $\pm$ keV)			$L^a$	$J^\pi^a$
(1975FA07) <sup>a</sup>	(1975BI06) <sup>b</sup>	(1973TS02) <sup>c</sup>		
0		0	1	$\frac{1}{2}^-$
5.27 + 5.30	5.27 $\pm$ 60	5.295 $\pm$ 10 <sup>c</sup>	2 + 0	
		6.332 $\pm$ 10		
		7.163 $\pm$ 10		
	7.24 $\pm$ 60			
		7.310 $\pm$ 10		
7.57	7.61 $\pm$ 60	7.566 $\pm$ 10	4	$\frac{7}{2}^+$
		8.320 $\pm$ 10		
8.58	8.59 $\pm$ 60	8.580 $\pm$ 10 <sup>c</sup>	2	$\frac{3}{2}^+$
9.15 + 9.15	9.17 $\pm$ 60	9.163 $\pm$ 10 <sup>c</sup>	1 + 2	f
	9.84 $\pm$ 60	9.828 $\pm$ 10 <sup>c</sup>		
		9.932 $\pm$ 10		
		10.072 $\pm$ 10		
		10.524 $\pm$ 10		
10.70	10.73 $\pm$ 60 <sup>e</sup>	10.700 $\pm$ 10 <sup>c</sup>	4	$\frac{9}{2}^+ \text{ f}$
		10.808 $\pm$ 10		
		11.430 $\pm$ 10		
	12.05 $\pm$ 60	11.951 $\pm$ 10		
	12.36 $\pm$ 60	12.320 $\pm$ 10 <sup>c</sup>		
	12.64 $\pm$ 60	12.559 $\pm$ 10 <sup>c,d</sup>		
		12.923 $\pm$ 10		
13.01		13.004 $\pm$ 10 <sup>c</sup>	5	$(\frac{11}{2}^-)$
13.19	13.15 $\pm$ 60 <sup>e</sup>	13.173 $\pm$ 10 <sup>c</sup>	2	
		13.614 $\pm$ 10		
		14.087 $\pm$ 10		
		14.720 $\pm$ 10		
		15.021 $\pm$ 10		
15.40	15.49 $\pm$ 60 <sup>e</sup>	15.373 $\pm$ 10	6	$\frac{13}{2}^+ \text{ f}$
		15.782 $\pm$ 10		

Table 15.9: States of  $^{15}\text{N}$  from  $^{12}\text{C}(\alpha, p)^{15}\text{N}$ ,  $^{12}\text{C}(^6\text{Li}, ^3\text{He})^{15}\text{N}$  and  $^{12}\text{C}(^7\text{Li}, \alpha)^{15}\text{N}$  (continued)

$E_x$ (MeV $\pm$ keV)			$L^a$	$J^\pi^a$
(1975FA07) <sup>a</sup>	(1975BI06) <sup>b</sup>	(1973TS02) <sup>c</sup>		
	15.88 $\pm$ 60	16.026 $\pm$ 10		
	16.18 $\pm$ 60	16.190 $\pm$ 10		
	16.41 $\pm$ 60			
	16.74 $\pm$ 60			
	18.02 $\pm$ 60			
	18.82 <sup>g</sup>			
	19.77 $\pm$ 60			

<sup>a</sup>  $E_\alpha = 96.8$  MeV.  $E_x$  are nominal.

<sup>b</sup>  $E(^6\text{Li}) = 60.1$  MeV: angular distributions measured for states with  $E_x < 16.2$  MeV.

<sup>c</sup>  $E(^7\text{Li}) = 35$  MeV: angular distributions have been measured for the states labeled by this footnote.

<sup>d</sup> (1973TS02) suggest that this state is not the  $T = \frac{3}{2}$  state at 12.52 MeV.

<sup>e</sup>  $\Gamma_\gamma/\Gamma = 0.9 \pm 0.2, < 0.25, < 0.25$  for  $^{15}\text{N}^*(10.69, 13.15, 15.5)$  (1977KR1A).

<sup>f</sup> See also (1979VA08).

<sup>g</sup> (1977ZE1E); preliminary work.

$$21. \text{ (a) } ^{12}\text{C}(^{16}\text{O}, ^{13}\text{N})^{15}\text{N} \quad Q_m = -10.184$$

$$\text{ (b) } ^{12}\text{C}(^{18}\text{O}, ^{15}\text{N})^{15}\text{N} \quad Q_m = -0.9861$$

For reaction (a) see (1979PR07). Angular distributions for reaction (b) are reported at  $E(^{18}\text{O}) = 32.3$  and 35 MeV (1978CH16).

$$22. ^{12}\text{C}(^{19}\text{F}, ^{16}\text{O})^{15}\text{N} \quad Q_m = 3.1481$$

At  $E(^{19}\text{F}) = 40, 60$  and 68.8 MeV angular distributions have been measured for the transitions involving  $^{15}\text{N}^*(0, 5.3)$  and various  $^{16}\text{O}$  states:  $^{15}\text{N}^*(5.3)$  is very strongly excited (1972SC17). See also (1975PU02, 1977KO38).

Table 15.10: Resonances in  $^{13}\text{C} + \text{d}$

$E_d$ (MeV)	Particles out	$\Gamma_{\text{lab}}$ (keV)	$^{15}\text{N}^*$ (MeV)	Refs. <sup>a</sup>
0.37	p		16.48	
0.64	n, p <sub>0</sub> , t <sub>0</sub>	≈ 100	16.71	
0.85	n, p <sub>0</sub>	≈ 400	16.90	
1.10	α <sub>0</sub>	broad	17.11	
1.24 ± 0.04	t <sub>0</sub> , (α <sub>0</sub> )	≈ 200	17.23	
1.40 ± 0.04	p <sub>0</sub> , t <sub>0</sub> , α <sub>0</sub>	≈ 400	17.37	
1.64 ± 0.04	t <sub>0</sub>	≈ 200	17.58	
1.74 ± 0.04	γ <sub>0</sub> , n, α <sub>0</sub>	≈ 600	17.67 <sup>b</sup>	(1978DE05)
1.80 ± 0.01	(p <sub>0</sub> ), t <sub>0</sub> , α <sub>1</sub>	55 ± 10	17.72	
2.20 ± 0.01	(n), α <sub>0</sub> , α <sub>1</sub>	22 ± 4	18.06	
2.23 ± 0.02	(n), p <sub>0</sub> , t	≈ 50	18.09	
2.45 ± 0.03	n, p <sub>0</sub> , α <sub>0</sub>	270 ± 70	18.28	
3.46 ± 0.03	n	≈ 150	19.16	
5.1	n <sub>1</sub> , p <sub>0</sub>	≈ 50	20.6	
6.65	γ <sub>0</sub>	≈ 700	21.92	(1976DE32, 1979SK04)
8.8	γ <sub>0</sub>	broad	23.8	(1976DE32)

<sup>a</sup> See references listed in Table 15.10 (1976AJ04).

<sup>b</sup>  $J^\pi = \frac{1}{2}^-$  or  $\frac{3}{2}^+$ ;  $T = \frac{1}{2}$  (1973WE12).

$$23. \text{}^{12}\text{C}(\text{}^{20}\text{Ne}, \text{}^{17}\text{F})\text{}^{15}\text{N} \quad Q_m = -9.0962$$

See (1979OR01).

$$24. \text{}^{13}\text{C}(\text{d}, \gamma)\text{}^{15}\text{N} \quad Q_m = 16.1594$$

The  $90^\circ - 95^\circ$  yields of  $\gamma_0$  have been measured for  $E_d = 1$  to 10 MeV: observed resonances are displayed in Table 15.10. The  $\gamma$ -ray angular distributions are consistent with the emission of predominantly E1 radiation except for evidence of M1/E2 transitions in the region  $E_x = 20-21.5$  MeV (1976DE32).

$$25. \text{}^{13}\text{C}(\text{d}, \text{n})\text{}^{14}\text{N} \quad Q_m = 5.3260 \quad E_b = 16.1594$$

Table 15.11: Energy levels in  $^{15}\text{N}$  from  $^{13}\text{C}(^3\text{He}, p)^{15}\text{N}$

$E_x$ (MeV $\pm$ keV)		
(1959YO25, 1966GA08) <sup>a</sup>	(1966WA08) <sup>c</sup>	(1967PH03)
5.283 $\pm$ 12		
6.333 $\pm$ 12		
7.169 $\pm$ 12		
7.310 $\pm$ 12		
7.577 $\pm$ 13		
8.323 $\pm$ 6	8.312	
8.581 $\pm$ 5	8.570	
9.056 $\pm$ 5	9.052	9.054 $\pm$ 4
9.159 $\pm$ 5		
9.225 $\pm$ 6		9.225 $\pm$ 3
9.760 $\pm$ 5		
9.827 $\pm$ 6		9.829 $\pm$ 4
9.929 $\pm$ 8		
10.064 $\pm$ 7	10.074	10.072 $\pm$ 4
10.454 $\pm$ 6	10.452	
10.536 $\pm$ 7		
10.704 $\pm$ 6		
10.805 $\pm$ 7	10.800	
	(10.94 $\pm$ 30)	b

<sup>a</sup> First five values are from (1959YO25).

<sup>b</sup> (1979HA1M) report states at 11.88, 11.98, 18.76  $\pm$  0.01 and 19.91  $\pm$  0.01 MeV.

<sup>c</sup>  $E_\gamma$ , except for  $E_x = 10.94$ ; errors for  $E_\gamma$  are nominal.



Observed resonances are shown in Table 15.10. See also (1976AJ04).

$$26. \text{}^{13}\text{C}(\text{d}, \text{p})\text{}^{14}\text{C} \qquad Q_{\text{m}} = 5.9519 \qquad E_{\text{b}} = 16.1594$$

Observed resonances are displayed in Table 15.10. At  $E_{\text{d}} = 13$  MeV, the vector analyzing power (VAP) has been measured for the transitions to  $^{14}\text{C}^*(0, 6.09, 7.34)$  (1978DA17).

$$27. \text{}^{13}\text{C}(\text{d}, \text{d})\text{}^{13}\text{C} \qquad E_{\text{b}} = 16.1594$$

Excitation functions for elastically scattered deuterons have been measured in the range  $E_{\text{d}} = 0.4$  to  $5.7$  MeV: see (1976AJ04). Polarization studies are reported at  $E_{\text{d}} = 12.5$  MeV (1975ZA08;  $\text{d}_0$ ) and  $15$  MeV (1974BU06;  $\text{d}_0$ ) and at  $E_{\text{d}} = 13$  MeV (1978DA17: VAP;  $^{13}\text{C}^*(0, 3.09, 3.68, 3.85)$ ).

$$28. \text{(a) } \text{}^{13}\text{C}(\text{d}, \text{t})\text{}^{12}\text{C} \qquad Q_{\text{m}} = 1.3109 \qquad E_{\text{b}} = 16.1594$$

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

Observed resonances are listed in Table 15.10. Polarization measurements have been reported at  $E_{\text{d}} = 12.1$  and  $15$  MeV [see reaction (a), (1976AJ04)] and at  $E_{\text{d}} = 13$  MeV (1978DA17: VAP;  $^{12}\text{C}^*(0, 4.4, 7.7)$ ) and  $29$  MeV (1979CO08: VAP;  $^{12}\text{C}^*(0, 4.4, 12.7, 15.1, 16.1)$ ,  $^{12}\text{B}_{\text{g.s.}}$ ). See also  $^{12}\text{B}$  and  $^{12}\text{C}$  in (1980AJ01).

$$29. \text{}^{13}\text{C}(\text{d}, \alpha)\text{}^{11}\text{B} \qquad Q_{\text{m}} = 5.1680 \qquad E_{\text{b}} = 16.1594$$

Observed resonances are listed in Table 15.10. See also (1976AJ04).

$$30. \text{}^{13}\text{C}(\text{}^3\text{He}, \text{p})\text{}^{15}\text{N} \qquad Q_{\text{m}} = 10.6658$$

Observed proton groups and  $\gamma$ -rays are listed in Table 15.11. Gamma ray branching ratios are displayed in Table 15.4 and  $\tau_{\text{m}}$  in Table 15.5. Angular distributions have been measured at  $E(\text{}^3\text{He}) = 4.37$  to  $5.57$  MeV (1978CH19;  $\text{p}_0$ ) and at  $20$  MeV (1977PE23: to  $^{15}\text{N}^*(0, 5.27 + 5.30, 6.32, 8.31, 8.57, 9.05, 9.15, 9.23, 9.76, 9.83, 9.93$  [parity probably  $-$ ],  $10.07$ )). The earlier work at  $E(\text{}^3\text{He}) = 5$  MeV led to an assignment of  $J^{\pi} = \frac{1}{2}^{-}$  for  $^{15}\text{N}^*(9.22)$  and is consistent with  $J = \frac{5}{2}$  for  $^{15}\text{N}^*(9.152)$  (1972ST22). The g-factor for  $^{15}\text{N}^*(5.27)$  [ $J^{\pi} = \frac{5}{2}^{+}$ ] is  $+(0.9 \pm 0.3)$  (1975FO06). See also  $^{16}\text{O}$  in (1982AJ01), (1976EP1A; astrophys.) and (1976AJ04).

Table 15.12: Resonances in  $^{14}\text{C} + \text{p}$  <sup>a</sup>

$E_p$ (MeV $\pm$ keV)	$\Gamma_{\text{c.m.}}$ (keV)	$\Gamma_n$ (keV)	$\Gamma_p$ (keV)	$\Gamma_\alpha$ (keV)	$\Gamma_\gamma$ (eV)	$J^\pi$	$E_x$ (MeV $\pm$ keV)	Refs.
0.261 $\pm$ 0.6	< 0.5		(0.08 $\pm$ 0.01) $\times 10^{-6}$		> 21 meV		10.4497 $\pm$ 0.3 <sup>f</sup>	A, (1975BE23, 1976BE1B)
0.352 $\pm$ 1					(3.4 $\pm$ 0.4) $\times 10^{-2}$ <sup>b</sup>		10.5333 $\pm$ 0.5 <sup>f</sup>	A, (1975BE23, 1976BE1B)
0.519 $\pm$ 1			(0.49 $\pm$ 0.10) $\times 10^{-6}$		> 40 meV		10.6932 $\pm$ 0.3 <sup>f</sup>	(1975BE23, 1976BE1B)
0.527 $\pm$ 1			0.2		0.37 $\pm$ 0.07		10.7019 $\pm$ 0.3 <sup>f</sup>	A, (1976BE1B)
0.634 $\pm$ 1			(0.22 $\pm$ 0.10) $\times 10^{-3}$		0.27 $\pm$ 0.14		10.804 $\pm$ 2 <sup>f</sup>	A, (1975BE23, 1976BE1B)
1.162 $\pm$ 2	7.9 $\pm$ 3	2.3	5.6	< 0.3	0.29 <sup>g</sup>		11.291	A, (1977NI03)
1.3188 $\pm$ 0.5	41.4 $\pm$ 1.1	34.6 $\pm$ 0.9	6.8 $\pm$ 0.5	< 0.3	4.2 $\pm$ 0.7 <sup>g</sup>		11.4376	A, (1977NI03)
1.509 $\pm$ 4	404.9 $\pm$ 6.3	4.0 $\pm$ 0.2	400.9 $\pm$ 6.3	< 0.3	19.2 $\pm$ 0.4 <sup>g,h</sup>	$\frac{1}{2}^+; T = \frac{3}{2}$	11.615	A, (1975HA39, 1977NI03)
1.688 $\pm$ 3	37	36.5	0.5	< 0.3			11.782	A, (1977NI03)
1.788 $\pm$ 3	24.5	24.5	0.03	< 0.3		$\frac{3}{2}^-; (\frac{5}{2}^-)$	11.875	A, (1977NI03)
1.884 $\pm$ 3	21.5	21.2	0.3	< 0.3			11.965	A, (1977NI03)
2.025 $\pm$ 4	14 $\pm$ 5	12.0	1.7	0.6			12.096	A, (1977NI03)
2.077 $\pm$ 3	47 $\pm$ 7	30.2	16.6	2.2			12.145	A, (1977NI03)
2.272 $\pm$ 4	22	21.7	0.3	< 0.3			12.327	A
2.450 $\pm$ 4	44 $\pm$ 3	28	0.3	5.5			12.493	A, (1977NI03)
2.482 $\pm$ 8	58 $\pm$ 4				4.6 $\pm$ 0.7	$\frac{2}{2}^+; T = \frac{1}{2}$	12.523	A, (1975HA39, 1977NI03)
2.908 $\pm$ 4	70	25	9.0	15			12.920	A, (1974WE06, 1977NI03)
2.93 $\pm$ 10	81	n.r.	0.5	80			12.940	A
3.19	5.5	r					13.18	A
3.38 $\pm$ 10	24	6	6.0	12			13.360	A, (1974WE06)
3.421 $\pm$ 10	57	20.6	35	5.5	3.0 $\pm$ 0.9		13.390	A, (1974WE06, 1975HA39, 1976KU01)
3.57 $\pm$ 10	124	$\approx 75$	8.0	$\approx 40$			13.537	A, (1974WE06)
3.65 $\pm$ 10	88	$\approx 16$	12.0	$\approx 60$			13.612	A, (1974WE06)
3.71		r					13.67	A
4.0	930		500		r		13.9	(1974WE06, 1975HA39)
4.1 $\pm$ 100	98 $\pm$ 10		25	r			14.0	(1974WE06, 1975WE09)
4.2 $\pm$ 100				r			14.1	(1975WE09)
4.6 $\pm$ 150	74 $\pm$ 7		20	r	(r)		14.5	(1974WE06, 1975WE09)
4.8	149 $\pm$ 18		39	r	(r)		14.7	(1972WE07, 1974WE06, 1975WE09)
4.83	750				r		14.71	(1975HA39)
5.08	158 $\pm$ 19		20		r		14.95	(1974WE06, 1975WE09, 1976WE07)
5.16 $\pm$ 130	28 $\pm$ 3		9.0	r			15.0	(1974WE06, 1975WE09)
5.54 $\pm$ 130	39 $\pm$ 5		12	r	(r)		15.4	(1972WE07, 1974WE06, 1975WE09)
5.62	750				r		15.45	(1975HA39)
6.4 $\pm$ 150	130 $\pm$ 14		19	r			16.2	(1974WE06, 1975WE09)

Table 15.12: Resonances in  $^{14}\text{C} + \text{p}$  <sup>a</sup> (continued)

$E_p$ (MeV $\pm$ keV)	$\Gamma_{\text{c.m.}}$ (keV)	$\Gamma_n$ (keV)	$\Gamma_p$ (keV)	$\Gamma_\alpha$ (keV)	$\Gamma_\gamma$ (eV)	$J^\pi$	$E_x$ (MeV $\pm$ keV)	Refs.
6.70	560				r		16.46	(1975HA39)
6.925	$90 \pm 10$			r	r	$(\frac{3}{2}^+; \frac{1}{2})^c$	16.67	(1975HA39, 1975WE09, 1976WE07)
$7.18 \pm 180$	$110 \pm 50$			r		$\frac{5}{2}$	16.9	(1975WE09)
$\approx 9$					r	$\frac{1}{2}^+; \frac{1}{2}$	19	(1973WE04, 1974WE01)
10.0	sharp		(1000)		r	$\frac{3}{2}^+; (T = \frac{3}{2})$	19.5 <sup>e</sup>	(1973WE04, 1974WE01, 1974WE07, 1975HA39, 1976SN01, 1976WE07)
11.0	sharp				r	$\frac{3}{2}^+$	20.5	(1973WE04, 1974WE01, 1975HA39, 1976SN01, 1976WE07)
12.35					r		21.72	(1975HA39, 1976WE07)
13.65					r		22.94	(1975HA39, 1976SN01)
16.4					r	$(T = \frac{3}{2})$	25.5 <sup>e</sup>	(1975HA39, 1976SN01)
$\approx 29$					r		$\approx 37$	(1975HA39)

A: see references listed for this state in Table 15.11 of (1970AJ04) and Table 15.12 of (1976AJ04).

r = resonant.

n.r. = non-resonant.

<sup>a</sup> See also Tables 15.5 in (1959AJ76) and 15.11 in (1970AJ04).

<sup>b</sup>  $\omega_\gamma$  (in eV) (1969SI04).

<sup>c</sup> See, however, (1976WE11).

<sup>d</sup> (1970RA22, 1972RA03) suggest that this state has  $T = \frac{3}{2}$ : however, no analog state has been observed in  $^{15}\text{C}$  (see, e.g., Fig. 13).

<sup>e</sup> Not observed in  $^{14}\text{N}(p, \gamma)^{15}\text{O}$  (1975HA39).

<sup>f</sup>  $E_x$  measured directly ((1976BE1B) and R.P. Beukens, private communication).

<sup>g</sup>  $\Gamma_{\gamma_0}$ . I am indebted to P.M. Endt for this correction.

<sup>h</sup> See also (1971KU01).

31.  $^{13}\text{C}(\alpha, \text{d})^{15}\text{N}$   $Q_{\text{m}} = -7.6874$

This reaction has been studied at  $E_{\alpha} = 40.1$  MeV: see Table 15.11 of (1976AJ04). See also (1976BU21, 1976LE1K) and (1978ZE03, 1979ZE1B; theor.).

32.  $^{13}\text{C}(^6\text{Li}, \alpha)^{15}\text{N}$   $Q_{\text{m}} = 14.6859$

Angular distributions have been measured at  $E(^6\text{Li}) = 32$  MeV to  $^{15}\text{N}^*(0, 5.30, 6.32, 7.16, 7.30, 7.57, 8.31, 8.57, 9.15, 9.23, 9.83, 10.07, 10.70, 11.94, 13.00)$ : the results are consistent with the previously known  $J^{\pi}$ , with (odd) parity for  $^{15}\text{N}^*(9.83)$  and with  $J^{\pi} = \frac{9}{2}^{-}$  for  $^{15}\text{N}^*(11.94)$  (1977HA30). See also (1976HA31) in reaction 19.

33.  $^{13}\text{C}(^{11}\text{B}, ^9\text{Be})^{15}\text{N}$   $Q_{\text{m}} = 0.3434$

At  $E(^{11}\text{B}) = 114$  MeV, strong population of  $^{15}\text{N}^*(7.57, 9.83, 11.94, 13.00, 15.1, 16.1, 18.7, 19.2)$  is reported by (1974AN36, 1975PO10): the dominant group is  $^{15}\text{N}^*(13.00)$ .

34.  $^{13}\text{C}(^{14}\text{N}, ^{12}\text{C})^{15}\text{N}$   $Q_{\text{m}} = 5.8870$

See (1976AJ04).

35.  $^{13}\text{C}(^{17}\text{O}, ^{15}\text{N})^{15}\text{N}$   $Q_{\text{m}} = 2.1121$

Angular distributions are reported at  $E(^{17}\text{O}) = 29.8$  and  $32.3$  MeV involving  $^{15}\text{N}^*(0, 5.27 + 5.30, 6.32)$  (1977CH22, 1978CH16).

36.  $^{14}\text{C}(\text{p}, \gamma)^{15}\text{N}$   $Q_{\text{m}} = 10.2074$

Observed resonances are displayed in Table 15.12; the branching ratios are shown in Table 15.4. In the  $\gamma_0$  yield for  $E_{\text{p}} = 2.8$  to  $30$  MeV (1975HA39) find that the  $T = \frac{1}{2}$  and  $\frac{3}{2}$  components of the GDR are located near  $E_{\text{x}} = 20$  and  $26$  MeV. Narrow anomalies are reported at  $E_{\text{p}} = 10.0$  and  $11.0$  MeV (relative strength is not in agreement with (1973WE04)),  $12.35, 13.6$  and  $16.4$  MeV. Above the giant dipole resonance region the  $90^{\circ}$   $\gamma_0$  cross section decreases smoothly with energy except for a small peak which would correspond to  $^{15}\text{N}^*(37.)$  (1975HA39). (1976SN01;  $E_{\text{p}} = 7.5$

to 19 MeV) find that a good fit to the total cross section is obtained with the GDR split into peaks at  $E_x = 21.0$  and  $25.5$  MeV with  $\Gamma = 6$  and  $2$  MeV respectively. The integrated E2 cross section for  $E_x = 19.5$  to  $27.0$  MeV is  $(6.8 \pm 1.4)\%$  of the isoscalar sum rule. The reaction thus shows no sign of a collective E2 resonance in that  $E_x$  region. This is confirmed by (1976WE07;  $E_p = 4.0$  to  $16.2$  MeV) who find no appreciable E2 strength concentration for  $E_x = 14.3$  to  $23.3$  MeV. See also (1978WE07, 1979SN1A).

$$37. \ ^{14}\text{C}(p, p)^{14}\text{C} \qquad E_b = 10.2074$$

Observed anomalies are displayed in Table 15.12. Polarization measurements are reported for  $E_p = 3.2$  to  $5.7$  MeV (1974WE06). See also (1976AJ04).

$$38. \ ^{14}\text{C}(p, n)^{14}\text{N} \qquad Q_m = -0.6259 \qquad E_b = 10.2074$$

Observed resonances are listed in Table 15.12. Polarization measurements are reported at several energies in the range  $E_p = 1.79$  to  $2.45$  MeV (1977NI03) and  $7.2$  to  $13.3$  MeV (1971WO03). See (1977NI03) for a discussion of an  $R$ -matrix analysis of resonance parameters for  $11.2 < E_x < 14.4$  MeV.

$$39. \ ^{14}\text{C}(p, \alpha)^{11}\text{B} \qquad Q_m = -0.7839 \qquad E_b = 10.2074$$

Observed resonances are displayed in Table 15.12. See also (1976AJ04).

$$40. \ ^{14}\text{C}(d, n)^{15}\text{N} \qquad Q_m = 7.9828$$

Angular distributions have been measured for  $E_d = 1.3$  to  $6.5$  MeV: see (1970AJ04) and (1975BO34, 1975BO35;  $6.5$  MeV; to  $E_x < 12.1$  MeV; spectroscopic factors). See also (1976AJ04) and (1976SH13, 1977RI08; theor.).

$$41. \ ^{14}\text{C}(^3\text{He}, d)^{15}\text{N} \qquad Q_m = 4.7139$$

Angular distributions have been studied at  $E(^3\text{He}) = 23$  MeV to  $^{15}\text{N}^*(0, 5.27+5.30, 6.32, 7.16, 7.30)$  (1979SE07; see for  $S$  values). For the earlier work to  $E(^3\text{He}) = 14$  MeV see (1976AJ04).

Table 15.13: Gamma radiation from  $^{14}\text{N}(n, \gamma)^{15}\text{N}$ 

Transition in $^{15}\text{N}$	$E_\gamma$ <sup>a</sup> (keV)	$E_x$ (keV)	$I_\gamma$ <sup>c</sup>	
	(1974GR37, 1980GR1E)	(1974GR37, 1979GR1M)	(1967TH05)	(1971BE34)
C $\rightarrow$ 0	10829.10 $\pm$ 0.04	10833.24 $\pm$ 0.04	13.3 $\pm$ 2.0	13.8 $\pm$ 0.2
C $\rightarrow$ 5.27	5562.07 $\pm$ 0.04		10.3 $\pm$ 0.5	10.3 $\pm$ 0.4
C $\rightarrow$ 5.30	5533.40 $\pm$ 0.04		18.8 $\pm$ 0.9	18.9 $\pm$ 0.4
C $\rightarrow$ 6.32	4508.67 $\pm$ 0.05		16.6 $\pm$ 0.8	15.3 $\pm$ 0.4
C $\rightarrow$ 7.16	3677.75 $\pm$ 0.06		15.9 $\pm$ 0.8	16.2 $\pm$ 0.3
C $\rightarrow$ 7.30	3532.10 $\pm$ 0.15		9.9 $\pm$ 0.5	10.2 $\pm$ 0.1
C $\rightarrow$ 8.31	2520.62 $\pm$ 0.11		6.1 $\pm$ 0.3	5.8 $\pm$ 0.3
C $\rightarrow$ 9.05				0.7 $\pm$ 0.4
C $\rightarrow$ 9.152	1681.59 $\pm$ 0.23		1.4 $\pm$ 0.3 <sup>d</sup> 9.2 $\pm$ 0.5	
C $\rightarrow$ 9.155	1678.26 $\pm$ 0.06			9.5 $\pm$ 0.3
C $\rightarrow$ 9.76		9757.5 $\pm$ 3 <sup>e</sup>		0.2 $\pm$ 0.05
C $\rightarrow$ 9.93				0.1 $\pm$ 0.04
5.27 $\rightarrow$ 0	5269.12 $\pm$ 0.04	5270.12 $\pm$ 0.04 <sup>f</sup>	30.6 $\pm$ 1.5	31.2 $\pm$ 0.7
5.30 $\rightarrow$ 0	5297.79 $\pm$ 0.04	5298.80 $\pm$ 0.04 <sup>f</sup>	21.4 $\pm$ 1.1	22.2 $\pm$ 0.4
6.32 $\rightarrow$ 0	6322.47 $\pm$ 0.06	6323.91 $\pm$ 0.06 <sup>f</sup>	18.8 $\pm$ 0.9	18.1 $\pm$ 1.3
7.16 $\rightarrow$ 0		7155.06 $\pm$ 0.06 <sup>f</sup>		
7.16 $\rightarrow$ 5.27	1884.82 $\pm$ 0.05		19.7 $\pm$ 1.0	20.5 $\pm$ 0.2
7.16 $\rightarrow$ 5.30	1857 $\pm$ 2 <sup>b</sup>		0.8 $\pm$ 0.2	
7.30 $\rightarrow$ 0	7299.18 $\pm$ 0.17	7301.09 $\pm$ 0.17	10.0 $\pm$ 0.5	9.2 $\pm$ 0.2
7.30 $\rightarrow$ 5.30				1.2 $\pm$ 0.4
8.31 $\rightarrow$ 0	8310.32 $\pm$ 0.14	8312.79 $\pm$ 0.14	4.4 $\pm$ 0.4	3.6 $\pm$ 0.1
				1.1 $\pm$ 0.4
8.31 $\rightarrow$ 6.32	1989 $\pm$ 2 <sup>b</sup>		1.5 $\pm$ 0.3	1.5 $\pm$ 0.2
8.57 $\rightarrow$ 0	8570 $\pm$ 4 <sup>b</sup>	8573 $\pm$ 4 <sup>b</sup>	0.2 $\pm$ 0.03	0.2 $\pm$ 0.04
9.05 $\rightarrow$ 0	9047 $\pm$ 4 <sup>b</sup>	9050 $\pm$ 4 <sup>b</sup>	0.2 $\pm$ 0.03	0.3 $\pm$ 0.05
9.152 $\rightarrow$ 0	9148.61 $\pm$ 0.23	9151.61 $\pm$ 0.23 <sup>f</sup>	1.7 $\pm$ 0.2	
9.155 $\rightarrow$ 0		9154.92 $\pm$ 0.07 <sup>f</sup>		1.6 $\pm$ 0.07
9.155 $\rightarrow$ 5.27	3884.38 $\pm$ 0.10		0.8 $\pm$ 0.1	0.8 $\pm$ 0.2
9.155 $\rightarrow$ 5.30	3855 $\pm$ 2 <sup>b</sup>		1.0 $\pm$ 0.1	0.4 $\pm$ 0.04

Table 15.13: Gamma radiation from  $^{14}\text{N}(n, \gamma)^{15}\text{N}$  (continued)

Transition in $^{15}\text{N}$	$E_\gamma$ <sup>a</sup> (keV)	$E_x$ (keV)	$I_\gamma$ <sup>c</sup>	
	(1974GR37, 1980GR1E)	(1974GR37, 1979GR1M)	(1967TH05)	(1971BE34)
9.155 $\rightarrow$ 6.32	$2831.13 \pm 0.11$		$2.0 \pm 0.2$	$2.4 \pm 0.4$
9.155 $\rightarrow$ 7.16	$1999.73 \pm 0.08$		$4.6 \pm 0.2$	$3.9 \pm 0.4$
9.155 $\rightarrow$ 7.30				$0.9 \pm 0.2$

C = capturing state.

<sup>a</sup> See also Table 15.13 in (1976AJ04) and (1979GR1M).

<sup>b</sup> (1967TH05).

<sup>c</sup> In units of photons/100 captures.

<sup>d</sup> (1968GR14).

<sup>e</sup> (1971BE34).

<sup>f</sup> E.K. Warburton, private communication.

42. (a)  $^{14}\text{C}(^{14}\text{C}, ^{13}\text{B})^{15}\text{N}$   $Q_m = -10.624$   
 (b)  $^{14}\text{C}(^{14}\text{N}, ^{13}\text{C})^{15}\text{N}$   $Q_m = 2.6568$

For reaction (a) see (1980NA14); for (b) see (1975VO1B).

43. (a)  $^{14}\text{C}(^{16}\text{O}, ^{15}\text{N})^{15}\text{N}$   $Q_m = -1.9201$   
 (b)  $^{14}\text{C}(^{18}\text{O}, ^{17}\text{N})^{15}\text{N}$   $Q_m = -5.735$

The angular distributions leading to the ground state (reaction (a)) have been studied at  $E(^{16}\text{O}) = 20, 25$  and  $30$  MeV (1975SC42). For reaction (b) see (1972EY01).

44.  $^{14}\text{N}(n, \gamma)^{15}\text{N}$   $Q_m = 10.8334$   
 $Q_0 = 10833.395 \pm 0.030$  keV (1975SM02);  
 $Q_0 = 10833.297 \pm 0.039$  keV (1979GR1J; see also (1974SP04)).

The thermal cross section is  $75 \pm 7.5$  mb (see (1973MU14)). This large cross section is not understood in terms of the level structure in  $^{15}\text{N}$ : see (1959AJ76).

Observed  $\gamma$ -rays are displayed in Table 15.13. See also Tables 15.4 and 15.5. The  $90^\circ$   $\gamma_0$  yield has been measured for  $E_n = 6.0$  to  $13.0$  MeV. The angular distributions of  $\gamma_0$  are consistent with essentially pure E1 radiation in the region  $E_x = 16.5$  to  $23.0$  MeV (1979WE1G; prelim.). See also (1978DU1E; applied).

Table 15.14: Resonances in  $^{14}\text{N} + \text{n}$ 

$E_{\text{res}}$ (MeV $\pm$ keV)	$\Gamma_{\text{lab}}$ (keV)	$\Gamma_{\text{n}}$ (keV)	$\Gamma_{\text{p}}$ (keV)	$\Gamma_{\alpha}$ (keV)	$J^{\pi}$	$^{15}\text{N}^*$ (MeV)
$0.430 \pm 5$	3.5	$< 3$	$< 0.01$		$\geq \frac{3}{2}^{\frac{3}{2}}$	11.235
$0.4926 \pm 0.65$	7.5	$< 3$	$< 10$		$\frac{1}{2}^{-}$	11.2929
$0.639 \pm 5$	43	34	9		$\frac{1}{2}^{+}$	11.429
$0.998 \pm 5$	46	45	0.8		$\frac{3}{2}^{\frac{3}{2}+}$	11.764
$1.120 \pm 6$	19	19	0.20		$\frac{3}{2}^{\frac{3}{2}-}$	11.878
$1.188 \pm 6$	$\leq 3.2$	$< 2$	$< 0.1$		$\geq \frac{3}{2}^{\frac{3}{2}}$	11.942
$1.211 \pm 7$	13	12	0.4		$\frac{1}{2}^{-}$	11.963
$1.350 \pm 7$	21	20	0.9	0.4	$\frac{5}{2}^{\frac{5}{2}+}$ (+)	12.093
$1.401 \pm 8$	54	41	11	1.8	$\frac{5}{2}^{\frac{5}{2}+}$ (+)	12.140
$1.595 \pm 8$	22	21	0.2	$< 0.1$	$\frac{5}{2}^{\frac{5}{2}-}$ (-)	12.321
$1.779 \pm 10$	47	37	0.5	9.0	$(\frac{5}{2}^{\frac{5}{2}+})$	12.493
2.23	65	39	7.8	18	$\frac{3}{2}^{\frac{3}{2}-}$	12.91
2.47	$< 3$			r		13.14
2.52	$\approx 7$	r		r		13.18
2.71	40			r	$\frac{3}{2}^{\frac{3}{2}-}$	13.36
2.74	95		r		$\frac{5}{2}^{\frac{5}{2}+}$	13.39
2.95	20	16	1.1	3.2	$\frac{5}{2}^{\frac{5}{2}+}$	13.59
3.09	60		r	r		13.72
3.21	85	r	r	r	$\frac{3}{2}^{+}$	13.83
3.51	$\approx 20$	r	r	r		14.11
3.57	30	r	r	r	$\frac{3}{2}^{+}$ (+)	14.16
$\approx 3.8$	$\approx 2000$	$\approx 1000$	200	$\approx 1000$		14.4
4.09	50	r	r	r		14.65
$\approx 4.2$	$\approx 300$	r	r	r		14.8
4.38	40			r		14.92
4.60		r		r		15.12
5.03				r		15.52
5.60	100			r		16.06
5.94				r		16.37
6.16	75			r		16.58
6.26	100	r		r		16.67



Table 15.14: Resonances in  $^{14}\text{N} + \text{n}$  (continued)

$E_{\text{res}}$ (MeV $\pm$ keV)	$\Gamma_{\text{lab}}$ (keV)	$\Gamma_{\text{n}}$ (keV)	$\Gamma_{\text{p}}$ (keV)	$\Gamma_{\alpha}$ (keV)	$J^{\pi}$	$^{15}\text{N}^*$ (MeV)
6.55	170	r		r		16.94
6.94	200	r		r		17.31
7.16				r		17.51
7.34	120			r		17.68
7.48	180	r		r		17.81
7.92	170	r		r		18.22
8.00	120			r		18.29

r = resonant.

<sup>a</sup> See references for this state in Tables 15.14 in (1970AJ04, 1976AJ04).

45.  $^{14}\text{N}(\text{n}, \text{n})^{14}\text{N}$

$$E_{\text{b}} = 10.8334$$

The scattering amplitude (bound)  $a = 9.37 \pm 0.03$  fm,  $\sigma_{\text{free}} = 10.05 \pm 0.12$  b,  $\sigma_{\text{inc.}}^{\text{spin}}$  (bound nucleus) =  $0.49 \pm 0.11$  b (1979KO26). See also (1976KO1H).

Cross-section measurements are displayed in (1976GAYV). Recent measurements of  $\sigma_{\text{t}}$  are reported for  $E_{\text{n}} = 1.0$  to  $5.2$  MeV by (1976BO17). See also (1976AJ04). Observed resonances are shown in Table 15.14: for a discussion of the evidence leading to  $J^{\pi}$  assignments see (1959AJ76).

Cross sections for production of  $\gamma$ -rays due to the decay of excited states of  $^{14}\text{N}$  have been measured in the range  $E_{\text{n}} = 4$  to  $20$  MeV [see (1976AJ04)]. See also (1975RO30; to  $E_{\text{n}} = 19$  MeV) and (1977DI1A; 2.0 to 20.0 MeV). See also (1973DI1A, 1978SU1E) and (1975YO1A).

46.  $^{14}\text{N}(\text{n}, 2\text{n})^{13}\text{N}$

$$Q_{\text{m}} = -10.554$$

$$E_{\text{b}} = 10.8334$$

For older cross-section measurements [ $E_{\text{n}} = 10$  to  $37$  MeV] see Table 15.13 of (1970AJ04) and (1976GAYV). The cross section has recently been reported for  $E_{\text{n}} = 14.7$  to  $19.0$  MeV by (1978RY02). See also (1974BO1E).

47.  $^{14}\text{N}(\text{n}, \text{p})^{14}\text{C}$

$$Q_{\text{m}} = 0.6259$$

$$E_{\text{b}} = 10.8334$$

The thermal cross section is  $1.81 \pm 0.05$  b (1973MU14). Reported resonances are displayed in Table 15.14. For cross section measurements see (1976GAYV), and (1979MO09;  $p_0$ ; to 7.0 MeV), (1976FE02; 14.7 MeV), (1975RO30;  $\gamma_{6.09}$ ,  $\gamma_{6.73}$ ; to 19 MeV). See also (1973DI1A, 1974SH1E, 1979RO1F) and (1974BO1E, 1976SL2A).

$$48. \text{ (a) } {}^{14}\text{N}(n, d){}^{13}\text{C} \quad Q_m = -5.3260 \quad E_b = 10.8334$$

$$\text{ (b) } {}^{14}\text{N}(n, np){}^{13}\text{C} \quad Q_m = -7.55063$$

Differential cross sections for production of  $\gamma$ -rays from  ${}^{13}\text{C}^*(3.09, 3.68)$  have been measured for  $E_n = 10$  to 11 MeV by (1970DI1A). See also (1975RO30) and (1976AJ04, 1976SL2A).

$$49. \text{ (a) } {}^{14}\text{N}(n, t){}^{12}\text{C} \quad Q_m = -4.0151 \quad E_b = 10.8334$$

$$\text{ (b) } {}^{14}\text{N}(n, t){}^4\text{He}^4\text{He} \quad Q_m = -11.2899$$

$$\text{ (c) } {}^{14}\text{N}(n, 2\alpha){}^7\text{Li} \quad Q_m = -8.823$$

See (1975RO30, 1978QA01) and (1976AL02, 1976SL2A).

$$50. \text{ (a) } {}^{14}\text{N}(n, \alpha){}^{11}\text{B} \quad Q_m = -0.1580 \quad E_b = 10.8334$$

$$\text{ (b) } {}^{14}\text{N}(n, n\alpha){}^{10}\text{B} \quad Q_m = -11.6133$$

Observed resonances are listed in Table 15.14. For cross-section measurements see (1976GAYV), and (1979MO09;  $\alpha_0$ ,  $\alpha_1$ ; 1  $\rightarrow$  15 MeV and 4 to 15 MeV, respectively), (1978MO09;  $\alpha_0$ ; 13.9 MeV) and (1977DI1A;  $\gamma_{4.4}$ ; to 19 MeV). See also (1973DI1A, 1975RO30, 1978SU1D) and (1976AJ04, 1976SL2A).

$$51. {}^{14}\text{N}(p, \pi^+){}^{15}\text{N} \quad Q_m = -129.516$$

See (1979MA38, 1979MA39).

$$52. {}^{14}\text{N}(d, p){}^{15}\text{N} \quad Q_m = 8.6087$$

Proton groups corresponding to levels of  ${}^{15}\text{N}$  are listed in Table 15.15. Angular distributions have been measured in the range  $E_d = 0.5$  to 27 MeV [see (1959AJ76, 1970AJ04, 1976AJ04)] and at  $E_d = 0.324$  to 0.626 MeV (1976VA20;  $p_0, p_{1+2}, p_3 \rightarrow p_5$ ),  $E_d = 2.0$  and 2.2 MeV (1979US01;

Table 15.15:  $^{15}\text{N}$  states from  $^{14}\text{N}(\text{d}, \text{p})^{15}\text{N}$ 

$E_x$ (MeV $\pm$ keV)		$l_n^b$	$J^\pi^c$	$S^d$
A	B			
0		1	$\frac{1}{2}^-$	$1.45 \pm 0.15^g$
$5.276 \pm 6$	$5.27159 \pm 0.46$	2	$\frac{5}{2}^+$	$< 0.15 \pm 0.07$
$5.305 \pm 6$	$5.30003 \pm 0.43$	e		$< 0.02 \pm 0.01$
$6.328 \pm 6$		1	$\frac{3}{2}^-$	$0.07 \pm 0.02 (j_n = \frac{1}{2});$ $0.04 \pm 0.01 (j_n = \frac{3}{2})$
$7.164 \pm 6$	$7.1555 \pm 1.7$	2	$\frac{5}{2}^+$	$0.92 \pm 0.07$
$7.309 \pm 6^a$		0 + 2	$\frac{3}{2}^+$	$0.87 \pm 0.07 (j_n = \frac{1}{2});$ $0.07 \pm 0.04 (j_n = \frac{5}{2})$
$7.570 \pm 8$	$7.5671 \pm 1.0$	2	$\frac{7}{2}^+$	$0.89 \pm 0.05$
$8.315 \pm 6^a$	$8.309 \pm 4.1$	0 + 2	$\frac{1}{2}^+$	$0.77 \pm 0.08 (j_n = \frac{1}{2});$ $0.11 \pm 0.05 (j_n = \frac{3}{2})$
$8.582 \pm 5^a$	$8.573 \pm 3.2$	0 + 2	$\frac{3}{2}$	$0.05 \pm 0.03 (j_n = \frac{1}{2});$ $0.12 \pm 0.05 (j_n = \frac{5}{2}(\frac{3}{2}))$
$9.056 \pm 5$		0	$(\frac{1}{2}, \frac{3}{2})^+$	
$9.159 \pm 6$		f		
$9.226 \pm 6$		1	$(\frac{1}{2}^-)$	
$9.764 \pm 6$		1	$(\frac{1}{2}^-)$	
$9.831 \pm 6$				
$9.929 \pm 6$		e		
$10.071 \pm 6$		2, 0	$\frac{3}{2}^+$	
$10.456 \pm 7$		(1)		
$10.541 \pm 7$				
$10.702 \pm 7$		2, 0	$\frac{3}{2}^+$	
$10.809 \pm 9$		1	$\leq \frac{5}{2}^-$	
11.2		1	$\leq \frac{5}{2}^-$	

A: (1950MA65, 1954SP01, 1956DO41, 1966GA08).

B: (1965AL19, 1965WA16, 1966AL18, 1967CH19).

<sup>a</sup> 7307, 8319 and 8577 keV ( $\pm 8$  keV) (1956DO41).

<sup>b</sup> See also Tables 15.15 in (1970AJ04, 1976AJ04).

<sup>c</sup> (1980KR01) and Tables 15.15 in (1970AJ04, 1976AJ04).

<sup>d</sup> (1980KR01). See also (1969PH02) and (1972AM06). values shown are close to those given by the extreme weak coupling model (1980KR01).

<sup>e</sup> No clear stripping pattern.

<sup>f</sup> Doublet.

<sup>g</sup>  $S_{\text{DWBA}} = 0.89 \pm 0.2$ ,  $S_{\text{IA}} = 0.82 \pm 0.08$  (1977HE01;  $E_d = 52$  MeV).

$p_5$ ),  $E_{\bar{d}} = 10$  MeV (1980KR01; see Table 15.15),  $E_d = 10.03$  and  $11.65$  MeV (1979AO01;  $p_0$ ) and  $E_{\bar{d}} = 52$  MeV (1977HE01;  $p_0$ ).

Branching ratios and multiplicities are shown in Table 15.4;  $\tau_m$  in Table 15.5. The two states of  $^{15}\text{N}$  at  $E_x = 9.15$  MeV are separated by  $2.8 \pm 0.5$  keV: see (1976AJ04). See also (1977KO33), (1977RI08), (1976EP1A; astrophys.), (1978GO1R; applications) and  $^{16}\text{O}$  in (1982AJ01).

$$53. \quad ^{14}\text{N}(t, d)^{15}\text{N} \qquad Q_m = 4.5760$$

The  $d_0$  angular distributions have been measured at  $E_t = 1.5$  to  $2.0$  MeV (1964SC09).

$$54. \quad ^{14}\text{N}(\alpha, ^3\text{He})^{15}\text{N} \qquad Q_m = -9.7444$$

At  $E_\alpha = 56$  MeV, the angular distribution of the ground state  $^3\text{He}$  particles has been measured by (1969GA11) and analyzed by DWBA: the ratio of the  $(\alpha, ^3\text{He})$  and  $(\alpha, t)$  cross sections at this energy is  $1.50 \pm 0.15$ .

$$\begin{aligned} 55. \quad (a) \quad ^{14}\text{N}(^9\text{Be}, ^8\text{Be})^{15}\text{N} & \qquad Q_m = 9.1682 \\ (b) \quad ^{14}\text{N}(^{11}\text{B}, ^{10}\text{B})^{15}\text{N} & \qquad Q_m = -0.6219 \\ (c) \quad ^{14}\text{N}(^{12}\text{C}, ^{11}\text{C})^{15}\text{N} & \qquad Q_m = -7.888 \end{aligned}$$

For reaction (a) see (1970AJ04). For reaction (b) see (1976AJ04). At  $E(^{12}\text{C}) = 114$  MeV, the strongly populated states are  $^{15}\text{N}^*(0, 7.5)$  (1974AN36).

$$56. \quad ^{14}\text{N}(^{14}\text{N}, ^{13}\text{N})^{15}\text{N} \qquad Q_m = 0.280$$

Angular distributions to the ground state of  $^{15}\text{N}$  have been measured for  $E(^{14}\text{N})(\text{c.m.}) = 5.5$  to  $16$  MeV: see (1976AJ04). Below  $\approx 6.5$  MeV, the tunneling theory of neutron transfer gives a good account of the data. At higher energies, nuclear absorption of the incident  $^{14}\text{N}$  ions occur (1965HI1A, 1966GA04). See (1976SW02) for a comparison of the nuclear reaction  $S$ -factors for this reaction and for  $^{14}\text{N} + ^{14}\text{N}$  fusion.

$$\begin{aligned} 57. \quad (a) \quad ^{14}\text{N}(^{18}\text{O}, ^{17}\text{O})^{15}\text{N} & \qquad Q_m = 2.789 \\ (b) \quad ^{14}\text{N}(^{19}\text{F}, ^{18}\text{F})^{15}\text{N} & \qquad Q_m = 0.4021 \end{aligned}$$

Table 15.16: Beta decay of  $^{15}\text{C}$  <sup>a</sup>

Decay to $^{15}\text{N}^*$ (keV)	$J^\pi$	Branch (%)	$\log ft$
g.s.	$\frac{1}{2}^-$	$32 \pm 2$	$5.99 \pm 0.03$
$5298.87 \pm 0.15$ <sup>b</sup>	$\frac{1}{2}^+$	$68 \pm 2$	$4.08 \pm 0.01$
$6323.3 \pm 0.6$	$\frac{3}{2}^-$	$\leq 0.4 \times 10^{-2}$	$\geq 7.8$
$7301.1 \pm 0.5$	$\frac{3}{2}^+$	$(0.74 \pm 0.08) \times 10^{-2}$	$6.89 \pm 0.05$
$8312.9 \pm 0.5$	$\frac{1}{2}^+$	$(4.1 \pm 0.5) \times 10^{-2}$	$5.18 \pm 0.05$
$8571.4 \pm 1.0$	$\frac{3}{2}^+$	$(1.3 \pm 0.2) \times 10^{-2}$	$5.34 \pm 0.07$
$9050.0 \pm 0.7$	$\frac{1}{2}^+$	$(3.4 \pm 0.3) \times 10^{-2}$	$4.05 \pm 0.04$

<sup>a</sup> (1979AL23).

<sup>b</sup> (1976AL16).

See (1976AJ04).

$$58. \quad ^{15}\text{C}(\beta^-)^{15}\text{N} \quad Q_m = 9.7717$$

The  $\beta^-$  decay takes place to  $^{15}\text{N}^*(0, 5.30, 7.30, 8.31, 8.57, 9.05)$ : see Table 15.16.

$$59. \quad \begin{array}{ll} \text{(a) } ^{15}\text{N}(\gamma, n)^{14}\text{N} & Q_m = -10.8334 \\ \text{(b) } ^{15}\text{N}(\gamma, p)^{14}\text{C} & Q_m = -10.2074 \\ \text{(c) } ^{15}\text{N}(e, p_0e')^{14}\text{C} & Q_m = -10.2074 \\ \text{(d) } ^{15}\text{N}(\gamma, d)^{13}\text{C} & Q_m = -16.1594 \\ \text{(e) } ^{15}\text{N}(\gamma, t)^{12}\text{C} & Q_m = -14.8484 \end{array}$$

Below  $E_\gamma = 15$  MeV, the giant resonance of  $^{15}\text{N}$  decays entirely by ground state transitions. The total integrated cross section up to 35 MeV for transitions to excited states [ $^{14}\text{N}^*(2.31, 3.95, 5.11 + 5.83, 7.03)$ ,  $^{14}\text{C}^*(6.09 + 6.59 + 6.90, 7.01)$ ,  $^{12}\text{C}^*(4.4)$ ] is 44 MeV · mb. The nature of the transitions is such as to indicate a very strong  $(1p_{3/2})^0(1p_{1/2})^3$  component in  $^{15}\text{N}_{\text{g.s.}}$ . The presence of  $T = \frac{1}{2}$  in the main giant resonance region is indicated by the strong population of  $^{14}\text{N}^*(7.03)$  (1976PA22).

A study at  $E_e = 18.8, 20.8, 25.7$  and  $29.7$  MeV (reaction (c)) shows a “pigmy” resonance at  $E_x = 14.8$  MeV, a shoulder at 15.6 MeV, a peak at 16.7 MeV [probably  $\frac{1}{2}^+$  but  $\frac{3}{2}^+$  is not ruled out], and the giant dipole resonance, which exhibits a great deal of structure, centered at 22 MeV.

The data on the pigmy resonance are consistent with an admixture of  $\approx 1\%$   $\frac{3}{2}^-$  (E2) or  $\frac{1}{2}^-$  (M1) to a predominantly  $\frac{1}{2}^+$  (E1) state. The experiment shows that for  $14 < E_x < 28$  MeV the reaction goes predominantly via  $\frac{1}{2}^+$  or  $\frac{3}{2}^+$  (E1) states in  $^{15}\text{N}$ ; the  $T = \frac{3}{2}$  strength is concentrated above 18 MeV (1975MU07) [see also (1975HA39)].

The cross section for  $d_0$  [reaction (d)] is reported at  $90^\circ$  for  $E_\gamma \approx 20.5$  to 28.5 MeV: a resonance is observed at  $E_x \approx 21.9$  MeV (1979SK04: see Table 15.10).

The  $(\gamma, t_0)$  cross section (reaction (e)) at  $90^\circ$  decreases from a value of  $30 \mu\text{b/sr}$  at 20 MeV to  $5 \mu\text{b/sr}$  at 22 MeV and remains flat out to 25 MeV. Comparison of this cross section, and those of other photonuclear reactions, suggests an isospin splitting of  $\approx 6$  MeV with the  $T = \frac{1}{2}$  strength concentrated between 16 and 21 MeV and the  $T = \frac{3}{2}$  strength between 21 and 28 MeV.  $^{15}\text{N}^*(21.9)$  is not observed (1979UE01). See also (1977SP06, 1978JU1A) and (1977AL32; theor.).

#### 60. $^{15}\text{N}(\gamma, \gamma)^{15}\text{N}$

$\Gamma_{\gamma_0} = 2.9 \pm 0.3$  eV for  $^{15}\text{N}^*(6.32)$  (1976MO14) and  $4.2 \pm 1.5$  eV for  $^{15}\text{N}^*(10.07)$  (1976PA22). See also (1980SH05).

#### 61. $^{15}\text{N}(e, e)^{15}\text{N}$

The r.m.s. radius of  $^{15}\text{N}$  is  $2.580 \pm 0.026$  fm (1973FE13, 1975SC18). Inelastic groups are displayed in Table 15.17. The giant resonance is split into two main peaks at  $E_x = 22$  and 25.5 MeV with some structure around 20 MeV.  $\Gamma_{\gamma_0}(\text{C1}) = (1.1 \pm 0.3) \times 10^3$  eV (14–18.5 MeV),  $\Gamma_{\gamma_0}(\text{C2}) = (12.5 \pm 2.0)$  eV assuming the states responsible are  $\frac{3}{2}^+$  and  $\frac{3}{2}^-$ , respectively. For  $E_x = 18.5$  to 30 MeV,  $\Gamma_{\gamma_0}(\text{C1}) = (1.96 \pm 0.04) \times 10^4$  eV while  $\Gamma_{\gamma_0} < 0.1$  eV for any C2 strength (1978AN12). See also (1976MA30, 1979SHIT), (1979MO19) and (1976SU07, 1977HO04, 1977SU1H; theor.).

#### 62. $^{15}\text{N}(n, n)^{15}\text{N}$

See (1976AJ04).

#### 63. $^{15}\text{N}(p, p)^{15}\text{N}$

Angular distributions of elastically scattered protons have been measured at  $E_p$  to 39.8 MeV [see (1976AJ04)] and at  $E_p = 5.85$  MeV (1977SA1B) and 18.0 to 44.2 MeV (1980FA06, 1980FA07). See also (1976NO02, 1979MA2M), (1977BL07, 1979RO1B; theor.) and  $^{16}\text{O}$  in (1982AJ01).

64.  $^{15}\text{N}(\text{d}, \text{d})^{15}\text{N}$

Angular distributions of elastic scattered deuterons have been measured at  $E_{\text{d}} = 5 - 6$  MeV: see (1972FO17, 1976AJ04).

Table 15.17: Ground state radiative widths <sup>a</sup> from  $^{15}\text{N}(\text{e}, \text{e}')$

$E_{\text{x}}$ (MeV $\pm$ keV)	$J^{\pi}$	Trans.	$\Gamma_{\gamma_0}$ (eV)	$B(\lambda) \uparrow$ ( $e^2 \cdot \text{fm}^{2L}$ )
5.27	$\frac{5}{2}^{+}$	E3	$(4.2 \pm 0.3) \times 10^{-6}$	$4.40 \pm 40$
		M2	$(1.2 \pm 0.7) \times 10^{-4}$	$0.30 \pm 0.07$
5.30	$\frac{1}{2}^{+}$	E1	$2.2 \pm 2.3$	
6.32	$\frac{3}{2}^{-}$	E2	$0.060 \pm 0.004^{\text{b}}$	$14.8 \pm 1.0$
		M1	$1.9 \pm 0.4$	
7.16	$\frac{5}{2}^{+}$	E3	$(0.86 \pm 0.10) \times 10^{-5}$	
7.30	$\frac{3}{2}^{+}$	E1	$2.6 \pm 1.0$	
		M2	$(0.3 \pm 0.2) \times 10^{-5}$	
7.57	$\frac{7}{2}^{+}$	E3	$(1.84 \pm 0.16) \times 10^{-5}$	
9.152	$\frac{3}{2}^{-}$	E2	$0.095 \pm 0.005^{\text{c}}$	$3.85 \pm 0.2$
		M1	$0.2 \pm 0.8$	
9.76	$\frac{5}{2}^{-}$	E2	$0.20 \pm 0.05$	$8.4 \pm 2.1$
10.8	$\frac{3}{2}^{+}$	M2	$(1.8 \pm 0.8) \times 10^{-2}$	
11.88	$\frac{3}{2}^{-}$	E2	$0.44 \pm 0.10$	$4.6 \pm 1$
		M1	$4.4 \pm 3.8$	
12.5	$\frac{5}{2}^{+}$	M2	$(5.2 \pm 2.0) \times 10^{-2}$	
(13.98) <sup>d</sup>				
14.7	$\frac{5}{2}^{-}$	E2	$1.8 \pm 0.2$	
20.10 <sup>d</sup>				
23.25 <sup>d</sup>				

<sup>a</sup> (1975KI08, 1975KI09, 1977AN25, 1977MA42, 1978AN12). See also Tables 15.4 and 15.5.

<sup>b</sup>  $\delta(\text{E2/M1}) = 0.16 \pm 0.03$ .

<sup>c</sup>  $\delta(\text{E2/M1}) > 0.3$ .

<sup>d</sup> See also (1980SIIF) and the text.

65.  $^{15}\text{N}({}^3\text{He}, {}^3\text{He})^{15}\text{N}$

Angular distributions have been studied at  $E(^3\text{He}) = 11$  to  $39.8$  MeV: see reaction 68 and Table 15.17 in (1976AJ04).

66.  $^{15}\text{N}(\alpha, \alpha)^{15}\text{N}$

At  $E_\alpha = 40.5$  MeV, a number of particle groups have been observed, and angular distributions have been measured: see Table 15.17 of (1976AJ04) (1966HA19).  $B(E2)_\downarrow / e^2 = 4.7 \text{ fm}^4$  for  $^{15}\text{N}^*(6.32)$ :  $B(E3)_\downarrow / e^2 = 60 \text{ fm}^6$  for both  $^{15}\text{N}^*(5.27, 7.57)$  (1966HA19). At  $E_\alpha = 22, 24$  and  $28$  MeV, the intensity of the back scattering is greatly enhanced over pure Coulomb scattering (1972OE01, 1973OE01). Angular distributions are also reported at  $E_\alpha = 20.1$  MeV ( $\alpha_0$ ; back angles) and at  $23.7$  MeV ( $\alpha_0, \alpha_{1+2}, \alpha_3$ , groups to unresolved states and to  $^{15}\text{N}^*(10.07)$ ) (1977FE1C). (1976WO11) find  $S_\alpha = 0.42$  for  $^{15}\text{N}_{\text{g.s.}}$ . See also (1977KN1E), (1975GR41, 1977MA2E, 1979KN1F) and (1976CO27, 1977OH01, 1977SA19, 1979LE18; theor.).

67.  $^{15}\text{N}(^{12}\text{C}, ^{12}\text{C})^{15}\text{N}$

Angular distributions of elastic scattering have been measured at  $E(^{15}\text{N}) = 31.5, 36, 39.5$  and  $47$  MeV (1978CO20). For fusion cross sections see (1978CO20, 1979KO20). See also (1977PH1C) and (1977BA3E; theor.).

68. (a)  $^{15}\text{N}(^{15}\text{N}, ^{15}\text{N})^{15}\text{N}$

(b)  $^{15}\text{N}(^{16}\text{O}, ^{16}\text{O})^{15}\text{N}$

(c)  $^{15}\text{N}(^{19}\text{F}, ^{19}\text{F})^{15}\text{N}$

For reaction (a) see (1980KR06; theor.). For reaction (b) see (1976AJ04). Elastic angular distributions (reaction (c)) have been studied at  $E(^{15}\text{N}) = 23, 26$  and  $29$  MeV (1973GA14).

69. (a)  $^{15}\text{N}(^{27}\text{Al}, ^{27}\text{Al})^{15}\text{N}$

(b)  $^{15}\text{N}(^{28}\text{Si}, ^{28}\text{Si})^{15}\text{N}$

(c)  $^{15}\text{N}(^{40}\text{Ca}, ^{40}\text{Ca})^{15}\text{N}$

Elastic distributions (reaction (a)) have been measured at  $E(^{15}\text{N}) = 32.8, 47.9, 62.1$  and  $69.8$  MeV (1980PR06; see also for fusion cross sections). An elastic distribution (reaction (b)) is reported at  $E(^{15}\text{N}) = 44$  MeV (1978PE13). See also (1979KA27; theor.). For reaction (c) see (1979SA27; theor.).



70.  $^{15}\text{O}(\beta^+)^{15}\text{N}$   $Q_m = 2.7539$

See  $^{15}\text{O}$ .

71. (a)  $^{16}\text{O}(\gamma, p)^{15}\text{N}$   $Q_m = -12.1276$

(b)  $^{16}\text{O}(e, ep)^{15}\text{N}$   $Q_m = -12.1276$

Over the giant resonance region in  $^{16}\text{O}$ , the decay takes place to the odd parity states  $^{15}\text{N}^*(0, 6.32)$  and less strongly to the even parity states  $^{15}\text{N}^*(5.27, 5.30, 8.31, 9.05)$  and to  $^{15}\text{N}^*(9.23)$ : see (1970HO21) and the earlier references in (1970AJ04). At  $E_e = 500$  MeV most of the 1p hole-hole strength is concentrated in the groups to  $^{15}\text{N}^*(0, 6.32)$ . The 1s state shows up as a very wide asymmetric structure centered at  $E_x \approx 41$  MeV (1977MO1F, 1977BE1Q, 1979MO1G). See also (1977MA01) and  $^{16}\text{O}$  in (1982AJ01). See also (1979GO1V, 1979KI1H), (1976HA1Q) and (1977WA1R, 1978SC11, 1979LO03, 1979WA1G; theor.).

72.  $^{16}\text{O}(n, d)^{15}\text{N}$   $Q_m = -9.9029$

Angular distributions of the  $d_0$  group have been reported at  $E_n = 14$  and 14.4 MeV: see (1976AJ04). See also (1976KI1D, 1978NE1B).

73.  $^{16}\text{O}(p, 2p)^{15}\text{N}$   $Q_m = -12.1276$

At  $E_p = 460$  MeV, the summed proton spectrum shows two peaks corresponding to the knock-out of  $p_{1/2}$  and  $p_{3/2}$  protons with binding energies of 12.4 and 19.0 MeV, respectively [ $^{15}\text{N}^*(0, 6.32)$ ] (1966TY01). The ground state angular correlation has been studied at  $E_p = 45$  MeV (1971EI06). See also (1976SI1A) and (1978HA36, 1979KU07, 1979MA20; theor.).

74.  $^{16}\text{O}(d, ^3\text{He})^{15}\text{N}$   $Q_m = -6.6340$

Angular distributions of  $^3\text{He}$  groups have been measured for  $E_d = 20$  to 82 MeV (see (1976AJ04)). Recent measurements are reported at  $E_d = 29$  MeV (1976FI01: to  $^{15}\text{N}$  states with  $E_x < 10.1$  MeV; see for spectroscopic factors), at  $E_d = 29$  MeV (1978CO13: to  $^{15}\text{N}^*(0, 6.32)$ ) and 52 MeV (1977BE70: to  $^{15}\text{N}^*(0, 6.32, 9.94 \pm 0.02, 10.705 \pm 0.01)$ ). The spectra are dominated by transitions to  $^{15}\text{N}^*(0, 6.32)$ . A ZRDWBA analysis of the 29 MeV data leads to  $C^2S = 2.25$  and 3.25 for these two states [and to 2.37 and 3.31 for the analog states in  $^{15}\text{O}$  studied with the (d, t) reaction] ( $C^2S$  are average of values obtained from two parameter sets) (1978CO13). The  $E_d = 52$  MeV

work leads to  $J^\pi = \frac{3}{2}^-$  for both  $^{15}\text{N}^*(9.94, 10.71)$  (1977BE70). See also (1975FA06, 1976CH21; theor.).

$$75. \ ^{16}\text{O}(t, \alpha)^{15}\text{N} \quad Q_m = 7.6865$$

Angular distributions have been measured at  $E_t = 13$  MeV (1965AJ01;  $\alpha_0, \alpha_{1+2}, \alpha_3$ ).

$$\begin{aligned} 76. \text{ (a) } & \ ^{16}\text{O}(^7\text{Li}, ^8\text{Be})^{15}\text{N} & Q_m &= 5.1279 \\ \text{ (b) } & \ ^{16}\text{O}(^{10}\text{B}, ^{11}\text{C})^{15}\text{N} & Q_m &= -3.437 \\ \text{ (c) } & \ ^{16}\text{O}(^{11}\text{B}, ^{12}\text{C})^{15}\text{N} & Q_m &= 3.8294 \end{aligned}$$

For reaction (a) see (1979MA2N). The ground state angular distribution has been studied at  $E(^{10}\text{B}) = 100$  MeV (1975NA15). At  $E(^{11}\text{B}) = 115$  MeV  $^{15}\text{N}^*(0, 6.32)$  are populated (1979RA10).

$$\begin{aligned} 77. \text{ (a) } & \ ^{16}\text{O}(^{14}\text{N}, ^{15}\text{O})^{15}\text{N} & Q_m &= -4.8305 \\ \text{ (b) } & \ ^{16}\text{O}(^{16}\text{O}, ^{17}\text{F})^{15}\text{N} & Q_m &= -11.5272 \\ \text{ (c) } & \ ^{16}\text{O}(^{19}\text{F}, ^{20}\text{Ne})^{15}\text{N} & Q_m &= 0.7171 \end{aligned}$$

Angular distributions are reported at  $E(^{14}\text{N}) = 76.2$  MeV and  $E(^{16}\text{O}) = 95.2$  MeV (1979MO14, 1977MO1A), and  $E(^{14}\text{N}) = 155$  MeV (1975NA15, 1975VO05). Angular distributions are also reported at  $E(^{19}\text{F}) = 36$  MeV involving  $^{15}\text{N}_{\text{g.s.}}$  and  $^{20}\text{Ne}^*(0, 1.63)$  (1973GA14).

$$78. \ ^{17}\text{O}(p, ^3\text{He})^{15}\text{N} \quad Q_m = -8.5537$$

At  $E_p = 39.8$  MeV angular distributions of the groups to  $^{15}\text{N}^*(0, 6.32)$  have been compared with those to the analog states in  $^{15}\text{O}$  (1970OL1B, 1971OL04).

$$79. \ ^{17}\text{O}(d, \alpha)^{15}\text{N} \quad Q_m = 9.7995$$

See (1976AJ04).

$$\begin{aligned} 80. \text{ (a) } & \ ^{18}\text{O}(p, \alpha)^{15}\text{N} & Q_m &= 3.9796 \\ \text{ (b) } & \ ^{18}\text{O}(p, \text{tp})^{15}\text{N} & Q_m &= -15.8345 \end{aligned}$$

Angular distributions of  $\alpha_0$  have been measured for  $E_p = 0.84$  to  $2.00$  MeV and at several energies in the range  $20.6$  to  $42.2$  MeV [see (1976AJ04)] as well as at  $E_p = 125$  to  $850$  keV (1979LO01),  $296$  to  $549$  keV (1978MA30) and  $6.6$  to  $10.4$  MeV (1979WI09). For astrophysical considerations see  $^{19}\text{F}$  in (1983AJ01) and (1978MA30, 1979LO01). See also (1977CO1W). For angular correlation measurements see (1976AJ04). For reaction (b) see reaction 82 in  $^{16}\text{O}$  (1977AJ02).

$$81. \text{}^{18}\text{O}(\text{}^{18}\text{O}, \text{}^{20}\text{F})\text{}^{15}\text{N} \quad Q_m = -1.6505$$

See (1976AJ04).

$$82. \text{(a) } ^{19}\text{F}(\gamma, \alpha)^{15}\text{N} \quad Q_m = -4.0138$$

$$\text{(b) } ^{19}\text{F}(\text{p}, \text{p}\alpha)^{15}\text{N} \quad Q_m = -4.0138$$

$$\text{(c) } ^{19}\text{F}(\alpha, 2\alpha)^{15}\text{N} \quad Q_m = -4.0138$$

The cross section for reaction (a) to  $^{15}\text{N}^*(5.27, 5.30)$  has been measured for  $E_{\text{bs}} = 14$  to  $30$  MeV (1979TH05, 1976TH1E). See also (1972SH07). For reaction (c) see  $^{19}\text{F}$ . See also (1970AJ04) and (1977SP06).

$$83. \text{}^{19}\text{F}(\text{d}, \text{}^6\text{Li})\text{}^{15}\text{N} \quad Q_m = -2.5404$$

Angular distributions involving  $^{15}\text{N}_{\text{g.s.}}$  have been measured at  $E_d = 9.0$  to  $2.8$  MeV [see (1976AJ04)]; also at  $E_d = 19.5$  MeV to  $^{15}\text{N}^*(5.3, 6.3)$  and at  $E_d = 13.6$  MeV (1975GO21).

$$84. \text{}^{19}\text{F}(\text{}^3\text{He}, \text{}^7\text{Be})\text{}^{15}\text{N} \quad Q_m = -2.428$$

Angular distributions have been measured at  $E(^3\text{He}) = 30$  MeV (1970DE12) and  $40.7$  MeV (1971DE04, 1971DE37) involving  $^{15}\text{N}_{\text{g.s.}}$  and  $^7\text{Be}^*(0, 0.43)$ .

**<sup>15</sup>O**  
(Figs. 12 and 13)

GENERAL: (See also (1976AJ04).):

*Shell model:* (1976LI16, 1976SA37, 1977EM01, 1977PO16).

*Special states:* (1976LI16, 1977RI08).

*Electromagnetic transitions:* (1976LI16, 1976SH04, 1977HO04, 1978KR19).

*Astrophysical questions:* (1977BA1V, 1977SI1D, 1978BU1B, 1978WO1E, 1979PE1E).

*Special reactions involving <sup>15</sup>O:* (1976AB04, 1976BU16, 1976HE1H, 1976HI05, 1976LE1F, 1977AR06, 1977SC1G, 1978AB08, 1978BO1W, 1979AL22).

*Pion capture and pion reactions:* (1975KA1G, 1977BA24, 1977BA2G, 1978MO01, 1979LI11, 1979OS1F).

*Applied work:* (1976BE1X, 1977ST1M, 1977SU1G, 1977TH1H, 1978BI1M, 1978HI1D, 1978TI1A, 1978WI1F, 1978WO1C, 1979AL1Q, 1979DE1H, 1979WI1G).

*Other topics:* (1976SA1H, 1977BA3P, 1977EM01, 1978SH1B, 1979BE1H, 1979KA13).

*Ground state properties of <sup>15</sup>O:* (1976FU06, 1976SA1H, 1977KO28, 1977PO16, 1977YO1D, 1978AR1R, 1978SL1B, 1979NO05).

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

1.  $^{15}\text{O}(\beta^+)^{15}\text{N}$   $Q_m = 2.7539$

The half-life of <sup>15</sup>O is  $122.24 \pm 0.14$  sec based on the values listed in Table 15.19 of (1970AJ04) and on  $\tau_{1/2} = 122.23 \pm 0.23$  sec (1977AZ01).  $\log f_0 t = 3.637$  [calculated from tables of (1971GO40)]. The  $K/\beta^+$  ratio is  $(10.7 \pm 0.6) \times 10^{-4}$  (1972LE33). See also (1977BA48, 1978RA2A), (1978TA1U, 1979DA1D; astrophys.) and (1977AZ02, 1977RI08, 1977YO1E, 1979BA08, 1979OS1E, 1979TO1B; theor.).

2.  $^{10}\text{B}(^6\text{Li}, n)^{15}\text{O}$   $Q_m = 15.212$

See (1976AJ04).

3.  $^{10}\text{B}(^{14}\text{N}, ^9\text{Be})^{15}\text{O}$   $Q_m = 0.712$

Table 15.18: Energy levels of  $^{15}\text{O}$  <sup>a</sup>

$E_x$ in $^{15}\text{O}$ (MeV $\pm$ keV)	$J^\pi, T$	$\tau$ or $\Gamma_{\text{c.m.}}$ (keV)	Decay	Reactions
0	$\frac{1}{2}^-; \frac{1}{2}$	$\tau_{1/2} = 122.24 \pm 0.16$ sec	$\beta^+$	1, 2, 3, 4, 5, 6, 7, 10, 11, 12, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34
$5.183 \pm 1$	$\frac{1}{2}^+$	$\tau_m = 8.2 \pm 1.0$ fsec	$\gamma$	3, 7, 10, 12, 21, 25, 26, 28, 29, 34
$5.2409 \pm 0.3$	$\frac{5}{2}^+$	$3.25 \pm 0.30$ psec	$\gamma$	3, 7, 8, 10, 12, 13, 21, 22, 24, 25, 26, 28, 29
$6.1763 \pm 1.7$	$\frac{3}{2}^-$	$< 2.5$ fsec	$\gamma$	7, 12, 21, 22, 25, 26, 27, 28, 29, 33, 34
$6.7931 \pm 1.7$	$\frac{3}{2}^+$	$< 28$ fsec	$\gamma$	3, 7, 12, 21, 22, 25, 29
$6.8594 \pm 0.9$	$\frac{5}{2}^+$	$16.0 \pm 2.5$ fsec	$\gamma$	3, 7, 12, 21, 22, 25, 26, 29
$7.2759 \pm 0.6$	$\frac{7}{2}^+$	$0.70 \pm 0.15$ psec	$\gamma$	7, 8, 10, 12, 13, 21, 22, 25, 29
$7.5565 \pm 0.8$	$\frac{1}{2}^+$	$\Gamma = 1.6 \pm 0.5$ keV	$\gamma, p$	12, 14, 21, 22, 25, 29
$8.2840 \pm 0.9$	$\frac{3}{2}^+$	$3.6 \pm 0.7$	$\gamma, p$	7, 12, 14, 21, 22, 29
$8.743 \pm 6$	$\frac{1}{2}^+$	32	$\gamma, p$	12, 14, 29
$8.922 \pm 2$	$\frac{5}{2}^+$	$3.3 \pm 0.3$	$\gamma, p$	7, 12, 14, 16, 29
$8.922 \pm 2$	$\frac{1}{2}^+$	7.5	$\gamma, p$	7, 12, 14, 16, 29
$8.9821 \pm 1.7$	$(\frac{1}{2})^-$	$3.9 \pm 0.4$	$\gamma, p$	7, 12, 14, 29
$9.488 \pm 3$	$\frac{5}{2}^-$	$10.1 \pm 0.5$	$\gamma, p$	7, 12, 14, 29
$9.527 \pm 17$	$(\frac{3}{2})^+$	$280 \pm 25$	$\gamma, p$	12, 14, 16, 29
$9.609 \pm 2$	$\frac{3}{2}^-$	$8.8 \pm 0.5$	$\gamma, p$	7, 8, 12, 14, 28, 29
$9.662 \pm 3$	$(\frac{7}{2}, \frac{9}{2})^-$	$2 \pm 1$	p	7, 8, 12, 16, 29
$10.29^b$	$(\frac{5}{2})^-$	$3 \pm 1$	p	7, 12, 16, 29
$10.30^b$	$\frac{5}{2}^+$	$11 \pm 2$	p	7, 12, 16
$10.461 \pm 5$	$(\frac{9}{2})^+$	$< 2$	$\gamma, p$	7, 8, 14, 29
10.48	$(\frac{3}{2})^-$	$25 \pm 5$	$\gamma, p$	(8), 12, 14, 16, 28, 29
(10.506)	$(\frac{3}{2})^+$	$140 \pm 40$	$\gamma, p$	14, 16, 26
$10.917 \pm 12$	$\frac{7}{2}^+$	90	p	16, 29
$10.938 \pm 3$	$\frac{1}{2}^+$	$99 \pm 5$	$\gamma, p$	14, 16, 29

Table 15.18: Energy levels of  $^{15}\text{O}$  <sup>a</sup> (continued)

$E_x$ in $^{15}\text{O}$ (MeV $\pm$ keV)	$J^\pi, T$	$\tau$ or $\Gamma_{\text{c.m.}}$ (keV)	Decay	Reactions
11.025 $\pm$ 3	$\frac{1}{2}^-$	25 $\pm$ 2	$\gamma, \text{p}$	14, 16, 29
11.151 $\pm$ 7		< 10	$\text{p}$	7, 16, 29
11.218 $\pm$ 3	$\frac{3}{2}^+$	40 $\pm$ 4	$\gamma, \text{p}$	14, 16, 29
11.565 $\pm$ 15		< 10	$\text{p}$	7, 16, 29
11.569 $\pm$ 15	$\frac{5}{2}^-$	20 $\pm$ 15	$\gamma, \text{p}$	7, 14, 16, 29
11.616 $\pm$ 15	$(\frac{3}{2}, \frac{1}{2})^-$	80 $\pm$ 50	$\gamma, \text{p}$	14, 16
11.719 $\pm$ 8		< 10	$\text{p}$	7, 16
11.748 $\pm$ 3	$\frac{5}{2}^+$	99 $\pm$ 5	$\gamma, \text{p}$	14, 16
11.846 $\pm$ 3	$\frac{5}{2}^-$	65 $\pm$ 3	$\gamma, \text{p}$	14, 16
11.980 $\pm$ 10	$\frac{5}{2}^-$	20 $\pm$ 5	$\text{p}$	7, 16, 29
12.129 $\pm$ 15	$\frac{5}{2}^+$	200 $\pm$ 50	$\text{p}$	16, 29
12.222 $\pm$ 20		100 $\pm$ 50	$\text{p}$	16
12.255 $\pm$ 13	$\frac{5}{2}^+; \frac{3}{2}$	135 $\pm$ 15	$\text{p}$	33
12.295 $\pm$ 10				7
12.471 $\pm$ 3	$\frac{5}{2}^-(\frac{3}{2}^-)$	77 $\pm$ 4	$\text{p}$	16
12.60 $\pm$ 10				7
12.80		$\approx$ 250	$\gamma, \text{p}$	14
12.835 $\pm$ 3	$(\frac{1}{2}^-)$	16 $\pm$ 1	$\text{p}$	7, 8, 9, 10, 16
13.008 $\pm$ 3		215 $\pm$ 3	$\text{p}$	16
13.025 $\pm$ 3		40 $\pm$ 30	$\text{p}, ({}^3\text{He})$	5, 16
13.45	$(\frac{1}{2}, \frac{3}{2})^+$	$\approx$ 1000	$\gamma, \text{p}, (\alpha)$	14, 16, 20
(13.49)	$(\frac{3}{2}^+)$		( $\text{p}$ )	16
13.60	$\frac{5}{2}^+$		$\text{p}, \alpha$	20
13.70	$\frac{3}{2}^-$		$\text{p}$	16
13.79	$\frac{3}{2}^-$		$\text{n}, \text{p}, {}^3\text{He}, \alpha$	5, 7, 16, 20
13.87		$\approx$ 150	$\gamma, \text{p}$	14
14.03 $\pm$ 40	$(\frac{1}{2}^-, \frac{3}{2}^-)$	160 $\pm$ 20	$\text{n}, \text{p}, {}^3\text{He}$	5
14.17	$\frac{5}{2}^-$		$\text{p}, \alpha$	20
14.27 $\pm$ 10	$\frac{1}{2}^+$	340 $\pm$ 30	$\text{n}, \text{p}, {}^3\text{He}, \alpha$	5, 7, 15, 16, 19, 20
14.34	$\frac{5}{2}^+$	(240)	$\text{p}, ({}^3\text{He}), \alpha$	5, 20

Table 15.18: Energy levels of  $^{15}\text{O}$  <sup>a</sup> (continued)

$E_x$ in $^{15}\text{O}$ (MeV $\pm$ keV)	$J^\pi, T$	$\tau$ or $\Gamma_{\text{c.m.}}$ (keV)	Decay	Reactions
14.465 $\pm$ 10	$\frac{3}{2}^+, \frac{5}{2}^+$	100 $\pm$ 10	n, p, $^3\text{He}, \alpha$	5, 15, 16, 20
14.70 $\pm$ 40		170 $\pm$ 35	n, p, $^3\text{He}$	5, 15
14.95 $\pm$ 40		400 $\pm$ 25	n, p, $^3\text{He}, \alpha$	5, 15, 16, 19, 20
15.05 $\pm$ 10	$((\frac{13}{2}^+))$			7, 9, 10
15.1	$(\frac{1}{2}, \frac{3}{2})^+$	$\approx$ 1000	$\gamma, \text{p}$	14
15.45 $\pm$ 30		70 $\pm$ 20	p, $^3\text{He}, \alpha$	5, 7, 8
15.54 $\pm$ 10			(p, $^3\text{He}, \alpha$ )	5, 7
15.60 $\pm$ 10			(p, $^3\text{He}, \alpha$ )	5, 7
15.65 $\pm$ 10				7
15.80 $\pm$ 10			n, $^3\text{He}$	5, 7
15.90 $\pm$ 15	$\frac{1}{2}^-, \frac{3}{2}^-$	350	$^3\text{He}, \alpha$	5, 8
16.05 $\pm$ 20		$\approx$ 185	n, p, $^3\text{He}, \alpha$	5, 15, 16, 20
16.10 $\pm$ 20			(n) $^3\text{He}, \alpha$	5
16.21 $\pm$ 20		$\approx$ 140	(n), p, $^3\text{He}, \alpha$	5, 16, 19, 20
16.43 $\pm$ 50	$\frac{1}{2}^+$	560 $\pm$ 100	$^3\text{He}, \alpha$	5
16.75 $\pm$ 50			n, $^3\text{He}$	5, 29
17.04 $\pm$ 60	$(\frac{1}{2}, \frac{3}{2})^+$	700 $\pm$ 70	$\gamma, \text{p}, ^3\text{He}$	5, 8, 14
17.46 $\pm$ 20				7
17.51 $\pm$ 20	$\frac{1}{2}^-, \frac{3}{2}^-$	600	n, $^3\text{He}, \alpha$	5, 7
17.99 $\pm$ 50	$\frac{1}{2}^-, \frac{3}{2}^-$	200	$^3\text{He}$	5
18.23 $\pm$ 50			n, p, $^3\text{He}$	5
18.65 $\pm$ 60	$(\frac{1}{2}^+, \frac{3}{2}^+); \frac{1}{2}$	520 $\pm$ 110	$\gamma, ^3\text{He}$	5
19.03 $\pm$ 50			n, $^3\text{He}$	5
19.55 $\pm$ 80	$(\frac{1}{2}^+, \frac{3}{2}^+); \frac{1}{2}$	780 $\pm$ 270	$\gamma, ^3\text{He}$	5
19.91 $\pm$ 50			n, $^3\text{He}$	5
20.40 $\pm$ 70	$(\frac{1}{2}^+, \frac{3}{2}^+); \frac{1}{2}$	970 $\pm$ 240	$\gamma, \text{p}, ^3\text{He}$	5, 14
21.61 $\pm$ 70	$(\frac{1}{2}^+, \frac{3}{2}^+); \frac{1}{2}$	730 $\pm$ 120	$\gamma, \text{p}, ^3\text{He}$	5, 14
(26.0)	$(\frac{13}{2}^-)$	$\approx$ 600	$^3\text{He}$	5
(28.0)	$(\frac{9}{2}^-, \frac{11}{2}^-)$	$\approx$ 2500	$^3\text{He}$	5
(29.0)		$\approx$ 2500	$^3\text{He}$	5

<sup>a</sup> See also Table 15.19.

<sup>b</sup> It is possible that these two are in fact a single state: see (1976AJ04).

Angular distributions have been measured at  $E(^{14}\text{N}) = 73.9$  MeV (1977MO1A; to g.s.) and 100 MeV (1975NA15; to  $^{15}\text{O}^*(0, 5.18 + 5.24, 6.79 + 6.86)$ ).

$$4. \ ^{11}\text{B}(^{14}\text{N}, ^{10}\text{Be})^{15}\text{O} \quad Q_m = -3.932$$

Elastic angular distributions have been studied at  $E(^{14}\text{N}) = 41, 77$  and 113 MeV (1971LI11). See also (1978MA1F).

5. (a) $^{12}\text{C}(^3\text{He}, \gamma)^{15}\text{O}$	$Q_m = 12.0759$	
(b) $^{12}\text{C}(^3\text{He}, n)^{14}\text{O}$	$Q_m = -1.1484$	$E_b = 12.0759$
(c) $^{12}\text{C}(^3\text{He}, p)^{14}\text{N}$	$Q_m = 4.7788$	
(d) $^{12}\text{C}(^3\text{He}, d)^{13}\text{N}$	$Q_m = -3.5501$	
(e) $^{12}\text{C}(^3\text{He}, t)^{12}\text{N}$	$Q_m = -17.357$	
(f) $^{12}\text{C}(^3\text{He}, ^3\text{He})^{12}\text{C}$		
(g) $^{12}\text{C}(^3\text{He}, \alpha)^{11}\text{C}$	$Q_m = 1.856$	
(h) $^{12}\text{C}(^3\text{He}, ^7\text{Li})^8\text{B}$	$Q_m = -22.899$	
(i) $^{12}\text{C}(^3\text{He}, ^8\text{Be})^7\text{Be}$	$Q_m = -5.781$	

Excitation functions and polarization measurements for these reactions have been measured over a wide range of energies: see Tables 15.20 in (1970AJ04, 1976AJ04) and the text below. Observed resonances are displayed in Table 15.20. For angular distributions see the write-ups of the residual nuclei in (1979AJ01, 1980AJ01) and in  $^{13}\text{N}$ ,  $^{14}\text{N}$  and  $^{14}\text{O}$ . The  $90^\circ$  yield of  $\gamma_0$ , measured for  $E(^3\text{He}) = 5.24$  to 13.95 MeV shows five resonances attributed to E1 transitions from  $J^\pi = \frac{1}{2}^+$  or  $\frac{3}{2}^+$ ,  $T = \frac{1}{2}$  states in the GDR characterized by a considerable 3p-4h admixture: see Table 15.20 (1978DE33; see also for  $\omega_\gamma$ ). The yield of  $n_0$  (reaction (b)) shows resonances for  $E(^3\text{He}) < 10$  MeV and little structure above, to 30.6 MeV: see (1976AJ04) and (1978FE03;  $n_0$ , 11.5 to 23.5 MeV; also  $n_1$  and  $n_{2+3+4}$ , 14.5 to 26 MeV). The yield of protons (reaction (c)) shows some clear resonances below  $E(^3\text{He}) = 4.5$  MeV and some uncorrelated structures [see Fig. 3 in (1973SO04)] at higher energies (to  $E(^3\text{He}) = 12$  MeV), with the possible exception of states at  $E_{\text{res}} = 7.8, 9.2-9.6$  and (10.5) MeV (1973SO04). For  $E(^3\text{He}) = 16$  to 30.6 MeV no appreciable structure is observed in the  $p_0, p_1$  and  $p_2$  yields (1970SI15).

For reaction (d) see (1976AJ04) and (1976KA23;  $E(^3\text{He}) = 33.3$  MeV; polarization measurements;  $d_0, d_{2+3}$ ). For reaction (e) see (1976AJ04). The elastic scattering (reaction (f)) shows some resonant structure near 3, 5 and 6 MeV and some largely uncorrelated structures in the range



$E(^3\text{He}) = 16.5$  to  $24$  MeV. There is some suggestion, however, of two resonances at  $E(^3\text{He}) = 17$  and  $20$  MeV (1972MC01). Polarization measurements have been carried out for  $E(^3\vec{\text{He}}) = 20.5$  to  $32.6$  MeV for the groups to  $^{12}\text{C}^*(0, 4.4)$ . The elastic  $66.8^\circ$  data show a resonance-like behavior at  $E(^3\vec{\text{He}}) = 29$  MeV (1977KA25). See also (1976AJ04). The yield of  $\alpha$ -particles displays resonance structure below  $8$  MeV, and broad fluctuations for  $E(^3\text{He}) = 12$  to  $18.6$  MeV: see (1976AJ04). Polarization measurements are reported for  $E(^3\vec{\text{He}}) = 33.3$  MeV for the  $\alpha_0$  and  $\alpha_1$  groups (1976KA23). For reaction (h) see (1976AJ04). For reaction (i) see (1976PA07; cross section in range  $7$  to  $20$  MeV). For  $\pi^0$  production see (1976WA10). See also (1976KR1C, 1976TO1E) and (1974LO1B, 1976RO1L, 1976WA1B).

$$6. \ ^{12}\text{C}(\alpha, \text{n})^{15}\text{O} \quad Q_{\text{m}} = -8.5019$$

Angular distributions of the  $n_0$  group have been measured for  $E_\alpha = 18.4$  to  $23.1$  MeV: see (1976AJ04).

$$7. \ ^{12}\text{C}(^6\text{Li}, \text{t})^{15}\text{O} \quad Q_{\text{m}} = -3.7180$$

States observed in this reaction are displayed in Table 15.21 (1975BI06:  $E(^6\text{Li}) = 59.8$  MeV). Comparisons of angular distributions of the triton groups in this reaction and of the  $^3\text{He}$  groups to analog states in  $^{15}\text{N}$  have been made: analog correspondence is established for  $(10.48\text{--}10.80)$ ,  $(12.84\text{--}13.15(\text{u}))$  and  $(15.05\text{--}15.49(\text{u}))$  [ $E_x$  in  $^{15}\text{O}$ ,  $E_x$  in  $^{15}\text{N}$ ; u = unresolved] (1975BI06). See also (1976AJ04) for the earlier work on this reaction, (1977MA2G) and (1977FO1E).

$$8. \ ^{12}\text{C}(^{10}\text{B}, ^7\text{Li})^{15}\text{O} \quad Q_{\text{m}} = -5.712$$

At  $E(^{10}\text{B}) = 100$  MeV  $^{15}\text{O}^*(12.89, 15.36)$  are very strongly populated (1973NA09). See also reaction 20 in  $^{15}\text{N}$  and (1977FO1E, 1979NA1G).

$$9. \ ^{12}\text{C}(^{11}\text{B}, ^8\text{Li})^{15}\text{O} \quad Q_{\text{m}} = -15.134$$

At  $E(^{11}\text{B}) = 114$  MeV,  $\theta_{\text{lab}} = 7^\circ$  the spectrum is dominated by  $^{15}\text{O}^*(12.84, 15.05)$ .  $^{15}\text{O}^*(7.28, 10.48)$  are also populated (1974AN36).

$$10. \ ^{12}\text{C}(^{12}\text{C}, ^9\text{Be})^{15}\text{O} \quad Q_{\text{m}} = -14.2034$$

At  $E(^{12}\text{C}) = 187$  MeV,  $\theta_{\text{lab}} = 8^\circ$  the spectrum is dominated by  $^{15}\text{O}^*(12.84, 15.05)$  [assumed

Table 15.19: Radiative decays in  $^{15}\text{O}$ 

$E_i$ (MeV)	$J_i^\pi$	$E_f$ (MeV)	$J_f^\pi$	Branch (%)	$\delta^b$	Refs.
5.24	$\frac{5}{2}^+$	0	$\frac{1}{2}^-$	100	$+0.10 \pm 0.04$ (E3/M2)	<sup>b</sup>
6.18	$\frac{3}{2}^-$	0	$\frac{1}{2}^-$	100	$-0.141 \pm 0.016$ $-0.121 \pm 0.008$ (E2/M1)	(1965WA16, 1974KE02) (1971AV04)
6.79	$\frac{3}{2}^+$	5.18	$\frac{1}{2}^+$	< 2.5		(1965WA16)
		5.24	$\frac{5}{2}^+$	< 2.5		(1965WA16)
		0	$\frac{1}{2}^-$	100	$-0.02 \pm 0.02$ (M2/E1)	(1965WA16, 1968GI11, 1971AV04)
6.86	$\frac{5}{2}^+$	5.18	$\frac{1}{2}^+$	< 3		(1968GI11)
		5.24	$\frac{5}{2}^+$	< 3		(1968GI11)
		6.18	$\frac{3}{2}^-$	< 7		(1965WA16)
		0	$\frac{1}{2}^-$	< 10		(1965WA16)
		5.18	$\frac{1}{2}^+$	< 4		(1968GI11)
7.28	$\frac{7}{2}^+$	5.24	$\frac{5}{2}^+$	100	$+0.04 \pm 0.03$ (E2/M1)	(1965WA16, 1968GI11, 1971AV04)
		6.18	$\frac{3}{2}^-$	< 0.4		(1965WA16)
		0	$\frac{1}{2}^-$	< 30 < 12 $3.8 \pm 1.2$		(1965WA16) (1968GI11) (1969KU01)
		5.18	$\frac{1}{2}^+$	< 10 < 4		(1965WA16) (1968GI11)
		5.24	$\frac{5}{2}^+$	100		(1965WA16, 1968GI11)
		6.18	$\frac{3}{2}^-$	$96.2 \pm 1.2$		(1969KU01)
		6.18	$\frac{3}{2}^-$	< 2		(1965WA16)
		0	$\frac{1}{2}^-$	$\approx 3$ $3.5 \pm 0.5$		(1960TA17) (1963HE11)
		5.18	$\frac{1}{2}^+$	$16.2 \pm 2$ $15.8 \pm 0.6$		(1960TA17) (1963HE11)
		6.18	$\frac{3}{2}^-$	$57.9 \pm 0.6$ $57.4 \pm 0.6$		(1960TA17) (1963HE11)
7.56	$\frac{1}{2}^+$	6.79	$\frac{3}{2}^+$	$22.9 \pm 2$ $23.3 \pm 0.6$		(1960TA17) (1963HE11)

Table 15.19: Radiative decays in  $^{15}\text{O}$  (continued)

$E_i$ (MeV)	$J_i^\pi$	$E_f$ (MeV)	$J_f^\pi$	Branch (%)	$\Gamma_\gamma$ (eV)	Refs.
8.28	$\frac{3}{2}^+$	6.86	$\frac{5}{2}^+$	c	f	
		0	$\frac{1}{2}^-$	$53.8 \pm 0.25$	0.531	(1966EV01)
		5.24	$\frac{3}{2}^+$	$42.7 \pm 0.5$	0.405	(1966EV01)
		6.18	$\frac{3}{2}^-$	$2.2 \pm 0.6$	0.021	(1966EV01)
8.74	$\frac{1}{2}^+$	6.86	$\frac{3}{2}^+$	$1.2 \pm 0.3$	0.011	(1966EV01)
		5.18	$\frac{1}{2}^+$	67	0.32	(1966EV01)
		6.18	$\frac{3}{2}^-$	33	0.16	(1966EV01)
8.922 <sup>d</sup>	$\frac{1}{2}^-$	0	$\frac{1}{2}^-$	$50 \pm 25$		(1972KR14)
		5.18	$\frac{1}{2}^+$	$20 \pm 10$		(1972KR14)
		6.18	$\frac{3}{2}^-$	$20 \pm 10$		(1972KR14)
		6.86	$\frac{3}{2}^+$	$(10 \pm 10)$		(1972KR14)
8.982	$(\frac{3}{2})^-$	0	$\frac{1}{2}^-$	$94 \pm 1$		(1972KR14)
		5.18	$\frac{1}{2}^+$	$6 \pm 1$		(1972KR14)
		6.18	$\frac{3}{2}^-$	$< 1$		(1972KR14)
		6.86	$\frac{3}{2}^+$	$< 1$		(1972KR14)
		7.28	$\frac{7}{2}^+$			(1967EV02)
9.49	$\frac{5}{2}^-$	0	$\frac{1}{2}^-$	86	2.1	(1967EV02)
		5.24	$\frac{3}{2}^+$	6.5	0.15	(1967EV02)
		6.18	$\frac{3}{2}^-$	0.7	0.22	(1967EV02)
		6.86	$\frac{3}{2}^+$	3.4	0.08	(1967EV02)
		7.28	$\frac{7}{2}^+$	5.1	0.11	(1967EV02)
9.50 <sup>e</sup>	$\frac{3}{2}^+$ ( $\frac{1}{2}^+$ )	0	$\frac{1}{2}^-$	$\approx 100$		(1967EV02)
9.61	$\frac{3}{2}^-$	0	$\frac{1}{2}^-$	79	4.0	(1967EV02)
		5.24	$\frac{3}{2}^+$	19	1.0	(1967EV02)
		6.18	$\frac{3}{2}^-$	2	0.1	(1967EV02)
		7.28	$\frac{7}{2}^+$			(1967EV02)
10.46	$(\frac{9}{2}^+)$	5.24	$\frac{3}{2}^+$	$62 \pm 6$	$18 \pm 6^g$	(1977KU03)
		6.86	$\frac{3}{2}^+$	$< 4$	$< 1.5$	(1977KU03)
		7.28	$\frac{7}{2}^+$	$38 \pm 6$	$11 \pm 4^g$	(1977KU03)
10.48	$(\frac{3}{2})^-$	0	$\frac{1}{2}^-$	$60 \pm 8$	$0.21 \pm 0.07^g$	(1977KU03)
		5.24	$\frac{3}{2}^+$	$40 \pm 6$	$0.14 \pm 0.01^g$	(1977KU03)
		6.18	$\frac{3}{2}^-$	$< 4$	$< 0.02$	(1977KU03)
		9.79	$\frac{3}{2}^+$	$< 4$	$< 0.02$	(1977KU03)
		10.94	$\frac{1}{2}^+$	0	$\frac{1}{2}^-$	$44 \pm 8$
5.18	$\frac{1}{2}^+$	$34 \pm 3$		$11 \pm 2$	(1972PH02)	

Table 15.19: Radiative decays in  $^{15}\text{O}$  (continued)

$E_i$ (MeV)	$J_i^\pi$	$E_f$ (MeV)	$J_f^\pi$	Branch (%)	$\Gamma_\gamma$ (eV)	Refs.
11.03	$\frac{1}{2}^-$	6.18	$\frac{3}{2}^-$	$22 \pm 8$	$7 \pm 2$	(1972PH02)
		6.79	$\frac{3}{2}^+$	$< 8$	$< 3$	(1972PH02)
		0	$\frac{1}{2}^-$	100	$1.4 \pm 0.4$	(1972PH02)
11.22	$\frac{3}{2}^+$	6.79	$\frac{3}{2}^+$	$< 25$	$< 0.4$	(1972PH02)
		0	$\frac{1}{2}^-$	$74 \pm 5$	$5.5 \pm 0.5$	(1972PH02)
		5.18	$\frac{1}{2}^+$	$14 \pm 5$	$1.0 \pm 0.2$	(1972PH02)
11.57	$\frac{5}{2}^-$	5.24	$\frac{5}{2}^+$	$12 \pm 5$	$0.9 \pm 0.2$	(1972PH02)
		6.79	$\frac{3}{2}^+$	$< 4$	$< 0.4$	(1972PH02)
		0	$\frac{1}{2}^-$	$18 \pm 9$	$0.3 \pm 0.2$	(1972PH02)
		5.24	$\frac{5}{2}^+$	$63 \pm 9$	$1.2 \pm 0.1$	(1972PH02)
11.75	$\frac{5}{2}^+$	6.18	$\frac{3}{2}^-$	$20 \pm 9$	$0.4 \pm 0.2$	(1972PH02)
		6.79	$\frac{3}{2}^+$	$< 3$	$< 0.1$	(1972PH02)
		0	$\frac{1}{2}^-$	$< 30$		(1972PH02)
		5.18	$\frac{1}{2}^+$	$< 25$		(1972PH02)
		5.24	$\frac{5}{2}^+$	$47 \pm 7$	$5 \pm 1$	(1972PH02)
11.85	$\frac{5}{2}^-$	6.18	$\frac{3}{2}^-$	$53 \pm 7$	$5 \pm 1$	(1972PH02)
		6.79	$\frac{3}{2}^+$	$< 20$		(1972PH02)
		0	$\frac{1}{2}^-$	$< 50$		(1972PH02)
		5.24	$\frac{5}{2}^+$	100	$1.4 \pm 0.6$	(1972PH02)
		6.79	$\frac{3}{2}^+$	$< 40$		(1972PH02)

<sup>a</sup>  $\delta$  = multipole mixing ratio.

<sup>b</sup> Average of results of (1966GO15, 1968GI01, 1971AV04) (P.M. Endt, private communication).

<sup>c</sup> Intensity  $< 25\%$  of transition to  $^{15}\text{O}^*(6.79)$ .

<sup>d</sup> See, however, (1977DR02) and the comments in reaction 14.

<sup>e</sup> Unresolved doublet: see Table 15.23.

<sup>f</sup> Sum is 0.97 eV, but see Table 15.23 [ $\Gamma_\gamma = 1.4$  eV].

<sup>g</sup>  $\Gamma_\gamma$  values assume  $J$  values in column 2.

$J^\pi = \frac{1}{2}^-, \frac{13}{2}^+$ , respectively].  $^{15}\text{O}^*(7.28)$  [ $J^\pi = \frac{7}{2}^+$ ] is populated but  $^{15}\text{O}^*(0, 6.79)$  are not observed (1974AN36). The situation is similar at  $E(^{12}\text{C}) = 114$  MeV but at  $E(^{12}\text{C}) = 72$  MeV ( $\theta_{\text{lab}} = 11^\circ$ )  $^{15}\text{O}^*(0, 5.2, 7.28)$  are populated with comparable intensities (1974AN36). See also (1977FO1E, 1977PH1D, 1978HO1C, 1978MA1F).

11. (a)  $^{12}\text{C}(^{14}\text{N}, ^{11}\text{B})^{15}\text{O}$

$Q_m = -8.6599$

Table 15.20: Resonances in  $^{12}\text{C} + ^3\text{He}$ 

$E(^3\text{He})$ (MeV $\pm$ keV)	Resonant for	$\Gamma_{\text{c.m.}}$ (keV)	$J^\pi$	$E_x$ (MeV)	Refs.
1.21	$p_0, p_2$		$(\frac{5}{2})^-$	13.04	A
1.3	$p_0 \rightarrow p_3$			13.1	A
2.15	$n, p_0$		$(> \frac{5}{2})$	13.79	A
$2.45 \pm 40$	$n_0, p_0 \rightarrow p_3$	$160 \pm 20$	$(\frac{1}{2}^-, \frac{3}{2}^-)$	14.03	A
$2.75 \pm 40$	$n_0, p_1, p_2, ^3\text{He}, \alpha_0$	$340 \pm 30$	$\frac{1}{2}^+$	14.27	A
(2.87)	$p_0, p_2$	240		(14.37)	A
$2.990 \pm 10$	$n_0, p_0, p_1, p_2, p_4, p_5, p_8, ^3\text{He}, \alpha_0$	$100 \pm 10$	$\frac{3}{2}^+, \frac{5}{2}^+$	14.465	A
$3.28 \pm 40$	$p_0, (p_1, p_2)$	$180 \pm 40$		14.70	A
$3.60 \pm 40$	$p_0, p_1, p_2$	$400 \pm 25$		14.95	A
$4.20 \pm 10$	$p_5, p_6, \alpha_0$	$65 \pm 15$		15.43	A
$4.37 \pm 40$	$p_0, p_1, p_2, p_4, p_7, p_8, \alpha_0$	$80 \pm 25$		15.57	A
$4.65 \pm 50$	$n_0$			15.79	A
$4.78 \pm 50$	$^3\text{He}, \alpha_0$	350	$\frac{1}{2}^-, \frac{3}{2}^-$	15.90	A
$4.97 \pm 20$	$\alpha_0$			16.05	A
$5.03 \pm 20$	$n_0, ^3\text{He}, \alpha_0$			16.10	A
$5.15 \pm 20$	$n_0, ^3\text{He}, \alpha_0$			16.19	A
$5.45 \pm 50$	$^3\text{He}, \alpha_0$	170	$\frac{1}{2}^+$	16.43	A
$5.85 \pm 50$	$n_0, ^3\text{He}$			16.75	A
$6.23 \pm 70$	$\gamma_0$	$700 \pm 70$	a	$17.05 \pm 0.06^b$	(1978DE33)
$6.80 \pm 50$	$n_0, ^3\text{He}, \alpha_0$	600	$\frac{1}{2}^-, \frac{3}{2}^-$	17.51	A
$7.40 \pm 50$	$^3\text{He}$	200	$\frac{1}{2}^-, \frac{3}{2}^-$	17.99	A
$7.70 \pm 50$	$n_0, p_0$			18.23	A
$8.25 \pm 70$	$\gamma_0$	$520 \pm 110$	$(\frac{1}{2}, \frac{3}{2})^+ \text{ A}$	$18.65 \pm 0.06^b$	(1978DE33)
$8.70 \pm 50$	$n_0$			19.03	A
$9.38 \pm 100$	$\gamma_0$	$780 \pm 270$	a	$19.55 \pm 0.08$	(1978DE33)
$9.80 \pm 50$	$n_0$			19.91	A
$10.45 \pm 90$	$\gamma_0, (p_0)$	$970 \pm 240$	a	$20.40 \pm 0.07$	A, (1978DE33)
$11.87 \pm 80$	$\gamma_0$	$730 \pm 120$	a	$21.61 \pm 0.07$	(1978DE33)
(17.0) <sup>c</sup>	$^3\text{He}$	$\approx 600$	$(\frac{13}{2}^-)$	(26.0)	A
(20.0) <sup>c</sup>	$^3\text{He}$	$\approx 2500$	$(\frac{9}{2}^-, \frac{11}{2}^-)$	(28.0)	A
(21.5)	$^3\text{He}$ to $^{12}\text{C}^*(15.1)$	$\approx 2500$		(29.0)	A

A: See references listed for this state in Table 15.21 (1976AJ04).

<sup>a</sup> See text.

<sup>b</sup>  $\Gamma_{^3\text{He}}/\Gamma_{\text{p}} = 0.17 \pm 0.07$  and  $0.09 \pm 0.04$  for  $^{15}\text{O}^*(17.04, 18.65)$ .

<sup>c</sup>  $\Gamma_{\text{p}} = 0.06$  and  $\geq 0.1$  MeV for  $^{15}\text{O}^*(26, 28)$  (1972MC01).

Table 15.21: Levels of  $^{15}\text{O}$  from  $^{12}\text{C}(^6\text{Li}, t)^{15}\text{O}$  <sup>a</sup>

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

<sup>a</sup> (1975BI06):  $E(^6\text{Li}) = 59.8$  MeV.

<sup>b</sup> Angular distributions measured and compared with those of the ( $^6\text{Li}, ^3\text{He}$ ) reaction to analog states in  $^{15}\text{N}$ .

<sup>c</sup> Angular distributions measured: analog states in  $^{15}\text{N}$  not known.

<sup>d</sup> Unresolved in angular distribution.

<sup>e</sup>  $\Gamma_\gamma/\Gamma < 0.13$ . (1977KR1A)

$$\begin{aligned} \text{(b) } {}^{12}\text{C}({}^{16}\text{O}, {}^{13}\text{C}){}^{15}\text{O} & \quad Q_m = -10.7175 \\ \text{(c) } {}^{12}\text{C}({}^{20}\text{Ne}, {}^{17}\text{O}){}^{15}\text{O} & \quad Q_m = -9.089 \end{aligned}$$

For reaction (a) see (1976AJ04); for (b) see (1979PR07); for (c) see (1979OR01).

$$12. {}^{13}\text{C}({}^3\text{He}, \text{n}){}^{15}\text{O} \quad Q_m = 7.1295$$

Observed groups are displayed in Table 15.22.

$$13. {}^{13}\text{C}({}^{11}\text{B}, {}^9\text{Li}){}^{15}\text{O} \quad Q_m = -16.018$$

At  $E({}^{11}\text{B}) = 114$  MeV the states which are strongly populated are  ${}^{15}\text{O}^*(5.24, 7.28, 11.2, 11.7)$  (1974AN36).

$$14. {}^{14}\text{N}(\text{p}, \gamma){}^{15}\text{O} \quad Q_m = 7.2971$$

Observed resonances in the yield of  $\gamma$ -rays are listed in Table 15.23. Branching ratios are displayed in Table 15.19.

The cross section increases from  $(8.5 \pm 3.7) \times 10^{-12}$  b at 100 keV to  $(140 \pm 30) \times 10^{-12}$  b at 135 keV (1957LA13). Extrapolation from the  $E_p = 0.28$  MeV resonance gives  $S(0) = 2.75 \pm 0.50$  keV · b, with zero slope to  $E_p = 0.05$  MeV (1963HE11). Measurements of  $E_\gamma$  lead to  $E_x = 5183 \pm 1, 5240.9 \pm 0.4, 6175 \pm 2, 6794 \pm 2, 6858 \pm 2, 8284.1 \pm 0.8, 8922 \pm 2$  and  $8978 \pm 2$  keV (1972KR14, 1972NE05, 1977DR02). See also Table 15.24 in (1976AJ04). (1977DR02) find, on the basis of the analysis of (p, p) excitation curves and  $\gamma\gamma$  correlation data, that the two states at  $E_x = 8922$  keV are separated by  $\Delta E = 0.5 \pm 0.5$  keV: for their parameters see Table 15.23. This is in disagreement with the earlier work of (1972KR14) which assumed a larger  $\Delta E$ , and suggests that the branching ratios for the  $\frac{5}{2}^+$  and  $\frac{1}{2}^-$  states at  $E_x = 8.92$  MeV shown in Table 15.19 should be remeasured (1977DR02).

The  $90^\circ \gamma_0$  yield curve has been measured for  $E_p = 2.2$  to 19.0 MeV: resonances are observed over most of the range in the  $\gamma_0$  yield. The  $(\gamma_1 + \gamma_2)$  yield is relatively weak (1970KU09). For

Table 15.22: Levels of  $^{15}\text{O}$  from  $^{13}\text{C}(^3\text{He}, \text{n})^{15}\text{O}$

$E_x^a$ (MeV)	$J^\pi^a$	$L^b$	$S^e$
g.s.	$\frac{1}{2}^-$	0	1 <sup>g</sup>
5.18 <sup>c</sup>	$\frac{1}{2}^+$	1	0.15
5.24 <sup>c</sup>	$\frac{5}{2}^+$	3	0.17
$6.180 \pm 4^f$	$\frac{3}{2}^-$	2	0.10 <sup>h</sup>
6.79 <sup>c</sup>	$\frac{3}{2}^+$	1	0.12
$6.857 \pm 3.2^f$	$\frac{5}{2}^+$	3	0.29
$7.284 \pm 7^f$	$\frac{7}{2}^+$	3	(< 0.03)
7.56	$\frac{1}{2}^+$	1	0.02
8.28	$\frac{3}{2}^+$	1	(0.38)
8.74	$\frac{1}{2}^+$	1	
8.92 <sup>l</sup>		1	0.55 <sup>i</sup>
8.98	$(\frac{1}{2})^-$	0	0.44 <sup>j</sup>
9.49	$\frac{5}{2}^-$	2	
9.53	$(\frac{1}{2})^+$	1	
9.61	$\frac{3}{2}^-$	2	1.05 <sup>j</sup>
9.66	$(\frac{7}{2}, \frac{9}{2})^-$	0 <sup>k</sup>	
10.29 <sup>l</sup>		$\geq 3^d$	
10.48 <sup>l</sup>		0 <sup>c</sup> , 2 <sup>d</sup>	

<sup>a</sup> Nominal energies and known  $J^\pi$ : see Table 15.18, except where uncertainties are shown.

<sup>b</sup> (1971ET1A, 1972ET01):  $E(^3\text{He}) = 5.5$  and  $6.2$  MeV; used codes DWUCK and MANDY.

<sup>c</sup> These states were unresolved.

<sup>d</sup> (1972GE02):  $E(^3\text{He}) = 6$  MeV.

<sup>e</sup> (1971HI04); see also (1972GE02).

<sup>f</sup> From  $\gamma$ -ray measurements: see Table 15.19 (1965WA16).

<sup>g</sup>  $(p_{1/2})^2$ .

<sup>h</sup>  $(p_{3/2}, p_{1/2})$ .

<sup>i</sup>  $(p_{1/2}, d_{3/2})$ .

<sup>j</sup>  $(d_{5/2})^2$ .

<sup>k</sup> (1971HI04) report  $L = 4$ .

<sup>l</sup> Known to be a doublet: see Table 15.19.



Table 15.23: Resonances in  $^{14}\text{N} + \text{p}$  <sup>a</sup>

$E_p$ (keV)	$\Gamma_{\text{lab}}$ (keV)	$\omega\Gamma_\gamma$ (eV)	Particles out	$J^\pi$	$E_x$ (MeV)	Refs.
$278.1 \pm 0.4$	$1.7 \pm 0.5$	0.014	$\gamma$	$\frac{1}{2}^+$	7.5565	A
$1058.0 \pm 0.5$ <sup>b</sup>	$3.9 \pm 0.7$ <sup>b</sup>	0.95	$\gamma$	$\frac{3}{2}^+$	8.2840	A
$1550 \pm 6$	34	0.16	$\gamma$	$\frac{1}{2}^+$	8.743	A
$1742 \pm 2$	$3.5 \pm 0.3$	0.16	$\gamma, \text{p}_0$	$\frac{5}{2}^+$	8.922	A, (1977DR02)
$1742 \pm 2$	8	0.06	$\gamma, \text{p}_0$	$\frac{1}{2}^+$	8.922	A
$1806.4 \pm 1.5$	$4.2 \pm 0.4$	0.52	$\gamma$	$(\frac{3}{2})^-$	8.9821	A
$2348 \pm 3$	$10.8 \pm 0.5$	2.4	$\gamma$	$\frac{5}{2}^-$	9.488	A
$2368 \pm 32$	$300 \pm 26$		$\gamma$	$(\frac{3}{2})^+$	9.506	A
$2479 \pm 1.7$	$9.4 \pm 0.5$	3.3	$\gamma$	$\frac{3}{2}^-$	9.609	A
$2537 \pm 4$	$2 \pm 1$		$\text{p}_0$	$(\frac{7}{2}, \frac{9}{2})^-$	9.664	A
3209	$3 \pm 1$		$\text{p}_0$	$(\frac{5}{2})^-$	10.291	A
3215	$12 \pm 2$		$\text{p}_0$	$\frac{5}{2}^+$	10.296	A
$3392 \pm 5$	$< 2$	$0.029 \pm 0.010$	$\gamma_2, \gamma_6$	$(\frac{9}{2})^+$	10.461	(1977KU03)
3410	$27 \pm 5$		$\gamma_0, \gamma_2, \text{p}_0$	$(\frac{3}{2})^-$	10.478	A, (1977KU03)
3440	$150 \pm 45$		$\gamma, \text{p}_0$	$(\frac{3}{2})^+$	10.506	A
$3880 \pm 15$	97		$\text{p}_0$	$\frac{7}{2}^+$	10.916	A
		$\Gamma_{\gamma_0}$ (eV)				A
$3903 \pm 3$	$106 \pm 5$	$14 \pm 3$	$\gamma, \text{p}_0, \text{p}_1$	$\frac{1}{2}^+$	10.938	A
$3996 \pm 3$	$27 \pm 2$	$1.4 \pm 0.4$	$\gamma, \text{p}_0, \text{p}_1$	$\frac{1}{2}^-$	11.025	A
$4130 \pm 15$	$< 10$		$\text{p}_0$		11.150	A
$4203 \pm 3$	$43 \pm 4$	$5.2 \pm 0.4$	$\gamma, \text{p}_0$	$\frac{3}{2}^+$	11.218	A
$4575 \pm 15$	$< 10$		$\text{p}_0$		11.565	A
$4580 \pm 15$	$21 \pm 15$	$0.7 \pm 0.2$	$\gamma, \text{p}_0$	$\frac{5}{2}^-$	11.569	A
4580	150		$\gamma$		11.57	A
$4630 \pm 15$	$86 \pm 50$		$\gamma, \text{p}_0$	$(\frac{3}{2}, \frac{1}{2})^-$	11.616	A
$4740 \pm 15$	$< 10$		$\text{p}_0$		11.718	A
$4772 \pm 3$	$106 \pm 5$		$\gamma, \text{p}_0, \text{p}_1$	$\frac{5}{2}^+$	11.748	A
$4877 \pm 3$	$70 \pm 3$		$\gamma, \text{p}_0, \text{p}_1$	$\frac{5}{2}^-$	11.846	A
$5025 \pm 15$	$21 \pm 5$		$\text{p}_0, \text{p}_1$	$\frac{5}{2}^-$	11.984	A
$5180 \pm 15$	$214 \pm 50$		$\text{p}_0, \text{p}_1$	$\frac{5}{2}^+$	12.129	A
$5280 \pm 20$	$106 \pm 50$		$\text{p}_1$ <sup>c</sup>		12.222	A
$5547 \pm 3$	$82 \pm 4$		$\text{p}_1, \text{p}_2$	$\frac{5}{2}^- (\frac{3}{2}^-)$	12.471	A
5900	$\approx 250$		$\gamma$		12.80	A
$5937 \pm 3$	$17 \pm 1$		$\text{p}_2$ <sup>d</sup>		12.835	A
(6100)	30		$\text{p}_0 \rightarrow \text{p}_2, \alpha_0$	$\frac{5}{2}^+$	(12.99)	A
$6123 \pm 3$	$230 \pm 30$		$\text{p}_2$ <sup>d</sup>		13.008	A
$6141 \pm 3$	$43 \pm 30$		$\text{p}_2$ <sup>d</sup>		13.025	A
6600	$\approx 1000$		$\gamma, (\text{p}_2, \alpha_0)$	$(\frac{1}{2}, \frac{3}{2})^+$	13.45	A

Table 15.23: Resonances in  $^{14}\text{N} + \text{p}$  <sup>a</sup> (continued)

$E_p$ (keV)	$\Gamma_{\text{lab}}$ (keV)	$\omega\Gamma_\gamma$ (eV)	Particles out	$J^\pi$	$E_x$ (MeV)	Refs.
6640			(p <sub>0</sub> ), (p <sub>2</sub> )	$(\frac{3}{2}^+)$	13.49	A
6760			$\alpha_0$	$\frac{5}{2}^+$	13.60	A
6870			p <sub>2</sub>	$\frac{3}{2}^-$	13.70	A
6960			p <sub>1</sub> , p <sub>2</sub> , p <sub>4</sub> , $\alpha_0$	$\frac{3}{2}^-$	13.79	A
7050	$\approx 150$		$\gamma$		13.87	A
7370			$\alpha_0$	$\frac{5}{2}^-$	14.17	A
7500	$\approx 500$		n, p <sub>0</sub> $\rightarrow$ p <sub>2</sub> , $^3\text{He}$ , $\alpha$		14.29	A
7550			$\alpha_0$	$\frac{5}{2}^+$	14.34	A
7700			n, p <sub>0</sub> , $\alpha_0$		14.48	A
7950	$170 \pm 50$		n		14.71	A
8200			n, p <sub>2</sub> $\rightarrow$ p <sub>6</sub> , $^3\text{He}$ , $\alpha_0$ , $\alpha_1$		14.94	A
8400	$\approx 1000$		$\gamma$	$(\frac{1}{2}, \frac{3}{2})^+$	15.1	A
9050			n		15.74	A
e						
9370 $\pm$ 20	$\approx 200$		n, p <sub>2</sub> , p <sub>8</sub> , $\alpha_1$		16.04	A
9580 $\pm$ 20	$\approx 150$		p <sub>0</sub> , p <sub>1</sub> , p <sub>3</sub> $\rightarrow$ p <sub>7</sub> , p <sub>9</sub> , $^3\text{He}$ , $\alpha_1$		16.23	A
9850 $\pm$ 50	$600 \pm 100$		n, $^3\text{He}$		16.48	A
10300	$\approx 1000$		$\gamma$	$(\frac{1}{2}, \frac{3}{2})^+$	16.9	A
10600			p <sub>4</sub> $\rightarrow$ p <sub>9</sub> , $\alpha_0$ , $\alpha_1$		17.2	A
11900	$\approx 1000$		$\gamma$	$(\frac{1}{2}, \frac{3}{2})^+$	18.4	A
14200	$\approx 2000$		$\gamma$	$(\frac{1}{2}, \frac{3}{2})^+$	20.5	A
15800	$\approx 2000$		$\gamma$	$(\frac{1}{2}, \frac{3}{2})^+$	22.0	A

A: See earlier references for this resonance in (1970AJ04) and Table 15.25 of (1976AJ04).

<sup>a</sup> See also Table 15.19.

<sup>b</sup> (1978LA1M; prelim.) report  $E_p = 1057.7 \pm 0.5$  keV,  $\Gamma = 3.5 \pm 0.5$  keV.

<sup>c</sup> Weak.

<sup>d</sup> Strong.

<sup>e</sup> (1974HU02) report three large structures in the  $\alpha_0$  yield [ $E_p = 9$  to 12 MeV] corresponding to excitations of 16.2, 17.2 and 17.8 MeV in  $^{15}\text{O}$ : these appear to be composed of substructures. For instance  $^{15}\text{O}^*(16.2)$  appears to have components at  $E_x = 15.9, 16.1$  and 16.25 MeV;  $^{15}\text{O}^*(17.2)$  appears to involve  $E_x = 17.0$  and a sharper peak at 17.25 MeV;  $^{15}\text{O}^*(17.8)$  involves  $E_x = 17.7$  and 17.9 MeV. It appears that this region is better studied via the  $^{12}\text{C} + ^3\text{He}$  reaction: see Table 15.20.

$E_p = 18$  to 28 MeV the excitation function for  $\gamma_0$  decreases smoothly with energy: there is no evidence for structures (1975HA39). See also (1976AJ04).

Lifetime measurements are reported by (1977KE15):  $\tau_m = 8.2 \pm 1.0, > 3000, < 2.5, 16.0 \pm 2.5$  and  $750 \pm 200$  fsec for  $^{15}\text{O}^*(5.18, 5.24, 6.18, 6.86, 7.28)$ , respectively. For questions re-

lated to astrophysics see (1974FO1F, 1975ZI1A, 1976AJ04, 1976BR1H, 1977CO1W). See also (1976TR1D), (1974LO1B) and (1977YO1F, 1979RO1C, 1979TR1G; applications).

$$15. \text{}^{14}\text{N}(p, n)\text{}^{14}\text{O} \qquad Q_m = -5.9273 \qquad E_b = 7.2971$$

The excitation function has been measured for  $E_p = 6.3$  to 12 MeV (1964KU06). Observed resonances are displayed in Table 15.23. See also (1978WA1D), (1977YO1G; applications) and  $^{14}\text{O}$ .

$$16. \text{}^{14}\text{N}(p, p)\text{}^{14}\text{N} \qquad E_b = 7.2971$$

The yields of elastic and inelastic protons, and of  $\gamma$ -rays, have been studied at many energies: see (1959AJ76, 1970AJ04, 1976AJ04). Observed resonances are displayed in Table 15.23. At higher energies excitation functions have been measured for the  $p_0$ ,  $p_1$  and  $p_2$  groups for  $E_p = 17$  to 26.5 MeV: there is no evidence for resonant behavior but the  $p_1$  yield shows a large increase between  $E_p = 20$  and 23 MeV (1972LU10). Total cross sections for the  $p_0 \rightarrow p_9$  groups have been measured at  $E_p = 8.6, 10.6, 12.6$  and 14.6 MeV by (1973HA54). See also (1980FO05) and  $^{14}\text{N}$ .

Polarization measurements have been reported for  $E_p = 3.0$  to 155 MeV: see Table 15.25 in (1970AJ04), and (1976AJ04). A recent measurement of VAP for the  $p_0$  and  $p_1$  groups is reported at  $E_p = 21$  MeV (1979AO02). The depolarization parameter,  $D$ , has been determined for  $p_0$  at  $E_p = 16.15$  MeV (1976CL1B; prelim.). See also (1978GO05) and (1976TH06; theor.).

$$17. \text{}^{14}\text{N}(p, d)\text{}^{13}\text{N} \qquad Q_m = -8.3290 \qquad E_b = 7.2971$$

See  $^{13}\text{N}$ .

$$18. \text{}^{14}\text{N}(p, t)\text{}^{12}\text{N} \qquad Q_m = -22.135 \qquad E_b = 7.2971$$

See  $^{12}\text{N}$  in (1980AJ01).

$$19. \text{}^{14}\text{N}(p, \text{}^3\text{He})\text{}^{12}\text{C} \qquad Q_m = -4.7788 \qquad E_b = 7.2971$$

Excitation functions for the ground state groups have been measured at  $E_p = 7$  to 11 MeV: some resonant structure is indicated (see Table 15.23) (1970ME30). Total cross sections for the transitions to  $^{12}\text{C}^*(0, 4.4)$  have been measured in the range  $E_p = 20.5$  to 44.6 MeV (1974PI05). See also  $^{12}\text{C}$  in (1980AJ01).

$$20. \text{ (a) } ^{14}\text{N}(p, \alpha)^{11}\text{C} \qquad Q_m = -2.922 \qquad E_b = 7.2971$$

$$\text{ (b) } ^{14}\text{N}(p, 2\alpha)^7\text{Be} \qquad Q_m = -10.468$$

Excitation functions and total cross section measurements have been carried out for the  $\alpha_0$  group for  $E_p = 3.8$  to 45 MeV: see (1976AJ04). Fairly sharp structures persist until  $E_p = 15$  MeV (1974JA11): see Table 15.23 for the parameters of observed resonances and in particular footnote <sup>e</sup>. Reaction (b), whose cross section has been measured to  $E_p = 52$  MeV, displays a broad peak at  $\approx 20$  MeV (1974JA11, 1976IN04). For spallation studies see (1977MO1C, 1979RA20, 1979VD02, 1979WE06). See also (1975ZI1A; astrophys.).

$$21. ^{14}\text{N}(d, n)^{15}\text{O} \qquad Q_m = 5.0725$$

Angular distributions have been studied at many energies in the range  $E_d = 0.9$  to 11.8 MeV: see Table 15.27 in (1970AJ04), and (1976AJ04). Observed states are displayed in Table 15.19. Lifetimes have been measured for  $^{15}\text{O}^*(5.24, 6.79, 7.28)$ :  $\tau_m = 3.2 \pm 0.5$  psec (1967BI11),  $< 28$  fsec,  $700 \pm 150$  fsec (1968GI11), respectively: see also Table 15.26 in (1970AJ04). See also (1974LO1B), (1976LO1B; applied) and  $^{16}\text{O}$  in (1982AJ01).

$$22. ^{14}\text{N}(^3\text{He}, d)^{15}\text{O} \qquad Q_m = 1.8035$$

Angular distributions have been obtained at  $E(^3\text{He}) = 11$  and 14 MeV: see (1976AJ04) and Table 15.24.

$$23. ^{14}\text{N}(\alpha, t)^{15}\text{O} \qquad Q_m = -12.5170$$

Angular distributions of the  $t_0$  group have been studied at  $E_\alpha = 56$  MeV: see (1976AJ04).

$$24. ^{14}\text{N}(p, n)^{15}\text{O} \qquad Q_m = -3.5363$$

Table 15.24: Levels of  $^{15}\text{O}$  from  $^{14}\text{N}(\text{d}, \text{n})$  and  $^{14}\text{N}(^3\text{He}, \text{d})$

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

<sup>a</sup> Nominal energies if uncertainty is not indicated.

<sup>b</sup> From  $\gamma$ -ray measurements: see Table 15.26 in (1976AJ04) for references for these and other measurements displayed in this table.

<sup>c</sup> See (1971BO35: (d, n)) also for a review of spectroscopic factors derived from other work.

<sup>d</sup> From both (d, n) and ( $^3\text{He}$ , d) work: see (1976AJ04).

<sup>e</sup> From ( $^3\text{He}$ , d).

Angular distributions have been measured for the  $n_0$  group at  $E_p = 3.95$  to 18.5 MeV [and for the  $n_2$  group at  $E_p = 5.5$  MeV]: see (1970AJ04) for a listing of the older references, and (1978CH09:  $n_0$ ;  $E_p = 11.98, 12.98, 14.58, 15.13, 15.28$  MeV). See also (1980BY1A) and  $^{16}\text{O}$  in (1982AJ01).

$$25. \ ^{15}\text{N}(^3\text{He}, \text{t})^{15}\text{O} \quad Q_m = -2.7725$$

Angular distributions for the  $t_0, t_{1+2}, t_3, t_{4+5}, t_6$  and  $t_7$  groups have been studied for  $E(^3\text{He}) = 16.5$  to 44.6 MeV: see (1976AJ04). See also Table 15.27 in (1976AJ04).

$$26. \ ^{16}\text{O}(\gamma, \text{n})^{15}\text{O} \quad Q_m = -15.6639$$

The spectrum of photoneutrons has been investigated at many energies. Measurements over the giant dipole resonance region show the predominant strength is to the  $J^\pi = \frac{1}{2}^-$  and  $\frac{3}{2}^-$  states  $E_x = 0$  and 6.18 MeV, consistent with the basic validity of the single-particle, single-hole theory

of photoexcitation in  $^{16}\text{O}$ . However, the positive parity states at  $E_x = 5.18, 5.24, 6.86$  MeV are also populated suggesting some more complicated excitations in  $^{16}\text{O}$ : see (1970HO21) and the earlier references in (1970AJ04). See also (1979PH07) and  $^{16}\text{O}$  in (1982AJ01). The angular distributions of the ground state neutrons have been measured from threshold to  $E_\gamma = 28$  MeV [see (1976AJ04)] and at  $E_\gamma = 57.8$  and 80 MeV (1979GO1V). Polarization measurements are reported for  $E_\gamma = 21.6$  to 25.7 MeV (1979NA1R). See also (1977CO1Y, 1977MA2H, 1978EL05, 1978SC11; theor.).

$$\begin{aligned} 27. \text{ (a) } & ^{16}\text{O}(\text{p}, \text{d})^{15}\text{O} & Q_{\text{m}} &= -13.4392 \\ & \text{(b) } & ^{16}\text{O}(\text{p}, \text{pn})^{15}\text{O} & Q_{\text{m}} &= -15.6639 \end{aligned}$$

Reaction (a) goes primarily to  $^{15}\text{O}^*(0, 6.18)$ . Angular distributions have been reported at many energies for  $E_{\text{p}} = 18.5$  to 155.6 MeV: see Table 15.30 in (1970AJ04) and (1975RO27:  $E_{\text{p}} = 65$  MeV;  $d_0, d_3$ ). See (1975RO27) for a review of spectroscopic factors. See also (1978WH1A, 1979BO1A, 1979CA1A, 1979WH1A),  $^{17}\text{F}$  in (1982AJ01), (1976SI1A, 1980WH1A) and (1978HE03; theor.). For reaction (b) see (1976AJ04).

$$28. \ ^{16}\text{O}(\text{d}, \text{t})^{15}\text{O} \quad Q_{\text{m}} = -9.4065$$

Angular distributions have been reported at a number of energies in the range  $E_{\text{d}} = 20$  to 52 MeV [see (1970AJ04, 1976AJ04)] and at  $E_{\text{d}} = 29$  MeV (1978CO13;  $t_0, t_3$ ). For determinations of  $C^2S$  for  $^{15}\text{O}^*(0, 6.2)$ , and for a comparison of the results in the mirror reaction, see reaction 74 in  $^{15}\text{N}$  (1978CO13). See also  $^{18}\text{F}$  in (1978AJ03, 1983AJ01) and (1975FA06; theor.).

$$29. \ ^{16}\text{O}({}^3\text{He}, \alpha)^{15}\text{O} \quad Q_{\text{m}} = 4.9140$$

The  $p_{1/2}$  and  $p_{3/2}$  hole states at  $E_x = 0$  and 6.18 MeV are strongly populated. Information on these and other states are displayed in Table 15.25. Angular distributions have been measured at  $E({}^3\text{He}) = 5.2$  to 36.6 MeV [see (1976AJ04) and Table 15.32 of (1970AJ04)], at  $E({}^3\vec{\text{He}}) = 33.3$  MeV (1980LU03;  $\alpha_0, \alpha_3$ ) and at 217 MeV (1974GE09, 1978VA05;  $\alpha_0, \alpha_3$  and groups to higher, unresolved states). Branching ratios and multipole mixing ratios are displayed in Table 15.19. (1978BE73) report  $\tau_{\text{m}}$  of  $^{15}\text{O}^*(5.24) = 3.25 \pm 0.30$  psec,  $|g| = 0.260 \pm 0.028$ .

$^{15}\text{O}^*(7.28)$  has an excitation energy of  $7274.2 \pm 1.4$  keV (1967HE1A) (which is 23.2 keV below the  $E_{\text{b}}$  of  $^{14}\text{N} + \text{p}$ ) and  $J^\pi = \frac{7}{2}^+$ ; thus it plays no significant role in determining the rate of the  $^{14}\text{N}(\text{p}, \gamma)^{15}\text{O}$  reaction in stars (1967HE1A). See also (1978CH1P) and  $^{16}\text{O}$  in (1982AJ01).

$$30. \ ^{16}\text{O}({}^6\text{Li}, {}^7\text{Li})^{15}\text{O} \quad Q_{\text{m}} = -8.413$$

Table 15.25: States of  $^{15}\text{O}$  from  $^{16}\text{O}(^3\text{He}, \alpha)$

$E_x^a$ (MeV $\pm$ keV)	$l_n$	$S$	$E_x^a$ (MeV $\pm$ keV)	$l_n$	$S$
0	1	0.9	9.67	1	
5.18	0	$\leq 0.10$	$10.286 \pm 10^b$	(2)	
5.24	2	0.04	$10.469 \pm 10^b$		
6.18	1	1	$10.900 \pm 20$		
6.79	2		10.94		
6.86	2		11.03		
$7.2742 \pm 1.4$	(4)		11.15		
7.56	0		11.22		
8.28	2		$11.57^b$		
8.74	0		11.72		
$8.92^b$	2		$11.960 \pm 20$		
8.98	1		$11.995 \pm 20$		
$9.49^b$			$16.8^c$	$c$	
$9.535 \pm 20$			$23.0^c$	$c$	
9.61	1		$(32.0)^c$	$c$	

<sup>a</sup> Nominal values except when uncertainties are shown. See Table 15.28 in (1976AJ04) for actual measured values and references.

<sup>b</sup> Unresolved.

<sup>c</sup> (1974GE09, 1978VA05):  $E(^3\text{He}) = 217$  MeV.

At  $E(^6\text{Li}) = 36$  MeV angular distributions have been measured for the transitions  $^{15}\text{O}_{\text{g.s.}} + ^7\text{Li}_{\text{g.s.},0.48}$  (1973SC26).

$$31. \ ^{16}\text{O}(^{10}\text{B}, ^{11}\text{B})^{15}\text{O} \quad Q_m = -4.209$$

Angular distributions involving  $^{15}\text{O}_{\text{g.s.}}$  have been investigated at  $E(^{10}\text{B}) = 100$  MeV (1975NA15).

$$32. \ ^{16}\text{O}(^{14}\text{N}, ^{15}\text{N})^{15}\text{O} \quad Q_m = -4.8305$$

See reaction 77 in  $^{15}\text{N}$ .

33.  $^{17}\text{O}(\text{p}, \text{t})^{15}\text{O}$

$$Q_{\text{m}} = -11.326$$

At  $E_{\text{p}} = 39.8$  MeV angular distributions of  $t_0$  and  $t_3$  groups have been compared to those of the  $^3\text{He}$  groups to the analog states in  $^{15}\text{N}$  (1971OL04). At  $E_{\text{p}} = 45$  MeV a state, assumed to be the  $J^{\pi} = \frac{5}{2}^{+}$ ,  $T = \frac{3}{2}$  analog of  $^{15}\text{C}^*(0.74)$ , is observed at  $E_{\text{x}} = 12.255 \pm 0.013$  MeV,  $\Gamma_{\text{c.m.}} = 135 \pm 15$  keV. The state decays by proton emission to the  $T = 1, 0^{+}$  state  $^{14}\text{N}^*(2.31)$  (1978BE26; population of some  $T = \frac{1}{2}$  states is also reported).

34.  $^{19}\text{F}(^3\text{He}, ^7\text{Li})^{15}\text{O}$

$$Q_{\text{m}} = -4.320$$

Angular distributions are reported at  $E(^3\text{He}) = 40.7$  MeV involving ( $^{15}\text{O}_{\text{g.s.}} + ^7\text{Li}_{\text{g.s.,0.48}}^*$ ), ( $^{15}\text{O}_{5.19+5.24}^* + ^7\text{Li}_{\text{g.s.,0.48}}^*$ ) and ( $^{15}\text{O}_{6.18}^* + ^7\text{Li}_{\text{g.s.}}$ ) (1971DE37, 1971DE04): see also the analog reaction  $^{19}\text{F}(^3\text{He}, ^7\text{Be})^{15}\text{N}$  [reaction 84 in  $^{15}\text{N}$ ].



**<sup>15</sup>F**  
(Fig. 13)

GENERAL: (See also (1976AJ04).):

*General reviews and calculations:* (1978GU10, 1979BE1H).

*Mass of <sup>15</sup>F:* The atomic mass excess of <sup>15</sup>F is  $16.77 \pm 0.13$  MeV, based on the mean of the reported  $Q$ -values of the  $^{20}\text{Ne}(^3\text{He}, ^8\text{Li})^{15}\text{F}$  reaction. <sup>15</sup>F is unstable with respect to breakup into  $^{14}\text{O} + \text{p}$  by 1.47 MeV.

$$\begin{aligned}
 1. \ ^{20}\text{Ne}(^3\text{He}, ^8\text{Li})^{15}\text{F} \quad & Q_m = -29.83 \\
 & Q_0 = -29.73 \pm 0.18 \text{ MeV (1978KE06);} \\
 & Q_0 = -29.96 \pm 0.2 \text{ MeV (1978BE26).}
 \end{aligned}$$

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

Table 15.26: Energy levels of <sup>15</sup>F

$E_x$ in <sup>15</sup> F (MeV)	$J^\pi; T$	$\Gamma_{\text{c.m.}}$ (MeV)	Decay	Reaction
g.s.	$(\frac{1}{2}^+); \frac{3}{2}$	$1.0 \pm 0.2$	p	1
$1.3 \pm 0.1$	$(\frac{5}{2}^+); \frac{3}{2}$	$0.24 \pm 0.03$	p	1

## 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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