Energy Levels of Light Nuclei
$A = 18$

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Abstract: An evaluation of $A = 18$–20 was published in *Nuclear Physics A*300 (1978), 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}Be

(Not illustrated)

^{18}Be has not been observed: it is predicted to have a mass excess of 78.43 MeV (1976JA23; and see (1976WA18)). ^{18}Be is then unstable with respect to breakup into ^{16}Be + 2n, ^{15}Be + 3n, ^{14}Be + 4n, ^{13}Be + 5n, ^{12}Be + 6n, ^{11}Be + 7n and ^{10}Be + 8n by, respectively, 3.02, 3.01, 5.42, 2.88, 4.99, 1.75 and 1.25 MeV (using the (1976WA18) masses for the residual nuclei). See also (1974TH01).

^{18}B

(Not illustrated)

^{18}B has not been observed: it is predicted to have a mass excess of 53.85 MeV. ^{18}B is then unstable with respect to ^{17}B + n by 1.39 MeV (1976JA23; and see (1976WA18)). See also (1974TH01) and (1975BE31; theor.).

^{18}C

(Not illustrated)

^{18}C is particle stable. It has been observed in the bombardment of ^{232}Th by 122 MeV ^{18}O ions (1969AR13) and by 172 MeV ^{22}Ne ions (1975VO09) and in the 4.8 GeV proton irradiation of uranium (1974BO05). At $E_{\rm p} = 4.8$ GeV, the production cross section is ≈ 100 μb (1974BO05). See also (1972AJ02).

The atomic mass excess of ^{18}C is calculated to be 25.37 MeV by (1977WA08), and we adopt this value. The binding energy of a neutron in ^{18}C is then 3.76 MeV and of two neutrons is then 4.46 MeV, using the (1977WA08) masses for ^{17}C and ^{16}C. For other recent mass calculations of ^{18}C see (1974TH01, 1975JE02, 1976JA23). See also (1972TH13, 1973TO16, 1976WA18, 1977AR06, 1977BH1B) and (1971ST40, 1973WI15, 1975BE31, 1976BE1G; theor.).

^{18}N

(Figs. 1 and 4)

GENERAL: (See also (1972AJ02).)

See (1972GA1F, 1973TO16, 1973WI15, 1974TH01, 1975BE31, 1977AR06).

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

Table 18.1: Energy levels of ^{18}N

E_x (MeV)	$J^\pi; T$	$\tau_{1/2}$ (sec)	Decay	Reactions
0	$(0, 1, 2)^-; 2$	0.63 ± 0.03	β^-	1, 2, 3, 4
(≈ 7.5)				2

The half-life of ^{18}N is 0.63 ± 0.03 sec (1964CH19): E_β(max) $= 9.4 \pm 0.4$ MeV. The decay is to ^{18}O*(4.46), which subsequently decays via ^{18}O*(3.63, 1.98) [see reaction 21 in ^{18}O]. The allowed nature [$\log ft = 4.88$] of the decay to the 1^- state at 4.46 MeV leads to $J^\pi = 0^-$, 1^- or 2^- for the ^{18}N ground state (1964CH19).

2. ^{18}O(π^-, γ)^{18}N $\qquad Q_m = 125.51$

Preliminary results show the excitation of the ^{18}N ground state and of another group with $E_x \approx 7.5$ MeV (1976TR1A).

3. ^{18}O(n, p)^{18}N $\qquad Q_m = -13.27$

See (1964CH19).

4. ^{18}O(t, ^{3}He)^{18}N $\qquad Q_m = -14.04$

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

^{18}O
(Figs. 1 and 4)

GENERAL: (See also (1972AJ02).)

Shell model: (1970FL1A, 1970SA1M, 1971KU1F, 1972BB07, 1972EN03, 1972GA02, 1972LE13, 1972MC1C, 1972PR08, 1972WA09, 1973BA1Q, 1973IG02, 1973JU1A, 1973LA1D, 1973MA1K, 1973MC06, 1973SA32, 1973SM1C, 1973TR09, 1973VA05, 1973VA1D, 1974AV05, 1974DE50, 1974KU1F, 1974LO04, 1974TR07, 1974WA17, 1974WE1J, 1974WR1A, 1975BA81, 1975DR01, 1975LE1H, 1975SA04, 1976DE13, 1976PI01, 1976SZ1A, 1977GO1U, 1977IB01, 1977SA13, 1977SH11, 1977VA1E, 1977VA1F).

Cluster, collective and deformed models: (1972NE1B, 1973AB01, 1974AV05, 1974TR07, 1975DR01, 1976AM03, 1976LA13, 1976PI14, 1977ER01, 1977IB01, 1977LE14, 1977SA13).

Electromagnetic transitions and giant resonances: (1970FL1A, 1970SI1J, 1972EN03, 1973CO1F, 1973HA1N, 1973HO29, 1974DE50, 1974LO04, 1974MC1F, 1974TR07, 1975HO20, 1976LA13, 1976SH04, 1976VO1C, 1977BR03, 1977ER01, 1977KN1F, 1977MO1V, 1977SA13).

Special states: (1972BB07, 1972EN03, 1972GA02, 1972HI17, 1972HO13, 1972LE13, 1972RA08, 1973BA1Q, 1973HO29, 1973JU1A, 1973KN1C, 1973MC06, 1973VA05, 1973VI11, 1974BA20, 1974BA71, 1974BO22, 1974CO25, 1974HO1F, 1974KI1B, 1974WE1J, 1975BA81, 1975GL03, 1975LO1G, 1976DE13, 1976EI02, 1976FE09, 1976HO14, 1976LA13, 1976PI01, 1976PI14, 1976PR07, 1976SZ1A, 1976VI1D, 1977ER01, 1977HA2D, 1977SA13, 1977SA05, 1977SH11, 1977VA1E, 1977VA1F).

Astrophysical questions: (1972CL1A, 1972CO1E, 1972UL1A, 1973AR1E, 1973AU1B, 1973AU1C, 1973EN1A, 1973TA1D, 1974BE1R, 1974SC1F, 1975AU1D, 1975CO1J, 1975EN1A, 1975LA1E, 1975TR1A, 1976BO1M, 1976FI1E, 1976KO1K, 1976ME1H, 1976WA1M, 1977CL1H, 1977CO1U, 1977HA2C, 1977NO1E, 1977TO1J).

Applied work: (1976GR1J).

Muon and pion capture and reactions: (1974EN10, 1974KA07, 1974LI1D, 1974LI1N, 1974TA18, 1975EI02, 1975LI04, 1976AL1L, 1976CO1V, 1976EN02, 1976HEZU, 1976TR1A, 1977AL1C, 1977HE1M, 1977IV1B, 1977MA02, 1977RO1U, 1977SI01).

Complex reactions involving ^{18}*O:* (1972MI11, 1973KO1D, 1973WI15, 1974KO25, 1975GL03, 1975LE1J, 1975RE17, 1975TA1C, 1975TS01, 1975VO09, 1976EI02, 1976GL06, 1976HI05, 1976LA04, 1976MO10, 1976PEZY, 1976VI01, 1977AR06, 1977BA3T, 1977BE10, 1977BO2F, 1977FE04, 1977GL03, 1977LO1L, 1977PE08, 1977RE1C).

Other topics: (1970SI1J, 1971KU1F, 1971ST40, 1972BA23, 1972CA37, 1972GA02, 1972GO17, 1972HO13, 1972KU1C, 1972MC1C, 1972PR08, 1972RA08, 1972TS02, 1973BE35, 1973CO1F, 1973GO1H, 1973IG02, 1973KR16, 1973MA48, 1973PA1F, 1973SA24, 1973SA32, 1973ST25, 1973TR09, 1973VA05, 1973VI11, 1974BA20, 1974BO22, 1974CO25, 1974HO1F, 1974KI1B,

1974KI1C, 1974KU1F, 1974RE03, 1974SA05, 1974SE1B, 1974SH09, 1974SH1G, 1974UH1A, 1974WA17, 1974ZU1A, 1975BA2F, 1975BA81, 1975HE10, 1975HE1H, 1975LE1H, 1975LO1G, 1975MI02, 1975SA04, 1975SH1H, 1975ST03, 1976BA2G, 1976HO14, 1976KR1D, 1976MA04, 1976OF1A, 1976PA03, 1976PI01, 1976PR07, 1976VI1D, 1977GO1T, 1977SA05, 1977SH11, 1977SH13, 1977SO11, 1977VA1E).

Table 18.2: Energy levels of ^{18}O [a]

E_x (MeV ± keV)	$J^\pi; T$	τ_m (psec) or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
0	$0^+; 1$		stable	2, 3, 4, 5, 8, 9, 11, 12, 19, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45
1.98216 ± 0.20	2^+	$\tau_m = 2.9 \pm 0.1$ $g = -0.287 \pm 0.015$	γ	2, 3, 4, 5, 8, 11, 12, 19, 21, 24, 25, 26, 27, 30, 33, 34, 35, 38, 39, 41, 42
3.55507 ± 0.45	4^+	$\tau_m = 24.8 \pm 1.2$ $g = -0.62 \pm 0.10$	γ	3, 5, 8, 11, 12, 13, 14, 19, 24, 25, 26, 27, 30, 34, 35, 39, 42
3.63450 ± 0.40	0^+	$\tau_m = 1.38 \pm 0.16$	γ	3, 5, 8, 12, 19, 21, 24, 25, 26, 27, 30, 34, 35, 38, 39, 41, 42
3.9206 ± 0.4	2^+	0.024 ± 0.010	γ	5, 8, 12, 19, 24, 25, 26, 27, 30, 34, 38, 42
4.4561 ± 0.5	1^-	0.065 ± 0.015	γ	8, 11, 12, 19, 21, 26, 27, 30, 34, 36, 38, 41, 42
5.0985 ± 1.2	3^-	0.062 ± 0.025	γ	8, 11, 12, 19, 24, 25, 26, 27, 30, 34, 36, 42
5.2604 ± 1.2	2^+	0.12 ± 0.03	γ	5, 8, 12, 19, 24, 25, 26, 30, 41, 42
5.3364 ± 0.6	0^+	0.20 ± 0.04	γ	12, 19, 24, 25, 27, 30, 41, 42
5.3778 ± 1.2	3^+	< 0.03	γ	12, 19, 25, 27, 42
5.5305 ± 0.6	2^-	< 0.025	γ	11, 12, 25, 26, 30, 42

Table 18.2: Energy levels of ^{18}O [a] (continued)

E_x (MeV $\pm$ keV)	$J^\pi; T$	τ_m (psec) or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
6.201 ± 2	1^-	$(3.2 \pm 0.6) \times 10^{-3}$	γ	11, 12, 19, 23, 30, 42
6.3513 ± 0.6	1, 2	< 0.035	γ	11, 12, 19, 30, 42
6.4044 ± 1.2	3^-	0.03 ± 0.015	γ	12, 30, 42
6.8816 ± 1.2	(0^-)	< 0.025	γ	30, 38, 41, 42
7.1169 ± 1.2	4^+	< 0.025	γ, α	5, 8, 11, 19, 26, 30, 34, 36, 42
7.620 ± 2	1^-	$\Gamma < 2.5$	γ, α	5, 30, 42
7.75 ± 20	$1 \rightarrow 4$		γ	42
7.848 ± 14				8, 11, 19, 30, 42
7.96 ± 20	$(3^+, 4^-)$		γ	19, 42
8.040 ± 2	1^-	< 2.5	γ, α	5, 7, 42
8.122 ± 10	5^-		γ, α	5, 8, 11, 42
8.214 ± 4	2^+	1.0 ± 0.8	n, α	6, 7, 30, 42
8.283 ± 3	3^-	8 ± 1	n, α	6, 7, 8, 30, 42
8.405 ± 7		8 ± 6	n, α	6, 42
8.48 ± 20				11, 42
8.64 ± 20				42
8.817 ± 12		70 ± 12	n, α	6, 7, 30
8.956 ± 4		43 ± 3	n, α	6, 7, 30
(9.03)				7, 30
(9.10)				7, 30
9.362 ± 15		27 ± 15	n, α	6, 7, 8, 11, 30
9.39 ± 40		≈ 120	n, α	6, 7, 8, 30
9.47 ± 40		≈ 65	n, α	6, 7
9.676 ± 10		60 ± 30	n, α	6, 7, 30
(9.72 ± 30)				30
9.88 ± 40		≈ 150	n, α	6, 7, 30
10.119 ± 10	3^-	16 ± 4	n, α	6, 7, 30
10.29 ± 20	4^+		n, α	6, 7, 8, 30
10.38 ± 20	3^-		n, α	6, 7, 30

Table 18.2: Energy levels of ^{18}O [a] (continued)

E_x (MeV ± keV)	$J^\pi; T$	τ_m (psec) or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
10.58 ± 20			n, α	6, 7, 11
10.82 ± 20			n, α	6, 7
10.91 ± 20			n, α	6, 7, 8
10.99 ± 20			n, α	6, 7
11.13 ± 20			n, α	6, 7, 8, 11, 41
11.39 ± 20	(2^+)		n, α	6, 7
11.41 ± 20	(4^+)		n, α	6, 7
11.62 ± 20	5^-		n, α	6, 7, 8, 30
11.69 ± 20	6^+		n, α	6, 7, 8, 11, 30
11.82 ± 20	(3^-)		n, α	6, 7
12.04 ± 20	(2^+)		n, α	6, 7
12.25 ± 20	(1^-)		n, α	6, 7, 41
12.33 ± 20	5^-		n, α	6, 7, 8
12.50 ± 20	4^+		n, α	6, 7
12.53 ± 20	6^+		n, α	6, 7, 8, 11
12.9			γ, n	22
13.8			γ, n	11, 22
14.6 ± 100			γ, n	11, 22, 41
15.6			γ, n	22
(15.95)				11
(16.40 ± 30)	$T = 2$	≤ 50		26
(17.02 ± 30)	$T = 2$	≤ 50		11, 26
(19.0)				11
23.4 [b]			γ, n, p	22

[a] See also Tables 18.3 and 18.4.
[b] Giant resonance (1976FA1F).

Ground state of ^{18}*O:* (1970SI1J, 1973HO29, 1973HO32, 1973LE07, 1973MC06, 1973SP1A, 1973VA1D, 1974DE50, 1974DE1E, 1974EN10, 1974MC1F, 1974RE03, 1974SH1G, 1975AL19, 1975BE31, 1975MI02, 1976AS07, 1976BE1G, 1976CH1T, 1976CO1V, 1976PA03, 1977AN21, 1977BR03, 1978FO05, 1977IB01).

^{18}O*(1.98):

$$g = |0.287 \pm 0.015| \text{ (1976AS04)};$$

$$g = -0.35 \pm 0.04 \text{ (1975FO03, 1975SP03)};$$

$Q = -0.073 \pm 0.027$ b $\cdot\, e$ (1977FL10)† ; -0.100 ± 0.030 b $\cdot\, e$ (1977FE04). See also (1977VO07).;

$$B(\text{E2}; 0^+_0 \rightarrow 2^+_1) = 0.00453 \pm 0.00025 \text{ b}^2 \cdot e^2 \text{ (1977FL10)}.$$

See also (1974SHYR, 1975KL09, 1976ARZX, 1976EN03, 1976FU06, 1976VI01, 1977KL1D). Relative spectroscopic factors for ^{18}O†(0, 1.98, 3.56):

1: 0.69 ± 0.06: 1.67 ± 0.17 (1976EI02).

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 $\quad Q_m = 4.759$
   (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 $\quad Q_m = 8.402$

Angular distributions have been measured at $E(^7\text{Li}) = 3.24$ to 3.64 MeV (1967MO23: p_0, p_1) and 16 and 18 MeV (1974FO1H; prelim.). See also (1974FO1J).

3. ^{13}C(^{7}Li, d)^{18}O $\quad Q_m = 5.680$

Gamma-ray energies of 1982.3 ± 0.8 [$1.98 \rightarrow 0$], 1571.9 ± 2.5 [$3.56 \rightarrow 1.98$], 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. ^{13}C(^{17}O, ^{12}C)^{18}O $\quad Q_m = 3.098$

Angular distributions have been studied at $E_{\text{c.m.}} = 12.9$ and 14 MeV for the transitions to ^{18}O*(0, 1.98) (1977CH22).

† Assuming constructive interference from the coupling through the second 2^+ state (1977FL10).

Table 18.3: Radiative decays in ^{18}O [a]

E_i (MeV)	J_i^π	E_f (MeV)	Branch (%)		Refs.
1.98	2^+	0	100	$\delta = 0$ [c]	
3.56	4^+	1.98	100	$\delta = 0$	(1973BE48, 1973OL02)
3.63	0^+	0		$\Gamma_\pi/\Gamma = (3.0 \pm 0.6) \times 10^{-3}$	(1975SO05)
		1.98	100	$\delta = 0$ [c]	(1973BE48, 1973OL02)
3.92	2^+	0	12 ± 5		(1971BE45)
			13 ± 3		(1973OL02)
			17 ± 2	$\delta = 0$ [c]	(1973BE48)
			15 ± 2		mean
		1.98	88 ± 5		(1971BE45)
			87 ± 3	$\delta = 0.12 \pm 0.04$ [c,A]	(1973OL02)
			83 ± 2	$\delta = 0.19 \pm 0.08$	(1973BE48)
			85 ± 2		mean
4.46	1^-	0	< 1		[a]
		1.98	32 ± 5		(1971BE45)
			25 ± 4	$\delta = -(0.09 \pm 0.36)$ [c,A]	(1973OL02)
			28 ± 2 [A]	$\delta \leq -0.17$; or > 5.7	(1973BE48)
		3.63	68 ± 5		(1971BE45)
			75 ± 4	$\delta = 0$	(1973OL02)
			72 ± 2 [A]		(1973BE48)
5.10	3^-	0	< 5		(1971BE45)
		1.98	75 ± 3		(1971BE45)
			71 ± 4	$\delta = 0$ [c,A]	(1973OL02)
			78 ± 2	$\delta = -0.04 \pm 0.05$; or 3.7 ± 0.6	(1973BE48)
			76 ± 2		mean
		3.56	9 ± 3		(1971BE45)
			11 ± 3	$\delta = (0)$	(1973OL02)
			6 ± 2		(1973BE48)
			8 ± 2		mean
		3.92	16 ± 3		(1971BE45)
			18 ± 4	$\delta = (0)$	(1973OL02)
			16 ± 2 [A]		(1973BE48)
5.26	2^+	0	32 ± 3		(1971BE45)
			32 ± 2 [A]	$\delta = 0$ [c]	(1973BE48)
		1.98	68 ± 3		(1971BE45)
			68 ± 2 [A]	$\delta = 0.15 \pm 0.04$ [c]	(1973BE48)
		3.56	< 4		(1967MO09)
		3.63	< 3		(1967MO09)

Table 18.3: Radiative decays in ^{18}O [a] (continued)

E_i (MeV)	J_i^π	E_f (MeV)	Branch (%)		Refs.
		3.92	< 5		(1967MO09)
		4.46	< 4		(1967MO09)
5.34	0^+	0		$\Gamma_\pi/\Gamma \leq 2.3 \times 10^{-3}$	(1975SO05)
				$\delta = 0$ [c]	
		1.98	61 ± 2		(1971BE45)
			54 ± 5		(1973OL02)
			60 ± 2		mean
		3.92	< 5		(1973OL02)
		4.46	39 ± 2		(1971BE45)
			46 ± 5	$\delta = 0$	(1973OL02)
			40 ± 2		mean
5.38	3^+	0	< 2		(1967MO09)
		1.98	88 ± 3		(1967MO09)
			85 ± 3	$\delta = 0.00 \pm 0.05$ [c]	(1973OL02)
			86.5 ± 2.2		mean
		3.56	< 3		(1967MO09)
		3.92	12 ± 3		(1967MO09)
			15 ± 3	$\delta = (0)$	(1973OL02)
			13.5 ± 2.2		mean
5.53	2^-	1.98	48 ± 4	$\delta = 0.00 \pm 0.02$ [c]	(1973OL02)
			48 ± 2 [A]	[b]	(1973BE48)
		3.92	26 ± 4	$\delta = (0)$	(1973OL02)
			23 ± 2		(1973BE48)
			24 ± 2		mean
		4.46	26 ± 4	$\delta = 0.00 \pm 0.04$ [c]	(1973OL02)
			29 ± 2		(1973BE48)
			28 ± 2		mean
6.20	1^-	0	88 ± 2		(1973BE48)
		1.98	≤ 10		(1973BE48)
		4.46	6 ± 2		(1973BE48)
		$5.26 + 5.34$	6 ± 2		(1973BE48)
6.35	1, 2	1.98	29 ± 3	$\delta = (0)$	(1973OL02)
			34 ± 2	[b]	(1973BE48)
			32 ± 2		mean value
		3.92	58 ± 3	$\delta = (0)$	(1973OL02)
			53 ± 2		(1973BE48)
			55 ± 2		mean value
		4.46	13 ± 3	$\delta = (0)$	(1973OL02)

Table 18.3: Radiative decays in ^{18}O [a] (continued)

E_i (MeV)	J_i^π	E_f (MeV)	Branch (%)		Refs.
			11 ± 2		(1973BE48)
			12 ± 2		mean value
6.40	3^-	1.98	90 ± 5 [A]	$\delta = 0$ [c]	(1971BE45)
		3.92	10 ± 5 [A]	$\delta = (0)$ [c]	(1971BE45)
6.88	(0^-)	4.46	100	$\delta = 0$ [c]	(1973OL02, 1973BE48)
7.12 [d]	4^+	1.98	26 ± 2	$\delta = -(0.035 \pm 0.020)$	(1967LE02)
			40 ± 10		(1973OL02)
			29 ± 2	$\delta = -(0.052 \pm 0.035)$	(1973BE48)
			27.7 ± 1.5		mean
		3.56	70 ± 3	$\delta = -(0.035 \pm 0.020)$	(1967LE02)
			60 ± 10		(1973OL02)
			71 ± 2	$\Gamma_\gamma/\Gamma_\alpha = 0.9 \pm 0.1$ [b]	(1973BE48)
			70.4 ± 1.7		mean value
		3.92	4 ± 1		(1967LE02)
		4.45	≤ 15		(1967CH1D, 1973BE48)
		5.09	≤ 15		(1967CH1D, 1973BE48)
7.62	1^-	0	24 ± 2		(1967LE02)
		1.98	62 ± 3	$\Gamma_\alpha\Gamma_\gamma/\Gamma = 0.34$ eV [e]	(1967LE02)
		3.56	< 15		(1958PH37)
		3.92	< 15		(1958PH37)
		4.46	8 ± 1		(1967LE02)
		5.34	6 ± 1		(1967LE02)
		6.20	< 2		(1967LE02)
7.75		1.98	50 ± 2	[b]	(1973BE48)
		4.46	11 ± 2		(1973BE48)
		5.10	39 ± 2		(1973BE48)
		5.26	≤ 10		(1973BE48)
		5.38	≤ 10		(1973BE48)
		6.35	≤ 10		(1973BE48)
		6.40	≤ 10		(1973BE48)
7.96	$(3^+, 4^-)$	3.56	67 ± 2	[b]	(1973BE48)
		5.10	12 ± 2		(1973BE48)
		5.38	21 ± 2		(1973BE48)
		6.40	≤ 15		(1973BE48)
8.04	1^-	0	16 ± 1		(1967LE02)
		1.98	68 ± 3	$\Gamma_\alpha\Gamma_\gamma/\Gamma = 0.89$ eV [e]	(1967LE02)
		3.56	< 15		(1958PH37)
		3.63	11 ± 1		(1967LE02)

Table 18.3: Radiative decays in ^{18}O [a] (continued)

E_i (MeV)	J^π_i	E_f (MeV)	Branch (%)		Refs.
		3.92	< 15		(1958PH37)
		5.26	5 ± 1		(1967LE02)
8.12	5^-	3.56	> 95	$\Gamma_\alpha \Gamma_\gamma / \Gamma = 0.22$ eV [e]	(1967LE02)

A = adopted.
[a] See Table 18.2 in (1972AJ02) for the earlier work.
[b] For discussion of δ see (1973BE48).
[c] See Table IV in (1973OL02).
[d] For values of $\Gamma_\alpha \Gamma_\gamma / \Gamma$ see Table 18.2 in (1972AJ02).
[e] For all transitions from this state.

5. ^{14}C(α, γ)^{18}O $\qquad Q_m = 6.2279$

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 18.5.

Gamma-ray angular distribution and correlation measurements lead to $J^\pi = 4^+, 1^-, 1^-$ and 5^- for ^{18}O*(7.12, 7.62, 8.04, 8.13), as well as to J^π assignments for lower states involved in the cascade decay: see Table 18.3 (1958GO1A, 1958PH37, 1966LE1B, 1967LE02). See also (1973CL1E, 1973MI1D, 1975KA1L; astrophys. questions).

6. ^{14}C(α, n)^{17}O $\qquad Q_m = -1.8167 \qquad E_b = 6.2279$

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 18.5 (1956SA06, 1966BA03, 1970MO13).

7. ^{14}C(α, α)^{14}C $\qquad E_b = 6.2279$

Observed anomalies in the scattering for $E_\alpha = 2$ to 8.2 MeV are shown in Table 18.5 (1958WE29, 1970MO13). The yield of elastic scattering has been measured up to $E_\alpha = 16.5$ MeV (1970MO13). See also (1973OE01) and ^{14}C in (1976AJ04).

8. ^{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, 7.12, 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). See also (1974DO03; theor.).

Table 18.4: Lifetime measurements of some ^{18}O states

^{18}O* (MeV)	τ_m (psec)	Reaction	Refs.
1.98	3.35 ± 0.20	^{16}O(t, p)	(1974MC17)
	3.10 ± 0.20	^{3}H(^{16}O, p)	(1977LIZS)
	2.81 ± 0.11	^{3}H(^{16}O, p)	(1975HE25, 1977HE12)
	2.99 ± 0.12	^{18}O(p, p)	(1976AS04)
	3.58 ± 0.18	^{18}O(α, α)	(1974BE25)
	2.9 ± 0.1		best
3.56	46.2 ± 3	^{16}O(t, p)	(1974CO01)
	24.5 ± 3.3	^{16}O(t, p)	(1974MC17)
	24.8 ± 1.3	^{18}O(α, α)	(1974BE25)
	24.8 ± 1.2		mean of last two values
3.63	1.45 ± 0.25	^{3}H(^{16}O, p)	(1973WA19)
	1.33 ± 0.20	^{19}F(t, α)	(1973OL02)
	1.38 ± 0.16		mean
3.92	0.024 ± 0.010	^{19}F(t, α)	(1973OL02)
4.46	0.065 ± 0.015	^{19}F(t, α)	(1973OL02)
5.10	0.062 ± 0.025	^{19}F(t, α)	(1973OL02)
5.26	0.12 ± 0.03	^{19}F(t, α)	(1973OL02)
5.34	0.20 ± 0.04	^{19}F(t, α)	(1973OL02)
5.38	< 0.03	^{19}F(t, α)	(1973OL02)
5.53	< 0.025	^{19}F(t, α)	(1973OL02)
6.20	$(3.2 \pm 0.6) \times 10^{-3}$	^{18}O(γ, γ)	(1974HA15)
6.35	< 0.035	^{19}F(t, α)	(1973OL02)
6.40	0.03 ± 0.015	^{19}F(t, α)	(1973OL02)
6.88	< 0.025	^{19}F(t, α)	(1973OL02)
7.12	< 0.025	^{19}F(t, α)	(1973OL02)

[a] See Table 18.3 in (1972AJ02) for some earlier measurements.

Table 18.5: 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	8.040	1^-	(1958PH37, 1958WE29, 1966LE1B, 1967LE02)
2.440 ± 12		γ	8.125	5^-	(1966LE1B, 1967LE02)
2.554 ± 4	1.3 ± 1	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	8.956 [g]		(1956SA06, 1958WE29, 1966BA03)
4.030 ± 15	35 ± 20	n, (α_0)	9.362		(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)	9.676		(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	[c]	n, α_0	12.25	$(0^+, 1^-)$	(1970MO13)
7.85	[b]	n, α_0	12.33	5^-	(1970MO13)
8.06	[b]	n, α_0	12.50	4^+	(1970MO13)
8.10	[b]	n, α_0	12.53	6^+	(1970MO13)

[a] For the first four states, see also Table 18.3.
[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).

9. ^{14}C(^{16}O, ^{12}C)^{18}O $\qquad Q_m = -0.9341$

Angular distributions at $E(^{16}\text{O}) = 20$, 25 and 30 MeV have been studied by (1973SC24, 1975SC35).

10. (a) ^{15}N(t, α)^{14}C $\qquad Q_m = 9.6066 \qquad E_b = 15.8345$
(b) ^{15}N(α, p)^{18}O $\qquad Q_m = -3.9796$

Excitation functions have been measured for α_0 and α_1 for $E_t = 0.8 - 1.7$ MeV (1973AB1E; unpublished). Some broad structures may be indicated. See also (1972AJ02). For reaction (b) see (1974NI1A; theor.).

11. ^{15}N(^{6}Li, ^{3}He)^{18}O $\qquad Q_m = 0.041$

At $E(^6\text{Li}) = 40$ MeV many groups are observed to ^{18}O states with $E_x < 20.5$ MeV: high-spin states are preferentially excited (1977MA1B, 1977MA2G; prelim.: see Table 18.2).

12. ^{16}O(t, p)^{18}O $\qquad Q_m = 3.7069$

Proton groups corresponding to states of ^{18}O are displayed in Table 18.6. Angular distributions have been measured at many energies to $E_t = 10.15$ MeV: see Table 18.6 in (1972AJ02) and (1974KA1N: 2.0 and 3.0 MeV; p_0 and p_3; abstract). Analysis of spectroscopic factors suggest that ^{18}O*(5.34) $[0_3^+]$ is largely $(s_{1/2})^2$ while ^{18}O*(3.63) $[0_2^+]$ has a dominantly collective nature as does ^{18}O*(5.25) $[2_3^+]$ (1974FO14, 1976LA13): see (1976LA13) for a general discussion of the properties of the states of ^{18}O. See also (1977MO1W).

Lifetime measurements are reported in Table 18.4 (1963LI07, 1973WA19, 1974CO01, 1974MC17, 1975HE25, 1977HE12, 1977LIZS). See also (1974WA1F, 1977HE1D). See also (1972AJ02) and (1972BR11, 1973FE06, 1974BA71, 1974BO22, 1975IB01; theor.).

Table 18.6: States in ^{18}O from ^{16}O(t, p)^{18}O

E_x (MeV ± keV)		L [b]	J^π
(1960JA17)	(1962HI06)		
0	0	0	0^+
1.979 ± 5	1.980 ± 5	2	2^+
3.552 ± 5	3.549 ± 5	3 or 4	3^- or 4^+
3.634 ± 5	3.627 ± 5	0	0^+
3.915 ± 5	3.915 ± 5	2	2^+
4.448 ± 5	4.449 ± 5	(3)	[c]
	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 19.

13. ^{16}O(α, 2p)^{18}O $\qquad$ $Q_m = -16.1071$

At $E_\alpha = 65$ MeV, the (α, ^{2}He) reaction populates ^{18}O*(3.56) [$J^\pi = 4^+$]. This reaction appears to preferentially populate $(d_{5/2})^2_{4+}$ states (1976JA13).

14. (a) ^{16}O(^{10}B, ^{8}B)^{18}O $\qquad$ $Q_m = -14.824$

(b) ^{16}O(^{12}C, ^{10}C)^{18}O $\qquad$ $Q_m = -19.6569$

At $E(^{12}\text{C}) = 114$ MeV, the population of ^{18}O*(3.56) is reported (1971SC1F, 1972SC21). In reaction (a) at $E(^{10}\text{B}) = 100$ MeV the reaction preferentially populates this state also [first $(d_{5/2})^2_{4+}$ state] (1977HA2E; prelim.).

15. ^{17}O(n, γ)^{18}O $\qquad Q_{\rm m} = 8.0446$

See (1972AJ02).

16. ^{17}O(n, n)^{17}O $\qquad E_{\rm b} = 8.0446$

The coherent scattering length (thermal, bound) is 5.78 ± 0.15 fm (1968VA1C). See also (1973MU14).

17. ^{17}O(n, p)^{17}N $\qquad Q_{\rm m} = -7.898 \qquad E_{\rm b} = 8.0446$

See (1972AJ02, 1974CA1J).

18. ^{17}O(n, α)^{14}C $\qquad Q_{\rm m} = 1.8167 \qquad E_{\rm b} = 8.0446$

The thermal cross section is 235 ± 10 mb: see (1973MU14). See also (1972AJ02).

19. ^{17}O(d, p)^{18}O $\qquad Q_{\rm m} = 5.8199$

Proton groups have been observed to ^{18}O states with $E_{\rm x} < 8$ MeV. Angular distributions have been obtained for $E_{\rm d} = 3.6$ to 18 MeV and spectroscopic factors have been obtained: see Table 18.7 (1965MO16, 1966WI07, 1975DR04, 1976LI01). See also the discussion in (1977PE08). At $E_{\rm d} = 18$ MeV (1976LI01) find that the results are consistent with a weak-coupling model. See also (1976SC36; theor.). Proton-gamma coincidence measurements by (1967MO09) are displayed in Table 18.3. See also (1972AJ02).

20. ^{17}O(^{17}O, ^{16}O)^{18}O $\qquad Q_{\rm m} = 3.900$

See (1972AJ02).

21. ^{18}N(β^-)^{18}O $\qquad Q_{\rm m} = 14.06$

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

E_x (MeV ± keV)		l_n [c]	J^{π} [c]	S [d]	S [e]
(1965MO16)	(1966WI07, 1976LI01) [b]				
0	0	2	0^+	1.22	1.35
1.982 ± 10	1.98	$0+2$	2^+	$0.21+0.83$	$0.16+0.85$
3.552 ± 10	3.56	2	4^+	1.57	1.18
	3.63	2	0^+	0.28	0.18
	3.92	$0+2$	2^+	$0.35+0.66$	0.28
	4.46	1	1^-	0.03	
	5.10	3	3^-	0.03	
5.255 ± 10	5.26	0	2^+	0.35	0.23
	5.34	2	0^+	0.16	< 0.20
5.375 ± 10	5.38	0	3^+	1.01	0.74
	6.20	1	1^-	0.03	
	6.35	1	$\leq 3^{(-)}$	$0.03-0.04$	
7.110 ± 15	7.12	2	4^+		0.13
7.855 ± 20					
7.962 ± 20					

[a] See also Table 18.7 in (1972AJ02).
[b] Nominal E_x.
[c] (1965MO16, 1966WI07, 1975DR04, 1976LI01).
[d] (1976LI01): $E_d = 18$ MeV.
[e] Based on (1965MO16 [5.6 MeV], 1966WI07 [10 MeV]): average of values quoted by (1976LI01); normalized to the ground-state value shown. See also (1975DR04).

The decay is to ^{18}O*(4.46): 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*(4.46) to ^{18}O*(3.63, 1.98) and the subsequent decay of these two states (1964CH19).

22. (a) ^{18}O(γ, n)^{17}O $\quad Q_m = -8.0446$
(b) ^{18}O(γ, 2n)^{16}O $\quad Q_m = -12.1889$
(c) ^{18}O(γ, p)^{17}N $\quad Q_m = -15.942$
(d) ^{18}O(γ, α)^{14}C $\quad Q_m = -6.2279$

Differential cross sections have been measured at $98°$ for the n_0 and n_1 groups for $E_x = 10$ to 17 MeV: structures are reported at $E_x = 10.2$, 10.4. 11.1, *11.4*, 11.6, 12.2, 12.9, *14.4*, *15.4* and *16.5* MeV (1975AL03: bremsstrahlung). [The first italicized structure is the strongest in the n_1 yield, the last three in the n_0 yield.] Preliminary work from threshold to 42 MeV also shows strong structures in the (γ, n) and (γ, 2n) cross section; the most prominent occur at 10.2, 11.3, 12.9, 13.6, 14.5 and 15.5 MeV. The main dipole giant resonance is centered at 23.3 MeV (1976BE1H, 1976FA1F, 1976KN07). The decay of the GDR to ^{14}C, ^{16}O, ^{17}N and ^{17}O states has been studied by (1976BA41). See also (1977KN1F; theor.).

Reaction (c) has been measured with monoenergetic photons from threshold to 30 MeV and shows peaks at $E_\gamma = 17.3$, 19.2, 20.8, 23.4 and 27.5 MeV. The measured integrated cross section is 29.8 MeV $\cdot$ mb up to 30.6 MeV (1976BE20). See also (1972DO19) and (1972AJ02).

23. ^{18}O(γ, γ)^{18}O

The width of ^{18}O*(6.20) is 0.18 ± 0.03 eV, assuming $\Gamma_{\gamma 0}/\Gamma = 0.88$; $E_x = 6202.7 \pm 0.8$ keV (1974HA15).

24. ^{18}O(e, e)^{18}O

The ^{18}O charge radius, $r_{\text{rms}} = 2.789 \pm 0.027$ fm (1973FE13, 1975SC18; analysis by a phase shift calculation assuming a harmonic oscillator shell model charge distribution). See also the earlier values by (1970SI02, 1970SI1K, 1971SC29).

At $E_e = 92.5$ and 105.9 MeV, and assuming B(E2) for the 1.98 MeV transition is 9.0 $e^2\cdot$ fm^4, the results of (1971GR33) are consistent with $B(\text{E2}) = (1.7)$ and $4.8 \pm 0.5\ e^2 \cdot$ fm^4 for ^{18}O*(3.92, 5.26), with $B(\text{E3}) = 160 \pm 15\ e^2\cdot$ fm^6 for ^{18}O*(5.10) and with $\Gamma_\pi(0^+ \to 0^+) = (3.4 \pm 0.4) \times 10^{-7}$ and $(2.4 \pm 0.7) \times 10^{-6}$ eV, respectively, for ^{18}O*(3.63, 5.34). See also (1976NOZW). For earlier reports of the excitation of ^{18}O states to $E_x = 27$ MeV see reaction 19 in (1972AJ02). See also (1973BI1A, 1973TH1B, 1974DE1E, 1977MI1F) and (1973HO29; theor.).

25. ^{18}O(n, n)^{18}O

See Table 18.8 in (1972AJ02).

26. ^{18}O(p, p)^{18}O

Angular distributions have been measured for $E_p = 0.84$ to 66.5 MeV: see Table 18.8 in (1972AJ02) and (1974ES02: 24.5 MeV; see below), (1977CO1G: 35.2 MeV; p_0) and (1972LE1G, 1972LE27, 1972LE28: 66.5 MeV; p_0). The difference of the rms matter radius for ^{18}O with that of ^{16}O is $\approx +0.37 \pm 0.07$ fm (1973LE07). The first excited state, ^{18}O*(1.98), has $|g| = 0.287 \pm 0.015$ and $\tau_m = 2.99 \pm 0.12$ psec (1976AS04): see also the "^{18}O*(1.98)" section here and Table 18.4.

At $E_p = 24.5$ MeV (1974ES02) have studied the angular distributions of the proton groups to ^{18}O*(1.98, 3.56, 3.63, 3.92, 4.46, 5.10, 5.26, 5.53, 7.12): a modified DWBA analysis leads to $J^\pi = 2^+, 4^+, 0^+, 2^+, 1^-, 3^-, 2^+, 2^-$ and 4^+ for these states. A coupled-channels calculation suggests $\beta_2 = 0.37 \pm 0.03, 0.56 \pm 0.06$ and 0.18 ± 0.04 for ^{18}O*(1.98, 5.10, 7.12). Such calculations also support evidence for a rotational band involving ^{18}O*(0, 1.98, 7.12). The 3^- state at 5.10 MeV is strongly excited and collective in nature: $B(\mathrm{E3}) = 1120\ e^2 \cdot \mathrm{fm}^6$. For ^{18}O*(1.98, 3.92, 5.26), $B(\mathrm{E2}) = 45$, 8.3 and 24 $e^2 \cdot \mathrm{fm}^4$ (1974ES02). (1974BE63) have measured the magnetic moment of the 4^+ state ^{18}O*(3.56): $|g| = 0.62 \pm 0.10$ suggesting a mainly $(d_{5/2})^2$ configuration for this state.

At $E_p = 27.8$ MeV, sharp states ($\Gamma \leq 50$ keV) are reported at $E_x = 16.40 \pm 0.03$ and 17.02 ± 0.03 MeV: they are presumed to be $T = 2$ states (1974NE1D; unpublished abstract). See also (1974PI05), (1972AJ02) for the earlier work and (1976ES1B; theor.). For polarization measurements see ^{19}F.

27. ^{18}O(d, d)^{18}O

Angular distributions of elastically scattered deuterons have been measured at $E_d = 7.0$ to 15 MeV (also d_1 at 15 MeV): see Table 18.8 in (1972AJ02) and (1974SE01: $E_d = 14.8$ MeV). The population of states with $E_x < 5.5$ MeV is also reported: see (1972AJ02). See also (1973ST1B, 1974NE1D) and ^{20}F.

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

The elastic scattering has been studied at $E_t = 6.4$ and 7.2 MeV (1964PU01).

29. ^{18}O(^{3}He, ^{3}He)^{18}O

The elastic scattering has been studied at $E(^3\mathrm{He}) = 11.0$ to 17.3 MeV: see Table 18.8 in (1972AJ02).

30. ^{18}O(α, α)^{18}O

Angular distributions of many α-groups have been measured at $E_\alpha = 21.4$ (1966LU05) and 40.5 MeV (1966HA19): see Table 18.8 in (1972AJ02). The elastic scattering has also been studied at $E_\alpha = 22$, 24 and 28 MeV (1972OE01, 1973OE01). The transitions to ^{18}O*(4.46, 5.10) are $L = 1$ and 3, respectively, fixing $J^\pi = 1^-$ and 3^- for these states. B(E2) values for ^{18}O*(1.98, 4.46) and B(E3) for ^{18}O*(5.10) 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, 3.56, 3.63, 3.92, 4.46, 5.10, 5.26, 5.34, 6.20, 6.40, 7.12, 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 $E_x = 5.38$, 8.48 and 8.64 MeV were not observed, and those at 5.53, 6.35 and 6.88 MeV were populated weakly indicating unnatural parity: $J^\pi = 3^+$ and 2^- respectively for ^{18}O*(5.38, 5.53) (1971OL06). See also (1977KN1E).

Alpha-gamma correlation measurements involving ^{18}O states below $E_x = 6.4$ MeV [see Table 18.3] lead to $J^\pi = 1^-$ and 3^- for ^{18}O*(6.20, 6.40). Other J^π values agree with previous assignments. The transitions $3.92 \to 1.98$ and $5.26 \to 1.98$ are almost pure M1 (1971BE45).

Lifetime measurements for ^{18}O*(1.98, 3.56) are displayed in Table 18.4 (1974BE25). See also (1971BE60). ^{18}O*(1.98) has a negative g-factor (1975FO03), $|g| = 0.35 \pm 0.04$ (1975SP03). See also (1975GR41, 1976GO1M) and (1973SU1A, 1974CH58, 1974KU15, 1975SU1C; theor.).

31. ^{18}O(^{7}Li, ^{7}Li)^{18}O

See (1972AJ02).

32. (a) ^{18}O(^{9}Be, ^{9}Be)^{18}O
(b) ^{18}O(^{10}B, ^{10}B)^{18}O

See (1971KN05).

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

Perturbed angular correlations have been measured between the 1.98 MeV γ-rays and the ^{18}O* particles which were resolved into their 8^+, 7^+ and 6^+ charge states: $|g| < 0.36$ for ^{18}O*(1.98) (1972GO06). Elastic scattering angular distributions (reaction (a)) have been measured at $E(^{18}\mathrm{O}) = 47.5$, 55 and 57.5 MeV (1976WE05). See also ^{30}Si in (1978EN06), (1976EY01) and (1977BA3E, 1977PE1J; theor.). For reaction (b) see (1974CH1Q). See also (1971BE60) and (1974GO1L).

34. ^{18}O(^{16}O, ^{16}O)^{18}O

Angular distributions have been measured at $E(^{16}O) = 24$, 28 and 32 MeV (1972GE18; elastic) and 39.7, 44.5, 49.6 and 54.5 MeV (1972SI16), and at $E(^{18}O) = 25$, 27, 29, 36 and 42 MeV (1975KA24; ^{18}O*(0, 1.98)), 35 MeV (1977CA1Q; ^{18}O*(0, 1.98, 4.46, 5.10)) and 42 and 52 MeV (1974VA22, 1975RE15; ^{18}O*(0, 1.98, 3.56 + 3.63, 3.92, 4.46, 5.10, 7.12); some are partial distributions). (1974VA22) find $\beta_2 R = 1.08 \pm 0.15$ and $\beta_3 R = 0.86 \pm 0.15$ for ^{18}O*(1.98, 5.10). (1975KA24) suggest that caution is indicated in analyzing data taken at energies above the Coulomb barrier when recoil effects cannot be neglected.

See also (1973FI1C, 1975GR41, 1975VO1B), (1973BO1H, 1973MC1D, 1974GE02, 1976GL08, 1976IM01, 1976OH03) and ^{34}S in (1978EN06).

35. (a) ^{18}O(^{17}O, ^{17}O)^{18}O
(b) ^{18}O(^{18}O, ^{18}O)^{18}O

Angular distributions for reaction (b) have been studied at $E(^{18}O) = 42$ and 52 MeV (1974VA22; ^{18}O*(0, 1.98, 3.56 + 3.63, 4.46, 5.10, 7.12)) and at 52 MeV (1976KUZX; elastic). See also (1973GO01), (1972AJ02, 1975VO1B), (1974KU1E, 1977PL02; theor.) and ^{36}S in (1978EN06). For reaction (a) see (1977KA2E).

36. ^{18}O(^{19}F, ^{19}F)^{18}O

The elastic scattering has been studied at $E(^{19}F) = 27$, 30 and 33 MeV (1973GA14). See also (1973VO1E, 1975VO1B).

37. ^{18}F(β^+)^{18}O $\qquad Q_m = 1.6555$

See ^{18}F.

38. (a) ^{19}F(γ, p)^{18}O $\qquad Q_m = -7.9934$
(b) ^{19}F(e, ep)^{18}O $\qquad Q_m = -7.9934$

At $E_{bs} = 19$, 21.5 and 25 MeV, the relative yield of γ-rays from ^{18}O*(1.98, 3.63) has been measured (1972TH15). At $E_{bs} = 26$ MeV the decay of ^{18}O*(1.98, 3.63, 3.92, 4.46, 6.88) has been studied by (1977TA1M). See also (1972SH07, 1976TH1E) and reaction 43 in ^{18}F. Proton spectra have been measured for $E_e = 15$ to 26 MeV (1975TS03): see ^{19}F.

Table 18.8: ^{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.

39. ^{19}F(n, d)^{18}O $\qquad Q_m = -5.7688$

Angular distributions have been measured at $E_n = 14$ to 14.4 MeV: see (1972AJ02). Gamma rays from the de-excitation of ^{18}O*(1.98, 3.56, 3.63) are reported by (1976PR08). See also ^{20}F and (1971MI12; theor.).

40. ^{19}F(p, 2p)^{18}O $\qquad Q_m = -7.9934$

The reaction to the ground state has been studied at $E_p = 42.7$ MeV (1972HI10). See also (1972PU1A) and ^{19}F.

41. ^{19}F(d, ^{3}He)^{18}O $\qquad Q_m = -2.4998$

Table 18.9: ^{18}O states from ^{19}F(t, $\alpha\gamma$) [a]

E_x (keV)	J^π	E_x (keV)	J^π
1982.16 ± 0.20		5530.5 ± 0.6	1, 2
3555.07 ± 0.45		6196.3 ± 1.2	1 [b]
3634.50 ± 0.40		6351.3 ± 0.6	1, 2
3920.6 ± 0.4		6404.4 ± 1.2	
4456.1 ± 0.5		6881.6 ± 1.2	0, (1) [b]
5098.5 ± 1.2		7116.9 ± 1.2	
5260.4 ± 1.2		7.75	$1 \rightarrow 4$ [b]
5336.4 ± 0.6		7.96	$1 \rightarrow 5$ [b]
5377.8 ± 1.2		[c]	

[a] (1973OL02): see Table 18.3 for branching ratios and Table 18.4 for τ_m.
[b] (1973BE48).
[c] (1962HI06) report α-groups to ^{18}O states with E_x = 7.60, 7.75, 7.84, 7.96, 8.02, 8.11, 8.19, 8.26, 8.39, 8.48, 8.64 MeV ($\pm$20 keV).

Many states of ^{18}O have been populated in this reaction: see Table 18.8 (1969KA1A, 1970KA31). See also (1972BU1E; abstract), (1977RO1T) and (1972EN03, 1973CO17; theor.) and reaction 46 in ^{18}F.

42. ^{19}F(t, α)^{18}O $\qquad$ $Q_m = 11.8207$

Alpha-particle groups are reported to the thirteen excited states observed in the ^{16}O(t, p) reaction [see Table 18.6] and to other states with $E_x < 8.7$ MeV [see footnote [c] in Table 18.9] (1962HI06). Table 18.9 displays the very accurate E_x measurements of (1973OL02) obtained from γ-measurements. This study, as well as the angular correlation work of (1973BE48), leads to some J-assignments, and to the branching ratios displayed in Table 18.3. (1975SO05) have determined Γ_π/Γ for the $0^+ \rightarrow 0^+$ transitions from ^{18}O*(3.63, 5.34) to be $(3.0 \pm 0.6) \times 10^{-3}$ and $\leq 2.3 \times 10^{-3}$. Using the adopted values of τ_m for these states [see Table 18.4] $\langle M \rangle_\pi = 6.0 \pm 0.7$ fm^2 and ≤ 4.5 fm^2. ^{18}O*(5.34) appears to be the expected nearly spherical $(s_{1/2})^2$ state (1975SO05). For lifetime measurements see Table 18.4 (1973OL02). For the earlier work see (1972AJ02).

43. ^{21}Ne(n, α)^{18}O $\qquad$ $Q_m = 0.696$

See (1961AB05).

44. ^{22}Ne(d, ^{6}Li)^{18}O $Q_{\rm m} = -8.195$

See (1975BE01).

45. ^{22}Ne(^{3}He, ^{7}Be)^{18}O $Q_{\rm m} = -8.082$

See (1971DE37).

^{18}F

(Figs. 2 and 4)

GENERAL: (See also (1972AJ02).)

Shell model: (1970FL1A, 1970SA1M, 1972EN03, 1972LE13, 1972PR08, 1973BA1Q, 1973CO03, 1973LA1D, 1973MA1K, 1973MC06, 1973SM1C, 1973VA05, 1974LO04, 1974WA17, 1975BA81, 1975GO1B, 1975SA1F, 1976DE13, 1976SA35, 1976SZ1A, 1977HA33, 1977HO1F, 1977SH11, 1977VA1E).

Cluster, collective and deformed models: (1971LIZI, 1972NE1B, 1975GO08, 1975SA1F, 1976SA35, 1977HO1F).

Electromagnetic transitions: (1970SI1J, 1972BE1E, 1972EN03, 1972EV03, 1972LO1D, 1973HA1N, 1973MI1C, 1974LO04, 1974MC1F, 1975GA03, 1976SA35, 1976SH04, 1977BR03, 1977HO1F, 1977SA13).

Special states: (1972EN03, 1972GA18, 1972HI17, 1972HO13, 1972LE13, 1972RA08, 1972YO1B, 1973BA1Q, 1973JO03, 1973KN1C, 1973KO42, 1973MC06, 1973MI1C, 1973VA05, 1974BO22, 1974KI1B, 1975BA81, 1975GA03, 1975LO1G, 1976BO1T, 1976DE13, 1976PR07, 1976SA35, 1976SZ1A, 1977HA33, 1977SA05, 1977SH11, 1977VA1E).

Astrophysical questions: (1974DE1M).

Muon and pion induced capture and reactions: (1972PL04, 1973CH20, 1973HO43, 1974LI1D, 1974LI1N, 1975KA1G).

Other topics: (1970SI1J, 1972BA23, 1972BA25, 1972CA37, 1972GO17, 1972HO13, 1972KU1C, 1972NA11, 1972PR08, 1972RA08, 1973BE35, 1973CO03, 1973GO1H, 1973JO03, 1973KO42, 1973KR16, 1973PA1F, 1973RA05, 1973VA05, 1974CO1E, 1974BO22, 1974GA36, 1974KI1B, 1974KI1C, 1974RE03, 1974SA05, 1974SH1G, 1974WA17, 1974ZU1A, 1975BA2F, 1975BA81, 1975BL1F, 1975GO1B, 1975GO08, 1975HE1H, 1975LO1G, 1975SH01, 1975SH1H, 1976BA2G, 1976BO1T, 1976PA03, 1976PR07, 1977GO1T, 1977SA05, 1977SH11, 1977SH13, 1977SO11, 1977VA1E).

Complex reactions involving ^{18}*F:* (1971BI22, 1971OG03, 1972PU1B, 1973DI05, 1973VA12, 1973WI15, 1974DI16, 1974HA61, 1974KA22, 1974OL06, 1974RA11, 1975DI03, 1975NO10, 1975VO09, 1976BE1K, 1976LE1F, 1977AR06).

Applied topics: (1973WE1N, 1975AL1B, 1976GU20, 1977DE1X, 1977PA1K).

Ground and 1.12 MeV states of ^{18}*F:* (1970SI1J, 1971SH26, 1971TA1A, 1972NA05, 1972VA36, 1972YO1B, 1973MC06, 1973MI1C, 1973SU1B, 1974MC1F, 1974RE03, 1974SH1G, 1974SHYR, 1976CH1T, 1976PA03, 1977BR03).

$Q_{1.12} = (1.33 \pm 0.08)Q(^{17}\mathrm{F_{g.s.}}) = 0.13 \pm 0.03$ b (1974MI21); see also (1977AJ02);

$\mu_{1.12} = +2.85$ nm (1976FU06).

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, 3, 4, 5, 6, 7, 11, 12, 15, 23, 24, 25, 26, 27, 29, 30, 31, 37, 39, 40, 41, 42, 43, 45, 46, 47, 48, 49, 51, 52
0.93720 ± 0.06	$3^+; 0$	0^+	$\tau_m = 67.6 \pm 2.5$ psec	γ	4, 7, 11, 12, 15, 23, 24, 25, 26, 31, 37, 39, 40, 41, 43, 44, 46, 47, 52
1.04155 ± 0.08	$0^+; 1$		4^{+3}_{-2} fsec	γ	7, 11, 24, 26, 31, 37, 39, 40, 41, 43, 46, 47, 51
1.08054 ± 0.12	$0^-; 0$	0^-	27.5 ± 1.9 psec	γ	7, 11, 12, 23, 24, 26, 39, 40, 43, 46, 47
1.12136 ± 0.15	$5^+; 0$	0^+	218 ± 8 nsec $\mu = +2.855 \pm 0.030$ nm $Q = 0.13 \pm 0.03$ b	γ	4, 7, 11, 12, 23, 24, 25, 26, 28, 31, 37, 39, 40, 44, 47, 52
1.70081 ± 0.18	$1^+; 0$	1^+	1.09 ± 0.10 psec	γ	7, 12, 23, 24, 25, 31, 39, 40, 41, 47, 51, 52
2.10061 ± 0.10	$2^-; 0$	0^-	4.3 ± 1.4 psec	γ	7, 12, 15, 24, 25, 26, 31, 39, 40, 43, 47, 52
2.52335 ± 0.18	$2^+; 0$	1^+	0.68 ± 0.11 psec	γ	7, 12, 24, 25, 31, 37, 39, 43, 47, 52
3.06184 ± 0.18	$2^+; 1$		< 1.5 fsec	γ	7, 24, 31, 37, 39, 40, 43, 47, 51, 52
3.13387 ± 0.15	$1^-; 0$	1^-	0.32 ± 0.10 psec	γ	7, 12, 24, 25, 31, 40, 43, 47, 52
3.3582 ± 1.0	$3^+; 0$	1^+	0.49 ± 0.07 psec	γ	7, 12, 24, 25, 31, 47, 52
3.72419 ± 0.22	$1^+; 0$		4 ± 2 fsec	γ	7, 12, 24, 26, 31, 40, 43, 47, 52
3.79149 ± 0.22	$3^-; 0$	1^-	224 ± 35 fsec	γ	7, 12, 24, 25, 26, 31, 40, 47
3.83917 ± 0.22	$2^+; 0$		29 ± 9 fsec	γ	7, 12, 24, 26, 31, 37, 40, 47, 52
4.11590 ± 0.25	$3^+; 0$		91 ± 22 fsec	γ	7, 12, 24, 25, 26, 31, 37, 40, 47, 52
4.2258 ± 0.7	$2^-; 0$	(1^-)	110 ± 15 fsec	γ	7, 12, 24, 26, 31, 40, 47, 52
4.36015 ± 0.26	$1^{(+)}$		27 ± 10 fsec	γ	7, 12, 24, 31, 40, 47, 52
4.3981 ± 0.7	$4^-; 0$	0^-	58 ± 12 fsec	γ	7, 12, 15, 24, 25, 26, 31, 40, 47, 52
4.652 ± 2	$4^+; 1$		< 10 fsec	γ	7, 24, 31, 37, 40, 47
4.753 ± 3	$(0^+; 1)$			γ	24, 40, 47
4.860 ± 2	$1^-; 0$		66 ± 18 fsec	γ, α	7, 24, 31, 47, 52
4.9636 ± 0.8	$2^+; 1$		< 4 fsec	γ, α	7, 24, 31, 37, 47
5.2976 ± 1.5	$4^+; 0$	1^+	30 ± 5 fsec	γ, α	7, 12, 24, 25, 47, 52
5.502 ± 2	$3^{(-)}; 0$		$\tau_m = 63 \pm 25$ fsec	γ, α	7, 12, 24, 31, 47, 52

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
5.60338 ± 0.27	1^+			γ	31, 52
5.60486 ± 0.28	$1^-; 0+1$		$\Gamma < 1.2$	γ, α	7, 10, 12, 24, 25, 26, 31, 37, 47, 52
5.668 ± 2	$1^-; 0+1$		$\Gamma < 0.8$	γ, α	7, 10, 12, 24, 31, 37, 47
5.786 ± 2.4	$2^-; 0$		$\tau_m = 15 \pm 10$ fsec	γ, α	7, 24, 25, 47, 52
6.0964 ± 1.1	$4^-; 0$	1^-	$\Gamma = 0.27 \pm 0.09$	γ, p, α	7, 12, 24, 31, 35, 47, 52
6.108 ± 3	1, 2, $3^{(-)}$; 0			γ, α	7, 10, 24, 47
6.13647 ± 0.33	$0^+; 1$		≤ 1	γ, p	24, 31, 47
6.1632 ± 0.9	3^+; (1)		13 ± 1	γ, p	24, 31, 33, 47, 52
6.2409 ± 0.9	$3^-; 1$		< 0.8	γ, p, α	7, 10, 24, 31, 33, 35, 47
6.262 ± 2.5	$1^+; 0$		< 3	γ, α	7, 12, 24, 35, 47, 52
6.2832 ± 0.9	$2^+; 1$		8.5 ± 1.0	γ, p	24, 31, 33
6.3105 ± 0.8	$3^+; 0$		≤ 1.2	γ, p, α	7, 24, 31, 33, 35
6.3855 ± 1.7	$2^+; 0+1$		≤ 1	γ, p, α	7, 24, 31, 35, 47
6.480 ± 1.5	3^+; (0)		≤ 2	γ, p, α	7, 24, 31, 35, 47
6.5670 ± 1.5	5^+	1^+	(< 0.8)	γ, α	7, 10, 12, 24, 25, 47, 52
6.6437 ± 1.2	$2^-; 1$		0.87 ± 0.09	γ, p, α	7, 9, 24, 31, 47
6.647 ± 4	1^-		91 ± 4	p, α	10, 12, 35, 52
6.777 ± 2	$4^+; 0$		9 ± 3	γ, p, α	24, 26, 31, 33, 47, 52
6.8031 ± 1.5	1^+, 2, 3^+; (0)		≤ 2	γ, p	12, 24, 25, 26, 31, 33, 47, 52
6.810 ± 5	2^-		79 ± 5	p, α	9, 10, 35
6.878 ± 2	$3^{(-)}$, 4^-; (0)		≤ 2	γ, p, α	24, 26, 31, 35, 47, 52
7.197 ± 4	(4^+); 0		< 4	α	10, 24, 25, 47
7.27	(1^+)		45 ± 10	α	10
7.313 ± 10	(3^-)		53 ± 6	p, α	9, 10, 47
7.500 ± 10	(3^-)		43 ± 9	p, α	9, 10, 24, 35, 47
7.57			60	p, α	9, 10, 24, 35
7.61			40	p, α	9, 10, 24
7.70			11	p, α	24, 35
7.74			120	p, α	9, 10, 35
7.877 ± 10 [d]	(2^-)		32 ± 5	p, α	24, 25, 35
7.92	(2^-)		30	p, α	9, 10, 35
7.95	(1^+)		70	p, α	9, 10
(8.050 ± 10) [d]			30 ± 10	p, α	24, 35
(8.21)			≈ 15	p, α	24, 35
(8.23)			≈ 10	p, α	24, 35
(8.37) [b]			≈ 50	p, α	35

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
8.46 [b]	1^+		88 ± 10	p, d, α	18, 19, 20
9.207 ± 15 [d]	$3, 4^-; 0$		108 ± 12	p, d, α	18, 19, 20, 24
9.31 ± 20	$2, 3^+; 0$		80 ± 20	n, p, d, α	17, 20, 24, 32
9.58 ± 20	6^+	1^+	55 ± 25		12, 24, 25
9.605 ± 10			35 ± 7	n, p, d	17, 18, 24, 32
9.694 ± 10			33	n, p	32
9.845 ± 20			≈ 100	n, p	32
10.12				n, p, d	17, 18, 19
10.23	$3, 4^-; 0$		≈ 140	n, p, d, α	20, 32
11.22 ± 30	7^+	1^+			12, 24
14.18 ± 40	[c]				12

[a] See also Tables 18.11 for radiative transitions and 18.12 for lifetime measurements.

[b] For other states with $7.3 < E_x < 9.6$ MeV, see also Tables 18.15 and 18.17 here, and Tables 18.18 and 18.19 in (1972AJ02).

[c] For other states with $10.3 < E_x < 19.4$ MeV and $J^\pi = 1^- \rightarrow 7^+$ [natural parity], see Tables 18.14, 18.15 and 18.16. Tables 18.14 and 18.16 display the states deduced from the yields of the isospin forbidden α_1 groups in ^{14}N + α and ^{16}O + d, respectively. (1976CH24) reports 151 isospin mixed natural parity states with $10.4 < E_x < 17.5$ MeV [^{14}N(α, α_1)] and (1973JO13) reports 138 such states with $9.2 < E_x < 19.4$ MeV [^{16}O(d, α_1)] of which 16 have $E_x > 17.5$ MeV. In addition (1971JA04) have reported α_1 resonances in ^{16}O + d corresponding to ^{18}F*(20.3, 20.8) with $\Gamma \approx 300$ and ≈ 550 keV. Thus in the region $10.4 < E_x < 20.8$ MeV some 169 states with mixed isospin and natural parity have been reported.

[d] Uncertainty estimated by reviewer.

1. ^{18}F(β^+)^{18}O $Q_m = 1.6555$

The positron decay is entirely to the ground state of ^{18}O [$J^\pi = 0^+$, $T = 1$]; the half-life is 109.77 ± 0.05 min [see Table 18.11 in (1972AJ02)]; $\log ft = 3.554$. The fact that the β^+ transition to ^{18}O$_{g.s.}$ is allowed indicates $J^\pi = 1^+$ for ^{18}F$_{g.s.}$. The ratio $\epsilon_K/\beta^+ = 0.030 \pm 0.002$ (1956DR38). See also (1972AJ02), (1973HO43), (1975RO20; astrophys. questions) and (1972WI28, 1972WI1C, 1973EM1B, 1973LA03, 1973WI11, 1974LE1G, 1974WI1L, 1975HA45, 1975KR14, 1975WI1E, 1977AZ02, 1977BA48, 1977KU1E; theor.).

2. (a) ^{12}C(^{6}Li, n)^{17}F $Q_m = 4.064$ $E_b = 13.215$
(b) ^{12}C(^{6}Li, p)^{17}O $Q_m = 7.608$

(c) $^{12}C(^{6}Li, d)^{16}O$ $Q_m = 5.6885$

(d) $^{12}C(^{6}Li, t)^{15}O$ $Q_m = -3.718$

(e) $^{12}C(^{6}Li, \alpha)^{14}N$ $Q_m = 8.7989$

(f) $^{12}C(^{6}Li, ^{6}Li)^{12}C$

Table 18.11: Radiative decays in ^{18}F

E_i (MeV)	$J_i^\pi; T$	E_f (MeV)	Branch (%)		Refs.
0.94	$3^+; 0$	0	100		
1.04	$0^+; 1$	0	100		Table 18.14 (1972AJ02)
1.08	$0^-; 0$	0	100		Table 18.14 (1972AJ02)
1.12	$5^+; 0$	0.94	100		Table 18.14 (1972AJ02)
1.70 [a]	$1^+; 0$	0	29.8 ± 1.3		(1973RO05)
		0.94	< 0.1		(1973RO05)
		1.04	70.2 ± 1.3		(1973RO05)
		1.08	< 0.2		(1973RO05)
2.10	$2^-; 0$	0	35.8 ± 1.5	$\Gamma_\gamma = (4.6 \pm 2.2) \times 10^{-5}$ eV	Table 18.14 (1972AJ02)
			38 ± 1 [A]		(1972RO04)
		0.94	32.0 ± 1.5	$\Gamma_\gamma = (4.0 \pm 1.9) \times 10^{-5}$ eV	Table 18.14 (1972AJ02)
			31 ± 1 [A]		(1972RO04)
		1.04	< 0.4		(1972RO04)
		1.08	32.5 ± 1.5		Table 18.14 (1972AJ02)
			31 ± 1 [A]		(1972RO04)
		1.13	< 2		(1967WA06)
		1.70	< 0.2		(1972RO04)
2.52 [a,b]	$2^+; 0$	0	74.9 ± 1.8	$\delta = 3.0 \pm 1.0$	(1973RO05)
		0.94	21.5 ± 1.2	$\delta = -(1.5 \pm 0.6)$	(1973RO05)
		1.04	< 0.3		(1973RO05)
		1.08	< 0.3		(1973RO05)
		1.70	3.6 ± 0.8	$\delta = 0.94 \pm 0.4$	(1973RO05)
			4.3 ± 1.0		Table 18.14 (1972AJ02)
		2.10	< 0.2		(1973RO05)
3.06 [c]	$2^+; 1$	0	25 ± 2		(1966OL03)
			23.2 ± 0.8 [A]		(1972RO24)
		0.94	75 ± 2		(1966OL03)
			76.7 ± 0.8		(1972RO24)
		1.04	0.11 ± 0.03		(1972RO24)
		1.08	< 8		(1967WA06)
		1.13	< 14		(1967WA06)
		1.70	< 8		(1967WA06)

Table 18.11: Radiative decays in ^{18}F (continued)

E_i (MeV)	$J_i^\pi; T$	E_f (MeV)	Branch (%)		Refs.
		2.10	< 5		(1967WA06)
		2.53	< 5		(1967WA06)
3.13	$1^-; 0$	0	32 ± 2		(1966OL03)
			39 ± 2 ^A^	$\delta = +(0.07 \pm 0.05)$	(1972RO04)
				$\Gamma_\gamma = (5.7 \pm 2) \times 10^{-4}$	(1967WA06)
		0.94	< 0.6		(1972RO04)
		1.04	34 ± 2 ^A^		(1972RO04)
				$\Gamma_\gamma = (7.3 \pm 2.7) \times 10^{-4}$	(1967WA06)
		1.08	25 ± 2 ^A^		(1972RO04)
				$\Gamma_\gamma = (4.8 \pm 1.8) \times 10^{-4}$	(1967WA06)
		1.13	< 8		(1967WA06)
		1.70	2.0 ± 0.5 ^A^	$\delta = +(0.22 \pm 0.15)$	(1972RO04)
		2.10	< 3.0		(1972RO04)
		2.53	< 0.3		(1972RO04)
3.36	$3^+; 0$	0	56 ± 6		(1966OL03)
			45 ± 5 ^A^		(1973RO05)
		0.94	6 ± 2		Table 18.14 (1972AJ02)
			9 ± 3 ^A^		(1973RO05)
		1.04	< 5		(1967WA06)
		1.08	< 5		(1967WA06)
		1.12	< 3		(1973RO05)
		1.70	30 ± 4		(1966OL03)
			40 ± 4 ^A^		(1973RO05)
		2.10	7 ± 4		(1966OL03)
			< 3 ^A^		(1973RO05)
		2.52	6 ± 3	$\delta = -0.4^{+0.3}_{-0.5}$	(1973RO05)
		3.06	< 5		(1973RO05)
3.72	$1^+; 0$	0	6.4 ± 1.6		Table 18.14 (1972AJ02)
			5 ± 2 ^A^		(1973RO04)
		0.94	< 2		(1973RO04)
		1.04	94 ± 2	$\Gamma_\gamma > 8.2 \times 10^{-3}$ eV	(1967GO07, 1967OL03)
			91 ± 2 ^A^		(1973RO04)
		1.08	< 1		(1973RO04)
		1.12	< 10		(1967OL03)
		1.70	< 1		(1973RO04)
		2.10	< 1		(1973RO04)
		2.53	< 1		(1973RO04)
		3.06	4 ± 2		(1973RO04)

Table 18.11: Radiative decays in ^{18}F (continued)

E_i (MeV)	$J_i^{\pi}; T$	E_f (MeV)	Branch (%)		Refs.
		3.13	< 1		(1973RO04)
		3.36	< 4		(1967OL03)
3.79 [b]	$3^-; 0$	0	< 1.5		(1973RO06)
		0.94	< 2.0		(1973RO06)
		1.12	< 1.0		(1973RO06)
		1.70	< 1.7		(1973RO06)
		2.10	68 ± 4	$\delta = -(0.22 \pm 0.06)$ [A]	(1973RO06)
				$\delta = -(0.10^{+0.07}_{-0.12})$	(1967OL03)
		2.52	2.2 ± 1.1		(1973RO06)
		3.06	30 ± 3	$\delta = -(0.09 \pm 0.09)$	(1973RO06)
		3.13	< 0.9		(1973RO06)
		3.36	< 1.8		(1973RO06)
3.84 [b]	$2^+; 0$	0	38 ± 2	$\delta = -(1.8 \pm 0.5)$	(1973RO06)
		0.94	8.9 ± 1.4	$\delta = -(0.3 \pm 0.3)$	(1973RO06)
		1.04	< 1.3		(1973RO06)
		1.08	< 1.3		(1973RO06)
		1.70	3.0 ± 1.0		(1973RO06)
		2.10	< 0.8		(1973RO06)
		2.52	< 1.3		(1973RO06)
		3.06	50 ± 3	$\delta = -(0.1 \pm 0.3)$	(1973RO06)
		3.13	< 0.7		(1973RO06)
		3.36	< 1.5		(1973RO06)
4.12 [d]	$3^+; 0$	0	5 ± 3 [A]		(1967OL03)
			< 7		(1973RO06)
		0.94	< 6		(1973RO06)
		1.12	< 8		(1967OL03, 1973RO06)
		1.70	< 8		(1967OL03, 1973RO06)
		2.10	< 5		(1973RO06)
		2.52	< 6		(1973RO06)
		3.06	95 ± 3 [A]	$\delta = +0.09^{+0.12}_{-0.09}$	(1967OL03)
			100	$\delta = 0.03 \pm 0.10$	(1973RO06)
		3.13	< 4		(1973RO06)
		3.36	< 7		(1973RO06)
4.23 [b]	$2^-; 0$	0	23 ± 2	$\delta = 0.15 \pm 0.15$	(1973RO06)
		0.94	49 ± 3	$\delta = 0.0 \pm 0.2$	(1973RO06)
		1.04	< 2.4		(1973RO06)
		1.08	3.2 ± 1.0		(1973RO06)
		1.70	9.3 ± 1.2		(1973RO06)

Table 18.11: Radiative decays in ^{18}F (continued)

E_i (MeV)	$J^\pi_i; T$	E_f (MeV)	Branch (%)		Refs.
		2.10	15 ± 5		(1973RO06)
		2.52	< 1.4		(1973RO06)
		3.06	< 1.4		(1973RO06)
		3.13	0.9 ± 0.6		(1973RO06)
		3.36	< 1.2		(1973RO06)
4.36	$1^{(+)}$	0	< 10		(1973RO04)
		0.94	< 8		(1973RO04)
		1.04	< 8		(1973RO04)
		1.08	< 8		(1973RO04)
		1.70	< 8		(1973RO04)
		2.10	< 8		(1973RO04)
		2.52	< 10		(1973RO04)
		3.06	100		(1973RO04)
		3.13	< 10		(1973RO04)
		3.36	< 8		(1973RO04)
		3.72	< 8		(1973RO04)
4.40	$4^-; 0$	0.94	13 ± 4	$\delta = -(0.2 \pm 0.3)$	(1973RO06)
		1.12	60 ± 6	$\delta = -(0.2 \pm 0.2)$	(1973RO06)
		2.10	27 ± 3		(1973RO06)
		2.52	< 4		(1973RO06)
		3.06	< 4		(1973RO06)
		3.36	< 4		(1973RO06)
		3.79	< 6		(1973RO06)
		3.84	< 6		(1973RO06)
4.65 [b]	$4^+; 1$	0.94	17 ± 3		(1973RO06)
		1.12	83 ± 3	$\delta = 0.15 \pm 0.15$	(1973RO06)
		2.10	< 0.9		(1973RO06)
		2.52	< 1.5		(1973RO06)
		3.06	< 1.2		(1973RO06)
		3.36	< 0.9		(1973RO06)
		3.79	< 0.9		(1973RO06)
		3.84	< 0.9		(1973RO06)
		4.12	< 0.9		(1973RO06)
4.75	$(0^+; 1)$	0	92 ± 4		(1973RO06)
		1.70	8 ± 4		(1973RO06)
		2.10	< 10		(1973RO06)
		2.52	< 10		(1973RO06)
		3.06	< 10		(1973RO06)

Table 18.11: Radiative decays in ^{18}F (continued)

E_i (MeV)	$J^\pi_i; T$	E_f (MeV)	Branch (%)		Refs.
		3.13	< 10		(1973RO06)
		3.72	< 10		(1973RO06)
		3.84	< 10		(1973RO06)
4.86 [b]	$1^-; 0$	0	< 4		(1973RO06)
		0.94	< 5		(1973RO06)
		1.04	65 ± 11		(1973RO06)
		1.08	8 ± 6		(1973RO06)
		1.70	< 8		(1973RO06)
		2.10	< 6		(1973RO06)
		2.52	< 8		(1973RO06)
		3.06	23 ± 7	$\delta = -(0.4 \pm 0.4)$	(1973RO06)
		3.13	4 ± 3		(1973RO06)
		3.36	< 6		(1973RO06)
		3.72	< 7		(1973RO06)
4.96 [e]	$2^+; 1$	0	100	$\delta = 1.2 \pm 0.7$	(1973RO06, 1973SE03)
5.30 [f]	$4^+; 0$	0.94	13 ± 3		(1968PA10)
			9 ± 2 [A]	$\delta = -(0.3 \pm 0.1)$	(1973RO03, 1973RO05)
		1.12	7 ± 2	$\delta = -(1.1 \pm 0.5)$	(1973RO03, 1973RO05)
		2.52	87 ± 3		(1968PA10)
			78 ± 3 [A]		(1973RO03)
				$\Gamma_\gamma = 12 \pm 4$ meV [j]	(1973RO05)
		3.36	5 ± 1	$\delta = 2.5 \pm 0.8$	(1973RO03, 1973RO05)
		4.65	1.3 ± 0.3		(1973RO03)
5.50 [g]	$3^{(-)}; 0$	3.06	100	$\Gamma_\gamma = 2.1 \pm 0.7$ meV	(1973RO03, 1973RO06)
5.63 [y]	1^+	0	16.7 ± 2.3		(1977BE46)
		1.04	3.8 ± 1.2		(1977BE46)
		3.06	79.5 ± 5.9		(1977BE46)
5.605 [z]	$1^-; 0+1$	0	6.7 ± 1.2		(1977BE46)
		1.04	4.2 ± 0.8		(1977BE46)
		1.08	54.3 ± 3.1		(1977BE46)
		3.06	2.6 ± 1.4		(1977BE46)
		3.13	32.2 ± 2.5	$\delta = -0.05 \pm 0.02$	(1977BE46)
5.67 [aa]	$1^-; 0+1$	0	6.2 ± 0.4	$\delta = -0.01 \pm 0.04$	(1977BE46)
		1.04	8.1 ± 0.7		(1977BE46)
		1.08	52 ± 3		(1977BE46)
		1.70	0.8 ± 0.3		(1977BE46)
		2.10	0.4 ± 0.2		(1977BE46)
		3.06	4.0 ± 0.4	$\delta = 0.04 \pm 0.06$	(1977BE46)

Table 18.11: Radiative decays in ^{18}F (continued)

E_i (MeV)	$J_i^\pi; T$	E_f (MeV)	Branch (%)		Refs.
		3.13	28.5 ± 2.0	$\delta = +0.10 \pm 0.03$	(1977BE46)
5.79 [h]	$2^-; 0$	0.94	40 ± 8		(1973RO03)
		1.08	60 ± 8		(1973RO03)
6.10 [i]	$4^-; 0$	0.94	4.9 ± 0.9 [A]	$\Gamma_\gamma = 51 \pm 10$ meV [j]	(1973RO03, 1973RO06)
			6 ± 2		(1973SE03)
		1.12	55 ± 3 [A]		(1973RO03, 1973RO06)
			66 ± 5		(1973SE03)
		2.10	27 ± 2 [A]		(1973RO03, 1973RO06)
			28 ± 4		(1973SE03)
		3.79	1.4 ± 0.3		(1973RO03, 1973RO06)
		4.12	1.8 ± 0.3		(1973RO03, 1973RO06)
		4.40	0.7 ± 0.3		(1973RO03, 1973RO06)
		4.65	8.7 ± 0.7		(1973RO03, 1973RO06)
6.11 [k]	$1, 2, 3^{(-)}; 0$	0	24 ± 3		(1973RO03)
		0.94	11 ± 3		(1973RO03)
		2.10	20 ± 6		(1973RO03)
		3.06	45 ± 5		(1973RO03)
6.14 [l]	$0^+; 1$	0	50 ± 3 [A]	$\Gamma_\gamma > 1.6$ eV	(1973RO03, 1973RO04)
			54 ± 3		(1973SE03)
		1.70	12 ± 2 [A]		(1973RO03, 1973RO04)
			10 ± 1		(1973SE03)
		3.72	36 ± 3 [A]		(1973RO03, 1973RO04)
			36 ± 2		(1973SE03)
		4.36	2.1 ± 0.4 [A]		(1973RO03, 1973RO04)
		5.603	0.19 ± 0.02		(1977BE46)
6.16 [m]	$3^+; (1)$	0	0.2 ± 0.2	$\Gamma_\gamma = 0.96 \pm 0.26$ eV [j]	(1973RO03)
		0.94	51 ± 3		(1973RO03, 1973SE03)
		1.12	1.0 ± 0.1		(1973RO03)
		2.52	5.5 ± 0.4 [A]		(1973RO03)
			8 ± 1		(1973SE03)
		3.06	1.3 ± 0.3		(1973RO03)
		3.79	11.6 ± 1.3 [A]		(1973RO03)
			13 ± 2		(1973SE03)
		3.84	25.0 ± 1.6 [A]		(1973RO03)
			28 ± 3		(1973SE03)
		4.12	1.5 ± 0.3		(1973RO03)
		4.23	0.9 ± 0.3		(1973RO03)
		4.40	2.0 ± 0.2		(1973RO03)

Table 18.11: Radiative decays in ^{18}F (continued)

E_i (MeV)	$J^{\pi}_i; T$	E_f (MeV)	Branch (%)		Refs.
6.24 [n]	$3^-; 1$	0.94	4.2 ± 0.4	$\Gamma_\gamma = 1.53 \pm 0.30$ eV [j]	(1973RO03, 1973RO06)
		2.10	71 ± 3		(1973RO03)
		3.36	1.0 ± 0.3		(1973RO03)
		3.79	11.4 ± 0.6		(1973RO03)
		3.84	1.1 ± 0.2		(1973RO03)
		4.12	0.8 ± 0.2		(1973RO03)
		4.23	7.8 ± 0.5		(1973RO03)
		4.40	2.7 ± 0.3		(1973RO03)
6.26	$1^+; 0$	0	(100)		(1973RO03)
6.28 [o]	$2^+; 1$	0	0.3 ± 0.1	$\Gamma_\gamma = 1.8 \pm 0.5$ eV [j]	(1973RO03)
		0.94	67 ± 3 [A]		(1973RO03)
			70 ± 4		(1973SE03)
		1.04	1.3 ± 0.1		(1973RO03)
		1.70	5.7 ± 0.6 [A]		(1973RO03)
			4 ± 1		(1973SE03)
		2.10	1.2 ± 0.3 [A]		(1973RO03)
			5 ± 2		(1973SE03)
		2.52	0.3 ± 0.2		(1973RO03)
		3.13	0.7 ± 0.3		(1973RO03)
		3.36	2.3 ± 0.3 [A]		(1973RO03)
			3 ± 1		(1973SE03)
		3.72	1.4 ± 0.5		(1973RO03)
		3.84	15.8 ± 1.4 [A]		(1973RO03)
			15 ± 2		(1973SE03)
		4.12	3.9 ± 0.2 [A]		(1973RO03)
			3 ± 1		(1973SE03)
		4.36	0.5 ± 0.4		(1973RO03)
6.31 [p]	$3^+; 0$	0	4.0 ± 0.7	$\Gamma_\gamma = 0.17 \pm 0.04$ eV [j]	(1973RO03)
		0.94	10.6 ± 1.0		(1973RO03)
		1.70	3.0 ± 0.8		(1973RO03)
		2.52	4.0 ± 0.5		(1973RO03)
		3.06	57 ± 3	$\delta = -(0.03 \pm 0.10)$	(1973RO03, 1973RO07)
		3.72	1.4 ± 0.7		(1973RO03)
		3.84	4.6 ± 1.0		(1973RO03)
		4.12	2.4 ± 1.7		(1973RO03)
		4.96	13.0 ± 1.5	$\delta = -(0.01 \pm 0.14)$	(1973RO03, 1973RO07)
6.39 [q]	$2^+; 0+1$	0	1.5 ± 0.5	$\Gamma_\gamma = 0.44 \pm 0.18$ eV [j]	(1973RO03)
		0.94	75 ± 3 [A]	$\delta = -(0.25 \pm 0.10)$	(1973RO03, 1973RO07)

Table 18.11: Radiative decays in ^{18}F (continued)

E_i (MeV)	$J^{\pi}_i; T$	E_f (MeV)	Branch (%)		Refs.
			80 ± 3		(1973SE03)
		1.70	6.8 ± 1.7 [A]		(1973RO03)
			7 ± 1		(1973SE03)
		3.84	14.1 ± 1.6 [A]	$\delta = 0.1 \pm 0.2$	(1973RO03, 1973RO07)
			13 ± 2		(1973SE03)
		4.12	2.3 ± 0.5		(1973RO03)
6.48 [r]	3^+; (0)	0	13 ± 2 [A]	$\Gamma_{\gamma} = 74 \pm 21$ meV [j]	(1973RO03)
			15 ± 2		(1973SE03)
		0.94	33 ± 2 [A]		(1973RO03)
			31 ± 3		(1973SE03)
		1.12	10 ± 2 [A]		(1973RO03)
			14 ± 2		(1973SE03)
		1.70	4 ± 2 [A]		(1973RO03)
			4 ± 1		(1973SE03)
		2.52	4 ± 2		(1973RO03)
		3.06	21 ± 3 [A]		(1973RO03)
			28 ± 3		(1973SE03)
		3.79	4 ± 2		(1973RO03)
		3.84	9 ± 2 [A]		(1973RO03)
			8 ± 1		(1973SE03)
		4.96	2 ± 2		(1973RO03)
6.57 [s]	5^+	0.94	15.2 ± 1.6		(1973RO03)
		3.36	83 ± 3	$\Gamma_{\gamma} = 26 \pm 5$ meV [t,j]	(1973RO03)
		5.30	2.3 ± 0.6		(1973RO03)
6.64 [u]	2^-; 1	0.94	8.9 ± 0.6 [A]	$\Gamma_{\gamma} = 1.4 \pm 0.4$ eV [j]	(1973RO03, 1973RO06)
			12 ± 1		(1973SE03)
		2.10	58 ± 3 [A]		(1973RO03)
			72 ± 3		(1973SE03)
		3.13	22.0 ± 1.3 [A]		(1973RO03)
			16 ± 2		(1973SE03)
		3.72	0.9 ± 0.2		(1973RO03)
		3.79	2.4 ± 0.2		(1973RO03)
		4.12	1.0 ± 0.3		(1973RO03)
		4.86	2.6 ± 0.2		(1973RO03)
		5.50	4.0 ± 0.3		(1973RO03)
6.78 [v]	4^+; 0	0.94	12.6 ± 0.9 [A]	{ $\Gamma_{\gamma} = 0.31 \pm 0.08$ eV [j]; $\delta = -(0.35 \pm 0.18)$ }	(1973RO03, 1973RO07)
			15 ± 3		(1973SE03)

Table 18.11: Radiative decays in ^{18}F (continued)

E_i (MeV)	$J_i^\pi; T$	E_f (MeV)	Branch (%)		Refs.
		1.12	25.2 ± 1.3 [A]	$\delta = -(1.4 \pm 1.1)$	(1973RO03, 1973RO07)
			38 ± 4		(1973SE03)
		4.65	62 ± 2 [A]	$\delta = 0.13 \pm 0.13$	(1973RO03, 1973RO07)
			47 ± 6		(1973SE03)
6.80 [w]	1^+, 2, 3^+; (0)	0	20 ± 2 [A]		(1973RO03)
			24 ± 2		(1973SE03)
		0.94	20 ± 2 [A]		(1973RO03)
			35 ± 3		(1973SE03)
		3.06	50 ± 3 [A]		(1973RO03)
			41 ± 4		(1973SE03)
		3.84	3.0 ± 1.6		(1973RO03)
		4.96	7.0 ± 1.7		(1973RO03)
6.88 [x]	$3^{(-)}$, 4^-; (0)	2.10	9 ± 2 [A]		(1973RO03)
			12 ± 3		(1973SE03)
		4.65	91 ± 2 [A]		(1973RO03)
			88 ± 3		(1973SE03)

A = adopted.
[a] See also (1972RO04, 1973RO04).
[b] See also Table 18.14 (1972AJ02).
[c] See also (1973RO04).
[d] Transitions to ^{18}F*(1.04, 1.08) are $< 8\%$ (1967OL03).
[e] Upper limits for transitions to other states range from 2% to 7% (1973RO06).
[f] Branching ratios are < 0.4, < 0.8, < 0.5, < 1.0, < 1.5, < 0.4, $< 0.4\%$ to ^{18}F*(2.10, 3.06, 3.79, 3.84, 4.12, 4.23, 4.40). $\Gamma_\alpha = 10 \pm 4$ meV; $\Gamma_\gamma/\Gamma = 0.55 \pm 0.18$ (1973RO05).
[g] Upper limits for branching ratios to other states range from 2.2% to 4.2% (1973RO06).
[h] Upper limits for branching ratios to other states range from 5% to 19% (1973RO06).
[i] Upper limits for transitions to ^{18}F*(2.52, 3.06, 3.36, 3.84, 4.23, 4.96) are 0.4% (1973RO06).
[j] Total Γ_γ for this state (1973RO06, 1973RO07, 1977BE46).
[k] Upper limits for branching ratios to other states range from 3% to 8% (1973RO06).
[l] Upper limits for transitions to ^{18}F*(2.10, 2.52, 3.06, 3.13, 3.84, 4.23, 4.86, 4.96, 5.60, 5.67) are 1% (1973RO04).
[m] Upper limits for transitions to other states range from 0.2% to 0.5% (1973RO07).
[n] Upper limits for transitions to ^{18}F*(0, 1.12, 1.70, 4.36) are $< 0.1\%$; those for transitions to ^{18}F*(2.52, 3.06, 3.13, 3.73, 4.65, 4.86, 4.96, 5.30, 5.50) are $< 0.2\%$ (1973RO06).
[o] Upper limits for transitions to other states range from 0.2% to 0.8% (1973RO07).
[p] Upper limits for transitions to other states range from 0.2% to 1.0% (1973RO07).
[q] Upper limits for transitions to other states range from 0.4% to 3.0% (1973RO07).
[r] Upper limits for transitions to other states range from 1% to 4%; this state may correspond to an unresolved doublet (1973RO07).
[s] Branching ratios are < 0.7, < 1.4, < 1.3, < 0.8, $< 0.9\%$ to ^{18}F*(1.12, 3.79, 4.12, 4.40, 4.65) (1973RO05).
[t] $\Gamma_\alpha = \Gamma \approx 560$ eV, $\Gamma_p < 4.5$ eV (1973RO05).
[u] Upper limits for transitions to other states range from 0.2% to 0.6% (1973RO06).
[v] Upper limits for transitions to other states range from 0.7% to 2.5% (1973RO07).
[w] Upper limits for transitions to other states range from 1.0% to 5% (1973RO07).

[x] Upper limits for transitions to other states range from 0.7% to 5.2% (1973RO06).
[y] Upper limits for transitions to other states range from 0.5% to 2.6% (1977BE46). See also (1973RO03).
[z] Upper limits for transitions to other states range from 0.3% to 1.5% (1977BE46). See also (1973RO03).
[aa] Upper limits for transitions to other states range from 0.3% to 0.6% (1977BE46). See also (1973RO03).

Cross section measurements have been carried out in the range $E(^6\text{Li}) = 1.9$ to 35.2 MeV: see Table 18.12 in (1972AJ02) for a listing of the earlier work and (1977LE1N: $5 - 9.2$ MeV; d_0, d_{1+2}), (1975SO1E: $9.0 - 14.0$ MeV; α_0, α_1, α_2, unpublished), (1973BA53: $19.2 - 24$ MeV; d_3, d_4) and (1973WH03: $32.5 - 35.2$ MeV; α to first nine $T = 0$ states in ^{14}N and ^{6}Li elastic). See also (1972PO07) and (1977ME1F; theor.).

The cross section for reactions (b), (c) and (e) rise monotonically and rapidly with energy up to $E(^6\text{Li}) = 4$ 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 describe the data (1970JO09). The cross section for the isospin-forbidden α_1 group [to ^{14}N*(2.31), 0^+, $T = 1$] shows an energy dependence very unlike those for the α_0 and α_2 groups, characterized 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). At the higher energies the d_3 and d_4 yields are smooth functions for $E(^6\text{Li}) = 19.2$ to 24 MeV (1973BA53) as are the α-yields and the yield of elastically scattered ^{6}Li for $E(^6\text{Li}) = 32.5$ to 35.2 MeV (1973WH03). The elastic scattering of vector polarized ^{6}Li ions has been studied at $E(^6\text{Li}) = 22.8$ MeV (1976WE10). See also ^{16}O and ^{17}O in (1977AJ02), ^{14}N and ^{15}O in (1976AJ04) and ^{12}C in (1975AJ02).

3. ^{12}C(^{7}Li, n)^{18}F $Q_m = 5.964$

See (1972AJ02).

4. (a) ^{12}C(^{10}B, α)^{18}F $Q_m = 8.754$
(b) ^{12}C(^{11}B, αn)^{18}F $Q_m = -2.701$

See (1974KL1B, 1976DA07, 1977KL1E) and ^{22}Na in (1978EN06) for reaction (a). A sharp γ-line is reported in reaction (b) at $E_\gamma = 3728 \pm 2$ keV as a cascade via ^{18}F*(1.12): it is suggested that it comes from the de-excitation of the $J^\pi(K^\pi)$ $5^-(0^-)$ state (1977KOZZ; abstract). Two γ-lines are reported with $E_\gamma = 937.21 \pm 0.12$ and 184.12 ± 0.07 keV [$(0.94 \to 0)$, $(1.12 \to 0.94)$]: $E_x = 937.24 \pm 0.12$ and 1121.36 ± 0.15 keV (E.K. Warburton, private communication).

5. ^{12}C(^{12}C, ^{6}Li)^{18}F $Q_m = -14.960$

See (1972AJ02).

Table 18.12: Lifetime measurements of some ^{18}F states [a]

^{18}F* (MeV)	τ_m	Reaction	Refs.
0.94	68 ± 7 psec	^{3}H(^{16}O, n)	(1966AL04)
	68.3 ± 3.1 psec	^{16}O(^{3}He, p)	(1974BR04)
	65.4 ± 5.3 psec	^{3}H(^{16}O, n)	(1974CO01)
	67.6 ± 2.5 psec		mean
1.04	4^{+3}_{-2} fsec	^{18}O(p, n)	(1967BL18)
1.08	30 ± 3 psec	^{3}H(^{16}O, n)	(1966AL04)
	26.1 ± 2.3 psec	^{3}H(^{16}O, n)	(1974CO01)
	27.5 ± 1.9 psec		mean
1.12	218 ± 9 nsec		mean value [a]
	199 ± 14 nsec	^{19}F(n, 2n)	(1972AD01)
	218 ± 8 nsec [A]	^{17}O(p, γ)	(1972BE37)
1.70	0.86 ± 0.20 psec	^{16}O(^{3}He, p)	(1966OL03)
	1.16 ± 0.12 psec	^{3}H(^{16}O, n)	(1973WA19)
	1.30 ± 0.40 psec }	^{16}O(^{3}He, p)	(1973RO05) [b]
	1.05 ± 0.30 psec }		
	1.09 ± 0.10 psec		mean
2.10	4.3 ± 1.4 psec	^{16}O(^{3}He, p)	(1966OL03) [a]
2.52	0.65 ± 0.13 psec	^{16}O(^{3}He, p)	(1966OL03, 1967WA06)
	0.73 ± 0.18 psec	^{16}O(^{3}He, p)	(1973RO05)
	0.75 ± 0.12 psec	^{14}N(α, γ)	(1973RO05)
	0.68 ± 0.11 psec		mean
3.06	< 1.5 fsec	^{14}N(α, γ)	(1972RO24)
3.13	0.32 ± 0.10 psec	^{16}O(^{3}He, p)	(1967WA06, 1972RO04)
3.36	$0.55^{+0.20}_{-0.15}$ psec	^{16}O(^{3}He, p)	(1967WA06)
	0.46 ± 0.10 psec	^{16}O(^{3}He, p)	(1966OL03)
	0.50 ± 0.10 psec	^{14}N(α, γ)	(1973RO05)
	0.49 ± 0.07 psec		mean
3.72	4 ± 2 fsec	^{17}O(p, γ)	(1973RO04)
3.79	224 ± 35 fsec	^{14}N(α, γ), ^{17}O(p, γ)	(1973RO06) [b]
3.84	29 ± 9 fsec	^{17}O(p, γ)	(1973RO06)
4.12	91 ± 22 fsec	^{17}O(p, γ)	(1973RO06)

Table 18.12: Lifetime measurements of some ^{18}F states [a] (continued)

^{18}F* (MeV)	τ_m	Reaction	Refs.
4.23	110 ± 15 fsec	^{17}O(p, γ)	(1973RO06)
4.36	27 ± 10 fsec	^{17}O(p, γ)	(1973RO04)
4.40	58 ± 12 fsec	^{17}O(p, γ)	(1973RO06)
4.65	< 10 fsec	^{17}O(p, γ)	(1973RO06)
4.86	66 ± 18 fsec	^{14}N(α, γ), ^{17}O(p, γ)	(1973RO06)
4.96	< 4 fsec	^{17}O(p, γ)	(1973RO06)
5.30	30 ± 5 fsec	^{14}N(α, γ)	(1973RO05)
5.50	63 ± 25 fsec	^{14}N(α, γ), ^{17}O(p, γ)	(1973RO06)
5.79	15 ± 10 fsec	^{14}N(α, γ)	(1973RO06)

A = adopted.

[a] See also Table 18.15 in (1972AJ02).

[b] See also (1973RO04).

6. ^{13}C(^{14}N, ^{9}Be)^{18}F $\qquad Q_m = -6.232$

See (1975KL1A).

7. ^{14}N(α, γ)^{18}F $\qquad Q_m = 4.4159$

A number of resonances have been observed for $E_\alpha < 3$ MeV: see Table 18.13. Recent studies of these by (1972CO1C), and by the Toronto group (1972RO24, 1973RO03, 1973RO05, 1973RO06, 1973RO07, 1977BE46), the latter in conjunction with work on the ^{17}O(p, γ) and ^{16}O(^{3}He, pγ) reactions (Tables 18.17 and 18.18) have led to the determination of the branching ratios, mixing ratios and widths (Table 18.11), lifetimes (Table 18.12) and excitation energies and J^π of ^{18}F states with $E_x < 6.9$ MeV. Studying the strengths of the γ-transitions (see Table 2 in the Introduction) has led Rolf and his collaborators to suggest K^π assignments for the first 0^+, 0^-, 1^+ and 1^- bands in ^{18}F: see Tables 18.10 and 18.17 for a listing of these. The reader is referred to the series of papers by the Toronto group for the most complete and definitive arguments on the parameters of the low-lying states of ^{18}F. For the earlier work see (1972AJ02). See also (1972VL1B).

The non-resonant S-factor for this reaction, $S \approx 0.7$ MeV · b (1972CO1C). See also (1971BA1A, 1972CO1E, 1973AR1E, 1973CL1E, 1975FO19, 1975SC1Y; astrophys. questions).

8. ^{14}N(α, n)^{17}F $\qquad Q_{\rm m} = -4.7347 \qquad E_{\rm b} = 4.4159$

The total cross-section ratios $\sigma(n_1)/\sigma(p_1)$ have been 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 (1969SC21) [see Table 18.13 in (1972AJ02) and compare with Tables 18.14, 18.15 and 18.16 here]. (1972GR10) find that the mean level width increases from 40 ± 9 keV for $E_\alpha = 10 - 13$ MeV to 100 ± 24 keV for $E_\alpha = 15 - 19$ MeV. See also (1977LI19).

9. ^{14}N(α, p)^{17}O $\qquad Q_{\rm m} = -1.1908 \qquad E_{\rm b} = 4.4159$

Observed resonances are displayed in Table 18.13. Excitation functions of several proton groups have been measured for $E_\alpha = 10$ to 25 MeV (1970ZE01); they show gross structures.

10. (a) ^{14}N(α, α)^{14}N $\qquad E_{\rm b} = 4.4159$

(b) ^{14}N(α, αp)^{13}C $\qquad Q_{\rm m} = -7.5506$

(c) ^{14}N(α, d)^{16}O $\qquad Q_{\rm m} = -3.1104$

(d) ^{14}N(α, ^{6}Li)^{12}C $\qquad Q_{\rm m} = -8.7989$

(e) ^{14}N(α, 2α)^{10}B $\qquad Q_{\rm m} = -11.6132$

Observed anomalies in the elastic scattering are exhibited in Table 18.13. Resonances in the α_1 isospin-forbidden yield are displayed in Table 18.14 (1974CH1T, 1976CH24). In the α_1 study, carried out for $E_\alpha = 7.6 - 16.9$ MeV, a partial wave analysis involving a method of removing ambiguities and parametrizing S-matrix elements gives the level parameters of 151 isospin mixed, natural parity states in ^{18}F with $10.4 < E_{\rm x} < 17.5$ MeV. Many of these states have also been reported in the ^{16}O(d, α_1) work of (1973JO13). The agreement is best for low-lying 2^+ or 4^+ states, and is quite good for 3^- and 5^- states, while for high-J states the greater centrifugal barrier for ^{16}O + d at the same $E_{\rm x}$ relatively suppresses high-J states in the ^{16}O + d work: see Table 18.16. A study of the energy dependence of averaged intensities of the partial waves shows some indication that the lower partial waves reconserve isospin as $E_{\rm x}$ increases (1976CH24). See also (1970TO03).

The total cross section for formation of ^{6}Li and ^{10}B (reactions (d) and (e)) has been studied for $E_\alpha = 21$ to 42 MeV by (1974JA11) who discuss the astrophysical importance of these processes. For the earlier work on reactions (a), (b) and (c), see (1972AJ02). See also (1973BO1J, 1974JE1A, 1976LE1K), (1974FA1A; theor.) and ^{14}N in (1976AJ04).

11. ^{14}N(^{6}Li, d)^{18}F $\qquad Q_{\rm m} = 2.942$

Table 18.13: Resonances in ^{14}N $+ \alpha$ below $E_\alpha = 5$ MeV

E_α (MeV $\pm$ keV)	Particles out	$\Gamma_{\text{c.m.}}$ (keV)	$(2J+1)\Gamma_\gamma\Gamma_\alpha/\Gamma$ (eV)	$J^\pi; T$	E_x (MeV)	Refs.
			$< 2 \times 10^{-5}$		4.657	(1972CO1C)
0.559	γ		$(2.8 \pm 0.5) \times 10^{-4}$	1; 0	4.851	(1972CO1C)
0.698			$< 0.5 \times 10^{-4}$	2^+; 1	4.959	(1972CO1C)
1.136 ± 3	γ		0.059 ± 0.021	4^+; 0	5.299	(1968PA10, 1972CO1C, 1973RO03, 1973RO05)
			0.084 ± 0.004			
			0.108 ± 0.015			
1.398 ± 3	γ		0.017 ± 0.003	$3^{(-)}$; 0	5.503	(1968PA10, 1973RO03, 1973RO06)
			0.027 ± 0.003			
1.527	γ		1.44 ± 0.14	1^+	5.603 [d]	(1977BE46)
1.529 ± 2	γ, α_0	< 1.2	2.60 ± 0.21	1^-; $0+1$	5.605 [d]	A, (1973RO03, 1977BE46)
1.618 ± 2	γ, α_0	< 0.8	1.4 ± 0.3	1^-; $0+1$	5.674	A, (1973RO03, 1977BE46)
			1.37 ± 0.19			
1.765 ± 4	γ		0.047 ± 0.018	2^-; 0	5.788	(1973RO03, 1973RO06)
2.160 ± 4	γ		0.20 ± 0.04	4^-; 0	6.096	(1973RO03, 1973RO06)
2.166 ± 7	γ, α_0		0.08 ± 0.03	1, 2, $3^{(-)}$; 0	6.100	(1973RO03)
			[a]			
2.348 ± 3	γ, α_0	< 0.8	7.5 ± 1.3	3^-; 1	6.242	A, (1973RO03, 1973RO06)
2.372 ± 3	γ	< 3		1^+; (0)	6.261	(1973RO03, 1973RO07)
			[b]			
2.438 ± 4	γ		0.52 ± 0.12	3^+; 0	6.312	(1973RO03, 1973RO07)
2.532 ± 4	γ		1.6 ± 0.4	2^+; $0+1$	6.385	(1973RO03, 1973RO07)
	γ		0.16 ± 0.06	3^+; (0)	6.480	(1973RO03, 1973RO07)

Table 18.13: Resonances in ^{14}N + α below $E_\alpha = 5$ MeV (continued)

E_α (MeV ± keV)	Particles out	$\Gamma_{\text{c.m.}}$ (keV)	$(2J+1)\Gamma_\gamma\Gamma_\alpha/\Gamma$ (eV)	$J^\pi; T$	E_x (MeV)	Refs.
2.767 ± 4	γ, α_0	(< 0.8)	0.29 ± 0.06	$5^+; 0$	6.568	A, (1973RO03, 1973RO05)
2.870 ± 4	γ, p_0	< 1.6	2.7 ± 0.5	$2^-; 1$	6.648	A, (1973RO03, 1973RO06)
2.870 ± 6	α_0	93 ± 5	$\Gamma_\alpha/\Gamma = 0.85$	1^-	6.648	A, (1973RO03)
			0.12 ± 0.07	$4^+; 0$	6.78	A, (1973RO03, 1973RO07)
			< 0.2	$1^+, 2, 3^+; (0)$	6.803	(1973RO03, 1973RO07)
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)

A: see references listed for this resonance in Table 18.13 of (1972AJ02).

[a] See Table 18.14 for higher resonances observed in ^{14}N(α, α_1).

[b] ≤ 0.07 for ^{18}F*(6.11, 6.16) (1973RO03).

[c] ≤ 0.03 for ^{18}F*(6.28) (1973RO03).

[d] See Table 18.19.

Table 18.14: Mixed isospin ^{18}F states from ^{14}N(α, α_1) [a]

	E_α [b] (MeV)	E_x in ^{18}F (MeV)	$\Gamma_{c.m.}$ (keV)	Strength $\lvert S(E_x)\rvert$	Footnote
$J^\pi = 1^-$					
1	8.142	10.748	535	0.062	c
2	8.319	10.884	147	0.075	d
3	8.813	11.268	147	0.107	
4	9.019	11.429	184	0.154	
5	9.057	11.458	313	0.058	
6	9.470	11.779	142	0.067	d
7	10.468	12.555	45	0.093	d
8	10.646	12.693	43	0.049	
9	10.788	12.804	98	0.082	
10	11.467	13.331	43	0.097	e
11	11.726	13.533	19	0.101	
12	11.858	13.635	44	0.110	d
13	12.017	13.759	120	0.071	
14	12.358	14.024	49	0.087	d
15	12.720	14.305	75	0.110	
16	13.247	14.715	129	0.116	d
17	13.500	14.912	79	0.097	
18	13.702	15.069	99	0.042	
19	14.424	15.630	101	0.098	
20	15.099	16.154	150	0.098	d
21	16.383	17.152	179	0.051	
$J^\pi = 2^+$					
1	7.879	10.542	43	0.227	d
2	8.072	10.692	138	0.177	d
3	8.239	10.822	47	0.047	d
4	8.567	11.077	23	0.203	
5	8.608	11.109	40	0.179	d
6	8.880	11.320	86	0.311	d
7	9.216	11.582	756	0.190	c
8	9.262	11.617	95	0.207	

Table 18.14: Mixed isospin ^{18}F states from ^{14}N(α, α_1) [a] (continued)

	E_α [b] (MeV)	E_x in ^{18}F (MeV)	$\Gamma_{c.m.}$ (keV)	Strength $\|S(E_x)\|$	Footnote
9	9.653	11.921	75	0.130	d
10	10.004	12.194	252	0.111	d
11	10.306	12.429	113	0.295	d,e
12	10.588	12.648	246	0.300	d
13	10.676	12.717	127	0.198	
14	10.868	12.866	174	0.236	
15	11.417	13.293	73	0.097	d
16	11.582	13.421	440	0.079	
17	12.246	13.937	46	0.057	
18	12.691	14.283	157	0.131	
19	13.082	14.587	51	0.024	
20	13.323	14.774	79	0.153	
21	13.704	15.070	264	0.038	
22	14.523	15.707	134	0.048	
23	15.121	16.171	195	0.110	
24	15.363	16.360	70	0.110	
25	16.438	17.195	524	0.057	d
$J^\pi = 3^-$					
1	7.755	10.446	49	0.381	d
2	7.949	10.597	48	0.032	
3	8.123	10.732	37	0.059	d
4	8.479	11.009	47	0.021	d
5	8.707	11.186	42	0.102	d,e
6	8.921	11.352	53	0.211	d
7	9.273	11.626	67	0.090	d
8	9.768	12.011	164	0.089	
9	10.097	12.267	69	0.102	
10	10.447	12.539	112	0.172	d
11	10.731	12.759	58	0.238	d
12	11.064	13.018	165	0.023	d
13	11.434	13.306	35	0.069	

Table 18.14: Mixed isospin ^{18}F states from ^{14}N(α, α_1) [a] (continued)

	E_α [b] (MeV)	E_x in ^{18}F (MeV)	$\Gamma_{c.m.}$ (keV)	Strength $\lvert S(E_x)\rvert$	Footnote
14	11.696	13.509	50	0.146	
15	11.808	13.597	69	0.142	
16	11.996	13.743	144	0.067	d
17	12.514	14.145	164	0.087	
18	12.979	14.507	138	0.114	
19	13.217	14.692	47	0.073	
20	13.556	14.955	71	0.059	
21	13.987	15.290	100	0.093	
22	14.267	15.508	131	0.045	d
23	14.954	16.042	190	0.062	
24	15.230	16.256	44	0.107	d
25	16.006	16.859	75	0.082	
26	16.266	17.061	298	0.040	
27	16.667	17.373	147	0.060	
$J^\pi = 4^+$					
1	8.349	10.908	45	0.025	
2	8.781	11.244	73	0.215	
3	8.906	11.341	56	0.304	d,e
4	8.959	11.382	111	0.382	
5	9.198	11.568	225	0.075	
6	9.485	11.791	67	0.019	
7	9.750	11.997	28	0.061	
8	9.973	12.170	22	0.077	
9	10.011	12.200	52	0.081	
10	10.316	12.437	183	0.218	
11	10.407	12.508	94	0.496	e
12	10.477	12.562	62	0.248	d
13	10.653	12.699	343	0.083	
14	10.787	12.803	35	0.039	
15	11.163	13.095	25	0.163	d
16	11.224	13.143	64	0.143	

Table 18.14: Mixed isospin ^{18}F states from ^{14}N(α, α_1) [a] (continued)

	E_α [b] (MeV)	E_x in ^{18}F (MeV)	$\Gamma_{c.m.}$ (keV)	Strength $\|S(E_x)\|$	Footnote
17	11.564	13.407	110	0.155	
18	11.702	13.514	71	0.167	e
19	11.939	13.698	63	0.319	d
20	12.125	13.843	228	0.226	d
21	12.247	13.938	61	0.056	
22	12.394	14.052	54	0.025	
23	12.703	14.292	107	0.145	
24	13.012	14.532	79	0.140	d
25	13.226	14.699	348	0.114	
26	14.162	15.426	127	0.175	
27	14.761	15.892	471	0.082	c
28	15.049	16.115	235	0.127	
29	15.313	16.321	55	0.100	
30	15.810	16.707	180	0.113	
31	16.494	17.238	232	0.048	
$J^\pi = 5^-$					
1	8.705	11.184	23	0.050	
2	10.615	12.669	80	0.171	e
3	10.689	12.727	37	0.306	d
4	11.275	13.182	149	0.109	d
5	11.481	13.342	273	0.239	
6	11.510	13.365	36	0.316	d,e
7	11.593	13.429	149	0.244	
8	12.047	13.782	293	0.186	
9	12.234	13.928	112	0.183	
10	12.345	14.014	29	0.021	
11	12.498	14.133	379	0.142	d
12	12.609	14.219	110	0.198	
13	12.801	14.368	149	0.136	
14	13.330	14.779	126	0.107	
15	13.628	15.011	147	0.130	d

Table 18.14: Mixed isospin ^{18}F states from ^{14}N(α, α_1) [a] (continued)

	E_α [b] (MeV)	E_x in ^{18}F (MeV)	$\Gamma_{c.m.}$ (keV)	Strength $\lvert S(E_x)\rvert$	Footnote
16	13.755	15.110	71	0.109	
17	13.935	15.250	114	0.043	
18	14.217	15.469	44	0.048	
19	14.440	15.642	92	0.054	d
20	14.587	15.756	109	0.036	
21	14.948	16.037	151	0.034	
22	15.430	16.412	137	0.110	
23	15.667	16.596	224	0.116	
24	16.016	16.867	270	0.024	d
25	16.468	17.218	486	0.024	c
$J^\pi = 6^+$					
1	10.970	12.945	98	0.031	
2	11.459	13.325	62	0.066	
3	11.665	13.485	102	0.059	
4	11.882	13.654	98	0.169	e
5	12.344	14.013	37	0.037	
6	12.501	14.135	78	0.037	
7	13.138	14.630	104	0.050	
8	13.471	14.889	165	0.067	d
9	13.639	15.020	82	0.063	
10	14.422	15.628	49	0.049	
11	15.273	16.290	76	0.079	
12	15.444	16.422	183	0.177	
13	15.713	16.632	415	0.154	
14	15.898	16.775	207	0.255	
15	16.015	16.866	140	0.344	d
16	16.300	17.088	186	0.013	
17	16.576	17.302	285	0.061	
18	16.757	17.443	95	0.043	
$J^\pi = 7^-$					
1	15.705	16.625	118	0.034	

Table 18.14: Mixed isospin ^{18}F states from ^{14}N(α, α_1) [a] (continued)

	E_α [b] (MeV)	E_x in ^{18}F (MeV)	$\Gamma_{c.m.}$ (keV)	Strength $\lvert S(E_x)\rvert$	Footnote
2	15.965	16.827	73	0.142	
3	16.121	16.949	143	0.113	
4	16.760	17.445	109	0.051	

[a] (1976CH24). See also Table 18.13 in (1972AJ02) for the earlier work and Table 18.13 here for resonances in ^{14}N + α observed below $E_\alpha = 5$ MeV. See also (1970TO03).
[b] The absolute values of the narrow levels are uncertain to $\pm 10 - 20$ keV. The level widths are uncertain to $\pm 10\%$ for strong states. See (1976CH24) for further comments.
[c] There are large uncertainties in the level parameters of this broad state (1976CH24).
[d] A state of the same J^π, approximate width and E_x occurs in ^{16}O(d, α_1)^{14}N: see Table 18.16 (1976CH24).
[e] An ^{18}O state of the same J^π occurs at the corresponding E_x in ^{18}O. Therefore this state probably has a large $T = 1$ amplitude.

Angular distributions have been measured for $E(^6\text{Li}) = 5.3$ to 6.0 MeV (1968RI13: d_0, $d_{1\to4}$). See also (1972GA1E).

12. ^{14}N(^{7}Li, t)^{18}F $\qquad Q_m = 1.949$

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 the transfer of four nucleons into the (2s, 1d) shell (1968MI09). At $E(^7\text{Li}) = 36$ MeV the $K^\pi = 1^+$ band also appears to be selectively populated. States at $E_x = 9.58\pm0.02, 11.22\pm0.03$ and 14.18 ± 0.04 MeV are strongly populated. It is suggested that the first two are the 6^+ and 7^+ members of that band (1977CO09). [Angular distributions are reported for ^{18}F*(1.70, 2.10, 2.52, 3.36, 4.40, 5.30, 6.57, 9.58, 11.22, 14.18).] See also (1972GA1E).

13. ^{15}N(^{3}He, p)^{17}O $\qquad Q_m = 8.554 \qquad E_b = 14.1603$

See ^{17}O in (1971AJ02) and (1973AB1D).

Table 18.15: Maxima in the yields of ^{16}O + d [a]

E_d (MeV ± keV)	Particles out	$\Gamma_{c.m.}$ (keV)	$J^\pi; T$	E_x (MeV)	Refs.
0.895	p_1, α_0	210 ± 25		(8.321)	(1964AM1A)
1.048	p_1, d_0, α_0	88 ± 10	1^+	8.457	(1960AM03, 1964AM1A, 1968MA53)
1.199	α_0	230 ± 30		(8.591)	(1964AM1A, 1965MA59)
1.298	p_1, d_0, α_0	13 ± 3		(8.679)	(1960AM03, 1964AM1A)
1.325	d_0, α_0			(8.703)	(1964AM1A)
1.482	α_0	40 ± 5		(8.843)	(1960AM03, 1964AM1A)
1.563	d_0, α_0	121 ± 15		(8.914)	(1960AM03, 1964AM1A)
1.616	α_0	19 ± 15		(8.962)	(1960AM03, 1964AM1A)
1.765	d_0, α_0	141 ± 10		(9.094)	(1960AM03, 1964AM1A)
1.885	p_0, p_1, d_0, α_0	108 ± 12	$3, 4^-; 0$	9.20	(1956RO1A, 1964AM1A, 1965MA59, 1973JO13)
2.22	n_0, α_0		$2, 3^+; 0$	9.50	(1955MA85, 1961DI06, 1973JO13)
2.28	α_0		$2, 3^+; 0$	(9.55)	(1973JO13)
2.34	n_0, p_1			(9.60)	(1955MA85, 1956RO1A, 1961DI06)
2.55	p_1			(9.79)	(1955ST1A, 1956RO1A)
2.92	n_0, p_0, p_1			10.12	(1955MA85, 1955ST1A, 1956RO1A)
3.05	α_0		$3, 4^-; 0$	10.24	(1973JO13)
3.13	n, p_1, α_0, α_1		$\geq 2; 0$	10.31	(1973JO13)
3.37	n_0, p_0, p_1, α_1			10.52	(1955MA85, 1955ST1A, 1956RO1A, 1970JO1C, 1972AN21)
3.47	α_0		$4, 5^+; 0$	10.61	(1973JO13)
3.68	n, p_0, p_1, α_1		2^+	10.79	(1955MA85, 1955ST1A, 1956RO1A, 1968MA1C, 1969JO1C, 1973JO13)

Table 18.15: Maxima in the yields of ^{16}O + d [a] (continued)

E_d (MeV $\pm$ keV)	Particles out	$\Gamma_{c.m.}$ (keV)	$J^\pi; T$	E_x (MeV)	Refs.
3.80	p_0, α_0		$\geq 2^+; 0$	10.90	(1956RO1A, 1957BA14, 1973JO13)
3.94	n, p_1, α_1			11.03	(1955MA85, 1956RO1A, 1973JO13)
3.95	p_1, α_0	≈ 35	$3, 4^-; 0$	11.03	(1956RO1A, 1957BA14, 1973JO13)
4.07	n, p_1			11.14	(1955MA85, 1956RO1A)
4.38	p_1, α_0		$4, 5^+; 0$	11.42	(1956RO1A, 1973JO13)
4.57	α_0		$5, 6^-; 0$	11.58	(1973JO13)
4.80	d_0, α_0		$\geq 3; 0$	11.79	(1956BE1B, 1973JO13)
4.93	α_0		$5, 6^-; 0$	11.90	(1973JO13)
5.05 ± 15	α_4	40		12.01	(1968JO07)
5.11	$\alpha_0, \alpha_2, \alpha_4$	60	$4, 5^+; 0$	12.06	(1968JO07, 1973JO13)
5.17	α_0	55	$T = 0$	12.12	(1968JO07)
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)
5.47	α_4	80		12.38	(1968JO07)
5.49	$\alpha_2, \alpha_3, \alpha_4$	120		12.40	(1968JO07)
5.59	α_0, α_2	120		12.49	(1968JO07, 1969JO1C, 1973JO13)
5.65	α_0, α_2	140		12.54	(1968JO07)
5.77	α_0	180	2^+	12.65	(1968JO07, 1969JO1C)
5.80	$\alpha_0, \alpha_2, \alpha_4$	160		12.68	(1968JO07)
5.81	α_3, α_4	80	5^-	12.69	(1968JO07, 1969JO1C)
5.91	α_2	160		12.77	(1968JO07)

Table 18.15: Maxima in the yields of ^{16}O + d [a] (continued)

E_d (MeV ± keV)	Particles out	$\Gamma_{c.m.}$ (keV)	$J^\pi; T$	E_x (MeV)	Refs.
6.00	α_0	120		12.85	(1968JO07)
6.11	α_0, α_4	120		12.95	(1968JO07)
6.19	α_2, α_3	200	≥ 4; 0	13.02	(1968JO07, 1973JO13)
6.25	α_0, α_4	150	$T = 0$	13.08	(1968JO07)
6.30	α_0, α_2	160		13.12	(1968JO07)
6.34	α_0, α_3	160	5, 6^-; 0	13.16	(1968JO07, 1973JO13)
6.38	α_0, α_3	145	$T = 0$	13.19	(1968JO07)
6.43	α_0, α_2	120		13.24	(1968JO07)
6.46	α_0, α_4	100		13.26	(1968JO07)
6.54	α_0, α_2	135		13.33	(1968JO07)
6.61	α_2, α_3, α_4	120		13.40	(1956BR36, 1968JO07)
6.64	α_0, α_2	200		13.42	(1968JO07)
6.66	α_0	100		13.44	(1968JO07)
6.72	α_2	100		13.49	(1968JO07)
6.73	α_2	100		13.50	(1968JO07)
6.80	α_2, α_3	140		13.56	(1968JO07)
6.84	α_0, α_2, α_4	150		13.60	(1968JO07)
6.94	α_0, α_3	90		13.69	(1968JO07)
7.12	α_3, α_4	60		13.85	(1968JO07)
7.27	α_3	150		13.98	(1968JO07)
7.30	α_2	110		14.01	(1968JO07)
7.34	α_0, α_3, α_4	200		14.04	(1968JO07)

Table 18.15: Maxima in the yields of ^{16}O + d [a] (continued)

E_d (MeV ± keV)	Particles out	$\Gamma_{c.m.}$ (keV)	$J^\pi; T$	E_x (MeV)	Refs.
7.38	α_0, α_3	210		14.08	(1968JO07)
7.43	α_3	300		14.12	(1968JO07)
7.49	α_0	220		14.18	(1968JO07)
7.58	α_0	200	$\geq 4; 0$	14.26	(1968JO07, 1973JO13)
7.62	α_4	85		14.29	(1968JO07)
7.66	$\alpha_0, \alpha_2, \alpha_4$	130	$T = 0$	14.33	(1968JO07)
7.67	$\alpha_0, \alpha_2, \alpha_3, \alpha_4$	250	$T = 0$	14.34	(1968JO07)
7.74	α_3	235		14.40	(1968JO07)
7.80	α_0, α_4	70		14.45	(1968JO07)
7.82	α_0, α_2	225		14.47	(1968JO07)
7.99	α_4	200		14.62	(1968JO07)
8.02	α_0	150		14.65	(1968JO07)
8.03	α_3	310		14.66	(1968JO07)
8.07	α_0	120		14.69	(1968JO07)
8.08	α_3, α_4	310		14.70	(1968JO07)
8.21	α_2	250		14.82	(1968JO07)
8.25	α_4	380		14.85	(1968JO07)
8.30	$\alpha_0, \alpha_2, \alpha_3$	210		14.90	(1968JO07)
8.34	α_4	115		14.93	(1968JO07)
8.37	α_0	130		14.96	(1968JO07)
8.37	α_0, α_3	250		14.96	(1968JO07)
8.40	α_0	310		14.99	(1968JO07)

Table 18.15: Maxima in the yields of $^{16}O + d$ [a] (continued)

E_d (MeV ± keV)	Particles out	$\Gamma_{c.m.}$ (keV)	$J^\pi; T$	E_x (MeV)	Refs.
8.43	α_4	120		15.01	(1968JO07)
8.50	α_3, α_4	190		15.07	(1968JO07)
8.52	α_2	150		15.09	(1968JO07)
8.56	α_2	220		15.13	(1968JO07)
8.58	α_4	180		15.15	(1968JO07)
8.61	α_0, α_3	200		15.17	(1968JO07)
8.65	α_0, α_2	135		15.21	(1968JO07)
8.72	α_2, α_4	120		15.27	(1968JO07)
8.76	α_2	160		15.30	(1968JO07)
8.79	α_0	200		15.33	(1968JO07)
8.82	$\alpha_0, \alpha_3, \alpha_4$	230		15.36	(1968JO07)
8.89	α_3	110		15.42	(1968JO07)
8.93	α_3, α_4	190		15.46	(1968JO07)
8.97	α_2, α_4	210		15.49	(1968JO07)
9.00	α_0, α_2	190		15.52	(1968JO07)

[a] These do not include the structures in α_1 leading to mixed isospin states in ^{18}F: for the latter see Table 18.16. See also Table 18.17 in (1972AJ02) and (1959AJ76).

Table 18.16: Isospin-mixed states in ^{18}F from ^{16}O(d, α_1) (1973JO13) [a]

	E_d (MeV)	$E_x(^{18}F)$ (MeV)	$\Gamma_{c.m.}$ (keV)	Strength $\lvert S(E_x)\rvert$	Footnote
$J^\pi = 1^-$					
1	3.021	10.209	93	0.132	
2	3.179	10.349	269	0.136	b
3	3.454	10.594	157	0.054	b
4	3.492	10.627	58	0.036	
5	3.809	10.909	241	0.053	b
6	4.031	11.106	1009	0.028	c
7	4.847	11.831	179	0.108	b
8	5.390	12.313	100	0.078	d,e
9	5.571	12.474	35	0.098	d,e
10	6.353	13.168	184	0.038	d,e
11	6.662	13.442	77	0.049	d,e
12	6.847	13.606	88	0.023	d,e
13	7.244	13.959	69	0.046	d,e
14	7.832	14.481	203	0.036	d,e
15	8.082	14.703	169	0.121	d,e
16	8.865	15.398	157	0.056	d,e
17	9.255	15.744	249	0.056	d,e
18	9.692	16.132	355	0.044	d,e
19	9.781	16.211	181	0.084	d,e
20	10.499	16.849	78	0.037	d,e
21	11.367	17.619	313	0.032	d,e
22	11.799	18.002	203	0.033	d,e
23	12.682	18.786	1072	0.017	d,e
$J^\pi = 2^+$					
1	2.020	9.320	40		f,g
2	2.620	9.853	195	0.037	b
3	3.138	10.313	572	0.034	
4	3.366	10.516	46	0.105	b
5	3.471	10.609	151	0.062	b
6	3.547	10.676	62	0.041	

Table 18.16: Isospin-mixed states in ^{18}F from ^{16}O(d, α_1) (1973JO13) [a] (continued)

	$E_{\rm d}$ (MeV)	$E_{\rm x}(^{18}{\rm F})$ (MeV)	$\Gamma_{\rm c.m.}$ (keV)	Strength $\lvert S(E_{\rm x})\rvert$	Footnote
7	3.578	10.704	375	0.168	h
8	3.684	10.798	85	0.034	
9	3.849	10.944	402	0.061	h
10	3.904	10.993	222	0.061	h
11	3.944	11.029	78	0.179	
12	3.989	11.069	51	0.149	
13	4.253	11.303	475	0.088	
14	4.267	11.316	94	0.083	
15	4.480	11.505	126	0.076	
16	4.655	11.660	240	0.057	
17	5.000	11.967	124	0.074	
18	5.190	12.135	219	0.087	
19	5.441	12.358	78	0.135	
20	5.462	12.377	116	0.266	
21	5.742	12.625	231	0.088	d,e
22	5.786	12.664	288	0.090	d,e
23	5.954	12.184	441	0.113	d,e
24	6.151	12.988	648	0.056	d,e
25	6.487	13.287	99	0.078	d,e
26	6.726	13.499	146	0.077	d,e
27	6.954	13.701	78	0.048	d,e
28	7.074	13.808	263	0.097	d,e
29	7.400	14.097	166	0.166	d,e
30	8.228	14.833	124	0.069	d,e
31	8.310	14.905	1201	0.055	d,e
32	9.349	15.828	20	0.040	d,e
33	9.643	16.089	103	0.038	d,e
34	9.909	16.325	292	0.032	d,e
35	10.494	16.844	47	0.038	d,e
36	11.567	17.797	78	0.025	d,e

Table 18.16: Isospin-mixed states in ^{18}F from ^{16}O(d, α_1) (1973JO13) [a] (continued)

	E_d (MeV)	E_x(^{18}F) (MeV)	$\Gamma_{c.m.}$ (keV)	Strength $\lvert S(E_x)\rvert$	Footnote
37	12.951	19.025	1894	0.023	d,e
38	13.366	19.393	483	0.039	d,e
		$J^\pi = 3^-$			
1	1.950	9.258	30		b,f,g
2	2.448	9.700	372	0.019	
3	3.126	10.302	179	0.065	b
4	3.254	10.416	48	0.089	b
5	3.508	10.642	236	0.140	b
6	3.562	10.690	75	0.122	b
7	3.892	10.983	119	0.020	b
8	4.069	11.140	35	0.102	b,g
9	4.208	11.263	238	0.088	b
10	4.276	11.324	65	0.190	b,g
11	4.543	11.561	67	0.032	b
12	4.993	11.960	32	0.072	b
13	5.175	12.122	36	0.036	b
14	5.414	12.334	187	0.043	b
15	5.606	12.505	88	0.082	b,i
16	5.867	12.736	63	0.055	b.i
17	6.048	12.897	120	0.072	d,e,g
18	6.198	13.030	248	0.122	d,e
19	6.650	13.432	233	0.107	d,e
20	7.025	13.764	206	0.086	d,e
21	8.530	15.101	115	0.067	d,e
22	8.616	15.177	299	0.045	d,e
23	8.906	15.434	123	0.033	d,e
24	9.403	15.876	272	0.082	d,e
25	9.771	16.202	77	0.023	d,e
26	10.333	16.701	296	0.034	d,e
27	10.533	16.879	251	0.042	d,e

Table 18.16: Isospin-mixed states in ^{18}F from ^{16}O(d, α_1) (1973JO13) [a] (continued)

	$E_{\rm d}$ (MeV)	$E_{\rm x}$(^{18}F) (MeV)	$\Gamma_{\rm c.m.}$ (keV)	Strength $\|S(E_{\rm x})\|$	Footnote
28	10.911	17.214	112	0.023	d,e
29	11.592	17.819	273	0.016	d,e
			$J^\pi = 4^+$		
1	4.264	11.313	38	0.040	b,g
2	5.617	12.514	47	0.083	b,g,i
3	6.235	13.063	10	0.0	b,f
4	6.393	13.203	254	0.168	
5	6.461	13.264	359	0.129	
6	6.839	13.599	41	0.027	
7	6.936	13.685	61	0.074	i
8	7.067	13.802	132	0.045	i
9	7.406	14.103	73	0.036	
10	7.839	14.487	76	0.051	
11	8.308	14.904	304	0.057	
12	8.570	15.136	156	0.039	
13	9.032	15.546	319	0.030	d,e
14	9.223	15.716	237	0.031	d,e
15	9.476	15.940	153	0.030	d,e
16	9.748	16.182	149	0.046	d,e
17	10.049	16.449	52	0.022	d,e
18	10.406	16.766	135	0.035	d,e
19	10.777	17.095	86	0.017	d,e
20	11.332	17.588	208	0.045	b,d
21	12.990	19.060	416	0.030	d,e
			$J^\pi = 5^-$		
1	5.785	12.664	379	0.026	b
2	5.799	12.676	46	0.151	b,g,i
3	6.383	13.194	94	0.054	b,i
4	6.561	13.353	33	0.056	b,g,i
5	6.721	13.495	75	0.032	b

Table 18.16: Isospin-mixed states in ^{18}F from ^{16}O(d, α_1) (1973JO13) [a] (continued)

	E_d (MeV)	$E_x(^{18}F)$ (MeV)	$\Gamma_{c.m.}$ (keV)	Strength $\lvert S(E_x)\rvert$	Footnote
6	6.877	13.633	313	0.029	b
7	7.286	13.996	177	0.038	b,i
8	7.404	14.101	250	0.045	b,i
9	8.350	14.941	126	0.033	b
10	8.385	14.972	491	0.044	b
11	9.073	15.583	174	0.042	b
12	9.329	15.810	1044	0.035	b,c
13	10.357	16.722	212	0.064	b
14	10.431	16.788	209	0.052	b
15	10.728	17.052	180	0.019	
16	12.135	18.301	554	0.022	b
17	12.556	18.674	208	0.011	b
$J^\pi = 6^+$					
1	8.216	14.822	91	0.021	b
2	8.766	15.310	100	0.018	b
3	9.200	15.695	174	0.014	b
4	10.457	16.811	86	0.023	b
5	10.888	17.194	88	0.015	b
6	11.704	17.918	155	0.025	b
7	13.307	19.341	911	0.013	c
$J^\pi = 7^-$					
1	11.869	18.065	223	0.017	b
2	12.495	18.620	395	0.009	b
3	13.080	19.139	477	0.012	b

[a] This table does not include other maxima observed in ^{16}O + d: see Table 18.15 for the latter. See also Table 18.17 in (1972AJ02) and (1969JO09, 1970JO1C). (1971JA04) also report α_1 resonances at $E_p = 14.35$ and 14.95 ± 0.10 MeV ($\Gamma \approx 300$ and ≈ 550 keV) corresponding to ^{18}F*(20.3, 20.8).

[b] This level is unambiguous in the S-matrix elements and the uncertainties in E_x and Γ are estimated to be $\approx 15\%$ of Γ.

[c] May be several narrower levels.

[d] Possibly an Ericson fluctuation.
[e] Uncertain because of ambiguities in the S-matrix analysis.
[f] This level was not used in fitting the S-matrix elements.
[g] An ^{18}O state of same J^π has been identified near the corresponding $E_x(^{18}O)$.
[h] Main components of the 2^+ structure near $E_d = 3.7$ MeV. The structure may possibly be reproduced by another set of levels.
[i] A level of the same J^π, approximate width, and $E_x(^{18}F)$ occurs in $^{14}N(\alpha, \alpha_1)^{14}N$.

14. $^{15}N(\alpha, n)^{18}F$ $\qquad Q_m = -6.4175$

See (1966AD07, 1973CL1E).

15. $^{15}N(^6Li, t)^{18}F$ $\qquad Q_m = -1.634$

At $E(^6Li) = 30$ MeV preferential excitation of odd parity states of ^{18}F below $E_x = 5$ MeV is reported. Angular distributions of the tritons to ^{18}F*(0, 0.94, 2.10, 4.40) [$J^\pi = 1^+, 3^+, 2^-, 4^-$] are all strongly forward peaked (1972LI24). See also (1972BA1P, 1977MA2G).

16. $^{16}O(d, \gamma)^{18}F$ $\qquad Q_m = 7.5263$

The capture cross section rises from 0.1 μb at $E_d = 0.4$ MeV to 25 μb 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).

17. $^{16}O(d, n)^{17}F$ $\qquad Q_m = -1.6243$ $\qquad E_b = 7.5263$

Excitation functions have been measured for the n_0 and n_1 groups from threshold to 17 MeV: see Table 18.16 in (1972AJ02) for a listing of the earlier work and (1972AN1G, 1972AN21: $E_d =$ 3 to 4 MeV), (1969WO09: 3.2 MeV; yield of ^{17}F), (1972GR10: threshold to 15.8 MeV; yield of ^{17}F) and (1974AU1B: 7 to 17 MeV; ratio of $(\sigma_{n_1}/\sigma_{p_1})$: it decreases slowly with increasing energy). Some structure is observed: that which is attributed to states in ^{18}F is displayed in Table 18.15 (1955MA85, 1961DI06, 1968MA1C). The mean level widths range from 53 ± 11 keV at $E_d \approx 10 - 13$ MeV to 70 ± 17 keV at $E_d \approx 13 - 16$ MeV (1972GR10). See also (1970DA14). Polarization measurements have been carried out for $E_d = 3$ to 15 MeV: see Table 18.16 in (1972AJ02) and (1972AN1G, 1972AN21: $E_d = 3$ to 4 MeV; n_0, n_1) and (1975WA1L, 1976LI1R: 4.3 to 15 MeV; n_0, n_1). See also (1974LO1B) and ^{17}F in (1977AJ02).

18. ^{16}O(d, p)^{17}O $\quad Q_m = 1.9197 \quad E_b = 7.5263$

Excitation functions and polarization studies have been reported for several proton groups for $E_d = 0.3$ to 13.3 MeV: see Table 18.16 in (1972AJ02) for the earlier work. Recent polarization work is by (1972SL10: 1.9 to 3.0 MeV; p_1), (1972CO15, 1973DA17: 9.3 and 13.3 MeV; p_0, p_1, p_3, p_4, p_5, p_8) and (1973JO10: 12.3 MeV; p_1). Some of the maxima in the yield measurements are interpreted in terms of resonances: these are shown in Table 18.15 (1955ST1A, 1956RO1A, 1964AM1A, 1968MA53). 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 ranges $E_d = 4.0$ to 6.0 MeV (1970DA14). See also (1973CA30). The ratio $\sigma_{n_1}/\sigma_{p_1}$ has been studied for $E_d = 7$ to 17 MeV by (1974AU1B). See also (1971GR2B, 1974DA13), (1973ME18, 1975CR05, 1975GR12, 1976BO48, 1976SA04; theor.) and ^{17}O in (1977AJ02).

19. ^{16}O(d, d)^{16}O $\quad E_b = 7.5263$

The yield of elastically scattered deuterons and elastic polarization measurements have been reported for $E_d = 0.65$ to 15 MeV: see Table 18.16 in (1972AJ02) for the earlier work, the recent yield measurements by (1973CA30: $E_d = 1.0$ to 2.0 MeV) and the polarization work of (1972SL10: 1.9 to 3.0 MeV), (1972CO15: 9.3 and 13.3 MeV), (1973BR15: 11.6 MeV) and (1974BU06: 15 MeV). See also (1973CO40, 1974BO50, 1975BO41, 1975BO1P, 1975CR05, 1976LE1U, 1977FL13, 1977FR12; theor.) and ^{16}O in (1977AJ02).

20. (a) ^{16}O(d, t)^{15}O $\quad Q_m = -9.4065 \quad E_b = 7.5263$

(b) ^{16}O(d, ^{3}He)^{15}N $\quad Q_m = -6.6340$

The ground-state polarization has been studied at $E_d = 15$ MeV by (1974LU06). Vector analyzing powers have been studied at $E_{\vec{d}} = 29$ MeV for the transitions to the first two states of ^{15}N and ^{15}O (1977MA2R).

21. ^{16}O(d, α)^{14}N $\quad Q_m = 3.1104 \quad E_b = 7.5263$

The yields of various groups of α-particles have been measured for $E_d \leq 20$ MeV: see Table 18.16 in (1972AJ02) for the earlier work and (1973CA30: $1.0 - 2.0$ MeV; α_0), (1974CH1U, 1975CH1N, abstracts: $6.0 - 7.0$ MeV; α_3) and (1973JO13: $2 - 14$ MeV; α_0, α_1).

The yield curves have been fitted in terms of a large number of states in ^{18}F: see Tables 18.15 and 18.16.

A detailed study by (1973JO13) of the isospin-forbidden α_1 yield, analyzed by S-matrix theory, identifies a large number of isospin mixed states in ^{18}F, possibly as many as 138 with $9.2 < E_x < 19.4$ MeV. The reaction mechanism appears to be almost entirely compound nuclear. The isospin impurity, averaged over 1 MeV intervals, is $3-10\%$ for the above E_x range. The average coherence width increases from $\approx$ 100 keV at E_x = 14 MeV to $\approx$ 500 keV at E_x = 20 MeV. The level densities appear to be consistent with predictions of the Fermi-gas model (1973JO13). [For mixed isospin states observed in ^{14}N(α, α_1) see Table 18.14.]

For polarization measurements see (1977ST06: $E_{\bar{d}}$ = 6.84 MeV, θ_{lab} = 29° and 34°, α_3, $iT_{11} = 0.856 \pm 0.006$ and 0.842 ± 0.015), (1976PE08: $E_{\bar{d}}$ = 11, 12, 13, 14 MeV: many α groups) and (1976LU1A: 16 MeV; α_0, α_2). See also (1971GR2B, 1974JO1F, 1976GO1B, 1976RIZP), (1972AJ02, 1974LO1B), (1973TU07; applied) and (1973FR04; theor.).

22. ^{16}O(d, ^{6}Li)^{12}C $\qquad Q_m = -5.6885 \qquad E_b = 7.5263$

The ground-state polarization has been studied at $E_{\bar{d}}$ = 16 MeV (1976JA1G). See also (1976JA1H).

23. ^{16}O(t, n)^{18}F $\qquad Q_m = 1.2690$

Measurements of lifetimes are displayed in Table 18.12 (1966AL04, 1973WA19, 1974CO01). (1966AL04) report that $\Delta E_x(1.13 \rightarrow 0.94) = 194 \pm 1$ 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, however, Table 18.17. Angular distributions are reported at $E_t = 1.1$ to 1.7 MeV by (1976MA54: n_0). See also (1974NO15) and ^{19}F.

24. ^{16}O(^{3}He, p)^{18}F $\qquad Q_m = 2.0328$

Excitation energies derived from measurements of γ-rays (1973RO03) are displayed in Table 18.17, together with l-assignments obtained from distorted wave analyses (see (1972AJ02, 1976SE12)) and (J^π; T) assignments from branching ratios and radiative widths coupled with angular correlations, linear polarization and γ-ray angular distribution studies [see Table 18.11 and (1972RO04, 1973RO03, 1973RO05, 1973RO06)] and τ_m measurements [see Table 18.12 (1966OL03, 1967WA06, 1973RO05, 1974BR04)]. Together with studies of ^{14}N(α, γ) and ^{17}O(p, γ), the work on the ^{16}O(^{3}He, p)^{18}F reaction completes the definitive study of the low-lying states of ^{18}F by Rolf and his co-workers. See (1972AJ02) for the earlier work.

The magnetic moment of ^{18}F*(1.13) = $+2.855 \pm 0.030$ nm, in agreement with shell-model predictions for a $(1d^2_{5/2})_{5^+}$ state (1967PO09, 1967SC09). Parity mixing is being studied by observing the γ-decay of ^{18}F*(1.04, 1.08) [$J^\pi = 0^+$ and 0^-; $T = 1$ and 0, respectively] with two transmission Compton polarimeters whose magnetizations are opposite and reversed once per second (1976AD1B, 1977BA3R; prelim. discussion). See also (1973DO1D) and (1977GO01; theor.).

Table 18.17: States in ^{18}F from ^{16}O(^{3}He, pγ)^{18}F [a]

E_x (keV) [b]	l [a]	$J^\pi; T$ [c]	K^π [e]
0	0	$1^+; 0$	0^+
937.1 ± 0.4	2	$3^+; 0$	0^+
1040.9 ± 0.5	0	$0^+; 1$	
1080.1 ± 0.5		$0^-; 0$	0^-
1119.0 ± 0.6	4	$5^+; 0$	0^+
1701.4 ± 0.7	0	$1^+; 0$	1^+
2099.9 ± 0.6		$2^-; 0$	0^-
2523.4 ± 0.7	2	$2^+; 0$	1^+
3061.2 ± 0.5	2	$2^+; 1$	
3132.8 ± 0.6		$1^-; 0$	1^-
3358.2 ± 1.0		$3^+; 0$	1^+
3725.4 ± 0.8		$1^+; 0$	
3790.6 ± 0.9		$3^-; 0$	1^-
3838.4 ± 0.7	2	$2^+; 0$	
4114.5 ± 0.9		$3^+; 0$	
4225.8 ± 0.7		$2^{(-)}; 0$	(1^-)
4361.0 ± 0.7		$1^{(+)}$	
4398.1 ± 0.7		$4^-; 0$	0^-
4652 ± 2	4	$4^+; 1$	
4753 ± 3		$(0^+; 1)$	
4860 ± 2		$1^{(-)}; 0$	
4963.6 ± 0.8		$2^+; 1$	
5297.6 ± 1.5		4^+	1^+
5502 ± 2		$3^{(-)}; 0$	
5603 ± 2		$1^-; 0 + 1$	
5669 ± 2		$1^-; 0 + 1$	
5785 ± 3		$2^-; 0$	
6097.4 ± 1.4		$4^-; 0$	1^-
6108 ± 3		$1, 2, 3^{(-)}; 0$	
6138.3 ± 1.0		$0^+; 1$	
6164.0 ± 1.0		$3^+; 1$	

Table 18.17: States in ^{18}F from ^{16}O(^{3}He, pγ)^{18}F [a] (continued)

E_x (keV) [b]	l [a]	$J^\pi; T$ [c]	K^π [e]
6241.2 ± 1.0		$3^-; 1$	
6263 ± 3		1^+	
6284.0 ± 1.0		$2^+; 0 + 1$	
6310.5 ± 0.8		$3^+; 0$	
6383 ± 3		$2^+; 0 + 1$	
6480 ± 2		$3^+; (0)$	
6567.0 ± 1.5		5^+	1^+
6643.0 ± 1.5		$2^-; 1$	
6777 ± 2 [d]		4^+	
6803.0 ± 1.5		$1^+, 2, 3^+; (0)$	
6878 ± 2		$3^{(-)}, 4^-; (0)$	
[e]			

[a] For earlier results derived from measurements of proton spectra and of γ-rays, see Table 18.18 in (1972AJ02).

[b] (1973RO03): γ-ray measurements. See also (1976SE12).

[c] See Table 18.11 and (1972RO04, 1973RO03, 1973RO05, 1973RO06).

[d] $\Gamma = 22^{+6}_{-8}$ keV (1976SE12).

[e] (1968MA33) also report proton groups to states with $E_x = 6.779 \pm 0.007$ [2^-; 0], 7.206 ± 0.009 [(1^+)], 7.646 ± 0.014 [$T = 0$], 7.874 ± 0.002 MeV [(2^-); 0], and seven additional states with $E_x < 11.2$ MeV. (1976SE12) report proton groups to states with $E_x = 7190 \pm 4$, 7398 ± 3 [22 ± 8], 7422 ± 5 [< 15], 7503 ± 5 [43 ± 9], 7578 ± 4 [18^{+6}_{-8}], 7696 ± 7 [41 ± 8], 7877 ± 4 [32 ± 5], 8050 ± 7 [30 ± 10], 8239 ± 6 [34 ± 5], 8791 ± 6 [20^{+5}_{-10}], 9207 ± 9 [35 ± 8], 9312 ± 10 [80 ± 20], 9487 ± 10 [< 12], 9523 ± 40 [55 ± 25] and 9570 ± 10 [35 ± 7] keV [Γ in keV, in brackets].

25. ^{16}O(α, d)^{18}F $\quad Q_m = -16.3204$

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]. Many other states have also been observed: see Table 18.19 in (1972AJ02) (1968MA33; note energy resolution problems).

26. ^{16}O(^{6}Li, α)^{18}F $\qquad Q_m = 6.053$

Angular distributions for the α_0 group have been measured at $E(^{6}\text{Li}) = 5.5$ to 13.3 MeV (1968GR22) and at 26 MeV (1969DA19). At $E(^{6}\text{Li}) = 34$ MeV angular distributions are reported to ^{18}F*(0, 0.94, 1.1 [unres.]) and forward angle data has been obtained for ^{18}F*(2.10, 3.73, 3.79, 3.84). The angular distributions for the first three groups are forward peaked and show little structure at back angles. An attempt has been made to fit the data to zero-range two-particle transfer DWBA calculations with partial success. At back angles there is no agreement suggesting the necessity of including in the mechanism the exchange of an α-particle in ^{16}O with the incident ^{6}Li ion. ^{18}F*(1.04, 3.06) were not observed, as expected from isospin conservation. States at $E_x = 4.12$, 4.23, 4.4, 5.61, 6.11, 6.20, 6.53, 6.80 and 6.88 were populated (1976MO24). See also (1975MI1A), (1977GO01; theor.) and (1972AJ02).

27. ^{16}O(^{11}B, ^{9}Be)^{18}F $\qquad Q_m = -8.290$

See (1968OK06, 1975PO10).

28. ^{16}O(^{12}C, ^{10}B)^{18}F $\qquad Q_m = -17.661$

At $E(^{12}\text{C}) = 114$ MeV, the population of the 5^{+} state ^{18}F*(1.12) is reported (1972SC21). See also (1971SC1F).

29. ^{16}O(^{14}N, ^{12}C)^{18}F $\qquad Q_m = -2.7461$

See (1972AJ02).

30. ^{16}O(^{16}O, ^{14}N)^{18}F $\qquad Q_m = -13.2100$

See (1974RO04).

31. ^{17}O(p, γ)^{18}F $\qquad Q_m = 5.607$

$Q_0 = 5606.2 \pm 0.6$ keV (1975RO05); see also (1973SE03).

Table 18.18: Resonances in $^{17}O + p$ [a]

E_p (keV)	Yield [b] of	$\Gamma_{c.m.}$ (keV)	$(2J+1)\Gamma_\gamma\Gamma_p/\Gamma$ [c] (eV)	$J^\pi; T$	E_x (MeV $\pm$ keV)	Refs.
517.0 ± 1.0	γ, α_0	0.27 ± 0.09	0.26 ± 0.05	$4^-; 0$	6.095	(1962BR08, 1973RO03, 1973RO06, 1973RO34, 1973SE03)
561.2 ± 1.0	γ	≤ 1	2.2 ± 0.6	$0^+; 1$	6.137	(1973RO03, 1973RO04, 1973SE03, 1977BE46)
587.1 ± 1.0	γ, p_0	13 ± 1 [e]	6.7 ± 1.8	$3^+; 1$	6.161	(1973RO03, 1973RO07, 1973RO34, 1973SE02, 1973SE03)
670.5 ± 1.0	γ, p_0, α_0	< 2	3.2 ± 0.7	$3^-; 1$	6.240	(1973RO03, 1973RO06, 1973RO34, 1973SE02, 1973SE03)
690 ± 4	α_0		≤ 0.02	$1^+; 0$	6.258	(1973RO07, 1973RO34, 1973SE02)
714.2 ± 1.0	γ, p_0	8.5 ± 1.0 [f]	9.1 ± 2.3	$2^+; 1$	6.281	(1973RO03, 1973RO07, 1973SE02, 1973SE03)
741 ± 2	γ, p_0, α_0	≤ 1.2 [g]	0.64 ± 0.17	$3^+; 0$	6.307	(1962BR08, 1973RO03, 1973RO07, 1973RO34, 1973SE02, 1973SE03)
826 ± 2	γ, α_0	≤ 1 [c]	0.60 ± 0.18	$2^+; 0+1$	6.387	(1962BR08, 1973RO03, 1973RO07, 1973RO34, 1973SE02, 1973SE03)
926 ± 2	γ, α_0	≤ 2	0.36 ± 0.15	$3^+; 0$	6.481	(1962BR08, 1973RO03, 1973RO07, 1973RO34, 1973SE02)
			≤ 0.0023	$5^+; 0$	6.57	(1973RO05, 1973SE03)
1098.9 ± 0.4	γ	0.87 ± 0.09	4.3 ± 1.2	$2^-; 1$	6.6444	(1973RO03, 1973RO06, 1973RO34, 1973SE03, 1975RO05)
1101 ± 4	α_0	89 ± 5			6.646	(1962BR08, 1973RO06, 1973SE02)
1240 ± 2 [d]	γ, p_0	9 ± 3 [c]	2.8 ± 0.7	$4^+; 0$	6.778	(1962BR08, 1973RO03, 1973RO07, 1973RO34, 1973SE02, 1973SE03)
1269	γ, p_0	≤ 2	0.54 ± 0.20	$1^+, 2, 3^+; 0$	6.8031 ± 1.5	(1973RO03, 1973RO07, 1973RO34, 1973SE02, 1973SE03)
1274 ± 5	α_0	79 ± 5		2^-	6.810	(1962BR08, 1973RO06, 1973SE02)
1345 ± 3	γ, α_0	≤ 2	1.0 ± 0.4	$3, 4^-; 0$	6.877	(1962BR08, 1973RO03, 1973RO06, 1973RO34, 1973SE03)
1786	α_0	≈ 65			7.293	(1957AH20)
2021	α_0	11			7.515	(1957AH20)
2048	α_0	90			7.540	(1957AH20)

Table 18.18: Resonances in $^{17}O + p$ [a] (continued)

E_p (keV)	Yield [b] of	$\Gamma_{c.m.}$ (keV)	$(2J+1)\Gamma_\gamma\Gamma_p/\Gamma$ [c] (eV)	$J^\pi; T$	E_x (MeV $\pm$ keV)	Refs.
2218	α_0	11			7.701	(1957AH20)
2235	α_0	100			7.717	(1957AH20)
2406	α_0	≈ 25			7.878	(1957AH20)
2435	α_0	≈ 25			7.906	(1957AH20)
2623	α_0	≈ 40			8.083	(1957AH20)
2753	α_0	≈ 15			8.206	(1957AH20)
2775	α_0	≈ 10			8.226	(1957AH20)
2928	α_0	≈ 50			8.371	(1957AH20)
3915 ± 20	n	95			9.302	(1973BA31)
(4163 ± 20)	n	19			(9.537)	(1973BA31)
4235 ± 10	n	33			9.605	(1973BA31)
4330 ± 10	n	33			9.694	(1973BA31)
4490 ± 20	n	≈ 100			9.845	(1973BA31)
(4790 ± 10)	n	28			(10.128)	(1973BA31)
4900 ± 20	n	≈ 140			10.232	(1973BA31)

[a] See also Table 18.20 in (1972AJ02) and Table 18.19 here.
[b] For observed γ-decay and branching ratios from this state see Table 18.11.
[c] $\Gamma_p = 2.5 \pm 0.2$ keV, $\theta_p^2 = 0.062$ (1973SE02). See also (1973SE03).
[d] (1973RO03) quote $E_p = 1140$ keV but $E_x = 6777$ keV. In (1973RO07), E_p is given as 1240 keV. We assume 1140 keV to be a typographical error.
[e] (1973SE02) report $\Gamma_{c.m.} = 14.7 \pm 1.5$ keV, $\Gamma_p = \Gamma$, $\theta_p^2 = 0.14$.
[f] $\Gamma_p = \Gamma$, $\theta_p^2 = 0.035$ (1973SE02).
[g] $\Gamma_p < 0.5$ keV, $\theta_p^2 < 0.0024$ (1973SE02).

Table 18.19: Excited states of ^{18}F from ^{17}O(p, γ)^{18}F (1977BE46)

E_x (keV)	E_x (keV)
937.18 ± 0.06	3724.19 ± 0.22
1041.55 ± 0.08	3791.49 ± 0.22
1080.54 ± 0.12	3839.17 ± 0.22
1700.81 ± 0.18	4115.90 ± 0.25
2100.52 ± 0.13	4360.15 ± 0.26
2523.35 ± 0.18	5603.38 ± 0.27
3061.84 ± 0.18	5604.86 ± 0.28
3133.87 ± 0.15 [a]	5668 ± 2
	6136.47 ± 0.33

[a] (1975RO05).

A study of direct capture cross sections at $E_p = 1.36$ to 1.65 MeV concludes that the upper limits on the reduced proton widths for the three states of ^{18}F near 5.607 MeV (Q_m) [^{18}F*(5.603, 5.604, 5.668, 5.785) with $J^\pi = 1^+, 1^-, 1^-$ and 2^-: the 1^- states having mixed isospin] are a factor of 60 smaller than previously assumed. The stellar reaction rate for ^{17}O(p, α) is thus correspondingly reduced and becomes of the same order as for the (p, γ) process (1974RO1N, 1975RO20). The direct capture yield has also been studied by (1973RO34) from $E_p = 0.3$ to 1.9 MeV: spectroscopic factors are derived for ^{18}F states below $E_x = 6.2$ MeV. The agreement with stripping data is good (1973RO34).

Twelve resonances have been observed in this reaction for $E_p < 1.4$ MeV: Table 18.18 displays the parameters of the corresponding states in ^{18}F; Table 18.11 lists the branching ratios, radiative widths and multipole mixing ratios; Table 18.12 the lifetimes of the observed states and Table 2 in the Introduction displays the transition strengths. The study of this reaction and of ^{14}N(α, γ) and ^{16}O(^{3}He, pγ) (for band assignments see Table 18.17) has led to a quite complete understanding of the low lying states of ^{18}F. This work has been discussed in a series of papers by the Toronto group (1973RO03, 1973RO04, 1973RO05, 1973RO06, 1973RO07, 1977BE46). (1972BE37) have determined $E_x = 1119.0 \pm 0.6$ keV for the $J^\pi = 5^+$ state (based on $E_x = 937.1 \pm 0.4$ keV), while (1973SE03) report 1121.0 ± 0.3 keV based on $E_x = 936.9 \pm 0.2$ keV, and (1975RO05) have determined $E_x = 2100.68 \pm 0.14$ and 3133.87 ± 0.15 keV: see Table 18.19. See also (1970ZA1D).

32. ^{17}O(p, n)^{17}F $\quad$ $Q_m = -3.544$ $\quad$ $E_b = 5.607$

Several resonances have been observed in the total yield of neutrons measured from threshold to $E_p = 5$ MeV: see Table 18.18 (1973BA31). At higher energies the yields of n_0 ($E_p = 7 - 13.5$ MeV) and n_1 ($7 - 12.5$ MeV) exhibit some gross structures (1969AN06).

33. ^{17}O(p, p)^{17}O $E_b = 5.607$

The elastic scattering has been studied for $E_p = 0.5$ to 1.33 MeV (1973SE02), 8.5 to 10.5 MeV (1975CR04; also p_1 and p_2) and 11.0 to 13.0 MeV (1967AL06): observed anomalies are displayed in Table 18.18.

34. ^{17}O(p, d)^{16}O $Q_m = -1.920$ $E_b = 5.607$

See (1975CR05).

35. ^{17}O(p, α)^{14}N $Q_m = 1.191$ $E_b = 5.607$

The yield of α_0 shows a number of resonances for $E_p = 0.49$ to 3.0 MeV: see Table 18.18 (1957AH20, 1962BR08, 1973SE02). For astrophysical questions see ^{17}O(p, γ)^{18}F (1974RO1N, 1975RO20) and (1971BA1A, 1973CL1E, 1974DE1M, 1977CL1F).

36. ^{17}O(d, n)^{18}F $Q_m = 3.382$

For a report of angular distributions see (1972AJ02): the work quoted was not published.

37. ^{17}O(^{3}He, d)^{18}F $Q_m = 0.113$

At $E(^3\text{He}) = 15$ MeV, DWBA analysis of angular distributions of deuteron groups corresponding to the ground state of ^{18}F [$l = 2$] and to the excited states at 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 [$l = 0+2$] have been obtained by (1969PO11) who also report spectroscopic information. Thus all these states have even parity and ^{18}F*(4.11) may be assigned $J^\pi = (2^+)$ or 3^+. Since $l = 2$ for ^{18}F*(4.65), $J^\pi \leq 5^+$, with 4^+ most likely (1969PO11). At $E(^3\text{He}) = 25$ MeV ^{18}F*(5.606, 5.674) [$J^\pi = 1^-$] have been studied to estimate their proton widths which are of astrophysical significance (1974BR1C; abstract). See also (1972EN03, 1976SC36; theor.).

38. ^{17}O(α, t)^{18}F $Q_{\rm m} = -14.207$

Not reported.

39. ^{18}O(p, n)^{18}F $Q_{\rm m} = -2.4379$

Angular distributions have been measured for $E_{\rm p} = 5.53$ to 6.12 MeV (1973FR10: $\rm n_0 \rightarrow n_4$) and 6.9 to 13.5 MeV (1969AN06: $\rm n_0 \rightarrow n_8$; not all resolved). See also (1971DR09), (1972AJ02), (1973CL1E; astrophys. questions), (1976KA13; theor.) and ^{19}F.

40. ^{18}O(^{3}He, t)^{18}F $Q_{\rm m} = -1.6742$

At $E(^3{\rm He}) = 16$ 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 $E_{\rm x} = 1.04$ 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, 1.12, 1.70, 2.10, 3.13, 3.36, 3.73, 3.79, 3.84, 4.11, 4.23, 4.36, 4.40, 4.65, 4.75). The angular distributions are consistent with the J^π assignments shown in Table 18.10, except for the distribution to ^{18}F*(1.04) (1970DU08). At $E(^3{\rm He}) = 17.3$ MeV, angular distributions to ^{18}F states with $E_{\rm x} < 4$ 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).

41. ^{18}O(^{6}Li, ^{6}He)^{18}F $Q_{\rm m} = -5.165$

At $E(^6{\rm Li}) = 34$ MeV angular distributions have been obtained for the transitions to ^{18}F*(0, 0.94) [$J^\pi = 1^+, 3^+$]: there appears to be a sizable contribution due to two-step processes (1974WH07, 1974WH1E, 1975WH01). See also (1974DU15).

42. ^{18}Ne(β^+)^{18}F $Q_{\rm m} = 4.447$

The half-life of ^{18}Ne is 1672 ± 4 msec (see ^{18}Ne). The decay is to ^{18}F*(0, 1.04, 1.70): see Table 18.20 for the branching ratios and $\log ft$ values.

43. ^{19}F(γ, n)^{18}F $Q_{\rm m} = -10.4313$

Table 18.20: Branching in ^{18}Ne(β^+)^{18}F [a]

Decay to ^{18}F* (MeV)	$J^\pi; T$	E_{γ_0} (keV)	Branch (%)	log f_0t [b]	Refs.
0	$1^+; 0$		92.5 ± 0.2		(1970AS06)
			92.11 ± 0.21 [A]	3.094(5)	(1975HA21)
1.04	$0^+; 1$	1043 ± 1	7.3 ± 0.2		(1968GO05, 1970AS06)
		1041.3 ± 1.0	7.66 ± 0.21 [A]	3.456(12)	(1975HA21)
1.08	$0^-; 0$		< 0.7		(1968GO05)
1.70	$1^+; 0$	1699.6 ± 2.0 [c]	0.23 ± 0.03 [A]	2.7(2)	(1975HA21)
			0.17 ± 0.05		(1970AS06)
2.10	$2^-; 0$		< 1.5		(1968GO05)

A = Adopted.

[a] For the earlier data see Table 18.21 in (1972AJ02).

[b] Based on Q_m and $\tau_{1/2} = 1672 \pm 4$ msec.

[c] And 659.4 ± 1.0 keV for the 70% transition to ^{18}F*(1.04) (1975HA21).

[d] Calculated with aid of results of (1975HA21, 1975HA45) but does not include the charge dependent factor.

Photoneutron spectra have been studied by (1976SH12) and the yield of 0.94 and 1.04 MeV γ-rays by (1972TH15), and the γ-rays from ^{18}F*(0.94, 1.04, 1.08, 2.10, 2.52, 3.06, 3.13, 3.72) by (1977TA1M): see ^{19}F. See also (1976TH1E).

44. ^{19}F(n, 2n)^{18}F $\qquad Q_m = -10.4313$

The lifetime of the 5^+ state ^{18}F*(1.12) has been measured by (1972AD01): see Table 18.12. Several γ-rays, including an intense line at 0.94 MeV, are reported by (1976PR08). See also ^{20}F.

45. (a) ^{19}F(p, d)^{18}F $\qquad Q_m = -8.2067$

(b) ^{19}F(p, pn)^{18}F $\qquad Q_m = -10.4313$

Angular distributions of the d_0 group have been measured at $E_d = 16$ to 155.6 MeV; $l_n = 0$: see (1972AJ02). Angular distributions to excited states reported in (1972AJ02) have not been published. See also (1973OR09; theor.). For reaction (b) see (1968DE21).

46. ^{19}F(d, t)^{18}F $\qquad Q_m = -4.1740$

Angular distributions of triton groups have been reported at $E_d = 8.9$ (t_0, t_1, t_3) and 14.8 MeV (t_0): see (1972AJ02). The angular distribution to ^{18}F*(1.04) [$J^\pi = 0^+$, $T = 1$] (1972BU1E; unpublished abstract; $E_d = 28$ MeV) is compared with that for the transition to the $^{18}O_{g.s.}$ in the mirror reaction (1973CO17). For a polarization study at $E_d = 12.3$ MeV see (1976NE1C) and ^{21}Ne in (1978EN06).

47. ^{19}F(^{3}He, α)^{18}F $\qquad Q_m = 10.1465$

At $E(^3\text{He}) = 5.9$ MeV, 41 α-particle groups have been observed, corresponding to the ground state of ^{18}F and to excited states with $E_x < 7.5$ MeV (1959HI67): see Table 18.21. Angular distributions of the α-particles corresponding to ^{18}F*(3.06, 3.13) are reported by (1966MA43; $E(^3\text{He}) = 4.0$, 6.0 and 8.0 MeV): $l = 2$ and 1, respectively. Alpha-α_0 angular correlations measured in the range $E(^3\text{He}) = 5.0$ to 6.0 MeV establish $J^\pi = 1^-$ for both ^{18}F*(5.60, 5.67): $\Gamma_\alpha/\Gamma \approx 1$ (1971LI27). See also (1976GA27) and ^{22}Na in (1978EN06).

48. ^{19}F(^{10}B, ^{11}B)^{18}F $\qquad Q_m = 1.024$

See (1971BA68) and (1972AJ02).

49. (a) ^{19}F(^{14}N, ^{15}N)^{18}F $\qquad Q_m = 0.4021$
(b) ^{19}F(^{19}F, ^{20}F)^{18}F $\qquad Q_m = -3.830$

See (1972AJ02).

50. ^{20}Ne(n, t)^{18}F $\qquad Q_m = -14.794$

Not reported.

51. ^{20}Ne(p, ^{3}He)^{18}F $\qquad Q_m = -15.558$

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).

Table 18.21: 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): $E(^{3}\mathrm{He}) = 5.9$ MeV.

52. ^{20}Ne(d, α)^{18}F $\quad Q_m = 2.7954$

$Q_0 = 2.790 \pm 0.010$ (1975BO59)

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 (1969PO11). Angular distributions at $E_d = 6.66$, 7.29, 7.93 and 12.95 MeV have been obtained for the α-groups to ^{18}F*(2.10 [not 12.95 MeV], 2.52, 3.06 [2^+; 1], 3.13, 3.36, 4.12). The ratio of the total cross section for the isospin-forbidden transition to ^{18}F*(3.06) to the total cross section of four $T = 0$ states ranges from 6% to 40%. The average is 21% suggesting isospin mixing in the compound nucleus: the yield curves show strong structures particularly in the region 5 to 9 MeV (1973HR03): see also ^{22}Na in (1978EN06). Angular distributions have also been measured at $E_d = 2$ to 14.7 MeV: see (1972AJ02) for the earlier work and (1971MO40: 2.0, 3.0, 3.2 MeV; α_0, α_1, α_3, $\alpha_5 \rightarrow \alpha_7$). Measurements of the tensor analyzing power near $180°$ for $10.5 < E_d < 12.0$ MeV lead to natural π for ^{18}F*(4.85) and to unnatural π for ^{18}F*(4.23, 5.60, 5.79) (1977DA1F). ^{18}F*(6.16) is seen with moderate intensity suggesting that the previous $T = 1$ assignment is doubtful (H.T. Richards, private communication). See also (1976GU20; applied work) and (1974NO15; theor.).

53. ^{21}Ne(p, α)^{18}F $\quad Q_m = -1.742$

Not reported.

^{18}Ne

(Figs. 3 and 4)

GENERAL: (See also (1972AJ02).)

Model calculations: (1972EN03, 1974LO04).

Electromagnetic transitions: (1970SI1J, 1972EN03, 1974LO04, 1976SH04, 1977BR03, 1977SA13).

Special states: (1972EN03, 1972RA08).

Muon- and pion-induced capture and reactions (See also reaction 5.): (1972MI11, 1974LI1N, 1975LI04, 1976HEZU, 1977MA02, 1977RO1U).

Other theoretical calculations: (1970SI1J, 1972CA37, 1972RA08, 1973BE35, 1973GO1H, 1973PA1F, 1974RE03, 1974SH09, 1977SH13).

Ground state of ^{18}*Ne:* (1974RE03, 1977BR03).

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

The half-life of ^{18}Ne is 1687 ± 9 msec (1975HA21), 1669 ± 4 msec (1975AL27): the weighted mean of these two values is 1672±5 msec. For earlier measurements see Table 18.24 in (1972AJ02) and (1970AS1C, 1972HA58). The decay is to ^{18}F*(0, 1.04, 1.70) with $J^\pi = 1^+$, 0^+ and 1^+; $T = 0$, 1 and 0, respectively: the branching ratios and $\log ft$ values are displayed in Table 18.20. The mirror asymmetry $\delta = -0.86 \pm 0.80\%$ (1975AL27). See also (1972AJ02, 1975RA37) and (1972WI28, 1972WI1C, 1973LA03, 1973TO04, 1974WI1L, 1974WI02, 1975HA45, 1975WI1E, 1976LO01, 1977AZ02, 1977KU1E, 1977SZ03, 1977TO11; theor.).

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

Excitation energies of ^{18}Ne states derived from neutron spectra and γ-ray measurements are displayed in Table 18.23. Table 18.27 in (1972AJ02) summarizes the earlier angular distribution studies for $E(^3$He) to 17.8 MeV. Recent measurements include those by (1977EV01: $E(^3$He$) = 15$ and 18 MeV; see Table 18.24) and (1975PE11: 18.3 MeV; n_0, n_1). Branching ratios and lifetimes of the first four excited states of ^{18}Ne are shown in Table 18.24. Comparison of the $\tau_{\rm m}$ of ^{18}Ne*(1.89), which leads to B(E2) $= 52 \pm 5\ e^2 \cdot {\rm fm}^4$, with that of ^{18}O*(1.98), its analog, suggests the presence of two-body contributions to the E2 transition strength (1976MC02). See also (1974GO23) and (1972AJ02).

3. ^{16}O(^{10}B, ^{8}Li)^{18}Ne $\quad\quad Q_{\rm m} = -18.951$

Table 18.22: Energy levels of ^{18}Ne [a]

E_x (MeV $\pm$ keV)	$J^\pi; T$	τ or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
0	$0^+; 1$	$\tau_{1/2} = 1672 \pm 5$ msec	β^+	1, 2, 5, 6
1.8873 ± 0.2	2^+	$\tau_m = 0.67 \pm 0.06$ psec	γ	2, 6
3.3762 ± 0.4	4^+	$\tau_m = 4.4 \pm 0.6$ psec	γ	2, 3, 6
3.5763 ± 2.0	0^+	$\tau_m = 4 \pm 2$ psec	γ	2, 6
3.6164 ± 0.6	2^+	$\tau_m = 63^{+30}_{-20}$ fsec	γ	2, 6
4.519 ± 8	1^-	$\Gamma \leq 40$	(p)	2, 6
4.590 ± 8	0^+	≤ 40	(p)	2, 6
5.085 ± 10	$(2^+, 3^-)$	≤ 60	(p)	2, 6
5.140 ± 10	(3^-)	≤ 50		2, 6
5.453 ± 10		≤ 50		6
6.297 ± 10		180 ± 60		2, 6
6.353 ± 10		≤ 60		6
7.059 ± 10	2^+	180 ± 50		2
7.713 ± 10		≤ 50		2, 6
7.910 ± 10		≤ 50		2
7.950 ± 10		≤ 60		6
8.086 ± 10		≤ 50		2
8.500 ± 30		≤ 120		2
9.201 ± 9		≤ 50		6

[a] See also Table 18.24.

At $E(^{10}\text{B}) = 100$ MeV the first $(d_{5/2})^2_{4+}$ state is preferentially excited (1977HA2E; prelim.). See also (1976TOZV).

4. ^{16}O(^{12}C, ^{10}Be)^{18}Ne $\qquad Q_m = -22.664$

See (1971SC1F, 1972SC21).

5. ^{18}O(π^+, π^-)^{18}Ne $\qquad Q_m = -6.101$

Table 18.23: States in ^{18}Ne from ^{16}O(^{3}He, n)^{18}Ne and ^{20}Ne(p, t)^{18}Ne [a]

(1968GI09, 1969RO08) [b]	E_x (MeV ± keV)				$\Gamma_{c.m.}$ [d]	J^π [e]
	(1970AD02) [b]	(1974NE04) [b]	(1974NE04) [c]	(1972PA02) [c]	(keV)	
0	0			0		0^+
1.8873 ± 0.2	1.89	1.886 ± 7 [h]	1.886 ± 10	1.894 ± 10		2^+
3.3762 ± 0.4	3.375 ± 15	3.374 ± 7 [h]	3.375 ± 10	3.390 ± 14		4^+
3.5763 ± 2.0	3.564 ± 20		3.580 ± 10			0^+
3.6164 ± 0.6	3.610 ± 15	3.603 ± 15 [h]	3.612 ± 10	3.614 ± 13		2^+
	4.505 ± 15	4.513 ± 13 [j]	4.522 ± 10		≤ 40	1^-
				4.576		
	4.571 ± 15	4.587 ± 13	4.592 ± 10		≤ 40	0^+
		5.075 ± 13	5.095 ± 15		≤ 60	$(2^+, 3^-)$
	5.14 ± 20 [f]	5.135 ± 12 [i]	5.149 ± 15	5.150 ± 14	≤ 50	$(2^+, 3^-)$
			5.453 ± 10		≤ 50	
		6.291 ± 30	6.297 ± 10 [g]		180 ± 60	
				6.326 ± 18		(4^+)
			6.353 ± 10		≤ 60	
	7.051 ± 18 [h]	7.062 ± 12			180 ± 50	2^+
		7.712 ± 20	7.713 ± 10		≤ 50	
	7.903 ± 15 [h]	7.915 ± 12			≤ 50	
			7.949 ± 10	7.957 ± 25	≤ 60	
	8.070 ± 15 [h]	8.100 ± 14			≤ 50	
		8.500 ± 30			≤ 120	
			9.198 ± 10	9.215 ± 20	≤ 50	

[a] See also Tables 18.25 and 18.28 in (1972AJ02).
[b] ^{16}O(^{3}He, n)^{18}Ne.
[c] ^{20}Ne(p, t)^{18}Ne.
[d] (1970AD02, 1974NE04).
[e] (1972PA02, 1974NE04, 1977EV01). See also Table 18.28 in (1972AJ02).
[f] No other narrow states observed with $E_x < 7.5$ MeV (1970AD02).
[g] $\Gamma \leq 60$ keV.
[h] (1977EV01).
[i] $J^\pi = 3^-$ assignment suggested by (1977EV01): $E_x = 5.130 \pm 10$.
[j] 4.537 ± 10 (1977EV01).

Table 18.24: Branching ratios and lifetimes of ^{18}Ne states [a]

E_i (MeV)	J_i^π	E_f (MeV)	Branch (%) (1968GI09, 1969RO08, 1972GI01)	Branch (%) (1969RO22)	τ_m (psec)
1.89	2^+	0	100		0.67 ± 0.06 [c]
3.38	4^+	0	< 4	< 1	
		1.89	100	100	4.4 ± 0.6 [d]
3.58	0^+	0	< 17	< 5	
		1.89	100	100	4 ± 2 [d]
3.62	2^+	0	12.5 ± 2.5	$7 \pm 2, 9 \pm 2$ [A]	
		1.89	87.5 ± 2.5 [b]	93 ± 2	$0.063^{+0.030}_{-0.020}$ [e]

A = Adopted.

[a] See also Table 18.26 in (1972AJ02).

[b] Mixing ratio, $\delta = +0.03 \pm 0.09$ (1972GI01).

[c] (1976MC02). See also (1968GI09, 1969RO08, 1974MC17).

[d] (1972GI01).

[e] (1968GI09, 1969RO08).

At $E_{\pi^+} = 139$ MeV the transition to ^{18}Ne(0) has been observed with $d\sigma/d\Omega(0°) = 1.78 \pm 0.30$ μb/sr (1977MA02).

6. ^{20}Ne(p, t)^{18}Ne $\qquad Q_m = -20.023$

Transitions have been reported to fifteen states of ^{18}Ne with $E_x < 10$ MeV: these are displayed in Table 18.23 as are J^π derived from DWBA analysis of angular distributions (1972PA02, 1974NE04). The 0_3^+ state, identified at $E_x = 4.59$ MeV appears to have a largely $s^2_{1/2}$ configuration based on its large downward shift with respect to the analog state in ^{18}O (1974NE04). See also (1972AJ02) and (1975OL03; theor.).

^{18}Na
(Not illustrated)

^{18}Na has not been observed: its atomic mass excess has been estimated to be 25.32 MeV: it is then unbound with respect to proton emission by 1.55 MeV (1977WA08). See also (1976JA23, 1976WA1E).

References

(Closed 01 November 1977)

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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