Energy Levels of Light Nuclei
$A = 18$

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Abstract: An evaluation of $A = 18$–20 was published in *Nuclear Physics A*190 (1972), p. 1. This version of $A = 18$ differs from the published version in that we have corrected some errors discovered after the article went to press. Figures and introductory tables have been omitted from this manuscript. Reference key numbers have been changed to the NNDC/TUNL format.

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^{18}C

(Not illustrated)

^{18}C is particle stable. Therefore its atomic mass excess, $M - A$, must be < 29.84 MeV [^{16}C + 2n] (1970WA1G). ^{18}C has been observed in the bombardment of ^{232}Th by 122 MeV ^{18}O ions (1969AR13, 1970AR1D) and in the 3 GeV proton bombardment of Au (1970RA1A). See also (1960ZE03, 1968PO04, 1971BU1E).

^{18}N

(Fig. 4)

GENERAL: See (1960ZE03, 1961BA1C, 1962GO31, 1969AR13, 1971AR02).

Mass of ^{18}*N:* From the Q-value of the ^{18}O(t, ^{3}He)^{18}N reaction, $M - A$ for ^{18}N is 13.274 ± 0.030 MeV (1969ST07).

1. ^{18}N(β^-)^{18}O $\qquad Q_m = 14.06$

The half-life of ^{18}N is 0.63 ± 0.03 sec (1964CH19). $\log ft = 4.88$[†] . E_β(max) $= 9.4 \pm 0.4$ MeV. The decay is to ^{18}O*(4.45), whose subsequent γ-decay has been studied using $\beta - \gamma$ coincidences: see ^{18}O. The allowed nature of the decay to the 1^- state at 4.45 MeV leads to $J^\pi = 0^-$, 1^- or 2^- for the ^{18}N ground state (1964CH19).

2. ^{18}O(n, p)^{18}N $\qquad Q_m = -13.27$

This reaction has been studied at $E_n = 19$ MeV: see above (1964CH19).

3. ^{18}O(t, ^{3}He)^{18}N $\qquad Q_m = -14.04$

$Q_0 = -14.038 \pm 0.030$ (1969ST07).

At $E_t = 22$ MeV, ^{3}He groups corresponding to the ground state of ^{18}N have been observed by (1969ST07).

[†] B.A. Zimmerman, private communication.

^{18}O

(Figs. 1 and 4)

GENERAL: (See also (1959AJ76).)

Shell model: (1957WI1E, 1960TA1C, 1962HO1C, 1962TA1B, 1962TA1D, 1963HA05, 1963PA03, 1963SA07, 1964CO24, 1964IN03, 1964MC1A, 1964PA1D, 1964WA1F, 1965BA1J, 1965BE1T, 1965DE1H, 1965EL06, 1965EN02, 1965FE1B, 1965FE02, 1965NA1A, 1965ZA1B, 1966AR10, 1966BA2E, 1966BA2C, 1966BO25, 1966BR1R, 1966HU09, 1966IN01, 1966KU05, 1966LA1E, 1966LE11, 1966RI1F, 1966RO01, 1967BA04, 1967BR1G, 1967EN01, 1967FE01, 1967FL01, 1967GR09, 1967GR1D, 1967HO11, 1967IN03, 1967KU09, 1967KU13, 1967LA1H, 1967LY02, 1967MO1J, 1967PA05, 1967PA1K, 1967PI1B, 1967RO1F, 1967ST02, 1967VI1B, 1967WO1C, 1968AR02, 1968BE1T, 1968BH1B, 1968CL03, 1968CO1N, 1968DE1M, 1968DE13, 1968DW1A, 1968EL1C, 1968FR03, 1968GA06, 1968GA16, 1968GU1E, 1968GU1C, 1968GU1G, 1968HA17, 1968HA1P, 1968HE1H, 1968KA1E, 1968KA1C, 1968KO1L, 1968KU1E, 1968NA09, 1968NA19, 1969BA2F, 1969BE1T, 1969BU15, 1969EL1B, 1969FE1A, 1969GU1E, 1969HO32, 1969IG1A, 1969KA07, 1969KA09, 1969KU1G, 1969MA1T, 1969ME06, 1969SA1F, 1969ST1G, 1969UL03, 1969VO1E, 1969ZU03, 1970BA2E, 1970EL1G, 1970EL08, 1970GA1J, 1970HA49, 1970KA32, 1970TA1J, 1970TR08, 1970TR07, 1971AR1R, 1971EL07, 1971HO12, 1971JA06, 1971LO23, 1971MO05, 1971PR16, 1971QU01, 1971UL04, 1971VI08, 1971WI01, 1972GA02).

Cluster, collective and deformed models: (1959YU1A, 1963MA1D, 1964BR1H, 1965FE1B, 1965FE02, 1966BE29, 1966BR1Q, 1966HA1K, 1966RI1F, 1966RO01, 1967BH07, 1967BR1G, 1967FE01, 1967GR1D, 1967PA1K, 1967RO1F, 1968EL1C, 1969BA2E, 1969DR1B, 1969FE1A, 1969ZA1D, 1970BA2B, 1970TR07, 1971AR1R, 1971UL04).

Astrophysical questions: (1970BA1M).

Electromagnetic transitions: (1963BU11, 1964BR1H, 1965EL06, 1965EN02, 1965FE02, 1965ST22, 1966BO25, 1967GR1D, 1967IN03, 1967LA1H, 1968EL1C, 1968HA17, 1968LA1G, 1968LE02, 1968SH06, 1969BE1T, 1969BE22, 1970EL08, 1970HA49, 1970TR07).

Special levels: (1960EV1A, 1962DA04, 1962TA1B, 1964BR1H, 1964EN1A, 1964MC1A, 1965BE1T, 1965LE1C, 1966BO25, 1966BR1R, 1966HU09, 1966MI1G, 1967BH07, 1967EN01, 1967FL01, 1967GR09, 1967PA1K, 1967VI1B, 1968AR02, 1968BH1B, 1968CO1N, 1968FR03, 1968GA06, 1968GA16, 1968HA1P, 1968KA1C, 1968LE02, 1968NA09, 1969BA1Z, 1969BE1T, 1969FE1A, 1969KA09, 1969KA29, 1969MA1T, 1969ME06, 1969OS01, 1970EL1G, 1970EL08, 1970GA1J, 1970HO17, 1971AR1R, 1971EL07, 1971JA06, 1971PR16, 1971QU01, 1971UL01, 1971WI01, 1972GA02).

Other theoretical topics: (1961BA1D, 1962DA04, 1963BU11, 1963VL1A, 1964EN1A, 1964HE1C, 1964IN03, 1964TR1A, 1964WA1E, 1965DE1H, 1965ER04, 1965GO1F, 1965KA1B, 1965KA1C, 1965NA1A, 1965NI1A, 1965ZA1B, 1966BR1R, 1966BR1P, 1966DA1E, 1966DO1C, 1966GI1A, 1966KU05, 1966LE11, 1966OL1C, 1966SU1D, 1966WA1H, 1966YO1B, 1967FE01, 1967FL01, 1967GR09, 1967KU1G, 1967KU13, 1967MO1J, 1967ST02, 1967VA31, 1967WO1C, 1968BA2H, 1968BE1T, 1968BL1G, 1968CO1N, 1968DE1M, 1968DW1A, 1968EL1C, 1968GU1E, 1968GU1C,

1968GU1F, 1968GU1G, 1968JO1E, 1968KA1C, 1968KO1K, 1968LE02, 1968MU1B, 1968NE1C, 1968SU1C, 1968SU1D, 1968VA24, 1969DE06, 1969JA1P, 1969JO1L, 1969KA29, 1969MU09, 1969OS01, 1969RA28, 1969SO08, 1970AG1C, 1970BA1Z, 1970DI1G, 1970EL08, 1970GA1J, 1970PR1D, 1970SU1B, 1971BA14, 1971BO21, 1971DZ06, 1971EL07, 1971LA1D, 1971LE1H, 1971LO23, 1971PR16, 1971SC01, 1971UL01, 1971VI08, 1972GA02).

Table 18.1: Energy levels of ^{18}O [a]

E_x (MeV $\pm$ keV)	$J^\pi; T$	τ_m (psec) or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
0	$0^+; 1$	stable		2, 3, 4, 7, 10, 15, 16, 17, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 33, 34, 36
1.9821 ± 0.8	2^+	$\tau_m = 3.8 \pm 0.6$	γ	2, 3, 4, 7, 10, 15, 17, 19, 20, 21, 22, 25, 32, 34, 35
3.5529 ± 2.1	4^+	> 3	γ	3, 4, 7, 10, 15, 22, 25, 34, 35
3.6317 ± 2.0	0^+	3 ± 1	γ	2, 3, 4, 7, 10, 15, 17, 21, 22, 25, 34, 35
3.9191 ± 2.0	2^+	0.18 ± 0.06	γ	2, 3, 4, 7, 10, 15, 21, 22, 25, 34, 35
4.4488 ± 3.5	1^-	$0.11^{+0.08}_{-0.06}$	γ	2, 7, 10, 15, 17, 19, 21, 22, 25, 34, 35
5.090 ± 5	3^-		γ	7, 10, 15, 21, 22, 25, 35
5.250 ± 6	2^+		γ	4, 7, 10, 15, 21, 25, 34, 35
5.329 ± 7	0^+		γ	10, 15, 21, 22, 25, 34, 35
5.372 ± 7	3^+		γ	10, 15, 21, 22, 25, 35
5.517 ± 9	2^-		γ	10, 15, 19, 21, 25, 35
6.191 ± 9	1^-		γ	10, 15, 25, 34, 35
6.341 ± 10			(γ)	10, 15, 25, 34, 35
6.391 ± 10	3^-		γ	10, 25, 35
6.86 ± 20	(0^-)		γ	25, 35
7.114 ± 2	4^+		γ, α	4, 7, 15, 25, 34, 35

Table 18.1: Energy levels of ^{18}O [a] (continued)

E_x (MeV ± keV)	$J^\pi; T$	τ_m (psec) or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
7.620 ± 2	1^-	$\Gamma < 2.5$ keV	γ, α	4, 25, 34, 35
7.75 ± 20			γ	35
7.848 ± 14				7, 15, 25, 34, 35
7.961 ± 14	$(3^+, 4^-)$		γ	15, 25, 35
8.039 ± 2	1^-	< 2.5	γ, α	4, 25, 35
8.122 ± 10	5^-		γ, α	4, 7, 25, 35
8.213 ± 4	2^+	1.0 ± 0.8	γ, n, α	4, 5, 6, 25, 35
8.283 ± 3	3^-	8 ± 1	n, α	5, 6, 7, 25, 35
8.403 ± 7		8 ± 6	n, α	5, 35
8.480 ± 20				25, 35
8.640 ± 20				25, 35
8.817 ± 12		70 ± 12	n, α	5, 6, 25
8.955 ± 4		43 ± 3	n, α	5, 6, 25
9.03			n, α	6, 25
9.10			n, α	6, 25
9.361 ± 15		27 ± 15	n, α	5, 6, 7, 25
9.39 ± 40		≈ 120	n, α	5, 6, 7, 25
9.47 ± 40		≈ 65	n, α	5, 6
9.675 ± 10		60 ± 30	n, α	5, 6, 25, 34
9.72 ± 30			(n, α)	5, 25
9.88 ± 40		≈ 150	n, α	5, 6, 25, 34
10.119 ± 10	3^-	16 ± 4	n, α	5, 6, 25
10.29 ± 20	4^+		n, α	5, 6, 7, 25
10.38 ± 20	3^-		n, α	5, 6, 25
10.58 ± 20			n, α	5, 6
10.82 ± 20			n, α	5, 6
10.91 ± 20			n, α	5, 6, 7
10.99 ± 20			n, α	5, 6
11.14 ± 20	$(0, 1, 2)^-$		n, α	5, 6, 7, 34
11.39 ± 20	(2^+)		n, α	5, 6

Table 18.1: Energy levels of ^{18}O [a] (continued)

E_x (MeV ± keV)	$J^\pi; T$	τ_m (psec) or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
11.41 ± 20	(4^+)		n, α	5, 6
11.62 ± 20	5^-		n, α	5, 6, 7, 25
11.69 ± 20	6^+		n, α	5, 6, 7, 25, 34
11.82 ± 20	(3^-)		n, α	5, 6, 34
12.04 ± 20	(2^+)		n, α	5, 6
12.25 ± 20	1^-		n, α	5, 6, 34
12.33 ± 20	5^-		n, α	5, 6, 7
12.49 ± 20	4^+		n, α	5, 6
12.53 ± 20	6^+		n, α	5, 6, 7
14.05 ± 140				19, 34
14.56 ± 100				34
15.1 ± 200			γ, n	19
15.95 ± 200				19
18.4 ± 200				19
20.2 ± 200				19
21.9 ± 200				19
23.7 ± 200				19
25.2 ± 200				19
26.9 ± 200				19

[a] See also Tables 18.2 and 18.3.

Reactions involving pions and muons: (1965PA1F, 1967BA78, 1968BA2G, 1968TA1C, 1968WI1B, 1969CH1C, 1969KO1F, 1969WU1A, 1970BA1E, 1970CH25, 1970CH1C, 1970HA46).

Complex reactions involving ^{18}O: (1968GA03, 1969AR13, 1971AR02).

Ground state: (1971MO05).

1. (a) ^{11}B(^{7}Li, p)^{17}N $\quad Q_m = 8.417 \quad E_b = 24.359$
   (b) ^{11}B(^{7}Li, d)^{16}N $\quad Q_m = 4.758$
   (c) ^{11}B(^{7}Li, t)^{15}N $\quad Q_m = 8.525$
   (d) ^{11}B(^{7}Li, α)^{14}C $\quad Q_m = 18.131$

Cross sections to various of the final states have been measured at $E(^7\text{Li}) = 5.00$ MeV (1966MC05).

2. ^{12}C(^{7}Li, p)^{18}O $\quad Q_{\text{m}} = 8.402$

Radiative decay and lifetime measurements are reported by (1964ES02): see Tables 18.2 and 18.3. Angular distributions have been measured at $E(^7\text{Li}) = 3.24$ to 3.64 MeV (1967MO23; p$_0$, p$_1$). See also (1960SH05, 1970CA1N).

3. ^{13}C(^{7}Li, d)^{18}O $\quad Q_{\text{m}} = 5.681$

Gamma-ray energies of 1982.3 ± 0.8 [$1.98 \rightarrow 0$], 1571.9 ± 2.5 [$3.55 \rightarrow 1.98$], 1649.8 ± 2.2 [$3.63 \rightarrow 1.98$] and 1938.6 ± 2.1 keV [$3.92 \rightarrow 1.98$], due to the transitions shown in brackets, have been measured by (1969TH01).

4. ^{14}C(α, γ)^{18}O $\quad Q_{\text{m}} = 6.228$

Four resonances in the yield of capture γ-rays are observed for $E_\alpha = 0.50$ to 3.00 MeV at $E_\alpha = 1.14$, 1.79, 2.33 and 2.44 MeV: see Table 18.4. Gamma-ray angular distribution and correlation measurements lead to $J^\pi = 4^+$, 1^-, 1^- and 5^- for ^{18}O*(7.11, 7.62, 8.04, 8.12), as well as to J^π assignments for lower states involved in the cascade decay: see Table 18.2 (1958GO1A, 1958PH37, 1966LE1B, 1967LE02). (1970DU1D) report resonance at $E_{\text{p}} = 2.56$ MeV ($E_{\text{x}} = 8.22$) with $J^\pi = 2^+$.

5. ^{14}C(α, n)^{17}O $\quad Q_{\text{m}} = -1.819 \quad E_{\text{b}} = 6.228$

The relative neutron yield has been measured for $E_\alpha = 2.3$ to 8.5 MeV: the parameters of observed resonances are displayed in Table 18.4 (1956SA06, 1966BA03, 1970MO13).

6. ^{14}C(α, α)^{14}C $\quad E_{\text{b}} = 6.228$

Observed anomalies in the scattering for $E_\alpha = 2$ to 8.2 MeV shown in Table 18.4 (1958WE29, 1970MO13). The yield of elastic scattering has been measured up to $E_\alpha = 16.5$ MeV (1970MO13).

Table 18.2: Radiative decays in ^{18}O

E_i (MeV)	J^{π}_{i}	E_f (MeV)	Branch [a] (%)	$\Gamma_\alpha\Gamma_\gamma/\Gamma$ (eV)	Refs.
1.98	2^+	0	100	$B(\text{E2}) = (4.9 \pm 1.1)$ [d]	(1967DEZW)
				$= (4.6 \pm 1.4)$ [d]	(1968AN20)
3.55	4^+	0	< 4		(1959GO74)
		1.98	> 96		(1959GO74, 1961LI03)
			100		(1967LE02, 1967CH1D, 1971BE45)
3.63	0^+	0		$\Gamma_\pi = 1.9 \times 10^{-3}\,\Gamma_\gamma$	(1963GO32)
		1.98	> 85		(1961LI03)
			100		(1967LE02, 1967CH1D, 1971BE45)
3.92 [b]	2^+	0	6.5		(1964ES02)
			15		(1967MO09)
			15 ± 5		(1964GO11)
			15 ± 2		(1965OL02)
			12 ± 5		(1971BE45)
		1.98	93.5		(1964ES02)
			85		(1967MO09)
			> 85		(1961LI03)
			85 ± 5		(1964GO11)
			85 ± 2		(1965OL02)
			88 ± 5		(1971BE45)
4.45 [c]	1^-	0	< 2		(1964ES02, 1964GO11)
			< 4		(1965OL02)
			< 5		(1971BE45)
			< 1		(1967LE02, 1967CH1D)
		1.98	26		(1964ES02)
			28		(1967CH1D)
			37 ± 5		(1964GO11)
			36 ± 5		(1965OL02)
			32 ± 5		(1971BE45)
		3.63	74		(1964ES02)
			72		(1967CH1D)
			63 ± 5		(1964GO11)
			64 ± 5		(1965OL02)

Table 18.2: Radiative decays in ^{18}O (continued)

E_i (MeV)	J_i^π	E_f (MeV)	Branch [a] (%)	$\Gamma_\alpha\Gamma_\gamma/\Gamma$ (eV)	Refs.
			68 ± 5		(1971BE45)
5.09	3^-	0	< 10		(1965OL02)
			< 5		(1971BE45)
		1.98	> 90		(1965OL02)
			78		(1967CH1D)
			81		(1966LO12)
			75 ± 3		(1971BE45)
		3.55	6		(1967CH1D)
			5		(1966LO12)
			9 ± 3		(1971BE45)
		3.92	14		(1966LO12)
			16 ± 3		(1971BE45)
5.25 [b]	2^+	0	32		(1967CH1D)
			40		(1966LO12)
			40 ± 8		(1965OL02)
			41 ± 6		(1967MO09)
			32 ± 3		(1971BE45)
		1.98	68		(1967CH1D)
			60		(1966LO12)
			60 ± 8		(1965OL02)
			59 ± 6		(1967MO09)
			68 ± 3		(1971BE45)
		3.55	< 4		(1967MO09)
		3.63	< 3		(1967MO09)
		3.92	< 5		(1967MO09)
		4.45	< 4		(1967MO09)
5.33 [b]	0^+	1.98	63		(1966LO12)
			61 ± 2		(1971BE45)
		3.92	10		(1966LO12)
		4.45	27		(1966LO12)
			39 ± 2		(1971BE45)
5.37	3^+	0	< 2		(1967MO09)

Table 18.2: Radiative decays in ^{18}O (continued)

E_i (MeV)	J^π_i	E_f (MeV)	Branch [a] (%)	$\Gamma_\alpha \Gamma_\gamma / \Gamma$ (eV)	Refs.
		1.98	85		(1966LO12)
			88 ± 3		(1967MO09)
		3.55	< 3		(1967MO09)
		3.92	15		(1966LO12)
			12 ± 3		(1967MO09)
		4.45	< 2		(1967MO09)
5.52	(2^-)	1.98	48		(1967CH1D)
			65		(1966LO12)
		3.92	23		(1967CH1D)
			10		(1966LO12)
		4.45	29		(1967CH1D)
			25		(1966LO12)
6.19	1^-	0	> 90		(1967LE02)
			88		(1967CH1D)
			100		(1971BE45)
		1.98	< 5		(1967LE02)
			≤ 10		(1967CH1D)
		4.45	< 5		(1967LE02)
			12		(1967CH1D)
$6.34 + 6.39$					(1967CH1D)
6.39	3^-	1.98	90 ± 5		(1971BE45)
		3.92	10 ± 5		(1971BE45)
6.86	(0^-)	4.45	100		(1967CH1D)
7.11	4^+	1.98	44	1.2×10^{-2}	(1959GO74, 1961LI03)
			29		(1967CH1D)
			26 ± 2		(1967LE02)
		3.55	56	1.5×10^{-2}	(1959GO74, 1961LI03)
			71		(1967CH1D)
			70 ± 3	4.2×10^{-2} [e]	(1967LE02)
		3.92	4 ± 1		(1967LE02)
		4.45	≤ 15		(1967CH1D)
		5.09	≤ 15		(1967CH1D)

Table 18.2: Radiative decays in ^{18}O (continued)

E_i (MeV)	J_i^π	E_f (MeV)	Branch [a] (%)	$\Gamma_\alpha\Gamma_\gamma/\Gamma$ (eV)	Refs.
7.62	1^-	0	35		(1958PH37)
			33	8×10^{-2}	(1959GO74, 1961LI03)
			24 ± 2		(1967LE02)
		1.98	65		(1958PH37)
			67	0.16	(1959GO74, 1961LI03)
			62 ± 3	0.34 [e]	(1967LE02)
		3.55	<15		(1958PH37)
		3.92	<15		(1958PH37)
		4.45	8 ± 1		(1967LE02)
		5.33	6 ± 1		(1967LE02)
		6.19	<2		(1967LE02)
7.75		1.98	50		(1967CH1D)
		4.45	11		(1967CH1D)
		5.09	39		(1967CH1D)
		5.25	≤10		(1967CH1D)
		5.37	≤10		(1967CH1D)
		6.34	≤10		(1967CH1D)
7.96	$(3^+,4^-)$	3.55	67		(1967CH1D)
		5.09	12		(1967CH1D)
		5.37	21		(1967CH1D)
		6.39	<15		(1967CH1D)
8.04	1^-	0	30		(1958PH37)
			16 ± 1		(1967LE02)
		1.98	70		(1958PH37)
			68 ± 3	0.89 [e]	(1967LE02)
		3.55	<15		(1958PH37)
		3.63	11 ± 1		(1967LE02)
		3.92	<15		(1958PH37)
		5.25	5 ± 1		(1967LE02)
8.12	5^-	3.55	>95	0.22 [e]	(1967LE02)
8.21	2^+	0	100		(1970DU1D)

[a] The last value listed for each transition is believed to be the most reliable.

[b] See also (1967LE02).

[c] See also (1964CH19, 1967LE02).

[d] $e^2 \times 10^{-51}$ cm^4.

[e] $\Gamma_\gamma \Gamma_\alpha / \Gamma$ for *all* transitions from this state.

7. ^{14}C(^{7}Li, t)^{18}O $\qquad Q_m = 3.761$

At $E(^7\text{Li}) = 20.4$ MeV, triton groups are observed corresponding to a number of states of ^{18}O with $E_x < 12.6$ MeV. Angular distributions were obtained for some of these, including ^{18}O*(0, 1.98, 7.11, 11.69) with $J^\pi = 0^+, 2^+, 4^+, 6^+$. The latter two are the most strongly populated in this reaction: they appear to be part of the ground state rotational band (1970MO17).

8. ^{15}N(t, p)^{17}N $\qquad Q_m = -0.108 \qquad E_b = 15.834$

See (1956SH96).

9. ^{15}N(α, p)^{18}O $\qquad Q_m = -3.980$

Not reported.

10. ^{16}O(t, p)^{18}O $\qquad Q_m = 3.707$

Proton groups corresponding to many states of ^{18}O have been reported by (1960JA13, 1960JA17, 1962HI06): see Table 18.5. The L assignments displayed there have been derived from PWBA analysis of angular distributions, principally those obtained by (1964MI05). For a complete summary of angular distribution measurements, see Table 18.6.

Measurements of the angular correlation of cascade γ-rays require $J = 0$ and 2 for ^{18}O*(3.63, 3.92). Lifetime measurements are reported by (1961LI03, 1963LI07): see Table 18.3.

See also (1964GA1B), (1967CH1L, 1967OG1A) and (1963RO1C, 1964TR1A, 1965GL07, 1965MA1L, 1965SH1E, 1966GL1C, 1966GL1D, 1966SH1F, 1966ST1F, 1967DO1B, 1967MA1E, 1967VE1B, 1968KO04, 1968KO1K, 1969LI1G, 1969SO08; theor.).

11. ^{17}O(n, γ)^{18}O $\qquad Q_m = 8.047$

Table 18.3: Lifetime measurements of some ^{18}O states

^{18}O* (MeV)	τ_m (psec) [a]	Reaction	Refs.
1.98 [b]	> 1	^{17}O(d, p)	(1969NI09)
	$6.1^{+5.0}_{-2.0}$	^{12}C(^{7}Li, p)	(1964ES02)
	3.3 ± 1.5	^{18}O(e, e′)	(1961LA09)
	3.7 ± 0.7	^{16}O(t, p)	(1963LI07)
	$4.2^{+1.5}_{-1.0}$	^{16}O(t, p)	(1971HI06)
3.55	> 3	^{16}O(t, p)	(1963LI07)
3.63	> 1	^{16}O(t, p)	(1961LI03)
	≥ 2.6	^{12}C(^{7}Li, p)	(1964ES02)
	3 ± 1	^{16}O(t, p)	(1963LI07)
3.92	$0.35^{+0.3}_{-0.2}$	^{12}C(^{7}Li, p)	(1964ES02)
	0.18 ± 0.06	^{16}O(t, p)	(1963LI07)
4.45	< 0.1	^{16}O(t, p)	(1963LI07)
	$0.11^{+0.08}_{-0.06}$	^{12}C(^{7}Li, p)	(1964ES02)

[a] The last value quoted for each state is believed to be the most reliable.

[b] See also (1968AN20).

See (1968FOZY, 1970CL1C).

12. ^{17}O(n, n)^{17}O $\qquad E_b = 8.047$

The coherent scattering length (thermal, bound) is 5.79 fm (1969BA1P). See also (1970TA1E; theor.).

13. ^{17}O(n, p)^{17}N $\qquad Q_m = -7.896 \qquad E_b = 8.047$

At $E_n = 14.1$ MeV, the cross section is 21.5 ± 1.7 mb (1970ME31). See also (1958RO1A, 1964AM02).

14. ^{17}O(n, α)^{14}C $\qquad Q_m = 1.819 \qquad E_b = 8.047$

The thermal cross section is 235 ± 5 mb (1961HA43). See also (1964ST25), (1964GA1A; theor.) and (1968FOZY) for a discussion of astrophysical implications.

Table 18.4: Resonances in $^{14}C(\alpha, \gamma)^{18}O$, $^{14}C(\alpha, n)^{17}O$ and $^{14}C(\alpha, \alpha)^{14}C$

E_α (MeV ± keV)	Γ_{lab} (keV)	Particles out [a]	$^{18}O^*$ (MeV)	J^π	Refs.
1.140 ± 2		γ	7.114	4^+	(1959GO74, 1966LE1B, 1967LE02)
1.790 ± 2	< 3	γ	7.620	1^-	(1958PH37, 1959GO74, 1966LE1B, 1967LE02)
2.330 ± 2	< 3	γ, α_0	8.039	1^-	(1958PH37, 1958WE29, 1966LE1B, 1967LE02)
2.440 ± 12		γ	8.125	5^-	(1966LE1B, 1967LE02)
2.554 ± 4	1.3 ± 1	γ, n, α_0	8.214	2^+	(1956SA06, 1958WE29, 1966BA03)
2.643 ± 3	10 ± 1	n, α_0	8.283	3^-	(1956SA06, 1958WE29, 1966BA03)
2.800 ± 7	10 ± 7	n	8.405		(1956SA06, 1966BA03)
3.330 ± 12	90 ± 15	n, α_0	8.817		(1956SA06, 1958WE29, 1966BA03)
3.508 ± 4	55 ± 3	n, α_0	8.955 [g]		(1956SA06, 1958WE29, 1966BA03)
4.030 ± 15	35 ± 20	n, (α_0)	9.361		(1966BA03, 1970MO13)
4.07 ± 40	≈ 150	n, (α_0)	9.39		(1966BA03, 1970MO13)
4.17 ± 40	≈ 70	n, (α_0)	9.47		(1966BA03, 1970MO13)
4.434 ± 10	80 ± 40	n, (α_0)	9.675		(1966BA03, 1970MO13)
4.70 ± 40	≈ 200	n, (α_0)	9.88		(1966BA03, 1970MO13)
5.004 ± 10	21 ± 5	n, α_0	10.119	3^-	(1966BA03, 1970MO13)
5.23 [f]	[b]	n, α_0	10.29	4^+	(1970MO13)
5.34	[b]	n, α_0	10.38	3^-	(1970MO13)
5.60	[c]	n, α_0	10.58		(1970MO13)
5.90	[d]	n, α_0	10.82		(1970MO13)
6.02	[d]	n, α_0	10.91		(1970MO13)
6.13	[d]	n, α_0	10.99		(1970MO13)
6.30	[c]	n, α_0	11.13		(1970MO13)
6.64	[b]	n, α_0	11.39	(2^+)	(1970MO13)
6.67	[b]	n, α_0	11.41	(4^+)	(1970MO13)
6.93	[b]	n, α_0	11.62	5^-	(1970MO13)
7.03	[b]	n, α_0	11.69	6^+	(1970MO13)
7.19	[d]	n, α_0	11.82	(3^-)	(1970MO13)
7.47	[d]	n, α_0	12.04	(2^+)	(1970MO13)
7.75	[e]	n, α_0	12.25	$(0^+, 1^-)$	(1970MO13)
7.85	[b]	n, α_0	12.33	5^-	(1970MO13)
8.06	[b]	n, α_0	12.49	4^+	(1970MO13)
8.10	[b]	n, α_0	12.53	6^+	(1970MO13)

[a] For the first four states, see also Table 18.2.
[b] Γ_α, large; Γ_n, large.
[c] Γ_α, small; Γ_n, small.
[d] Γ_α, small; Γ_n, large.
[e] Γ_α, large; Γ_n, small.
[f] $\pm 10 - 20$ keV for this and all higher resonances (G.E. Mitchell, private communication).
[g] Two states with $E_x = 9.0$ to 9.2 MeV and $J^\pi = (2^+, 3^-)$ or $(4^+, 3^-)$ are reported by (1958WE29).

15. ^{17}O(d, p)^{18}O — $Q_m = 5.822$
$Q_0 = 5.820 \pm 0.010$ (1965MO16).

Proton groups have been observed to most of the ^{18}O states with $E_x < 8$ MeV (1963YA03, 1965MO16, 1966WI07): see Table 18.7. See also (1959AJ76) and (1964HE11, 1965WI1B). Angular distributions of the protons to the relatively strongly populated states have been measured at $E_d = 5.55$ to 14.95 MeV and analyzed by PWBA (1957BI80, 1964MO25, 1965MO16, 1966WI07). Proton-γ coincidence measurements by (1967MO09) are displayed in Table 18.2 and a lifetime measurement for ^{18}O*(1.98) by (1969NI09) is shown in Table 18.3.

See also (1963EL04, 1964BA1G, 1966AR10, 1968SU1C; theor.).

16. ^{17}O(^{17}O, ^{16}O)^{18}O — $Q_m = 3.904$

See (1967DA1E).

17. ^{18}N(β^-)^{18}O — $Q_m = 14.06$

The decay is to ^{18}O*(4.45): γ-rays with $E_\gamma = 0.82 \pm 0.02$, 1.65 ± 0.02, 1.98 ± 0.02 and 2.47 ± 0.03 MeV with intensities 0.60 ± 0.03, 0.63 ± 0.04, 1.00 ± 0.04 and 0.43 ± 0.03 have been observed. These are due to the decay of ^{18}O*(4.45) to ^{18}O*(3.63, 1.98) and the subsequent decay of these two states (1964CH19).

18. (a) ^{18}O(γ, n)^{17}O — $Q_m = -8.047$
(b) ^{18}O(γ, p)^{17}N — $Q_m = -15.943$
(c) ^{18}O(γ, α)^{14}C — $Q_m = -6.227$

For reaction (a) see (1963FU06, 1964MU12). For reaction (b) see (1955AJ61, 1964KO09, 1969HO16). See also (1965DO1E). For reaction (c), see (1964GR08).

Table 18.5: States in ^{18}O from ^{16}O(t, p)^{18}O

E_x (MeV ± keV)			L [b]	J^π
(1960JA17)	(1960JA13)	(1962HI06)		
0	0	0	0	0^+
1.979 ± 5	[a]	1.980 ± 5	2	2^+
3.552 ± 5	3.560 ± 15	3.549 ± 5	3 or 4	3^- or 4^+
3.634 ± 5	3.639 ± 15	3.627 ± 5	0	0^+
3.915 ± 5	3.925 ± 15	3.915 ± 5	2	2^+
4.448 ± 5	4.457 ± 15	4.449 ± 5	(3)	[c]
	5.084 ± 18	5.090 ± 5	3	3^-
		5.247 ± 7	2	2^+
		5.329 ± 7	0	0^+
		5.368 ± 10	(2)	(2^+) [d]
		5.521 ± 10		
		6.189 ± 10		
		6.341 ± 10		
		6.391 ± 10		

[a] Observed but not measured.

[b] From PWBA analysis of angular distributions: see (1964MI05). See also (1960JA17).

[c] $J^\pi = 1^-$. See, e.g. discussion in (1964MI05).

[d] See, however, reaction 15.

19. ^{18}O(e, e)^{18}O

The ^{18}O charge radius, $r_{\rm rms} = 2.727 \pm 0.020$ fm (using a distorted wave approximation), 2.766 ± 0.020 fm (using a Born approximation) (1970SI02). See also (1967DA1D, 1970SI1M).

At $E_e = 69$ MeV, the $180°$ scattering spectrum shows, in addition to the elastic peak, some weak structure corresponding to $E_x = 2.0$, 4.45 and 5.6 MeV. Somewhat stronger inelastic peaks are found corresponding to $E_x = 10.9$, 12.6, 14.0 and 15.1 MeV. In addition six prominent peaks, each of about the same strength and assumed to arise from giant dipole excitations, are observed at $E_x = 16.6$, 18.4, 20.2, 21.9, 23.7, 25.2 and 26.9 MeV [all E_x values, ± 0.2 MeV] (1965VA04). See also (1961LA09, 1970CA1P).

See also (1962BA1D) and (1963BI05, 1963WI1B, 1966GR1H, 1967GR1B; theor.).

20. ^{18}O(n, n)^{18}O

Table 18.6: ^{16}O(t, p)^{18}O angular distribution studies

E_t (MeV)	Distribution of proton groups	Refs.
$0.67 - 1.40$	p	(1963KU07)
$0.9 - 1.7$	p_0, p_1	(1967KO1G)
$1.15 - 1.95$	p_0, p_1	(1959JO32)
5	p_1	(1963RE06)
5.5	$p_0 \rightarrow p_5$	(1960JA17)
5.5	p_0	(1960JA11)
5.55	$p_0 \rightarrow p_5$	(1965MO19)
10.0	$p_0 \rightarrow p_9$	(1964MI05)
10.15	p_0, p_1	(1962PU01)

Angular distribution measurements are listed in Table 18.8 (1964EX1A, 1969ME15).

21. ^{18}O(p, p)^{18}O

A proton group is observed to the first excited state: $E_x = 1.981 \pm 0.004$ MeV (1957YO04). Angular distribution measurements reported by (1961CA02, 1965PR1D, 1971LE1R, 1971RE20) are displayed in Table 18.8. The transition from ^{18}O*(3.63) to the ground state has been determined to be EO: $J^\pi = 0^+$ for the 3.63 MeV state (1963GO32, 1965GO11, 1967CO30). Proton-γ angular correlation measurements establish $J = 2$ and 1 for ^{18}O*(3.92, 4.45) (1965OL02), and $J = 3$, 2, 0, 3 and (2) for ^{18}O*(5.09, 5.25, 5.33, 5.37, 5.52), respectively (1966LO12): see Table 18.2 for branching ratios obtained by (1964GO11, 1965OL02, 1966LO12). Angular distributions to ^{18}O*(0, 1.98, 7.11) [$J^\pi = 0^+$, 2^+, 4^+, respectively] using polarized protons with $E_p = 22.5$ and 24.5 MeV have been analyzed with the rotational model: $\beta_2 = 0.37 \pm 0.03$ and $\beta_4 = 0.18 \pm 0.04$. The results confirm the assignment of ^{18}O*(7.11) to the ground state rotational band (1971RE20).

See also (1964SC01, 1968BE34) and (1966RE1C, 1967LO1F, 1967SC16, 1970AG1C; theor.).

22. ^{18}O(d, d)^{18}O

At $E_d = 15$ MeV, inelastically scattered deuteron groups are reported to ^{18}O states with $E_x =$ 1.982, 3.564 ± 0.025, 3.655 ± 0.030, 3.949 ± 0.030, 4.501 ± 0.040, 5.139 ± 0.030, 5.301 ± 0.030, 5.413 ± 0.035 MeV (1961AR06). Angular distribution measurements by (1961AR06, 1964WI05, 1965DI1C, 1965LU1A, 1966DE09) are listed in Table 18.8. See also (1959AJ76).

Table 18.7: States of ^{18}O from ^{17}O(d, p)^{18}O

E_x (MeV ± keV)			l_n [f]	J^π [g]
(1963YA03) [a]	(1965MO16) [d]	(1966WI07) [e]		
	0	0	2	0^+
	1.982 ± 10	1.98	$0+2$	2^+
	3.552 ± 10	3.55	2	4^+
		3.63	(2)	0^+
		3.92	0	2^+
4.440 ± 25 [b]		4.45	1	1^-
5.092 ± 25		5.09		
[c]	5.255 ± 10	5.25	0	2^+ [h]
[c]		5.33		
(5.375 ± 25)	5.375 ± 10	5.37	0	3^+ [h]
5.492 ± 25				
6.200 ± 25		6.19		
[c]		6.34		
	7.110 ± 15	7.10	2	4^+
	7.855 ± 20			
	7.962 ± 20			

[a] $E_d = 14.95$ MeV. Angular distribution measured for protons to ^{18}O*(4.45).

[b] Lower energy states were not investigated.

[c] This part of the spectrum could not be observed.

[d] $E_d = 5.56$ MeV. Angular distributions measured for protons to the first six states shown.

[e] $E_d = 10.0$ MeV. The energies shown are nominal. Proton groups to ^{18}O*(5.52, 6.39, 6.86) were not observed. Angular distributions were measured for all the listed states.

[f] (1965MO16, 1966WI07), except for the assignment for ^{18}O*(4.45) (1963YA03). The levels for which l-values are not given by (1965MO16, 1966WI07) are weakly populated.

[g] Known J^π from this and other experiments.

[h] See also (1964MO25, 1967MO09).

Table 18.8: ^{18}O(n, n), (p, p), (d, d), (t, t), (^{3}He, ^{3}He), (α, α) angular distribution studies

E (MeV)	Angular distribution of groups	Refs.
2.9 – 4.2	n_{0+1}	(1964EX1A)
14.1	n_0, n_1, $n_{2\to4}$, $n_{6\to10}$	(1969ME15)
0.84 – 2.00	p_0	(1961CA02)
2.64 – 2.93	$\gamma_{1.98}$	(1965PR1D)
22.5, 24.5	p_0, p_1, p to ^{18}O*(7.11)	(1971RE20)
65	p_0	(1971LE1R)
7.0	d_0	(1964WI05)
12.3	d_0	(1965LU1A)
15	d_0	(1965DI1C, 1966DE09)
15	d_1	(1961AR06)
6.4, 7.2	t_0	(1964PU01)
11.0	^{3}He(0)	(1970BO25, 1970GR04)
15	^{3}He(0)	(1969ZU02)
17.3	^{3}He(0)	(1968HA30, 1969HA1U)
21.4	α to ^{18}O*(0 [a], 1.98, 3.55 + 3.63, 3.92, 4.45, 5.1, 6.19, 7.1)	(1966LU05)
40.5	α to ^{18}O*(0, 1.98, 3.92, 4.45, 5.09, 6.34 + 6.39, 7.96 + 8.04 + 8.08)	(1966HA19)

[a] See also (1966WE04).

23. ^{18}O(t, t)^{18}O

The angular distributions of elastically scattered tritons have been measured at $E_t = 6.4$ and 7.2 MeV (1964PU01). See also (1968HO1C).

24. ^{18}O(^{3}He, ^{3}He)^{18}O

Angular distributions of elastically scattered ^{3}He ions have been studied at $E(^3\text{He}) = 11.0$ to 17.3 MeV: see Table 18.8 (1968HA30, 1969HA1U, 1969ZU02, 1970BO25, 1970GR04). See also (1968HO1C) and (1969MA1G; theor.).

25. ^{18}O(α, α)^{18}O

Angular distributions of elastically scattered α-particles have been measured at $E_\alpha = 21.4$ (1966LU05) and 40.5 MeV (1966HA19): see Table 18.8. The transitions to ^{18}O*(4.45, 5.09) are $L = 1$ and 3, respectively, fixing $J^\pi = 1^-$ and 3^- for these states. B(E2) values for ^{18}O*(1.98, 4.45) and B(E3) for ^{18}O*(5.09) are also reported (1966HA19).

Measurements of α groups near $180°$ for $E_\alpha = 20.0$ to 23.4 MeV confirm assignments of natural parity for ^{18}O*(1.98, 3.55, 3.63, 3.92, 4.45, 5.09, 5.25, 5.33, 6.19, 6.39, 7.11, 7.62, 7.85, 8.21, 8.28, 8.82, 8.96, 9.03, 9.10, 9.36, 9.39, 9.68, 9.72 ± 0.03, 9.88, 10.12, 10.29, 10.38, 11.62, 11.69). The levels at $E_x = 5.37$, 8.48 and 8.64 MeV were not observed, and those at 5.52, 6.34 and 6.86 MeV were populated weakly indicating unnatural parity: $J^\pi = 3^+$ and 2^-, respectively for ^{18}O*(5.37, 5.52) (1971OL06).

Alpha-γ correlation measurements involving ^{18}O states below $E_x = 6.4$ MeV [see Table 18.2] lead to $J^\pi = 1^-$ and 3^- for ^{18}O*(6.19, 6.39). Other J^π values agree with previous assignments. The transitions $3.92 \to 1.98$ and $5.25 \to 1.98$ are almost pure M1 (1971BE45). See also (1968FA1A).

26. (a) ^{18}O(^{7}Li, ^{7}Li)^{18}O
(b) ^{18}O(^{9}Be, ^{9}Be)^{18}O
(c) ^{18}O(^{10}B, ^{10}B)^{18}O

For reaction (a) see (1969NE1E). For reactions (b) and (c) see (1971KN05).

27. (a) ^{18}O(^{12}C, ^{12}C)^{18}O
(b) ^{18}O(^{13}C, ^{13}C)^{18}O

For reaction (a) see (1967GO1A, 1968GO1H). For reaction (b) see (1971KN05).

28. ^{18}O(^{16}O, ^{16}O)^{18}O

See (1968GO1H, 1970FO1F, 1970SI09). See also (1965GO1G).

29. ^{18}O(^{18}O, ^{18}O)^{18}O

See (1970MO35, 1970SH07, 1971GO1T, 1971RA1C, 1971VA1H).

30. ^{18}F(β^+)^{18}O $\qquad Q_m = 1.655$

Table 18.9: ^{18}O states from ^{19}F(d, ^{3}He)^{18}O [a]

E_x (MeV ± keV)	l	C^2S [d]
0	0 [c]	1.00
1.97 ± 20	2 [c]	1.39
3.63 ± 100 [b]	$0+2+4$	≈ 0.2
4.45 ± 10	1 [c]	1.31
5.28 ± 30 [b]	$0+2$	≈ 1.2
6.27 ± 10 [b]	1	0.70
6.90 ± 20	1	1.03
7.67 ± 30 [b]	1	0.42
9.76 ± 150 [b]		
11.14 ± 70	1	0.65
11.75 ± 70 [b]	1	0.72
12.25 ± 70	1	0.89
14.10 ± 200		
14.56 ± 100		

[a] (1969KA1A, 1970KA31): $E_d = 51.7$ MeV; DWBA analysis.
[b] Corresponds to unresolved states.
[c] See also (1965ZE04).
[d] Normalized to 1.00 for the ground-state transition.

See ^{18}F.

31. (a) ^{19}F(γ, p)^{18}O $\quad Q_m = -7.993$
(b) ^{19}F(e, ep)^{18}O $\quad Q_m = -7.993$

See (1962DO1A). See also (1968AB09).

32. ^{19}F(n, d)^{18}O $\quad Q_m = -5.768$

Angular distributions are reported at $E_n = 14$ MeV (1965SA14; d_0), 14.1 MeV [(1957RI44; d_0, d_1), (1959VE19, 1960VE06; d_0) and (1968FA01; d_0, d_1)] and at 14.4 MeV (1968AN1F, 1968RE07; d_0, d_1). See also (1961BO1A, 1961KO06, 1961LE1D, 1969BE1R, 1971MI1H).

33. ^{19}F(p, 2p)^{18}O $Q_m = -7.993$

See (1971DE1F) and ^{19}F.

34. ^{19}F(d, ^{3}He)^{18}O $Q_m = -2.499$

Many states of ^{18}O have been populated in this reaction: see Table 18.9 (1965ZE04, 1969KA1A, 1970KA31). See also (1967WI1F) and (1968BA2J; theor.).

35. ^{19}F(t, α)^{18}O $Q_m = 11.821$

Alpha groups are reported at $E_t = 5.75$ to the thirteen excited states reported in the ^{16}O(t, p)^{18}O reaction [see Table 18.5] and to states with $E_x = 6.86$, 7.10, 7.60, 7.75, 7.84, 7.96, 8.02, 8.11, 8.19, 8.26, 8.39, 8.48, 8.64 MeV (± 20 keV) (1962HI06). Branching ratios are reported by (1967CH1D): see Table 18.2. See also (1966BE1G, 1967CH1L, 1967CHZY, 1968BE1U). See also (1967CA1L).

36. ^{21}Ne(n, α)^{18}O $Q_m = 0.698$

See (1961AB05).

^{18}F

(Figs. 2 and 4)

GENERAL: (See also (1959AJ76).)

Shell model: (1957WI1E, 1959BR1E, 1960TA1C, 1961TR1B, 1962TA1D, 1964FE02, 1964IN03, 1964PA1D, 1964YO1B, 1965BA1J, 1965DE1H, 1965GI1B, 1966BA2E, 1966BA2C, 1966HU09, 1966IN01, 1966KU05, 1966RI1F, 1967EN01, 1967EV1C, 1967FE01, 1967FL01, 1967HO11, 1967IN03, 1967KU09, 1967KU13, 1967LY02, 1967MO1J, 1967PA1K, 1967PI1B, 1967VI1B, 1967WO1C, 1968AR02, 1968BE1T, 1968BH1B, 1968CL03, 1968CO11, 1968DE1M, 1968DE13, 1968EL1C, 1968FR03, 1968GA16, 1968GU1E, 1968HA17, 1968HA1P, 1968HE1H, 1968KA1C, 1968KU1E, 1968NA09, 1968ZU02, 1969BA2F, 1969BE1T, 1969BU15, 1969KA09, 1969KU1G, 1969MA1T, 1969ME06, 1969ST1G, 1969ZU1B, 1969ZU03, 1970BA2E, 1970EL1G, 1970EL08, 1970HA49, 1970KA32, 1970TR08, 1970WA1T, 1971AR1R, 1971EL07, 1971GU21, 1971HO12, 1971JA06, 1971LO23, 1971PE1A, 1971PR16, 1971QU01, 1971WI01, 1972KA01, 1972LE1L).

Cluster, collective and deformed models: (1964KE1A, 1964MA1G, 1966PI1B, 1966RI1F, 1967FE01, 1967PA1K, 1968EL1C, 1969BA2E, 1969ZA1D, 1970BA2B, 1970WA1T, 1971AR1R, 1972LE1L).

Astrophysical questions: (1970BA1M).

Electromagnetic transitions: (1962MO1A, 1963BU11, 1966HA31, 1967IN03, 1968EL1C, 1968HA17, 1968HE1G, 1968LE02, 1969BE1T, 1969HA1F, 1969WA1C, 1970EL08, 1970HA49, 1970WA31, 1970WA1T).

Special levels: (1964KE1A, 1965GI1B, 1966HU09, 1966MI1G, 1966NA1B, 1967EN01, 1967EV1C, 1967FL01, 1967PA1K, 1967VI1B, 1968AR02, 1968BH1B, 1968CO11, 1968FR03, 1968GA16, 1968HA1P, 1968HE1G, 1968KA1C, 1968LE02, 1968NA09, 1968NO1C, 1969BA1Z, 1969BE1T, 1969CH1K, 1969EL1A, 1969FE1A, 1969HA1F, 1969KA09, 1969KA29, 1969MA1T, 1969ME06, 1969OS01, 1970EL1G, 1970EL08, 1971AR1R, 1971EL07, 1971GU21, 1971JA06, 1971PE1A, 1971PR16, 1971QU01, 1972KA01).

Other theoretical topics: (1961MA1B, 1962IN1A, 1963BU11, 1963VL1A, 1964IN03, 1964ST1B, 1965DE1H, 1965FO1E, 1965KA1B, 1966GI1A, 1966HE1E, 1966KU05, 1967FE01, 1967FL01, 1967KU13, 1967MA1B, 1967MO1J, 1967VA31, 1967WO1C, 1968BA2H, 1968BE1T, 1968DE1M, 1968EL1C, 1968GU1E, 1968JO1C, 1968KA1C, 1968KU1E, 1968LE02, 1968MU1B, 1968PE16, 1968VA24, 1969DE16, 1969GA1Q, 1969KA29, 1969MU09, 1969OS01, 1969RA28, 1969WA1F, 1970BA1Z, 1970EL08, 1970PR1D, 1971BA14, 1971BO21, 1971EL07, 1971LO23, 1971PR16, 1972DE05, 1972KA01, 1972LE1L).

Reactions involving pions: (1968BE1F).

Complex reactions involving ^{18}F: (1965LO1D, 1966LA1G, 1967AU1B, 1967WI16, 1967WI20, 1968MO1C, 1968SH26, 1968ST1L, 1969FE04, 1969KR21, 1970BR13, 1970FA01, 1970FE05, 1970KO43, 1970KR12, 1970KR1C, 1970MO38, 1971AR02).

Table 18.10: Energy levels of ^{18}F [a]

E_x (MeV ± keV)	$J^\pi; T$	K^π	τ or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
0	$1^+; 0$	0^+	$\tau_{1/2} = 109.77 \pm 0.05$ min	β^+	1, 2, 3, 4, 5, 9, 10, 11, 12, 17, 18, 19, 20, 21, 22, 23, 27, 28, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 41, 42
0.9370 ± 0.2	$3^+; 0$	0^+	$\tau_m = 68 \pm 7$ psec	γ	5, 9, 10, 17, 18, 19, 23, 27, 28, 30, 31, 35, 36, 37, 42
1.0419 ± 0.8	$0^+; 1$		4^{+3}_{-2} fsec	γ	5, 9, 18, 28, 30, 31, 32, 35, 37, 41
1.0809 ± 0.8	$0^-; 0$		30 ± 3 psec	γ	5, 9, 10, 17, 18, 30, 31, 35, 36, 37
1.1218 ± 0.7	$5^+; 0$	0^+	218 ± 9 nsec	γ	5, 9, 10, 17, 18, 19, 23, 28, 30, 31, 35, 37, 42
1.7007 ± 0.8	$1^+; 0$	1^+	0.86 ± 0.20 psec	γ	5, 9, 10, 17, 18, 19, 23, 30, 31, 32, 35, 37, 41, 42
2.1013 ± 0.5	$2^-; 0$		4.3 ± 1.4 psec	γ	9, 10, 17, 18, 19, 23, 31, 35, 37, 42
2.5240 ± 0.8	$2^+; 0$	1^+	0.65 ± 0.13 psec	γ	5, 10, 17, 18, 19, 23, 27, 28, 35, 37, 42
3.0598 ± 2.6	$2^+; 1$		≤ 1.2 fsec	γ	5, 18, 20, 23, 27, 28, 31, 35, 37, 41, 42
3.1349 ± 1.6	$1^-; 0$		$0.37^{+0.15}_{-0.10}$ psec	γ	5, 10, 18, 19, 23, 31, 35, 37, 42
3.3569 ± 2.6	$3^+; 0$	1^+	0.48 ± 0.09 psec	γ	5, 10, 18, 19, 23, 27, 31, 35, 37, 42
3.7242 ± 2.7	$1^+; 0$		< 0.08 psec	γ	10, 18, 23, 31, 37, 42
3.787 ± 7	$(3^-); 0$			γ	10, 18, 23, 31, 35, 37
3.836 ± 3	$2^+; 0$		< 0.073 psec	γ	10, 18, 19, 23, 27, 28, 31, 35, 37, 42
4.119 ± 4	$3^+; 0$			γ	10, 18, 19, 23, 28, 31, 35, 37, 42
4.229 ± 4	(2)			γ	10, 18, 23, 31, 35, 37, 42
4.361 ± 3	2, 3		< 0.61 psec	γ	10, 18, 20, 31, 35, 37, 42
4.402 ± 5	$\geq 2; 0$			γ	10, 18, 19, 31, 35, 37, 42
4.6503 ± 1.0	$4^+; 1$			γ	5, 10, 18, 23, 28, 31, 35, 37
4.739 ± 4	$0^+; 1$			γ	18, 31, 37
4.849 ± 4	$1; 0$			γ	5, 10, 18, 19, 37, 42
4.957 ± 5	$2^+; 1$			γ	18, 23, 27, 28, 37
5.301 ± 4	$4^+; 0$	1^+	31 ± 6 fsec	γ, α	5, 10, 18, 19, 23, 37, 42
5.501 ± 5				γ, α	5, 10, 37, 42
5.599 ± 11	$(4^+; 0)$				18, 19, 35, 37
5.606 ± 2	$1^-; 0, 1$		$\Gamma < 1.2$ keV	γ, α	5, 8, 10, 27, 35, 37, 42
5.674 ± 2	$1^-; 0, 1$		< 0.8	γ, α	5, 8, 10, 27, 37

Table 18.10: Energy levels of ^{18}F [a] (continued)

E_x (MeV ± keV)	$J^\pi; T$	K^π	τ or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
5.785 ± 10	$(T = 0)$				19, 37, 42
6.095 ± 2	$4^-; 0$		< 2.0	γ, p, α	8, 10, 18, 19, 23, 26, 37, 42
6.135 ± 2	$0^+; 1$			γ	23, 37, 42
6.161 ± 2	$3^+; 1$		15	γ	23, 25
6.240 ± 2	(3^-) [b]		< 0.8	γ, p, α	5, 8, 23, 25, 26, 37, 41, 42
6.261 ± 3	(1)		< 3	α	8, 10, 18, 37, 41, 42
6.280 ± 2	$2^+; 1$		7.5	γ, p	23, 25
6.309 ± 2	$2^+, 3^+$		3.1 ± 1.4	γ, p, α	23, 25, 26
6.385 ± 3	$(1^+), 2, 3^-$		< 4.5	γ, p, α	23, 26, 37
6.483 ± 3	$(1^+), 2, 3^-$		< 1.2	γ, p, α	23, 26, 37
6.565 ± 4	$5^+; 0$	1^+	(< 0.8)	γ, α	5, 8, 10, 19, 23, 37, 42
6.646 ± 4	1^-		89 ± 4	p, α	8, 10, 26, 37, 42
6.6474 ± 2.5	(2^-) [b]		< 1.6	γ, p, α	5, 7, 10, 23, 25, 26, 37, 42
6.780 ± 2	$4^+, 5^+; 0$		10 ± 3	γ, p, α	23, 25, 26, 37, 42
6.808 ± 3	$2^+, 3^+$		5 ± 3	γ, p, α	10, 19, 23, 25, 26, 37, 42
6.808 ± 5	$2^-; 0$		90 ± 10	p, α	7, 8, 18, 26
6.871 ± 2				γ, p, α	23, 26, 37, 42
7.194 ± 3	$(4^+); 0$		< 4	α	8, 10, 19, 37
7.206 ± 9	(1^+)		45 ± 10	(p), α	8, 10, 18, 26
7.313 ± 10	(3^-)		53 ± 6	p, α	7, 8, 10, 37
7.395 ± 10	$(3^-; 0)$		35	p, α	7, 8, 19, 26, 37
7.57			60	p, α	7, 8, 26
7.653 ± 9	$T = 0$		40	p, α	7, 8, 18, 19, 26
7.74			120	p, α	7, 8, 26
7.872 ± 10	$(2^-); 0$		30	p, α	7, 8, 18, 19, 26
7.95	(1^+)		70	p, α	7, 8, 26
(8.21)			≈ 15	p, α	26
(8.23)			≈ 10	p, α	26
(8.37)			≈ 50	p, α	26
8.46				p, d, α	8, 14, 15, 16
8.596 ± 19	$T = 0$				19
8.861 ± 190	$T = 0$				19
9.145 ± 32	$3, 4^-; 0$		108 ± 12	p, d, α	14, 15, 16, 18
9.26	3^- [b]		≈ 30	d, α	16
9.32	2^+ [b]		≈ 40	(p), d, α	14, 16, 18
9.494 ± 15	$(6^-); 0$				19
9.50	$2, 3^+; 0$			n, d, α	13, 16, 18
(9.55)	$2, 3^+; 0$			d, α	16

Table 18.10: Energy levels of ^{18}F [a] (continued)

E_x (MeV $\pm$ keV)	$J^\pi; T$	K^π	τ or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
(9.70)	3^{-} [b]		370	n, d, α	13, 16
9.82 ± 40	2^{+} [b]		200	d, α	16, 18, 19
10.06 ± 45				n, p, d	13, 14, 18, 19
(10.21)	1^{-} [b]		90	d, α	16
(10.24)	$3, 4^{-}$			d, α	16
10.268 ± 12	3^{-} [b]		180	n, p, d, α	13, 14, 16, 19
(10.31)	2^{+} [b]		570	d, α	16
10.352 ± 25	1^{-} [b]		270	(n), d, α	13, 16, 18
10.42	3^{-} [b]		50	(n), d, α	13, 16
10.541 ± 10	2^{+} [b]		50	n, p, d, α	13, 14, 16, 19
10.59	1^{-} [b]		160	d, α	16
(10.61)	$4, 5^{+}; 0$			d, α	16
10.61	2^{+} [b]		150	d, α	16
(10.63)	1^{-} [b]		60	d, α	16
10.64	3^{-} [b]		240	d, α	16
(10.68)	2^{+} [b]		60	d, α	16
10.69	3^{-} [b]		75	d, α	16
(10.71)	2^{+} [b]		375	d, α	16
10.73 ± 30	$(2^{-}); 0$			(n, p), α	6, 7
10.80	2^{+} [b]		85	n, p, d, α	13, 14, 16
(10.90)	$(2, 3)^{+}; 0$			p, d, α	14, 16
10.91	1^{-} [b]		240	d, α	16
(10.95)	2^{+} [b]		400	d, α	16, 18
10.98	3^{-} [b]		120	d, α	16, 18
(10.99)	2^{+} [b]		220	d, α	16
(11.03)	2^{+} [b]		80	d, α	16
(11.03)	$3, 4^{-}; 0$		≈ 35	p, d, α	14, 16
11.073 ± 37	2^{+}		50	d, α	16, 19
(11.11)	1^{-} [b]		1000	d, α	16
11.13 ± 50	3^{-} [b]		35	n, p, d, α	13, 14, 16, 18
11.26	3^{-} [b]		240	d, α	16
(11.30)	2^{+} [b]		475	d, α	16
11.31	4^{+} [b]		40	d, α	16
(11.32)	2^{+} [b]		95	d, α	16
11.32	3^{-} [b]		65	d, α	16
11.384 ± 18	$4, 5^{+}; 0$			p, d, α	14, 16, 19
(11.51)	2^{+} [b]		125	d, α	16
11.56	3^{-} [b]		70	d, α	16

Table 18.10: Energy levels of ^{18}F [a] (continued)

E_x (MeV $\pm$ keV)	$J^\pi; T$	K^π	τ or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
(11.59)	$5, 6^-; 0$			d, α	16
(11.66)	2^+ [b]		240	d, α	16
(11.79)	$\geq 3; 0$			(n, p), d, α	6, 7, 15, 16
11.83	1^- [b]		180	(n, p), d, α	6, 7, 16
(11.91)	$5, 6^-; 0$			d, α	16
11.96	3^- [b]		30	d, α	16
(11.97)	2^+ [b]		125	d, α	16
12.01			40	d, α	16
12.055 ± 16	$T = 0$		60	d, α	16, 19
12.12	$T = 0$		55	d, α	16
12.12	3^- [b]		35	d, α	16
(12.14)	2^+ [b]		220	d, α	16
12.25			70	d, α	16
12.25 ± 30	$(2^-, 3); 0$		170	(n, p), d, α	6, 7, 16
12.32			130	d, α	16
(12.31)	1^- [b]		100	d, α	16
12.34	3^- [b]		190	d, α	16
12.36	2^+ [b]		80	d, α	16
12.38	2^+ [b]		120	d, α	16
(12.47)	1^- [b]		35	d, α	16
(12.48)	(3^-)		120	d, α	16
12.484 ± 15	4^+ [b]		60	d, α	8, 16
12.526 ± 15	3^- [b]		80	d, α	8, 16
12.565 ± 15	2^+ [b]		≈ 300	(n, p), d, α	6, 7, 8, 16
(12.63)	2^+		210	d, α	16
(12.67)	2^+ [b]		290	d, α	16
12.68			160	d, α	16
12.683 ± 15	5^- [b]		45	n, p, d, α	6, 7, 8, 16, 19
12.702 ± 15	3^- [b]		70	d, α	8, 16
(12.78)			160	d, α	16
(12.81)	2^+ [b]		440	d, α	16
(12.86)			120	d, α	16
(12.90)	3^- [b]		120	d, α	16
(12.96)			120	d, α	16
(12.99)	2^+ [b]		650	d, α	16
(13.03)	3^- [b]		250	d, α	16
13.06 ± 15	4^+		40	d, α	8, 16
(13.08)	$T = 0$		150	d, α	16

Table 18.10: Energy levels of ^{18}F [a] (continued)

E_x (MeV ± keV)	$J^\pi; T$	K^π	τ or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
(13.12)			160	d, α	16
13.129 ± 15	(4^+)		35	d, α	8, 16
(13.16)			160	d, α	16
(13.17)	1^- [b]		185	d, α	16
13.198 ± 15	5^- [b]		140	d, α	8, 16
(13.20)	$T = 0$		145	d, α	16
(13.20)	4^+ [b]		255	d, α	16
(13.24)			120	d, α	15, 16
(13.26)			100	d, α	16
(13.26)	4^+ [b]		360	d, α	16
(13.29)	2^+ [b]		100	d, α	16
13.332 ± 15	5^- [b]		50	d, α	8, 16
(13.34)			135	d, α	16
(13.40)			120	d, α	16
13.398 ± 15	6^+		85	α	8
(13.43)			200	d, α	16
(13.43)	3^- [b]		235	d, α	16
(13.44)	1^- [b]		100	d, α	16
13.464 ± 15	4^+		100	d, α	8, 16
13.50	5^- [b]		65	d, α	16
(13.50)	2^+ [b]		145	d, α	16
(13.57)			140	d, α	16
13.597 ± 15	6^+		100	α	8
(13.60)			150	d, α	16
(13.60)	4^+ [b]		40	d, α	16
(13.61)	1^- [b]		90	d, α	16
13.65	5^- [b]		300	d, α	16
13.652 ± 15	3^-		60	α	8
13.671 ± 15	(2^+)		60	α	8
13.679 ± 15	4^+ [b]		70	d, α	8, 16
(13.70)	2^+ [b]		80	d, α	16
(13.77)	3^- [b]		205	d, α	16
13.780 ± 15	4^+ [b]		130	d, α	8, 16
(13.81)	2^+ [b]		265	d, α	16
(13.85)			60	d, α	16
(13.92)			210	d, α	16
13.917 ± 15	$(4^+, 2^+)$			α	8
(13.96)	1^- [b]		70	d, α	16

Table 18.10: Energy levels of ^{18}F [a] (continued)

E_x (MeV ± keV)	$J^\pi; T$	K^π	τ or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
(13.99)			150	d, α	16
13.980 ± 15	5^- [b]		170	d, α	8, 16
(14.01)			110	d, α	16
(14.05)			200	d, α	16
(14.08)			210	d, α	16
(14.10)	2^+ [b]		170	d, α	16
(14.10)	4^+ [b]		75	d, α	16
14.162 ± 5	5^- [b]		200	d, α	8, 16
(14.18)			220	d, α	16
(14.26)			200	d, α	16
(14.30)			85	d, α	16
(14.33)	$T = 0$		130	d, α	16
14.323 ± 15	4^+		95	α	8
(14.34)	$T = 0$		250	d, α	16
[d]					
16.513 ± 15 [c]	$6^+(7^-)$		≈ 50	α	8
16.606 ± 15 [c]	5^-		≈ 50	α	8
16.723 ± 15 [c]	6^+		≈ 150	α	8
16.870 ± 15 [c]	7^-		≈ 200	α	8
16.948 ± 15 [c]	6^+		≈ 150	α	8

[a] See also Tables 18.14, 18.15 and 18.17.

[b] Isospin mixed state: see (1970JO1C) and Table 18.20.

[c] State not reported in ^{16}O(d, α)^{14}N: see Table 18.17.

[d] [92 additional states with $14.36 < E_x < 20.80$ MeV are reported in ^{16}O(d, α)^{14}N: see Table 18.17].

Ground state: (1970WA1T, 1971GU21, 1971WI01, 1972LE1L).

1. ^{18}F(β^+)^{18}O $\qquad Q_m = 1.655$

The positron decay is entirely to the ground state if ^{18}O [$J^\pi = 0^+; T = 1$]: E_β(max) $= 635 \pm 2$ keV (1964HO28). See also (1959AJ76). The half-life is 109.77 ± 0.05 min: see Table 18.11. $\log ft = 3.554$: see also (1969KA1B). The fact that the β^+ transition to ^{18}O(0) is allowed indicates $J^\pi = 1^+$ for ^{18}F(0). The ratio $\epsilon_K/\beta^+ = 0.030 \pm 0.002$ (1956DR38). See also (1959PE1B, 1966KU1F, 1968DA1J, 1968LE02, 1970MC23, 1971BL12, 1971DE1E, 1971VA1C, 1971WI18; theor.).

Table 18.11: The half-life of ^{18}F

$\tau_{1/2}$ (min)	Refs.
112 ± 1	(1949BL26)
111 ± 1	(1955JA1A)
110 ± 1	(1958BE74)
110.5 ± 0.6	(1964HO28)
109.72 ± 0.06	(1964MA12)
111.0 ± 2.0	(1965BO42)
109.87 ± 0.12	(1965EB01)
109.77 ± 0.05	mean

2. (a) ^{12}C(^{6}Li, n)^{17}F $\quad Q_{\rm m} = 4.064 \quad E_{\rm b} = 13.215$
   (b) ^{12}C(^{6}Li, p)^{17}O $\quad Q_{\rm m} = 7.606$
   (c) ^{12}C(^{6}Li, d)^{16}O $\quad Q_{\rm m} = 5.688$
   (d) ^{12}C(^{6}Li, t)^{15}O $\quad Q_{\rm m} = -3.723$
   (e) ^{12}C(^{6}Li, α)^{14}N $\quad Q_{\rm m} = 8.799$

Cross section measurements have been carried out in the range $E(^{6}{\rm Li}) = 1.9$ to 14.0 MeV: see Table 18.12. The cross sections for reactions (b), (c) and (e) rise monotonically and rapidly with energy up to $E(^{6}{\rm Li}) = 4$ MeV due to Coulomb barrier effects. At higher energies, Ericson-type fluctuations are observed (1967DZ01, 1970JO09). Neither the direct reaction nor the statistical compound nucleus model alone is adequate to decsribe the data (1970JO09). The cross section for the isospin-forbidden α_1 group [to ^{14}N*(2.31), $J^{\pi} = 0^{+}$; $T = 1$] shows an energy dependence very unlike those for the α_0 and α_2 groups, charaterized by a maximum at ≈ 4 MeV, a minimum at ≈ 5 MeV, and a further rise to 6 MeV. Typically the cross section for the α_1 group is two orders of magnitude lower than those for the α_0 or α_2 groups (1965CA06, 1967DZ01). See also (1968NO1C; theor.). For angular distribution studies see ^{16}O and ^{17}O in (1971AJ02) and ^{14}N in (1970AJ04).

3. ^{12}C(^{7}Li, n)^{18}F $\quad Q_{\rm m} = 5.964$

See (1957NO17, 1961NO05) and ^{19}F.

4. ^{12}C(^{12}C, ^{6}Li)^{18}F $\quad Q_{\rm m} = -14.960$

See (1962CH01).

Table 18.12: ^{12}C + ^{6}Li studies [a]

$E(^6\text{Li})$ (MeV)	Measurement of	Refs.
$1.9-3.5$	α_0, α_2	(1966BE07)
$2.2-3.4$	^{17}F yield	(1961NO05)
$2.4-8.5$	$\text{p}_0 \rightarrow \text{p}_3$, d_0, α_0	(1967DZ01)
$3.0-5.5$	p_0, d_0, α_0, α_2	(1965CA06)
	(σ_t)	
$3.2-4.0$	α_0, α_2	(1962HO06)
$3.4-4.0$	$\text{p}_0 \rightarrow \text{p}_3$, d_0	(1962BL13)
	(σ_t)	
$3.5-6.5$	α_1	(1967DZ01)
$3.5-7.5$	α_2	(1967DZ01)
$3.8-4.0$	α_1	(1962HO06)
$3.8-5.5$	α_1	(1965CA06)
	(σ_t)	
$4.5-5.5$	$\text{p}_0 \rightarrow \text{p}_4$, d_0, d_{1+2}, d_3, d_4, α_0, α_2	(1966HE05)
	(σ_t)	
$5.6-14.0$	$\text{p}_0 \rightarrow \text{p}_3$, d_0, d_{1+2}, d_{3+4}, α_0, α_2, α_{3+4}	(1970JO09)
	(σ_t)	
$9.0-14.0$	p_4, d_5	(1970JO09)
	(σ_t)	
$12.0-14.0$	t_0	(1970JO09)
	(σ_t)	

[a] At $E_{\text{c.m.}} = 7$ and 8 MeV, σ_t for various deuteron groups are reported by (1967LO01).

Table 18.13: Resonances in ^{14}N + α

E_α (MeV)	Particle out	$\Gamma_{c.m.}$ (keV)	$J^\pi; T$	$(2J+1)\Gamma_\gamma\Gamma_\alpha/\Gamma$ (eV)	E_x (MeV)	Refs.
0.559	γ		1; 0	$(2.79 \pm 0.5) \times 10^{-4}$	4.851	(1971CO27)
1.140 ± 5	γ		4^+; 0	0.084 ± 0.004 [b]	5.303	(1968PA10, 1971CO27, 1971RO25)
1.395 ± 5	γ			0.027 ± 0.003	5.501	(1968PA10)
1.531 ± 2	γ, α_0	< 1.2	1^-; 0, 1	4.80 ± 0.40	5.606	(1955PR1A, 1958AL03, 1958PH37, 1961SI09, 1968PA10, 1971CH1F)
1.618 ± 2	γ, α_0	< 0.8	1^-; 0, 1	1.35 ± 0.15	5.674	(1955PR1A, 1958PH37, 1959WA16, 1961SI09, 1968PA10, 1971CH1F)
2.165 ± 3	α_0		2, 3, 4		6.100	(1961SI09)
2.351 ± 3	γ, α_0	< 0.8	$2^{(+)}$; 1	≈ 9	6.244	(1958HE54, 1958HE56, 1958PH37, 1959WA16, 1961SI09)
2.372 ± 3	α_0	< 3	1		6.261	(1961SI09)
2.767 ± 4	γ, α_0	(< 0.8)	5^+; 0	[c]	6.568	(1958HE54, 1958HE56, 1971RO25)
2.870 ± 4	γ, p_0	< 1.6		≈ 3	6.648	(1958HE54, 1958HE56, 1958PH37)
2.870 ± 6	α_0	93 ± 5	1^-	$\Gamma_\alpha/\Gamma = 0.85$	6.648	(1958HE54, 1958HE56, 1958KA32)
3.080 ± 6	p_0, α_0	101 ± 5	2^-		6.811	(1958HE54, 1958HE56)
3.576 ± 4	α_0	< 4	(4^+)		7.197	(1958HE54, 1958HE56, 1958KA32)
3.67	α_0	45 ± 10	(1^+)		7.27	(1958HE54, 1958HE56, 1958KA32)
3.72	p_0, α_0	53 ± 6	(3^-)		7.31	(1958HE54, 1958HE56, 1958KA32)
4.00	p_0, α_0	35	(3^-)		7.53	(1958KA32)
4.05	p_0, α_0	60			7.57	(1958KA32)
4.11	p_0, α_0	40			7.61	(1958KA32)
4.28	p_0, α_0	120			7.74	(1958KA32)
4.50	p_0, α_0	30	(2^-)		7.92	(1958KA32)
4.55	p_0, α_0	70	(1^+)		7.95	(1958KA32)
5.2	α				8.5	(1939BR1A, 1939DE1A)
8.12 ± 30	(n_1, p_1)		(2^-); 0		10.73	(1969SC21)
9.5	(n_1, p_1)				11.8	(1969SC21)
10.07 ± 30	(n_1, p_1)		$(2^-, 3)$; 0		12.25	(1969SC21)
10.376 ± 15	α_1 [d]	75	4^+		12.484	(1966CH1E, 1970TO03)
10.431 ± 15	α_1	75	3^-		12.526	(1970TO03)
10.481 ± 15 [a]	α_1	350	2^+		12.565	(1970TO03)

Table 18.13: Resonances in $^{14}N + \alpha$ (continued)

E_α (MeV)	Particle out	$\Gamma_{c.m.}$ (keV)	$J^\pi; T$	$(2J+1)\Gamma_\gamma\Gamma_\alpha/\Gamma$ (eV)	E_x (MeV)	Refs.
10.632 ± 15	α_1	54	5^-		12.683	(1970TO03)
10.657 ± 15	α_1	74	3^-		12.702	(1970TO03)
11.110 ± 15	α_1	37	(4^+)		13.054	(1970TO03)
11.206 ± 15	α_1	43	(4^+)		13.129	(1970TO03)
11.295 ± 15	α_1		5^-		13.198	(1970TO03)
11.467 ± 15	α_1	60	5^-		13.332	(1966CH1E, 1970TO03)
11.553 ± 15	α_1	85	6^+		13.398	(1970TO03)
11.638 ± 15	α_1	93	4^+		13.464	(1970TO03)
11.809 ± 15	α_1	100	6^+		13.597	(1970TO03)
11.879 ± 15	α_1	62	3^-		13.652	(1970TO03)
11.904 ± 15	α_1	62	(2^+)		13.671	(1970TO03)
11.914 ± 15	α_1	78	4^+		13.679	(1970TO03)
12.044 ± 15	α_1		4^+		13.780	(1970TO03)
12.220 ± 15	α_1		$(4^+, 2^+)$		13.917	(1970TO03)
12.301 ± 15	α_1		5^-		13.980	(1970TO03)
12.535 ± 15	α_1		5^-		14.162	(1966CH1E, 1970TO03)
12.743 ± 15	α_1	93	4^+		14.323	(1966CH1E, 1970TO03)
15.56 ± 15	α_1	≈ 50	$6^+(7^-)$		16.513	(1970TO03)
15.68 ± 15	α_1	≈ 50	5^-		16.606	(1970TO03)
15.83 ± 15	α_1	≈ 150	6^+		16.723	(1970TO03)
16.02 ± 15	α_1	≈ 200	7^-		16.870	(1970TO03)
16.12 ± 15	α_1	≈ 150	6^+		16.948	(1970TO03)
19.8	α	broad			19.8	(1962JO14)

[a] May be a cluster of levels (1970TO03).

[b] $\Gamma_\gamma = \Gamma_\alpha = 12 \pm 4$ meV (1971RO25).

[c] $\Gamma_\gamma = 26 \pm 6$ meV, $\Gamma_\alpha \gg \Gamma_\gamma$ (1971RO25).

[d] This and the following resonances are observed in the isospin-forbidden channel (H.T. Richards, private communication).

Table 18.14: Radiative decays in ^{18}F

E_i (MeV)	$J_i^\pi; T$	E_f (MeV)	Branch (%)	Γ_γ (eV)	Refs.
0.94	$3^+; 0$	0	100		
1.04	$0^+; 1$	0	100		
1.08	$0^-; 0$	0	100	$(2.2 \pm 0.2) \times 10^{-5}$	(1966AL04, 1966CH12, 1967GO07)
1.13	$5^+; 0$	0.94	100	$\lvert M(\mathrm{E2})\rvert^2 = 4.62 \pm 0.16$ W.u.	(1960RA18, 1966AL04, 1967OL03, 1967PO09, 1967WA19)
1.70 [h]	$1^+; 0$	0 [a]	35 ± 3		(1965PO01)
			28 ± 3		(1966OL03)
		0.94	< 1		(1967WA06)
		1.04 [a]	65 ± 3		(1965PO01)
			72 ± 3		(1966OL03)
		1.08	< 3.5		(1967WA06)
		1.13	< 3		(1967WA06)
2.10 [h]	$2^-; 0$	0 [b]	38 ± 3		(1965PO01)
			36 ± 2		(1966OL03)
			33 ± 3		(1967GO07)
			36	$(4.6 \pm 2.2) \times 10^{-5}$	(1967WA06)
			35.8 ± 1.5		mean
		0.94 [b]	30 ± 4		(1965CH10, 1965PO01)
			32 ± 2		(1966OL03)
			33 ± 3		(1967GO07)
			31	$(4.0 \pm 1.9) \times 10^{-5}$	(1967WA06)
			32.0 ± 1.5		mean
		1.04	< 3		(1966OL03, 1967GO07)
			< 0.8		(1967WA06)
		1.08 [b]	32 ± 4		(1965CH10, 1965PO01)
			32 ± 2		(1966OL03)
			34 ± 3		(1967GO07)
				$\lvert M(\mathrm{E2})\rvert^2 = 20 \pm 7$ W.u.	(1967PO02)
			32.5 ± 1.5		mean
		1.13	< 3		(1966OL03, 1967GO07)
			< 2		(1967WA06)
		1.70	< 4		(1967WA06)
2.53 [h]	$2^+; 0$	0 [c]	73 ± 4		(1965PO01)
			75 ± 4		(1966OL03)
		0.94 [c]	23 ± 2		(1965PO01)
			21 ± 4		(1966OL03)
		1.04	< 0.5		(1967WA06)

Table 18.14: Radiative decays in ^{18}F (continued)

E_i (MeV)	$J^{\pi}_i; T$	E_f (MeV)	Branch (%)	Γ_γ (eV)	Refs.
		1.08	< 0.5		(1967WA06)
		1.13	< 4		(1967WA06)
		1.70 [b]	4 ± 2		(1965PO01)
			4 ± 1.5		(1966OL03)
			5 ± 2		(1967WA06)
			4.3 ± 1.0		mean
		2.10	< 4		(1967WA06)
3.06	$2^+; 1$	0	24 ± 4		(1965PO01)
			25 ± 2		(1966OL03)
		0.94	76 ± 4		(1965PO01)
			75 ± 2		(1966OL03)
		1.04	< 8		(1967WA06)
		1.08	< 8		(1967WA06)
		1.13	< 14		(1967WA06)
		1.70	< 8		(1967WA06)
		2.10	< 5		(1967WA06)
		2.53	< 5		(1967WA06)
3.13	$1^-; 0$	0	31 ± 3		(1965PO01)
			32 ± 2		(1966OL03)
				$(5.7 \pm 2) \times 10^{-4}$	(1967WA06)
		0.94	< 2		(1967WA06)
		1.04 [d]	41 ± 4	$(7.3 \pm 2.7) \times 10^{-4}$	(1967WA06)
		1.08 [d]	27 ± 4	$(4.8 \pm 1.8) \times 10^{-4}$	(1967WA06)
		1.13	< 8		(1967WA06)
		1.70	< 6		(1967WA06)
		2.10	< 6		(1967WA06)
		2.53	< 1		(1967WA06)
3.36	$3^+; 0$	0	53 ± 5		(1965PO01)
			56 ± 6		(1966OL03)
		0.94	4 ± 4		(1965PO01)
			7 ± 4		(1966OL03)
			7 ± 3		(1967WA06)
			6 ± 2		mean
		1.04	< 5		(1967WA06)
		1.08	< 5		(1967WA06)
		1.13	< 25		(1967WA06)
		1.70	38 ± 4		(1965PO01)

Table 18.14: Radiative decays in ^{18}F (continued)

E_i (MeV)	$J_i^\pi; T$	E_f (MeV)	Branch (%)	Γ_γ (eV)	Refs.
			30 ± 4		(1966OL03)
		2.10	5 ± 4		(1965PO01)
			7 ± 4		(1966OL03)
		2.53	< 25		(1967WA06)
3.72	$1^+; 0$ [f]	0	6 ± 2		(1967GO07)
			6 ± 3		(1967OL03)
			16 ± 8		(1967WA06)
			6.4 ± 1.6		mean
		0.94	< 6		(1967WA06)
		1.04	94 ± 2		(1967GO07)
			94 ± 3	$> 8.2 \times 10^{-3}$	(1967OL03)
		1.08	< 15		(1967WA06)
		1.13	< 10		(1967OL03)
		1.70	< 6		(1967OL03)
		2.10	< 10		(1967OL03)
		2.53	< 3		(1967OL03)
		3.06	< 5		(1967OL03)
		3.13	< 3		(1967OL03)
		3.36	< 4		(1967OL03)
3.79	$(3^-); 0$	0	< 15		(1967OL03)
		0.94	< 10		(1967OL03)
		1.04	< 15		(1967OL03)
		1.08	< 15		(1967OL03)
		1.13	< 10		(1967OL03)
		1.70	< 10		(1967OL03)
		2.10	76 ± 10		(1967OL03)
		2.53	4 ± 4		(1967OL03)
		3.06	20 ± 8		(1967OL03)
		3.13	< 10		(1967WA06)
		3.36	< 20		(1967WA06)
3.84	2^+	0	39 ± 6		(1967GO07)
			41 ± 4	$> 2.2 \times 10^{-3}$	(1967OL03)
		0.94	5 ± 4		(1967GO07)
			5 ± 3		(1967OL03)
		1.04	< 4		(1967OL03)
		1.08	< 3		(1967OL03)
		1.13	< 3		(1967OL03)

Table 18.14: Radiative decays in ^{18}F (continued)

E_i (MeV)	$J^{\pi}_i; T$	E_f (MeV)	Branch (%)	Γ_γ (eV)	Refs.
		1.70	4 ± 4		(1967GO07)
			4 ± 3		(1967OL03)
		2.10	< 5		(1967OL03)
		2.53	< 2		(1967OL03)
		3.06	61 ± 6		(1967GO07)
			50 ± 4		(1967OL03)
		3.13	< 6		(1967OL03)
		3.36	< 9		(1967OL03)
4.12	3^{+} [g]	0	5 ± 3		(1967OL03)
		0.94	< 8		(1967OL03)
		1.04	< 8		(1967OL03)
		1.08	< 8		(1967OL03)
		1.13	< 8		(1967OL03)
		1.70	< 8		(1967OL03)
		2.10	< 15		(1967OL03)
		2.53	< 15		(1967OL03)
		3.06	95 ± 3		(1967OL03)
		3.13	< 13		(1967OL03)
		3.36	< 10		(1967OL03)
4.23	(2)	0 [e]	32 ± 5		(1967GO07)
		0.94 [e]	55 ± 5		(1967GO07)
		1.04	< 5		(1967OL03)
		1.08	(≤ 5)		(1967OL03)
		1.13	< 10		(1967OL03)
		1.70	5 ± 3		(1967OL03)
		2.10 [e]	13 ± 5		(1967GO07)
		2.53	< 4		(1967OL03)
		3.06	< 3		(1967OL03)
		3.13	(≤ 5)		(1967OL03)
		3.36	< 5		(1967OL03)
4.36	2, 3	0.94	< 20		(1967GO07, 1967OL03)
		3.06	(100)		(1967GO07)
			> 60		(1967OL03)
4.40	≥ 2; 0	0.94	< 40		(1967GO07)
			≤ 30		(1967OL03)
		1.13	(100)		(1967GO07)
			> 70		(1967OL03)

Table 18.14: Radiative decays in ^{18}F (continued)

E_i (MeV)	$J_i^\pi; T$	E_f (MeV)	Branch (%)	Γ_γ (eV)	Refs.
4.66	$4^+; 1$ [g]	0	< 5		(1967OL03)
		0.94	15 ± 5		(1967OL03)
		1.04	< 5		(1967OL03)
		1.08	< 5		(1967OL03)
		1.13	85 ± 5		(1967OL03)
		1.70	< 5		(1967OL03)
		2.10	< 10		(1967OL03)
		2.53	< 10		(1967OL03)
		3.06	< 4		(1967OL03)
		3.13	< 4		(1967OL03)
		3.36	< 3		(1967OL03)
4.74	$0^+; 1$	0	(100)		(1967GO07)
4.85	1; 0	0	< 6		(1967GO07)
		0.94	< 4		(1967OL03)
		1.04	65 ± 4		(1967GO07)
			60 ± 10		(1967OL03)
		1.08	< 15		(1967OL03)
		1.13	< 15		(1967OL03)
		1.70	< 10		(1967OL03)
		2.10	< 15		(1967OL03)
		2.53	< 10		(1967OL03)
		3.06	35 ± 4		(1967GO07)
			40 ± 10		(1967OL03)
		3.13	< 15		(1967OL03)
		3.36	< 15		(1967OL03)
4.96	$2^+; 1$	0	(100)		(1967GO07)
5.30	$4^+; 1$	0.94	13 ± 3		(1968PA10)
			9		(1971RO25)
		1.13	7		(1971RO25)
		2.53	87 ± 3		(1968PA10)
			78		(1971RO25)
				$\Gamma_\gamma/\Gamma = 0.38 \pm 0.12$	(1967GO07)
		3.36	5		(1971RO25)
		4.66	1		(1971RO25)
5.50				$\omega\Gamma_\gamma = 0.027 \pm 0.003$ eV	(1968PA10)
5.61 [i]	$1^-; 0, 1$	0	10 ± 1		(1971CH1F)
		1.04	4 ± 1		(1971CH1F)

Table 18.14: Radiative decays in ^{18}F (continued)

E_i (MeV)	$J_i^\pi; T$	E_f (MeV)	Branch (%)	Γ_γ (eV)	Refs.
		1.08	35 ± 2		(1971CH1F)
		3.06	30 ± 2		(1971CH1F)
		3.13	21 ± 2		(1971CH1F)
5.67	$1^-; 0, 1$	0	6 ± 1		(1971CH1F)
		1.04	8 ± 1		(1971CH1F)
		1.08	52 ± 3		(1971CH1F)
		3.06	4 ± 1		(1971CH1F)
		3.13	29 ± 2		(1971CH1F)
6.10	$4^-; 0$	0.94	6		(1971BE1E)
			6		(1971SE1H)
		1.13	57	$\left\{ \begin{array}{l} 0.17 \pm 0.09 \\ \Gamma_\gamma = 66 \pm 21 \text{ meV} \end{array} \right.$	(1971BE1E)
			66	0.063	(1971SE1H)
		2.10	25		(1971BE1E)
			28		(1971SE1H)
		3.79	2		(1971BE1E)
		4.12	2		(1971BE1E)
		4.66	8		(1971BE1E)
6.14	0^+	0	54	0.57	(1971SE1H)
		1.70	10		(1971SE1H)
		3.72	36		(1971SE1H)
6.16	3^+	0.94	51	1.72	(1971SE1H)
		2.53	8		(1971SE1H)
		3.79	13		(1971SE1H)
		3.84	28		(1971SE1H)
6.24 [j]	3^-	0.94	5	1.00	(1971SE1H)
		2.10	76		(1971SE1H)
		3.79	12		(1971SE1H)
		4.23	7		(1971SE1H)
6.27	2^+	0.94	70	1.91	(1971SE1H)
		1.70	4		(1971SE1H)
		2.10	5		(1971SE1H)
		3.36	3		(1971SE1H)
		3.84	15		(1971SE1H)
		4.12	3		(1971SE1H)
6.31	$2^+, 3^+$	0	4		(1971SE1H)
		0.94	33		(1971SE1H)

Table 18.14: Radiative decays in ^{18}F (continued)

E_i (MeV)	$J^\pi_i; T$	E_f (MeV)	Branch (%)	Γ_γ (eV)	Refs.
		3.06	55	0.18	(1971SE1H)
		4.96	8		(1971SE1H)
6.39		0.94	80	0.16	(1971SE1H)
		1.70	7		(1971SE1H)
		3.84	13		(1971SE1H)
6.48		0	15		(1971SE1H)
		0.94	31	0.094	(1971SE1H)
		1.13	14		(1971SE1H)
		1.70	4		(1971SE1H)
		3.06	28		(1971SE1H)
		3.84	8		(1971SE1H)
6.57	$5^+; 0$	0.94	(100)	0.043	(1971SE1H)
			15		(1971RO25)
		3.36	83		(1971RO25)
		5.30	2		(1971RO25)
6.65 [j]	(2^-)	0.94	12		(1971SE1H)
		2.10	72	1.23	(1971SE1H)
		3.13	16		(1971SE1H)
6.78	$4^+, 5^+$	0.94	15		(1971SE1H)
		1.13	38		(1971SE1H)
		4.66	47	0.48	(1971SE1H)
6.81	2^-	0	24		(1971SE1H)
		0.94	35		(1971SE1H)
		3.06	41	0.17	(1971SE1H)
6.86		0.94	12		(1971SE1H)
		4.66	88	0.15	(1971SE1H)

[a] See also (1960RA18, 1961KU02, 1963LI07, 1967WA06).
[b] See also (1961KU02, 1966CH12).
[c] See also (1961KU02, 1967WA06).
[d] See also (1965PO01, 1966OL03).
[e] See also (1967OL03).
[f] Parity is positive: see (1970RO1F).
[g] Parity is positive: see (1970DU08).
[h] See also (1966HA31).
[i] See also (1955PR1A, 1958AL03).
[j] See also (1958PH37).

5. ^{14}N(α, γ)^{18}F $\quad Q_{\rm m} = 4.416$

Resonances have been observed at $E_\alpha = 0.56$, 1.14, 1.40, 1.53, 1.62, 2.35, 2.77 and 2.88 MeV, corresponding to ^{18}F* $= 4.85$, 5.30, 5.50, 5.61, 5.68, 6.24, 6.57 and 6.65 MeV: see Table 18.13 (1955PR1A, 1958PH37, 1968PA10, 1971CH1F, 1971CO27, 1971RO25). See also (1969AL13). Capture resonances are not observed corresponding to ^{18}F*(4.66, 4.96), $(2J + 1)\Gamma_\alpha\Gamma_\gamma/\Gamma < 2 \times 10^{-5}$ and $< 0.5 \times 10^{-4}$ eV, respectively (1971CO27).

The branching ratios for ^{18}F*(5.30, 5.61, 5.68, 6.57) are displayed in Table 18.14.

The sequence of the ^{18}F states with $E_{\rm x} = 1.70$ [$J^\pi = 1^+$], 2.53 [2^+], 3.36 [3^+], 5.30 [4^+] and 6.57 MeV [5^+] as well as the enhanced E2 strengths of the γ-transitions show that these states can be considered to be members of a predominantly 4p-2h $K^\pi = 1^+$ rotational band. ^{18}F*(3.36) is found to have $J = 3$ (1971RO25). The M1 transitions between the $J^\pi = 1^-$ states at $E_{\rm x} = 5.61$ and 5.68 MeV and ^{18}F*(1.08, 3.13) have $|M|^2$ between 0.1 and 1 W.u. implying $T = 1$ for these resonant states but both also decay by E1 transitions to the $T = 1$ states at $E_{\rm x} = 1.04$ and 3.06 MeV, implying $T = 0$. This result is in agreement with ^{18}F*(5.61, 5.68) both being 1^- members of a $T = 0, 1$ isospin doublet. The $T = 1$ strength is split nearly equally between the two levels (1971CH1F). See also (1967CH1J, 1967CH1K).

The non-resonant S factor for this reaction, $S \leq 1.5 \times 10^6$ keV · b (1968PA10), ≈ 0.7 MeV · b (1971CO27). See also (1966IB1A, 1971CO1G).

6. ^{14}N(α, n)^{17}F $\quad Q_{\rm m} = -4.735 \quad E_{\rm b} = 4.416$

The total cross section ratios of ^{14}N(α, n)^{17}F(0.50)/^{14}N(α, p)^{17}O(0.87) were measured for $E_\alpha = 7$ to 12 MeV: major maxima are observed at $E_\alpha = 8.12$, 9.5, 10.07 and 11.52 MeV. Symmetric angular distributions at three of these maxima lead to $J^\pi = (2^-)$, (2^-, 3) and (2^-, 3^+) at $E_{\rm x} = 10.73$, 12.25 and 13.36 MeV. These states are primarily $T = 0$ (1969SC21): see Table 18.13.

7. ^{14}N(α, p)^{17}O $\quad Q_{\rm m} = -1.193 \quad E_{\rm b} = 4.416$

Observed resonances are displayed in Table 18.13 (1953HE58, 1958HE54, 1958KA32). Excitation functions showing a number of structures have been measured for $E_\alpha = 10$ to 25 MeV (p_0, p_1), 13 to 25 MeV (p_2) and 15 to 25 MeV (p_3) (1970ZE01). See also (1961YA02).

8. (a) ^{14}N(α, α)^{14}N $\quad E_{\rm b} = 4.416$

(b) ^{14}N(α, αp)^{13}C $\quad Q_{\rm m} = -7.551$

(c) ^{14}N(α, d)^{16}O $\quad Q_{\rm m} = -3.111$

Table 18.15: Lifetime measurements of some ^{18}F states

^{18}F* (MeV)	τ_m	Reaction	Refs.
0.94	68 ± 7 psec	^{3}H(^{16}O, ^{18}F)n	(1966AL04) [a]
1.04	4^{+3}_{-2} fsec	^{18}O(p, n)^{18}F	(1967BL18) [b,c]
1.08	30 ± 3 psec	^{3}H(^{16}O, ^{18}F)n	(1966AL04) [b]
1.13	220 nsec	^{16}O(^{3}He, p)^{18}F	(1970BL1F)
	190 ± 45 nsec	^{16}O(^{3}He, p)^{18}F	(1959AL99)
	221 ± 21 nsec	^{16}O(^{3}He, p)^{18}F	(1967BE14)
	219 ± 10 nsec	^{16}O(^{3}He, p)^{18}F	(1967PO09)
	218 ± 9 nsec		mean value
1.70	2.0 ± 1.0 psec	^{3}H(^{16}O, ^{18}F)n	(1963LI07)
	0.86 ± 0.20 psec	^{16}O(^{3}He, p)^{18}F	(1966OL03)
	0.86 ± 0.20 psec		best value
2.10	0.70 ± 0.20 psec	^{3}H(^{16}O, ^{18}F)n	(1963LI07)
	5 ± 3 psec	^{3}H(^{16}O, ^{18}F)n	(1966AL04)
	4.1 ± 1.6 psec	^{16}O(^{3}He, p)^{18}F	(1966OL03)
	4.3 ± 1.4 psec		best value
2.53	1.1 ± 0.2 psec	^{3}H(^{16}O, ^{18}F)n	(1963LI07)
	$0.63^{+0.18}_{-0.14}$ psec	^{16}O(^{3}He, p)^{18}F	(1967WA06)
	0.67 ± 0.18 psec	^{16}O(^{3}He, p)^{18}F	(1966OL03)
	0.65 ± 0.13 psec		best value
3.06	< 0.20 psec	^{16}O(^{3}He, p)^{18}F	(1967WA06)
	< 0.17 psec	^{16}O(^{3}He, p)^{18}F	(1966OL03)
	≤ 1.2 fsec	^{17}O(d, n)^{18}F	(1971LE29)
3.13	$0.37^{+0.15}_{-0.10}$ psec	^{16}O(^{3}He, p)^{18}F	(1967WA06)
3.36	$0.55^{+0.20}_{-0.15}$ psec	^{16}O(^{3}He, p)^{18}F	(1967WA06)
	0.46 ± 0.10 psec	^{16}O(^{3}He, p)^{18}F	(1966OL03)
	0.48 ± 0.09 psec		mean value
3.72	< 0.08 psec	^{16}O(^{3}He, p)^{18}F	(1967WA06)
3.84	< 0.1 psec	^{16}O(^{3}He, p)^{18}F	(1967WA06)
	< 0.073 psec	^{16}O(^{3}He, p)^{18}F	(1966OL03)
4.36	< 0.61 psec	^{16}O(^{6}Li, α)^{18}F	(1969TH01)
5.30	31 ± 6 fsec	^{14}N(α, γ)^{18}F	(1971RO25)

[a] See also (1963LI07, 1963LO03).
[b] See also (1963LI07).
[c] See also (1966OL03).

Observed amomalies in the elastic scattering are exhibited in Table 18.13 (1939BR1A, 1939DE1A, 1953HE58, 1958HE54, 1958HE56, 1958KA32, 1961SI09, 1962JO14, 1970TO03). Resonances in the α_1 (isospin "forbidden") and α_2 yield are also displayed (1970TO03). See also (1966CH1E). Excitation functions have recently been reported for $E_\alpha = 1.0$ to 2.4 MeV (1961SI09; α_0), 10.2 to 18.3 MeV (1970TO03; α_0, α_1, α_2), 15 to 23 MeV (1962JO14; α_0) and 18.2 to 23.5 MeV (1970CH1D; α_1). See also (1963NO1B, 1967BO1M, 1969FE10).

In the range $E_\alpha = 10.2$ to 17.3 MeV compound nucleus formation dominates the α_0, α_1 and α_2 channels. The α_1 channel [to the $J^\pi = 0^+$; $T = 1$ state at 2.31 MeV] displays relatively isolated resonances which imply ^{18}F states with large isospin impurities [$\approx 10 - 25\%$]. Comparison of this work with the results from ^{16}O(d, α_1) [reaction 16] suggests that the same ^{18}F states are usually involved in both reactions (1970TO03). These data do not support the suggestions by (1968NO1C, 1969NO1B) concerning the importance of direct reactions in isospin violating reactions (1970TO03). See also (1970JO1G).

For reaction (b), see (1967BE30). For spallation cross sections see (1968JA1J, 1968JU04, 1970BA48, 1970JA1Q, 1970JU05). For reaction (c), see (1971TH03) and reaction 16. See also (1970VI02) and ^{14}N in (1970AJ04).

9. ^{14}N(^{6}Li, d)^{18}F $\qquad Q_m = 2.943$

Angular distributions have been measured for $E(^6\text{Li}) = 5.3$ to 6.0 MeV (1968RI13; d_0, $d_{1\to4}$).

10. ^{14}N(^{7}Li, t)^{18}F $\qquad Q_m = 1.950$

At $E(^7\text{Li}) = 15$ MeV, triton groups are observed to the known $T = 0$ states with $E_x < 7.4$ MeV: the $T = 1$ states are not excited although such transitions are not forbidden in principle, suggesting a direct α-transfer mechanism. The transitions to ^{18}F*(1.70, 2.53, 3.36, 4.23, 5.30, 6.57) account for more than one half of the summed cross section at $15°$. It is proposed that these states (which are only weakly excited in ^{16}O(^{3}He, p)^{18}F and ^{17}O(^{3}He, d)^{18}F) are predominantly of a 4p-2h nature and are excited by transfer of four nucleons into the (2s, 1d) shell (1968MI09). [See also reaction 5]. See also (1968OG1A).

11. ^{15}N(α, n)^{18}F $\qquad Q_m = -6.418$

See (1966AD07).

12. ^{16}O(d, γ)^{18}F $\qquad Q_m = 7.527$

Table 18.16: Recent ^{16}O + d yield curves and polarization studies

E_d (MeV)	Yield of	Refs.
0.4 – 3.5	γ	(1965OW01)
13.0 – 18.5	γ	(1969AL13)
thresh. – 2.4	n_0	(1961DI06)
thresh. – 12	n	(1968MA1C)
2.0 – 4.2	n_0, n_1	(1970BA31)
2.1 – 3.4	n_0	(1968DI06)
2.5 – 5.5	n_0, n_1	(1970LO01)
2.8 – 3.4	n_1	(1968DI06)
4.5 – 6.0	n_0, n_1	(1970DA14)
0.3 – 1.0	p_0	(1965LO03)
0.32 – 1.07	p_1	(1968NG1B)
0.35 – 1.05	p_1	(1969DU11)
0.45 – 1.0	p_1	(1965LO03)
0.7 – 2.1	p_0, p_1	(1963SE12)
0.8 – 1.7	p_0, p_1	(1964KI05)
0.8 – 2.0	p_0, p_1	(1962CA20, 1963AM1A, 1964AM1A)
1.55 – 1.85	p_0	(1959LO59, 1961LO1C)
1.9 – 3.6	p_0, p_1	(1968DI06)
4.0 – 6.0	p_0, p_1	(1970DA14)
4.4 – 8.4	p_0, p_1	(1969CO12)
4.5 – 6.0	p_3	(1970DA14)
6.0 – 11.0	p_0, p_1	(1968NA06)
10.5 – 13.0	p_0, p_1, p_3, p_5	(1967AL06)
0.65 – 2.0	d_0	(1963SE12)
0.8 – 2.0	d_0	(1963AM1A, 1964AM1A)
1.0 – 2.5	d_0	(1968MA53)
1.8 – 3.6	d_0	(1968DI06)
4.0 – 6.0	d_0	(1970DA14)
4.4 – 8.4	d_0	(1969CO12)
10.0 – 13.0	d_0	(1967AL06)
0.3 – 1.0	α_0	(1965LO03)

Table 18.16: Recent ^{16}O + d yield curves and polarization studies (continued)

E_d (MeV)	Yield of	Refs.
$0.7 - 2.1$	α_0	(1963SE12)
$0.8 - 1.7$	α_0	(1964KI05)
$0.8 - 2.0$	α_0	(1962CA20, 1963AM1A, 1964AM1A)
$0.85 - 2.0$	α_0	(1960AM03)
$1.1 - 2.5$	α_0	(1965MA59)
$1.8 - 14$	α_0, α_1	(1970JO1C)
$1.9 - 3.6$	α_0	(1968DI06)
$3 - 5$	α_0, α_1	(1969JO1M, 1970JO1G)
$3 - 15$	α_1	(1969JO09)
$3.9 - 5.3$	α_0	(1967TH1E, 1968TH1J, 1971TH03)
$4.4 - 8.4$	α_0	(1969CO12)
$5.0 - 9.0$	α_0, $\alpha_2 \rightarrow \alpha_5$, $\alpha_7 \rightarrow \alpha_{10}$	(1968JO07)
$5.5 - 7.0$	α_0, α_2	(1965SA18)
$7.0 - 12.5$	α_0	(1969AL13)
$7 - 14$	α_2	(1970JO1C)
$9.0 - 12.5$	α_2	(1969AL13)
$9.0 - 15.0$	α_0, α_2, α_3, α_4	(1968JO07)
$14.0 - 18.1$	α_1	(1971JA04)
$15 - 20$	α_0, α_1, α_2	(1963YA1B)
E_d (MeV)	Polarization measurements of	Refs.
$3 - 4$	n_0, n_1	(1971AN1A)
$3.96 - 5.35$	n_0, n_1	(1971TH10)
$6.5 - 9.5$	p_1	(1963AL1D)
$6.5 - 9.55$	p_1	(1963EV05)
8	p_0, p_1	(1971KO21)
$9.0 - 10.3$	p_0, p_1	(1969CU10)
9.3, 13.3	p_0, p_1, p_3, p_4, p_5	(1970CO1P)
12.3	p_0, p_1	(1971BR44, 1971HU1C)
6.34	d_0	(1969CO12)
8	d_0	(1971KO21)

Table 18.16: Recent ^{16}O + d yield curves and polarization studies (continued)

E_d (MeV)	Yield of	Refs.
9.3, 13.3	d_0	(1970CO1P)

The capture cross section rises from $0.1\ \mu$b at $E_d = 0.4$ MeV to $25\ \mu$b at 3.5 MeV: Γ_γ over this range is ≈ 2 eV. The results can be interpreted satisfactorily in terms of compound nucleus formation (1965OW01). See also (1969AL13) and Table 18.16.

13. (a) ^{16}O(d, n)^{17}F $\quad Q_m = -1.624 \quad E_b = 7.527$
(b) ^{16}O(d, np)^{16}O $\quad Q_m = -2.225$

Excitation functions have been measured for the n_0 and n_1 groups from threshold to 12 MeV: see Table 18.16 (1961DI06, 1968DI06, 1968MA1C, 1970BA31, 1970DA14, 1970LO01). Some structure is observed: that which is attributed to states in ^{18}F is displayed in Table 18.17 (1955MA85, 1961DI06, 1968MA1C). The coherence energy determined from the yield for $E_d = 4.5$ to 6.0 MeV is 70 keV for n_0 and 67 keV for n_1 (1970DA14). See also ^{17}F in (1971AJ02). For polarization measurements see (1971AN1A, 1971TH10) and Table 18.16.

For reaction (b) see (1968CU04).

14. ^{16}O(d, p)^{17}O $\quad Q_m = 1.918 \quad E_b = 7.527$

Excitation functions have been reported recently for several proton groups up to $E_d = 13.0$ MeV: see Table 18.16 (1959LO59, 1961LO1C, 1962CA20, 1963AM1A, 1963SE12, 1964AM1A, 1964KI05, 1965LO03, 1968DI06, 1968NG1B, 1969CO12, 1969DU11, 1970DA14). See also (1963DO1B, 1970CA1C).

Some of the maxima in the yield are interpreted in terms of resonances: these are shown in Table 18.17 (1955ST1A, 1956RO1A, 1963AM1A, 1964AM1A, 1968MA53). See also (1959AJ76). The coherence energy determined from the yields is 75 keV for p_0, 63 keV for p_1 and 62 keV for p_3 in the range $E_d = 4.0$ to 6.0 MeV (1970DA14).

Polarization measurements are reported by (1963AL1D, 1963EV05, 1969CU10, 1970CO1P, 1971BR44, 1971HU1C, 1971KO21): see Table 18.16. Large values of the polarization are observed for $E_d = 6.5$ to 12.3 MeV: the results are interpreted in terms of a direct interaction mechanism (1963EV05). See also (1967BA1R, 1967MA1F, 1970PE1B; theor.) See also ^{17}O in (1971AJ02).

15. ^{16}O(d, d)^{16}O $\quad E_b = 7.527$

Table 18.17: Maxima in the yield of ^{16}O + d reactions

E_d	Particles out	$\Gamma_{c.m.}$	$J^\pi; T$	E_x	Refs.
0.895 [a]	p_1, α_0	210 ± 25		(8.322)	(1963AM1A, 1964AM1A)
1.048 [b]	p_1, d_0, α_0	88 ± 10	1^+	8.458	(1960AM03, 1963AM1A, 1964AM1A, 1968MA53)
1.199	α_0	230 ± 30		(8.592)	(1963AM1A, 1964AM1A, 1965MA59)
1.298	p_1, d_0, α_0	13 ± 3		(8.680)	(1960AM03, 1963AM1A, 1964AM1A)
1.325	d_0, α_0			(8.704)	(1963AM1A, 1964AM1A)
1.482	α_0	40 ± 5		(8.843)	(1963AM1A, 1964AM1A)
1.563	d_0, α_0	121 ± 15		(8.915)	(1960AM03, 1963AM1A, 1964AM1A)
1.616 [c]	α_0	19 ± 15		(8.962)	(1960AM03, 1963AM1A, 1964AM1A)
1.765 [d]	d_0, α_0	141 ± 10		(9.095)	(1960AM03, 1963AM1A, 1964AM1A)
1.885 [d,e]	p_0, p_1, d_0, α_0	108 ± 12	$3, 4^-; 0$	9.201	(1956RO1A, 1963AM1A, 1964AM1A, 1965MA59, 1970JO1C)
1.95 [f]	α_1	≈ 30	3^-	9.26	(1970JO1C)
2.02 [f]	$(p_1), \alpha_1$	≈ 40	2^+	9.32	(1956RO1A, 1970JO1C)
2.22	n_0, α_0		$2, 3^+; 0$	9.50	(1955MA85, 1961DI06, 1970JO1C)
2.28	α_0		$2, 3^+; 0$	9.55	(1970JO1C)
2.34	n_0, p_1			(9.61)	(1955MA85, 1956RO1A, 1961DI06)
2.448 [f]	n, α_1	372	3^-	9.701	(1955MA85, 1970JO1C)
2.55	p_1			(9.79)	(1955ST1A, 1956RO1A)
2.620 [f]	α_1	195	2^+	9.854	(1970JO1C)
2.92	n, p_0, p_1			10.12	(1955MA85, 1955ST1A, 1956RO1A)
3.021 [f]	α_1	93	1^-	10.210	(1970JO1C)
3.05	α_0		$3, 4^-$	10.24	(1970JO1C)
3.126 [f]	$n, p_1, \alpha_0, \alpha_1$	179	3^-	10.303	(1955MA85, 1956RO1A, 1970JO1C)
3.138 [f]	α_1	572	2^+	10.314	(1970JO1C)
3.179 [f]	$(n), \alpha_1$	269	1^-	10.350	(1955MA85, 1970JO1C)
3.254 [f]	$(n), \alpha_1$	48	3^-	10.417	(1955MA85, 1969JO09, 1970JO1C)
3.366 [f]	n, p_0, p_1, α_1	46	2^+	10.516	(1955MA85, 1955ST1A, 1956RO1A, 1969JO09, 1970JO1C)
3.454 [f]	α_1	157	1^-	10.594	(1970JO1C)
3.47	α_0		$4, 5^+; 0$	10.61	(1970JO1C)
3.471 [f,g]	α_1	151	2^+	10.610	(1969JO09, 1970JO1C)
3.492 [f]	α_1	58	1^-	10.628	(1970JO1C)
3.508 [f]	α_1	236	3^-	10.642	(1970JO1C)
3.547 [f,g]	α_1	62	2^+	10.677	(1970JO1C)
3.562 [f]	α_1	75	3^-	10.690	(1970JO1C)
3.578 [f,g]	α_1	375	2^+	10.705	(1970JO1C)
3.684 [f,g]	n, p_0, p_1, α_1	85	2^+	10.799	(1955MA85, 1955ST1A, 1956RO1A,

Table 18.17: Maxima in the yield of ^{16}O+ d reactions (continued)

E_d	Particles out	$\Gamma_{c.m.}$	$J^\pi; T$	E_x	Res.
					1968MA1C, 1969JO09, 1969JO1C, 1970JO1C)
3.80	p_0, α_0		$(2, 3)^+; 0$	10.90	(1956RO1A, 1957BA14, 1970JO1C)
3.809 [f]	α_1	241	1^-	10.910	(1970JO1C)
3.849 [f,g]	α_1	402	2^+	10.945	(1969JO09, 1969JO1C, 1970JO1C)
3.892 [f]	α_1	119	3^-	10.983	(1970JO1C)
3.904 [f,g]	α_1	222	2^+	10.994	(1970JO1C)
3.944 [f,g]	n, p_1, α_1	78	2^+	11.030	(1955MA85, 1956RO1A, 1970JO1C)
3.95	p_1, α_0	≈ 35	$3, 4^-; 0$	11.03	(1956RO1A, 1957BA14, 1970JO1C)
3.989 [f,g]	α_1	51	2^+	11.070	(1969JO09, 1969JO1C, 1970JO1C)
4.031 [f,h]	α_1	1009	1^-	11.107	(1970JO1C)
4.069 [f]	n, p_1, α_1	35	3^-	11.141	(1955MA85, 1956RO1A, 1969JO09, 1969JO1C, 1970JO1C)
4.208 [f]	α_1	238	3^-	11.264	(1969JO09, 1969JO1C, 1970JO1C)
4.253 [f]	α_1	475	2^+	11.304	(1970JO1C)
4.264 [f]	α_1	38	4^+	11.314	(1970JO1C)
4.267 [f]	α_1	94	2^+	11.316	(1970JO1C)
4.276 [f]	α_1	65	3^-	11.324	(1970JO1C)
4.38	p_1, α_0		$4, 5^+; 0$	11.42	(1956RO1A, 1970JO1C)
4.480 [f]	α_1	126	2^+	11.505	(1970JO1C)
4.543 [f]	α_1	67	3^-	11.561	(1970JO1C)
4.57	α_0		$5, 6^-; 0$	11.59	(1970JO1C)
4.655 [f]	α_1	240	2^+	11.661	(1970JO1C)
4.80	d_0, α_0		$\geq 3; 0$	11.79	(1956BE1B, 1970JO1C)
4.847 [f]	α_1	179	1^-	11.831	(1970JO1C)
4.93	α_0		$5, 6^-; 0$	11.91	(1970JO1C)
4.993 [f]	α_1	32	3^-	11.961	(1969JO09, 1969JO1C, 1970JO1C)
5.000 [f]	α_1	124	2^+	11.967	(1970JO1C)
5.05 ± 15	α_4	40		12.01	(1968JO07)
5.10	$\alpha_0, \alpha_2, \alpha_4$	60	$T = 0$	12.06	(1968JO07, 1970JO1C)
5.17	α_0	55	$T = 0$	12.12	(1968JO07, 1970JO1C)
5.175 [f]	α_1	36	3^-	12.123	(1970JO1C)
5.190 [f]	α_1	219	2^+	12.136	(1970JO1C)
5.32	α_0	70		12.25	(1968JO07)
5.34	α_0, α_2	170		12.27	(1968JO07)
5.40	α_0, α_4	130		12.32	(1968JO07)
5.390 [f]	α_1	100	1^-	12.314	(1970JO1C)
5.414 [f]	α_1	187	3^-	12.335	(1970JO1C)

Table 18.17: Maxima in the yield of ^{16}O+ d reactions (continued)

E_d	Particles out	$\Gamma_{c.m.}$	$J^\pi; T$	E_x	Res.
5.441 [f]	α_1, α_4	80	2^+	12.359	(1968JO07, 1970JO1C)
5.462 [f]	$\alpha_1, \alpha_2, \alpha_3, \alpha_4$	120	2^+	12.377	(1968JO07, 1970JO1C)
5.58	$\alpha_0, \alpha_1, \alpha_2$	120	(3^-)	12.48	(1968JO07, 1969JO09, 1969JO1C, 1970JO1C)
5.571 [f]	α_1	35	1^-	12.474	(1970JO1C)
5.606 [f]	$(\alpha_0), \alpha_1, (\alpha_2)$	88	3^-	12.505	(1968JO07, 1969JO09, 1969JO1C, 1970JO1C)
5.617 [f]	$(\alpha_0), \alpha_1, (\alpha_2)$	47	4^+	12.515	(1968JO07, 1969JO09, 1969JO1C, 1970JO1C)
5.742 [f]	α_0, α_1	210	2^+	12.626	(1968JO07, 1969JO1C, 1970JO1C)
5.786 [f]	α_1	288	2^+	12.665	(1970JO1C)
5.80	$\alpha_0, \alpha_2, \alpha_4$	160		12.68	(1968JO07)
5.804 [f]	$\alpha_1, \alpha_3, \alpha_4$	36	5^-	12.681	(1968JO07, 1969JO09, 1969JO1C, 1970JO1C)
5.867 [f]	α_1	63	3^-	12.737	(1969JO1C, 1970JO1C)
5.91	α_2	160		12.78	(1968JO07)
5.954 [f]	α_1	441	2^+	12.814	(1970JO1C)
6.00	α_0	120		12.86	(1968JO07)
6.048 [f]	α_1	120	3^-	12.898	(1970JO1C)
6.11	$\alpha_0, \alpha_1, \alpha_4$	120		12.96	(1968JO07)
6.14 [i]	α_1	100		(12.98)	(1968JO07)
6.151 [f]	α_1	648	2^+	12.989	(1970JO1C)
6.198 [f]	$\alpha_1, \alpha_2, \alpha_3$	250	3^-	13.031	(1968JO07, 1970JO1C)
6.25	α_0, α_4	150	$T = 0$	13.08	(1968JO07, 1970JO1C)
6.25	α_1	≈ 10	4^+ [i]	13.08	(1956BR36, 1968JO07, 1969JO09)
6.30	α_0, α_2	160		13.12	(1968JO07)
6.31	α_1	35		13.13	(1968JO07)
6.34	α_0, α_3	160		13.16	(1968JO07)
6.353 [f]	α_1	184	1^-	13.169	(1970JO1C)
6.369 [f]	α_1	137	5^-	13.183	(1968JO07, 1970JO1C)
6.38	α_0, α_3	145	$T = 0$	13.20	(1968JO07, 1970JO1C)
6.393 [f]	α_1	254	4^+	13.204	(1970JO1C)
6.43	d_0, α_2	120		13.24	(1956BE1B, 1968JO07)
6.46	$\alpha_0, \alpha_1, \alpha_4$	100		13.26	(1968JO07)
6.461 [f]	α_1	359	4^+	13.264	(1970JO1C)
6.487 [f]	α_1	99	2^+	13.288	(1968JO07, 1970JO1C)
6.54	α_0, α_2	135		13.34	(1968JO07)
6.563 [f]	α_1	42	5^-	13.355	(1970JO1C)

Table 18.17: Maxima in the yield of ^{16}O+ d reactions (continued)

E_d	Particles out	$\Gamma_{c.m.}$	$J^\pi; T$	E_x	Res.
6.61	(α_1), α_2, α_3, α_4	120		13.40	(1956BR36, 1968JO07)
6.64	α_0, α_2	200		13.43	(1968JO07)
6.650 [f]	α_1	233	3^-	13.432	(1970JO1C)
6.662 [f]	α_0, α_1	100	1^-	13.443	(1968JO07, 1970JO1C)
6.72	α_2	100		13.49	(1968JO07)
6.724 [f]	α_1	65	5^-	13.498	(1968JO07, 1970JO1C)
6.726 [f]	α_1, α_2	146	2^+	13.500	(1968JO07, 1970JO1C)
6.80	α_1, α_2, α_3	140		13.57	(1968JO07)
6.84	α_0, α_2, α_4	150		13.60	(1968JO07)
6.839 [f]	α_1	41	4^+	13.600	(1970JO1C)
6.847 [f]	α_1	88	1^-	13.607	(1970JO1C)
6.894 [f]	α_1	297	5^-	13.649	(1970JO1C)
6.936 [f]	α_0, α_1, α_3	60	4^+	13.686	(1968JO07, 1969JO09, 1970JO1C)
6.954 [f]	α_1	78	2^+	13.702	(1970JO1C)
7.025 [f]	α_1	206	3^-	13.765	(1969JO09, 1970JO1C)
7.067 [f]	α_1	132	4^+	13.802	(1970JO1C)
7.074 [f]	α_1	263	2^+	13.809	(1968JO07, 1970JO1C)
7.12	α_3, α_4	60		13.85	(1968JO07)
7.19	α_1	210		13.92	(1968JO07)
7.244 [f]	α_1	69	1^-	13.960	(1970JO1C)
7.27	α_1, α_3	150		13.99	(1968JO07)
7.286 [f]	α_1	168	5^-	13.997	(1970JO1C)
7.30	α_2	110		14.01	(1968JO07)
7.34	α_0, α_1, α_3, α_4	200		14.05	(1968JO07)
7.38	α_0, α_1, α_3	210		14.08	(1968JO07)
7.400 [f]	α_1, α_3	170	2^+	14.098	(1968JO07, 1970JO1C)
7.406 [f]	α_1	73	4^+	14.103	(1970JO1C)
7.410 [f]	α_1	200	5^-	14.107	(1969JO09, 1970JO1C)
7.49	α_0	220		14.18	(1968JO07)
7.58	α_0	200		14.26	(1968JO07)
7.62	α_4	85		14.30	(1968JO07)
7.66	α_0, α_2, α_4	130	$T = 0$	14.33	(1968JO07, 1970JO1C)
7.67	α_0, α_2, α_3, α_4	250	$T = 0$	14.34	(1968JO07, 1970JO1C)
7.73	α_1	145		14.39	(1968JO07)
7.74	α_3	235		14.40	(1968JO07)
7.80	α_0, α_4	70		14.46	(1968JO07)
7.82	α_0, α_2	225		14.48	(1968JO07)
7.832 [f]	α_1	203	1^-	14.482	(1968JO07, 1970JO1C)

Table 18.17: Maxima in the yield of ^{16}O+ d reactions (continued)

E_d	Particles out	$\Gamma_{c.m.}$	$J^\pi; T$	E_x	Res.
7.839 [f]	α_1	76	4^+	14.488	(1969JO09, 1970JO1C)
7.99	α_4	200		14.63	(1968JO07)
8.02	α_0	150		14.65	(1968JO07)
8.03	α_3	310		14.66	(1968JO07)
8.07	α_0, α_1	120		14.70	(1968JO07)
8.08	α_3, α_4	310		14.70	(1968JO07)
8.082 [f]	α_1	169		14.704	(1968JO07, 1970JO1C)
8.14	α_1	90		14.77	(1968JO07)
8.21	α_2	250		14.82	(1968JO07)
8.216 [f]	α_1	91	6^+	14.823	(1970JO1C)
8.228 [f]	α_1	124	2^+	14.833	(1970JO1C)
8.25	α_4	380		14.86	(1968JO07)
8.30	$\alpha_0, \alpha_2, \alpha_3$	210		14.90	(1968JO07)
8.308 [f]	α_1	304	4^+	14.904	(1970JO1C)
8.310 [f]	α_1	1201	2^+	14.906	(1970JO1C)
8.34	α_4	115		14.93	(1968JO07)
8.340 [f]	α_1	119	5^-	14.933	(1970JO1C)
8.37	α_0, α_1	130		14.96	(1968JO07)
8.37	α_0, α_3	250		14.96	(1968JO07)
8.385 [f]	α_1	491	5^-	14.973	(1970JO1C)
8.40	α_0	310		14.99	(1968JO07)
8.43	α_1, α_4	120		15.02	(1968JO07)
8.50	α_3, α_4	190		15.08	(1968JO07)
8.52	α_2	150		15.10	(1968JO07)
8.530 [f]	α_1	115	3^-	15.101	(1968JO07, 1970JO1C)
8.56	α_2	220		15.13	(1968JO07)
8.570 [f]	α_1	156	4^+	15.137	(1970JO1C)
8.58	α_4	180		15.15	(1968JO07)
8.61	α_0, α_3	200		15.17	(1968JO07)
8.616 [f]	α_1	299	3^-	15.178	(1970JO1C)
8.65	α_0, α_2	135		15.21	(1968JO07)
8.72	α_2, α_4	120		15.28	(1968JO07)
8.76	α_2	160		15.31	(1968JO07)
8.766 [f]	α_1	100	6^+	15.311	(1970JO1C)
8.79	α_0	200		15.34	(1968JO07)
8.82	$\alpha_0, \alpha_3, \alpha_4$	230		15.36	(1968JO07)
8.865 [f]	α_1	157	1^-	15.399	(1970JO1C)
8.89	α_3	110		15.43	(1968JO07)

Table 18.17: Maxima in the yield of ^{16}O+ d reactions (continued)

E_d	Particles out	$\Gamma_{c.m.}$	$J^\pi; T$	E_x	Res.
8.906 [f]	α_1	123	3^-	15.435	(1969JO09, 1970JO1C)
8.93	α_3, α_4	190		15.46	(1968JO07)
8.97	α_2, α_4	210		15.50	(1968JO07)
9.00	$\alpha_0, \alpha_1, \alpha_2$	190		15.52	(1968JO07)
9.032 [f]	α_1	319	4^+	15.547	(1970JO1C)
9.073 [f]	α_1	174	5^-	15.583	(1970JO1C)
9.200 [f]	α_1	174	6^+	15.696	(1970JO1C)
9.223 [f]	α_1	237	4^+	15.717	(1970JO1C)
9.255 [f]	α_1	249	1^-	15.745	(1970JO1C)
9.329 [f]	α_1	1044	5^-	15.811	(1970JO1C)
9.349 [f]	α_1	20	2^+	15.828	(1970JO1C)
9.403 [f]	α_1	272	3^-	15.876	(1970JO1C)
9.476 [f]	α_1	153	4^+	15.941	(1970JO1C)
9.643 [f]	α_1	103	2^+	16.089	(1970JO1C)
9.692 [f]	α_1	355	1^-	16.133	(1970JO1C)
9.748 [f]	α_1	149	4^+	16.183	(1970JO1C)
9.771 [f]	α_1	77	3^-	16.203	(1970JO1C)
9.781 [f]	α_1	181	1^-	16.212	(1970JO1C)
9.909 [f]	α_1	292	2^+	16.325	(1970JO1C)
10.049 [f]	α_1	52	4^+	16.450	(1969JO09, 1970JO1C)
10.333 [f]	α_1	296	3^-	16.703	(1970JO1C)
10.357 [f]	α_1	212	5^-	16.723	(1970JO1C)
10.406 [f]	α_1	135	4^+	16.767	(1970JO1C)
10.431 [f]	α_1	209	5^-	16.789	(1970JO1C)
10.457 [f]	α_1	86	6^+	16.812	(1970JO1C)
10.494 [f]	α_1	47	2^+	16.845	(1970JO1C)
10.499 [f]	α_1	78	1^-	16.849	(1970JO1C)
10.533 [f]	α_1	251	3^-	16.879	(1970JO1C)
10.728 [f]	α_1	180	5^-	17.052	(1970JO1C)
10.777 [f]	α_1	86	4^+	17.096	(1970JO1C)
10.888 [f]	α_1	88	6^+	17.195	(1970JO1C)
10.911 [f]	α_1	112	3^-	17.215	(1970JO1C)
11.332 [f]	α_1	208	4^+	17.580	(1970JO1C)
11.367 [f]	α_1	313	1^-	17.620	(1970JO1C)
11.567 [f]	α_1	78	2^+	17.797	(1970JO1C)
11.592 [f]	α_1	273	3^-	17.819	(1970JO1C)
11.704 [f]	α_1	155	6^+	17.919	(1970JO1C)
11.799 [f]	α_1	203	1^-	18.003	(1970JO1C)

Table 18.17: Maxima in the yield of ^{16}O+ d reactions (continued)

E_d	Particles out	$\Gamma_{c.m.}$	$J^\pi; T$	E_x	Res.
11.869 [f]	α_1	223	7^-	18.065	(1970JO1C)
12.135 [f]	α_1	554	5^-	18.301	(1970JO1C)
12.495 [f]	α_1	395	7^-	18.621	(1970JO1C)
12.556 [f]	α_1	208	5^-	18.675	(1970JO1C)
12.682 [f,h]	α_1	1072	1^-	18.787	(1970JO1C)
12.951 [f,h]	α_1	1894	2^+	19.026	(1970JO1C)
12.990 [f]	α_1	416	4^+	19.060	(1970JO1C)
13.080 [f]	α_1	477	7^-	19.140	(1970JO1C)
13.307 [f]	α_1	911	6^+	19.342	(1970JO1C)
13.366 [f]	α_1	483	2^+	19.394	(1970JO1C)
14.35 ± 100	α_1	≈ 300		20.27	(1971JA04)
14.95 ± 100	α_1	≈ 550		20.80	(1971JA04)

[a] Maxima at lower energies are reported by (1965LO03, 1968NG1B).
[b] See also (1962CA20, 1965LO03, 1968NG1B, 1969DU11).
[c] See also (1959LO59).
[d] See also (1968MA53).
[e] For this and the following levels, see also (1959AJ76).
[f] Isospin mixed state: See (1970JO1C). Resonances in italics are definitely real: their influence on the S-matrix elements is certain and the ambiguities in the S-matrix elements do not allow the effect to be redistributed into other partial waves; and the interference effects are relatively small. All widths for states identified by the footnote [f] are uncertain to $\geq 10\%$ and the resonance energies are uncertain to $\geq 10\%$ of the widths (P. L. Jolivette, private communication).
[g] These are the main components of the 2^+ strength from $3.4 < E_d < 4$ MeV. The resonances are not well defined and the shape can probably be built up from a different set of levels (1970JO1C).
[h] Possibly should be broken up into several more levels but data are insufficient (1970JO1C).
[i] P.L. Jolivette, private communication.

The yield of elastically scattered deuterons has been measured for $E_d \leq 13.0$ MeV: see Table 18.16 (1963AM1A, 1963SE12, 1964AM1A, 1967AL06, 1968DI06, 1968MA53, 1969CO12, 1970DA14). Fluctuations are observed. Some of the maxima are interpreted in terms of ^{18}F states: for these see Table 18.17 (1956BE1B, 1963AM1A, 1964AM1A, 1968MA53). See also (1963DO1B, 1966AL09, 1970VE06, 1971GA1D, 1971SC1Q) and ^{16}O in (1971AJ02). For polarization measurements, see (1969CO12, 1970CO1P, 1971KO21) and Table 18.16.

16. ^{16}O(d, α)^{14}N $\qquad Q_m = 3.110 \qquad E_b = 7.527$

The yields of various groups of α-particles have been measured for $E_d \leq 20$ MeV: see Table 18.16 (1960AM03, 1962CA20, 1963AM1A, 1963SE12, 1963YA1B, 1964AM1A, 1964KI05, 1965LO03, 1965MA59, 1965SA18, 1967TH1E, 1968DI06, 1968JO07, 1968TH1J, 1969CO12,

1969JO09, 1969JO1M, 1969AL13, 1970JO1G, 1970JO1C, 1971JA04, 1971TH03). See also (1963DO1B, 1970CA1C) and (1969NO1C, 1971SC1Q; theor.).

The yield curves have been fitted in terms of a large number of states in ^{18}F: see Table 18.17 (1956BR36, 1957BA14, 1960AM03, 1963AM1A, 1964AM1A, 1965MA59, 1968JO07, 1969JO09, 1969JO1C, 1970JO1C, 1971JO11). See also (1970JO1F). A detailed study by (1970JO1C) of the isospin-forbidden α_1 yield shows that there are no very strong states seen for $J > 5$, and those seen in $J = 7$, the highest partial wave needed to fit the yield, are wide, $\Gamma \approx 300$ keV. This contradicts the prediction that isospin violation should be negligable for low spin states while large for those with high J. See also (1971JO11). The average coherence width is ≈ 150 keV for $12 < E_x < 15.5$ MeV (1968JO07).

For the isospin-forbidden α_1 yield, virtually all the observed levels overlap several others of the same spin and parity in the tail of the resonance. The α_1 yield has a smaller cross section than the yield of ^{14}N(α, α_1)^{14}N at the same E_x in ^{18}F [see (1970TO03)]. This is most pronounced at high excitation energy and is thought to be related to the very small binding energy of the deuteron. Thus reaction 8 appears to be a better tool to study ^{18}F at high E_x (1970JO1C).

For polarization studies, see (1970PR1C, 1971KE1E). See also ^{14}N. Very accurate cross section measurements of the ^{16}O(d, α)^{14}N reaction and of its inverse, ^{14}N(α, d)^{16}O, are consistent with the principle of detailed balance. The lowest uncertainty was $\pm 0.5\%$. An upper limit of 0.2% is assigned to the time-reversal non-invariant part of the reaction amplitudes (1971TH03).

17. ^{16}O(t, n)^{18}F $\qquad Q_m = 1.269$

Measurements of the strengths and of lifetimes of the radiative decays are displayed in Tables 18.14 and 18.15 (1963LI07, 1966AL04). (1966AL04) report that ΔE_x $(1.13 \rightarrow 0.94) = 194 \pm 1$ keV: E_x of ^{18}F*(1.13) is then 1131.0 ± 1 keV [based on $E_x = 937.0 \pm 0.2$ keV]. See also (1967WA1C) and (1959AJ76).

18. ^{16}O(^{3}He, p)^{18}F $\qquad Q_m = 2.033$

Excitation energies derived from measurements of proton spectra (1959HI67, 1959YO25, 1967MA1G, 1968GR1G, 1968GR1H, 1968MA33) and of γ-rays (1960RA18, 1961DU02, 1965CH10, 1967WA06) are displayed in Table 18.18.

Angular distributions of proton groups have been obtained at $E(^3\text{He}) = 4.00$ MeV (1964MA50), 5.9 and 9.2 MeV (1959HI74), 15 MeV (1968PO1B, 1969PO11), 18 MeV (1967PU03, 1971BE19) and 19.8 MeV (1967MA1G, 1968MA33). Distorted wave analyses lead to the l-assignments shown in Table 18.18. (1960JA11) have compared the angular distribution they obtained for the ^{16}O(t, p)^{18}O reaction to ^{18}O(0) with the angular distributions obtained by (1959HI74) for ^{18}F*(1.04, 1.08) in this reaction. It is clearly ^{18}F*(1.04) which is the analog to the ground state of ^{18}O: J^π is then 0^+ and $T = 1$.

Table 18.18: States of ^{18}F from ^{16}O(^{3}He, p)^{18}F

E_x (MeV ± keV)							l [f]	$J^{\pi}; T$ [g]
(1959HI67) [a]	(1959YO25) [a]	(1960RA18, 1961DU02) [c]	(1965CH10) [c]	(1967WA06) [c]	(1968GR1G, 1968GR1H) [a]	(1967MA1G, 1968MA33) [a]		
0	0					0	0	$1^+; 0$
0.934 ± 10	0.943 ± 7	0.939 ± 5	0.9374 ± 1.5	0.9370 ± 1	[e]	0.937 ± 8	2	$3^+; 0$
1.038 ± 10	1.047 ± 7	1.041 ± 5	1.0446 ± 1.5	1.0413 ± 1.5			0	$0^+; 1$
1.076 ± 10 [b]	1.089 ± 7	1.070 ± 20	1.0817 ± 1.5	1.0803 ± 1				$0^-; 0$
1.119 ± 10	1.128 ± 7	1.170 ± 10 [d]	(1.1197 ± 2)		1.120 ± 5	1.111 ± 7	4	$5^+; 0$
1.698 ± 10	1.708 ± 7	1.680 ± 20	1.7035 ± 2	1.7003 ± 1.5	[e]	1.680 ± 24	0	$1^+; 0$
2.096 ± 10	2.102 ± 7	2.090 ± 10	2.1026 ± 2	2.1005 ± 1.5	[e]	2.096 ± 13		$2^-; 0$
2.517 ± 10	2.521 ± 10	2.510 ± 10	2.5297 ± 2	2.5235 ± 1.5	[e]	2.509 ± 18	2	$2^+; 0$
3.055 ± 10	3.058 ± 10	3.060 ± 50		3.0603 ± 3		3.062 ± 15	2	$2^+; 1$
3.128 ± 10	3.130 ± 10	3.110 ± 50		3.1339 ± 3				$1^-; 0$
3.352 ± 10	3.355 ± 10	3.350 ± 100	(3.3505 ± 3)	3.3581 ± 3		3.352 ± 16		$(3)^+$
3.715 ± 10	3.724 ± 10			3.7248 ± 3				$1^+; 0$
3.783 ± 10								$(3^-); 0$
3.830 ± 10	3.843 ± 10	3.840 ± 100		3.8385 ± 3.5	[e]	3.830 ± 12	2	$2^+; 0$
4.108 ± 10					4.120 ± 5	4.134 ± 11		$\leq 3; 0$
4.218 ± 10					4.232 ± 5			(2)
4.350 ± 15					4.362 ± 5	4.378 ± 9		2, 3
					4.403 ± 5			$\geq 2; 0$
					4.659 ± 5	4.651 ± 12	4	$4^+; 1$
					4.739 ± 5			$0^+; 1$
					4.852 ± 5	4.843 ± 12		1; 0
					4.955 ± 5	4.967 ± 21		$2^+; 1$
						5.297 ± 25		$T = 0$
						5.601 ± 12		$(4^+); 0$
						6.105 ± 8		
						6.265 ± 13		(1^+)
						6.779 ± 7		$2^-; 0$
						7.206 ± 9		(1^+)
						7.646 ± 14		$T = 0$
						7.874 ± 22		$(2^-); 0$
						9.145 ± 32		
						9.404 ± 31		
						9.82 ± 40		
						10.06 ± 45		
						10.352 ± 25		
						10.96 ± 60		
						11.13 ± 50		

[a] From measurements of proton groups.
[b] (1958KU81) report $E_x = 1.080 \pm 0.010$ MeV.
[c] From measurements of γ-rays.
[d] The transition $1.13 \rightarrow 0.94$ is observed: $E_{\gamma} = 189 \pm 4$ keV (1960RA18).
[e] Observed but E_x not determined.
[f] (1959HI74, 1967PU03, 1968PO1B, 1969PO11).
[g] See discussion in (1968MA33) and Table 18.14.

The magnetic moment of ^{18}F*(1.13), $\mu = +(0.568 \pm 0.013)J$ (1967PO09), $+(0.572 \pm 0.006)J$ (1967SC09). If $J = 5$, and all data are consistent with this assignment, $\mu = 2.855 \pm 0.030$ nm. This value is in agreement with shell-model predictions for a 5^+ state remaining from $1d^2_{5/2}$ (1967PO09).

The γ-decay of many states has been studied: Table 18.14 displays observed branching ratios and radiative widths. Studies of these parameters, coupled with angular correlation and γ-ray angular distribution studies (1961KU02, 1965PO01, 1966CH06, 1966CH12, 1966OL03, 1967GO07, 1967OL03, 1967PO02, 1967WA06), lifetime measurements [see Table 18.15 (1959AL99, 1963LO03, 1966OL03, 1967BE14, 1967PO09, 1967WA06, 1970BL1F)] and the l-values shown in Table 18.18 lead to the J^π assignments displayed in Table 18.14. See also (1963HI06).

The linear polarization of the 2.10 MeV γ-ray [$2.10 \to 0$], together with the mixing ratio obtained by (1967GO07), leads to an assignment of negative parity to ^{18}F*(2.10), and also to ^{18}F*(1.08). The latter results from the value of $\tau_{\rm m}$ for ^{18}F*(2.10) and the observation of a $P_4(\cos\,\theta)$ term in the $2.10 \to 1.08$ transition (1967PO02).

See also (1964MA57, 1966AG1B, 1970CA28), (1959FA1A) and (1960NE1A; theor.).

19. ^{16}O(α, d)^{18}F $\qquad Q_{\rm m} = -16.321$

At $E_\alpha = 40$ to 52 MeV, deuteron spectra are dominated by the groups to ^{18}F*(1.13), $J^\pi = 5^+$ [$1d^2_{5/2}$ configuration] (1962HA40, 1966RI04, 1967MA1G, 1968MA33). Many other states of ^{18}F have also been observed: see Table 18.19 (1966RI04, 1967MA1G, 1968MA33). For configuration assignments, see (1968MA33). See also (1960AG01), (1969BR1D) and (1963GL1C, 1965GR1F, 1967IM1A; theor.).

20. ^{16}O(^{6}Li, α)^{18}F $\qquad Q_{\rm m} = 6.053$

Angular distributions of the α-particles to the ground state of ^{18}F have been measured at $E(^6{\rm Li}) = 5.5$ to 13.3 MeV (1968GR1H, 1968GR22) and at 26 MeV (1969DA19). The lifetime of ^{18}F*(4.36) is < 0.61 psec (1969TH01): the γ-ray energy for the transition $4.36 \to 3.06$, $E_\gamma = 1297.4 \pm 2.5$ keV. Assuming $E_{\rm x} = 3.0598$, the energy of ^{18}F*(4.36), $E_{\rm x} = 4.357 \pm 0.004$ MeV (1969TH01). See also (1967CA1D).

21. ^{16}O(^{11}B, ^{9}Be)^{18}F $\qquad Q_{\rm m} = -8.290$

See (1966PO1E, 1967PO1E).

22. ^{16}O(^{14}N, ^{12}C)^{18}F $\qquad Q_{\rm m} = -2.746$

See (1966GA10, 1969BR1D, 1969RO1G, 1970AN1D).

Table 18.19: States of ^{18}F from ^{16}O(α, d)^{18}F [a]

E_x (MeV $\pm$ keV)	$J^\pi; T$
0.0	1^+; 0
0.934 ± 14	3^+; 0
1.119 ± 16	5^+; 0
1.716 ± 18	1^+; 0
2.100 ± 11	2^-; 0
2.541 ± 19	2^+; 0
3.122 ± 14	1^-; 0
3.363 ± 20	$(3)^+$; 0
3.808 ± 12	2^+; 0
4.140 ± 12	≤ 3; 0
4.393 ± 9	≥ 2; 0
4.852 ± 10	1; 0
5.266 ± 34	$T = 0$
5.590 ± 27	(4^+); 0
5.785 ± 31	$T = 0$
6.139 ± 12	$T = 0$
6.548 ± 18	$(\leq 5^+)$; 0
6.807 ± 10	2^-; 0
7.191 ± 8	(4^+); 0
7.434 ± 13	(3^-); (0)
7.658 ± 12	$(T = 0)$
7.871 ± 11	(2^-); 0
8.596 ± 19	$T = 0$
8.861 ± 190	$(T = 0)$
9.494 ± 15	$T = 0$ [b]
9.96 ± 120	$T = 0$
10.268 ± 12	
10.541 ± 10	$(T = 0)$
11.073 ± 37	$T = 0$
11.384 ± 18	$T = 0$
12.055 ± 16	$T = 0$

Table 18.19: States of ^{18}F from ^{16}O(α, d)^{18}F [a] (continued)

E_x (MeV $\pm$ keV)	$J^\pi; T$
12.67 ± 60	$T = 0$

[a] (1967MA1G, 1968MA33). See also (1962HA40, 1966RI04).
[b] $J^\pi = (6^-)$ (1966RI04).

23. ^{17}O(p, γ)^{18}F $Q_m = 5.609$

The yield of 0.94 MeV γ-rays (γ_1) has been measured for $E_p = 0.2$ to 1.5 MeV. A number of resonances are observed: see Table 18.20 (1969ZA1C, 1971BE1E, 1971SE1H). A strong resonance for 1.04 MeV γ-rays (γ_2) is observed, corresponding to ^{18}F*(6.14) (1969ZA1C, 1971SE1H). A study of this resonance shows that ^{18}F*(6.14) has $J^\pi = 0^+$. The parity of ^{18}F*(3.72) is found to be even (1970RO1F).

Branching ratios for the decay of ^{18}F* states with $6.09 < E_x < 6.87$ MeV are displayed in Table 18.15. DSAM measurements show $\tau_m < 15$ fsec for these states. From the γ-decay of the resonant states, accurate excitation energies have been determined for a number of low-lying states: $E_x = 0.9369 \pm 0.2, 1.041 \pm 1, 1.121 \pm 0.4, 1.700 \pm 1, 2.1013 \pm 0.5, 2.523 \pm 1, 3.136 \pm 2, 4.650 \pm 1$ and 4.965 ± 1 MeV ($\pm$keV) (1971SE1H).

24. ^{17}O(p, n)^{17}F $Q_m = -3.542$ $E_b = 5.609$

The yields of n_0, measured for $E_p = 7$ to 13.5 MeV, and of n_1, measured for $E_p = 7$ to 12.5 MeV, show some gross structures (1969AN06). See also (1965BL07).

25. ^{17}O(p, p)^{17}O $E_b = 5.609$

The elastic scattering has been studied for $E_p = 0.5$ to 1.33 MeV (1971SE1J) and for $E_p = 11.0$ to 13.0 MeV (1967AL06): observed anomalies are displayed in Table 18.20 (1971SE1J).

26. ^{17}O(p, α)^{14}N $Q_m = 1.193$ $E_b = 5.609$

The yield of ground state α-particles shows a number of resonances for $E_p = 0.49$ to 3.0 MeV: see Table 18.20 (1957AH20, 1962BR08, 1971SE1J). Astrophysical considerations are discussed by (1962BR08, 1967FO1B).

Table 18.20: Resonances in $^{17}O + p$

E_p (MeV ± keV)	Yield of	$\Gamma_{c.m.}$ (keV)	$J^\pi; T$	E_x (MeV)	Refs.
0.515 ± 2	γ_1, α_0	< 2.0	$4^-; 0$	6.095	(1962BR08, 1969ZA1C, 1971BE1E, 1971SE1H)
0.557 ± 2	γ_2		$0^+; (1)$	6.135	(1969ZA1C, 1970RO1F, 1971SE1H, 1971SE1J)
0.585 ± 1	γ_1, p_0	15	$3^+; 1$	6.161	(1969ZA1C, 1971SE1H, 1971SE1J)
0.668 ± 2	γ_1, α_0, p_0	< 2.0	3^- [a]	6.240	(1962BR08, 1969ZA1C, 1971SE1H, 1971SE1J)
0.690	α_0			6.260	(1971SE1J)
0.711 ± 1	γ_1, p_0	7.5	$2^+; 1$	6.280	(1969ZA1C, 1971SE1H, 1971SE1J)
0.742 ± 2	γ_1, α_0, p_0	3.1 ± 1.4	$2^+, 3^+$	6.309	(1962BR08, 1969ZA1C, 1971SE1H, 1971SE1J)
0.822 ± 3	γ_1, α_0	< 4.5	$(1^+), 2, 3^-$	6.385	(1962BR08, 1969ZA1C, 1971SE1H, 1971SE1J)
0.926 ± 3	γ_1, α_0	< 1.2	$(1^+), 2, 3^-$	6.483	(1962BR08, 1969ZA1C, 1971SE1H, 1971SE1J)
1.096 ± 6	α_0	85 ± 5		6.644	(1962BR08)
1.100 ± 1	γ_1, α_0, p_0	< 3.0	(2^-) [a]	6.647	(1957AH20, 1962BR08, 1969ZA1C, 1971SE1H, 1971SE1J)
1.245 ± 1	$\gamma_1, \alpha_0, p_0, p_1$	10 ± 3	$4^+, 5^+; 0$	6.780	(1962BR08, 1969ZA1C, 1971SE1H, 1971SE1J)
1.270 ± 3	$\gamma_1, \alpha_0, p_0, p_1$	5 ± 3	$2^+, 3^+$	6.808	(1969ZA1C, 1971SE1H, 1971SE1J)
1.270 ± 5	α_0	79 ± 5		6.808	(1957AH20, 1962BR08, 1971SE1J)
1.337 ± 2	γ_1, α_0, p_1			6.871	(1962BR08, 1971SE1H)
1.786	α_0	≈ 65		7.295	(1957AH20)
2.021	α_0	11		7.517	(1957AH20)
2.048	α_0	90		7.542	(1957AH20)
2.218	α_0	11		7.703	(1957AH20)
2.235	α_0	100		7.719	(1957AH20)
2.406	α_0	≈ 25		7.880	(1957AH20)
2.435	α_0	≈ 25		7.908	(1957AH20)
2.623	α_0	≈ 40		8.085	(1957AH20)
2.753	α_0	≈ 15		8.208	(1957AH20)
2.775	α_0	≈ 10		8.228	(1957AH20)
2.928	α_0	≈ 50		8.373	(1957AH20)

[a] Mixed $T = 0$ and 1.

27. ^{17}O(d, n)^{18}F $Q_m = 3.384$

At $E_d = 4.4$ MeV angular distributions of the neutrons corresponding to ^{18}F*(0.94, 2.52, 3.06, 3.36, 3.84, 4.96, 5.61, 5.67) have been measured. The cross section for formation of ^{18}F*(5.61) is an order of magnitude greater than for ^{18}F*(5.67), consistent with the interpretation that these (1^-) states contain a substantial isospin admixture (1971GA1B, 1971LI1D). See also (1971AR33). For a lifetime measurement, see Table 18.15 (1971LE29). See also ^{19}F.

28. ^{17}O(^{3}He, d)^{18}F $Q_m = 0.115$

At $E(^3\mathrm{He}) = 15$ MeV, DWBA analysis of angular distributions of deuteron groups corresponding to the ground state of ^{18}F [$l = 2$] and to the excited states of 0.94 [$l = 0 + 2$], 1.04 [2]. 1.12 [2], 2.53 [$0 + 2$], 3.06 [$0 + 2$], 3.84 [$0 + 2$], 4.12 [$0 + 2$], 4.66 [2] and 4.96 MeV [$0 + 2$] have been obtained by (1968PO1B, 1969PO11) who also report spectroscopic information. Thus all these states have even parity and ^{18}F*(4.12) may be assigned $J^\pi = (2^+)$ or 3^+. Since $l = 2$ for ^{18}F*(4.66), $J^\pi \leq 5^+$, with 4^+ most likely (1969PO11).

29. ^{17}O(α, t)^{18}F $Q_m = -14.205$

Not reported.

30. ^{18}O(p, n)^{18}F $Q_m = -2.438$

$$E_{\mathrm{thresh.}} = 2.57372 \pm 0.00077 \text{ (1964BO13)};$$
$$E_{\mathrm{thresh.}} = 2.577 \pm 0.003 \text{ (1967PR04)};$$
$$E_{\mathrm{thresh.}} = 2.576 \pm 0.001,\ Q_0 = -2.439 \pm 0.001 \text{ (1969BE57). See also (1959AJ76).}$$

Gamma rays are observed with $E_\gamma = 938 \pm 6$, 1043 ± 8 and 1082 ± 10 keV (1960RA18). See also (1968BE34). The lifetime of ^{18}F*(1.04) is 4^{+3}_{-2} fsec (1967BL18). Angular distributions have been measured at $E_p = 6.9$ to 13.5 MeV (n_0, $n_{1\to4}$), 6.9 to 9.25 MeV (n_5), 7.55 to 9.25 MeV (n_6), 7.95 to 9.25 MeV (n_7) and 8.4 to 13.5 MeV (n_8) (1969AN06). See also (1965BL07, 1967WI1H, 1971TH1D) and (1969SC1H; theor.). See also ^{19}F.

31. ^{18}O(^{3}He, t)^{18}F $Q_m = -1.674$

Table 18.21: Branching in ^{18}Ne(β^+)^{18}F

Decay to ^{18}F*	E_γ (keV)	Branch (%)	log ft [a]	Refs.
g.s.		92.5 ± 0.2		(1970AS06)
1.04	1041 ± 5	7 ± 2		(1961BU05)
	1035 ± 5			(1961EC02)
	1030 ± 20	9 ± 3		(1963FR10, 1964FR1B, 1965FR09)
	1043 ± 1			(1968GO05)
		7.3 ± 0.2		(1970AS06)
	1042.6 ± 1.0	7.3 ± 0.2		mean value
1.08		< 0.7		(1968GO05)
1.70		0.17 ± 0.05		(1970AS06)
2.10		< 1.5		(1968GO05)

[a] Based on Q_m and $\tau_{1/2} = 1.67 \pm 0.02$ sec: see Table 18.24.

At $E(^3\text{He}) = 16$ MeV, the triton spectrum is dominated by strong groups to the ground and 0.94 MeV excited states and to the 0^+ and 2^+; $T = 1$ states at $E_x = 1.04$ and 3.06 MeV. Angular distributions have been measured and analyzed by DWBA for the tritons corresponding to these states and to ^{18}F*(1.08, 1.13, 1.70, 2.10, 3.13, 3.36, 3.72, 3.79, 3.84, 4.12, 4.23, 4.36, 4.40, 4.66, 4.74). The angular distributions are consistent with the J^π assignments shown in Table 18.14, except for the distribution to ^{18}F*(1.04) (1970DU08). At $E(^3\text{He}) = 17.3$ MeV, angular distributions to ^{18}F states with $E_x < 4$ MeV have been analyzed using DWBA and a two-body interaction between the incident and target nucleons. An exact coupled-channel calculation was also made for the transition to ^{18}F*(1.04) (1968HA30, 1969HA1U, 1969MA1G). See also (1971HE1F).

32. ^{18}Ne(β^+)^{18}F $\qquad Q_m = 4.447$

The decay is to ^{18}F*(0, 1.04, 1.70): see Table 18.21 for the branching ratios and log ft values. See also ^{18}Ne.

33. ^{19}F(γ, n)^{18}F $\qquad Q_m = -10.431$

See ^{19}F.

34. ^{19}F(n, 2n)^{18}F $Q_{\rm m} = -10.431$

See ^{20}F.

35. (a) ^{19}F(p, d)^{18}F $Q_{\rm m} = -8.206$
(b) ^{19}F(p, pn)^{18}F $Q_{\rm m} = -10.431$

Angular distributions have been measured of the ground state deuterons at $E_{\rm p} = 16$ and 18 (1967AN1B, 1968AN1A, 1971AN1B), 17.5 (1969HAZD), 18 (1956RE04), 18.6 (1961BE12), 30.3 (1967DI1C) and 155.6 MeV (1966BA44): $l_{\rm n} = 0$. (1969HAZD) also reports angular distributions at $E_{\rm p} = 17.5$ MeV to the ^{18}F states at $E_{\rm x} = 0.94$ [$l_{\rm n} = 2$], 1.04 [0], 1.08 [1], 1.13, 1.70 [0], 2.10 [(1)], 2.53 [2], 3.06 [2], 3.13 [1], 3.36 [2], 3.8 (unresolved), 4.12, 4.23, $4.36 + 4.40$, 4.66 and 5.6 MeV. Spectroscopic factors are also listed. Similar results are reported by (1967AN1B, 1968AN1A, 1971AN1B). See also (1961BE12, 1966BA44). See also (1961LE1A, 1962CO17) and (1969BE1T, 1969DO08; theor.). For reaction (b), see (1968DE21).

36. ^{19}F(d, t)^{18}F $Q_{\rm m} = -4.173$

Angular distributions of triton groups are reported at $E_{\rm d} = 8.9$ MeV (1957EL12; t_0, t_1, t_3) and 14.8 MeV (1959HA1E, 1960HA22; t_0). See also (1959VL23) and (1963DA1B, 1963OG1A, 1964DA1D, 1964EL1B; theor.).

37. ^{19}F(^{3}He, α)^{18}F $Q_{\rm m} = 10.147$

At $E(^3{\rm He}) = 5.9$ MeV, 41 α-particle groups have been observed, corresponding to the ground state of ^{18}F and to excited states with $E_{\rm x} < 7.5$ MeV (1959HI67): see Table 18.22. Angular distributions of the α-particles corresponding to ^{18}F*(3.06, 3.13) are reported by (1966MA43; $E(^3{\rm He}) = 4.0$, 6.0 and 8.0 MeV): $l = 2$ and 1, respectively. See also (1964BR1G, 1966HA21, 1966HO1E, 1971BA2A).

Alpha-α_0 angular correlations measured in the range $E(^3{\rm He}) = 5.0$ to 6.0 MeV establish $J^\pi = 1^-$ for both ^{18}F*(5.61, 5.67): $\Gamma_\alpha/\Gamma \approx 1$ (1971LI27).

38. ^{19}F(^{10}B, ^{11}B)^{18}F $Q_{\rm m} = 1.025$

See (1968GA03, 1970GO1B, 1971KN05).

Table 18.22: Energy levels of ^{18}F from ^{19}F(^{3}He, α)^{18}F

E_x [a] (MeV $\pm$ keV)	E_x [a] (MeV $\pm$ keV)
0	4.965 ± 13
0.940 ± 10	5.292 ± 10
1.042 ± 10	5.500 ± 10
1.087 ± 10	5.603 ± 13
1.129 ± 10	5.666 ± 10
1.699 ± 10	5.785 ± 10
2.105 ± 10	6.093 ± 10
2.525 ± 10	6.137 ± 10
3.063 ± 10	6.232 ± 10
3.131 ± 10	6.264 ± 13
3.352 ± 10	6.374 ± 10
3.727 ± 10	6.470 ± 10
3.790 ± 10	6.551 ± 10
3.841 ± 10	6.633 ± 10
4.116 ± 10	6.765 ± 10
4.227 ± 10	6.790 ± 10
4.358 ± 10	6.857 ± 10
4.400 ± 10	7.183 ± 10
4.649 ± 10	7.313 ± 10
4.741 ± 10	7.495 ± 10
4.840 ± 10	

[a] (1959HI67): $E(^3\text{He}) = 5.9$ MeV.

39. (a) ^{19}F(^{14}N, ^{15}N)^{18}F $Q_m = 0.403$

(b) ^{19}F(^{19}F, ^{20}F)^{18}F $Q_m = -3.829$

For reaction (a) see (1965GA1B, 1971GA13); for reaction (b) see (1971GA13).

40. ^{20}Ne(n, t)^{18}F $Q_m = -14.793$

Not reported.

41. ^{20}Ne(p, ^{3}He)^{18}F $Q_m = -15.557$

At $E_p = 45$ MeV, ^{3}He groups are observed to ^{18}F*(0, 1.04, 1.70, 3.06, 6.27 ± 0.03) (1969HA38). See also (1968FA1G, 1970OL1B).

42. ^{20}Ne(d, α)^{18}F $Q_m = 2.796$

At $E_d = 11$ MeV α-groups are observed to many states of ^{18}F with $E_x < 7$ MeV. Weak or absent (each $\leq 0.3\%$ of the total yield at $30°$) are the groups corresponding to ^{18}F*(1.04, 3.06, 4.66, 4.74, 4.96): $T = 1$ for these states (1968PO1B, 1969PO11). However, (1971HR1A) report a significant yield (as high as 30% of the yield to the $J^\pi = 2^+$; $T = 0$ state at 2.52 MeV) for the 2^+; 1 state at 3.06 MeV in the range $E_d = 6$ to 10 MeV. The yield is particularly large in the range $E_d = 6$ to 8 MeV. Angular distributions are reported at 2 MeV (1966LA15; α_0, α_1, α_2, α_5, α_6), 4 MeV (1964MA50; α_0, α_5, α_6, α_7, α_8, α_9, α_{10}), 6.75, 7.37 and 8 MeV (1971HR1A; α_7, α_8, α_9), and 14.7 MeV (1962TA07; α_0, $\alpha_{1\rightarrow 4}$, α_5, α_6, α_7). See also (1951MI1A, 1961LO10, 1964MA57) and (1966BR1G, 1966KU1D, 1969DE29).

43. ^{21}Ne(p, α)^{18}F $Q_m = -1.740$

Not reported.

^{18}Ne

(Figs. 3 and 4)

GENERAL:

Shell and cluster model calculations: (1957WI1E, 1969BE1T, 1970BA2E, 1970EL08, 1970HA49, 1972KA01).

Electromagnetic transitions: (1970EL08, 1970HA49).

Special levels: (1966MI1G, 1969KA29, 1972KA01).

Pion reactions: (1965PA1F).

Other theoretical calculations: (1965GO1F, 1966KE16, 1967VA31, 1968BA2H, 1968BE1V, 1968MU1B, 1968NE1C, 1968VA24, 1969BA1Z, 1969GA1G, 1969KA29, 1969MU09, 1969RA28, 1969SO08, 1970BA1Z, 1970DI1G, 1970EL08, 1972KA01).

1. ^{18}Ne(β^+)^{18}F $\qquad Q_{\rm m} = 4.447$

The half-life of ^{18}Ne is 1.67 ± 0.02 sec: see Table 18.24 (1970AL11, 1970AS06). The decay is to ^{18}F*(0, 1.04, 1.70) with $J^\pi = (1^+); T = (0)$, (0^+; 1), (1^+; 0), respectively: the branching ratios and $\log ft$ values are displayed in Table 18.21. The ratio of the ft values for the ^{18}Ne $\rightarrow$ ^{18}F(0) and ^{18}F $\rightarrow$ ^{18}O transitions is 0.992 ± 0.015 (1970AL11): see also (1969KA1B, 1970AS06). See also (1966ZA03, 1968BO1U, 1968FR03, 1970MC23, 1971BL12, 1971DE1E).

2. ^{16}O(^{3}He, n)^{18}Ne $\qquad Q_{\rm m} = -3.196$

$Q_0 = -3.206 \pm 0.013$ (1961DU02);

$Q_0 = -3.199 \pm 0.006$ (1961TO03).

Excitation energies of ^{18}Ne states derived from neutron spectra and γ-ray measurements are displayed in Table 18.25 (1961TO03, 1968GI09, 1969RO08, 1970AD02, 1970NE1J, 1970NE1N, 1970SH04). Branching ratios and lifetimes of the first four excited states of ^{18}Ne are shown in Table 18.26 (1968GI09, 1969RO08, 1969RO22, 1970SH04, 1971RO18, 1972GI01). Table 18.27 summarizes the neutron angular distribution studies. Angular correlation studies, together with PWBA and DWBA double stripping analysis of neutron angular distributions, and the branching ratio and lifetime measurements, lead to assignments of $J^\pi = 0^+, 2^+, 4^+, 0^+$ and 2^+ for ^{18}Ne*(0, 1.89, 3.38, 3.58, 3.62), respectively (1968GI09, 1968TO09, 1969RO08, 1969RO22, 1970AD02, 1970SH04, 1971RO18, 1972GI01). It is also suggested that ^{18}Ne*(4.58) has $J^\pi = 0^+$ and a predominantly two-particle structure (1970NE1J). See also (1961BU05, 1961EC02, 1963FR10, 1964BR13, 1964FR1B, 1965BR1H, 1965FR09, 1968GO05, 1970AL11, 1970AS06), (1969BA1Z) and (1964HE06; theor.).

Table 18.23: Energy levels of ^{18}Ne [a]

E_x (MeV ± keV)	$J^\pi; T$	τ or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
0	$0^+; 1$	$\tau_{1/2} = 1.67 \pm 0.02$ sec	β^+	1, 2, 3
1.8873 ± 0.2	2^+	$\tau_m = 0.49^{+0.17}_{-0.09}$ psec	γ	2, 3
3.3762 ± 0.4	4^+	4.4 ± 0.6 psec	γ	2, 3
3.576 ± 2	0^+	$2 < \tau_m < 6$ psec	γ	2, 3
3.6164 ± 0.6	2^+	$0.063^{+0.030}_{-0.020}$ psec	γ	2, 3
4.510 ± 10	(1^-)	$\Gamma \leq 40$		2, 3
4.580 ± 10	(0^+)	≤ 40		2, 3
5.075 ± 13		≤ 60		2, 3
5.135 ± 12		≤ 60		2, 3
6.30 ± 20		180 ± 60		2, 3
7.062 ± 12	$(2^+, 1^-)$	180 ± 50		2
7.712 ± 20		≤ 50		2
7.915 ± 12	$(2^+, 1^-)$	≤ 50		2, 3
8.100 ± 14		≤ 50		2, 3
8.50 ± 30		≤ 120		2
9.20 ± 20				3

[a] See also Table 18.26.

Table 18.24: The half-life of ^{18}Ne

$\tau_{1/2}$ (sec)	Refs.
1.6 ± 0.2	(1954GO17)
1.7 ± 0.4	(1961EC02)
1.46 ± 0.07	(1961BU05)
1.47 ± 0.10	(1963FR10, 1964FR1B, 1965FR09)
1.67 ± 0.02	(1970AL11)
1.69 ± 0.04	(1970AS06)
1.67 ± 0.02	Weighted average of last two values

Table 18.25: Excitation energies from $^{16}O(^{3}He, n)^{18}Ne$

E_x (MeV ± keV)					Γ (keV) [d]	J^{π} [d]
(1961TO03)	(1968GI09, 1969RO08)	(1970AD02)	(1970NE1J, 1970NE1N) [d]	(1970SH04)	c.m.	
0	0	0		0		
1.880 ± 10	1.8873 ± 0.2	[a]		1.890 ± 2		
3.362 ± 11	3.3762 ± 0.4	3.375 ± 15		3.383 ± 4		
	3.5763 ± 2.0	3.564 ± 20				
3.608 ± 12	3.6164 ± 0.6	3.610 ± 15		3.623 ± 3		
		4.505 ± 15 [b]	4.513 ± 13			
		4.571 ± 15 [b]	4.587 ± 13 [e]			$0^{+}(1^{-})$
			5.075 ± 13 [f]		≤ 60	
		5.14 ± 20 [c]	5.135 ± 12 [f]		≤ 60	
			6.291 ± 30		180 ± 60	
			7.062 ± 12		180 ± 50	$(2^{+}, 1^{-})$
			7.712 ± 20		≤ 50	
			7.915 ± 12		≤ 50	$(2^{+}, 1^{-})$
			8.100 ± 14		≤ 50	
			8.50 ± 30		≤ 120	

[a] Observed but energy not determined.

[b] $\Gamma \leq 40$ keV.

[c] No other narrow states observed with $E_x < 7.5$ MeV (1970AD02).

[d] A. Nero, private communication.

[e] (1968TO09) report $E_x = 4.59 \pm 0.03$ MeV, $\Gamma \leq 130$ keV; the 4.51 MeV state was not resolved.

[f] One of these two states has $J^{\pi} = 3^{-}$.

Table 18.26: Branching ratios and lifetimes of ^{18}Ne states

E_i (MeV)	J^{π}_i	E_f (MeV)	Branch (%)			τ_m (psec)
			(1968GI09, 1969RO08, 1972GI01)	(1969RO22)	(1970SH04)	
1.887	2^+	0	100			$0.49^{+0.17}_{-0.09}$ [a]
3.376	4^+	0	< 4	< 1	< 1	$1.9^{+1.0}_{-0.4}$ [a]
		1.887	100	100	100	4.4 ± 0.6 [b]
3.576	0^+	0	< 17	< 5		> 2 [a]
		1.887	100	100		< 6 [b]
3.616	2^+	0	12.5 ± 2.5	7 ± 2	< 3	
		1.887	87.5 ± 2.5	93 ± 2	100	$0.063^{+0.030}_{-0.020}$ [a]

[a] (1968GI09, 1969RO08).
[b] (1972GI01).

Table 18.27: ^{16}O(^{3}He, n)^{18}Ne angular distribution studies

E(^{3}He) (MeV)	Distribution of neutron groups to ^{18}Ne*	Refs.
4.9, 5.2, 5.6	g.s.	(1967MC03)
5.51	g.s.	(1960AJ03)
5.6, 6.1	g.s.	(1961GA01)
9.0 – 11.5	3.38, 3.58 + 3.62	(1970AD02)
9.0 – 12.5	g.s., 1.89	(1970AD02)
9.15	g.s., 3.38, 3.58 + 3.62	(1968TO09)
10.15	g.s., 3.38, 3.58 + 3.62, 4.58	(1968TO09)
11	g.s., 1.89	(1966KR05, 1967KR1B)
11.5, 12.5	4.51 + 4.58, 5.08 + 5.13	(1970AD02)
13.8 – 17.8	g.s., 1.89, 3.5, 4.5, 5.1, 6.29, 7.06, 7.71, 7.92, 8.10, 8.50	(1970NE1N)

Table 18.28: States in ^{18}Ne from ^{20}Ne(p, t)^{18}Ne [a]

E_x (MeV ± keV)				L [b]	J^π
(1969HA38)	(1970FA17)	(1970LE08)	(1971PA1L)		
0	0	0	0	0	0^+
1.890 ± 20	1.89	1.83 ± 50	1.894 ± 10	2	2^+
3.375 ± 30	3.38	3.36 ± 50	3.390 ± 14	4	4^+
3.588 ± 25	3.61	3.58 ± 50	3.614 ± 13	0	0^+
4.580 ± 30	4.53 ± 20	4.46 ± 50	4.576 ± 17	1	1^-
5.115 ± 25	5.10 ± 20	5.12 ± 50	5.150 ± 14	$2 + 3$	$(2^+ + 3^-)$
	6.28 ± 20		6.326 ± 18	4	(4^+)
			7.957 ± 25		
	9.17 ± 30		9.215 ± 20		

[a] See, however, Table 18.25 for states not resolved in this reaction.

[b] (1970FA17, 1970LE08, 1971PA1L). See also (1969HA38).

3. ^{20}Ne(p, t)^{18}Ne $\qquad Q_m = -20.022$

Transitions have been reported to nine states of ^{18}Ne at $E_p = 42.6$ to 50 MeV. L values derived from DWBA analysis of angular distributions are displayed in Table 18.28 (1969HA38, 1970FA17, 1970LE08, 1971PA1L). See also (1968PA1R, 1970OL1B) and (1969SO08; theor.).

^{18}Na

(Not illustrated)

A calculation using an isobaric mass formula predicts that the mass excess of ^{18}Na is 25.4 ± 0.4 MeV (1966KE16): ^{18}Na is then unbound with respect to proton emission by 1.6 MeV. See also (1965JA1C).

References

(Closed 31 December 1971)

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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