Energy Levels of Light Nuclei
$A = 20$

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Abstract: An evaluation of $A = 18$–20 was published in *Nuclear Physics A*300 (1978), p. 1. This version of $A = 20$ 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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^{20}B

(Not illustrated)

^{20}B has not been observed. The mass excess is predicted to be 69.08 MeV (1974TH01). ^{20}B is then unstable with respect to breakup into ^{19}B + n by 0.9 MeV [see ^{19}B]. See also (1976JA23, 1976WA18) and (1975BE31; theor.).

^{20}C

(Not illustrated)

^{20}C has not been observed in the 4.8 GeV proton irradiation of a uranium target (1974BO05). The mass excess is predicted to be 37.17 MeV (1974TH01), 37.41 MeV (1976JA23, 1976WA18). Assuming the mass excess of ^{20}C to be 37.3 MeV, ^{20}C is then stable with respect to ^{19}C + n and ^{18}C + 2n by 3.2 and 4.2 MeV, respectively [see ^{18}C and ^{19}C]. See also (1972TH13) and (1971ST40, 1975BE31, 1976BE1G; theor.).

^{20}N

(Not illustrated)

^{20}N has been observed. It is particle stable: see (1972AJ02). Recent calculations of the atomic mass excess of ^{20}N are 21.67 MeV (1974TH01), 21.60 (1975JE02; transverse form of IMME), 21.88 (1976JA23) and 22.2 MeV (1977WA08). Assuming that the atomic mass excess is 22.0 MeV, ^{20}N is then stable with respect to ^{19}N + n by 1.9 MeV (see ^{19}N). See also (1972TH13, 1973TO16, 1975VO09, 1976WA18, 1977AR06, 1977BH1B) and (1973WI15, 1975BE31; theor.).

^{20}O

(Figs. 9 and 13)

GENERAL: (See also (1972AJ02).)

Shell model: (1972LE13, 1973JU1A, 1973LA1D, 1973MA1K, 1973MC06, 1974CO40, 1975BA81).

Cluster, collective and deformed models: (1973AB01).

Electromagnetic transitions: (1976VO1C).

Special states: (1972LE13, 1972SA04, 1973JU1A, 1973MC06, 1975BA81).

Complex reactions involving ^{20}*O:* (1973BA81, 1973VO1G, 1973WI15, 1974BA89, 1975VO09, 1976VA29, 1977AR06).

Other topics: (1971ST40, 1972CA37, 1972SA04, 1973GR11, 1973SA24, 1973SP1A, 1974CO40, 1974HA17, 1974SE1B, 1975BA81, 1977DA10, 1977SH13).

Table 20.1: Energy levels of ^{20}O

E_x (MeV $\pm$ keV)	$J^\pi; T$	τ	Decay	Reactions
0	$0^+; 2$	$\tau_{1/2} = 13.57 \pm 0.1$ sec	β^-	1, 2, 4, 5
1.67368 ± 0.15	2^+	$\tau_m = 9.8 \pm 0.7$ psec	γ	2
		$g = -0.39 \pm 0.04$		
3.568 ± 5	4^+		(γ)	2
4.065 ± 5	2^+		γ	2
4.446 ± 7	0^+		γ	2
4.838 ± 7			(γ)	2
4.997 ± 7			γ	2
5.220 ± 7			γ	2
5.298 ± 7			(γ)	2
5.382 ± 7	(0^+)		γ	2
5.603 ± 7			(γ)	2
(5.83 ± 20)			(γ)	2

Table 20.2: Branching in ^{20}O$(\beta^-)^{20}$F (1970MA42)

Decay to ^{20}F* (MeV)	J^π	Branch (%)	log ft
0.98	1^-	< 0.6	> 6.0
1.06	1^+	100.0	3.73
1.31	2^-	< 0.8	> 5.7
1.84	2^-	< 1.9	> 4.8
1.97	(3^-)	< 1.4	> 4.8
2.04	2^+	< 2.0	> 4.6
2.19	(3^+)	< 1.0	> 4.7

Table 20.3: Energy levels of ^{20}O from ^{18}O(t, p)^{20}O

E_x (MeV $\pm$ keV) (1962HI06)	L	J^π
0	0 [a,b]	0^+
1.672 ± 5 [c]	2 [a,b]	2^+
3.568 ± 5	4 [a]	4^+
4.065 ± 5 [d]	2 [a,b]	2^+
4.446 ± 7 [d]	0 [a]	0^+
4.838 ± 7		
4.997 ± 7		
5.220 ± 7 [d]		
5.298 ± 7 [d]		
5.382 ± 7 [d]		
5.603 ± 7		
(5.83 ± 20)		

[a] (1964MI05): $E_t = 10.0$ MeV.
[b] (1965MO19): $E_t = 5.55$ MeV.
[c] E_γ measurements lead to $E_x = 1.67368 \pm 0.15$ (1973WA19), 1.6750 ± 1.0 (1975BE15).
[d] Preliminary results by K. Young (private communication) show that ^{20}O*(4.07) decays to ^{20}O*(0, 1.67) with branching ratios of 26 ± 4 and 74 ± 4%: δ(E2/M1) $= -0.18 \pm 0.10$; the work also favors 0^+ for ^{20}O*(4.45, 5.38) (decay is to ^{20}O*(1.67)). ^{20}O*(5.22, 5.30) appear to decay predominantly through ^{20}O*(1.67) also.

Ground state of ^{20}*O:* (1973MC06, 1973SP1A, 1974CO40, 1974MC1F, 1974SHYR, 1975BE31, 1976BE1G).

1. $^{20}O(\beta^-)^{20}F$ $\quad Q_m = 3.816$

^{20}O decays to ^{20}F*(1.06) [$J^\pi = 1^+$] with a half-life of 13.57 ± 0.1 sec (1970MA42: $\log ft = 3.73$). See also (1972EY01). Upper limits for the branching to other states of ^{20}F are shown in Table 20.2. See also (1972WI1C, 1973LA03, 1973WI11, 1974WI1L, 1975NA20, 1975NA21, 1977AZ02; theor.).

2. ^{18}O(t, p)^{20}O $\quad Q_m = 3.079$

Observed proton groups are displayed in Table 20.3 (1962HI06, 1964MI05, 1965MO19). The excitation energy of ^{20}O*(1.67) is 1673.68 ± 0.15 keV (1973WA19), 1675.0 ± 1.0 keV (1975BE15); $J = 2$ (1970NI03); $\tau_m = 14.2 \pm 0.8$ psec (1975BE15), 9.8 ± 0.7 psec (1977HE12, 1977HE1D); g $= -0.39 \pm 0.04$ (1975BE15, 1976GE01). See also (1972AJ02).

3. ^{18}O(^{14}C, ^{12}C)^{20}O $\quad Q_m = -1.562$

See (1972EY01).

4. ^{18}O(^{16}O, ^{14}O)^{20}O $\quad Q_m = -17.327$

See (1976HI10).

5. ^{18}O(^{18}O, ^{16}O)^{20}O $\quad Q_m = -0.628$

At $E(^{18}O) = 52$ MeV angular distributions have been measured to four states of ^{20}O (1976KUZX; abstract). See also (1972EY01).

^{20}F

(Figs. 10 and 13)

GENERAL: (See also (1972AJ02).)

Shell model: (1972LE13, 1972WI13, 1973LA1D, 1973MA1K, 1973MC06, 1974CO39, 1975BA81).

Electromagnetic transitions: (1970HE1B, 1974MC1F).

Special states: (1972LE13, 1973MC06, 1975BA81, 1975MI03).

Complex reactions involving ^{20}*F:* (1972MI11, 1973BA81, 1973WI15, 1974BA89, 1974HA61, 1976HI05, 1977AR06).

Muon and pion capture and reactions: (1974LI1D).

Other topics: (1972CA37, 1972NA11, 1972WI13, 1973GR11, 1974CO39, 1974HA17, 1974MA1E, 1975BA81, 1977DA10, 1977SH13).

Ground state of ^{20}*F:* (1971SH26, 1972AC03, 1973AC1A, 1973MC06, 1973SU1B, 1974CO39, 1974MC1F, 1974MI21, 1974SHYR, 1976CH1T).

$\mu = 2.094\ (2)$ nm ((1976FU06) and V. Shirley, private communication);

$Q = 0.064 \pm 0.012$ b (1974ST10).

1. ^{20}F(β^-)^{20}Ne $\qquad Q_m = 7.0259$

Recent values of the half-life of ^{20}F are 11.03 ± 0.06 (1970WI05), 10.996 ± 0.020 (1975AL27) and 11.18 ± 0.01 sec (1976GE08). We adopt $\tau_{1/2} = 11.00 \pm 0.02$ sec. See also (1970AS1C, 1974AL11, 1975SA1D) and Table 20.5 in (1972AJ02) for the earlier values. ^{20}F decays principally to ^{20}Ne*(1.63): see ^{20}Ne and Table 20.36. See also (1976CA1E) and (1971WI1C, 1972BE1E, 1972EM02, 1972WI1C, 1973BE35, 1973LA03, 1973WI11, 1974WI1L, 1975NA20, 1975NA21, 1975WI1E, 1977AZ02, 1977CA11; theor.).

2. ^{12}C(^{9}Be, p)^{20}F $\qquad Q_m = 4.0761$

See (1974HA25).

3. ^{14}N(^{7}Li, p)^{20}F $\qquad Q_m = 12.054$

Table 20.7 shows the ^{20}F states observed in this reaction at $E(^7\text{Li})$ = 16 MeV. The cross sections for forming states of known J^π are linear with $2J_f + 1$ with slopes which are different for the even- and the odd-parity states. Extrapolation of these relationships to states of unknown J^π leads to the assignments shown in Table 20.7: ^{20}F*(2.86, 2.97, 3.59, 3.68, 4.52, 4.76) and one or both of the unresolved states at 4.2, 4.6 and 4.9 MeV, must, on the basis of the σ_t for their population, have large values of J (1975BI04). See also (1973FO1A, 1975HO1L).

Table 20.4: Energy levels of ^{20}F [a]

E_x (MeV ± keV)	$J^\pi; T$	τ	Decay	Reactions
0	$2^+; 1$	$\tau_{1/2} = 11.0 \pm 0.02$ sec	β^-	1, 2, 3, 13, 16, 17, 25, 28, 31, 34, 37, 38, 39
0.65594 ± 0.15	3^+	$\tau_m = 0.39 \pm 0.03$ psec	γ	3, 13, 17, 25, 28, 34, 38
0.82288 ± 0.20	4^+	79 ± 6 psec	γ	3, 12, 13, 17, 25, 34, 38
0.98371 ± 0.20	1^-	2.03 ± 0.20 psec	γ	3, 12, 13, 17, 25, 34, 38
1.05693 ± 0.20	1^+	45 ± 13 fsec	γ	3, 13, 17, 25, 30, 34, 38
1.30923 ± 0.20	2^-	1.16 ± 0.20 psec	γ	3, 12, 13, 17, 25, 34, 38
1.8244 ± 1.2	5^+	≤ 65 fsec	γ	3, 12, 13, 25, 38
1.84337 ± 0.30	2^-	30 ± 20 fsec	γ	3, 13, 17, 25, 34, 38
1.9707 ± 0.4	(3^-)		γ	3, 12, 13, 17, 38
2.04400 ± 0.30	2^+	37 ± 16 fsec	γ	3, 13, 17, 25, 28, 34, 38
2.1948 ± 0.4	(3^+)	< 12 fsec	γ	3, 13, 17, 25, 34, 38
2.8649 ± 1.5	(2, 3, 4)		γ	3, 13, 25, 38
2.9661 ± 0.4	3^+	60 ± 40 fsec	γ	3, 13, 17, 25, 38
3.1740 ± 1.5	(1^+)		γ	13, 25, 38
3.48843 ± 0.25	1^+	44 ± 11 fsec	γ	13, 17, 25, 38
3.5260 ± 0.4	0^+	30 ± 15 fsec	γ	13, 17, 25
3.5871 ± 0.3	$(1, 2, 3)^+$	≤ 60 fsec	γ	3, 13, 17, 25, 38
3.6810 ± 0.4	$(1, 2, 3)^+$		γ	3, 13, 17, 25, 38
3.7611 ± 1.9			γ	13, 25, 38
3.9660 ± 1.5	1^+		γ	13, 17, 25, 38
4.0823 ± 0.4	$(1)^+$		γ	13, 17, 25, 38
4.1989 ± 2.7			(γ)	3, 25, 38
4.2077 ± 2.6			(γ)	3, 25, 38
4.2766 ± 0.5	$(1, 2, 3)^+$		γ	17, 25, 38
4.313 ± 3	$(0, 1)^+$		(γ)	25, 38
4.372 ± 4			(γ)	38
4.518 ± 4			(γ)	3, 38

Table 20.4: Energy levels of ^{20}F [a] (continued)

E_x (MeV ± keV)	$J^{\pi}; T$	τ	Decay	Reactions
4.5838 ± 3.0			(γ)	3, 25, 38
4.5922 ± 2.9			(γ)	3, 25, 38
4.7302 ± 2.9			(γ)	25, 38
4.7638 ± 2.7			(γ)	3, 25, 38
4.8916 ± 2.8			(γ)	3, 25, 38
4.8982 ± 2.8			(γ)	3, 25, 38
5.0402 ± 3.1	$(0, 1, 2)^-$		(γ)	25, 38
5.0655 ± 3.1			(γ)	25, 38
5.131 ± 5			(γ)	38
5.2240 ± 2.8	$(0, 1, 2)^-$		(γ)	25, 38
5.279 ± 3	$(0, 1, 2)^-$		(γ)	25, 38
5.3171 ± 2.7			(γ)	25, 38
5.3445 ± 3.3			(γ)	25, 38
5.4131 ± 0.6			γ	17, 38
5.4503 ± 3.8			(γ)	25, 38
5.4554 ± 3.2			(γ)	25, 38
5.4634 ± 3.3			(γ)	25
5.556 ± 4			γ	17, 38
5.574 ± 6			(γ)	38
5.621 ± 3			(γ)	25, 38
5.713 ± 2			γ	17, 38
5.7640 ± 2.5			(γ)	25, 38
5.8104 ± 2.5			(γ)	25, 38
5.9361 ± 0.3	$(0, 1, 2)^-$		γ	17, 25, 38
6.0174 ± 0.3	$(0, 1, 2)^-$		γ	17, 25, 38
6.0446 ± 0.4			γ	17, 25, 38
6.163 ± 6			(γ)	38
6.205 ± 6			(γ)	38
6.240 ± 7			(γ)	38
6.300 ± 5			(γ)	38
6.337 ± 5			(γ)	38
6.370 ± 6			(γ)	38
6.407 ± 12			(γ)	38

Table 20.4: Energy levels of ^{20}F [a] (continued)

E_x (MeV ± keV)	$J^{\pi}; T$	τ	Decay	Reactions
6.441 ± 9			(γ)	38
6.480 ± 5			(γ)	38
6.519 ± 3	$0^+; 2$		γ	13, 37
6.588 ± 5			(γ)	38
6.6013 ± 0.3	$0^+, 1^+$		γ	17
6.6269 ± 0.6	2^-	0.310 ± 0.020	γ, n	17, 18
6.6425 ± 0.6	(3, 4)	< 0.08	γ, n	17, 38
6.6474 ± 0.7	1^-	1.59 ± 0.10	γ, n	17, 18, 38
6.6933 ± 0.8	1^-	13.8 ± 0.8	γ, n	17, 18, 38
6.7660 ± 1.1		≤ 0.6	γ, n	17, 38
6.829			n	19
6.8566 ± 1.2	2	10 ± 2	γ, n	17, 19, 38
(6.858 ± 8)	1		γ, n	17
6.905 ± 8				38
6.9677 ± 1.2	1^-	5 ± 1	γ, n	17, 19
(7.0670 ± 1.2)	0^-	(2.4 ± 0.6)	γ, n	17, 19
7.076	(1^+)	24	n	18
7.166 ± 2	$2^{(+)}$	8 ± 1	γ, n	17, 18, 19
7.311	(1)	33	γ, n	17, 18
7.361	(1)	19	n	18, 19
7.410	(2^+)	10	γ, n	17, 18, 19
7.50	(2)	80	γ, n	17, 18
7.67	(2^+)	65	γ, n	17, 18, 19
7.79		140	n	18, 19
(7.831 ± 12)	1^-	(50 ± 10)	γ, n	17
7.988 ± 3	1	14 ± 2	γ, n	17
8.05 ± 100	$2^+; 2$			37
8.13		195	γ, n	17, 18, 19
8.163		15	n	19
8.421		27	n	19
8.50		140	n	18
8.728		≤ 30	n	18, 19
8.77		76	n	18

Table 20.4: Energy levels of ^{20}F [a] (continued)

E_x (MeV ± keV)	$J^\pi; T$	τ	Decay	Reactions
8.942		73	n	18, 19
9.165			n	19
9.521		110	n	19
9.654		100	n	18, 19
9.830		33	n	19
9.85		120	n	18
(9.886 ± 10)			n	18
9.901		≤ 30	n	19
(9.929 ± 10)			n	18
(9.981 ± 10)			n	18
10.024 ± 10		150	n, α	18, 19, 24
10.10 ± 50			n, α	24
10.228 ± 10	0^-, 1	≈ 200	n, α	18, 24
10.480 ± 10		≈ 10	n, α	18, 24
10.641 ± 10	1, 2	70	n	18, 19
10.807 ± 10	0^-, 1	≈ 310	n, α	18, 24
10.988		190	n	19
(11.045 ± 10)		≈ 30	n	18
(11.130 ± 10)		< 25	n	18
(11.244 ± 10)		< 25	n	18, 19
(11.287 ± 10)			n	18
11.49 ± 50			n, α	24
12.0			n, α	24
12.2 ± 100			n, α	24
12.39			n, α	24
12.82			n, α	24
13.2			n, α	24
13.66			n, α	19, 24
14.0			n, α	24

[a] See also Tables 20.5 and 20.6.

Table 20.5: Radiative transitions in ^{20}F

E_i (MeV)	J^π_i	E_f (MeV)	J^π_f	Branching (%)	δ	Refs.
0.66	3^+	0	2^+	100	0.10 ± 0.05	[a], (1973HA14)
0.82	4^+	0	2^+	41 ± 4		(1969HE20, 1970QU04)
		0.66	3^+	60 ± 5		(1969HE20, 1970QU04)
0.98	1^-	0	2^+	≥ 96	[b]	(1973PR01)
		0.66	3^+	≤ 2		(1973PR01)
				< 1		(1968SP01)
		0.82	4^+	≤ 2		(1973PR01)
				< 1		(1968SP01)
1.06 [c]	1^+	0	2^+	≥ 96		(1973PR01)
				100		(1968SP01, 1970QU04)
		0.66	3^+	≤ 2		(1973PR01)
				< 1		(1968SP01)
		0.82	4^+	≤ 2		(1973PR01)
				< 1		(1968SP01)
1.31	2^-	0	2^+	100	[b]	[a]
		0.66	3^+	≤ 14		(1969HE20)
		0.82	4^+	< 2		(1968SP01)
		0.98	1^-	< 1		(1968SP01)
		1.06	1^+	< 1		(1968SP01)
1.82	5^+	0	2^+	< 3		(1972AL26, 1973PR01)
		0.66	3^+	< 3		(1972AL26)
		0.82	4^+	≥ 95	-0.03 ± 0.07	(1973PR01)
1.84 [d]	2^-	0	2^+	≥ 94		(1973PR01)
		0.66	3^+	≤ 6		(1973PR01)
		0.82	4^+	< 4		(1973PR01)
				< 3		(1972AL26)
		0.98	1^-	< 4		(1973PR01)
		1.31	2^-	< 4		(1973PR01)
1.97 [d]	(3^-)	0	2^+	16 ± 4	-0.06 ± 0.14	(1973PR01)
		0.66	3^+	< 3		(1973PR01)

Table 20.5: Radiative transitions in ^{20}F (continued)

E_i (MeV)	J^{π}_{i}	E_f (MeV)	J^{π}_{f}	Branching (%)	δ	Refs.
		0.82	4^+	55 ± 3	$+0.27 \pm 0.30$	(1973PR01)
		0.98	1^-	< 3		(1973PR01)
		1.31	2^-	29 ± 3		(1973PR01)
2.04 [e]	2^+	0	2^+	8 ± 4		(1973PR01)
		0.66	3^+	92 ± 4	$0.08^{+0.06}_{-0.1}$	(1973PR01, 1973HA14)
		0.82	4^+	< 5		(1973PR01)
2.19 [e]	(3^+)	0	2^+	58 ± 4	0 ± 0.09	(1973PR01)
		0.66	3^+	< 5		(1973PR01)
		0.82	4^+	42 ± 4	$+0.07 \pm 0.10$	(1973PR01)
2.86		0	2^+	(100)		(1970QU04)
2.97 [e]	3^+	0	2^+	24 ± 3		(1969HE20)
				19 ± 5		(1973PR01)
		0.66	3^+	14 ± 2		(1969HE20)
				17 ± 5		(1973PR01)
		0.82	4^+	62 ± 6		(1969HE20)
				35 ± 4		(1973PR01)
		1.97	(3^-)	29 ± 4		(1973PR01)
3.17 [f]	(1^+)	0	2^+	< 5		(1970QU04)
		0.98	1^-	> 95		(1970QU04)
3.49	1^+	0	2^+	68 ± 4		(1969HO20)
		0.98	1^-	7 ± 1		(1969HO20)
		1.06	1^+	7 ± 1		(1969HO20)
		1.31	2^-	10 ± 2		(1969HO20)
		1.84	2^-	8 ± 2		(1969HO20)
3.53	0^+	1.06	1^+	100		(1968SP01, 1969HO20)
3.59	$(1, 2, 3)^+$	0	2^+	66		(1968SP01)
				60		(1969HO20)
		2.04	2^+	34		(1968SP01)
				40		(1969HO20)
3.68	$(1, 2, 3)^+$	0	2^+	33		(1968SP01)

Table 20.5: Radiative transitions in ^{20}F (continued)

E_i (MeV)	J^π_i	E_f (MeV)	J^π_f	Branching (%)	δ	Refs.
		0.66	3^+	67		(1968SP01)
3.76		0.66	3^+	observed		(1973PR01)
3.97 [g]	1^+	0.98	1^-	22 ± 7		(1973PR01)
		1.31	2^-	78 ± 7		(1973PR01)
4.08 [h]	$(1)^+$	0	2^+	35 ± 5		(1969HO20)
				45 ± 7		(1973PR01)
		1.06	1^+	65 ± 5		(1969HO20)
				55 ± 7		(1973PR01)
4.28	$(1, 2, 3)^+$	1.06	1^+	100		(1968SP01)
5.41		2.04	2^+	100		(1968SP01)
5.56		0	2^+	24		(1968SP01)
		1.31	2^-	76		(1968SP01)
5.71		1.06	1^+	60		(1969HA04)
		4.28	$(1, 2)^+$	40		(1969HA04)
5.94 [g]	$(0, 1, 2)^-$	0	2^+	7		(1968SP01)
		0.66	3^+	35		(1968SP01)
		0.98	1^-	4		(1968SP01)
		1.31	2^-	1		(1968SP01)
		1.84	2^-	7		(1968SP01)
		1.97	(3^-)	31		(1968SP01)
		2.19	(3^+)	5		(1968SP01)
		3.49	1^+	10		(1968SP01)
6.02 [g]	$(0, 1, 2)^-$	0	2^+	29		(1968SP01)
				40		(1968BL1C)
		0.66	3^+	3		(1968SP01)
		0.98	1^-	19		(1968SP01)
				23		(1968BL1C)
		1.06	1^+	1		(1968BL1C)
		1.31	2^-	2		(1968BL1C)
		1.84	2^-	6		(1968SP01)

Table 20.5: Radiative transitions in ^{20}F (continued)

E_i (MeV)	J_i^π	E_f (MeV)	J_f^π	Branching (%)	δ	Refs.
				6		(1968BL1C)
		2.19	(3^+)	3		(1968SP01)
		2.97	3^+	8		(1968SP01)
		3.49	1^+	19		(1968SP01)
				18		(1968BL1C)
		3.59	$(1, 2, 3)^+$	10		(1968SP01, 1968BL1C)
		4.08		3		(1968SP01)
6.04		1.31	2^-	46		(1968SP01)
		1.84	2^-	54		(1968SP01)
6.60	$0^+, 1^+$	see Table 20.10				
6.63	2^-	see Tables 20.9 and 20.10				
6.65	1^-	see Tables 20.9 and 20.10				

[a] See Table 20.6 in (1972AJ02).
[b] Pure E1 (1973HA14).
[c] See also (1973HA14).
[d] See also (1970QU04, 1974KE18).
[e] See also (1970QU04).
[f] See also (1972AL26).
[g] See also (1969HA04).
[h] See also (1974KE18).

4. ^{16}O(^{7}Li, ^{3}He)^{20}F $\quad Q_m = -4.743$

See (1974BI1D).

5. ^{17}O(t, p)^{19}O $\quad Q_m = 3.520 \quad E_b = 14.157$

See ^{19}O.

Table 20.6: Lifetime measurements of some ^{20}F states [a]

^{20}F* (MeV)	τ_m	Refs.
0.66	0.36 ± 0.07 psec	(1969HE20)
	0.37 ± 0.06 psec	(1970HO05)
	0.42 ± 0.05 psec	(1973WA10)
	0.39 ± 0.04 psec	(1975SE04)
	0.39 ± 0.03 psec	mean
0.82	79 ± 6 psec [A]	(1971PR10)
0.98	$1.3^{+0.6}_{-0.4}$ psec	(1969HE20)
	1.8 ± 0.4 psec	(1970HO05)
	2.30 ± 0.25 psec	(1973WA19)
	2.03 ± 0.20 psec	mean
1.06	45 ± 13 fsec [A]	(1970HO05)
1.31	$1.1^{+0.4}_{-0.3}$ psec	(1969HE20)
	0.8 ± 0.3 psec	(1970HO05)
	1.45 ± 0.25 psec	(1973WA19)
	1.16 ± 0.20 psec	mean
1.82	≤ 65 fsec [A]	(1973PR01)
1.84	30 ± 20 fsec [A]	(1970HO05)
1.97 [b]	1.4 ± 0.4 psec [A]	(1973WA19)
2.04	37 ± 16 fsec [A]	(1970HO05)
2.19	< 12 fsec [A]	(1970HO05)
2.97	60 ± 40 fsec [A]	(1970HO05)
3.49	44 ± 11 fsec [A]	(1970HO05)
3.53	30 ± 15 fsec [A]	(1970HO05)
3.59	30 ± 30 fsec [A]	(1970HO05)

A = Adopted.

[a] See also Table 20.14 in (1972AJ02).

[b] See also (1973PR01).

Table 20.7: States of ^{20}F from ^{14}N(^{7}Li, p)^{20}F [a]

E_x [b] (MeV)	J^π	σ_t (μb)	E_x (MeV)	J^π	σ_t (μb)
0	2^+	23.8	2.86	$2^-, 3, 4^+$ [d]	40.7
0.66	3^+	37.4	2.97	$4^-, 5, 6^+, 7^+$ [d]	68.2
0.82	4^+	48.2	3.50 [c]	$1^+ + 0^+$	19.6
0.98	1^-	20.2	3.59	$2^-, 3, 4, 5^+$ [d]	47.6
1.06	1^+	15.0	3.68	$3^-, 4, 5, 6^+$ [d]	58.6
1.31	2^-	33.8	$4.20 + 4.21$	[e]	130
1.83 [c]	$5^+ + 2^-$	85.7	4.52	$3^-, 4^-, 5, 6^+, 7^+$ [d]	63.8
1.97	(3^-)	48.9	$4.58 + 4.59$		80
2.04	2^+	24.5	4.76	$3^-, 4^-, 5, 6^+$ [d]	61.4
2.19	3^+	35.4	$4.89 + 4.90$		54

[a] (1975BI04): $E(^{7}\text{Li}) = 16$ MeV.
[b] Nominal energy.
[c] Unresolved.
[d] Based on σ_t measurements: see text.
[e] One of these two states has $J^\pi \geq 4^-$ or 5^+.

6. ^{17}O(α, p)^{20}F $\qquad Q_m = -5.657$

Not reported.

7. ^{17}O(^{6}Li, ^{3}He)^{20}F $\qquad Q_m = -1.637$

See (1977MA2G).

8. ^{18}O(d, n)^{19}F $\qquad Q_m = 5.7685 \qquad E_b = 12.3699$

See ^{19}F.

9. ^{18}O(d, p)^{19}O $\qquad Q_m = 1.732 \qquad E_b = 12.3699$

Vector analyzing power measurements have been carried out at $E_{\bar{d}} = 14.8$ MeV for the proton groups to ^{19}O*(0, 1.47, 3.15, 3.95, 4.12, 4.58, 4.71, $5.00 + 5.09$, 5.15, 5.46, 5.71, 6.28) (1974SE01): see ^{19}O. Measurements at $E_{\bar{d}} = 10$ MeV are reported by (1973ST1B; abstract). See also (1974FO1J, 1976DA1K).

10. ^{18}O(d, d)^{18}O $E_b = 12.3699$

Vector analyzing power measurements involving the elastic group have been carried out at $E_{\bar{d}} = 14.8$ MeV (1974SE01).

11. ^{18}O(d, α)^{16}N $Q_m = 4.246$ $E_b = 12.3699$

Excitation functions have been measured for $E_d = 0.9$ to 3.0 MeV and 9.6 to 11.5 MeV: see (1972AJ02). At the lower energies a number of sharp structures are reported.

12. ^{18}O(t, n)^{20}F $Q_m = 6.1126$

Measurements of τ_m of several ^{20}F states are reported by (1971PR10, 1973PR01, 1973WA19): see Table 20.6.

13. ^{18}O(^{3}He, p)^{20}F $Q_m = 6.8764$

Proton groups have been observed to states of ^{20}F with $E_x < 4.1$ MeV (1970RO06, 1974CR04): see Table 20.8. Angular distribution measurements at $E(^3\text{He}) = 18$ (1974CR04) and 19 MeV (1976ME14), γ-ray polarization data (1973LO13) and branching ratio and life-time measurements (1972AL26, 1973PR01) lead to the J^π values shown in Table 20.8 [see also Tables 20.5 and 20.6]. At $E(^3\text{He}) = 5$ MeV, a state is populated at $E_x = 6519 \pm 3$ keV (1976MI01), which decays principally ($> 90\%$) to ^{20}F*(1.06): the γ-rays are isotropic [$\Gamma_\gamma = 3.6 \pm 0.6$ eV, based on the analog decay in ^{20}Ne]. ^{20}F*(6.52) is the 0^+; $T = 2$ analog of the ground state of ^{20}O (1976MI01, 1977BA50). See also (1971NE1E).

14. ^{18}O(α, d)^{20}F $Q_m = -11.4769$

Not reported.

Table 20.8: States in ^{20}F from ^{18}O(^{3}He, p)^{20}F

E_x (keV)		L [b]	J^π [b]
(1970RO06)	(1974CR04)		
0	0	2	2_1^+
657.2 ± 1.3	656	$2 + 4$	3_1^+ [d]
823.5 ± 1.5	822.6 ± 1.9	4	4_1^+ [d]
982.9 ± 1.3	983.3 ± 5.3	[c]	1^- [e]
1058.1 ± 1.4	1057.5 ± 2.4	$0 + 2$	1_1^+
1309.1 ± 1.4	1310.2 ± 3.1	[c]	2^- [e]
1824.4 ± 1.6 [a]	1824.1 ± 3.6	4	5_1^+ [d]
1843.0 ± 1.7 [a]			(2^-) [e]
1971.9 ± 1.6	1978.0 ± 2.8	[c]	(3^-) [g]
2044.0 ± 1.6	2044.9 ± 2.2	2	2_2^+
2195.5 ± 2.0	2194.7 ± 2.8		(3^+) [g]
2868.2 ± 2.3	2863.6 ± 3.9	[c]	
2967.1 ± 2.0	2961.4 ± 3.5		see [b]
	3167.2 ± 3.8 [i]	$(0 + 2)$ [h]	(1^+) [h]
3487.8 ± 2.2	3485.9 ± 2.3	$0 + 2$	1_2^+
	3.53 [j]	[c]	(0^+) [j]
3586.3 ± 2.2	3583.1 ± 2.7		see [b]
3681.0 ± 2.5	3669.4 ± 4.9		see [b]
3761.0 ± 3.1 [f]	3760 ± 10	[c]	
3966.9 ± 2.8		$0 + 2$ [h]	1^+ [h]
4083.7 ± 2.9			
6519 ± 3 [k]			$0^+; T = 2$ [k]

[a] (1967QU01) find $E_x = 1824.4 \pm 2.1$ and 1843.0 ± 2.2 keV.
[b] $E(^{3}\text{He}) = 18$ MeV (1974CR04): predominant L-values.
[c] Weakly populated.
[d] Also (1973LO13, 1973PR01).
[e] (1973LO13).
[f] $E_x = 3765 \pm 6$ keV, based on $E_x = 657 \pm 1$ keV (1973PR01).
[g] Suggested by (1973PR01).
[h] (1976ME14): $E(^{3}\text{He}) = 19$ MeV.
[i] $E_x = 3175 \pm 6$ keV (1972AL26), based on $E_x = 983 \pm 1$ keV.
[j] See (1971FO14).
[k] (1976MI01).

15. (a) ^{18}O(^{6}Li, α)^{20}F $\qquad Q_{\rm m} = 10.896$

(b) ^{18}O(^{7}Li, αn)^{20}F $\qquad Q_{\rm m} = 3.646$

See (1972AJ02).

16. ^{18}O(^{18}O, ^{15}N)^{20}F $\qquad Q_{\rm m} = -1.6505$

See (1972EY01).

17. ^{19}F(n, γ)^{20}F $\qquad Q_{\rm m} = 6.6012$

$Q_0 = 6600.4 \pm 0.5$ keV (1974SP04).

The thermal capture cross section is 9.8 ± 0.7 mb (1974SH1E). See also (1973MU14). A number of resonances have been observed for $E_{\rm n} \leq 1.65$ MeV: see Table 20.9 (1959GA08, 1971NY02, 1973MA14). The primary γ-rays resulting from capture at thermal energies (^{20}F*(6.60); $J^\pi = 0^+$, 1^+) and at $E_{\rm n} = 27$, 44 and 49 keV (^{20}F*(6.63, 6.643, 6.647); $J^\pi = 2^-$, (3, 4) and 1^-, respectively) have been studied by several groups: see (1972AJ02) and Table 20.10 here (1967BE36, 1968SP01, 1969HA04, 1974KE18). It appears that the decay of ^{20}F*(6.60) is dominated by two intense transitions (probably E1) to ^{20}F*(5.94, 6.02) [thus $J^\pi = 1^-, 2^-$]. If the ground-state transition is mainly M1, these two E1 transitions are (in terms of W.u.) about 150 times stronger than the M1 transition (1968SP01). It appears also that at ^{20}F*(6.63, 6.64, 6.65) [$J^\pi = 2^-$, (3, 4) and 1^-, respectively] the E1 transitions to the ground state are very weak, even though other E1 transitions in the decay of these two states have approximately normal strengths (1967BE36, 1974KE18). The strongest transitions from the 27 keV resonance appear to be M1. On the basis of the J^π of the final states involved in the decay of the 44 keV resonance, $J = 3$ or 4, assuming dipole transitions (1974KE18). Branching ratios for other ^{20}F states involved in this reaction are shown in Table 20.5.

Table 20.11 displays excitation energies for ^{20}F states involved in cascade and in primary γ transitions (1968SP01, 1969HA04, 1972OP01).

18. ^{19}F(n, n)^{19}F $\qquad E_{\rm b} = 6.6012$

The scattering amplitude (bound) is $a = 5.66 \pm 0.02$ fm (1975KO29). The value of the coherent scattering cross section recommended by (1973MU14) is 4.0 ± 0.1 b. (1974DI1D) find 3.58 ± 0.02 b and $a = 5.60 \pm 0.01$ fm. The spin-dependent part of the scattering amplitude $\beta \equiv a_+ - a_- = -0.135 \pm 0.002$ fm (1972AB20).

Table 20.9: Resonances in ^{19}F(n, γ)^{20}F

E_n (keV)	J^π [a]	Γ_γ (eV)	$\Gamma_{c.m.}$ (keV)	E_x in ^{20}F (MeV)	Refs.
27.07 ± 0.05	2^-	1.4 ± 0.3	0.355 ± 0.03	6.6269	(1973MA14, 1971NY02)
43.5 ± 0.1	(3, 4) [f]	[b]	< 0.08	6.6425	(1973MA14)
48.7 ± 0.3	1^-	1.6 ± 0.3	1.96 ± 0.3	6.6474	(1973MA14, 1971NY02)
97.0 ± 0.5	1^-	6.0 ± 1.8 [c]	13.5 ± 1.5	6.6933	(1973MA14)
173.5 ± 0.9		[d]	≤ 0.6	6.7660	(1973MA14)
269 ± 1	2	3.5 ± 0.8	10 ± 2	6.8566	(1973MA14)
(270 ± 8)	1	≤ 4.4		(6.858)	(1973MA14)
386 ± 1	1^-	2.4 ± 0.8 [g]	5 ± 1	6.9677	(1973MA14)
(490.5 ± 1)	0^-	$(\geq 10 \pm 3)$	(2.4 ± 0.6)	(7.0670)	(1973MA14)
595 ± 2	2	6.3 ± 1.2 [g]	8 ± 1	7.166	(1973MA14)
760		2.9	60	7.32	(1959GA08)
865			60	7.42	(1959GA08)
950		2.8	95	7.50	(1959GA08)
1125		3.9	80	7.67	(1959GA08)
(1295 ± 12)	1^-	8.6 [g]	(50 ± 10)	(7.831)	(1973MA14, 1959GA08)
1460 ± 3	1	$\geq 11 \pm 3$	14 ± 2	7.988	(1973MA14)
1635		11 ± 3 [g]	180	8.15	(1959GA08)

[a] Assumed: (1973MA14).
[b] $g\Gamma_n = 0.086 \pm 0.02$ eV (1973MA14).
[c] May be two resonances.
[d] $g\Gamma_n = 0.35 \pm 0.1$ eV (1973MA14).
[e] See also Table 20.8 in (1972AJ02) and (1973MU14).
[f] (1974KE18).
[g] (1973MU14).

Table 20.10: Primary capture transitions in ^{19}F(n, γ)^{20}F [a]

Final state ^{20}F* (MeV)	I_γ [b] from ^{20}F*(6.60)		I_γ [b] from ^{20}F*(6.63)		I_γ [b] from ^{20}F*(6.64)	I_γ [b] from ^{20}F*(6.65)
	(1968SP01)	(1969HA04)	(1974KE18)	(1967BE36)	(1974KE18)	(1974KE18)
0	11	10	2.0 ± 0.5			
0.66	< 0.1		6 ± 1	6 ± 2	42 ± 7	
0.82	< 0.1				23 ± 7	
0.98	1.5	2				18 ± 4
1.06 [c]	5	6				9 ± 4
1.31	3	3	31 ± 2	32 ± 2		
1.84	2	2	8 ± 2			
1.97	0.1		46 ± 4	50 ± 2		
2.04	6	6	1.5 ± 1			59 ± 6
2.19						
2.87						
2.97	< 0.2				35 ± 9	
3.49	2.5	2	3 ± 1			14 ± 5
3.53	2			8 ± 1		
3.59	4.4	4				
3.68	1	1				
3.97		1				
4.08		1	2.5 ± 1	5 ± 2		
4.28	1	1				
5.04						
5.41	0.5					
5.55	3					
5.94	17	13				
6.02 [c]	38	48				
6.04	2					

[a] See also Tables 20.5 and 20.9.

[b] In units of photons/100 captures.

[c] E_γ for the transitions (6.60 $\rightarrow$ 0), (6.60 $\rightarrow$ 1.06) and (6.60 $\rightarrow$ 6.02) are, respectively, 6599.8 ± 3.0, 5534.9 ± 2.0 and 583.6 ± 0.5 keV (1967VA08).

Table 20.11: States of ^{20}F involved in ^{19}F(n, γ)^{20}F [a]

E_x (keV)	
(1968SP01)	(1969HA04)
0	0
656.3 ± 0.3 [b]	656 ± 1
822.9 ± 0.3	
983.8 ± 0.3 [b]	984 ± 1
1057.2 ± 0.3	1057 ± 1
1309.1 ± 0.3	1309 ± 1
1843.4 ± 0.3	1843 ± 1
1970.6 ± 0.3	
2044.2 ± 0.4	2044 ± 1
2194.5 ± 0.6	2194 ± 2
2965.8 ± 0.5	2966 ± 2
3488.3 ± 0.3	3488 ± 2
3526.0 ± 0.5	
3587.3 ± 0.3	3588 ± 2
3681.0 ± 0.4	3681 ± 2
	3967 ± 2
4082.2 ± 0.5	4085 ± 2
4276.7 ± 0.5	4275 ± 2
5413.1 ± 0.6	
5554.7 ± 6	
	5713 ± 2
5936.0 ± 0.3	5937 ± 1
6017.3 ± 0.3	6018 ± 1
6044.6 ± 0.4	
6601.1 ± 0.3	6602.0 ± 0.6

[a] For measurements of I_γ, see (1968SP01, 1969HA04) and Table 20.10.
[b] 656.1 ± 0.3 and 983.4 ± 0.4 keV (1972OP01).

The total cross section has been measured for $E_n = 0.5$ to 29.1 MeV: see the listings in (1972AJ02, 1973MU14), the display in (1976GAYV) and (1974SI27: $E_n = 0.5$ to 200 keV), (1974JO1H: $E_n = 20$ keV to 10 MeV; abstract). Observed resonances are displayed in Table 20.12. For angular distribution measurements see ^{19}F. For polarization measurements see (1972AJ02). See also (1971KO1W) and (1973BA1U, 1974HU07; theor.).

19. ^{19}F(n, n′)^{19}F* $E_b = 6.6012$

Recent excitation functions have been measured for the 0.11 and 0.20 MeV γ-rays for E_n from threshold to 19.4 and 18.6 MeV, respectively: the differential cross section at 92° for the 0.11 MeV γ-ray shows a number of resonances the most pronounced of which are displayed in Table 20.13. The 0.20 MeV γ-ray yield does not show clear resonance structure (1976MO13). See also (1974RO03: $E_n = 0.2$ to 1.7 MeV). (1973MA14) has studied the inelastic yield involving the states of ^{19}F near 1.5 MeV: observed resonances are also displayed in Table 20.13. See also (1969RO1F, 1977DI11), (1975FU1D) and (1972AJ02) for the earlier work.

20. ^{19}F(n, 2n)^{18}F $Q_m = -10.4313$ $E_b = 6.6012$

Cross sections have been measured for $E_n = 10$ to 37 MeV: see (1972AJ02) for the earlier work, (1972MO15: $E_n = 14.1$ MeV) and (1973RO29: $E_n = 14.78$ MeV) and the summary in (1976GAYV). See also (1973BO1K, 1974BO1E, 1974CA1J, 1974KO35).

21. ^{19}F(n, p)^{19}O $Q_m = -4.036$ $E_b = 6.6012$

The differential cross section at 92° for production of the 96 keV γ-ray has been studied by (1976MO13: $E_n = 4.0$ to 18.6 MeV): the cross section increases sharply at $E_n = 6$ MeV and then gradually decreases beyond $E_n = 12$ MeV. Cross sections have also been measured for $E_n = 12.6$ to 21 MeV: see (1972AJ02) and the summary in (1976GAYV). See also (1972BA1T, 1973BA1T; abstracts) and (1972ED01, 1974BO1E, 1974CA1J, 1976SL2A, 1977DI11).

22. ^{19}F(n, d)^{18}O $Q_m = -5.7688$ $E_b = 6.6012$

See (1972AJ02) and (1976PR08, 1976SL2A).

23. ^{19}F(n, t)^{17}O $Q_m = -7.556$ $E_b = 6.6012$

Table 20.12: Resonances in ^{19}F(n, n)^{19}F

E_n (keV)	Γ_{lab} (keV)	J^π	^{20}F* (MeV)	Refs.
26.99	0.325 ± 0.020	2^-	6.6268	(1974JO1H, 1974SI27)
48.78	1.67 ± 0.10	1^-	6.6475	(1974JO1H, 1974SI27)
97.50	14.5 ± 0.8	1^-	6.6938	(1974JO1H, 1974SI27)
[a]				
500	25 [b]	(1^+)	7.076	(1966CA14)
600	15 [b]	(2^+)	7.171	(1966CA14)
747	35 [b]	(1)	7.311	(1966CA14)
794	20	(1)	(7.355)	(1966CA14)
852	11 [b]	(2^+)	7.410	(1966CA14)
935	60	(2)	7.489	(1958WI36, 1966CA14)
1100	50	(2^+)	7.65	(1958WI36, 1966CA14)
1250	150		7.79	(1958WI36)
1620	220		8.14	(1958WI36)
2000	150		8.50	(1958WI36)
2250	≤ 30		8.74	(1958WI36)
2280	80		8.77	(1958WI36)
2520	150		8.99	(1958WI36)
3250	150		9.69	(1958WI36)
3420	130		9.85	(1958WI36, 1960TS02)
3460 ± 10			(9.886)	(1960TS02)
3505 ± 10			(9.929)	(1960TS02)
3560 ± 10			(9.981)	(1960TS02)
3605 ± 10	200		10.024	(1958WI36, 1960TS02)
3820 ± 10	≈ 200	0^-, 1	10.228	(1960TS02)
4085 ± 10	≈ 10		10.480	(1960TS02)
4255 ± 10	≈ 60	1, 2	10.641	(1960TS02)
4430 ± 10	≈ 330	0^-, 1	10.807	(1960TS02)
4680 ± 10	≈ 30		11.045	(1960TS02)
4770 ± 10	< 25		11.130	(1960TS02)
4890 ± 10	< 25		11.244	(1960TS02)
(4935)			(11.287)	(1960TS02)

[a] See (1976GAYV) for resonances in σ_t derived unpublished work.
[b] $\Gamma_\gamma = 3.3\pm1.0, 6.3\pm1.2, 2.4\pm0.8$ and 1.5 ± 0.5 eV for ^{20}F*(7.08, 7.17, 7.31, 7.41) (1973MU14).

Table 20.13: States of ^{20}F from resonances in ^{19}F(n, n′γ)^{19}F

E_n (keV)	Γ_{lab} (keV)	Resonance in		E_x in ^{20}F
		$\gamma_{0.11}$ [a]	$\gamma_{1.5}$ [b]	(MeV)
240		r		6.829
270		r		6.858
386		r		6.968
420		r		7.000
490		r		7.066
620		r		7.190
800		r		7.361
860		r		7.418
1150 [c]		r		7.693
1250		r		7.788
1580		r		8.101
1645	15	r	r	8.163
1916	28		r	8.421
2240	45		r	8.728
2465	75	r	r	8.942
2700		r		9.165
3075	120		r	9.521
3215	80		r	9.654
3400	35		r	9.830
3475	≤ 30		r	9.901
3620	120	r	r	10.038
4240	90	r	r	10.627
4620	200		r	10.988
4900	≤ 50		r	11.254
7300		r		13.532

r = resonant.

[a] Resonances in yield of 0.11 MeV γ-rays at $\theta = 92°$: values for E_n read by reviewer from differential cross section tables (1976MO13).

[b] Resonances in yields to states of ^{19}F with $E_x \approx 1.5$ MeV: see (1973MA14).

[c] Appears to be unresolved.

Table 20.14: Resonances in ^{19}F(n, α)^{16}N

E_n (MeV ± keV)			E_x (MeV)
(1955MB01)	(1960SM03)	(1961DA16)	
3.4			9.8
3.61 ± 50			10.03
3.69 ± 50			10.10
3.77 ± 50	3.75 ± 50	3.85	10.17
4.11 ± 50	4.08 ± 50	4.1	10.49
4.42 ± 50	4.36 ± 50	4.35	10.77
	4.52 [a]		10.89
4.86 ± 50	4.79 ± 50	4.80	11.18
	5.15 ± 50		11.49
	5.40 [a]		11.73
		5.7	12.0
5.9 ± 100	5.9 [a]		12.2
		6.10	12.39
		6.55	12.82
		6.9	13.2
		7.44	13.66
		7.8	14.0

[a] Not resolved.

See ^{17}O in (1977AJ02) and (1976SL2A).

24. ^{19}F(n, α)^{16}N $\qquad Q_m = -1.522 \qquad E_b = 6.6012$

Observed resonances are shown in Table 20.14: see graph in (1976GAYV). See also (1972FO21: $E_n = 5.85$ MeV, $\sigma_{n,\alpha} = 135 \pm 27$ mb). See also (1972BA1T) and (1974BO1E, 1974CA1J, 1976SL2A).

25. ^{19}F(d, p)^{20}F $\qquad Q_m = 4.3765$

Measurements of proton groups and of γ-rays have led to the identification of a number of ^{20}F states: see Table 20.15. Angular distributions have been measured for $E_d = 0.6$ to 13 MeV (see (1972AJ02)) and at $E_d = 1.00 - 1.50$ MeV (1976BE51), 1.20 to 2.20 MeV (1975CO18: p$_1$), 3 MeV (1972LA18; l_n and $(2J+1)S$ values for a number of states) and at 12 (1974FO21) and 16 MeV (1972FO11). The J^π and $(2J+1)S$ values derived from the experiments at 12 and 16 MeV are displayed in Table 20.15. (1975MC1J) have studied the $l_n = 2$ transitions to ^{20}F*(0.66, 2.04, 2.19, 2.97) with $E_{\vec{d}} = 11$ MeV while (1973JO10) report a study at $E_{\vec{d}} = 12.3$ MeV involving ^{20}F$_{g.s.}$. (1970QU1A), also using polarized deuterons, have looked at the protons corresponding to ^{20}F*(0.66, 2.04). These two states are found to be populated by a $j = \frac{5}{2}$ neutron transfer. This result, together with (p-γ) correlation data, provides a unique $J^\pi = 3^+$ assignment for ^{20}F*(0.66) and is in agreement with 2^+ for ^{20}F*(2.04). Transitions to ^{20}F*(2.19, 2.97) appear to involve admixed $j = \frac{3}{2}, \frac{5}{2}$ transfer implying $J = 2$ for both these states (1970QU1A).

Table 20.15: States in ^{20}F from ^{19}F(d, p)^{20}F

E_x (keV)			l_n [d,e]	J^π [d,e]	$(2J+1)S$		
(1970RO06) [a]	(1969HO20) [b,c]	(1972FO11) [a]			$E_d = 12$ MeV [d]	16 MeV [e]	n, l, j [h]
0			2	2^+	0.054	≤ 0.06	1d$_{5/2}$
654.9 ± 1.0	655.9 ± 0.2	655 ± 1	2	3^+	2.32	2.59	1d$_{5/2}$
821.6 ± 1.0	823.0 ± 0.3	823 ± 5	[i]	4^+	0.32	0.36	1g$_{9/2}$
983.3 ± 1.0	983.9 ± 0.3	983 ± 5	[i]	1^-	0.014	0.016	1p$_{1/2}$
1056.3 ± 1.0	1057.0 ± 0.2	1056 ± 3	$0+2$	1^+	0.013	0.019	2s$_{1/2}$
1310.8 ± 1.1	1309.3 ± 0.2	1309 ± 5	[i]	2^-	0.017	0.013	1p$_{3/2}$
		1820 ± 10	[i]	(5^+)	0.35	0.32	1g$_{9/2}$
1843.4 ± 1.2	1843.5 ± 0.7	1845 ± 4	[i]	2^-	0.007	0.03	2p$_{3/2}$
		1970 ± 10	[i]	(3^-)	0.038	0.042	1f$_{7/2}$
	2043.7 ± 0.5	2044 ± 1	2	2^+	2.32	2.32	1d$_{5/2}$
2195.1 ± 1.5	2194.5 ± 0.6	2196 ± 1	2	3^+	0.55	0.50	1d$_{5/2}$
2863.7 ± 1.6		2871 ± 5	[i]		0.044		1f$_{7/2}$
2966.6 ± 1.7	2966.8 ± 0.6	2966 ± 1	2	3^+	0.38	0.36	1d$_{3/2}$
3171.8 ± 2.2	3175.6 ± 1.3	3176 ± 5	[i]		0.019	0.014	1d$_{5/2}$
	3488.5 ± 0.3	3489 ± 1	0	1^+		1.20	2s$_{1/2}$
3525.5 ± 2.6	3525.9 ± 0.5	3531 ± 3	0	0^+		0.28	2s$_{1/2}$
3586.4 ± 2.7	3586.5 ± 0.6	3590 ± 1	2	$\pi = +$	0.038	0.42	1d$_{3/2}$
3681.0 ± 2.5		3686 ± 4	2	$\pi = +$	0.031	≤ 0.04	1d$_{5/2}$
3760.8 ± 2.7			[i]		see [d]		
3964.5 ± 2.5		3977 ± 5	2	$\pi = +$	0.036	0.043	1d$_{5/2}$
4080.9 ± 2.5	4082.5 ± 0.8	4089 ± 3	$0+2$	$\pi = +$	0.13	0.18	1s$_{1/2}$
4198.9 ± 2.7							
4207.7 ± 2.6			[i]		0.083	0.10	1d$_{3/2}$
4276.3 ± 2.8		4282 ± 5	2	$\pi = +$			
4311.5 ± 2.6		4318 ± 5	0	$(0, 1)^+$			

Table 20.15: States in ^{20}F from ^{19}F(d, p)^{20}F (continued)

E_x (keV)			l_n [d,e]	J^π [d,e]	$(2J+1)S$		
(1970RO06) [a]	(1969HO20) [b,c]	(1972FO11) [a]			$E_d = 12$ MeV [d]	16 MeV [e]	n, l, j [h]
4583.8 ± 3.0							
4592.2 ± 2.9							
4730.2 ± 2.9							
4763.8 ± 2.7							
4891.6 ± 2.8							
4898.2 ± 2.8							
5040.2 ± 3.1			1 [j]	(0, 1, 2) $^-$			
5065.5 ± 3.1							
5224.0 ± 3.1			1 [j]	(0, 1, 2) $^-$			
5281.0 ± 3.3			1 [j]	(0, 1, 2) $^-$			
5317.1 ± 2.7							
5344.5 ± 3.3							
5450.3 ± 3.8							
5455.4 ± 3.2							
5463.4 ± 3.3							
5620.3 ± 3.3							
5762.8 ± 3.4							
5809.1 ± 2.9							
5933.9 ± 3.3 [f]			1 [j]	(0, 1, 2) $^-$			
6015.0 ± 3.8 [f]			1 [f]	(0, 1, 2) $^-$			
6043.3 ± 3.7		[g]					

[a] From measurements of proton groups.
[b] From measurements of γ-rays.
[c] (1969HE20) find $E_x = 655.4 \pm 0.5$, 822.6 ± 0.7, 983.4 ± 0.7, 1055.2 ± 0.6, 1308.0 ± 0.9 and 2964.5 ± 2.0 keV.
[d] (1974FO21): $E_d = 12$ MeV.
[e] (1972FO11): $E_d = 16$ MeV.
[f] (1971RO06) find $E_x = 5932 \pm 5$ and 6013 ± 5 keV, respectively.
[g] (1956EL1A) find additional transitions to states with $E_x = 6250$, 6520, 6630, 6810, 6980 and 7200 [± 20] keV: the last four involve $l_n = 1$.
[h] For $(2J+1)S$ values for other n, l, j, see (1974FO21).
[i] Weak states: see (1972FO11, 1974FO21).
[j] (1956EL1A).

Branching ratio, angular correlation and γ-ray polarization measurements, as well as τ_m determinations, permit a unique choice of J^π in many cases from among the J^π values stemming from direct interaction analyses of angular distributions: see Table 20.5 and (1973HA14, 1973WA10). See also (1971BE2F, 1972BA1V) and (1973DO02; theor.).

26. ^{19}F(t, d)^{20}F $Q_m = 0.3438$

See (1972AJ02).

27. ^{19}F(^{9}Be, ^{8}Be)^{20}F $Q_m = 4.9360$

See (1977SW05).

28. ^{19}F(^{13}C, ^{12}C)^{20}F $Q_m = 1.6548$

Total cross section measurements for formation of ^{20}F*(0, 0.66) (1974LA27) and of ^{20}F*(0.66) (1975SE03) have been measured for $E(^{13}\mathrm{C}) = 10$ to 25 MeV and $E(^{19}\mathrm{F}) = 13$ to 24 MeV, respectively. In the latter experiment σ_t is compared with DWBA assuming $S_1 S_2 = 0.54$; the population of ^{20}F*(2.04) is also reported (1975SE03). τ_m for ^{20}F*(0.66) $= 390 \pm 40$ fsec (1975SE04): see Table 20.6.

29. ^{19}F(^{19}F, ^{18}F)^{20}F $Q_m = -3.830$

See (1972AJ02).

30. ^{20}O(β^-)^{20}F $Q_m = 3.816$

See ^{20}O.

31. ^{20}Ne(n, p)^{20}F $Q_m = -6.2435$

See (1971KA18, 1976KI1D).

32. ^{20}Ne(t, ^{3}He)^{20}F $Q_m = -7.0073$

Not reported.

Table 20.16: Analog states of $A = 20$ observed in ^{21}Ne(d, ^{3}He)^{20}F and ^{21}Ne(d, t)^{20}Ne [a]

^{20}F* (MeV) [b]	J^{π}	^{20}Ne* (MeV ± keV)	l	C^2S			
				^{20}F		^{20}Ne	
0	2^+	10.27 [b]	$0+2$	$0.24+0.58$		$0.08+0.25$	
0.66	3^+	10.880 ± 10	2	0.66		0.42	
0.82	4^+	11.086 ± 10	2	0.26		0.18	
0.98	1^-		1		0.84		0.52
		11.27					
1.06	1^+		$0+2$	$0.08+0.25$		$0.03+0.18$	
1.31	2^-	11.601 ± 10	1		0.86		0.50
1.84	2^-	12.100 ± 10	1		0.69		0.43
2.04	2^+		2	0.15			
2.19	(3^+)		2	0.16			
				$l = 0+2$	$l = 1$	$l = 0+2$	$l = 1$
			sums:	2.38	2.39	1.14	1.45

[a] (1974MI13); $E_d = 26$ MeV; DWBA analysis of angular distributions. See Table 20.38 for $T = 0$ states in ^{20}Ne observed in the (d, t) reaction.
[b] E_x are nominal.

33. ^{21}Ne(n, d)^{20}F $\qquad Q_m = -10.780$

Not reported.

34. ^{21}Ne(d, ^{3}He)^{20}F $\qquad Q_m = -7.511$

The ^{20}F states observed, at $E_d = 26$ MeV, in this reaction and analog [$T = 1$] states observed in ^{20}Ne in the (d, t) reaction are displayed in Table 20.16. The spectroscopic factors of analog states are consistent to within 20% for states excited by a single l-transfer (1974MI13).

35. ^{21}Ne(t, α)^{20}F $\qquad Q_m = 6.809$

Not reported.

Table 20.17: States of ^{20}F from ^{22}Ne(d, α)^{20}F [a]

E_x (keV)	E_x (keV)	E_x (keV)	E_x (keV)
655 ± 2	3680 ± 3	5224 ± 6	6205 ± 6
824 ± 3	3762 ± 4	5276 ± 5	6240 ± 7
983 ± 3	3964 ± 4	5321 ± 4 [b]	6300 ± 5
1056 ± 4	4083 ± 4	5405 ± 5	6337 ± 5
1307 ± 3	4206 ± 4 [b]	5451 ± 5 [b]	6370 ± 6
1830 ± 7 [b]	4279 ± 4 [b]	5557 ± 5	6407 ± 12
1970 ± 4	4372 ± 4	5574 ± 6	6441 ± 9
2042 ± 3	4518 ± 4	5623 ± 4	6480 ± 5
2192 ± 3	4597 ± 4 [b]	5710 ± 11	6588 ± 5
2864 ± 3	4728 ± 8	5765 ± 3	6645 ± 5 [b]
2967 ± 3	4764 ± 7	5813 ± 4	6711 ± 5 [b]
3174 ± 3	4888 ± 4 [b]	5940 ± 5	6772 ± 6
3491 ± 4 [b,c]	5048 ± 4 [b]	6040 ± 4 [b]	6860 ± 13
3589 ± 3	5131 ± 5	6163 ± 6	6905 ± 8

[a] (1976FO16): $E_d = 10$ MeV.

[b] Unresolved.

[c] Earlier results showed that ^{20}F*(3.49) is strongly populated and that ^{20}F*(3.53) is weakly populated, and has an angular distribution which is roughly symmetric about 90°. These results are consistent with $J^\pi = 1^+$ and 0^+, respectively (1971FO14).

36. ^{21}Ne(n, t)^{20}F $\qquad Q_m = -14.8875$

Not reported.

37. ^{22}Ne(p, ^{3}He)^{20}F $\qquad Q_m = -15.6513$

At $E_p = 43.7$ to 45.0 MeV analog states have been studied in ^{20}F and ^{20}Ne [the latter via ^{22}Ne(p, t)^{20}Ne]. The experimental cross-section ratio, R, for the transitions to ^{20}Ne*(10.28) and ^{20}F(0) [2^+; $T = 1$] is 2.00 ± 0.20; R for the transitions to ^{20}Ne*(12.25 ± 0.03) and ^{20}F*(1.82) [5^+; $T = 1$] is 1.40 ± 0.15 (1969HA19). Angular distributions for the ^{3}He ions and the tritons corresponding to the first $T = 2$ states ($J^\pi = 0^+$) [^{20}Ne*(16.722 ± 0.025) and ^{20}F*(6.513 ± 0.033)]

have also been compared. There is indication also for the excitation of the 2^+; $T = 2$ states [at $E_x = 8.05$ MeV in ^{20}F and at 18.5 MeV in ^{20}Ne (estimated errors ± 0.1 MeV)] (1964CE05, 1969HA38).

38. ^{22}Ne(d, α)^{20}F $\qquad Q_m = 2.7019$

Angular distributions have been obtained at $E_d = 10$ MeV to all ^{20}F states with $E_x < 4.4$ MeV: they are generally featureless. The cross sections for ^{20}F*(3.68, 3.97) are consistent with their being the second 4^+ and the third 1^+ states in ^{20}F. A listing of all the states observed in this experiment is displayed in Table 20.17 (1976FO16). See also (1971MO40: $E_d = 2$ and 3 MeV; $\alpha_0 \rightarrow \alpha_7$).

39. ^{23}Na(n, α)^{20}F $\qquad Q_m = -3.866$

See (1975SA1D) and (1972AJ02).

^{20}Ne
(Figs. 11 and 13)

GENERAL: (See also (1972AJ02).)

Shell model: (1970CR1A, 1971DE56, 1971RA1B, 1971ZO1A, 1972AB12, 1972AR1F, 1972AS13, 1972BO38, 1972BR1G, 1972JA24, 1972KA39, 1972KA67, 1972KH08, 1972KR1D, 1972KU1F, 1972LE13, 1972LE38, 1972MA07, 1972NI14, 1972RE03, 1972SA1B, 1972VO09, 1972WH04, 1973CO03, 1973DH1A, 1973EL04, 1973EN1C, 1973GI09, 1973HA05, 1973HE1F, 1973IC01, 1973IR01, 1973MA1K, 1973MC06, 1973MC1E, 1973ME1D, 1973PA05, 1973PU1A, 1973SM1C, 1973SV1A, 1973YA1A, 1974AY02, 1974KH03, 1974KR17, 1975BA81, 1975DR01, 1975GI03, 1975GR1M, 1975HA1U, 1975HA1V, 1975MP01, 1975MU13, 1975TA1H, 1976NG04, 1976PO01, 1976SC08, 1976SH07, 1977CA08, 1977FE07, 1977HA33, 1977MA09, 1977NE1D, 1977RO1V, 1977SH11).

Collective and deformed models: (1970CR1A, 1970FL1A, 1971RA1B, 1972BO38, 1972DE1F, 1972HA1Q, 1972HI17, 1972HO1D, 1972HO56, 1972JA24, 1972KU1F, 1972TE02, 1972VO09, 1973CA16, 1973CU03, 1973DE06, 1973EL04, 1973GO26, 1973HO1H, 1973HO40, 1973HO41, 1973IC01, 1973IR01, 1973KO1F, 1973KR1E, 1973LA35, 1973MC1E, 1973MI1F, 1973NG1B, 1973NO1B, 1973RE11, 1973SE15, 1973ST25, 1973SV1A, 1973VA1H, 1973YA1A, 1974AR04, 1974KR17, 1974MA11, 1974MP01, 1974NO14, 1974RI1B, 1974SC34, 1974TA19, 1975AB04, 1975BU1L, 1975DR01, 1975GR1M, 1975HA1U, 1975HE1L, 1975HE10, 1975HO1H, 1975MA26, 1975NE04, 1975TA1H, 1976BA11, 1976CH23, 1976JA1F, 1976KE03, 1976MA36, 1976NO10, 1976PA02, 1976SH07, 1976ST09, 1976UL1D, 1977CA08, 1977FE07, 1977HO1F, 1977KA2F, 1977MA09, 1977PA07, 1977RO13, 1977ST21, 1977TH03).

Cluster and α-particle models: (1971AB1B, 1971AR1V, 1971LIZI, 1971RI1D, 1971SA1A, 1971WO1C, 1972AR12, 1972AR1F, 1972BA59, 1972FR1B, 1972GO16, 1972GR42, 1972HI17, 1972HO56, 1972IK1A, 1972KA39, 1972KA67, 1972LA08, 1972NE1B, 1972VO09, 1973AR1C, 1973CH1E, 1973CU03, 1973HO1H, 1973HO40, 1973IC01, 1973KR1E, 1973LA35, 1973MA50, 1973SU1D, 1973VA21, 1973YA1A, 1974AB05, 1974GO12, 1974MO01, 1974YA11, 1975AR1J, 1975BU03, 1975BU1L, 1975HA1V, 1975HE1L, 1975HE10, 1975IK1A, 1975MA26, 1975NE04, 1976BA11, 1976BA1N, 1976FU1K, 1976KI18, 1976SA1F, 1977FL1E, 1977FU1P, 1977HE10, 1977HO1E, 1977HO1F, 1977KA2F, 1977RO13, 1977ST21, 1977TO1L).

Astrophysical questions: (1972CL1A, 1972KO1A, 1973AR1E, 1973AR1H, 1973AU1D, 1973CA1B, 1973CO1J, 1973HO1G, 1973RA1D, 1974AR1G, 1974AR1H, 1974PA1E, 1975BA2D, 1975EN1A, 1975IB1A, 1975LA1E, 1975MA1R, 1975PE1E, 1975RA1M, 1975RO08, 1975TA1G, 1975TR1A, 1975WO1D, 1976GI1C, 1976NO1C, 1976RO1J, 1976RU1C, 1976SI1D, 1977AR1H, 1977BU1Q, 1977CA1N, 1977DW1B, 1977KI1M, 1977PA1J, 1977VO1A).

Giant resonance (See also reaction 46.): (1973HA1Q, 1974HA1C, 1975AB04, 1975GR1M, 1976BE1P, 1976SC08, 1977AB08, 1977KN02, 1977SC08).

Electromagnetic transitions: (1971DE56, 1972AB12, 1972AS13, 1972BE1E, 1972BO38, 1972DE1F,

Table 20.18: Energy levels of ^{20}Ne [a]

E_x (MeV ± keV)	$J^\pi; T$	K^π	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
0	$0^+; 1$	0^+_1		stable	2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 14, 19, 20, 22, 23, 25, 26, 27, 29, 30, 31, 32, 33, 34, 40, 41, 42, 43, 44, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 59, 62, 64, 65, 66, 67, 68
1.6337 ± 0.3	$2^+; 0$	0^+_1	$\tau_m = 1.05 \pm 0.06$ psec $\|g\| = 0.54 \pm 0.04$	γ	2, 3, 7, 8, 9, 10, 12, 14, 19, 20, 22, 23, 25, 27, 29, 31, 32, 33, 34, 40, 41, 42, 43, 45, 47, 49, 50, 52, 53, 56, 57, 58, 59, 62, 64, 65, 66, 67, 68
4.2477 ± 1.1	$4^+; 0$	0^+_1	$\tau_m = 93 \pm 9$ fsec	γ	2, 3, 7, 8, 9, 14, 19, 20, 22, 23, 24, 25, 27, 29, 31, 32, 33, 40, 41, 42, 43, 49, 50, 52, 53, 56, 59, 62, 64, 65, 66, 67, 68
4.9679 ± 0.7	$2^-; 0$	2^-	4.8 ± 0.5 psec	γ	2, 3, 7, 8, 9, 14, 19, 22, 25, 31, 34, 40, 41, 42, 43, 45, 49, 59, 62, 64
5.6214 ± 1.7	$3^-; 0$	2^-	200 ± 50 fsec	γ, α	2, 3, 7, 8, 14, 19, 29, 40, 41, 42, 43, 49, 60, 62, 64, 66, 67
5.784 ± 2	$1^-; 0$	0^-		γ, α	2, 3, 7, 8, 14, 19, 20, 22, 29, 31, 32, 41, 42, 43, 49, 60, 62, 66, 67
6.724 ± 5	$0^+; 0$	0^+_2	$\Gamma = 15 \pm 7$ keV	γ, α	3, 7, 8, 14, 15, 19, 31, 40, 41, 43, 47, 49, 63
7.004 ± 3.6	$4^-; 0$	2^-	$\tau_m = 440 \pm 90$ fsec	γ	2, 3, 7, 8, 14, 19, 25, 41, 42, 49, 63
7.168 ± 5	$3^-; 0$	0^-	$\Gamma = 8$ keV	α	2, 3, 7, 8, 15, 19, 20, 25, 31, 32, 40, 41, 42, 43, 49
7.191 ± 3	$0^+; 0$	0^+_3	4	γ, α	3, 7, 14, 15, 22, 40, 42, 47, 49
7.4214 ± 1.0	$2^+; 0$	0^+_2	8	γ, α	2, 3, 5, 7, 14, 15, 19, 40, 41, 43, 47, 49, 58, 60
7.8290 ± 2.0	$2^+; 0$	0^+_3	2.4	γ, α	2, 3, 7, 14, 15, 31, 40, 41, 47, 49, 58, 60
≈ 8.3	$0^+; 0$	0^+_4	> 800	α	3, 15, 41
8.4486 ± 2.3	$5^-; 0$	2^-	0.013 ± 0.004	γ, α	2, 3, 6, 7, 14, 15, 19, 25, 41, 49
8.694 ± 6	$1^-; 0$	(1^-_1)	2.5		3, 7, 15, 40, 41, 49

Table 20.18: Energy levels of ^{20}Ne [a] (continued)

E_x (MeV $\pm$ keV)	$J^\pi; T$	K^π	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
8.7767 ± 2.3	$6^+; 0$	0_1^+	0.11 ± 0.02	γ, α	2, 3, 6, 7, 9, 14, 15, 19, 20, 22, 23, 24, 25, 31, 41, 49
≈ 8.8	$2^+; 0$	0_4^+	> 800	α	15, 41, 58
8.848 ± 5	$1^-; 0$	(1_1^-)	19	α	7, 15, 32, 41, 60
9.030 ± 5	$4^+; 0$	0_3^+	3.2	γ, α	2, 3, 6, 7, 14, 15, 31, 41, 49, 60
9.115 ± 4	$3^-; 0$		3.2	α	2, 7, 15, 40, 41, 49
9.318 ± 6					5, 7, 41, 49, 60
9.508 ± 12	$2^+; 0$		29 ± 15	γ, α	3, 7, 14, 15, 40, 41, 49, 58
9.873 ± 4	$3^+; 0$			γ	7, 41, 58
9.92 ± 20	$(1^+); 0$		$\tau_m < 35$ fsec	γ	3, 31, 41, 60
9.99 ± 20	$4^+; 0$	0_2^+	$\Gamma = 155 \pm 30$	γ, α	2, 7, 14, 15, 41
10.261 ± 4	$5^-; 0$	0^-	145 ± 40	α	2, 3, 7, 15, 19, 20, 22, 23, 25, 32
10.2724 ± 2.0	$2^+; 1$		0.4 ± 0.2	γ, α	2, 3, 14, 15, 31, 41, 58, 60, 62
10.403 ± 5	$3^-; 0$		80	α	7, 15, 32, 41, 60
10.548 ± 5	$4^+; 0$		16	α	3, 7, 15, 19, 41
10.583 ± 6	$2^+; 0$		24	α	15, 41, 58
10.609 ± 6	$6^-; 0$	2^-	$\tau_m = 23 \pm 7$ fsec	γ	2, 3, 6, 7
10.694 ± 6	$4^-, 3^+; 0$			γ	6, 7
10.79 ± 100	$4^+; 0$	0_4^+	$\Gamma = 350$	α	15, 24
10.838	3^-		45	α	7, 15, 60
10.840 ± 5	$2^+; 0$		13	α	7, 15, 41, 58
10.89 ± 10	$3^+; 1$		$\tau_m < 30$ fsec	γ	6, 7, 41, 58, 60
10.97	$0^+; 0$		$\Gamma = 580$	α	15
11.015 ± 6	$4^+; 0$		24	α	6, 7, 10
11.073 ± 8	$4^+; 1$		≤ 0.5	γ, α	14, 15, 41, 60
11.23 ± 30	$1^-; 0$		170	α	15
11.23 ± 10	$1^+; 1$			γ	34, 47, 58, 60
11.256 ± 8	$1^-; 1$		≤ 0.3	γ, α	14, 15
11.322 ± 7	$2^+; 0$		40 ± 10	α	15, 41, 58
11.528 ± 6	$3^+, 4^-; 0$		$\tau_m \leq 30$ fsec	γ	7, 31
11.552 ± 8	$(2^+, 0^+)$		$\Gamma = 1.0 \pm 0.5$ keV	γ, α	14, 15, 31, 40, 41
11.555 ± 6	$1^+, 2^-, 3^+$			γ	7, 31
11.601 ± 10	$2^-; 1$				31, 60
11.656	$(3^+); 0$			γ	6, 7
11.866 ± 9	$2^+; 0$		60	α	7, 15, 41, 58
11.926 ± 5	$4^+; 0$		0.44 ± 0.15	$(\gamma), \alpha$	14, 15, 40

Table 20.18: Energy levels of ^{20}Ne [a] (continued)

$E_{\rm x}$ (MeV ± keV)	$J^\pi; T$	K^π	$\tau_{\rm m}$ or $\Gamma_{\rm c.m.}$ (keV)	Decay	Reactions
11.949 ± 5	$8^+; 0$	0_1^+	0.035 ± 0.010	γ, α	6, 7, 8, 9, 14, 15, 19, 20, 22, 23, 41
11.962 ± 8	$1^-; 0$		30 ± 5	α	15
12.100 ± 10	$2^-; 1$				60
12.134 ± 10	$6^+; 0$	0_3^+	0.13 ± 0.07	$(\gamma), \alpha$	6, 7, 8, 14, 19
12.215 ± 5	$2^+; 1$		< 0.1	γ, α	14, 34, 41, 62
12.24 ± 30	$4^+; 0$		148 ± 20	α	15
12.254 ± 6	$3^-, 2^+$		≈ 5	γ, α	14, 40
(12.35 ± 100)	(2^+)		≈ 500	α	15
12.39 ± 10	$3^-; (1)$		33 ± 4	γ, α	6, 7, 14, 15, 40, 41
12.412 ± 5	$(0^+); 0$		≤ 8	α	7, 15, 31, 41
12.49 ± 30				γ, α	14, 41
12.591 ± 10	$6^+; 0$	0_4^+	88 ± 10	α	6, 7, 15, 19, 20, 22
12.683 ± 15	$5^-; 0$		97	α	15
12.730 ± 10	$4^+; 0$		100	α	6, 7, 15
12.83 ± 30			55	α	15, 31, 41
12.919 ± 10				γ	7
13.010 ± 10	$(4^+; 0)$		60	α	7, 15
13.049 ± 10	$(4^+; 0)$		70	α	6, 7, 15
13.060 ± 3.5	2^-		1.0	p, α	37, 40, 41
13.1680 ± 0.6	$1^+; (1)$		2.3 ± 0.2	γ, p, α	34, 35, 37, 40, 41
13.190 ± 10	$(4^+; 0)$		60	α	6, 7, 15
13.225	1^-		95	p, α	37
13.225	0^+		95	p, α	37
13.3038 ± 0.7	1^+		0.9 ± 0.1	γ, p, α	7, 34, 35, 37, 41
13.334 ± 6	$7^-; 0$	2^-	$(8 \pm 3) \times 10^{-4}$	α	6, 7, 8, 15, 31
13.343 ± 6	$4^+; 0$		20 ± 5	α	15, 31
13.412 ± 1	2^-		29 ± 3	γ, p, α	15, 34, 35
(13.42 ± 140)	$(4^+; 0)$		110	α	15
13.462 ± 20	1^-		190	p, α	37
13.482 ± 1	$1^+; 1$		5.7 ± 0.7	γ, p, α	31, 34, 35, 40
13.519	(1^-)		33	p, α	37
13.569 ± 15	2^+		63	p, α	7, 31, 35, 37
13.583	2^+		≈ 10	p, α	37
13.64 ± 15	$0^+; 1$		22	p, α	7, 31, 35, 37, 40
(13.66)	(1^-)		110	p, α	37
13.6729 ± 0.7	2^-		4.5 ± 0.2	γ, p, α	6, 7, 34, 35, 37
13.7 ± 400	$(3, 7)^-$		320	α	15

Table 20.18: Energy levels of ^{20}Ne [a] (continued)

E_x (MeV $\pm$ keV)	$J^\pi; T$	K^π	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
(13.73)	(0^+)		≈ 170	p, α	37
13.733 ± 1.4	1^+		7.7 ± 0.5	γ, p, α	34, 35, 37
13.845 ± 15	(1^-)		≈ 190	p, α	7, 37
13.886 ± 15	2^-		0.8	γ, p	6, 7, 8, 31, 34, 35, 40
13.904	2^+		47	p, α	37
13.904 ± 20	6^+		≈ 100	α	15, 19, 20
13.946	0^+		≈ 70	p, α	37
14.017	1^-		≈ 70	p, α	37
14.03	2^+		≈ 140	p, α	37
14.124 ± 1.2	2^-		4.7 ± 0.7	γ, p, α	34, 35, 37
14.144 ± 15	2^+		50	p, α	7, 15, 37
14.148 ± 1.2	2^-		11.8 ± 1.0	γ, p, α	34, 35, 37
14.195	1^+		14 ± 1	γ, p	34, 35
14.307 ± 10	6^+		< 100		6, 7, 19, 20, 24
14.44 ± 20	0^+		110	p, α	6, 7, 35, 37
14.453 ± 1.8			33 ± 3	p, α	37
14.6 ± 300	(4^+)		240	α	15
14.60 ± 20	1^-		140	p, α	7, 35, 37
14.695 ± 2.6			36 ± 10	p, α	37
14.772 ± 3.0			110 ± 20	p, α	37
14.812 ± 15	$(2^+, 4^+)$		≈ 100	p, α	6, 7, 15, 37
15.034 ± 15	(2^+)		≈ 100	p, α	7, 15, 37
15.16 ± 15	6^+			α	6, 7
15.23			28	p, α	37
15.27	(1^-)		285	p, α	37
15.30	(0^+)		285	p, α	37
15.336 ± 15	7^-	0^-	380 ± 60	α	6, 7, 15, 19, 20, 22, 32
15.39			85	p, α	37
15.47			55	p, α	37
[b]					
15.50 ± 20	(8^-)	(2^-)			7, 32
15.70 ± 15	(6^+)			α	6, 7, 15
15.879 ± 15	(8^+)		< 250	α	6, 7, 19
(15.97)	(6^+)			α	15
16.01 ± 25	$(2^+; 1)$		100	p, α	31, 37
16.139 ± 15			38	p, α	6, 7, 15, 37
16.25				α	6, 15
16.326 ± 15	4^+		43	p, α	15, 37

Table 20.18: Energy levels of ^{20}Ne [a] (continued)

E_x (MeV ± keV)	$J^\pi; T$	K^π	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
16.434 ± 15	$(0, 2, 4)^+$		34	p, α	15, 37
16.510 ± 10	$(2, 4, 6)^+$		23	α	6, 7, 15
16.52	7^-			α	7
16.63 ± 20	7^-		190 ± 40	α	7, 15, 19, 20, 22
16.719 ± 15	$(1, 3, 7)^-$		10	α	15
16.730 ± 3	$0^+; 2$		2.0 ± 0.5	γ, p, α	6, 31, 34, 35, 37, 62
16.8	7^-			α	7
16.854 ± 15	5^-		10	α	15
16.98			100	p, α	37
17.162 ± 15	$5^-, (7^-)$		37	α	15
17.30 ± 20	8^+		220 ± 40	α	15, 19, 20, 22
17.38 ± 15	9^-	2^-	< 10	α	6, 7, 8, 15, 23
17.542 ± 15	6^+		136	α	15
17.55 ± 10	$(2^+; 1)$		19	n, p, α	31, 36, 37
17.752 ± 15	$4^+, (0^+)$		50	p, α	15, 37
17.91 ± 20	(0^+)			n, p	31, 36
18.002 ± 15	7^-		< 10	α	15
18.022 ± 15	$(2^+, 5^-, 6^+)$		45	α	15
18.113 ± 15	7^-		33	α	6, 7, 8, 15
18.32 ± 20	(6^+)		240	α	6, 15
18.427 ± 7	$2^+; 2$		9.5 ± 3	γ, n, p, α	34, 35, 36, 37, 47
18.7 ± 100	$(6^+, 7^-)$		600	α	15, 19
19.16 ± 250	(6^+)		200	α	8, 15
19.40 ± 350	6^+		280	α	15
19.4 ± 100	7^-		400		19
19.84 ± 350	6^+		280	α	15
20.0 ± 100	7^-		300	α	15, 19
20.4 ± 180	6^+		360	α	7, 15
20.4 ± 100	7^-		200	α	7, 15
20.67 ± 40	9^-		120	α	7, 15, 20
20.8 ± 100	$7^-, (6^+)$			α	19
21.0 ± 100	7^-		200	α	15
21.08 ± 30	9^-		100 ± 50	α	15, 20, 22, 23
21.3 ± 100	$7^-, 8^+$		300	α	15, 19
21.8 ± 100	$7^-, 8^+$		300	α	15, 19
22.3 ± 100	$7^-, 8^+$		500	α	15, 19
22.7 ± 250	9^-		500	α	15
22.87 ± 40	9^-		225 ± 40	α	15, 20, 22

Table 20.18: Energy levels of ^{20}Ne [a] (continued)

E_x (MeV ± keV)	$J^\pi; T$	K^π	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
23.70 ± 30	9^-, (8^+)		≤ 200	α	15, 19, 20, 24
24.21 ± 25	8^+		≈ 500	α	15, 20
25.10 ± 50	8^+		≤ 200	α	15, 20
25.67 ± 50			≈ 500	α	15, 20
27.1 ± 100	(9^-)		700	α	15, 19
28	8^+		1600	α	15, 28
28.1 ± 100	(10^+)		700	α	15, 19

[a] See also Tables 20.19 and 20.20.
[b] For other states with $E_x > 15.5$ MeV see Tables 20.30, 20.31, 20.32, 20.33 and reactions 46 and 47. It is clear that there are many states with low angular momentum and with unnatural parity which have not been located at high E_x.

1972HA1Q, 1972HI17, 1972LE38, 1972LO1D, 1972MA20, 1972NA05, 1973CA16, 1973CU03, 1973EL04, 1973GO26, 1973HA1N, 1973HA1Q, 1973HA1V, 1973HO41, 1973LE1E, 1973PU1A, 1973ST25, 1973UN01, 1974AB05, 1974HA1G, 1974HA1C, 1974KH03, 1974MA11, 1974MC1F, 1974NO14, 1974SC34, 1975BU03, 1975BU1L, 1975MA26, 1975NA21, 1975NA20, 1975TA1H, 1976BA11, 1976FU1K, 1976SC08, 1976VO1C, 1977HO1F, 1977KN02, 1977MA09, 1977NE1D, 1977RO1V, 1977SC08).

Special levels: (1972AR12, 1972BE1E, 1972FO29, 1972HA1R, 1972HI17, 1972JA24, 1972KH08, 1972LE13, 1972MA07, 1972MA20, 1972NI14, 1972SA04, 1972TE02, 1973CH1E, 1973CU03, 1973DH1A, 1973EN1C, 1973HO40, 1973IR01, 1973JU1A, 1973KO42, 1973MA50, 1973MC06, 1973MI1F, 1973NO1B, 1973PU1A, 1973SU1D, 1973UN01, 1973YA1A, 1974AR04, 1974GO12, 1974GO37, 1974HA1G, 1974IT1A, 1974KH03, 1974KR17, 1974MA1K, 1974MO01, 1975AR1J, 1975BA81, 1975BU03, 1975BU1L, 1975HA1V, 1975MA10, 1975MA1W, 1975MI03, 1975NA21, 1975NE04, 1976BA11, 1976SA21, 1976SC08, 1977CA08, 1977FU1P, 1977HA33, 1977NE1D, 1977SC08, 1977SH11, 1977ST21).

Applied work: (1976CH1P).

Special reactions: (1972BO1H, 1973WI15, 1974HA61, 1974KU15, 1975AR17, 1975AR14, 1975DR01, 1975HO1K, 1975RE08, 1975VO09, 1976CO1W, 1976EG02, 1976HI05, 1977CO14, 1977LE1T, 1977NA03, 1977RA1D, 1977TA07).

Muon and neutrino capture and reactions: (1972VA1F, 1973BE53, 1974EN10, 1974GR1M, 1974KA1Q, 1975DO10, 1975PF01).

Pion and kaon capture and reactions: (1971JH1A, 1971MO1P, 1972BU1G, 1972EC1A, 1974HA61, 1974HU14, 1974LI1D, 1974TA18, 1974UL02, 1975BU1K, 1975EL1A, 1975HU1D, 1975SC1N, 1975TA1C, 1976KA1M, 1976RO14, 1977BA2H, 1977MC1K, 1977WA1W).

Other topics: (1969FU1A, 1971GR35, 1971GR52, 1971RA1B, 1971ZO1A, 1972AB12, 1972BR1G, 1972EL1C, 1972FR1B, 1972JA24, 1972KA67, 1972KH08, 1972KR11, 1972KR1D, 1972LA08,

1972MU08, 1972NI14, 1972PA36, 1972PL1C, 1972RE03, 1972SA04, 1972SA1B, 1972SH24, 1972TE02, 1973BE35, 1973CA32, 1973CO03, 1973CU03, 1973EL04, 1973ER10, 1973FO1F, 1973GI09, 1973GO26, 1973GR11, 1973GR36, 1973HA05, 1973HA1W, 1973HE1F, 1973HO1H, 1973KE1C, 1973KO26, 1973KO42, 1973KR1B, 1973LA35, 1973MA1K, 1973MA48, 1973ME1G, 1973MI1F, 1973NG1A, 1973NG1B, 1973PA05, 1973RA1E, 1973SE17, 1973SE15, 1973SU1D, 1973SV1A, 1973UL01, 1973UN01, 1973VA01, 1973VA21, 1974AB05, 1974AR04, 1974AY02, 1974CO39, 1974GO12, 1974HA17, 1974MA1K, 1974MP01, 1974NG01, 1974RE03, 1974SC10, 1974SC11, 1974TI03, 1974TI04, 1974WO02, 1974ZU1A, 1975BA81, 1975GI03, 1975HE10, 1975MA10, 1975MA1W, 1975MI02, 1975MU13, 1975SO04, 1976VO1D, 1976HA1V, 1976MA04, 1976SA21, 1976SM1D, 1976ST09, 1976UL1D, 1977FL1E, 1977HE10, 1977PA07, 1977SH11, 1977SH13).

Ground-state properties: (1971GR52, 1971RU14, 1971SH26, 1972AB12, 1972AS13, 1972BR1G, 1972CA37, 1972GR42, 1972KR11, 1972KR1D, 1972LE38, 1972NI14, 1972OL02, 1972SC27, 1972YO1B, 1973AR1C, 1973CA16, 1973CU03, 1973ER10, 1973FO1F, 1973GO26, 1973GR36, 1973HO41, 1973KO26, 1973LE1E, 1973MA1K, 1973MC06, 1973ME1G, 1973NG1A, 1973PA05, 1973PU1A, 1973RE11, 1973SCYT, 1973SV1A, 1973UN01, 1973VA01, 1974AB05, 1974AR04, 1974CO39, 1974DE1E, 1974EN10, 1974KH03, 1974KR17, 1974MA11, 1974MC1F, 1974MP01, 1974RE03, 1974RI1B, 1974SC34, 1974SHYR, 1974TI03, 1975AL19, 1975BU03, 1975HO1H, 1975LE05, 1975MA26, 1975MI02, 1975MP01, 1976CH1T, 1976FU06, 1976KE03, 1976PO01, 1976ST09, 1977AN12, 1977AN21, 1977KN02, 1977MP01, 1977PA07, 1977SU04, 1977TH03).

$$Q_{1.63} = -0.20 \pm 0.05 \text{ b (1974OL01)};$$

$$B(\text{E2})\uparrow[0 \rightarrow 1.63] = 0.032 \pm 0.003\ e^2 \cdot \text{b}^2 \text{ (1977SC36)};$$

$$= 0.037 \pm 0.003\ e^2 \cdot \text{b}^2 \text{ (1974OL01)};$$

$$= 0.028 \pm 0.004\ e^2 \cdot \text{b}^2 \text{ (1973SI31)};$$

$$|M|^2 = 23.0 \pm 1.9 \text{ W.u. (1974OL01)}.$$

1. (a) ^{10}B(^{10}B, ^{10}B)^{10}B $E_b = 31.1464$

(b) ^{10}B(^{10}B, α)^{16}O $Q_m = 26.4155$

The total reaction cross section has been measured for $E(^{10}\text{B}) = 3.7$ to 7.3 MeV (1976HI05), and the elastic excitation function has been studied for 8 to 30 MeV (1975DI08). Excitation functions for reactions (a) and (b) have been measured for $E_{\text{c.m.}} = 3$ to 10 MeV: large resonant structures are observed in most channels of reaction (b) (1978MA07): see (1978EN06). See also ^{10}B in (1979AJ01).

2. ^{10}B(^{14}N, α)^{20}Ne $Q_m = 19.5332$

At $E(^{14}N) = 25$ and 35 MeV angular distributions of the α-particles to ^{20}Ne*(0, 1.63, 4.25, 4.97, 5.62, 5.78, 7.00, 7.17, 7.42, 7.83, 8.45, 8.78, $9.03 + 9.12$, 9.99, 10.26, 10.61) have been measured by (1974MA38, 1975LE23). The average behavior of the cross section is generally well described by a statistical mechanism but the reaction mechanism is not purely statistical (1975LE23). For excitation functions see (1972VO02, 1975LE23, 1977MA2V, 1977MA2W): see also (1978EN06). See also (1973ST1A) and (1975KL05; theor.).

3. ^{10}B(^{16}O, ^{6}Li)^{20}Ne $\qquad Q_m = 0.270$

At $E(^{16}O) = 19.5$, 24.3, 31.5, 35.9 and 42 MeV angular distributions have been measured for the ^{6}Li ions corresponding to transitions to ^{20}Ne*(0, 1.63, 4.25, 4.97, $5.62 + 5.78$, $6.7 - 7.2$). Hauser-Feshbach calculations are generally in good agreement with the data (1976LO03). Differential cross sections at 7° have been measured at $E(^{16}O) = 45.6$ MeV for many states of ^{20}Ne with $E_x < 10.62$ MeV (1974FO15). For fusion cross sections see (1977MO1X). See also (1974ST1L, 1978EN06).

4. ^{11}B(^{16}O, ^{7}Li)^{20}Ne $\qquad Q_m = -3.934$

This reaction has been studied at $E(^{16}O) = 60$ MeV (1972SC17) and at $E(^{11}B) = 114$ MeV (1973ST24): a number of states of ^{20}Ne are populated but they are not excited strongly at either energy. See also (1973SC1J).

5. ^{12}C(^{9}Be, n)^{20}Ne $\qquad Q_m = 10.3196$

At $E(^{9}Be) = 16$, 20 and 24 MeV, angular distributions have been measured for ^{20}Ne*(7.4, 9.3, 11.0, 12.2) (1977EL1E).

6. (a) ^{12}C(^{10}B, d)^{20}Ne $\qquad Q_m = 5.9589$
(b) ^{12}C(^{11}B, t)^{20}Ne $\qquad Q_m = 0.7610$

At $E(^{12}C) = 45$ MeV the population of states of ^{20}Ne with $E_x = 8.46$, *8.78*, 9.03, 10.61, 10.67, 10.99, 11.01, 11.66, *11.94*, *12.14*, *12.39*, *12.58*, 12.73, 13.05, 13.17, *13.34* [7^-], *13.69*, 13.91, 14.29, 14.36, 14.81, *15.17* [6^+], *15.38* [7^-], *15.71* [(7, 8)], *15.89* [(7)], 16.16, 16.22, *16.51* [(8)], 16.73, *17.39* [9^-], 18.18 and *18.32* MeV is reported. [Values in brackets are J^π suggested on basis of Hauser-Feshbach calculations. The states in italics are well resolved: the authors indicate ±20 keV for such states.] The relative intensities of the groups to ^{20}Ne*(17.39, 15.38) [$J^\pi = 9^-$, 7^-] argue against the existence of a superband (1974KL05, 1976KL03). See also (1973MI1E, 1974ME1C, 1977HI01), (1973BR1C, 1973FO1A, 1973FO1E, 1974FO1J, 1977KL1G), (1975KL05, 1975KL08; theor.) and ^{22}Na in (1978EN06). For reaction (b) see (1977HI01).

Table 20.19: Radiative decays in ^{20}Ne [a]

E_i (MeV)	$J^{\pi}_i; T$	E_f (MeV)	Branch (%)	Γ_γ (meV)	$\|M\|^2$ (W.u.)	Refs.
1.63	$2^+; 0$	0	100		17.8 ± 2.5 (E2)	(1971HA26)
4.25	$4^+; 0$	1.63	≈ 100		21.9 ± 2.1 (E2)	(1971HA26)
4.97	$2^-; 0$	0	0.6 ± 0.2		$(2.5 \pm 0.9) \times 10^{-3}$ (M2)	(1967BR22, 1971HA26)
		1.63	99		$(7.0 \pm 1.0) \times 10^{-6}$ (E1)	(1971HA26)
					$(1.7 \pm 0.7) \times 10^{-2}$ (M2) [b]	(1971HA26)
					6 ± 5 (E3) [c]	(1971HA26)
5.62	$3^-; 0$	0	7.6 ± 1.0		10.6 ± 2.7 (E3)	(1964BR18, 1971HA26)
		1.63	87.6 ± 1.0		$(6.6 \pm 1.5) \times 10^{-6}$ (E1)	(1964BR18, 1971HA26)
		4.97	4.8 ± 1.6		35 ± 9 (E2)	(1971HA26)
5.78	$1^-; 0$	0	18 ± 5		7.2×10^{-6} (E1)	(1965VA14)
		1.63	82 ± 5	4.0	9.2×10^{-5} (E1)	(1965VA14)
6.72	$0^+; 0$	0			7.4 ± 2.0 fm^2 [o]	(1972MI06)
		1.63	100	33	3.8 (E2)	(1965VA14)
7.00	$4^-; 0$	1.63	0.5 ± 0.2			(1967BR22)
		4.25	63.5		$(1.7 \pm 0.4) \times 10^{-5}$ (E1)	(1967BR22, 1971HA26)
		4.97	11		10.4 ± 1.8 (E2)	(1967BR22, 1971HA26)
		5.62	25		24 ± 5 (E2)	(1967BR22, 1971HA26)
7.19	$0^+; 0$	0		$\Gamma_\pi = 3.9 \times 10^{-2}$	6.9 ± 1.4 fm^2 [o]	(1972MI06, 1973SI31)
		1.63	100	4.35 ± 0.75	0.37 ± 0.07 (E2)	(1972AL32)
7.42	$2^+; 0$	0	$\leq 9.4 \pm 1.4$	$\leq 3.0 \pm 0.6$	$\leq 0.05 \pm 0.01$ (E2) [p]	(1972AL32)
		1.63	$\geq 90.6 \pm 1.4$ [d]	29 ± 4	1.65 ± 0.27 (E2)	(1972AL32)
					$(1.0 \pm 0.3) \times 10^{-4}$ (M1)	(1972AL32)
		4.25	≤ 7.6		< 2.6 (E2)	(1972AL32)
7.83	$2^+; 0$	0	83 ± 1	57 ± 7	0.73 ± 0.09 (E2) [p]	(1972AL32)

Table 20.19: Radiative decays in ^{20}Ne [a] (continued)

E_i (MeV)	$J^\pi_i; T$	E_f (MeV)	Branch (%)	Γ_γ (meV)	$\lvert M\rvert^2$ (W.u.)	Refs.
		1.63	17 ± 1	11.7 ± 1.6	0.48 ± 0.07 (E2)	(1972AL32)
		4.25	< 3	< 2	< 1.3 (E2)	(1972AL32)
8.45	$5^-; 0$	5.62	100	13 ± 3	26 ± 6 (E2)	(1971RO33)
8.78	$6^+; 0$	4.25	100	100 ± 15	20.4 ± 2.4 (E2)	(1971DI08, 1971RO13)
9.03	$4^+; 0$	1.63	100	340 ± 42	5.8 ± 0.7 (E2)	(1972AL32)
		4.25	< 2	< 6.8	< 1 (E2)	(1972AL32)
9.51	$2^+; 0$	0		$\lesssim 60$	$\lesssim 0.3$ (E2)	(1964PE05)
		1.63	(100)	260 ± 100	3.2 (E2)	(1964PE05)
					0.03 (M1)	(1964PE05)
9.87	$3^+; 0$	0	< 0.5			(1977MA07)
		1.63	78	[e]		(1977MA07)
		4.25	12 ± 3			(1977MA07)
		4.97	≤ 5			(1977MA07)
		5.63	≈ 7			(1977MA07)
		7.42	≈ 3			(1977MA07)
9.92	$(1^+); 0$	1.63	78 ± 5			(1976FI10)
		4.97	22 ± 5			(1976FI10)
9.99	$4^+; 0$	0		$\lesssim 70$		(1964PE05)
		1.63	(100)	900 ± 400	6.9 (E2)	(1964PE05)
10.27 [f]	$2^+; 1$	0	0.65 ± 0.14	29 ± 8	0.10 ± 0.03 (E2)	(1977FI08)
		1.63	88.9 ± 0.5	4080 ± 440	0.31 ± 0.03 (M1)	(1977FI08)
		4.97	1.3 ± 0.1	60 ± 8	$(8.3 \pm 1.0) \times 10^{-4}$ (E1)	(1977FI08)
		5.62	2.1 ± 0.2	97 ± 14	$(2.0 \pm 0.3) \times 10^{-3}$ (E1)	(1977FI08)
		7.42	6.9 ± 0.4	310 ± 40	0.65 ± 0.008 (M1)	(1977FI08)

Table 20.19: Radiative decays in ^{20}Ne [a] (continued)

E_i (MeV)	$J^\pi_i; T$	E_f (MeV)	Branch (%)	Γ_γ (meV)	$\|M\|^2$ (W.u.)	Refs.
		7.83	0.22 ± 0.06	8 ± 2	0.027 ± 0.006 (M1)	(1977FI08)
10.61 [g]	$6^-; 0$	7.00	95.5 ± 1.2		17^{+7}_{-4} (E2)	(1971HA26)
		8.45	4.5 ± 1.2		10 ± 4 (E2)	(1971HA26)
10.69	$4^-, 3^+; 0$	4.25	25 ± 4			(1976FI10)
		4.97	75 ± 4			(1976FI10)
10.89	$3^+; 1$	1.63	26 ± 3			(1971HA26, 1976FI10)
		4.25	74 ± 3	[h]		(1971HA26, 1976FI10)
11.07	$4^+; 1$	1.63	≤ 2	$\lesssim 80$	$\lesssim 0.4$ (E2)	(1964PE05)
		4.25	(100)	4800 ± 500	0.72 (M1), 7.3 (E2)	(1964PE05)
				3400 ± 300	0.50 (M1)	(1978ST08)
		7.00		$\lesssim 1400$	$\lesssim 0.04$	(1964PE05)
11.26 [f]	$1^-; 1$	0	≈ 70	190 ± 20	2.8×10^{-4} (E1)	(1978ST08)
		1.63	≈ 30			(1978ST08)
11.53 [i]	$3^+, 4^-; 0$	4.25	30 ± 3 [n]			(1971HA26, 1976FI10)
		4.97	70 ± 3 [n]			(1971HA26, 1976FI10)
		7.00	[j]			
11.55	$(2^+, 0^+)$	1.63	≈ 70	80 ± 10 [n]	3.9×10^{-3} (M1)	(1978ST08)
		4.25	≈ 30			(1978ST08)
11.56 [i]	$1^+, 2^-, 3^+; 0$	1.63	[j,n]			(1976FI10)
		7.00	[j,n]			(1976FI10)
11.66	(3^+)	1.63	14 ± 3			(1976FI10)
		4.25	86 ± 3			(1976FI10)
11.95	$8^+; 0$	8.78	100	12 ± 3	7.5 ± 2.5 (E2)	(1972AL05)
12.22	$2^+; 1$	1.63	100	[k]		(1964PE05, 1977MA07)

Table 20.19: Radiative decays in ^{20}Ne [a] (continued)

E_{i} (MeV)	$J^{\pi}_{\mathrm{i}}; T$	E_{f} (MeV)	Branch (%)	Γ_{γ} (meV)	$\|M\|^2$ (W.u.)	Refs.
12.39	3^-; (1)	0	≈ 1			(1978ST08)
		1.63	≈ 29			(1978ST08)
		4.25	≈ 70	280 ± 20	1.1×10^{-3} (E1)	(1978ST08)
12.49		1.63	100			(1978ST08)
13.48	1^+; 1	1.63	95			(1961GO21)
		4.97	5			(1961GO21)
13.89		1.63	20			(1961GO21)
		4.97	80			(1961GO21)
16.73	0^+; 2	1.63			< 1.3 (E2) [l]	(1976MA01)
		5.78			$< 4.2 \times 10^{-3}$ (E1) [l]	(1976MA01)
		11.23	(100)	≈ 5000 [l]		(1967KU06)
18.43	2^+; 2	0		[m]	$< 1.4 \times 10^{-3}$ (E2)	(1976MA01)
		1.63		[m]	$< 5.4 \times 10^{-4}$ (M1)	(1976MA01)
		4.25			$< 2.9 \times 10^{-2}$ (E2)	(1976MA01)
		4.97			$< 5.1 \times 10^{-5}$ (E1)	(1976MA01)
		5.62			$< 6.6 \times 10^{-5}$ (E1)	(1976MA01)
		5.78			$< 5.8 \times 10^{-5}$ (E1)	(1976MA01)
		7.19			$< 9.9 \times 10^{-5}$ (E1)	(1976MA01)
		7.42			$< 3.7 \times 10^{-3}$ (M1)	(1976MA01)
		12.22	(100)	≈ 300		(1972KU24)

[a] See also Table 20.17 in (1972AJ02) and Tables 20.22 and 20.26 here.

[b] From δ(M2/E1) $= 0.076 \pm 0.011$ (1967BR22).

[c] From δ(E3/E1) $= 0.043 \pm 0.016$ (1967BR22).

[d] δ(E2/M1) $= -8.36^{+1.0}_{-1.5}$.

[e] Γ_γ(total)/$\Gamma = 0.82 \pm 0.27$. See also (1976FI10).

[f] See also (1964PE05, 1976IN05).

[g] See also (1976FI10).

[h] Γ_γ(total)/$\Gamma < 0.3$ (1977MA07).

[i] See also (1977MA07).

[j] See discussion in (1976FI10).

[k] Γ_γ(total)/$\Gamma \geq 0.25$; upper limits for transitions to ^{20}Ne*(0, 4.25, 4.97) are 1.5, 3 and 4% (1977MA07). See also (1978ST08).

[l] See, however, footnote [a] in Table 2 of (1976MA01).

[m] See also (1972KU24).

[n] If $J = 2$.

[o] Monopole matrix element.

[p] See also (1972MI06).

7. ^{12}C(^{12}C, α)^{20}Ne $\qquad\qquad Q_m = 4.6181$

Particle group and γ-ray energy measurements have been made for many states of ^{20}Ne: see Table 20.21. Angular correlation and γ-ray branching measurements [see Table 20.19] lead to the J^π assignments shown in Table 20.21, which also show level assignments to rotational bands. Angular distributions have been reported at $E(^{12}\text{C}) = 5.6$ to 28.3 MeV [see (1972AJ02)] and at $E(^{12}\text{C}) = 4.9$ to 9.8 MeV (1973MA09: $\alpha_1 \rightarrow \alpha_3$, α_{4+5}, α_6, α_7), 8.5 to 12.5 MeV (1977GA04, 1977GA05: α_0, α_3), 13 to 22 MeV (1976ER03, 1977ER1F: $\alpha_0 \rightarrow \alpha_3$, α_6), 13 to 24 MeV (1977VO05: $\alpha_0 \rightarrow \alpha_{11}$), 15 MeV (1976BA53: α to ^{20}Ne states with $E_x < 8$ MeV), 36.6, 36.8 and 37.4 MeV (1976FO15: α_0), 37 MeV (1976EB01: α_0), 37 MeV (1975ME04: see Table 20.21), 37, 41, 45, 48 and 51 MeV (1975GR21: α to ^{20}Ne*(7.42, 7.83, 9.04)), 38 MeV (1976FO09: α_0, α_6), 45 MeV (1975GR21: α to many states of ^{20}Ne with $E_x < 13.4$ MeV) and 50 MeV (1977PA19: α-particles to ^{20}Ne*(0, 1.63, 4.25, 5.62, 5.78, 7.42, 7.83, 8.45). Both compound nucleus and direct reaction mechanisms appear to contribute to this reaction in the range $E(^{12}\text{C}) = 36$ to 51 MeV. Strong fluctuations in the yield require the presence of narrow compound nuclear levels while the selective population of particular states indicates the presence of a strong direct component. Hauser-Feshbach theory predicts lower cross sections for low-J states than are experimentally observed (1975GR21).

For lifetime measurements see Table 20.20. (1975HO15) have determined $|\text{g}| = 0.54 \pm 0.04$ for ^{20}Ne*(1.63).

Studies of yields of particular α-groups are also reported for $E(^{12}\text{C}) = 8$ to 16 MeV (1977GA04, 1977GA05: α_0, α_3), 11 to 13 MeV (1973VO01, 1974VO09: α to ^{20}Ne*(6.72, 7.2)), 11.6 to 16 MeV (1977ER1F: α_1, α_6), 13 to 24 MeV (1977VO05: $\alpha_0 \rightarrow \alpha_6$, α_{11}) and 25 to 27.1 MeV (1972CO30: $\alpha_0 \rightarrow \alpha_3$, α_{11}); only the yields of α_1, α_2, α_6 and α_{11} show strong fluctuations above $E(^{12}\text{C}) = 20$ MeV.

The yields of α-particle groups corresponding to ^{20}Ne states with $E_x < 17.5$ MeV have been studied in the range $E(^{12}\text{C}) = 32$ to 51 MeV by (1974FO20, 1974GR27, 1974SH16, 1975GR21, 1977FO01, 1977PA19). Many strong structures are observed which are interpreted in terms of states in the compound nucleus, ^{24}Mg: see (1978EN06). See also (1976BA22, 1976BA53, 1976EB01, 1976ER03, 1976FO15, 1976FO09, 1977ERZZ, 1977HI04, 1977KE02, 1977MA1M, 1977VAZZ).

See also (1972FI1B, 1973CO1K, 1973FE03, 1974KL1B, 1976NA11, 1977ERZZ), (1973BR1C, 1973FO1E, 1973FO1A, 1973GO1M, 1973SC1B, 1973ST1A, 1974FO25, 1974FO1J), (1973AR1F, 1973MA09, 1973TR1B, 1975FO19, 1977DA07; astrophys. considerations) and (1973SC1K, 1976DA1P, 1977DE2A, 1977MA2X; theor.).

8. ^{12}C(^{14}N, ^{6}Li)^{20}Ne $\qquad\qquad Q_m = -4.181$

Angular distributions of the ^{6}Li ions to ^{20}Ne*(0, 1.63, 4.25, 4.97, 5.62 + 5.78, 6.7 − 7.2) have been measured at $E(^{14}\text{N}) = 30$ and 36 MeV (1976LO03), 52 and 60 MeV (1971MA23), 52 and 78 MeV (1974HA11: additionally ^{20}Ne*(8.45 − 9.03)), and at $E(^{14}\text{N}) = 76.1$ MeV and

Table 20.20: Lifetime measurements of some ^{20}Ne states [a]

^{20}Ne* (MeV)	τ_m	Refs.
1.63	1.04 ± 0.07 psec	(1974OL01)
	1.15 ± 0.20 psec	(1971HA26)
	0.8 ± 0.2 psec	(1975HO15)
	1.05 ± 0.06 psec	"best" value [b]
4.25	134 ± 12 fsec	(1965EV03)
	150 ± 25 fsec	(1969AN08)
	93 ± 9 fsec	(1971HA26)
	93 ± 9 fsec	"best" value
4.97	$4.8^{+1.7}_{-1.1}$ psec	(1965EV03)
	4.8 ± 0.5 psec	(1971HA26)
	4.8 ± 0.5 psec	"best" value
5.62	350 ± 75 fsec	(1965EV03)
	200 ± 50 fsec	(1971HA26)
	200 ± 50 fsec	"best" value
7.00	405^{+110}_{-90} fsec	(1962BR35)
	470 ± 90 fsec	(1971HA26)
	440 ± 90 fsec	mean value
9.92	< 35 fsec	(1971HA26)
10.61	23 ± 7 fsec	(1971HA26)
10.89	< 30 fsec	(1971HA26)
11.53	< 30 fsec	(1971HA26)

[a] See also Table 20.18 in (1972AJ02).

[b] P.M. Endt, private communication.

$E(^{12}C) = 67.2$ MeV (1973BE11: not ^{20}Ne*(4.97) but additionally ^{20}Ne*(8.45 − 9.03, 10.26 − 11.02, 11.95 + 12.13, 13.33, 13.92, 16.67, 17.38)). The angular distributions are symmetric about 90° and compound nucleus formation appears to be dominant (1973BE11, 1974HA11). In the work of (1973BE11) states which are particularly strongly populated are ^{20}Ne*(16.67, 17.38, 18.11, 19.16, 19.6). The excitation functions for many states of ^{20}Ne with $E_x < 10$ MeV have been measured by (1975VO02) for $E(^{14}N) = 20$ to 60 MeV and by (1977MO1X) for $E(^{14}N) = 30$ to 90 MeV. In addition, see (1976ST07) and ^{26}Al in (1978EN06). See also (1975ZE1C), (1971BA2V, 1973BR1C, 1973FO1E, 1973SC1J, 1973SC1B, 1974ST1L) and (1974KL13, 1975KL05, 1975KL08, 1976KL03; theor.).

9. ^{12}C(^{18}O, ^{10}Be)^{20}Ne $\qquad Q_m = -6.3476$

At $E(^{18}O) = 80$ MeV, the population of ^{20}Ne*(0, 1.63, 4.25, 4.97, 8.78, 11.95) is observed (1974BA15).

10. ^{12}C(^{19}F, ^{11}B)^{20}Ne $\qquad Q_m = -3.1122$

At $E(^{19}F) = 40$, 68 and 68.8 MeV angular distributions involving $^{11}B_{g.s.}$ and ^{20}Ne*(0, 1.63) are reported (1972SC03). See also (1975PU02) and ^{31}P in (1978EN06) and (1972BO21; theor.).

11. ^{13}C(^{12}C, nα)^{20}Ne $\qquad Q_m = -0.3283$

See (1973SA1G, 1976DA13) and ^{25}Mg in (1978EN06).

12. ^{14}C(^{18}O, ^{12}Be)^{20}Ne $\qquad Q_m = -15.75$

See (1974BA15, 1974CE1A).

13. (a) ^{14}N(^{6}Li, p)^{19}F $\qquad Q_m = 11.1491 \qquad E_b = 23.994$
(b) ^{14}N(^{6}Li, d)^{18}F $\qquad Q_m = 2.942$
(c) ^{14}N(^{6}Li, α)^{16}O $\qquad Q_m = 19.2628$
(d) ^{14}N(^{6}Li, αn)^{15}O $\qquad Q_m = 3.5990$

Yield curves have been measured for $E(^{6}Li) = 4.1$ to 6.3 MeV for the protons to ^{19}F*(2.78) and for the d_0 and α_0 groups (1968RI13) and at 5 to 9.2 MeV for the p_0, p_1, d_0, d_{1+2}, α_0, α_{1+2} and α_{3+4} groups (1977LE1N): no structure is apparent.

Table 20.21: Excited states of ^{20}Ne from ^{12}C(^{12}C, α)^{20}Ne [a]

E_x (MeV ± keV)		J^{π} [d]	K^{π} [d]
(1971HA26) [b]	(1975ME04) [c]		
1.6329 ± 1.0		2^+	0^+_1
4.2456 ± 2.5		4^+	0^+_1
4.9663 ± 2.5	4.968	2^-	2^-
5.618 ± 4	5.618	3^-	2^-
	5.774	1^-	0^-
	6.725 [e]	0^+	0^+_2
7.004 ± 4	7.004 [e]	4^-	2^-
	7.169 [e]	3^-	0^-
	7.196 [e]	0^+	0^+_3
	7.435 [e]	2^+	0^+_2
	7.835 [e]	2^+	0^+_3
8.446 ± 9	8.451	5^-	2^-
	8.694	1^-	(1^-_1)
	8.779	6^+	0^+_1
	8.85	1^-	(1^-_1)
	9.033	4^+	0^+_3 [f]
	9.110	[d]	
	9.318	[d]	
	9.533		
	9.872	$1^+, 2^-, 3^+$ [d,g]	
9.950 ± 6		$1^+, 2^-, 3^+$ [g]	
	10.024		
	10.264	5^-	0^-
	10.407	[d]	
	10.545		
10.609 ± 7	10.609	6^-	2^-
	10.694	$4^-, 3^+$ [g]	
	10.840	[d]	
10.920 ± 7	10.915	3^+ [g]	
	11.013		

Table 20.21: Excited states of ^{20}Ne from ^{12}C(^{12}C, α)^{20}Ne [a] (continued)

E_x (MeV ± keV)		J^π [d]	K^π [d]
(1971HA26) [b]	(1975ME04) [c]		
11.528 ± 6 [g]			
	11.555	$1^+, 2^-, 3^+$ [d,g]	
	11.656	(3^+) [d,g]	
	11.871	[d]	
	11.949	8^+	0_1^+
	12.134 [h]	6^+	0_3^+ [f]
	12.381		
12.436 ± 5 [i]			
	12.594		
	12.730		
	12.919		
	13.010		
	13.049		
	13.190		
	13.277		
	13.335	7^-	2^-
	13.441	[e]	
	13.569		
	13.631		
	13.679		
	13.845		
	13.886		
	14.144		
	14.305		
	14.44		
	14.60		
	14.812		
	15.034	[d]	
	15.155 [j]	6^+ [j]	
	15.359	[d]	

Table 20.21: Excited states of ^{20}Ne from ^{12}C(^{12}C, α)^{20}Ne [a] (continued)

E_x (MeV ± keV)		J^π [d]	K^π [d]
(1971HA26) [b]	(1975ME04) [c]		
	15.50	(8$^-$)	(2$^-$)
	15.691		
	15.879	(8$^+$) [d,k,l]	(2$^-$)
	16.139		
	(16.50)		
	16.52 [m]	7$^-$ [m]	
	16.68 [m]	7$^-$ [m]	
	17.372 [n]	9$^-$ [n]	2$^-$ [n]
	18.11	(7$^-$) [l,m]	
	20.5 [o]		
	20.67 [m]	9$^-$ [m]	

[a] See Table 20.16 in (1972AJ02) for the earlier work.
[b] From measuremenets of γ-rays.
[c] From measurements of α-groups: approximately ±6 keV for $E_x < 13.5$ MeV and ±15 keV for higher E_x. Angular distributions have also been obtained at $E(^{12}C) = 37$ MeV.
[d] See discussion in (1975ME04).
[e] Previously reported as 6722, 7007, 7159, 7195, 7421 and 7833 (±4) keV (1971MI09).
[f] (1974FO20, 1974FO25).
[g] (1976FI10): see Table 20.19.
[h] Alpha decay is by α_2 to ^{16}O*(6.13), $\Gamma_{\alpha'}/\Gamma = (6.0 \pm 0.15)\%$: assuming $\Gamma_\alpha\Gamma_{\alpha'}/\Gamma = 7.7 \pm 3.8$ eV this leads to $\Gamma_\alpha = 0.128 \pm 0.072$ keV for this 6$^+$ state (1972BA97).
[i] (1977BA3W, 1977BA3X): $\Gamma_{lab} = 29 \pm 1$ keV.
[j] 15.18 ± 0.02 MeV. Alpha decay is $3 \pm 3\%$ by α_0, $49 \pm 3\%$ by $\alpha_1 + \alpha_2$ (mainly α_2, to ^{16}O*(6.13)) and $48 \pm 3\%$ by $\alpha_3 + \alpha_4$ (mainly α_3 to ^{16}O*(6.92)) (1973FI12, 1973ZU1A).
[k] Angular correlations suggest 8$^+$ for this state which decays $\approx$ 10% by α_0 and $\approx$ 90% by $\alpha_1 + \alpha_2$ (mainly the latter) (K. Young, private communication).
[l] See also (1972PA16).
[m] Alpha-α and $\alpha - \gamma$ correlations (1977YO1H) and (K. Young, private communication).
[n] Decays > 99% to ^{16}O*(6.13) by a pure $L = 6$ transition (1973FI12, 1973ZU1A).
[o] Reported by (1977COZX: preliminary results).

Table 20.22: Resonances in ^{16}O(α, γ)^{20}Ne

E_α (MeV $\pm$ keV)	$\Gamma_{\rm c.m.}$ (keV)	$\omega\gamma$ [a] (eV)	$E_{\rm x}$ (MeV $\pm$ keV)	$J^\pi; T$	Refs.
1.116 ± 4	2.6×10^{-6} [a]	$(1.7 \pm 0.3) \times 10^{-3}$	5.624	$3^-; 0$ [d]	(1965VA14, 1971TO06, 1971TO1C)
1.319 ± 3	$> 1.3 \times 10^{-2}$ [a]	$(14 \pm 3) \times 10^{-3}$	5.786	$1^-; 0$ [e]	(1965VA14, 1971TO06, 1971TO1C)
2.490 ± 8	15 ± 7 [a]	$(38 \pm 10) \times 10^{-3}$	6.722	$0^+; 0$	(1965VA14, 1971TO06, 1971TO1C)
3.074	4	$(4.35 \pm 0.75) \times 10^{-3}$	7.189 ± 3	$0^+; 0$	(1972AL32)
3.363	8	0.146 ± 0.019	7.421 ± 1	$2^+; 0$	(1972AL32)
3.872	2.4	0.343 ± 0.035	7.828 ± 3	$2^+; 0$	(1972AL32)
(4.647 ± 3)			(8.447)	$(5^-; 0)$	(1971RO33)
5.06	< 3	1.35 ± 0.15	8.776 ± 3.2	$6^+; 0$	(1967LI07, 1971DI08, 1971RO13)
5.368	3.2	3.05 ± 0.38	9.024 ± 3	$4^+; 0$	(1964PE05, 1972AL32)
5.94 ± 30	29 ± 15	1.3 ± 0.5	9.48	$2^+; 0$	(1964PE05)
6.61 ± 30	155 ± 30	8 ± 3	10.02	$(4^+); 0$	(1964PE05)
6.924 ± 7	≤ 1	19.5 ± 1.5 [g]	10.2712 ± 7 [f]	$2^+; 1$	(1964PE05, 1976IN05, 1977FI08, 1977MA07, 1978ST08)
7.932 ± 10	≤ 3	30.4 ± 3	11.074	$(4^+; 1)$	(1964PE05, 1978ST08)
8.161 ± 10	≤ 3	0.58 ± 0.05	11.257	$1^-; 1$	(1964PE05, 1978ST08)
8.53 ± 10	≤ 5	0.41 ± 0.05	11.55	$(2^+, 0^+)$	(1964PE05, 1978ST08)
[i]		0.104 ± 0.035	11.948	$8^+; 0$ [h]	(1972AL05)
(9.05 ± 50)	< 40		11.97		(1978ST08)
(9.15 ± 50)	< 40		12.05		(1978ST08)
9.359 ± 5 [b]	< 2		12.215	$2^+; 1$	(1977MA07)
9.407 ± 6 [c]	≈ 5		12.254	$3^-, 2^+$	(1977MA07)
9.57 ± 10	33 ± 4	1.94 ± 0.15	12.38	$3^-; (1)$	(1978ST08)
9.70 ± 30	≤ 10	0.17 ± 0.05	12.49		(1978ST08)

[a] This is also Γ_α.

[b] $\Gamma_{\alpha_0}\Gamma_{\gamma_1}/\Gamma = 0.292 \pm 0.044$ eV; $0.25 \leq \Gamma_{\alpha_0} \leq 1.34$ eV, strong support for the $T = 1$ assignment (1977MA07). See also (1978ST08).

[c] $(2J+1)\Gamma_{\alpha_0}\Gamma_{\gamma_1}/\Gamma = 3.9 \pm 0.8$ eV (1977MA07). See also (1978ST08).

[d] $K^\pi = 2^-$ (1973HA63).

[e] $K^\pi = 0^-$ (1973HA63).

[f] From E_γ measurements (1977FI08). The measurements of the decay of this state lead to $E_{\rm x} = 4247.9 \pm 1.3$, 4966.0 ± 1.9, 5621.0 ± 3.5, 7423.1 ± 3.0, 7828.1 ± 3.8 and 8776.7 ± 2.3 keV (1977FI08).

[g] $\omega\gamma = 19.2 \pm 1.9$ eV (1978ST08); $\Gamma_\alpha = 116 \pm 20$ eV (1976IN05); $\Gamma_\gamma = 4.26 \pm 0.23$ eV (1977FI08) [summary of several measurements].

[h] $K^\pi = 0^+_1$ (1972AL05).

[i] $E(^{16}{\rm O}) \approx 36.05$ MeV.

14. ^{16}O(α, γ)^{20}Ne $\qquad Q_m = 4.7309$

Observed resonances in the yield of capture γ-rays over the range $E_\alpha = 0.8$ to 10 MeV are displayed in Table 20.22. Information on the character of the radiative decay is shown in Table 20.19. For τ_m, see Table 20.20.

No resonances have been observed below $E_\alpha = 1$ MeV: see (1971TO06, 1971TO1C) for the data and for the astrophysical implications of this reaction. See also (1971BA1A, 1973CL1E).

The $J^\pi = 5^-$ state at $E_x = 8.45$ MeV [$E_\alpha = 4.65$ MeV] decays by an E2 transition [$|M|^2 = 26 \pm 6$ W.u.] to the 3^- state at $E_x = 5.62$ MeV (1971RO33). The $J^\pi = 6^+$ state at $E_x = 8.78$ MeV [$E_\alpha = 5.06$ MeV] decays by an E2 transition [$|M|^2 = 20.4 \pm 2.4$ W.u.] to the 4^+ state at $E_x = 4.25$ MeV (1971DI08, 1971RO13). See also (1971RO1C). The $J^\pi = 8^+$ state at $E_x = 11.95$ MeV decays by an E2 transition to the $E_x = 8.78$ MeV [$J^\pi = 6^+$] state which then decays via the 4^+ and 2^+ members of the ground-state rotational band. The transition probability of the $8^+ \rightarrow 6^+$ transition is 7.5 ± 2.5 W.u. which establishes ^{20}Ne*(11.95) as the 8^+ member of the ground-state band. The experimental E2 transition probabilities in the ground-state band deviate strongly from those predicted by the pure rotational model but agree reasonably well with simple shell-model predictions (1972AL05). The $T = 0$ isospin impurity of ^{20}Ne*(10.27) [2^+; 1] is quite large: see (1977FI08) for a discussion of this point and for CVC predictions of the weak magnetism form factors from the radiative widths for the transitions to ^{20}Ne*(1.63, 7.42) [see Table 20.19]. See also (1977WA1V), (1973AL1C, 1974HA1C) and (1973GA23; theor.).

15. (a) ^{16}O(α, α)^{16}O $\qquad E_b = 4.7309$

(b) ^{16}O(α, 2α)^{12}C $\qquad Q_m = -7.1620$

Excitation functions have been measured over a wide energy range for elastically and inelastically scattered α-particles, and γ-rays from the decay of ^{16}O*(6.13, 6.92, 7.12): see Table 20.20 in (1972AJ02) for the earlier work and (1973HA63: 4.6 MeV and 14.1 to 17.1 MeV; α_0, α_{1+2}; the latter in the higher energy range), (1978ST08: 6.9 to 10.2 MeV; α_0, $\alpha_2\gamma$), (1977MA07: 9.2 to 9.7 MeV; $\gamma_{6.13}$), (1975CE01: 12.8 to 14.8 MeV; α_0), (1975BI1H: 14.0 to 18.1 MeV; α_0, α_{1+2}, α_3, α_4) and (1972BU1H: 22.75 to 28.40 MeV). See also (1974BE41) and ^{16}O in (1977AJ02).

A number of anomalies are observed: they are displayed in Table 20.23. Identifying various of the observed states as members of different rotational bands is discussed by (1972HA07, 1973HA63). The reduced α-widths in the first $K^\pi = 0^+$, 2^- and 0^- bands are small, indicating that the bands could be described in terms of the spherical shell model. The reduced widths within bands are found to decrease sharply with increasing spin (1972HA07, 1973HA63).

For reaction (b) see (1972AJ02). For spallation reactions involving the emission of ^{6}Li, ^{7}Li, ^{7}Be, ^{8}Be and ^{9}Be ions see (1972RU03, 1974JE1A, 1974RA11). See also (1973AL1C) and (1972HO1E, 1972HO56, 1972SU10, 1973AR1C, 1973EB1A, 1973HO1L, 1973IC01, 1974CA31, 1974FR06, 1974KA1P, 1974KU15, 1974TA17, 1974WA1D, 1975BA05, 1975CU1B, 1975KO28, 1975MA26, 1975NE04, 1975TA1A, 1976CU07, 1976HE19, 1976JA1F, 1976LE20, 1976PA1J, 1977AB03, 1977AN1B, 1977BA12, 1977FL13, 1977IK1C, 1977OH01; theor.).

Table 20.23: Resonances in ^{16}O(α, α)^{16}O [a]

E_α (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	Outgoing particles	θ^2 (%) [a]	E_x (MeV)	J^π	Refs.
2.490 ± 10	19	α_0	22	6.722	0^+ [i]	(1953CA44)
3.045 ± 10	8	α_0	36	7.166	3^- [g]	(1953CA44)
3.090 ± 10	4	α_0	1.1	7.202	0^+ [j]	(1953CA44)
3.380 ± 10	8	α_0	4.7	7.434	2^+ [i]	(1953CA44)
3.885 ± 10	2	α_0	0.6	7.838	2^+ [j]	(1953CA44)
4.653 ± 5	0.013 ± 0.004	α_0	0.07	8.452	5^- [h]	(1973HA63)
≈ 4.9	> 800	α_0	≈ 70	≈ 8.6	0^+ [k]	(1960MC09)
5.002	2.5	α_0	0.23	8.731	1^-	(1960MC09)
5.058 ± 3	0.11 ± 0.02	α_0	8.5 ± 1.5	8.776	6^+ [f]	(1972HA07)
≈ 5.1	> 800	α_0	≈ 95	≈ 8.8	2^+ [k]	(1960MC09)
5.11	< 1	α_0		8.82	(5^-)	(1960MC09)
5.152 ± 5	19	α_0	1.1	8.851	1^-	(1960MC09, 1969JO18)
5.395 ± 5	3	α_0	3.9	9.046	4^+ [j]	(1960MC09, 1969JO18)
5.486 ± 5	3.2	α_0	0.49	9.118	3^-	(1960MC09, 1969JO18)
5.955 ± 10	24	α_0	1.4	9.493	2^+	(1960MC09, 1967HU06, 1969JO18)
6.569 ± 10	97	α_0	17	9.984	4^+ [i]	(1967HU06, 1969JO18)
6.912 ± 5	141	α_0	66	10.259	5^- [g]	(1967HU06, 1969JO18)
6.92 ± 10	≤ 0.3	α_0	$\leq 1.3 \times 10^{-3}$	10.27	(2^+)	(1978ST08)
7.092 ± 5	81	α_0	4.8	10.403	3^-	(1967HU06, 1969JO18)
7.276 ± 5	16	α_0	1.8	10.550	4^+	(1969JO18)
7.314 ± 10	24	α_0	0.85	10.580	2^+	(1965MC02, 1967HU06, 1969JO18)
7.580 ± 100	349	α_0	33	10.79	4^+ [k]	(1967HU06, 1969JO18)
7.635 ± 5	13	α_0	0.42	10.837	2^+	(1965MC02, 1967HU06, 1969JO18)
7.636	45	α_0	2.1	10.838	3^-	(1969JO18)

Table 20.23: Resonances in $^{16}O(\alpha, \alpha)^{16}O$ [a] (continued)

E_α (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	Outgoing particles	θ^2 (%) [a]	E_x (MeV)	J^π	Refs.
(7.75)	80	α_0		(10.93)		(1967HU06)
7.80 ± 150	576	α_0	14	10.97	0^+	(1969JO18)
7.860 ± 10	24	α_0	2.0	11.017	4^+	(1965MC02, 1967HU06, 1969JO18)
7.93 ± 10	≤ 0.5	α_0	≤ 0.05	11.07	(4^+)	(1978ST08)
8.132 ± 30	172	α_0	4.2	11.234	1^-	(1969JO18)
8.16 ± 10	≤ 0.3	α_0	≤ 0.009	11.26	(1^-)	(1978ST08)
8.24 ± 10	40 ± 10	α_0	1.4	11.32	2^+	(1965MC02, 1967HU06, 1969JO18, 1978ST08)
8.528 ± 10	1.0 ± 0.5	α_0	0.03, 0.02	11.551	$(2^+, 0^+)$	(1978ST08)
(≈ 8.6)	≈ 500	α_0		(≈ 11.6)	(2^+)	(1967HU06)
8.930 ± 20	46	α_0	1.1	11.872	2^+	(1969JO18)
8.997 ± 5	0.44 ± 0.15	$\alpha_0, \gamma_{6.13}$	0.04 ± 0.01	11.926	4^+	(1972HA07)
9.026 ± 5	$(35 \pm 10) \times 10^{-3}$	α_0	1.0 ± 0.3	11.949	8^+ [f]	(1972HA07)
9.043 ± 10	30 ± 5	α_0	0.72	11.962	1^-	(1967HU06, 1969JO18, 1972HA07, 1978ST08)
(9.37 ± 20)	≤ 20	α_0	≤ 0.5	(12.22)	(2^+)	(1978ST08)
9.39 ± 30	148 ± 20	α_0	7.7	12.24	4^+	(1964PE05, 1967HU06, 1969JO18, 1978ST08)
9.530 ± 100	≈ 500	α_0	≈ 13	12.35	2^+	(1969JO18, 1978ST08)
9.58 ± 10 [b,c]	37 ± 5	$\alpha_0, \gamma_{6.13}$	1.2	12.39	3^-	(1964PE05, 1969JO18, 1977MA07, 1978ST08)
9.605 ± 5	≤ 8	α_0	< 0.15	12.412	0^+ [e]	(1969JO18)
9.790 ± 10	88 ± 10	α_0	28	12.560	6^+ [k]	(1967HU06, 1969JO18, 1978ST08)
(9.860 ± 100)		α_0		(12.62)		(1969JO18)
9.944 ± 15	97	α_0	7.3	12.683	5^-	(1969JO18)

Table 20.23: Resonances in ^{16}O(α, α)^{16}O [a] (continued)

E_α (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	Outgoing particles	θ^2 (%) [a]	E_x (MeV)	J^π	Refs.
10.050 ± 100 [d]	100	α_0		12.77	4^+	(1967ME10, 1969JO18)
10.14 ± 70	55	α_0, $\gamma_{6.13}$		12.84		(1967ME10)
10.32 ± 75	60	α_0, $\gamma_{6.13}$		12.98	(4^+)	(1967ME10)
10.43 ± 90	70	α_0, $\gamma_{6.13}$		13.07	(4^+)	(1967ME10)
10.57 ± 75	60	α_0, $\gamma_{6.13}$		13.18	(4^+)	(1967ME10)
10.759 ± 6	$(80 \pm 30) \times 10^{-5}$	α_0	0.08 ± 0.03	13.334	7^- [h]	(1972HA07)
10.770 ± 6	20 ± 5	α_0, $\gamma_{6.13}$	0.07 ± 0.03	13.343	4^+	(1967ME10, 1972HA07)
10.83 ± 50	40	$\gamma_{6.13}$		13.39		(1967ME10)
10.87 ± 140	110	α_0, $\gamma_{6.13}$		13.42	(4^+)	(1967ME10)
11.20 ± 400	320	α_0, $\gamma_{6.13}$		13.7	$(3, 7)^-$	(1967ME10)
11.51 ± 125	400	α_0, $\gamma_{6.13}$		13.93	(6^+)	(1967ME10)
11.77		α_0, $\gamma_{6.9+7.1}$		14.14		(1967ME10)
11.97 ± 300	240	α_0, $\gamma_{6.13}$, $\gamma_{6.9+7.1}$		14.3	6^+	(1967ME10)
(12.06)		α_0, $\gamma_{6.9+7.1}$		(14.37)		(1967ME10)
12.31 ± 300	240	α_0, $\gamma_{6.9+7.1}$		14.6	(4^+)	(1967ME10)
12.66 ± 150	120	α_0, $\gamma_{6.13}$, $\gamma_{6.9+7.1}$		14.85		(1967ME10)
12.86 ± 150	120	α_0, $\gamma_{6.13}$, $\gamma_{6.9+7.1}$		15.01		(1967ME10)
13.165 ± 150	120	α_0, $\gamma_{6.13}$		15.26		(1967ME10)
13.22		α_0		15.30		(1967ME10)
13.37 ± 470	380	α_0, $\gamma_{6.13}$, $\gamma_{6.9+7.1}$		15.4	7^- [g]	(1967ME10, 1975CE01)
13.58		α_0, $\gamma_{6.13}$, $\gamma_{6.9+7.1}$		15.59		(1967ME10)
13.73		α_0, $\gamma_{6.13}$, $\gamma_{6.9+7.1}$		15.71	(6^+)	(1967ME10, 1975CE01)
14.05		α_0, $\gamma_{6.13}$, $\gamma_{6.9+7.1}$		15.97	(6^+)	(1967ME10, 1975CE01)
14.26		$\gamma_{6.13}$, $\gamma_{6.9+7.1}$		16.13		(1967ME10)

Table 20.23: Resonances in ^{16}O$(\alpha, \alpha)^{16}$O [a] (continued)

E_α (MeV $\pm$ keV)	$\Gamma_{\text{c.m.}}$ (keV)	Outgoing particles	θ^2 (%) [a]	E_x (MeV)	J^π	Refs.
14.40		$\gamma_{6.13}$		16.25		(1967ME10)
14.501 ± 15	43	α_0, α_{1+2}		16.326	4^+	(1973HA63)
14.636 ± 15	34	α_0, α_{1+2}		16.434	$(0, 2, 4)^+$	(1973HA63)
14.732 ± 15	23	α_0, α_{1+2}		16.510	$(2, 4, 6)^+$	(1973HA63)
14.935 ± 15	110	α_0		16.673	$(0, 2)^+$	(1973HA63)
14.993 ± 15	10	α_0, α_{1+2}		16.719	$(1, 3, 7)^-$	(1973HA63)
15.162 ± 15	10	α_0, α_{1+2}		16.854	5^-	(1973HA63)
15.547 ± 15	37	α_0, α_{1+2}		17.162	$5^-, (7^-)$	(1973HA63)
15.695 ± 15	32	α_0, α_{1+2}		17.280	$1^-, 3^-, 4^+$	(1973HA63)
15.828 ± 15	< 10	α_{1+2}		17.387		(1973HA63)
16.023 ± 15	136	α_0, α_{1+2}		17.542	6^+	(1973HA63)
16.285 ± 15	36	α_0, α_{1+2}		17.752	$4^+. (0^+)$	(1973HA63)
16.598 ± 15	< 10	α_0, α_{1+2}		18.002	7^-	(1973HA63)
16.623 ± 15	45	α_0, α_{1+2}		18.022	$(2^+, 5^-, 6^+)$	(1973HA63)
16.737 ± 15	33	α_0, α_{1+2}		18.113	7^-	(1973HA63)
16.98 ± 300	240	$\alpha_0, \gamma_{6.13}, \gamma_{6.9+7.1}$		18.31	(6^+)	(1967ME10)
17.45	600	$\alpha_0, \gamma_{6.13}$		18.7	(6^+)	(1967ME10)
18.05 ± 250	200	$\alpha_0, \gamma_{6.9+7.1}$		19.16	(6^+)	(1967ME10)
18.35 ± 350	280	α_0		19.40	6^+	(1967ME10)
18.90 ± 350	280	α_0		19.84	6^+	(1967ME10)
19.30 ± 120	250	α_0		20.16	7^-	(1971BE17)
19.6 ± 180	360	α_0		20.4	6^+	(1971BE17)
19.6 ± 100	200	α_0		20.4	7^-	(1971BE17)
19.95 ± 60	120	α_0		20.68	9^-	(1971BE17)

Table 20.23: Resonances in ^{16}O(α, α)^{16}O [a] (continued)

E_{α} (MeV $\pm$ keV)	$\Gamma_{\text{c.m.}}$ (keV)	Outgoing particles	θ^2 (%) [a]	E_{x} (MeV)	J^{π}	Refs.
20.18		α_0		20.9		(1971BE17)
20.4 $\pm$ 100	200	α_0		21.0	7^-	(1971BE17)
20.45 $\pm$ 40	80	α_0		21.08	9^-	(1971BE17)
20.70	300	α_0		21.3	7^-	(1962JO14, 1971BE17, 1971TA05)
21.3 $\pm$ 200	300	α_0		21.8	7^-	(1971BE17, 1971TA05)
22.0 $\pm$ 200	500	α_0		22.3	7^-	(1971BE17, 1971TA05)
22.5 $\pm$ 250	500	α_0		22.7	9^-	(1971BE17)
22.65 $\pm$ 125	250	α_0		22.84	9^-	(1971BE17)
23.3 $\pm$ 250	500	α_0		23.4	8^+	(1971BE17, 1971TA05)
24.24 $\pm$ 150	350	α_0		24.11	8^+	(1971BE17, 1971TA05)
25.4 $\pm$ 300	600	α_0		25.0	8^+	(1971BE17)
26.2 $\pm$ 200	400	α_0		25.7		(1971BE17)
28.1 $\pm$ 350	700	α_0		27.2		(1971BE17)
29	1600	α_0		28	8^+	(1969CO19, 1970CO13)
29.4 $\pm$ 350	700	α_0		28.2		(1971BE17)

[a] See also discussion and Table 2 in (1973HA63).

[b] ^{20}Ne*(12.39) decays by α_2 to ^{16}O*(6.13) with $\omega\Gamma_\alpha\Gamma'_\alpha/\Gamma = 3 \pm 1$ keV (1964PE05), 2.0 ± 0.1 keV (1978ST08).

[c] $\omega\gamma = 0.8 \pm 0.2$ and 1.94 ± 0.15 eV to ^{20}Ne*(1.63, 4.25), respectively; $\omega\gamma_0 < 0.02$ eV (1978ST08).

[d] Values quoted are taken preferentially from the elastic scattering results (1967ME10).

[e] (1977BA3W, 1977BA3X) report a probable 0^+ state at $E_x = 12.436 \pm 0.005$ MeV, $\Gamma_{lab} = 29 \pm 1$ keV, $\Gamma_{\alpha_0} = 22.7 \pm 2.0$ keV, $\Gamma_{\alpha_1} = 6.3 \pm 2.0$ keV. These data are preliminary and are not used in Table 20.18.

[f] $K^\pi = 0^+_1$ (1972HA07, 1973HA63).

[g] $K^\pi = 0^-$ (1973HA63).

[h] $K^\pi = 2^-$ (1972HA07, 1973HA63).

[i] $K^\pi = 0^+_2$ (1973HA63).

[j] $K^\pi = 0^+_3$ (1973HA63).

[k] $K^\pi = 0^+_4$ (1973HA63).

16. ^{16}O(α, n)^{19}Ne $\quad Q_m = -12.1344 \quad E_b = 4.7309$

The excitation function (activation measurements) has been measured from threshold to $E_\alpha = 26.8$ MeV (1973GR29). See also (1974LO1B, 1977LI19) and ^{19}Ne.

17. ^{16}O(α, p)^{19}F $\quad Q_m = -8.1137 \quad E_b = 4.7309$

See ^{19}F.

18. ^{16}O(α, ^{3}He)^{17}O $\quad Q_m = -16.434 \quad E_b = 4.7309$

See ^{17}O in (1977AJ02) and (1972RI03; theor.).

19. ^{16}O(^{6}Li, d)^{20}Ne $\quad Q_m = 3.257$

Deuteron groups have been observed to many states of ^{20}Ne: see Table 20.24. Angular distributions have been measured at a number of energies for $E(^6\text{Li}) = 5.5$ to 25.8 MeV [see (1972AJ02)] and at 32 MeV (1973GO1K, 1973GO1L; abstracts; to most states shown in Table 20.24 with $E_x < 12.2$ MeV), (1977GU01: d to ^{20}Ne*(0, 1.63, 4.25, 4.97, 5.62, 7.00)) and at 35.3 to 45 MeV (1975AR20, 1975AR25, 1976AR04: see Table 20.24). (1977GU01) report that the forward peaks of the deuterons to ^{20}Ne*(4.97, 5.62) [$J^\pi = 2^-$ and 4^-] cannot be explained solely in terms of zero-range coupled-channel Born approximation α-transfer. The α-particle spectroscopic strengths for the ground state $K^\pi = 0^+$ states have been studied by (1973FO06, 1975AN13). (1973FO06) find 0.22 and 0.15 for the α reduced widths for ^{20}Ne*(8.78, 11.95) in agreement with their assignments as the 6^+ and 8^+ members of the $K^\pi = 0_1^+$ band. See also (1972PA16, 1977BE2R). (dγ) coincidences are being studied by (1977SU1M; abstract).

For excitation functions see (1976HOZJ) and ^{22}Na in (1978EN06). See also (1972BA1P, 1973ST1E), (1971BA2V, 1972GA1E, 1973FO1E, 1973FO1A, 1973OG1A, 1975GO15, 1976OG1A) and (1973YA1A, 1974DO03, 1974NE18, 1976KOZQ; theor.).

20. ^{16}O(^{7}Li, t)^{20}Ne $\quad Q_m = 2.264$

A number of ^{20}Ne states have been studied in this reaction: see Table 20.24 (1976CO23) and P.D. Parker, private communication. Angular distributions have been reported at $E(^7\text{Li}) = 15$ to 30.3 MeV [see (1972AJ02)] and at 38 MeV (1976CO23). Correlations between the tritons and the α-particles to ^{16}O have been studied for a number of states of ^{20}Ne at $E(^7\text{Li}) = 20$ and 24 MeV: it is suggested that the reaction mechanism is mainly direct (1974PA16). See also (1977DA1J). See also (1972BA1P, 1972CA1D, 1972PA16, 1973ST1E, 1977SA1X), (1971BA2V, 1972GA1E, 1973BR1C, 1973FO1A, 1973OG1A, 1975GO15) and (1972KU12, 1972KU13, 1973AR1C, 1973IC01, 1973MC17, 1974DO03, 1974NE18, 1975BI1J; theor.).

Table 20.24: States of ^{20}Ne from ^{16}O(^{6}Li, d), ^{16}O(^{7}Li, t) and ^{16}O(^{12}C, ^{8}Be)

E_x (MeV ± keV)			$\Gamma_{c.m.}$	Γ_{α_0}/Γ [g]	J^π	K^π
(^{6}Li, d) [a]	(^{7}Li, t) [b]	(^{12}C, ^{8}Be) [g]	(keV)			
0	0				0^{+} [c]	0^{+}_{1}
1.63	1.63				2^{+} [c]	0^{+}_{1}
4.25	4.25				4^{+} [c]	0^{+}_{1}
4.97					2^{-}	2^{-}
5.62					3^{-}	2^{-}
5.78	5.78				1^{-} [d]	0^{-}
6.72						
7.00					4^{-}	2^{-}
7.17	7.17	7.17			3^{-} [d]	0^{-}
7.42						
8.45						
8.78	8.78	8.78			6^{+}	0^{+}_{1}
10.3 ± 100	10.26	10.26	145 ± 40	1	5^{-}	0^{-}
10.7 ± 100					4^{+}	
11.95	11.95	11.95		0.85 ± 0.15	8^{+}	0^{+}_{1}
12.15						
12.6 ± 100	12.591 ± 10	12.59	110 ± 40	0.80 ± 0.10	6^{+}	0^{+} [e]
13.9	13.904 ± 20		≈ 100		6^{+}	
14.3	14.310 ± 20		< 100		6^{+}	
15.35 ± 100	15.336 ± 15	15.34	380 ± 60	0.90 ± 0.10	7^{-}	0^{-} [e]
15.9 ± 100			< 250		7^{-}	
16.7 ± 100	16.63 ± 20	16.63	190 ± 40	0.90 ± 0.10	7^{-}	
17.35 ± 100	17.30 ± 20	17.30	220 ± 40	0.40 ± 0.10	8^{+}	
18.7 ± 100					7^{-}	
19.4 ± 100			400		7^{-}	
19.9 ± 100			400		7^{-}	
	20.67 ± 40					
20.8 ± 100					7^{-} (6^{+})	
	21.08 ± 30	21.08	100 ± 50	0.65 ± 0.15	9^{-}	
21.3 ± 100			300		8^{+}	

Table 20.24: States of ^{20}Ne from ^{16}O(^{6}Li, d), ^{16}O(^{7}Li, t) and ^{16}O(^{12}C, ^{8}Be) (continued)

E_x (MeV ± keV)			$\Gamma_{c.m.}$ (keV)	Γ_{α_0}/Γ [g]	J^π	K^π
(^{6}Li, d) [a]	(^{7}Li, t) [b]	(^{12}C, ^{8}Be) [g]				
21.8 ± 100			300		8^+	
22.3 ± 100			300		8^+	
	22.87 ± 40	22.87	225 ± 40	0.90 ± 0.10	9^-	
23.5 ± 100	23.70 ± 30 [f]		≤ 200		9^- (8^+)	
	24.21 ± 25 [f]		≈ 500			
	25.10 ± 50 [f]		$\lesssim 200$			
	25.67 ± 50 [f]		≈ 500			
27.1 ± 100					(9^-)	
28.1 ± 100					(10^+)	

[a] Levels with energy uncertainties shown are from (1975AR20, 1975AR25, 1976AR04: $E(^{6}\mathrm{Li}) = 35.3$ to 45 MeV). The other states have been reported by other groups: see text.
[b] (1976CO23). $E(^{7}\mathrm{Li}) = 38$ MeV and P.D. Parker (private communication).
[c] Relative α-cluster spectroscopic factors for ^{20}Ne*(0, 1.63, 4.25) are 1.00, 0.81, 0.36 (FRDWBA), 1.00, 1.00, 0.75 (FRCCBA) (1976CO23).
[d] Spectroscopic factors are 0.30 and 0.15 for ^{20}Ne*(5.78, 7.17) (FRDWBA) (1976CO23).
[e] (1974PA16).
[f] $E(^{7}\mathrm{Li}) = 60$ MeV (P.D. Parker, private communication).
[g] (1977SA1X, 1977SA2A, 1977SA2F, 1977SA2G) and P.D. Parker (private communication): $E(^{12}\mathrm{C}) = 78$ MeV.

21. ^{16}O(^{9}Be, αn)^{20}Ne $\qquad Q_m = 3.1576$

See (1974VA31).

22. (a) ^{16}O(^{12}C, 2α)^{20}Ne $\qquad Q_m = -2.5439$
(b) ^{16}O(^{12}C, ^{8}Be)^{20}Ne $\qquad Q_m = -2.6358$

In reaction (a) at $E(^{16}\mathrm{O}) = 58.3$ MeV, ^{20}Ne*(0, 1.63, 4.25 + 4.97) are strongly populated (1974WI05). See also ^{24}Mg in (1978EN06). For fusion studies see (1976KO24, 1976SW02, 1976WE15, 1977CH10) and for other yield measurements see (1976EY01, 1977SW01) and ^{28}Si in (1978EN06). See also (1975SC2A).

Angular distributions in reaction (b) have been studied at $E(^{16}O) = 27.1$ to 37.1 MeV (1977HU1C; g.s.), 30.2, 30.7, 31.2 and 32.1 MeV (1976VI05, 1977BR24; g.s.) and 46.4 MeV (1976JA19; g.s.), at $E(^{12}C) = 56$ MeV (1976MA12: to $^{20}Ne^*$(0, 1.63, 4.25, 5.8, 7.2, 8.8, 10.34, $\approx$ 12)) and at 78 MeV (1977SA1X, 1977SA2A, 1977SA2F, 1977SA2G). At $E(^{12}C) = 56$ MeV the strongest groups are those to the 6^+ and 5^- states $^{20}Ne^*$(8.78, 10.26) (1976MA12). See also (1972WO10). At $E(^{12}C) = 78$ MeV, ^{8}Be-α correlations have led to a number of J^π determinations and to measurements of Γ_{α_0}/Γ: see Table 20.24 (P.D. Parker, private communication). For yield measurements see (1976JA19, 1976VI05, 1977BR24, 1977FL1F, 1977HU1C) and ^{28}Si in (1978EN06). See also (1972PA1G, 1974ME09) and (1973YO03, 1974KR1E, 1975BA2J, 1976BU22; theor.).

23. $^{16}O(^{13}C, ^{9}Be)^{20}Ne$ $\qquad Q_m = -5.9170$

At $E(^{13}C) = 105$ MeV the cross sections for formation of the $K^\pi = 0^+$ states $^{20}Ne^*$(0, 1.63, 4.25, 8.78, 11.95) are in excellent agreement with shell-model predictions. $^{20}Ne^*$(10.26, 17.38, 21.1), as well as the 4^+, 6^+ and 8^+ states above, are strongly populated (1976PI16).

24. $^{16}O(^{14}N, ^{10}B)^{20}Ne$ $\qquad Q_m = -6.8823$

At $E(^{14}N) = 155$ MeV states with high angular momentum appear to be preferentially excited (1976NA22).

25. $^{16}O(^{16}O, ^{12}C)^{20}Ne$ $\qquad Q_m = -2.4310$

Angular distributions have been reported at $E(^{16}O) = 23.9$ MeV (1974SP06; g.s.), $44.3 - 54.5$ MeV (1972SI17, 1973SI1D; to $^{20}Ne^*$(0, 1.63, 4.25)), 51.5 MeV (1974RO04; to $^{20}Ne^*$(0, 1.63, 4.3, $5.6 - 6.1$, $8.5 - 8.9$)) and 95.2 MeV (1977MO1H; to $^{20}Ne^*$(0, 1.63)). At 55.5 MeV (1973ER1B, 1974ER1A; prelim.), $^{20}Ne^*$(0, 1.63, 4.25, 4.97, 7.00) are populated. For yield measurements see (1972SI17, 1973PE1D, 1974ER1A, 1974RO04, 1974SP06, 1977KO16) and ^{32}S in (1978EN06). In particular the fusion cross section shows evidence of periodic structure between $E_{c.m.} = 14$ and 28 MeV, as predicted by the optical model (1977KO16): a resonance ($\Gamma \leq 1$ MeV) at $E_{c.m.} = 26.5$ MeV is suggested to be an α-exchange resonance. Polarization measurements are reported by (1977PO1E). See also (1973ST1A, 1973ST1F) and (1972AR11, 1973AR18; theor.).

26. $^{16}O(^{18}O, ^{14}C)^{20}Ne$ $\qquad Q_m = -1.4970$

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

27. ^{16}O(^{19}F, ^{15}N)^{20}Ne $\quad Q_{\rm m} = 0.7171$

At $E(^{19}{\rm F}) = 36$ MeV (1973GA14) and $E(^{16}{\rm O}) = 46$, 58 and 68 MeV (1975PO01) angular distributions involving ^{20}Ne*(0, 1.63) are reported. (1975PO01) have also studied ^{20}Ne*(4.25): the strong population of the 4^+ state may indicate evidence for a two-step process. See also (1976LO06; theor.).

28. (a) ^{17}O(^{3}He, n)^{19}Ne $\quad Q_{\rm m} = 4.299 \quad E_{\rm b} = 21.164$

(b) ^{17}O(^{3}He, α)^{16}O $\quad Q_{\rm m} = 16.4335$

For reaction (a) see ^{19}Ne. The ground state excitation energy for reaction (b) has been measured for $E(^3{\rm He}) = 7.0$ to 10.0 MeV: it shows a resonance corresponding to ^{20}Ne*(28.). This resonance is also observed in the ^{16}O(α, α) elastic scattering. It is interpreted in terms of a quasi-molecular α-particle cluster model (1969CO19).

29. ^{17}O(α, n)^{20}Ne $\quad Q_{\rm m} = 0.587$

Angular distributions have been measured at $E_\alpha = 9.8$ to 12.3 MeV by (1967HA14: n_1, n_2, n_{4+5}). The neutron decay of the lowest $T = \frac{3}{2}$ state in ^{21}Ne to ^{20}Ne*(1.63) has been studied by (1976MC12). The total neutron yield has been measured for $E_\alpha = 1.0$ to 5.3 MeV by (1973BA10). The astrophysical import of this reaction is discussed by (1973CL1E, 1975FO19). See also ^{21}Ne in (1978EN06).

30. ^{17}O(^{6}Li, t)^{20}Ne $\quad Q_{\rm m} = 5.370$

See (1973ST1E, 1977MA2G). See also (1974KU07; theor.).

31. ^{18}O(^{3}He, n)^{20}Ne $\quad Q_{\rm m} = 13.1199$

Neutron groups have been observed to a number of ^{20}Ne states: see Table 20.25 (1969AD02, 1970GU08, 1977EV01). Angular distributions have been measured at $E(^3{\rm He}) = 2.8$ to 7.3 MeV (see (1972AJ02)) and at 18 (1977EV01) and 18.3 MeV (1975PE11).

32. ^{18}O(^{11}B, ^{9}Li)^{20}Ne $\quad Q_{\rm m} = -10.027$

At $E(^{11}{\rm B}) = 114$ MeV, ^{20}Ne*(4.25, 8.9, 10.39, 15.43) [± 60 keV] are relatively strongly populated. ^{20}Ne*(0, 1.63, 5.78, 7.17) are also excited (1973ST24). See also (1973SC1J).

Table 20.25: States of ^{20}Ne from ^{18}O(^{3}He, n)^{20}Ne

E_x (MeV ± keV)		L [a]	$J^\pi; T$
(1977EV01)	(1970GU08)		
0	0	0	0^+
1.65 ± 15	1.63 ± 160	2	2^+
4.21 ± 30	4.22 ± 150	4	4^+
	4.96 ± 150		
5.71 ± 30	5.73 ± 120		
6.72 ± 90	6.72 ± 100		
7.15 ± 20			
	7.86 ± 100		
(8.74 ± 150)	8.79 ± 60		
	9.05 ± 60		
	9.98 ± 50		
10.24 ± 30	10.25 ± 50	2	$2^+; (1)$
10.83 ± 90	10.88 ± 50		
	11.27 ± 50		
11.48 ± 60		(0)	(0^+)
	11.59 ± 40		
12.21 ± 15	12.20 ± 30	2	2^+
	12.41 ± 30	0	0^+
	12.83 ± 30		
	13.10 ± 30	0	0^+
	13.34 ± 30		
	13.48 ± 30		
13.57 ± 20	13.63 ± 30	(2)	(2^+)
13.93 ± 30	13.88 ± 30	(2)	(2^+)
	14.22 ± 30		
(15.1)			
15.52 ± 15		(2)	$(2^+; 1)$
16.01 ± 25		(2)	$(2^+; 1)$
16.73 ± 10	16.730 ± 6 [b]	0	$0^+; T = 2$
(17.03)			

Table 20.25: States of ^{20}Ne from ^{18}O(^{3}He, n)^{20}Ne (continued)

E_x (MeV ± keV)		L [a]	$J^\pi; T$
(1977EV01)	(1970GU08)		
17.55 ± 10		(2)	(2^+; 1)
17.91 ± 20		(0)	(0^+)
19.33 ± 15			

[a] From analysis of angular distributions at $E(^3\mathrm{He}) = 3.1$ MeV (1970GU08), 18 MeV (1977EV01) and 18.3 MeV (1975PE11).
[b] $\Gamma < 20$ keV. This state is reported by (1969AD02).

33. ^{18}O(^{12}C, ^{10}Be)^{20}Ne $\qquad Q_m = -4.7816$

At $E(^{12}\mathrm{C}) = 46$ MeV angular distributions to ^{20}Ne*(0, 1.63, 4.25) have been studied: the 2p spectroscopic factors are 0.58, 0.24 and 0.20, respectively (1975CO15).

34. ^{19}F(p, γ)^{20}Ne $\qquad Q_m = 12.8447$

Over the range $E_p = 2.9$ to 12.8 MeV, the γ_0 and γ_1 yields are dominated by the E1 giant resonance ($\Gamma \approx 6$ MeV) with the γ_1 giant resonance displayed upward in energy. Strong, well correlated structure is observed with a characteristic $\Gamma \approx 175$ keV. Angular distributions taken over the energy range do not vary greatly with energy. They are incompatible with γ_0 and γ_1 coming from the same levels in ^{20}Ne (1967SE02). See also (1973AV1B).

The yield curve for 11.2 MeV γ-rays [from the decay of ^{20}Ne*(11.23), $J^\pi = 1^+; T = 1$, to the ground state] displays a resonance at $E_p = 4.090 \pm 0.005$ MeV [^{20}Ne*(16.73)]. The 11.2 MeV γ-rays are isotropic which is consistent with the presumed 0^+ character of this lowest $T = 2$ state in ^{20}Ne: $\Gamma_p\Gamma_\gamma/\Gamma \approx 0.5$ eV. Since Γ_p/Γ (from the elastic scattering) is ≈ 0.1, $\Gamma_\gamma \approx 5$ eV (1967KU06). For $E_p = 5.65$ to 6.21 MeV, the γ_0 and γ_1 yields are not resonant but the yield of 10.6 MeV γ-rays is resonant at 5.879 ± 0.007 MeV [$\Gamma_{\mathrm{c.m.}} = 9.5 \pm 3$ keV, $\Gamma_{p0}\Gamma_\gamma/\Gamma \approx 0.05$ eV; $\Gamma_\gamma \approx 0.3$ eV]. The 10.6 MeV γ-ray is due to the cascade decay of ^{20}Ne*(18.43), $J^\pi = 2^+; T = 2$ via ^{20}Ne*(12.22) to the 2^+ state at 1.63 MeV (1972KU24). (1976MA01) have determined the upper limits to the strengths of the transitions to various states of ^{20}Ne from the 0^+ and 2^+ $T = 2$ states: these are displayed in Table 20.19. No evidence is found for an isotensor transition amplitude (1976MA01).

Resonances observed in this capture reaction are displayed in Table 20.26. See also (1973GL1B, 1973GL1C, 1973HA1X, 1974AD1B, 1974HA1G, 1974HA1N) and (1977SC02, 1977SC08; theor.).

Table 20.26: Resonances in ^{19}F(p, γ)^{20}Ne [a]

E_p (keV)	Γ_{lab} (keV)	$\Gamma_{\gamma 0}$ (eV)	$\Gamma_{\gamma 1}$ (eV)	^{20}Ne* (MeV)	$J^\pi; T$	Refs.
340		< 0.07	0.28 ± 0.06	13.168		(1962KE03)
484		≈ 0.05	0.42	13.304		(1963BE19)
597 ± 1	30 ± 3	< 0.6	12	13.412		(1963BE19)
671 ± 1	6.0 ± 0.7	1.0×10^{-2}	2.2 [b]	13.482	1^+ [d]	A
874				13.675		(1955FA1A)
935				13.733		(1955FA1A)
980				13.775		(1955FA1A)
1091	0.8			13.881	2^- [e]	A, (1975SU1E)
1280				14.060		(1955FA1A)
1320 [b]	4.0			14.098		A
1350				14.127		(1955FA1A)
1370				14.146		(1955FA1A)
1420	15.7			14.193		A
4090 ± 5 [e]		$\Gamma_\gamma \approx 5$ eV [c]		16.728	$0^+; 2$	(1967KU06, 1976MA01)
5879 ± 7 [d]	10 ± 3	$\Gamma_\gamma \approx 0.3$ eV [c]		18.427	$2^+; 2$	(1972KU24, 1976MA01)

A: See references listed for this state in (1972AJ02) and in Table 20.13 of (1959AJ76) [see (1955HU1A)].

[a] See also Table 20.19.

[b] Γ_γ to ^{20}Ne*(4.97) $= 0.12$ eV (1961GO21), 0.24 eV (1960KA18).

[c] See text of reaction 34.

[d] Decays predominantly to ^{20}Ne*(1.63) via an M1 transition: see Table 20.19.

[e] Based on non-isotropic distribution of γ-rays from $13.88 \rightarrow 4.97$ transition, which leads to odd parity for ^{20}Ne*(13.88) assuming p-wave protons (1975SU1E; preliminary).

Table 20.27: Levels of ^{20}Ne from ^{19}F(p, p_0)^{19}F (1955BA1C)

E_p (keV)	Γ_{lab} (keV)	l	$J^\pi; T$	Γ_p/Γ	θ_p^2 (%)	^{20}Ne* (MeV)
340	2.9	0	1^+	0.016	3.8	13.168
483 [b]			1^+			13.303
598	37	1	2^-	0.0012	0.38	13.413
669	7.5	0	1^+	0.98	9.6	13.480
843	23	0	0^+	0.996	10.8	13.645
873	5.2	1	2^- [a]	0.21	1.5	13.674
935	8.0	0	1^+	0.17	0.44	13.733
1346	4.5	1	2^- [a]	0.067	0.07	14.123
1372	15	1	2^- [a]	0.17	0.52	14.148
1422	14.6	0	1^+	0.85	0.92	14.195
1694 [c]						14.453
1940 [c]		(0)	$(0^+, 1^+)$			14.687
2030 [c]						14.772
4094 ± 3 [d]	2.1 ± 0.5	0	$0^+; 2$	0.062 ± 0.004		16.732
5879 ± 7 [e]	10 ± 3	2	$2^+; 2$	≈ 0.2		18.427

[a] 1^- not excluded by elastic scattering alone.

[b] (1963BE19).

[c] (1956DE33).

[d] (1967BL19, 1967KU06).

[e] (1972KU24). Resonance also observed in p_1, p_3, p_4 and p_5 yields.

Table 20.28: Resonance parameters in ^{19}F + p (1955BA1C)

E_p (keV)	J^π	θ^2 [a]					
		p_0	p_1	p_2	α_1	α_2	α_3
340	1^+	3.8	< 15		18.8	1.0	7.2
598	2^-	0.38	< 28	< 145	31	< 0.5	< 5.1
669	1^+	9.6	0.6	< 0.4	0.26	0.005	0.27
843	0^+	10.8	≈ 0.14	< 0.92			
873	2^-	1.5	< 0.07	2.7	1.05 [b]	1.45 [b]	3.4
935	1^+	0.44	5.0	< 0.8	3.3	0.34	2.3
1346	2^-	0.07 [b]	0.92	0.24	0.36	0.21 [b]	2.1
1372	2^-	0.52 [b]	1.93	0.56	1.7 [b]	0.34 [b]	0.86
1422	1^+	0.92	0.56	< 0.11	total < 0.034		

[a] p_0, p_1, p_2 represent transitions to ^{19}F(0), (0.1), (0.2). α_1, α_2, α_3 represent transitions to ^{16}O(6.1), (6.9), (7.1).

[b] Assuming lowest possible values of l; see (1957MA1A).

35. (a) ^{19}F(p, p)^{19}F $\qquad E_b = 12.8447$

(b) ^{19}F(p, p′)^{19}F*

The elastic scattering has been studied in the range $E_p = 500$ to 2000 keV by (1954DE1A, 1954PE1A, 1955BA1C, 1955WE44, 1956DE33, 1963BE19). Parameters for the observed resonances are exhibited in Tables 20.27 and 20.28 taken mainly form (1955BA1C). Some unresolved structure is observed at $E_p = 900$, 1092 and 1137 keV, in addition to a broad structure near $E_p = 1700$ keV (1955WE44). A sharp anomaly is observed in the elastic scattering at $E_p = 4.096 \pm 0.003$ MeV (1967BL19), 4.090 ± 0.005 MeV (1967KU06). It is an s-wave resonance corresponding to the 0^+; $T = 2$ state at $E_x = 16.73$ MeV (1967BL19, 1967KU06). There is no indication of this resonance in the p_3, p_4 or p_5 yields (1967KU06). The amplitude of the $T = 1$ or $T = 0$ impurity in this state is $\approx 1.5\%$ (1967BL19). In the range $E_p = 5.65$ to 6.21 MeV, a single anomaly is seen in the elastic scattering at $E_p = 5.879 \pm 0.007$ MeV. The interference patterns show that the scattering is d-wave, corresponding to the excitation of the 2^+; $T = 2$ state at $E_x = 18.43$ MeV (1972KU24). The 5.88 MeV anomaly also appears in the p_1, p_3, p_4 and p_5 yields (1972KU24). The parameters of these two $T = 2$ states are shown in Table 20.27. The elastic scattering has also been studied for $E_p = 4.2$ to 7.5 MeV by (1967TH06). The total reaction cross section is reported for $E_p = 24.9$ to 46.3 MeV by (1974MC19: 8 energies in that range).

Resonances for inelastic scattering involving ^{19}F*(0.11) ($J^\pi = \frac{1}{2}^-$) and ^{19}F*(0.197) ($J^\pi = \frac{5}{2}^+$) [p_1 and p_2] are listed in Table 20.29 (1955BA94, 1963BE19). In general the resonances observed are identical with those reported from other ^{19}F + p reactions, although the relative intensities differ greatly. The p_2 scattering has been measured at $E_p = 5.6$ to 6.3 MeV (1967TH06), and at $E_p = 3.5$ to 7.0 MeV the yields of p_2, p_3, p_4 and p_5 show structures (1973BE1H; prelim.). The analyzing power has been measured for the p_0, p_2 and p_5 groups with polarized protons in the range 4 to 10 MeV: strong structures are observed for p_0 (1975EN1C, 1976EN1C; prelim. work; and R. Kaita, private communication). See also (1972AJ02, 1974HA1G) and ^{19}F.

36. ^{19}F(p, n)^{19}Ne $\qquad Q_m = -4.0207 \qquad E_b = 12.8447$

Yield measurements have been reported for $E_p = 4.23$ to 11 MeV: see (1972AJ02) and (1972KU24: 5.78 to 5.96 MeV; σ_t, n_0, n_{1+2}). Observed resonances are displayed in Table 20.30. A narrow anomaly is reported in the n_0 and n_{1+2} yields at $E_p = 5.879 \pm 0.007$ MeV, corresponding to the 2^+; $T = 2$ state of ^{20}Ne at 18.43 MeV (1972KU24). See also ^{19}Ne.

37. ^{19}F(p, α)^{16}O $\qquad Q_m = 8.1137 \qquad E_b = 12.8447$

Many resonances occur in this reaction. They are displayed in Tables 20.31, 20.32 and 20.33 depending on whether they are observed in the α_0 yield [Table 20.31], in the α_1 [or α_π] yield to ^{16}O*(6.05) [Table 20.32] or in the α_2, α_3 and α_4 yields [or in the yield of the γ-rays from ^{16}O*(6.13, 6.92, 7.12)] [Table 20.33]. Resonances for α_0 and α_1 are required to have even J, even π or odd J, odd π, while the α_2, α_3 and α_4 resonances are all odd-even or even-odd, with the exception of the $T = 2$ resonance discussed below.

A listing of the earlier yield studies is given in (1972AJ02). A detailed discussion of the evidence leading to many of the J^π assignments shown in Table 20.33 is given in (1959AJ76). Recent measurements are reported by (1974CA22: $E_p = 0.6$ to 1.8 MeV; $\alpha_0 \to \alpha_4$), (1972HE39: 1.3 to 2.2 MeV; $\gamma_{6.13}$, $\gamma_{6.92}$, $\gamma_{7.12}$) and (1972KU24: 5.65 to 6.20 MeV; $\alpha_0 \to \alpha_5$, $\alpha_7 \to \alpha_9$). The width of the forbidden decay of the 1^+ state at 13.17 MeV [see Table 20.33] by α_0, $\Gamma_{\gamma_0} \lesssim 7 \times 10^{-6}$ eV (1974KRZE; prelim. results). Anomalies are observed in α_0, α_1, α_2, α_4 and α_8 but not in α_3, α_5, α_7 and α_9 corresponding to the formation of the 2^+; $T = 2$ state at 18.43 MeV [$E_p = 5.88$ MeV] (1972KU24). The analyzing power for α_0, α_{1+2}, α_3 and α_4 have been measured for $E_p = 4$ to 10 MeV: strong structures are observed (1975EN1C, 1976EN1C; prelim. results; and R. Kaita, private communication). See also (1974HA1G, 1974LO1B, 1976CA1P), (1976GA1K; theor.), (1977CL1F; astrophys.) and ^{16}O in (1977AJ02).

38. ^{19}F(p, ^{8}Be)^{12}C $\qquad Q_m = 0.8599 \qquad E_b = 12.8447$

The excitation curves show strong resonant behavior (cross sections up to 1.5 mb/sr) for $E_x = 15.3$ to 18.7 MeV, over which region 28 angular distributions have been measured. Twelve states with $J^\pi \leq 4^+$ have been observed. The strongly populated states are in better agreement with those reported in the (p, α_1) yield to ^{16}O*(6.05) [$J^\pi = 0^+$] than those reported in the (p, α_0) yield

Table 20.29: Resonances in ^{19}F(p, p′)^{19}F* (1955BA94)

E_p (keV)	J^π	Γ_{lab} (keV)	Γ_{p_1} (eV)	Γ_{p_2} (eV)	$\theta^2_{p_1}$ [a] (%)	$\theta^2_{p_2}$ [a] (%)	E_x in ^{20}Ne (MeV)
340	1^+	2.9	< 0.5	< 0.1	< 15		13.168
483 [b]	1^+	2.2	< 1.3	< 1.2			13.303
598 [b]	2^-	37	< 100	< 60	< 28	< 145	13.413
669	1^+	7.5	46	< 0.5	0.6	< 0.4	13.480
720		≈ 30	< 10000	< 10000			13.528
780		≈ 10	< 400	≈ 9000			13.585
831		8.3	< 6	≈ 2300			13.634
845	0^+	23	≈ 50	< 10	≈ 0.14	< 0.92	13.647
873	2^-	5.2	< 2	570	< 0.07	2.7	13.674
900		4.8	< 30	≈ 2200			13.699
935	1^+	8.0	3000	< 20	5.0	< 0.8	13.733
1092		< 1.2					13.882
1137		3.7	< 40	≈ 2100			13.924
≈ 1250		≈ 80	≈ 70000	< 4000			14.03
1290		19	< 600	≈ 900			14.070
1346	2^-	4.5	300	600	0.92	0.24	14.123
1372	2^-	15	700	1400	1.93	0.56	14.148
1422	1^+	14.6 ± 1	2200	≤ 35	0.56	≤ 0.11	14.195
1610		≈ 5					14.374
1660							14.421
1700							14.459
5879 [c]	$2^+; 2$		r				18.427

r = resonant.

[a] (1955BA1C).

[b] (1963BE19).

[c] (1972KU24). Resonance also observed in p_3, p_4 and p_5 yields.

Table 20.30: Resonances in $^{19}F(p, n)^{19}Ne$

E_p (MeV)		Γ_{lab} (keV)	$^{20}Ne^*$ (MeV)
(1968RI08) [a]	(1963JE04) [b]	(1952WI27)	
4.30		45	16.93
4.46		80	17.08
4.52		20	17.14
4.61		60	17.22
4.72		25	17.33
4.75		45	17.35
4.87			17.47
4.95	4.96	20	17.55
5.03	5.03		17.62
5.11	5.11		17.70
5.26			17.81
5.25	5.26		17.84
5.37	5.37		17.94
(5.44)			(18.01)
5.50			18.07
5.57			18.13
(5.62)			(18.18)
(5.69)			(18.25)
5.72	5.73		18.28
5.77			18.32
5.84			18.39
	5.879 ± 0.007 [c]	10 ± 3 [c]	18.427
5.90			18.45
6.00	6.03		18.54
	6.15		18.68
	6.35		18.87
	6.53		19.04
	6.81		19.31
	7.14		19.62
	7.27		19.75

Table 20.30: Resonances in ^{19}F(p, n)^{19}Ne (continued)

E_p (MeV)		Γ_{lab} (keV)	^{20}Ne* (MeV)
(1968RI08) [a]	(1963JE04) [b]	(1952WI27)	
	7.41		19.88
	7.52		19.98
	7.74		20.19
	8.02		20.46
	8.15		20.58
	8.28		20.71
	8.37		20.79
	8.70		21.10
	8.82		21.22
	9.08		21.47
	9.2		21.6
	9.5		21.9
	9.8		22.1
	10.2		22.5

[a] ±5 keV.
[b] ±20 keV, except for the last four values.
[c] (1972KU24): 2^+; $T = 2$.

Table 20.31: Resonances for ground-state α-particles (α_0) in ^{19}F(p, α_0)^{16}O

E_p (keV)	Γ_{lab} (keV)	θ^2_α [a] (%)	J^π	^{20}Ne* (MeV)
400 [b]	100		1^-	13.225
400 [b]	100		0^+	13.225
650 ± 20 [b]	200		1^-	13.462
710 [a,b]	35	0.6	(1^-)	13.519
733	66	1.0	2^+	13.541
778	≈ 10	0.02	2^+	13.583
843	23	0.16 [j]	(2^+) [g]	13.645
≈ 860	120	2.1	1^-	13.66
≈ 930	≈ 180	2.9	0^+	13.73

Table 20.31: Resonances for ground-state α-particles (α_0) in ^{19}F(p, α_0)^{16}O (continued)

E_p (keV)	Γ_{lab} (keV)	θ_α^2 [a] (%)	J^π	^{20}Ne* (MeV)
≈ 1080	≈ 200	3.4	1^-	13.87
1115	50	0.55	2^+	13.904
1160	≈ 70	1.1	0^+	13.946
1235 [a,c]	≈ 70	1.2	1^-	14.017
≈ 1250 [a]	≈ 150	2.7	2^+	14.03
1358 [a,c,d]	54	0.49	2^+	14.134
1640 [c]	< 115			14.402
1709 [c,d]	140		0^+	14.468
1853 [c,d]	132		1^-	14.604
2110 [c,d,e]	75		$(2^+, 4^+)$	14.85
2310 [c,d,e]	90		(2^+)	15.04
2550 [e]	300		(1^-)	15.27
2390 [c,d,h]	300		(0^+)	15.30
2680 [c,h]	80			15.39
2730 [e]	60			15.44
2820 [e]	160			15.52
2940 [h]				(15.64)
3120 [h]	170			(15.81)
3340	105			16.02
3680	(100)			16.34
3860				16.51
3980	135			16.62
(4090) [k]			$0^+; T = 2$	16.73
4130	100			16.77
4360	100			16.98
4460	95			17.08
4690	65			17.30
4900	90			17.50
4990	40			17.58
5879 ± 7 [f]	10 ± 3		$2^+; T = 2$	18.427

[a] (1958IS10, 1958IS11).
[b] (1959BR67).
[c] (1958RA15).
[d] (1957CL42).
[e] (1964BR12).
[f] (1972KU24): $\Gamma_{\alpha_0} \approx 0.3$ keV.
[g] $J = 0$ from ^{19}F(p, p)^{19}F; possibly $T = 1$ (1955BA94, 1955BA1C).
[h] See, however, (1964BR12).
[i] (1967KU06).
[j] $\Gamma_{\alpha_0} \approx 0.06$ keV (1974CA22).
[k] See (1972AJ02): not published.

(1969GO1B, 1971GO1R). It is suggested that most of the observed states are of 8p-4h and 12p-8h configurations (1971GO1R). [(1969GO1B, 1971GO1R) are preliminary reports.]

39. (a) ^{19}F(p, t)^{17}F $Q_m = -11.0999$ $E_b = 12.8447$
(b) ^{19}F(p, ^{3}He)^{17}O $Q_m = -8.320$

For reaction (a) see ^{17}F in (1977AJ02) and (1974NE03). The polarization analyzing powers for the reaction to ^{17}O*(0, 0.87) have been measured at $E_p = 49.5$ MeV (1974NE03).

40. ^{19}F(d, n)^{20}Ne $Q_m = 10.6200$

Levels of ^{20}Ne derived from reported neutron groups are displayed in Table 20.34. Angular distributions have been measured at $E_d = 0.5$ to 6.1 MeV: see (1972AJ02) and at $E_{\vec{d}} = 8$ MeV (1976BEYD: n_1, n_6). The branching ratio for the γ-decay of the lowest 1^+; $T = 1$ state [^{20}Ne*(11.23)] to the ground state to ^{20}Ne*(1.63) is 0.53 ± 0.07 (1973KU1E: $E_d = 5.5$ MeV). See also (1975LE1K; applied) and (1972AJ02).

41. ^{19}F(^{3}He, d)^{20}Ne $Q_m = 7.3511$

Levels of ^{20}Ne observed in this reaction are displayed in Table 20.35. Deuteron angular distributions have been measured at $E(^3\text{He}) = 9.5$ and 10.0 MeV (1965SI18), 13.0 MeV (1963JA01), 16 MeV (1974VE03, 1976SE10), 18 MeV (1975BE02, 1976FO05) and 21 MeV (1973OB04). Spectroscopic factors obtained by (1973OB04, 1975BE02, 1976FO05, 1976SE10) are shown in Table 20.35. The angular distribution of the deuterons to ^{20}Ne*(4.25) is explained in terms of inelastic effects (1974VE03). See also (1965SI18) and (1977SU04; theor.).

Gamma-ray measurements are summarized in Tables 20.19 (1977MA07), 20.20 (1969AN08) and 20.35 (1969AN08, 1977MA07). See also (1972FO16, 1973FO1A, 1973FO1E, 1974FO1J).

Table 20.32: Nuclear pair resonances (α_π) in ^{19}F(p, α_π)^{16}O

E_p (keV)	Γ_{lab} (keV)	σ [c] (mb)	θ^2_α [c] (%)	J^π	^{20}Ne* (MeV)
710 [a]	35	≈ 0.2	2	1^-	13.519
780	≈ 10	≈ 0.2	0.15	2^+	13.585
842	23	3.4	0.27	2^+ [d]	13.644
1115	50	1.5	3.6	2^+	13.904
1236 [a,b]	≈ 70	3	1.0	1^-	14.018
1367 [a,b]	30	6.0	0.29	2^+	14.143
1630 [b]	60				14.39
1720	95	≈ 18			14.48
1880	170				14.63
2170	95				14.91
2330	≈ 100				15.06
2600	100				15.31
2680	100				15.39
2820	125				15.52
3120	145				15.81
3340	100				16.02
(3500)	(80)				(16.17)
(3590)	(115)				(16.25)
3960	200				16.60
4360	95				16.98
4690	< 150				17.30
4900	115				17.50
4990	40				17.58
5170	220				17.75

[a] See (1972AJ02).
[b] (1958RA15).
[c] (1958IS11).
[d] See footnote [g] in Table 20.31.

Table 20.33: Resonances for $6-7$ MeV γ-rays (α_2, α_3, α_4) in ^{19}F(p, α)^{16}O

E_{p} † (keV)	Γ_{lab} (keV)	Γ_{α_2} (eV)	Γ_{α_3} (eV)	Γ_{α_4} (eV)	J^{π}	^{20}Ne* (MeV)
226.9 ± 3.4 [a,b]	1.0	1000	< 2.5	< 2.5	2^-	13.060
340.46 ± 0.04 [c,d]	2.4 ± 0.2	2800	16	75	1^+	13.1680
483.8 ± 0.3 [e]	0.9 ± 0.1	700	19	190	1^+	13.3038
872.11 ± 0.20 [f,g]	4.7 ± 0.2	2200	620	180	2^-	13.6729
935.4 ± 1.3 [g]	8.1 ± 0.5	2900	110	720	1^+	13.733
1347.7 ± 1.0 [h,m]	4.9 ± 0.7	2250	650	1200	2^-	14.124
1373.0 ± 1.0 [i,m]	12.4 ± 1.0	6650	700	300	2^-	14.148
1694 ± 1.7 [j,m]	35 ± 3					14.453
1949 ± 2.5 [j,m]	40 ± 10					14.695
2030 ± 3.0 [j,m]	120 ± 20					14.722
2320 [k]	85					15.05
2510	30					15.23
2630	90					15.34
2800	60					15.50
3020	30					15.71
3190	80					15.87
3490	40					16.16
3920	30					16.57
4000	110					16.64
4090 [l]					$0^+; T=2$	16.73
4290	50					16.92
4490	30					17.11
4570	30					17.18
4710	30					17.32
4780	35					17.38
4990	20					17.58
5070	35					17.66
5200	70					17.78

[a] (1959KU79; assignment to this reaction probable but not certain). See also (1959AJ76).
[b] (1962KE03). $\Gamma_{\alpha_0} < 100$ eV.
[c] (1955BA94, 1959BO14, 1964SE1A, 1974KRZE). $\Gamma_{\alpha_0} \lesssim 7 \times 10^{-6}$ eV (1974KRZE).
[d] (1950AR1A, 1950BA1A, 1950CH1A). Values listed for E_p and Γ are those recommended by (1966MA60).
[e] (1959BO14, 1959KU79, 1960HU11, 1963BE19). $\Gamma_{\alpha_0} < 25$ eV (1963BE19).
[f] Values listed for E_p and Γ are those recommended by (1966MA60). Other values are $E_\mathrm{res} = 872.4 \pm 0.4$ keV (1959BO14), 873.5 ± 0.7 keV (1960HU11), 872.3 ± 0.5 keV (1961BE13), 871.80 ± 0.25 keV (1962RY01), 872.5 ± 1.1 keV (1965AS07). See also (1974CA22).
[g] (1965AS07).
[h] Other reported resonance energies are $E_\mathrm{p} = 1344.5 \pm 1.0$ keV (1959LI51), 1347.7 ± 1.0 keV (1960HU11), 1347.7 ± 1.8 keV (1965AS07).
[i] Other reported resonance energies are $E_\mathrm{p} = 1373.0 \pm 1.0$ keV (1959LI51), 1373.7 ± 1.2 keV (1960HU11), 1374.5 ± 1.8 keV (1965AS07).
[j] (1952WI27, 1955HU1A).
[k] (1952WI27); these values should be reduced by about 0.2%: see (1955KI28).
[l] Resonance in α_2 yield: see text (1967KU06).
[m] See also (1972HE39). The 1.69 MeV resonance may correspond to more than one state.

[†] *Footnote added in proof.* A number of other resonances shown in Table 20.13 of (1959AJ76) are not listed here because questions arose about their identification. However, (1978GO1F) report the observation of resonances at E_p = 597, 672, 835, 902, 1090, 1140, 1189 and 1283 keV: see (1959AJ76). I am indebted to F.C. Young for his comments.

42. ^{19}F(α, t)^{20}Ne $\qquad Q_\mathrm{m} = -6.9694$

At $E_\alpha = 28.5$ MeV angular distributions are reported for the tritons to ^{20}Ne*(0, 1.63, 4.25, 4.97, 5.62 + 5.78, 7.00 + 7.17 + 7.19) (1967HA23; DWBA). The distributions of the tritons to ^{20}Ne*(0, 1.63, 4.25) [$J^\pi = 0^+$, 2^+ and 4^+, respectively] have been reanalyzed in terms of the collective-model coupled-channels Born-approximation theory: C^2S for these three states are 0.08, 0.16 and 0.0 (CCBA) [the DWBA results are nearly the same]. Agreement with the values obtained in the (d, n) and (^{3}He, d) reactions is poor (1974OB02). Angular distributions have also been reported at $E_\alpha = 18.5$ and 28.4 MeV: see (1972AJ02).

43. ^{19}F(^{7}Li, ^{6}He)^{20}Ne $\qquad Q_\mathrm{m} = 2.867$

Angular distributions have been studied at $E(^7\mathrm{Li}) = 34$ MeV for the transitions to ^{20}Ne*(0, 1.63, 4.25, 4.97 (partial), 5.62, 5.78, 6.72, 7.1, 7.42). The spectroscopic factors, C^2S, for ^{20}Ne*(0, 1.63, 4.25, 5.78, 6.72, 7.42) are 0.36, 0.54, 0.06, 0.20 and 0.22, respectively, in good agreement with those reported in the (d, n) and (^{3}He, d) reactions (1975WI30).

Table 20.34: Neutron groups from ^{19}F(d, n)^{20}Ne [a]

E_x (MeV ± keV)		l_p [a]	$J^\pi; T$
(1958MO02, 1968LA03) [b]	(1969RI01)		
0		0	0^+
1.74 ± 30		2	2^+
4.20 ± 40			
4.96 ± 50			
5.62 ± 40			
6.80 ± 10		0	0^+
7.16 ± 90			
7.41 ± 50			
7.90 ± 40			
(8.71 ± 10)			
9.15 ± 40			
(9.50 ± 40)			
10.01 ± 30			
10.30 [c]	[d]		
	10.59		
10.853 ± 10	10.879 ± 40	2	$T = 1$ [f]
	11.03 ± 80 [d,h]		
11.233 ± 10	11.26 ± 40	0	1^+; (1) [f,g]
11.549 ± 10	11.568 ± 35	2	$(T = 1)$ [f]
	11.915 ± 30		
12.086 ± 10		[e]	$(T = 1)$ [f]
12.150 ± 10		[e]	$(T = 0)$ [f]
	12.179 ± 25		
12.200 ± 10		[e]	$(T = 1)$ [f]
12.245 ± 10		2	$T = 1$ [f]
12.379 ± 10	12.397 ± 20	0	$T = 0$ [f]
	13.086 ± 15		
	13.170 ± 15	0	1^+; (1) [g]
	13.481 ± 15	0	1^+; 1 [g]
	13.650 ± 15	0	(0^+); 1 [g]

Table 20.34: Neutron groups from ^{19}F(d, n)^{20}Ne [a] (continued)

E_x (MeV ± keV)		l_p [a]	$J^\pi; T$
(1958MO02, 1968LA03) [b]	(1969RI01)		
	13.882 ± 15		

[a] See also Table 20.31 in (1972AJ02).

[b] States below 10.1 MeV are from (1958MO02) who also report evidence for some other states; higher states are from (1968LA03). Data of (1968LA03) are adjusted downward by 26 keV: see (1969RI01).

[c] $E_x = 10.31 \pm 0.07$ (1964SA09), 10.33 ± 0.05 MeV (1966RI05).

[d] This state decays to ^{20}Ne*(1.63) (1966RI05).

[e] Weak group.

[f] (1968LA03).

[g] (1969RI01).

[h] A study of ^{19}F(d, n) thresholds by (1960BU07) suggested states at $E_x = 11.08$, 11.31, 11.66, 11.84, 12.16, 12.24 and 12.48 MeV [±20 keV]: see Table 20.32 in (1972AJ02).

Table 20.35: States of ^{20}Ne from ^{19}F(^{3}He, d)^{20}Ne

E_x [a] (MeV ± keV)	Γ [a] (keV)	nlj [a,b,c]	$J^\pi; T$ [a,b]	K^π [d]	$(2J+1)C^2S$		
					(1975BE02) [e]	(1976SE10) [f]	(1973OB04) [f]
0 [b]		$2s_{1/2}$	0^+	0_1^+		0.30	0.43
1.6353 ± 1.8 [h]		$1d_{5/2}$	2^+	0_1^+		1.43	1.90
4.249 ± 2.5 [h]		n.s.	4^+	0_1^+		0.08	0.0
4.968 ± 3 [h]		$1p_{3/2}$	2^-	2^-	(0.03)	0.021	0.040
5.623 ± 3 [h]		$1f_{7/2}$	3^-	2^-	(0.09)	0.10	0.028
5.785 ± 3		$2p_{3/2}$	1^-	0^-	0.16	0.10	0.12
6.722 ± 3		$2s_{1/2}$	0^+	0_2^+	0.52	0.39	0.22
7.00 [b]		$1f_{7/2}$	4^-	2^-		0.12	0.11
7.156 ± 8		$1f_{7/2}$	3^-	0^-	0.42	0.12	
7.422 ± 3		$1d_{5/2}$	2^+	0_2^+	0.79	0.39	0.60
7.829 ± 10		$1d_{5/2}$	2^+	0_3^+	0.06	0.046	0.045
≈ 8.3	≈ 800	$2s_{1/2}$	0^+	0_4^+	0.13		
8.45 [b]		n.s.	5^-	2^-			
8.70 [b]		n.s.	1^-				
8.769 ± 10		n.s.	6^+	0_1^+			

Table 20.35: States of ^{20}Ne from ^{19}F(^{3}He, d)^{20}Ne (continued)

E_x [a] (MeV ± keV)	Γ [a] (keV)	nlj [a,b,c]	$J^\pi; T$ [a,b]	K^π [d]	$(2J+1)C^2S$ (1975BE02) [e]	(1976SE10) [f]	(1973OB04) [f]
8.8 [g]	broad	$1d_{5/2}$	2^+		0.21 [g]		
8.841 ± 10		$2p_{3/2}$	1^-		(0.01)		
9.03 [b]		n.s.	4^+	0_3^+			
9.12 [b]		n.s.	3^-				
9.305 ± 10		$1d_{5/2}$	$(1, 2, 3)^+$		0.04		
9.469 ± 10		$1d_{5/2}$	2^+		0.03		
9.859 ± 3		$1d_{5/2}$	3^+ [i]		2.37		
9.92 [b]		n.s.	(1^+)				
9.99 [b]		n.s.	4^+	0_2^+			
10.257 ± 15		$1d_{5/2}$	$2^+; 1$		0.07		
10.40 [b]							
10.55 [b]							
10.568 ± 15	27	$1d_{5/2}$	2^+		0.05		
10.815 ± 15	12	$1d_{5/2}$	2^+		0.05		
10.860 ± 15		$1d_{5/2}$	$3^+; 1$ [i]		2.82		
10.951 ± 15							
11.067 ± 15		n.s.	$(4^+; 1)$				
11.239 ± 15					see [a]		
11.27 ± 15	73	n.s.					
11.549 ± 15		$1d_{5/2}$	3^+ [i]		1.00		
11.83 ± 15	81	$1d_{5/2}$			0.10		
11.992 ± 15		n.s.	(8^+)	0_1^+			
12.082 ± 15		$1d_{5/2}$			0.35		
12.190 ± 15	< 0.1 [i]	$1d_{5/2}$	$(1, 2, 3)$ [i]		2.10		
12.367 ± 15 [j]	< 200 [i]		3^- [i]		see [a,i]		
12.423 ± 15	160	$1d_{5/2}$	(2^+)		0.19		
12.503 ± 15		$1d_{5/2}$			0.02		
12.823 ± 15		$2s_{1/2}$			0.15		
13.037 ± 15		$1d_{5/2}$					
13.135 ± 15							
13.270 ± 15							

n.s. = not stripping.
[a] (1975BE02): $E(^3\text{He}) = 18$ MeV. The E_x measured by (1975BE02) appear to be systematically low by $14 - 30$ keV: see (1977MA07).
[b] (1976SE10): $E(^3\text{He}) = 16$ MeV.
[c] Orbital for direct transfer.
[d] (1973OB04): $E(^3\text{He}) = 21$ MeV.
[e] DWBA.
[f] CCBA.
[g] (1976FO05): $E(^3\text{He}) = 18$ MeV.
[h] Gamma-ray measurements (1969AN08).
[i] Gamma-ray measurements (1977MA07): $E_x = 9.88 \pm 0.03$, 10.89 ± 0.03, 11.59 ± 0.03, 12.22, 12.40 ± 0.04 MeV.
[j] α-decays to ^{16}O*(6.13) (1977MA07).

44. ^{19}F(^{10}B, ^{9}Be)^{20}Ne $\qquad Q_m = 6.259$

See (1973ME1F).

45. ^{20}F(β^-)^{20}Ne $\qquad Q_m = 7.0259$

The decay is principally to ^{20}Ne*(1.63) with a half-life of 11.00 ± 0.02 sec: see reaction 1 in ^{20}F and Table 20.36 for the branching to various ^{20}Ne states. The 0.02% branching to ^{20}Ne*(4.97) [$J^\pi = 2^-$] is consistent with the assignment $J^\pi = 2^+$ to the ground state of ^{20}F (1969GA05), as are measurements of the β-γ circularly polarized correlation (1961FR02, 1965MA28). When the β-γ correlation is described by $W(\theta) = 1 + p\cos^2\theta$, p has a value slightly different from zero and it varies linearly with E: dp/d$E = +0.09 \pm 0.05\%$ MeV^{-1} (1977MCZZ). (1977TR1H) report dp/d$E = +0.05 \pm 0.07\%$ MeV^{-1} and (1977RO1Y) find $+0.02 \pm 0.02$ MeV^{-1}. The β-decay asymmetry, $(ft)^+/(ft)^- = 1.044 \pm 0.010$ (1975AL27), 1.025 ± 0.013 (1976GE08): see also reaction 58 and (1974ST10). (1977RO1Y) find, by comparison with ^{20}Na, a vanishing second class current: the ratio of the second-class axial matrix element to the main first-class one is 1.1 ± 1.5 and a first-class second-forbidden axial contribution is 40 ± 8.

The energy of the γ-ray from ^{20}Ne*(1.63) is 1634.8 ± 0.6 keV (1967VA08), 1632.6 ± 0.8 keV (1966AL12), 1633.7 ± 0.3 keV (1968SP01), 1633.6 ± 0.3 keV (1972OP01). The γ-ray from the ($4.97 \rightarrow 1.63$) transition has $E_\gamma = 3334.3 \pm 0.7$ keV, $\Delta E_x = 3334.6 \pm 0.7$ keV, and using the E_x for ^{20}Ne*(1.63) shown in Table 20.18, E_x for ^{20}Ne*(4.97) $= 4968.4 \pm 0.8$ keV (1969GA05).

46. (a) ^{20}Ne(γ, n)^{19}Ne $\qquad Q_m = -16.8653$

(b) ^{20}Ne(γ, 2n)^{18}Ne $\quad Q_m = -14.419$

(c) ^{20}Ne(γ, p)^{19}F $\quad Q_m = -12.8447$

(d) ^{20}Ne(γ, α)^{16}O $\quad Q_m = -4.7309$

Table 20.36: Branching in ^{20}F(β^-)^{20}Ne

Decay to ^{20}Ne* (MeV)	J^π	Branch (%)	$\log ft$ [a]	Refs.
0	0^+	< 0.032		(1954WO23)
1.63	2^+	99.98	4.97	(1975AL27)
4.25	4^+	< 0.015		(1969GA05)
4.97	2^-	0.017 ± 0.003	6.88	(1969GA05)
5.62	3^-	< 0.048		(1963GL01)
5.78	1^-	< 0.1		(1963GL01)
6.72	0^+	< 0.67		(1963GL01)
7.00	4^-	< 0.2		(1963GL01)

[a] Based on $\tau_{1/2} = 11.00 \pm 0.02$ sec (1975AL27).

Bremsstrahlung measurements show peaks in the neutron yield (reaction (a)) at 17.8, 18.8, 19.1, 20.1, (22.0), (23.0) and (24.8) MeV [numbers in parentheses refer to relatively weak and broad structures]. The giant dipole resonance is centered at $\approx$ 20 MeV and the integral cross section to 28 MeV exhausts half of the dipole sum rule (1975WO06). The cross section for (γ, Tn) using monoenergetic photons shows a structure at 18 MeV and some fluctuations atop the broad giant dipole resonance, $\sigma_{max} \approx 7$ mb. The double photoneutron cross section, $\sigma(\gamma$, 2n), is dominated by a single peak at $\approx$ 20.5 MeV, $\sigma_{max} \approx 1.1$ mb (1974VE06). See also (1972AJ02, 1975BR1F, 1975WO06, 1977DA1B) and (1973ROYN, 1975SC05; theor.). For reaction (c) see (1962DO1A, 1963FI1B, 1969HO16) and (1975SC2B; theor.). For reaction (d) see (1959HA1C) and reaction 47.

47. (a) ^{20}Ne(e, e)^{20}Ne

(b) ^{20}Ne(e, ep)^{19}F $\quad Q_m = -12.8447$

(c) ^{20}Ne(e, eα)^{16}O $\quad Q_m = -4.7309$

The ^{20}Ne charge radius, $r_{rms} = 3.116 \pm 0.025$ fm (using a Born approx.) (1971MO15). See also the discussion in (1973SI31).

Form factors for many of the excited states of ^{20}Ne with $E_x < 8$ MeV have been reported: see (1973SI31; $E_e = 77.0, 81.3, 102.4, 110.5, 114.4$ MeV) and (1972MI06; 200 and 250 MeV). The monopole matrix elements for the $0^+ \rightarrow 0^+$ transitions are 7.4 ± 2.0 and 6.9 ± 1.4 fm^2 for ^{20}Ne*(6.72, 7.19) (1972MI06) while (1973SI31) calculate $\Gamma_\pi = 3.9 \times 10^{-5}$ eV for ^{20}Ne*(6.72). B(E2)↑ is $0.028 \pm 0.004\ e^2 \cdot \mathrm{b}^2$ for the transition to ^{20}Ne*(1.63). The transitions to ^{20}Ne*(4.25, 7.83) correspond to 23 ± 5 W.u. and 0.77 ± 0.25 W.u. (1973SI31). (1972MI06) report B(E2)↑ $=$ 0.13 ± 0.03 and 0.83 ± 0.13 W.u. for the transitions to ^{20}Ne*(7.42, 7.83).

At $E_e = 39$ and 56 MeV, the $180°$ inelastic scattering is dominated by the transition to a $J^\pi = 1^+$; $T = 1$ state at $E_x = 11.22 \pm 0.05$ MeV with $\Gamma_{\gamma_0} = 11.2^{+2.1}_{-1.8}$ eV. A subsidiary peak is observed corresponding to a state at an $E_x = 0.35 \pm 0.03$ MeV higher [if $J^\pi = 1^+$ or 2^+, $\Gamma_{\gamma_0} = 0.65 \pm 0.18$ or 0.40 ± 0.13 eV]. A number of small peaks are also reported corresponding to $E_x \approx 12.0$, 12.9, 13.9, 15.8, 16.9, 18.0 and 19.0 MeV ((1971BE18), and W.L. Bendel, private communication). See also (1975CH41, 1975SZ1B).

A study of reaction (b) at $E_e = 30$ MeV shows strong resonances (assuming ground-state transitions) at $E_x = 17.70$, 18.87, 19.87 and 21.02 MeV, respectively, as well as some weaker structures (1962DO1A).

Reaction (c) has been studied in order to obtain the (γ, α_0) cross section in the giant resonance region: the cross section at $90°$ for $E_x = 15$ to 24 MeV is dominated by an E1 resonance [1^-; $T = 1$, with an admixture of $T = 0$ which permits the α_0 decay] at $E_x = 20$ MeV; lesser E1 structures are reported at $E_x = 16.7$, 17.1, 21 and 22 MeV. A relatively strong 2^+; $T = 0$ resonance appears at $E_x = 18.5$ MeV, and evidence is reported for increasing E2 strength below 16 MeV (1975SK06).

See also (1972RI1B, 1972THZF, 1973TH1B, 1974DE1E, 1974HA1G, 1975BE1G, 1975FA1A, 1976HA1Q) and (1972HA25, 1972HI17, 1972HO1D, 1972SA1C, 1973AN30, 1973CH1F, 1973CU03, 1973HO41, 1973LE1D, 1974AB05, 1974DZ05, 1974HA1C, 1975AB04, 1975DO10, 1976FU1K, 1976NO10, 1977SU04; theor.).

48. ^{20}Ne(n, n)^{20}Ne

See ^{21}Ne in (1978EN06) and (1976ZA1E; theor.).

49. (a) ^{20}Ne(p, p)^{20}Ne

(b) ^{20}Ne(p, pα)^{16}O $\qquad Q_m = -4.7309$

(c) ^{20}Ne(p, 2p)^{19}F $\qquad Q_m = -12.8447$

Angular distributions of elastically scattered protons and of a number of inelastic groups have been measured for $E_p = 2.15$ to 41.8 MeV: see (1972AJ02) for the earlier work and (1969MA48: 3.66 to 5.90 MeV; p$_0$, p$_1$), (1976DE12, 1976SW1C: 24.5 MeV; p to ^{20}Ne*(0, 1.63, 4.25, 4.97, 5.62, 5.78, 6.72, 7.00, 7.17 + 7.19, 7.42, 7.83, 8.45, 8.69, 8.78, 9.03, 9.12, 9.31 + 0.02, 9.51)), (1973DE06, 1974DE46: 30 MeV; p_0, p_1, p_2) and (1977CO1G: 35.2 MeV; p_0). The $E_p = 24.5$ and 30 MeV angular distributions for the 0^+, 2^+ and 4^+ members of the ground-state $K^\pi = 0^+$ band are well fitted using coupled-channels calculations and deformation parameters of $\beta_2 = +0.47 \pm 0.04$ and $\beta_4 = +0.28 \pm 0.05$. When the 6^+ state is included [^{20}Ne*(8.78)], the fit is improved if $\beta_6 = -0.10$ is included (1973DE06, 1974DE46, 1976DE12, 1976SW1C). The state at $E_x = 9.31 \pm 0.02$ MeV is suggested to have $J^\pi = (4^+)$ and to be the 4^+ member of the $K^\pi = 0^+$ band based on ^{20}Ne*(6.72): $\beta_2 = 0.15$ (1976SW1C): see, however, Table 20.35.

For p-γ angular correlations see (1972AJ02). See also (1969MA48). For polarization measurements see (1972DE18, 1976DE12, 1977PL1C) and ^{21}Na in (1978EN06). For yield measurements see (1972HI1C, 1976SW1C) and ^{21}Na in (1978EN06). For reaction (b) see (1971EP03). See also (1970QU1C). For a study of spallation see (1974PA10). See also (1972AS13, 1976AM04, 1976ES1B; theor.). For reaction (c) see (1964KA1A; theor.).

50. ^{20}Ne(d, d)^{20}Ne

Angular distributions have been reported at $E_d = 10.95$ to 11.8 MeV and at 52 MeV [see (1972AJ02)], at $E_{\vec{d}} = 10.0$ to 12.0 MeV (1975DA1F; d_1), 11.6 MeV (1973BR15; d_0) and 11.66 MeV (1975DA1F; d_2) and at $E_d = 40$ MeV (1974EP1B; d_1 and d_2). See ^{22}Na in (1978EN06) for polarization and yield measurements. See also (1971SI24; theor.).

51. ^{20}Ne(t, t)^{20}Ne

The elastic scattering has been studied at $E_t = 1.80$ and 2.00 MeV (1969HE08). See also (1972SC10; theor.).

52. ^{20}Ne(^{3}He, ^{3}He)^{20}Ne

Angular distributions have been measured at $E(^3\text{He}) = 10$ to 35 MeV [see (1972AJ02)] and at 68 MeV (1974DE05: ^{3}He to ^{20}Ne*(0, 1.63, 4.25)). The angular distributions at $E(^3\text{He}) = 68$ MeV are well fitted by a coupled channels calculation with $\beta_2 = 0.47$ and $\beta_4 = 0.17$ (1974DE05). See also (1975MA25, 1976MA36; theor.).

53. (a) ^{20}Ne(α, α)^{20}Ne

(b) ^{20}Ne(α, 2α)^{16}O $\qquad Q_m = -4.7309$

(c) ^{20}Ne(α, ^{12}C)^{12}C $\qquad Q_m = -4.6181$

Angular distributions have been measured to low-lying states of ^{20}Ne at $E_\alpha = 3.8$ to 155 MeV: see (1972AJ02) and (1975AB1H, 1975DA1E: α_0; 3.8 to 8 MeV), (1977EN01: α_0; 20.2 − 23.0 MeV), (1975CO1K: α_0; 26.6, 27.2 and 27.8 MeV), (1972RE05: α_0, α_1, α_2; 104 MeV) and (1976KN05: α_1 and α to ^{20}Ne*(18.1 − 28.2); 155 MeV). A coupled-channel analysis of the work at $E_\alpha = 104$ MeV leads to $\beta_2 = +0.35 \pm 0.01$, $\beta_4 = +0.11 \pm 0.01$, $Q_{20} = +0.46 \pm 0.02$ b and $Q_{40} = +0.026 \pm 0.002$ b^2 (1972RE05). At $E_\alpha = 155$ MeV (1976KN05) find that the strength concentrated in the giant quadrupole resonance exhausts more than 30% of the isoscalar energy weighted sum rule. See also (1975MO04, 1976YO02). Yield measurements are reported by (1974BA76: $E_\alpha = 10.25$ to 14.82 MeV; most α-groups to ^{20}Ne* states with $E_x < 8$ MeV) and by (1975AB1H, 1975CO1K, 1975CO1M, 1975DA1E). See also (1974HA1C, 1976HA1Q) and (1971FE1F, 1972MA65, 1972RE01, 1972SH09, 1973RE11, 1974PI11, 1974MA11, 1975GI10, 1976BE1P, 1976MA19, 1976MA36, 1977KN02; theor.).

For reaction (b) see ^{16}O in (1977AJ02), (1974EP01: $E_\alpha = 78.6$ MeV) and (1977WA1M: $E_\alpha = 140$ MeV). See also (1974MU1D), (1975RO1B) and (1975MI11; theor.). For reaction (c) see (1963LA08). See also ^{24}Mg in (1978EN06).

54. ^{20}Ne(^{7}Li, ^{7}Li)^{20}Ne

The elastic angular distribution has been measured at $E(^7\text{Li}) = 36$ MeV (1976CO23).

55. ^{20}Ne(^{12}C, ^{12}C)^{20}Ne

Elastic angular distributions have been obtained at $E(^{12}\text{C}) = 22.2$, 27.2, 32.3, 37.3 and 42.7 MeV [see (1974VA18)] and at $E(^{20}\text{Ne}) = 65.7$ MeV (1975DO06). For a fusion study, see (1977CO1Q). See also (1977PR1F) and (1976VA12, 1977OS02; theor.).

56. ^{20}Ne(^{16}O, ^{16}O)^{20}Ne

Angular distributions have been studied at $E(^{20}\text{Ne}) = 50$ MeV (1976ST18) and 94.8 MeV (1977MO1H) involving ^{16}O$_{\text{g.s.}}$ and ^{20}Ne*(0, 1.63, 4.25): qualitative agreement is found with the assumption of an α-cluster exchange process dominating at backward angles (1976ST18). See also (1975ZI1C).

57. ^{20}Ne(^{32}S, ^{32}S)^{20}Ne

The static quadrupole moment of ^{20}Ne*(1.63), $Q_{20} = +0.94 \pm 0.38$ b (1969SC08).

Table 20.37: Decay of ^{20}Na

Decay to ^{20}Ne* (MeV $\pm$ keV)	$J^\pi; T$	Branching ratio (%) [a]		log ft
		(1973TO08)	(1976IN06) [d]	
1.633 ± 2 [b]	$2^+; 0$	79.47 ± 1.57	79.18 ± 1.58	4.988 ± 0.009 [f]
7.415 ± 5 [e]	$2^+; 0$	16.37 ± 1.28		4.19 ± 0.05
7.826 ± 7 [e]	$2^+; 0$	0.674 ± 0.055		5.417 ± 0.033
8.82 ± 10 [e]		0.034 ± 0.007		6.27 ± 0.08
9.481 ± 7 [e]	$2^+; 0$	0.247 ± 0.020		5.064 ± 0.034
9.873 ± 5 [b]	$3^+; 0$		0.0272 ± 0.0138	5.78 ± 0.18 [f]
10.274 ± 3 [b,c]	$2^+; 1$ [g]	2.89 ± 0.23	2.944 ± 0.224	3.471 ± 0.033 [f]
10.584 ± 7 [e]	$2^+; 0$	0.087 ± 0.009		4.76 ± 0.05
10.848 ± 7 [e]	$2^+; 0$	0.193 ± 0.016		4.179 ± 0.035
10.884 ± 3 [b]	$3^+; 1$		0.0392 ± 0.0139	4.84 ± 0.13 [f]
11.261 ± 5 [b]	$1^+; 1$		0.203 ± 0.026	3.73 ± 0.05
11.320 ± 15 [e]	$2^+; 0$	0.036 ± 0.004		4.41 ± 0.05
11.856 ± 20 [e]	$2^+; 0$	0.0016 ± 0.0004		4.98 ± 0.10

[a] For upper limits to other ^{20}Ne states see Table 20.34 in (1972AJ02) and (1973TO08, 1976IN06). For earlier values see (1972AJ02).

[b] (1976IN06).

[c] 10.278 ± 5 (1973TO08).

[d] Electron capture + β^+.

[e] (1973TO08).

[f] Includes radiative, nuclear size, lepton wavelength, electron screening and electron capture corrections (1976IN06).

[g] Assuming $\Gamma_\gamma = 5.6 \pm 0.6$ eV, $\Gamma_{\rm total} = 356 \pm 230$ eV (1973TO08).

58. ^{20}Na(β^+)^{20}Ne $\qquad$ $Q_m = 13.887$

^{20}Na has a half-life of 446 ± 3 msec: see reaction 1 in ^{20}Na. It decays to a number of states of ^{20}Ne, principally ^{20}Ne*(1.63): see Table 20.37. The ratio of the mirror decays ^{20}Na $\xrightarrow{\beta^+}$ ^{20}Ne*(1.63) and ^{20}F $\xrightarrow{\beta^-}$ ^{20}Ne*(1.63), $(ft)^+/(ft)^- = 1.026 \pm 0.024$ (1973TO08), 1.033 ± 0.022 (1976IN06). (1977RO20) obtain a correlation $W_+(\theta) = 1 + \cos^2\theta[(-4.0 \pm 0.7) \times 10^{-3}E + (1.3 \pm 0.9) \times 10^{-4}E^2](p/E)^2$: assuming the validity of CVC this leads to a vanishing second-class current. See also reaction 45. The β-α angular correlation involving the allowed transition to ^{20}Ne*(7.42) is consistent with the predictions of the CVC theory (1977FR08). See also (1972TO08, 1973IN01, 1974AL11, 1975RO1R, 1977RO1W) and (1971WI1C, 1972EM02, 1972WI1C, 1973LA03, 1974WI1L, 1975WI1E, 1977CA11, 1977OK1E, 1977WI02; theor.).

59. ^{21}Ne(p, d)^{20}Ne $\qquad$ $Q_m = -4.537$

Angular distributions have been measured for the first four deuteron groups at $E_p = 14.1$ MeV (1972HE24) and 20 MeV (1970HO19). (1972HE24) report spectroscopic factors of 0.50 and 0.14 for ^{20}Ne*(1.63, 4.97): the other two distributions do not show direct reaction features.

60. ^{21}Ne(d, t)^{20}Ne $\qquad$ $Q_m = -0.504$

The $T = 1$ states observed in this reaction, and the analog states observed in ^{20}F in the (d, ^{3}He) reaction, are displayed in Table 20.16. The spectroscopic factors of analog states are consistent to within 20% for states excited by a single l-transfer. $T = 0$ states are displayed in Table 20.38 (1974MI13).

61. ^{21}Ne(^{3}He, α)^{20}Ne $\qquad$ $Q_m = 13.816$

See (1973FO1E).

62. ^{22}Ne(p, t)^{20}Ne $\qquad$ $Q_m = -8.644$

Angular distributions have been reported at $E_p = 26.9$, 35.1 and 42.4 MeV (1971FA07: t_0, t_1, t_2, t_3, t_{4+5}, t_6) and at 43.7 MeV (1964CE05). At the higher energy the distributions of the tritons to the ground state of ^{20}Ne and to the first 0^+; $T = 2$ state [$E_x = 16.722 \pm 0.025$ MeV (1969HA38)] have been fitted by $L = 0$ and the tritons to ^{20}Ne*(18.5) by $L = 2$. The latter is the first 2^+;

Table 20.38: $T = 0$ states of ^{20}Ne from ^{21}Ne(d, t)^{20}Ne (1974MI13) [a]

E_x (MeV ± keV)	l	nlj [b]	C^2S	J^π [c]	K^π
$\equiv 5.622$	1	$1p_{3/2}$	0.02	3^-	
5.785 ± 4	1	$1p_{1/2}$	0.03	1^-	
$\equiv 7.424$	$0+2$	$2s_{1/2}$	0.05		
		$1d_{5/2}$	0.07	2^+	
7.827 ± 9	$0+2$	$2s_{1/2}$	0.005		
		$1d_{5/2}$	0.023	2^+	
8.839 ± 8	1	$1p_{1/2}$	0.33	1^-	(1^-)
9.084 ± 21 [d]	2	$1d_{5/2}$	≤ 0.12		
9.357 ± 17 [d]	1	$1p_{1/2}$	≤ 0.1	[e]	(1^-)
9.913 ± 19 [d]	2	$1d_{5/2}$	< 0.16		
10.385 ± 12	1	$1p_{3/2}$	0.08	3^-	
10.880 ± 10 [d]	1	$1p_{3/2}$	0.13		

[a] For $T = 1$ states see Table 20.16.

[b] Values used in DWBA calculations.

[c] From Table 20.18.

[d] Unresolved.

[e] See, however, discussion in (1974MI13).

$T = 2$ state (1974CE1A). The 0^+; $T = 2$ state [^{20}Ne*(16.73)] decays by α_0 [$-6 \pm 5\%$], $\alpha_1 + \alpha_2$ [$35\pm12\%$], $\alpha_3+\alpha_4$ [$29\pm12\%$], $p_0+p_1+p_2$ [$14\pm9\%$] and $p_3+p_4+p_5$ [$13\pm8\%$] [measured branching ratios in percent are given in the brackets] to final states in ^{16}O and ^{19}F (1970MC04). The ratios of the cross section for formation of the analog states ^{20}Ne*(10.27)/^{20}F*(0) and ^{20}Ne*(12.25 ± 0.03)/^{20}F*(1.85) are 2.00 ± 0.20 and 1.40 ± 0.15, respectively, at $E_p = 45$ MeV (1969HA19). See also (1971GO1Q).

At $E_p = 40$ MeV angular distributions of the tritons to ^{20}Ne*(4.97, 5.62, 7.00) [$J^\pi = 2^-$, 3^- and 4^-, respectively] have been measured. Coupled-channels calculations reproduce the distributions to the 2^- and 3^- states, but the distribution to the 4^- states cannot be explained entirely in terms of multistep inelastic processes (1975CH17). See also (1974VO11).

See also (1973FO1E) and (1972FE1A, 1972OL04, 1972SC10, 1973BA18, 1973OL03, 1973UD01, 1976KI09; theor.).

63. ^{22}Ne(α, ^{6}He)^{20}Ne $\qquad Q_m = -16.155$

See (1972AJ02).

64. ^{23}Na(p, α)^{20}Ne $Q_{\rm m} = 2.377$

The first five states of ^{20}Ne have been observed in this reaction, and angular distributions have been measured at $E_{\rm p} = 10.0$ and 45.5 MeV: see (1972AJ02).

For work dealing with resonances in the compound nucleus see (1972AJ02), (1974VO09) and ^{24}Mg in (1978EN06). See also (1973AR1F, 1973CL1E; astrophys. considerations).

65. ^{23}Na(^{3}He, ^{6}Li)^{20}Ne $Q_{\rm m} = -1.643$

At $E(^{3}{\rm He}) = 40.7$ MeV, angular distributions have been measured to ^{20}Ne*(0, 1.63, 4.25) and analyzed using zero-range DWBA (1972OH01).

66. (a) ^{24}Mg(γ, α)^{20}Ne $Q_{\rm m} = -9.3125$
(b) ^{24}Mg(p, pα)^{20}Ne $Q_{\rm m} = -9.3125$
(c) ^{24}Mg(α, 2α)^{20}Ne $Q_{\rm m} = -9.3125$

For reaction (a) see (1973CL1E; astrophys.). For reaction (b) see (1970LI08, 1975ST1Q). See also (1975BA2H), (1975RO1B) and (1975PA1K, 1977CH02; theor.). At $E_{\alpha} = 90$ MeV ^{20}Ne states at $E_{\rm x} = 0$, 1.63 ± 0.035, 4.25 ± 0.06, 5.70 ± 0.06, 6.72 ± 0.05 and 11.41 ± 0.05 MeV are populated: the ground states S_{α} (DWIA) $= 1.3 \pm 0.2$ (1976SH02).

67. ^{24}Mg(d, ^{6}Li)^{20}Ne $Q_{\rm m} = -7.839$

Angular distributions have been studied involving ^{20}Ne*(0, 1.63, 4.25) at $E_{\rm d} = 28$ MeV (1972CO23), 35 MeV (1976CO15; also ^{20}Ne*(5.62, 5.78)), 54.3 MeV (1977TA1D; also ^{20}Ne*(5.62+5.78)) and 80 MeV (1974DJ01; also ^{20}Ne*(5.62)). Using zero-range DWBA, (1976CO15) report $S_{\alpha} = 0.21$, 0.19, 0.87, 0.26, 0.04 for ^{20}Ne*(0, 1.63, 4.25, 5.62, 5.78). See also (1973FO1A, 1973FO1E, 1974FO1J).

68. ^{24}Mg(^{3}He, ^{7}Be)^{20}Ne $Q_{\rm m} = -7.726$

Angular distributions involving ^{7}Be$_{\rm g.s.}$ and ^{7}Be$^*_{0.43}$ and ^{20}Ne*(0, 1.63, 4.25) have been measured at $E(^3{\rm He}) = 25.5$ MeV (1976PI10) and 70 MeV (1976ST11; also ^{20}Ne*(4.97, 5.62)). Spectroscopic factors from a FRDWBA analysis of the 25.5 MeV data give 1.0, 15.4 and 3.5 [from ^{7}Be$_{\rm g.s.}$ data] and 1.0, 23.4 and 4.3 [from ^{7}Be$^*_{0.43}$ data] for ^{20}Ne*(0, 1.63, 4.25). The absolute spectroscopic factors for ^{20}Ne$_{\rm g.s.}$ are 0.67 [^{7}Be$_{\rm g.s.}$] and 0.63 [^{7}Be$^*_{0.43}$] (1976PI09, 1976PI10). See also (1973BR1C).

69. ^{25}Mg(d, ^{7}Li)^{20}Ne $\qquad Q_{\rm m} = -7.920$

See (1971MC04).

70. ^{26}Mg(p, t$_\alpha$)^{20}Ne $\qquad Q_{\rm m} = -19.255$

See (1967MC06).

^{20}Na

(Figs. 11, 12 and 13)

GENERAL: (See also (1972AJ02).)

(1973HA77, 1973SU1B, 1974HA17, 1976CH1T, 1977SH13).

$J = 2$ (1975SC20);

$\mu = 0.3694 \pm 0.0002$ nm (1975SC20).

1. ^{20}Na(β^+)^{20}Ne $\quad Q_{\rm m} = 13.887$

^{20}Na decays by positron emission to ^{20}Ne*(1.63) and to a number of other excited states of ^{20}Ne: see Table 20.37. The half-life of ^{20}Na is 442 ± 5 msec (1971GO18, 1971WI07), 446 ± 8 msec (1972MO08), 448 ± 4 msec (1973TO08): the weighted mean of these measurements is 446 ± 3 msec. The character of the β^+ decay sets $J^\pi = 2^+$ for the ground state of ^{20}Na. $J = 2$ is confirmed also by the work of (1975SC20) who studied the asymmetry in the β^+ decay of polarized ^{20}Na nuclei to detect r.f. transitions between h.f.s. Zeeman levels of the atomic ground state [see the "GENERAL" section here]. See also reaction 58 in ^{20}Ne.

2. ^{20}Ne(p, n)^{20}Na $\quad Q_{\rm m} = -14.669$

Observed neutron groups at $E_{\rm p} = 22.9$ MeV are displayed in Table 20.40 (1971MO34). See also (1972BA1U) and (1972AJ02).

3. ^{20}Ne(^{3}He, t)^{20}Na $\quad Q_{\rm m} = -13.906$

At $E(^3{\rm He}) = 32$ MeV, triton groups are observed to nine states of ^{20}Na: see Table 20.40 (1965DO04, 1965PE04).

4. ^{24}Mg(^{3}He, ^{7}Li)^{20}Na $\quad Q_{\rm m} = -20.751$

See (1976BE1L).

Table 20.39: Energy levels of ^{20}Na

E_x (MeV $\pm$ keV)	$J^\pi; T$	$\tau_{1/2}$ or $\Gamma_{c.m.}$	Decay	Reactions
0	$2^+; 1$	$\tau_{1/2} = 446 \pm 3$ msec	β^-	1, 2, 3, 4
0.591 ± 12				2, 3
0.768 ± 8				2, 3
(0.85 ± 50)				3
0.958 ± 8				2, 3
(1.010 ± 14)				2
1.310 ± 10				2, 3
1.92 ± 40				3
2.89 ± 50		[a]		3
4.33 ± 100		[a]		3

[a] Broad or unresolved.

Table 20.40: States of ^{20}Na from ^{20}Ne(p, n)^{20}Na and ^{20}Ne(^{3}He, t)^{20}Na

E_x (MeV $\pm$ keV)	
^{20}Ne(p, n)^{20}Na (1971MO34)	^{20}Ne(^{3}He, t)^{20}Na (1965DO04, 1965PE04)
0	0
0.591 ± 12	0.65 ± 50 [a]
0.768 ± 8	0.75 ± 50 [a]
	0.85 ± 50 [a]
0.958 ± 8	0.95 ± 50 [a]
(1.010 ± 14)	
1.310 ± 10	1.27 ± 50
	1.92 ± 40
	2.89 ± 50
	4.33 ± 100

[a] These states are not fully resolved.

^{20}Mg

(Fig. 13)

^{20}Mg has been populated in the ^{24}Mg(α, ^{8}He) reaction at $E_\alpha = 126.9$ MeV (1976TR03) and 156 MeV (1974RO17) with differential cross sections (lab) of 3 ± 1 nb/sr ($\theta = 5°$, lab) and ≈ 7 nb/sr (2°), respectively. Assuming the mass of ^{8}He to be 31.601 ± 0.013 MeV, the mass excess of ^{20}Mg is 17.57 ± 0.03 MeV. (1977WA08) adopt a mass excess of 17.568 ± 0.027 MeV, and so do we. ^{20}Mg is then stable with respect to breakup into ^{19}Na + p [see ^{19}Na] and ^{18}Ne + 2p by 2.65 ± 0.03 and 2.33 ± 0.03 MeV, respectively. See (1976WA18) for a display of calculations of the mass of ^{20}Mg and (1972AJ02) for the earlier work. The mass excess of ^{20}Mg appears to involve a deviation from the quadratic IMME prediction (1976TR03). Using the wave function predictions of (1973LA03) and the mass excess of ^{20}Mg (1976TR03) calculate the partial $\tau_{1/2}$ for the allowed Fermi transition from the 0^+; $T = 2$ ground state of ^{20}Mg to the 0^+; $T = 2$ state in ^{20}Na [not observed] to be ≈ 3.4 sec, corresponding to a β^+ branching of $\approx 4\%$. See also (1976BE1L, 1977SH13).

^{20}Al

(Not illustrated)

^{20}Al has not been observed: see (1966KE16).

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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