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Energy Levels of Light Nuclei
$A = 20$

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Abstract: An evaluation of $A = 18$–20 was published in *Nuclear Physics A*475 (1987), 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.

(References closed June 1, 1987)

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Table of Contents for $A = 20$

Below is a list of links for items found within the PDF document. Figures from this evaluation have been scanned in and are available on this website or via the link below. The introductory Table 2 is also available via the link.

^{20}n, ^{20}He, ^{20}Li, ^{20}Be

(Not observed)

See (1983ANZQ, 1983BE55; theor.).

^{20}B

(Not observed)

The mass excess of ^{20}B is predicted to be 69.08 MeV. ^{20}B is then unstable with respect to breakup into ^{19}B + n by 0.9 MeV: see ^{19}B and (1978AJ03). See also (1983ANZQ; theor.).

^{20}C

(Not illustrated)

^{20}C has been observed in the fragmentation of 60 MeV/A argon ions: its mass excess is 37.20 ± 1.13 MeV (1987GI1E). It is then stable with respect to ^{19}C + n and ^{18}C + 2n by 3.3 and 3.9 MeV, respectively. See also (1978AJ03, 1983AJ01). The half-life of ^{20}C is calculated to be 9.3×10^{-3} sec (1984KL06). See also (1985AN1B, 1985LA03, 1986AN07, 1986GU1D) and (1982AV1A, 1983ANZQ, 1987SA15; theor.).

^{20}N

(Not illustrated)

^{20}N is particle stable. Its atomic mass excess is 21.64 ± 0.26 MeV (1986VI09), 22.20 ± 0.36 MeV (1986GI10), 21.62 ± 0.14 MeV (1987GI1E). We adopt 21.62 ± 0.14 MeV. ^{20}N is then stable with respect to ^{19}N + n by 2.32 MeV (see ^{19}N). The half-life of ^{20}N is 100^{+30}_{-20} msec, $P_{\rm n} \approx 61\%$ (1987MU1J; prelim.). See also (1984KL06; theor.). See also (1985PIZZ, 1986PI09), (1983WI1A, 1984HI1A, 1986AN07, 1986GU1D) and (1983ANZQ; theor.).

^{20}O

(Figs. 10 and 13)

GENERAL: (See also (1983AJ01).)

Model calculations: (1978WI1B, 1982SH30, 1984CH1V, 1984HA14, 1984RA13, 1984SA37, 1985HA15, 1985HU08, 1985LE1L, 1986COZZ, 1986HE13, 1986HU1G, 1986VO07, 1986WA1R, 1987IA1B).

Complex reactions involving ^{20}*O:* (1983FR1A, 1983WI1A, 1984HI1A, 1985HA1N, 1985PO11, 1986HA1B, 1986IR01, 1986PO06, 1986PO15, 1987RI03).

Other topics: (1978WI1B, 1983SH32, 1984PO11, 1984SA37, 1985AN28, 1985MU10, 1986AN07).

Ground state of ^{20}O: (1978WI1B, 1983ANZQ, 1984FR13, 1987SA15).

Mass of ^{20}O: From the Q-value of the ^{18}O(t, p)^{20}O reaction the atomic mass excess of ^{20}O is stated to be 3796.3 ± 1 keV (1985AN17). See also (1982AN12, 1985WA02, 1986GU1D).

For B(E2) of ^{20}O*(1.67) and other parameters see (1987RA01) and Table 2 of the Introduction in this publication.

1. ^{20}O(β^-)^{20}F $\qquad Q_{\rm m} = 3.814$

^{20}O decays with a half-life of 13.51 ± 0.05 sec to the 1^+ states ^{20}F*(1.06, 3.49) with branching ratios (99.973 ± 0.003) and (0.027 ± 0.003)%, $\log f_0 t = 3.740 \pm 0.006$ and 3.65 ± 0.06, respectively (1987AL06). Upper limits for branching to other states of ^{20}F are shown in Table II of (1987AL06). See also (1985BR29).

2. ^{18}O(t, p)^{20}O $\qquad Q_{\rm m} = 3.082$

$Q_0 = 3082.4 \pm 1.3$ keV (1985AN17). See also (1982AN12).

Observed proton groups are displayed in Tables 20.2 of (1983AJ01) and 20.1 here. ^{20}O*(4.07) decays to ^{20}O*(0, 1.67) with branchings of (26 ± 4) and (74 ± 4)%. The p-γ angular correlations lead to $J = 2$; the strength of the transition favors $\pi = +[\delta$(E2/M1) $= -0.18 \pm 0.08$ for the $2^+ \rightarrow 2^+$ transition]. ^{20}O*(4.46) and ^{20}O*(5.39) decay primarily via ^{20}O*(1.67); the direct ground-state decay is < 4% for the first and < 7% for the second of these states. The angular correlations are essentially isotropic, favoring $J^\pi = 0^+$. The transition ^{20}O*$(5.39 \rightarrow 4.07)$ is not observed: the upper limit is 8%. See also (1978AJ03, 1983AJ01). For a discussion of $A = 20$ isobaric states see (1982AN12, 1985AN17).

3. ^{18}O(α, 2p)^{20}O $\qquad Q_{\rm m} = -16.732$

See (1983AJ01).

4. ^{18}O(^{18}O, ^{16}O)^{20}O $\qquad Q_{\rm m} = -0.624$

See (1983AJ01).

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, 3, 4
1.67368 ± 0.15	2^+	$\tau_m = 10.5 \pm 0.4$ psec	γ	2, 3, 4
		g $= -0.352 \pm 0.015$		
3.570 ± 7	4^+		(γ)	2, 3, 4
4.072 ± 4	2^+		γ	2, 4
4.456 ± 5	0^+		γ	2, 4
4.850 ± 15	4^+		(γ)	2
5.002 ± 6			(γ)	2
5.234 ± 5	2^+		(γ)	2
5.304 ± 6	2^+		(γ)	2
5.387 ± 6	0^+		γ	2
5.614 ± 3	(3^-)		(γ)	2
6.555 ± 8	(2)		(γ)	2
7.252 ± 8	5^-		(γ)	2
7.622 ± 7	$3^- + 4^+$			2
7.754 ± 5	4^+			2, 3
7.855 ± 6	(5^-)			2, 3
8.554 ± 8	4^+			2
8.804 ± 9	3^-			2, 3
8.962 ± 21	(0^+)			2
9.770 ± 8	0^+			2
10.125 ± 11	2^+			2, 3

^{20}F

(Figs. 11 and 13)

GENERAL (See also (1983AJ01).)

Model calculations: (1978WI1B, 1982HA43, 1983BR29, 1984FO16, 1984RA13, 1986CA27, 1986COZZ, 1986VO05, 1986WA1R, 1987HA08, 1987IA1B).

Complex reactions involving ^{20}F: (1983BE02, 1983DE26, 1983WI1A, 1984GR08, 1984HO23, 1984KO25, 1985BE40, 1985HA1N, 1985PO11, 1986GA1P, 1986HA1B, 1986ME06, 1986PO06, 1987RI03, 1987RO10).

Hypernuclei: (1984AS1D).

Other topics: (1978WI1B, 1983AR1J, 1983BR29, 1985AN28, 1986AN07, 1986VO05, 1987HA08).

Ground state of ^{20}F: (1978WI1B, 1983ANZQ, 1983AR1J, 1984KO25, 1986CA27).

$\mu = +2.094\ (2)$ nm (1978LEZA)

$Q = 0.070\ (13)$ b (1978LEZA)

1. ^{20}F(β^-)^{20}Ne $\qquad Q_m = 7.0289$

The half-life of ^{20}F is 11.00 ± 0.02 sec: see (1978AJ03). ^{20}F decays principally to ^{20}Ne*(1.63): see ^{20}Ne, reaction 33. See also (1984KO25, 1985HE08).

2. ^{12}C(^{9}Be, p)^{20}F $\qquad Q_m = 4.0760$

For excitation curves involving ^{20}F*(0, $1.82 + 1.84 + 1.97 + 2.04 + 2.19$) see (1982HU06, 1983JA09). At $E(^9\text{Be}) = 12$ to 27 MeV angular distributions are reported for p_0 and $p_{1+2+3+4}$: see (1983AJ01).

3. ^{13}C(^{7}Li, ^{7}Li)^{13}C $\qquad E_b = 18.0492$

For fusion cross sections see (1982DE30). See also ^{13}C in (1986AJ01) and (1983AJ01).

4. ^{13}C(^{9}Be, d)^{20}F $\qquad Q_m = 1.3542$

See (1983AJ01).

Table 20.2: Energy levels of ^{20}F [a]

E_x (MeV ± keV)	$J^\pi; T$	τ	Decay	Reactions
0	2^+; 1	$\tau_{1/2} = 11.00 \pm 0.02$ sec	β^-	1, 2, 4, 6, 7, 9, 10, 11, 14, 16, 17, 19, 20
0.65600 ± 0.04	3^+	$\tau_m = 0.39 \pm 0.03$ psec	γ	6, 7, 9, 10, 11, 14, 19
0.82268 ± 0.08	4^+	79 ± 6 psec	γ	5, 6, 7, 9, 10, 11, 14, 17, 19
0.98371 ± 0.05	1^-	2.0 ± 0.2 psec	γ	6, 7, 9, 11, 14, 17, 19
1.056818 ± 0.004	1^+	45 ± 13 fsec	γ	6, 7, 9, 10, 11, 14, 15, 16, 17, 19
1.30934 ± 0.05	2^-	1.6 ± 0.3 psec	γ	6, 7, 9, 11, 14, 16, 17, 19
1.8244 ± 1.2	5^+	≤ 65 fsec	(γ)	2, 6, 9, 10, 14, 19
1.84397 ± 0.08	2^-	30 ± 20 fsec	γ	2, 7, 9, 11, 14, 17
1.97080 ± 0.07	(3^-)		γ	2, 5, 6, 7, 9, 11, 14, 19
2.04405 ± 0.06	2^+	37 ± 16 fsec	γ	2, 6, 7, 9, 11, 14, 17, 19
2.19436 ± 0.08	(3^+)	< 12 fsec	γ	2, 6, 7, 9, 10, 11, 14, 17, 19
2.8649 ± 1.5	(3^-)		(γ)	6, 7, 9, 14, 19
2.96616 ± 0.08	3^+	60 ± 40 fsec	γ	6, 7, 9, 11, 14, 19
2.968 ± 1.5	(4^-)		(γ)	5, 6, 7, 19
3.17258 ± 0.42	(1^+)		γ	6, 7, 9, 11, 14, 19
3.48849 ± 0.06	1^+	44 ± 11 fsec	γ	6, 7, 9, 11, 14, 15, 19
3.52628 ± 0.07	0^+	30 ± 15 fsec	γ	9, 11, 14
3.58656 ± 0.09	$(1, 2)^+$	≤ 60 fsec	γ	6, 7, 9, 11, 14, 19
3.68013 ± 0.06	1, 2		γ	6, 7, 9, 11, 14, 19
3.7611 ± 1.9	$(2^-, 3^+)$		(γ)	6, 7, 9, 14, 19
3.96519 ± 0.16	1^+		γ	6, 7, 9, 11, 14, 19
4.08208 ± 0.11	$(1)^+$		γ	6, 7, 9, 11, 14, 19

Table 20.2: Energy levels of ^{20}F [a] (continued)

E_x (MeV $\pm$ keV)	$J^\pi; T$	τ	Decay	Reactions
4.1989 ± 2.7			(γ)	6, 14
4.2077 ± 2.6			(γ)	7, 14, 19
4.27722 ± 0.14	$(1, 2)^+$		γ	6, 7, 11, 14, 19
4.3154 ± 2.0	$(0, 1)^+$		(γ)	14
4.37138 ± 0.12	(2^+)		γ	6, 7, 11, 14, 19
4.5087 ± 0.4	1^+ (2)		γ	6, 7, 11, 14, 19
4.5808 ± 1.8			(γ)	6, 7, 14
4.5922 ± 2.9			(γ)	14, 19
4.7310 ± 2.0	$(3^-, 4^-, 4^+, 5^+)$		(γ)	6, 7, 14, 19
4.7656 ± 2.0			(γ)	6, 7, 14, 19
4.8916 ± 2.8			(γ)	6, 14, 19
4.8982 ± 2.8			(γ)	7, 14
5.047 ± 4	$(2)^-$		(γ)	6, 14, 19
5.068 ± 3	$(1^-, 2, 3^+)$		(γ)	6, 14
5.1310 ± 2.5	$(2^-, 3, 4^+)$		(γ)	6, 14, 19
5.2239 ± 2.3	$(1, 2)^-$		(γ)	6, 7, 14, 19
5.2819 ± 2.5			(γ)	6, 14, 19
5.31887 ± 0.17	0, 1, 2		γ	6, 11, 14, 19
5.349 ± 0.4	$(3)^+$		(γ)	6, 14
5.4131 ± 0.6			γ	6, 7, 14, 19
5.4503 ± 3.8			(γ)	14, 19
5.4554 ± 3.2			(γ)	14
5.463 ± 3	$(1, 2, 3)^+$		(γ)	14
5.55534 ± 0.13	$1, 2^+$		γ	7, 11, 14, 19
5.5881 ± 1.5			(γ)	14
5.620 ± 3			(γ)	7, 14, 19
5.713 ± 2			γ	6, 14, 19
5.7640 ± 2.5	$(3)^+$		(γ)	6, 14, 19
5.8104 ± 2.5	(1^+)		(γ)	6, 14, 19
5.93609 ± 0.05	2^-		γ	11, 14, 19
6.01777 ± 0.03	2^-		γ	11, 14

Table 20.2: Energy levels of ^{20}F [a] (continued)

E_x (MeV ± keV)	$J^\pi; T$	τ	Decay	Reactions
6.04498 ± 0.08	0, 1, 2		γ	11, 14, 19
6.090 ± 7	(0^-)		(γ)	6
6.161 ± 4	(2, 3^+)		(γ)	6, 19
6.200 ± 4	(2^-, 3, 4^+)		(γ)	6, 19
6.240 ± 7			(γ)	19
6.299 ± 4			(γ)	6, 19
6.339 ± 4			(γ)	6, 19
6.375 ± 4			(γ)	6, 19
6.416 ± 4			(γ)	6, 19
6.441 ± 9			(γ)	19
6.474 ± 3			(γ)	6, 19
6.519 ± 3	$0^+; T = 2$		γ	9, 18
6.588 ± 5			(γ)	19
6.6270 ± 0.3	2^-	0.31 ± 0.02	γ, n	11, 12
6.6426 ± 0.3	(3, 4)	< 0.08	γ, n	11
6.6475 ± 0.4	1^-	1.59 ± 0.10	γ, n	11, 12
6.6934 ± 0.6	1^-	13.8 ± 0.8	γ, n	6, 11, 12
6.7661 ± 0.9	(2^-, 3, 4^+)	≤ 0.6	γ, n	6, 11, 19
6.825 ± 5			n	6, 12, 19
6.8567 ± 1.0	2	10 ± 2	γ, n	11
6.905 ± 8				19
6.936 ± 4				6
6.9678 ± 1.0	1^-	5 ± 1	γ, n	6, 11, 12
(7.0670 ± 1.2)	0^-	(2.4 ± 0.6)	γ, n	11, 12
7.08	(1^+)	24	n	6, 12
7.166 ± 2	$2^{(+)}$	8 ± 1	γ, n	6, 11, 12, 13
7.232 ± 7				6
7.283 ± 4				6
7.319 ± 8	(1)	33	γ, n	6, 11, 12
7.37 ± 20	(1)	19	n	6, 12
7.42 ± 20	(2^+)	10	γ, n	6, 11, 12

Table 20.2: Energy levels of ^{20}F [a] (continued)

E_x (MeV ± keV)	$J^\pi; T$	τ	Decay	Reactions
7.495 ± 5	(2)	80	γ, n	6, 11, 12
7.655 ± 5	(2^+)	65	γ, n	6, 11, 12
7.734 ± 6		140	n	6, 12
7.843 ± 11	1^-	(50 ± 10)	γ, n	6, 11
7.985 ± 4	1	14 ± 2	γ, n	6, 11
8.05 ± 100	$2^+; T = 2$			18
8.062 ± 8				6
8.113 ± 4		195	γ, n	6, 11, 12
8.147 ± 6		15	n	6, 12
8.268 ± 12				6
8.349 ± 4				6
8.421		27	n	12
8.50		140	n	12
8.72		≤ 30	n	6, 12
8.77		76	n	6, 12
8.94		73	n	6, 12
9.01				6
9.2			n	10, 12
9.52		110	n	12
9.65		100	n	12
9.83		33	n	12
9.85		120	n	12
(9.886 ± 10)			n	12
9.90		≤ 30	n	12
(9.929 ± 10)			n	12
(9.981 ± 10)			n	12
10.024 ± 10		150	n, α	12, 13
10.10 ± 50			n, α	13
10.228 ± 10	0^-, 1	≈ 200	n, α	12, 13
10.480 ± 10		≈ 10	n, α	12, 13
10.641 ± 10	1, 2	70	n	12

Table 20.2: Energy levels of ^{20}F [a] (continued)

E_x (MeV $\pm$ keV)	$J^\pi; T$	τ	Decay	Reactions
10.807 ± 10	0^-, 1	≈ 310	n, α	12, 13
10.99		190	n	12
(11.045 ± 10)		≈ 30	n	12
(11.130 ± 10)		< 25	n	12
(11.244 ± 10)		< 25	n	12
(11.287 ± 10)			n	12
11.49 ± 50			n, α	13
12.0			n, α	13
12.2 ± 100			n, α	13
12.4			n, α	13
12.7			n, α	10, 13
13.2			n, α	13
13.7			n, α	12, 13
14.0			n, α	13

[a] See also Tables 20.3, 20.4 and 20.5.

5. ^{13}C(^{11}B, α)^{20}F $\qquad Q_m = 9.3854$

The upper of the two states at 2.97 MeV has an excitation energy of 2968 ± 1.5 keV and γ branching ratios of (61 ± 4) and (39 ± 4)%, respectively, to ^{20}F*(1.97, 0.82) [$J^\pi = (3^-), 4^+$]: this is consistent with $J^\pi = (4^-)$ for ^{20}F*(2.968).

6. ^{14}N(^{7}Li, p)^{20}F $\qquad Q_m = 10.4985$

Tables 20.5 here and in (1983AJ01) display ^{20}F states reported in this reaction.

7. ^{16}O(^{7}Li, ^{3}He)^{20}F $\qquad Q_m = -4.7442$

For reported states see Table 20.6 in (1983AJ01).

Table 20.3: Radiative transitions in ^{20}F [a]

E_i (MeV)	J_i^π	E_f (MeV)	Branching (%)	δ
0.66	3^+	0	100	0.10 ± 0.05
0.82	4^+	0	36 ± 3	
		0.66	64 ± 3 [d]	
0.98	1^-	0	100	[f]
1.06	1^+	0	100	
1.31	2^-	0	100	[f]
1.82	5^+	0.82	≥ 95	-0.03 ± 0.07
1.84	2^-	0	100	
1.97	(3^-)	0	16 ± 4	-0.06 ± 0.14
		0.82	55 ± 3	$+0.27 \pm 0.30$
		1.31	29 ± 3	
2.04	2^+	0	8.1 ± 1.9	
		0.66	91.9 ± 1.9	$0.08^{+0.06}_{-0.1}$
2.19	3^+	0	53.7 ± 2.1	0 ± 0.09
		0.82 [d]	46.3 ± 2.1	$+0.07 \pm 0.10$
2.86 [b]	(3^-)	0	(100)	
2.966 [c]	3^+	0	23 ± 3	
		0.66	21 ± 3	
		0.82	56 ± 3	
2.968	(4^-)	0.82	39 ± 4	
		1.97	61 ± 4	
3.17 [b]	(1^+)	0.98	> 95	
3.49 [c]	1^+	0	63 ± 4	
		1.06	22 ± 4	
		1.31	8 ± 2	
		1.84	7 ± 2	
3.53	0^+	1.06	100	
3.59	$(1, 2)^+$	0	30.5 ± 2.4	
		0.66	9.8 ± 1.2	
		0.98	3.5 ± 1.0	
		2.04	50 ± 3	

Table 20.3: Radiative transitions in ^{20}F [a] (continued)

E_i (MeV)	J^π_i	E_f (MeV)	Branching (%)	δ
		2.19	7 ± 3	
3.68	1, 2	0 [d]	66 ± 4	
		1.06	34 ± 4	
3.97	1^+	0.98	24 ± 6	
		1.31	76 ± 6	
4.08	$(1)^+$	0	34 ± 3	
		1.06	66 ± 3	
4.28	$(1, 2)^+$	1.06	100	
4.37	(2^+)	0.82	7 ± 3	
		0.98	34 ± 5	
		2.97	59 ± 5	
4.51	1^+, 2	0.66	100	
5.32	$0 - 2$	0	34 ± 7	
		0.98	66 ± 7	
5.56	1^-	0	29 ± 4	
		1.31	37 ± 5	
		3.53	34 ± 7	
5.94	2^-	0	6.4 ± 0.4	
		0.66	22.7 ± 1.4	
		0.98	11 ± 3	
		1.97	24.2 ± 1.4	
		2.04	2.5 ± 0.5	
		2.19	4.1 ± 0.6	
		2.97	2.5 ± 0.7	
		3.49	9.1 ± 1.2	
		3.59	7.8 ± 1.6	
		3.68	7.2 ± 0.8	
		3.97	(2.7 ± 0.9)	
6.02	2^-	0	24.3 ± 1.2	
		0.66	3.05 ± 0.17	
		0.98	15.1 ± 0.7	

Table 20.3: Radiative transitions in ^{20}F [a] (continued)

E_{i} (MeV)	J^{π}_{i}	E_{f} (MeV)	Branching (%)	δ
		1.31	0.83 ± 0.21	
		1.84	5.3 ± 0.4	
		1.97	1.04 ± 0.23	
		2.04	0.68 ± 0.15	
		2.19	3.8 ± 0.4	
		2.97	8.9 ± 0.5	
		3.49	20.8 ± 1.1	
		3.59	13.6 ± 2.4	
		4.08	2.6 ± 0.4	
6.05	$0 - 2$	1.31	21 ± 2	
		1.84	36 ± 3	
		3.49	15 ± 5	
		3.53	(28 ± 3)	
6.60 [g]	0^{+}, 1^{+}	0	8.5 ± 0.6	
		0.98	1.29 ± 0.10	
		1.06	3.4 ± 0.3	
		1.31	2.21 ± 0.13	
		1.84	1.62 ± 0.11	
		2.04	4.9 ± 0.3	
		3.49	2.31 ± 0.18	
		3.53	2.05 ± 0.21	
		3.59	4.7 ± 0.3	
		3.68	0.99 ± 0.18	
		3.97	0.82 ± 0.12	
		4.08	(0.90 ± 0.13)	
		4.28	1.42 ± 0.20	
		4.37	0.83 ± 0.14	
		4.51	0.53 ± 0.17	
		5.32	1.5 ± 0.5	
		5.56	2.4 ± 0.4	
		5.94	15.0 ± 1.5	

Table 20.3: Radiative transitions in ^{20}F [a] (continued)

E_i (MeV)	J^π_i	E_f (MeV)	Branching (%)	δ
		6.02	40 ± 3	
		6.05	4.8 ± 0.5	
[e]				

[a] Branching ratios from (1983HU12) and from the earlier work displayed in Tables 20.5 in (1978AJ03) and 20.4 in (1983AJ01). Branching ratios renormalized to add to 100%, except for ^{20}F*(6.60).
[b] The population of ^{20}F*(2.86) and the γ-decay of ^{20}F*(3.17) are not observed by (1983HU12) [(n, γ)]. See also (1987AL06).
[c] See, however, Table 20.5 in (1978AJ03).
[d] Transition not observed by (1983HU12) because of a background problem.
[e] For higher states see Tables 20.6 and 20.7.
[f] Pure E1.
[g] See Table 20.8.

8. (a) ^{18}O(d, n)^{19}F $\quad Q_m = 5.7697 \quad E_b = 12.3710$
(b) ^{18}O(d, p)^{19}O $\quad Q_m = 1.732$
(c) ^{18}O(d, d)^{18}O
(d) ^{18}O(d, ^{3}He)^{17}N $\quad Q_m = -10.449$
(e) ^{18}O(d, α)^{16}N $\quad Q_m = 4.247$

See (1983AJ01) for a listing of the polarization measurements. For VAP measurements at $E_{\vec{d}} = 52$ MeV (reaction (e)), see (1982MA25). See also ^{19}O and ^{19}F here, and ^{16}N and ^{17}N in (1986AJ04). See also (1986SE1B).

9. ^{18}O(^{3}He, p)^{20}F $\quad Q_m = 6.8774$

Proton groups have been observed to states of ^{20}F with $E_x < 4.1$ MeV: see Table 20.8 in (1978AJ03). Angular distributions, γ-ray polarization data and branching ratios lead to the J^π values shown in that table. A state at $E_x = 6519 \pm 3$ keV is also populated. It decays principally (> 90%) to ^{20}F*(1.06) [$J^\pi = 1^+$]: the γ-rays are isotropic. ^{20}F*(6.52) is the 0^+; $T = 2$ analog of the ground state of ^{20}O: see (1978AJ03).

Table 20.4: Lifetime measurements of some ^{20}F states [a]

^{20}F* (MeV)	$\tau_{\rm m}$
0.66	0.39 ± 0.03 psec
0.82	79 ± 6 psec
0.98	2.03 ± 0.20 psec [a]
	1.8 ± 0.3 psec [b]
	2.0 ± 0.2 psec [A]
1.06	45 ± 13 fsec
1.31	1.16 ± 0.20 psec [a]
	1.9 ± 0.3 psec [b]
	1.6 ± 0.3 psec [A]
1.82	≤ 65 fsec
1.84	30 ± 20 fsec
1.97	1.4 ± 0.4 psec
2.04	37 ± 16 fsec
2.19	< 12 fsec
2.97	60 ± 40 fsec
3.49	44 ± 11 fsec
3.53	30 ± 15 fsec
3.59	30 ± 30 fsec

A = adopted.

[a] For references see Table 20.6 in (1978AJ03).

[b] (1983KO01): ^{7}Li(^{18}O, αn)^{20}F; $E_{\rm x} = 983.58 \pm 0.16$ and 1309.19 ± 0.20 keV.

Table 20.5: Some states of ^{20}F reported in ^{14}N(^{7}Li, p) [a]

E_x (keV)	J^π	E_x (keV)	J^π
4512 ± 4	$(3^-, 4^-, 5^+, 6^+)$	6695 ± 3	[c]
4579 ± 4 [b]		6756 ± 3	$(2^-, 3, 4^+)$
4728 ± 5	$(3^-, 4^-, 4^+, 5^+)$	6823 ± 3	
4760 ± 5	$(4 \rightarrow 6^-, 6 \rightarrow 8^+)$	6936 ± 4	
4889 ± 4 [b]	[c]	6968 ± 4	
5032 ± 4	2^-	6991 ± 7	
5064 ± 5	$(1^-, 2, 3^+)$	7034 ± 9 [d]	
5128 ± 5	$(2^-, 3, 4^+)$	7080 ± 7	
5222 ± 4	$(1, 2)^-$	7154 ± 5	
5282 ± 11	[c]	7232 ± 7	
5316 ± 7	[c]	7283 ± 4	
5350 ± 5	3^+	7319 ± 8	
5405 ± 4	[c]	7370 ± 20	
5448 ± 6 [b]		7419 ± 20	
5560 ± 6 [b]		7495 ± 5	
5612 ± 5 [b]	[c]	7655 ± 5	
5725 ± 10	$(2 \rightarrow 5)$	7734 ± 6	
5765 ± 8	3^+	7865 ± 16	
5803 ± 7	1^+	7975 ± 5	
5940 ± 5	[c]	8062 ± 8	
6021 ± 4 [b]		8113 ± 4	
6090 ± 7	(0^-)	8147 ± 6	
6160 ± 5	$((1^-), 2, 3^+)$	8268 ± 12	
6193 ± 6	$(2^-, 3, 4^+)$	8349 ± 4	
6297 ± 5 [b]	[c]	8573	
6344 ± 9 [b]	[c]	8697	
6379 ± 5 [b]	[c]	8754	
6417 ± 4	$(3^-, 4, 5, (6^+))$	8792	
6470 ± 4	[c]	8907	
6565 ± 6 [b]	[c]	8946	
6600 ± 8 [b]	[c]	9022	
6633 ± 3 [b]			

[a] (1985FO07); $E(^7\text{Li}) = 16$ MeV. For the low-lying states reported in this reaction see Table 20.6 in (1983AJ01). Please note that the density of states is very high and that when J^π assignments are made [based on cross sections and the $2J_\text{f}+1$ relationship, with slopes which are different for even- and odd-parity states], these depend on the states having been resolved.
[b] Unresolved [based on data from other reactions and on spectrum shown].
[c] See (1985FO07).
[d] All the observed groups for $E_\text{x} \gtrsim 7.0$ MeV appear to be due to unresolved states. See (1985FO07) for $\sigma_\text{tot}(0° - 90°)$ and J^π.

10. ^{18}O(α, d)^{20}F $\qquad Q_\text{m} = -11.4758$

At $E_\alpha = 64.4$ MeV angular distributions have been reported to ^{20}F*(0, 0.66, 0.82, 1.06, 1.82, 2.20, 2.97, 4.24, 4.54, 5.07, 5.44, 5.80, 6.67, 7.29, 7.75, 8.34, 8.75, 9.00, 9.24, 9.78, 10.01, 10.51, 10.85, 11.56, 12.32, 12.72): L assignments are made [the groups above $E_\text{x} \approx 2.9$ MeV are probably unresolved] (1986KA36).

11. ^{19}F(n, γ)^{20}F $\qquad Q_\text{m} = 6.6013$

$$Q_0 = 6601.33 \pm 0.14 \text{ keV (1983HU12)}$$
$$Q_0 = 6601.344 \pm 0.055 \text{ keV (1986KE15)}$$

The thermal capture cross section is 9.8 ± 0.7 mb. A number of resonances have been observed: see Table 20.6. The primary γ-rays resulting from capture at thermal energies (^{20}F*(6.60); $J^\pi = 1^+$) and at $E_\text{n} = 27$, 44 and 49 keV (^{20}F*(6.63, 6.643, 6.647); $J^\pi = 2^-$, (3, 4) and 1^-) have been studied by several groups: see (1972AJ02) and Table 20.7 here. It appears that the thermal capture [^{20}F*(6.60)] is dominated by two intense transitions (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). See also (1983HU12). It appears also that at ^{20}F*(6.63, 6.64, 6.65) [$J^\pi = 2^-$, (3, 4) and 1^-] the E1 transitions to the ground state are very weak, even though other E1 transitions in the decay of these three states have approximately normal strengths. The strongest transitions from the 27 keV resonance appear to be M1. On the basis of J^π of the final states involved in the decay of the 44 keV resonance $J = 3$ or 4, assuming dipole transitions. Branching ratios for other ^{20}F states involved in this reaction are shown in Table 20.3.

Table 20.6: Resonances in $^{19}F(n, \gamma)^{20}F$ [a]

E_n (keV)	J^{π} [b]	Γ_{γ} (eV)	$\Gamma_{c.m.}$ (keV)	E_x in ^{20}F (MeV)
27.07 ± 0.05	2^-	1.4 ± 0.3	0.355 ± 0.03	6.6270
43.5 ± 0.1	(3, 4)	[c]	< 0.08	6.6426
48.7 ± 0.3	1^-	1.6 ± 0.3	1.96 ± 0.3	6.6475
97.0 ± 0.5	1^-	6.0 ± 1.8 [d]	13.5 ± 1.5	6.6934
173.5 ± 0.9		[e]	≤ 0.6	6.7661
269 ± 1	2	3.5 ± 0.8	10 ± 2	6.8567
(270 ± 8)	1	≤ 4.4		(6.859)
386 ± 1	1^-	2.4 ± 0.8	5 ± 1	6.9678
(490.5 ± 1)	0^-	$(\geq 10 \pm 3)$	(2.4 ± 0.6)	(7.0671)
595 ± 2	2	6.3 ± 1.2	8 ± 1	7.166
760		2.9	60	7.32
865			60	7.42
950		2.8	95	7.50
1125		3.9	80	7.67
(1295 ± 12)	1^-	8.6	(50 ± 10)	(7.831)
1460 ± 3	1	$\geq 11 \pm 3$	14 ± 2	7.988
1635		11 ± 3	180	8.15

[a] For complete references see Table 20.9 in (1978AJ03).

[b] Assumed.

[c] $g\Gamma_n - 0.086 \pm 0.02$ eV.

[d] May be two resonances.

[e] $g\Gamma_n = 0.35 \pm 0.1$ eV.

Table 20.7: Primary capture transitions in ^{19}F(n, γ)^{20}F [a]

Final state ^{20}F* (MeV)	I_γ [b] from		
	^{20}F*(6.63)	^{20}F*(6.64)	^{20}F*(6.65)
0	2.0 ± 0.5		
0.66	6 ± 1	42 ± 7	
0.82		23 ± 7	
0.98			18 ± 4
1.06			9 ± 4
1.31	31 ± 2		
1.84	8 ± 2		
1.97	46 ± 4		
2.04	1.5 ± 1		59 ± 6
2.97		35 ± 9	
3.49	3 ± 1		14 ± 5
3.53	8 ± 1		
4.08	2.5 ± 1		

[a] For complete references see Table 20.10 in (1978AJ03). See also Tables 20.3 and 20.6 here.

[b] In units of photons/100 captures.

Table 20.8: States of ^{20}F involved in ^{19}F(n, γ)^{20}F [a]

E_x (keV)	J^π	E_x (keV)	J^π
0	2^+	3586.56 ± 0.09	$(1, 2)^+$
656.00 ± 0.04	3^+	3680.13 ± 0.06	1, 2
822.68 ± 0.08	4^+	3965.19 ± 0.16	1^+
983.71 ± 0.05	1^-	4082.08 ± 0.11	$(1)^+$
1057.02 ± 0.04	1^+	4277.22 ± 0.14	$(1, 2)^+$
1309.34 ± 0.05	2^-	4371.38 ± 0.12	(2^+)
1843.97 ± 0.08	2^-	4508.7 ± 0.4	1^+, 2
1970.80 ± 0.07	(3^-)	5318.87 ± 0.17	$0 - 2$
2044.05 ± 0.06	2^+	5555.34 ± 0.13	1, 2^+
2194.36 ± 0.08	(3^+)	5936.09 ± 0.05	2^-
2966.16 ± 0.08	3^+	6017.77 ± 0.03	2^-
3488.49 ± 0.06	1^+	6044.98 ± 0.08	$0 - 2$
3526.28 ± 0.07	0^+	6601.33 ± 0.04	0^+, 1^+ [b]

[a] (1983HU12). For the earlier work see Table 20.11 in (1978AJ03). A state at 5713 ± 2 keV reported earlier is not seen here. (1987AL06) suggest that a 3428.4 ± 0.4 keV γ-ray reported by (1983HU12) feeds ^{20}F*(3.17) and that its excitation energy is then 3172.58 ± 0.42 keV [for the decay of this state see Table 20.3].
[b] The transition C $\rightarrow 3.53$ [$J^\pi = 0^+$] is observed.

Table 20.8 displays excitation energies for ^{20}F states involved in cascade and in primary γ-transitions (1983HU12). Fo the earlier references see (1978AJ03). See also (1984VO1H) and (1986KR16; theor.).

12. (a) ^{19}F(n, n)^{19}F $E_b = 6.6013$
(b) ^{19}F(n, n′)^{19}F*
(c) ^{19}F(n, 2n)^{18}F $Q_m = -10.4320$

The scattering amplitude (bound) $a = 5.654 \pm 0.010$ fm, $\sigma_{\rm free} = 3.641 \pm 0.010$ b (1979KO26). The difference in the bound-state scattering lengths, $b^+ - b^- = -0.019 \pm 0.002$ (1979GL12). The total cross section has been measured for $E_n = 0.5$ to 29.1 MeV: see (1978AJ03). Observed resonances are displayed in Table 20.9.

Observed resonances in the excitation functions involving ^{19}F*(0.11, 1.5(u)) are displayed in Table 20.10. For reaction (c) see (1983CSZX). See also (1986BAYL) and (1986SA40; theor.).

13. ^{19}F(n, α)^{16}N $Q_m = -1.523$ $E_b = 6.6013$

Reported resonances are shown in Table 20.11.

14. ^{19}F(d, p)^{20}F $Q_m = 4.3767$

States of ^{20}F observed in this reaction are displayed in Table 20.12. See (1978AJ03) for a discussion of the earlier work. See also (1983JI04).

15. ^{20}O(β^-)^{20}F $Q_m = 3.8136$

The decay is to ^{20}F*(1.06, 3.49), $J^\pi = 1^+$: see ^{20}O. The E_x of ^{20}F*(1.06) is 1056.848 ± 0.004 keV. The β branch to ^{20}F*(3.17) (1^+) is < 0.012%, $\log f_0 t > 5.1$ (1987AL06). [See also for general discussion of the low-lying states of ^{20}F].

16. ^{20}Ne(π^-, γ)^{20}F $Q_m = 132.505$

The branching ratio to ^{20}F*(1.06) [$J^\pi = 1^+$] is compared to the analogous M1 decay width ^{20}Ne*(11.24) [$J^\pi = 1^+$] $\rightarrow$ ^{20}Ne$_{\rm g.s.}$. The M1 amplitude contains (47 ± 16)% spin-flip, in agreement with shell-model calculations. The population of ^{20}F*(0, 1.31, 1.84) [$J^\pi = 2^+, 2^-, 2^-$] is also reported (1981MA04). See also (1986BA16) and (1983KN05; theor.).

Table 20.9: Resonances in $^{19}F(n, n)^{19}F$ [a]

E_n (keV)	Γ_{lab} (keV)	J^π	$^{20}F^*$ (MeV)
26.99	0.325 ± 0.020	2^-	6.6269
48.78	1.67 ± 0.10	1^-	6.6476
97.50	14.5 ± 0.8	1^-	6.6939
500	25 [b]	(1^+)	7.076
600	15 [b]	(2^+)	7.171
747	35 [b]	(1)	7.311
794	20	(1)	(7.355)
852	11 [b]	(2^+)	7.410
935	60	(2)	7.489
1100	50	(2^+)	7.65
1250	150		7.79
1620	220		8.14
2000	150		8.50
2250	≤ 30		8.74
2280	80		8.77
2520	150		8.99
3250	150		9.69
3420	130		9.85
3460 ± 10			(9.886)
3505 ± 10			(9.929)
3560 ± 10			(9.981)
3605 ± 10	200		10.024
3820 ± 10	≈ 200	$0^-, 1$	10.228
4085 ± 10	≈ 10		10.480
4255 ± 10	≈ 60	1, 2	10.641
4430 ± 10	≈ 330	$0^-, 1$	10.807
4680 ± 10	≈ 30		11.045
4770 ± 10	< 25		11.130
4890 ± 10	< 25		11.244
(4935)			(11.287)

[a] For references see Table 20.12 in (1978AJ03).
[b] $\Gamma_\gamma = 3.3 \pm 1.0, 6.3 \pm 1.2, 2.4 \pm 0.8$ and 1.5 ± 0.5 eV for $^{20}F^*$(7.08, 7.17, 7.31, 7.41).

Table 20.10: 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 (MeV)
		$\gamma_{0.11}$ [a]	$\gamma_{1.5}$ [b]	
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. See Table 20.13 in (1978AJ03) for references.

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

[c] Appears to be unresolved.

Table 20.11: Resonances in ^{19}F(n, α)^{16}N [a]

E_n (MeV $\pm$ keV)	E_x (MeV)
3.4	9.8
3.61 ± 50	10.03
3.69 ± 50	10.10
3.76 ± 40	10.17
4.09 ± 40	10.48
4.39 ± 40	10.77
4.52 [b]	10.89
4.82 ± 40	11.18
5.15 ± 50	11.49
5.40 [b]	11.73
5.7	12.0
5.9 ± 100 [b]	12.2
6.10	12.39
6.55	12.82
6.9	13.2
7.44	13.66
7.8	14.0

[a] For references see Table 20.14 in (1978AJ03). See also graph in (1976GAYV).
[b] Not resolved.

17. ^{21}Ne(d, ^{3}He)^{20}F $\qquad Q_{\rm m} = -7.514$

The ^{20}F states observed at $E_{\rm d} = 26$ MeV in this reaction and analog $[T = 1]$ states observed in ^{20}Ne in the (d, t) reaction are displayed in Table 20.16 of (1978AJ03). The spectroscopic factors of analog states are consistent to within 20% for states excited by a single l-transfer.

Table 20.12: States in ^{20}F from ^{19}F(d, p)^{20}F [a]

$E_{\rm x}$ (keV) [b]	$l_{\rm n}$ [c]	J^{π}	$(2J+1)S$	n, l, j [c]
0	2	2^+	0.054	$1d_{5/2}$
655.9 ± 0.2	2	3^+	2.32	$1d_{5/2}$
823.0 ± 0.3	[d]	4^+	0.32	$1g_{9/2}$
983.9 ± 0.3	[d]	1^-	0.014	$1p_{1/2}$
1057.0 ± 0.2	$0 + 2$	1^+	0.013	$2s_{1/2}$
1309.3 ± 0.2	[d]	2^-	0.017	$1p_{3/2}$
1820 ± 10	[d]	(5^+)	0.35	$1g_{9/2}$
1843.5 ± 0.7	[d]	2^-	0.007	$2p_{3/2}$
1970 ± 10	[d]	(3^-)	0.038	$1f_{7/2}$
2043.7 ± 0.5	2	2^+	2.32	$1d_{5/2}$
2194.5 ± 0.6	2	3^+	0.55	$1d_{5/2}$
2863.7 ± 1.6	[d]		0.044	$1f_{7/2}$
2966.8 ± 0.6	2	3^+	0.38	$1d_{3/2}$
3175.6 ± 1.3	[d]		0.019	$1d_{5/2}$
3488.5 ± 0.3	0	1^+	1.20 [e]	$2s_{1/2}$
3525.9 ± 0.5	0	0^+	0.28 [e]	$2s_{1/2}$
3586.5 ± 0.6	2	$\pi = +$	0.038	$1d_{3/2}$
3681.0 ± 2.5	2	$\pi = +$	0.031	$1d_{5/2}$
3760.8 ± 2.7	[d]		[c]	
3964.5 ± 2.5	2	$\pi = +$	0.036	$1d_{5/2}$
4082.5 ± 0.8	$0 + 2$	$\pi = +$	0.13	$1s_{1/2}$
4198.9 ± 2.7				
	[d]		0.083	$1d_{3/2}$
4207.7 ± 2.6				
4279.0 ± 2.0	2	$\pi = +$	0.087	$1d_{5/2}$
4315.4 ± 2.0	0	$(0, 1)^+$	0.20	$2s_{1/2}$

Table 20.12: States in ^{20}F from ^{19}F(d, p)^{20}F [a] (continued)

E_x (keV) [b]	l_n [c]	J^π	$(2J+1)S$	n, l, j [c]
4374.5 ± 2.0				
4509.5 ± 3.0				
4583.8 ± 3.0			0.02	$2p_{3/2}$
	1	$(0-2)^-$		
4592.2 ± 2.9			(< 0.05)	$(1f_{7/2})$
4730.2 ± 2.9	2, 3			
4763.8 ± 2.7	2, 3			
4891.6 ± 2.8				
4898.2 ± 2.8				
5048.7 ± 1.5				
5069.0 ± 3	2	$(1, 2, 3)^+$	0.09	$1d_{5/2}$
5132.4 ± 3.5				
5225.0 ± 3	1, 3		0.09	$2p_{3/2}$
5284.0 ± 3	0	$(1, 0)^+$	0.34	$2s_{1/2}$
5318.0 ± 3	2 or $1+3$	$(1, 2, 3)^+$ or 2^-	0.10	$1d_{5/2}$
5349.0 ± 4	2	$(1, 2, 3)^+$	0.06	$1d_{5/2}$
5408.2 ± 2.5				
5450.3 ± 3.8				
5455.4 ± 3.2				
5463.0 ± 3	2	$(1, 2, 3)^+$	0.27	$1d_{5/2}$
5562.9 ± 2.0	1	$(0, 1, 2)^-$	0.03	$2p_{3/2}$
5588.1 ± 1.5				
5620.0 ± 3	[d]			
5710.8 ± 6.0	[d]			
5764.0 ± 3	2	$(1, 2, 3)^+$	0.15	$1d_{5/2}$
5810.0 ± 3	$0+2$, or $1+3$	$(2^-, 1^+)$		
5935.0 ± 3	$1(+3)$	$(1^-, 2^-)$	0.43	$2p_{3/2}$
6015.0 ± 3.8	$1+3$	(2^-)	0.68	$2p_{3/2}$
			1.40	$1f_{7/2}$
6043.3 ± 3.7				

[a] For complete references see Table 20.15 in (1978AJ03) and see also Table 20.14 in (1983AJ01).

[b] Best values.

[c] Assumed in analysis; $E_d = 12$ MeV.

[d] Weak groups.

[e] At $E_d = 16$ MeV.

18. ^{22}Ne(p, ^{3}He)^{20}F $Q_m = -15.6516$

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]. 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 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 ± 0.1 MeV)]: see (1978AJ03).

19. ^{22}Ne(d, α)^{20}F $Q_m = 2.702$

Angular distributions have been obtained at $E_d = 10$ MeV to ^{20}F states with $E_x < 4.4$ MeV: they are generally featureless. Observed states are displayed in Table 20.17 of (1978AJ03).

20. ^{27}Al(^{20}Ne, ^{27}Si)^{20}F $Q_m = -11.840$

The Δ resonance is very strongly excited in the reaction at $E(^{20}\text{Ne}) = 950$ MeV/A (1986BA16).

^{20}Ne

(Figs. 11 and 13)

GENERAL: (See also (1983AJ01).)

Shell model: (1978WI1B, 1982BR08, 1982FL04, 1982RA1N, 1982SH30, 1983BR29, 1983DR04, 1983DR03, 1984JA15, 1984PA04, 1984RA13, 1985AN16, 1985HA15, 1985HU08, 1985MI23, 1985MU10, 1986CH28, 1986COZZ, 1986HU1G, 1986WA1R, 1987PR01).

Collective, deformed and rotational models: (1981OK02, 1982BR08, 1982RA1N, 1982RO06, 1982SC20, 1983DR04, 1983DR03, 1983LO05, 1983MA29, 1983MA68, 1983SC08, 1983VA16, 1983WA04, 1984DR01, 1984GR29, 1984KA11, 1984LO05, 1984PA04, 1984PR09, 1984RI01, 1984SA37, 1984SC41, 1985HA15, 1985LE1H, 1985OM01, 1985RO1G, 1985ST23, 1985WA08, 1986BA3P, 1986BE1D, 1986CEZW, 1986LE16, 1986SN1B, 1986STZT, 1986SU01, 1987MI07, 1987ZH1B).

Cluster and α-particle models: (1982AO06, 1982LE1P, 1982SU1B, 1983BI1F, 1983FU1D, 1983PI03, 1983MA68, 1984KA11, 1984SE20, 1984ZH07, 1985VO1E, 1986AB1H, 1986CO15, 1986GR1Q, 1986KA17, 1986KAZP, 1986LE06, 1986MAZC, 1986SU01).

Special states: (1978WI1B, 1981OK02, 1982AO06, 1982BR08, 1982FL04, 1982RA1N, 1982SC20, 1982SH30, 1982VA1E, 1983AD1D, 1983AR07, 1983BA50, 1983BI1C, 1983BR29, 1983LO05, 1983MA23, 1983VA21, 1983WA04, 1984AD1E, 1984AM03, 1984BY02, 1984DR01, 1984GR29, 1984HA14, 1984IA1A, 1984KA11, 1984RA13, 1984SA37, 1984SC01, 1984SC41, 1984SE20, 1984ZH07, 1985AD1A, 1985HA18, 1985HA1K, 1985HA15, 1985HU08, 1985LI19, 1985MI10, 1985MU10, 1985OM01, 1985RO1G, 1985VO1E, 1985WA08, 1986AN10, 1986AN07, 1986BA3P, 1986CA27, 1986CEZW, 1986CH28, 1986GR1Q, 1986HU1G, 1986KA17, 1986MAZC, 1986STZT, 1986SU01, 1986WI1P, 1987HA08, 1987IA1B, 1987KA18, 1987MI07, 1987PR01, 1987YA03).

Electromagnetic transitions and giant resonances: (1978WI1B, 1981OK02, 1982BR24, 1982RO06, 1983BA50, 1983BR29, 1983BR1P, 1983LO05, 1983VA16, 1984DR01, 1984HA14, 1984KA11, 1984LO05, 1984NA21, 1984SC01, 1984WE13, 1985AL21, 1985VE04, 1985WI17, 1986AN10, 1986CA15, 1986CA27, 1986CH28, 1986KA17, 1986KA2G, 1986KAZP, 1986SU01).

Astrophysical questions: (1981WA1Q, 1982CA1A, 1982HI1E, 1982NO1D, 1982WO1A, 1983AL23, 1983HA1P, 1983SI1B, 1983WE1A, 1984BA34, 1984CO1H, 1984TR1C, 1985AR1A, 1985DW1A, 1985NO1H, 1986MA1E, 1986TH1E, 1986TR1C, 1987BO1B, 1987CU1A, 1987MA1R, 1987ME1B, 1987MU1B, 1987PR1A).

Applications: (1984WI1E, 1986BO1L, 1986FO1D, 1986TR1B, 1987NA1D).

Complex reactions involving ^{20}Ne: (1982FA1D, 1982HO10, 1982KA33, 1982VI01, 1983BA2J, 1983DE26, 1983FR1G, 1983GA01, 1983HU1E, 1983IS1E, 1983JA05, 1983LE1F, 1983ME1R, 1983RA1E, 1983RO1H, 1983SC1M, 1983TO1H, 1983WE1C, 1983WI1A, 1984BE22, 1984DE1Q, 1984FI17, 1984GR08, 1984HO23, 1984KA1J, 1984NA12, 1984TS03, 1985AG1A, 1985BE40, 1985GAZT, 1985HA1N, 1985HO05, 1985KA1E, 1985KA1G, 1985KAZQ, 1985MC03, 1985MO08,

1985OS05, 1985SA40, 1985ST20, 1986AI1A, 1986BA1E, 1986BE2M, 1986BL06, 1986CH2G, 1986GR1A, 1986GR1B, 1986HA1B, 1986HE1A, 1986IK03, 1986MA19, 1986ME06, 1986PL02, 1986PO06, 1986SA2N, 1986SA30, 1986SC28, 1986SC29, 1986SH07, 1986SH1F, 1986SO10, 1986TR1B, 1986VA10, 1986VA18, 1986VA23, 1986WE1C, 1987FA09, 1987KO15, 1987NI04, 1987RI03, 1987RO10).

Table 20.13: Energy levels of ^{20}Ne [a]

E_x (MeV ± keV)	$J^\pi; T$	K^π	τ_m [b] or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
0	$0^+; 0$	0^+_1		stable	2, 3, 7, 8, 12, 15, 16, 18, 20, 24, 25, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 56, 57, 58, 59, 60, 61, 62, 63, 64
1.633674 ± 0.015	$2^+; 0$	0^+_1	$\tau_m = 1.05 \pm 0.06$ psec $g = +0.54 \pm 0.04$	γ	2, 3, 7, 8, 9, 11, 12, 15, 16, 18, 19, 20, 23, 24, 25, 29, 30, 31, 32, 33, 35, 36, 38, 40, 41, 42, 43, 46, 47, 49, 52, 53, 54, 55, 56, 57, 60, 61
4.2477 ± 1.1	$4^+; 0$	0^+_1	$\tau_m = 93 \pm 9$ fsec $g = +0.13 \pm 0.15$	γ	2, 3, 7, 8, 9, 12, 15, 16, 18, 19, 20, 23, 24, 29, 30, 31, 32, 33, 36, 38, 41, 42, 47, 54, 57, 60, 61
4.96651 ± 0.20	$2^-; 0$	2^-	$\tau_m = 4.8 \pm 0.5$ psec	γ	2, 3, 7, 8, 9, 12, 15, 24, 25, 29, 30, 31, 32, 33, 54, 56, 57, 60, 61
5.6214 ± 1.7	$3^-; 0$	2^-	200 ± 50 fsec	γ, α	2, 3, 7, 8, 12, 15, 29, 30, 32, 33, 55, 56, 57, 60, 61
5.7877 ± 2.6	$1^-; 0$	0^-	$\Gamma = (2.8 \pm 0.3) \times 10^{-2}$	γ, α	2, 3, 7, 8, 12, 14, 15, 16, 18, 30, 32, 33, 52, 55, 60
6.725 ± 5	$0^+; 0$	0^+_2	19.0 ± 0.9	γ, α	8, 12, 14, 15, 24, 29, 30, 32, 33, 36, 52, 60
7.004 ± 3.6	$4^-; 0$	2^-	$\tau_m = 440 \pm 90$ fsec	γ	2, 7, 8, 15, 30, 33, 56, 60
7.1563 ± 0.5	$3^-; 0$	0^-	$\Gamma = 8.2 \pm 0.3$	γ, α	2, 4, 7, 8, 12, 14, 15, 16, 18, 20, 23, 24, 29, 30, 52
7.191 ± 3	$0^+; 0$	0^+_3	3.4 ± 0.2	γ, α	5, 6, 7, 12, 14, 36, 60
7.4219 ± 1.2	$2^+; 0$	0^+_2	15.1 ± 0.7	γ, α	2, 5, 6, 7, 12, 14, 15, 29, 30, 32, 36, 53, 55, 60
7.829 ± 2.4	$2^+; 0$	0^+_3	2	γ, α	2, 6, 7, 12, 14, 24, 30, 36, 53, 55, 60
8.453 ± 4	$5^-; 0$	2^-	0.013 ± 0.004	γ, α	2, 6, 7, 12, 14, 15, 30, 60
≈ 8.7	$0^+; 0$	0^+_4	> 800	α	14

Table 20.13: Energy levels of ^{20}Ne [a] (continued)

E_x (MeV $\pm$ keV)	$J^\pi; T$	K^π	τ_m [b] or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
8.708 ± 7	$1^-; 0$		2.1 ± 0.8	γ, α	7, 12, 14, 30, 60
8.7776 ± 2.2	$6^+; 0$	0^+_1	0.11 ± 0.02	γ, α	2, 4, 6, 7, 12, 14, 15, 16, 18, 19, 20, 23, 24, 30, 52, 60
≈ 8.8	$2^+; 0$	0^+_4	> 800	α	14, 30
8.82	$(5^-); 0$		< 1	α	14
8.854 ± 5	$1^-; 0$	1^-	19	α	7, 14, 55
9.031 ± 7	$4^+; 0$	0^+_3	3	γ, α	2, 6, 7, 12, 14, 24, 30, 60
9.116 ± 3	$3^-; 0$		3.2	γ, α	2, 7, 12, 14, 29, 30, 60
9.318 ± 2	$(2^-); 0$			γ	7, 12, 30, 60
9.487 ± 5	$2^+; 0$		29 ± 15	γ, α	12, 14, 53, 60
9.873 ± 4	$3^+; 0$			γ	7, 30, 53
9.935 ± 12	$(1^+); 0$		$\tau_m < 35$ fsec	γ	7, 30, 60
9.990 ± 8	$4^+; 0$	0^+_2	$\Gamma = 155 \pm 30$	γ, α	2, 7, 12, 14, 29, 30, 60
10.262 ± 5	$5^-; 0$	0^-	145 ± 40	α	2, 4, 7, 14, 15, 16, 18, 20, 30, 52
10.274 ± 3	$2^+; 1$		≤ 0.3	γ, α	12, 14, 53, 55
10.406 ± 5	$3^-; 0$	1^-	80	α	7, 14, 30, 60
10.553 ± 5	$4^+; 0$		16	α	7, 14, 30
10.584 ± 5	$2^+; 0$		24	α	14, 30, 53, 60
10.609 ± 6	$6^-; 0$	2^-	$\tau_m = 23 \pm 7$ fsec	γ	2, 6, 7
10.694 ± 6	$4^-, 3^+; 0$			γ	6, 7
10.80 ± 75	$4^+; 0$	0^+_4	$\Gamma = 350$	α	14, 15, 30
10.843 ± 4	$2^+; 0$		13	α	14, 53, 60
10.840 ± 6	$3^-; 0$		45	γ, α	7, 14
10.884 ± 3	$3^+; 1$		$\tau_m < 30$ fsec	γ	53, 55
10.917 ± 6	$3^+; 0$			γ	7
10.97 ± 120	$0^+; 0$	0^+_5	$\Gamma = 580$	α	14
11.020 ± 8	$4^+; 0$		24	α	6, 7, 14, 60
11.090 ± 3	$4^+; 1$		≤ 0.5	γ, α	12, 14, 30, 55
11.24 ± 23	$1^-; 0$		175	α	14, 30
11.2623 ± 1.9	$1^+; 1$			γ	12, 35, 36, 38, 53
11.270 ± 5	$1^-; 1$		≤ 0.3	γ, α	12, 14
11.320 ± 9	$2^+; 0$		40 ± 10	α	14, 53
11.528 ± 6	$3^+, 4^-; 0$		$\tau_m \leq 30$ fsec	γ	7, 30
11.555 ± 6	$(3^+); 0$			γ	7, 30
11.558 ± 4	$0^+; 0$	0^+_6	$\Gamma = 1.1 \pm 0.4$	γ, α	12, 14
11.601 ± 10	$2^-; 1$				55
11.653 ± 5	$(3^+); 0$			γ	6, 7, 36

Table 20.13: Energy levels of ^{20}Ne [a] (continued)

E_x (MeV ± keV)	$J^\pi; T$	K^π	τ_m [b] or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
11.885 ± 7	$2^+; 0$		46	γ, α	7, 14, 30, 53, 60
11.928 ± 4	$4^+; 0$		0.44 ± 0.15	γ, α	12, 14, 60
11.951 ± 4	$8^+; 0$	0_1^+	$(3.5 \pm 1.0) \times 10^{-2}$	γ, α	4, 6, 7, 8, 12, 14, 15, 16, 18, 19, 23, 30, 52
11.985 ± 16	$1^-; 0$		30 ± 5	γ, α	7, 12, 14
12.098 ± 6	$2^-; 1$			γ	7, 30, 38, 55
12.137 ± 5	$6^+; 0$	0_3^+		α	5, 6, 7, 8, 14, 15
12.221 ± 4	$2^+; 1$		< 1	γ, α	7, 12
12.253 ± 10	$4^+; 0$		155 ± 15	α	14
12.256 ± 3	$3^-; 1$		< 1	γ, α	12, 14
12.327 ± 10	$2^+; 0$	0_5^+	390 ± 50	α	14
12.401 ± 5	$3^-; (1)$	0_7^+	37.3 ± 0.9	γ, α	6, 7, 12, 14, 29, 60
12.433 ± 5	$0^+; 0$		24.4 ± 0.5	γ, α	7, 12, 14
12.472 ± 10	$(2^+); 0$		124 ± 6	α	14
12.585 ± 5	$6^+; 0$	(0_2^+)	72 ± 9	α	6, 7, 14, 15, 16, 18, 19
12.592 ± 15	$(2^+); 0$		145 ± 25	α	14
12.713 ± 5	$5^-; 0$	1^-	84 ± 8	α	6, 7, 14
12.743 ± 10	$(2^+); 0$		61 ± 12	α	6, 7, 14
12.836 ± 5	$1^-; 0$		30 ± 5	α	7, 14
12.957 ± 5	$2^+; 0$	(0_7^+)	38 ± 4	α	7, 14, 60
13.048 ± 5	$4^+; 0$		18 ± 3	α	6, 7, 14
13.0607 ± 2.1	2^-		1.0	p, α	28
13.099 ± 10	$(0^+); 0$		53 ± 24	α	14
13.105 ± 5	$6^+; 0$	(0_2^+)	102 ± 5	α	14
13.137 ± 5	$3^-; 0$		48 ± 4	α	14
13.1713 ± 2.1	$1^+; (1)$		2.3 ± 0.2	γ, p, α	25, 26, 28, 29
13.222 ± 10	$0^+; 0$		40 ± 13	α	7, 14, 28
13.224 ± 15	$1^-; 0$		80	p, α	14, 28
13.226 ± 5	$3^-; 0$		53 ± 4	α	14
13.3075 ± 2.1	1^+		0.9 ± 0.1	γ, p, α	25, 26, 28
13.338 ± 5	$7^-; 0$	2^-	$(8 \pm 3) \times 10^{-2}$	α	6, 7, 8, 14
13.341 ± 5	$4^+; 0$		26 ± 3	α	14
13.414 ± 2	$3^-; 0$		24 ± 3	α	14, 25, 26, 28
13.426 ± 5	$(5^-); 0$		49 ± 7	α	14
13.461 ± 10	1^-		195 ± 25	p, α	14, 28
13.484 ± 2	$1^+; 1$		6.4 ± 0.3	γ, p, α	25, 26, 28, 38
13.507 ± 5	$1^-; 0$		24 ± 8	p, α	14, 26, 28
13.529 ± 5	$2^+; 0$		61 ± 8	α	14

Table 20.13: Energy levels of ^{20}Ne [a] (continued)

E_x (MeV ± keV)	$J^\pi; T$	K^π	τ_m [b] or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
13.530 ± 15	$(0^+); 0$		76 ± 32	α	14
13.573 ± 5	$2^+; 0$		12 ± 5	α	7, 14, 28
13.586 ± 3	2^+		9 ± 1	p, α	26, 28
13.642 ± 3	$0^+; 1$		17 ± 1	p, α	7, 26, 28, 29
13.676 ± 2.3	(2^-)		4.5 ± 0.2	γ, p, α	25, 26, 28
13.677 ± 5	$5^-; 0$		11 ± 2	α	6, 14
13.692 ± 10	$7^-; 0$	0^-	310 ± 30	α	14
13.736 ± 2.5	1^+		7.7 ± 0.5	γ, p, α	25, 26, 28
13.744 ± 20	$0^+; 0$		≈ 80	α	14
13.827 ± 10	$3^-; 0$		136 ± 15	α	7, 14
13.866 ± 30	$1^-; 0$		≈ 175	p, α	7, 14, 28
13.881 ± 2.3	$2^+; 1$		0.14 ± 0.05	γ, p, α	7, 8, 25, 26, 28, 29
13.908 ± 5	$2^+; 0$		74 ± 10	α	14, 28
13.926 ± 2.3	(0^+)		3.5 ± 0.4	p, α	28
13.928 ± 5	$6^+; 0$		65 ± 3	α	14, 15, 16
13.948 ± 10	$0^+; 0$		79 ± 15	α	14
13.965 ± 5	$4^+; 0$	(0_6^+)	8.1 ± 1	α	14
14.02	1^-		≈ 70	p, α	28
14.063 ± 2.3	2^+		≈ 140	p, α	26, 28
14.115 ± 5	$2^+; 0$		42 ± 6	α	14
14.128 ± 2	2^-		4.7 ± 0.7	γ, p, α	25, 26, 28
14.150 ± 2.3	2^-		11.8 ± 1.0	γ, p, α	25, 26, 28
14.20	1^+		14 ± 1	γ, p	25, 26
14.270 ± 10	$4^+; 0$		92 ± 9	α	14
14.304 ± 10	$(6^+); 0$		60 ± 13	α	6, 7, 14
14.311 ± 5	$6^+; 0$		117 ± 8	α	6, 7, 14, 15, 16, 18
14.313 ± 15	$(3^-); 0$		≈ 45	α	14
14.370 ± 3			≈ 5	p, α	26, 28
14.454 ± 5	$5^-; 0$		≈ 15	α	14
14.455 ± 3	$(0^+, 2^+); 0$		33 ± 3	p, α	14, 26, 28
14.475 ± 6	0^+		68 ± 2	p, α	26, 28
14.597 ± 7	$1^-; 0$		116 ± 5	p, α	14, 28
14.593 ± 10	$4^+; 0$		260 ± 25	α	14
14.653 ± 10	(0^+)		25	p, α	26, 28
14.699 ± 3.3	(1^+)		36 ± 10	p, α	14, 26, 28
14.731 ± 10	$(4^+); 0$		60 ± 25	α	14
14.761 ± 5	$6^+; 0$		7.3 ± 4.8	α	14
14.776 ± 4	(1^-)		110 ± 20	p, α	26, 28

Table 20.13: Energy levels of ^{20}Ne [a] (continued)

E_x (MeV ± keV)	$J^\pi; T$	K^π	τ_m [b] or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
14.807 ± 5	$6^+; 0$		86 ± 7	α	6, 14, 28
14.816 ± 5	$5^-; 0$		117 ± 13	α	6, 14
14.839 ± 10	$(4^+); 0$		79 ± 15	α	14
14.888 ± 10	$2^+; 0$		100 ± 30	p, α	14, 28
15.047 ± 10	$2^+; 0$		66 ± 20	p, α	7, 14, 28
15.073 ± 10	$5^-; 0$		160 ± 25	α	14
15.142 ± 15	$(2^+); 0$		≈ 60	α	14
15.174 ± 10	$5^-; 0$		230 ± 25	α	6, 14
15.23			28	p, α	28
15.27	(1^-)		285	p, α	28
15.319 ± 25	$7^-; 0$		280 ± 40	α	4, 6, 7, 14, 15, 16, 18
15.330 ± 5	$4^+; 0$		34 ± 10	α	4, 6, 7, 14
15.366 ± 5	$7^-; 0$		110 ± 10	α	14, 15, 16, 18, 19
15.436 ± 15	$(3^-); 0$		90 ± 20	p, α	7, 14, 28
15.5			55	p, α	14, 28
15.70 ± 15	$(8^-); 0$	(2^-)		α	6, 7, 14
15.874 ± 9	8^+		100 ± 15	α	5, 6, 7, 15, 18, 19
15.97	$(6^+); 0$			α	14
16.01 ± 25	$(2^+; 1)$		100	p, α	28
16.139 ± 15			38	α	6, 7, 14, 28
16.25				α	6, 14
16.329 ± 11	$4^+; 0$		45	p, α	14, 28
16.437 ± 11	$(0, 2, 4)^+; 0$		35	α	14
16.505 ± 15	$6^+; 0$	(0^+_6)	24 ± 4	α	6, 14
16.559 ± 15	$5^-; 0$		90 ± 30	α	14
16.581 ± 15	$7^-; 0$	1^-	92 ± 8	α	7, 14
16.628 ± 20	$3^-; 0$		80 ± 25	α	14
16.63 ± 20	(7^-)			α	15, 16, 18
16.667 ± 15	$4^+; 0$		100 ± 25	α	14
16.717 ± 15	$5^-; 0$		≈ 25	α	6, 7, 14
16.732 ± 5	$0^+; 2$		2.0 ± 0.5	γ, p, α	24, 25, 26, 28, 56
16.746 ± 25	$8^+; 0$		160 ± 50	α	14
16.847 ± 15	$5^-; 0$		16 ± 8	α	14
16.871 ± 20	$6^+; 0$		350 ± 50	α	14
17.072 ± 20	$4^+; 0$		180 ± 30	α	14
17.155 ± 15	$5^-; 0$		26 ± 5	α	14
17.213 ± 15	$4^+; 0$		225 ± 30	α	14
17.284 ± 15	$3^-; 0$		86 ± 25	α	14

Table 20.13: Energy levels of ^{20}Ne [a] (continued)

E_x (MeV ± keV)	$J^\pi; T$	K^π	τ_m [b] or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
17.295 ± 15	$8^+; 0$		200 ± 25	α	4, 14, 15, 16, 18, 19
17.390 ± 15			< 10	α	14
17.430 ± 15	$9^-; 0$	(0^-)	220 ± 25	α	6, 7, 8, 14
17.541 ± 15	$6^+; 0$		86 ± 9	α	14
17.55 ± 10	$(2^+; 1)$		19	n, p, α	27, 28
17.606 ± 15	$5^-; 0$		140 ± 20	α	14
17.769 ± 20	$4^+; 0$		≈ 125	p, α	14, 28
17.851 ± 15	$5^-; 0$		200 ± 30	α	14
17.91 ± 20	(0^+)			n, p	27
18.005 ± 15	$7^-; 0$		< 10	α	14
18.024 ± 5	$5^-; 0$		34 ± 7	α	14
18.083 ± 25	$4^+; 0$		140 ± 60	α	14
18.125 ± 5	$7^-; 0$		29 ± 6	α	6, 7, 8, 14
18.286 ± 10	$6^+; 0$		190 ± 30	α	6, 14
18.430 ± 7	$2^+; 2$		9.5 ± 3	γ, n, p, α	25, 26, 27, 28, 56
18.430 ± 20	$7^-; 0$		185 ± 40	α	14
18.494 ± 20	$5^-; 0$		130 ± 30	α	14
18.621 ± 20	$8^+; 0$	(0_6^+)	185 ± 30	α	14
18.745 ± 25	$6^+; 0$		140 ± 50	α	14
18.768 ± 20	$7^-; 0$		140 ± 35	α	14, 15
18.960 ± 25	$8^+; 0$		200 ± 60	α	14
19.051 ± 15	$5^-; 0$		≈ 90	α	14
19.15 ± 20	$6^+; 0$		200 ± 50	α	8, 14
19.284 ± 15	$6^+; 0$		140 ± 25	α	14
19.298 ± 25	$7^-; 0$		430 ± 60	α	14, 15
19.443 ± 10	$6^+; 0$	(0_7^+)	130 ± 15	α	14
19.536 ± 25	$6^+; 0$		250 ± 60	α	14
19.655 ± 20	$6^+; 0$		140 ± 35	α	14
19.731 ± 20	$8^+; 0$		330 ± 60	α	14
19.845 ± 40	$6^+; 0$		360 ± 120	α	14
19.859 ± 10	$5^-; 0$		170 ± 25	α	14
19.884 ± 40	$7^-; 0$		≈ 120	α	14, 15
19.991 ± 30	$4^+; 0$		130 ± 100	α	14
20.027 ± 15	$6^+; 0$		80 ± 35	α	14
20.106 ± 25	$7^-; 0$		190 ± 35	α	14
20.15 ± 150			broad	γ, n	34
20.168 ± 35	$6^+; 0$		285 ± 100	α	14
20.296 ± 15	$7^-; 0$		255 ± 40	α	14

Table 20.13: Energy levels of ^{20}Ne [a] (continued)

E_x (MeV ± keV)	$J^\pi; T$	K^π	τ_m [b] or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
20.341 ± 20	$5^-; 0$		190 ± 40	α	14
20.344 ± 15	$7^-; 0$		135 ± 35	α	14
20.419 ± 30	$6^+; 0$		215 ± 90	α	14
20.445 ± 25	$6^+; 0$		370 ± 55	α	14
20.468 ± 30	$5^-; 0$		280 ± 70	α	14
20.686 ± 6	$9^-; 0$	(1^-)	78 ± 11	α	7, 14, 16
20.76 ± 30	$7^-; 0$		240 ± 50	α	14, 15
20.800 ± 25	$5^-; 0$		170 ± 60	α	14
20.95 ± 40	$7^-; 0$		300 ± 50	α	7, 14
21.062 ± 6	$9^-; 0$	(1^-)	60 ± 6	α	4, 7, 14, 16, 18, 19
21.3 ± 100	$7^-; 0$		300	α	14, 15
21.8 ± 100	$7^-; 0$		300	α	7, 14, 15
22.3 ± 100	$7^-; 0$		500	α	7, 14, 15
22.6 ± 300			broad	γ, n	34
22.8 ± 60	$9^-; 0$		500	α	7, 14
22.87 ± 40	$9^-; 0$		225 ± 40	α	4, 7, 14, 16, 18
23.4 ± 200	$8^+; 0$		500	α	14
23.70 ± 30	(9^-)		≤ 200	α	15, 16
24.21 ± 25	$8^+; 0$		350	α	14, 16
24.9 ± 500			broad	γ, n	34
25.10 ± 50	$8^+; 0$		≈ 200	α	14, 16
25.67 ± 50			≈ 400	α	14, 16
27.1 ± 100	(9^-)		700	α	14, 15, 18
27.5			broad	γ, n	34
28	$8^+; 0$		1600	α	14
28.2 ± 300			700	α	14

[a] See also Tables 20.14 and 20.15. For other states with $E_x > 15.5$ MeV see Tables 20.30 in (1978AJ03) and 20.23, 20.24 and 20.25 here and reactions 1, 34 and 36. 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

[b] See Table 20.20 in (1978AJ03).

Muon and neutrino capture and reactions: (1983RO1E, 1984EL1D, 1984GR03, 1985MI1D, 1987SU06).

Pion and kaon capture and reactions: (1982BE1M, 1982BI08, 1982LE1P, 1982NA10, 1982OL03, 1982WO1E, 1983BA22, 1983CO08, 1983GE12, 1983GM1A, 1983MA16, 1983RA1J, 1984EF03, 1984EL1D, 1985AI1C, 1985AZ1A, 1985BI01, 1985CU1F, 1985SE21, 1986AN40, 1986BA3E, 1986LE06, 1986LE22, 1986RO03, 1986TK1C, 1987GI01, 1987SC03, 1987TE01).

Antiproton interactions: (1985BA2T, 1985CU1F, 1986BA22, 1986BA3Q, 1986BA2W, 1986VA04).

Hypernuclei: (1984AS1D, 1985OS1C).

Other topics: (1978WI1B, 1980KR24, 1981BL1K, 1981CL05, 1982BR08, 1982DR1E, 1982FL04, 1982GO1U, 1982VA1E, 1982VE02, 1983AR07, 1983AR1J, 1983BI1C, 1983BR29, 1983BR1P, 1983FU1D, 1983GR26, 1983IS03, 1983LO05, 1983MA23, 1983SH32, 1983VA21, 1984AM03, 1984JA15, 1984JE02, 1984KA11, 1984LO05, 1984SC41, 1985AD1A, 1985AL21, 1985AN28, 1985IV1B, 1985KA01, 1985LI19, 1985MI10, 1985MU10, 1985ST19, 1985VE04, 1986SA02, 1986TA1A, 1987HA08, 1987PR01).

Ground state of ^{20}*Ne:* (1978WI1B, 1980KR24, 1982BR24, 1982FL04, 1982LO13, 1982OL03, 1982SC20, 1982ZE1A, 1983ANZQ, 1983AR07, 1983AR1J, 1983BA50, 1983BR1P, 1983DR03, 1983MA68, 1983SP04, 1983TO1L, 1983VA16, 1984AN1B, 1984BR25, 1984DR01, 1984HA14, 1984JA15, 1984KA11, 1984LO05, 1984OK04, 1984SP06, 1984WE04, 1985AN16, 1985AN28, 1985CL1A, 1985HA18, 1985HU09, 1985KR1G, 1985MI23, 1985SP06, 1986CA27, 1986LE16, 1986RO03, 1986SA02, 1986TA1X, 1987AB03).

$$Q_{1.63} = -0.27 \pm 0.03\ e \cdot \mathrm{b}$$ (1978GR06)

$$\mathrm{g}_{1.63} = +0.54 \pm 0.04$$ (1975HO15)

$$B(\mathrm{E2}) \uparrow [0 \rightarrow 1.63] = 0.0330 \pm 0.0015\ e^2 \cdot \mathrm{b}^2$$ (1978GR06). See also (1987RA01).

$$Q_{4.25} = 0.022 \pm 0.003\ e^2 \cdot \mathrm{b}^2$$ (1978GR06)

$$\mathrm{g}_{4.25} = +0.13 \pm 0.15$$ (1986TR08). See also (1984BR15).

Isotopic abundance: (90.51 ± 0.09)% (1984DE53).

1. (a) ^{10}B(^{10}B, ^{10}B)^{10}B $\qquad E_b = 31.148$

   (b) ^{10}B(^{10}B, α)^{16}O $\qquad Q_m = 26.4137$

Excitation functions have been measured for $E(^{10}\mathrm{B}) = 6$ to 30 MeV (reaction (a)) and 6 to 20 MeV (reaction (b)). Large resonant structures are observed in reaction (b), particularly at $E_x \approx 38$ MeV (α_0) and 38.6 MeV (α to ^{16}O*(7.0, 10.3, 16.2(u)), $\Gamma \approx 0.6$ MeV. See also (1983KAZF) and (1978AJ03).

2. ^{10}B(^{14}N, α)^{20}Ne $\qquad Q_m = 19.535$

Angular distributions of α-particles to many states of ^{20}Ne below $E_x = 10.7$ MeV have been measured at $E(^{14}\mathrm{N}) = 23.5$ to 35 MeV. See also (1978AJ03, 1983AJ01).

3. ^{10}B(^{16}O, ^{6}Li)^{20}Ne $\qquad Q_m = 0.274$

At $E(^{16}O) = 19.5$ to 42 MeV angular distributions for the ^{6}Li ions corresponding to transitions to ^{20}Ne*(0, 1.63, 4.25, 4.97, $5.62 + 5.79$, 6.7–7.2) are in good agreement with Hauser-Feshbach calculations. See also (1978AJ03, 1985ST1B).

4. ^{11}B(^{16}O, ^{7}Li)^{20}Ne $\qquad Q_m = -3.930$

At $E(^{11}B) = 115$ MeV, angular distributions are reported to ^{20}Ne*(7.16, 8.78, 10.26, 11.95, 15.4). ^{20}Ne*(8.78, 15.4, 17.3, 21.0 ± 0.07, 22.78 ± 0.06) are particularly strongly populated. It is suggested that these five states have $J^\pi = 6^+$, 7^-, (8^+), 9^- and 9^-: see (1983AJ01).

5. ^{12}C(^{9}Be, n)^{20}Ne $\qquad Q_m = 10.323$

At $E(^{9}Be) = 16$ and 24 MeV, angular distributions have been measured for ^{20}Ne*(7.3 ± 0.4, 9.2 ± 0.4, 10.9 ± 0.3, 12.2 ± 0.3, 15.7 ± 0.3): see (1983AJ01).

6. (a) ^{12}C(^{10}B, d)^{20}Ne $\qquad Q_m = 5.961$
(b) ^{12}C(^{11}B, t)^{20}Ne $\qquad Q_m = 0.764$

At $E(^{12}C) = 45$ MeV the population of states of ^{20}Ne with $E_x = 8.45$, $\underline{8.78}$, 9.03, 10.61, 10.67, 10.99, 11.01, 11.66, $\underline{11.94}$, $\underline{12.14}$, $\underline{12.39}$, $\underline{12.58}$, 12.73, 13.05, 13.17, $\underline{13.34}$ [7^-], $\underline{13.69}$, 13.91, 14.29, 14.36, 14.81, $\underline{15.17}$ [6^+], $\underline{15.38}$ [7^-], 15.71 [(7, 8)], $\underline{15.89}$ [(7)], 16.16, 16.22, $\underline{16.51}$ [(8)], 16.73, $\underline{17.39}$ [9^-], 18.18 and $\underline{18.32}$ MeV is reported. [Values in brackets are J^π suggested on basis of Hauser-Feshbach calculations. The underlined states 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: see (1978AJ03). See also (1983AJ01).

7. ^{12}C(^{12}C, α)^{20}Ne $\qquad Q_m = 4.621$

Double and triple (α, α, γ) correlations and γ-ray branching measurements [see Table 20.14] lead to the J^π assignments shown in Table 20.16. See Table 20.15 for assignments to rotational bands. Angular distributions have been reported at $E(^{12}C) = 4.9$ to 51 MeV [see (1978AJ03, 1983AJ01)] and at 10.0 and 10.5 MeV (1982DA28; α_0), 11.38 to 13.23 MeV (1985BA43; α_0), 21 to 30 MeV (1984DH02, 1983FOZV; α_0), 29.5 to 30.5 MeV (1982KA17; many states) and 35.6 to 41.2 MeV (1984LE19; many states). At $E(^{12}C) = 38$ to 64 MeV, ^{20}Ne*(7.17, 7.83, 8.54, 8.78, 9.03, 11.95, 12.13, 12.59, 13.90) are strongly populated and decay to $^{16}O_{g.s.}$ (1987RA02). For γ-decay measurements see (1987FI01), Table 20.16 and (1978AJ03).

The yields of various groups of α-particles and their relevance to states of ^{24}Mg, and fusion cross sections, have been studied by many groups: see (1978AJ03, 1983AJ01) for the earlier work and (1982DA28, 1982KA17, 1982SA27, 1983FOZV, 1984AR20, 1984DH02, 1984LE19, 1985BA43, 1986WU01).

Table 20.14: Radiative decays in ^{20}Ne [a]

E_i (MeV)	$J^\pi_i; T$	E_f (MeV)	Branch (%)	Γ_γ (meV)
1.63	$2^+; 0$	0	100	0.63 ± 0.04 [b]
4.25	$4^+; 0$	1.63	≈ 100	7.1 ± 0.7 [b]
4.97	$2^-; 0$	0	0.6 ± 0.2	$(8 \pm 3) \times 10^{-4}$ [b]
		1.63	99	0.14 ± 0.02 [b]
				δ(M2/E1) $= 0.076 \pm 0.011$
				δ(E3/E1) $= 0.043 \pm 0.016$
5.62	$3^-; 0$	0	7.6 ± 1.0	0.018 ± 0.006
		1.63	87.6 ± 1.0	0.21 ± 0.06
		4.97	4.8 ± 1.6	0.012 ± 0.005
5.79	$1^-; 0$	0	18 ± 5	0.8 ± 0.3
		1.63	82 ± 5	3.8 ± 0.8
6.73	$0^+; 0$	0		$\lvert M\rvert^2 = 7.4 \pm 2.0$ fm^2 [d]
		1.63	100	33
7.00	$4^-; 0$	1.63	0.5 ± 0.2	$(7 \pm 3) \times 10^{-3}$ [b]
		4.25	63.5	0.95 [b]
		4.97	11	0.16 [b]
		5.62	25	0.37 [b]
7.16	$3^-; 0$	4.25	60 ± 5	0.97 ± 0.11
		5.79	40 ± 5	0.64 ± 0.10
7.20	$0^+; 0$	0		$\Gamma_\pi = 3.9 \times 10^{-2}$
				6.9 ± 1.4 fm^2 [d]
		1.63	100	4.35 ± 0.75
7.42	$2^+; 0$	0	$\leq 9.4 \pm 1.4$	$\leq 3.0 \pm 0.6$
		1.63	$\geq 90.6 \pm 1.4$ [f]	29 ± 4
		4.25	≤ 7.6	

Table 20.14: Radiative decays in ^{20}Ne [a] (continued)

E_i (MeV)	$J_i^\pi; T$	E_f (MeV)	Branch (%)	Γ_γ (meV)
7.83	2^+; 0	0	83 ± 1	57 ± 7
		1.63	17 ± 1	11.7 ± 1.6
		4.25	< 3	< 2
8.46	5^-; 0	5.62	100	13 ± 3
8.71	1^-; 0	0	87 ± 8	61 ± 16
		1.63	13 ± 8	9 ± 6
8.78	6^+; 0	4.25	100	100 ± 15
9.03	4^+; 0	1.63	100	340 ± 42
		4.25	< 2	< 6.8
9.12	3^-; 0	1.63	50 ± 5	13 ± 2
		4.97	33 ± 5	8.6 ± 1.7
		5.62	17 ± 4	4.4 ± 1.1
9.32 [l]	(2^-; 0)	1.63		
9.49	2^+; 0	0		$\lesssim 60$
		1.63	(100)	260 ± 100
9.87	3^+; 0	0	< 0.5	
		1.63	78	[g]
		4.25	12 ± 3	
		4.97	≤ 5	
		5.62	≈ 7	
		7.43	≈ 3	
9.94	(1^+); 0	1.63	78 ± 5	
		4.97	22 ± 5	
9.99	4^+; 0	0		$\lesssim 70$
		1.63	(100)	900 ± 400
10.27	2^+; 1	0	0.65 ± 0.14	29 ± 8
		1.63	88.9 ± 0.5	4080 ± 440
		4.97	1.3 ± 0.1	60 ± 8
		5.62	2.1 ± 0.2	97 ± 14
		7.43	6.9 ± 0.4	310 ± 40

Table 20.14: Radiative decays in ^{20}Ne [a] (continued)

E_i (MeV)	$J^{\pi}_i; T$	E_f (MeV)	Branch (%)	Γ_{γ} (meV)
		7.83	0.22 ± 0.06	8 ± 2
10.61	6^-; 0	7.00	95.5 ± 1.2	29 ± 9 [b]
		8.46	4.5 ± 1.2	1.3 ± 0.4
10.69	$4^-, 3^+$; 0	4.25	25 ± 4	
		4.97	75 ± 4	
10.88	3^+; 1	1.63	77 ± 5	[h]
		4.25	23 ± 5	
11.09 [c]	4^+; 1	1.63	0.5 ± 0.25	2 ± 1
		4.25 [i]	99.5 ± 0.25	338 ± 40
11.26 [j]	1^+; 1	0	84 ± 5	$(11.2 \pm 2.0) \times 10^3$
		1.63	16 ± 5	$(2.1 \pm 0.7) \times 10^3$
11.27 [c]	1^-; 1	0	55 ± 2	390 ± 47
		1.63	2.5 ± 1	18 ± 7
		4.97	6.5 ± 1	46 ± 9
		8.85	27 ± 1.5	189 ± 24
		9.32	9 ± 1	63 ± 10
11.53	$3^+, 4^-$; 0	4.25	30 ± 3	
		4.97	70 ± 3	
		7.00	[f]	
11.555	(3^+; 0)	1.63		
		7.00		
11.558	0^+; 0	1.63	100	
		4.25	< 8	
11.65	(3^+); 0	1.63	14 ± 3	
		4.25	86 ± 3	
11.93	4^+; 0	1.63	21 ± 11	5.5 ± 3.0
		4.25	79 ± 11	20.5 ± 5.5
11.95	8^+; 0	8.78	100	7.7 ± 1.1
12.22 [k]	2^+; 1	1.63	(100)	
12.26	3^-; 1	1.63	63 ± 1.5	

Table 20.14: Radiative decays in ^{20}Ne [a] (continued)

E_i (MeV)	$J^\pi_i; T$	E_f (MeV)	Branch (%)	Γ_γ (meV)
		5.62	37 ± 1.5	
12.40	3^-; (1)	0	≈ 1	
		1.63	≈ 29	80
		4.25	≈ 70	200
12.43	0^+; 0	1.63	100	170 ± 50
13.48	1^+; 1	1.63	95	
		4.97	5	
13.88	2^+; 1	1.63	20	
		4.97	80	
16.73	0^+; 2	1.63	[e]	
		5.79	[e]	
		11.23	(100)	≈ 5000 [e]
18.43	2^+; 2	12.22	(100)	≈ 300

[a] For earlier references see Tables 20.19 in (1978AJ03) and 20.18 in (1983AJ01). See also Tables 20.17 and 20.20 here.

[b] From τ_m: see Table 20.20 in (1978AJ03) and branching ratios.

[c] See also Table 20.19 in (1978AJ03).

[d] Monopole matrix element.

[e] See footnote (a) in Table 2 of (1976MA01).

[f] $\delta(E2/M1) = -8.36^{+1.0}_{-1.5}$.

[g] $\Gamma_\gamma(\text{total})/\Gamma = 0.82 \pm 0.27$.

[h] $\Gamma_\gamma(\text{total})/\Gamma < 0.3$ (1977MA07). See also (1987FI01).

[i] $\delta = +0.01 \pm 0.06$.

[j] (1983BE19): see reaction 35.

[k] (1984CA08).

[l] (1987FI01).

See also (1982BLZT, 1983SH1Z, 1984HU1E, 1985XI1E, 1986TR08), (1981DA13, 1982CO1X, 1983SI1L, 1984CU1B), (1986SZ02; applied), (1982BA1D, 1982SA1A, 1984FO1A, 1985AR1A, 1986TH1E; astrophysics) and (1982HO05, 1982MO1V, 1982SU06, 1983AH1A, 1984DA1B, 1986FA12; theor.).

8. (a) ^{12}C(^{14}N, ^{6}Li)^{20}Ne $\qquad Q_m = -4.176$

Table 20.15: K^π assignments to states of ^{20}Ne [a]

K^π	J^π	E_x (MeV)	K^π	J^π	E_x (MeV)
0_1^+	0^+	0		6^+	(16.51)
	2^+	1.63		8^+	(18.62)
	4^+	4.25	0_7^+ [b]	0^+	12.43
	6^+	8.78		2^+	(12.96)
	8^+	11.95		6^+	(19.44)
0_2^+	0^+	6.73	0^-	1^-	5.79
	2^+	7.42		3^-	7.16
	4^+	9.99		5^-	10.26
	6^+	(12.59, 13.11)		7^-	13.69
0_3^+	0^+	7.20		9^-	(17.43)
	2^+	7.83	1^-	1^-	8.85
	4^+	9.03		3^-	10.41
	6^+	12.14		5^-	12.71
0_4^+	0^+	8.7		7^-	16.58
	2^+	8.8		9^-	(20.69, 21.06)
	4^+	10.80	2^-	2^-	4.97
	6^+ [c]	(12.59)		3^-	5.62
	8^+ [c]	(17.30)		4^-	7.00
0_5^+	0^+	10.97		5^-	8.46
	2^+ [d]	12.33		6^-	10.61
0_6^+ [b]	0^+	11.55		7^-	13.34
	4^+	(13.97)		8^-	(15.70) [e]
				9^-	17.43

[a] See Tables 20.19, 20.20, 20.21, 20.22 and 20.23 in (1983AJ01) and (1984RI01, 1984RI07, 1985MU14, 1986MA48). I am greatly indebted to Prof. H.T. Richards for his comments on this table.

[b] See also (1985LAZZ; prelim.).

[c] However (1987MI07) predict the $J^\pi = 6^+$, 8^+ and 10^+ members of the 0_4^+ band to be at $E_x \approx 14 - 15$ MeV [$\Gamma \approx 1 - 2$ MeV], ≈ 21 MeV [$\Gamma \approx 2$ MeV], and ≈ 29 MeV [$\Gamma \approx 29$ MeV], suggesting that the 0_4^+ band has a moment of inertia which is very similar to that of the 0^- band.

[d] For the location of higher J^π members of this band see (1984RI01).

[e] See (1970PA08) and (1984RI01).

(b) ^{12}C(^{14}N, d)^{24}Mg $\rightarrow \alpha +$ ^{20}Ne $\qquad Q_m = -5.651$

Angular distributions of the ^{6}Li ions to many states of ^{20}Ne below 17.5 MeV have been reported for $E(^{14}\text{N}) = 30$ to 78 MeV and $E(^{12}\text{C}) = 67.2$ MeV. At the latter energy ^{20}Ne*(16.67, 17.38, 18.11, 19.16, 19.6) are particularly strongly populated: see (1978AJ03). For reaction (b) to ^{20}Ne$_{\text{g.s.}}$ see (1984AR20, 1986WU01). See also (1982HO1E, 1985ST1B, 1986AR04) and ^{6}Li in (1988AJ01).

Table 20.16: Excited states of ^{20}Ne from ^{12}C(^{12}C, α)^{20}Ne [a]

E_x (MeV ± keV) [b]	J^π [c]	Γ_γ/Γ [d]	$\Gamma_{\text{c.m.}}$ (keV)	θ^2_α [e]
1.6329 ± 1.0	2^+			
4.2456 ± 2.5	4^+			
4.9663 ± 2.5	2^-			
5.618 ± 4	3^-			
5.774 ± 6	1^-			
6.725 ± 6	0^+			
7.004 ± 4	4^-			
7.169 ± 6	3^-			
7.196 ± 6	0^+			0.026 [q]
7.435 ± 6	2^+			
7.835 ± 6	2^+			0.015 [q]
8.449 ± 6	5^-			$(1.6 \pm 0.5) \times 10^{-3}$ [r]
8.694 ± 6	1^-			0.0027 [q]
8.779 ± 6	6^+			
8.85	1^-			0.0179 [q]
9.033 ± 6	4^+			0.033 [q], 0.022 [r]
9.110 ± 6				
9.318 ± 6	2^-	> 0.90		
9.533 ± 6				
9.872 ± 6	$1^+, 2^-, 3^+$	> 0.8		
9.948 ± 5 [d]	$1^+, 2^-, 3^+$	> 0.7		
10.024 ± 6				
10.264 ± 6	5^-			
10.407 ± 6	(3^-)			0.078 [q]
10.545 ± 6				

Table 20.16: Excited states of ^{20}Ne from ^{12}C(^{12}C, α)^{20}Ne [a] (continued)

E_x (MeV ± keV) [b]	J^{π} [c]	Γ_γ/Γ [d]	$\Gamma_{c.m.}$ (keV)	θ^2_α [e]
10.609 ± 5	6^-	$\equiv 1$		
10.693 ± 5	$4^-, 3^+$	> 0.95		
10.840 ± 6	(3^-)			0.0099 [q]
10.917 ± 6	$3^+; T = 0$	> 0.7		
11.013 ± 6				
11.528 ± 5 [d]	$(3^+, 4^-)$	> 0.90		
11.568 ± 10 [d]	$(3^+; T = 0)$	0.75 ± 0.10		
11.653 ± 5 [d]	(3^+)	> 0.90		
11.892 ± 8 [d]		0.16 ± 0.02		
11.949 ± 6	8^+			$(7.6 \pm 2.2) \times 10^{-3}$ [r]
12.014 ± 10 [d]		> 0.10		
12.097 ± 8 [d]		> 0.20		
12.135 ± 5 [f]	6^+			$(4.9 \pm 2.6) \times 10^{-4}$ [r,t]
12.172 ± 8 [d]		> 0.45		
12.219 ± 10 [d]	$2^+; T = 1$	> 0.45		
12.379 ± 8 [d]		0.005 ± 0.001		
12.436 ± 5	0^+ [s]		24 ± 1	[r,s]
12.596 ± 5	6^+		50 ± 10	0.09 ± 0.02 [r]
12.730 ± 6	(5^-)			0.129 [q]
12.919 ± 6				
13.010 ± 6				
13.049 ± 6				
13.190 ± 6				
13.277 ± 6				
13.335 ± 6	7^-			$(2.4 \pm 1.0) \times 10^{-4}$ [r,u]
13.441 ± 6	(5^-)			≤ 0.023 [q]
13.569 ± 15				
13.631 ± 15				
13.679 ± 15				
13.845 ± 15				
13.886 ± 15				

Table 20.16: Excited states of ^{20}Ne from ^{12}C(^{12}C, α)^{20}Ne [a] (continued)

E_x (MeV ± keV) [b]	J^{π} [c]	Γ_γ/Γ [d]	$\Gamma_{c.m.}$ (keV)	θ_α^2 [e]
13.927 ± 5	6^+		113 ± 7	0.10 ± 0.01 [r]
14.144 ± 15				
14.308 ± 10	6^+		< 50 [r]	< 0.45 [r]
14.60				
14.812 ± 15				
15.034 ± 15	[a]			
15.159 ± 5 [g]	6^+		60 ± 15	$< 8 \times 10^{-4}$ [r,v]
15.364 ± 14 [h]	7^-		410 ± 130	
15.438 ± 10 [i]			100 ± 20	
15.691 ± 15				
15.874 ± 8 [j]	8^+		100 ± 15	0.047 ± 0.013 [r,w]
16.139 ± 15				
16.600 ± 15 [k]	7^-		160 ± 30	0.10 ± 0.02 [r,x]
16.717 ± 10			37 ± 10	
17.259 ± 11 [l]	$7^-(9^-)$		162 ± 20	0.019 ± 0.004 [r,y]
18.153 ± 10 [m]	7^-			
18.538 ± 7 [n]	8^+		138 ± 33	$(3.2 \pm 1.5) \times 10^{-3}$ [r,z]
20.478 ± 11 [o]	(8^+)		250 ± 30	0.11 ± 0.04 [r,aa]
20.704 ± 11 [p]	(9^-)		≈ 120	[r]
20.89 ± 30				
21.05 ± 20			140 ± 50	
21.65 ± 100	$(7^-, 9^-)$		240 ± 50	
22.03 ± 70	(8^+)		630 ± 80	
22.7 ± 70			490 ± 110	
23.2 ± 100			300 ± 100	
23.74 ± 100			230 ± 100	
24.374 ± 30	$7^-(5^-)$		210 ± 50	

[a] For complete references see Table 20.21 in (1978AJ03). Table 20.19 in (1983AJ01) has a number of errors.
[b] Uncertainties shown for $E_x > 5.7$ MeV are approximate, except for states flagged (d): see footnote [c] in Table 20.21 in (1978AJ03).
[c] See discussions in (1975ME04), (1983HI06), (1984LE19) and (1987FI01). See also Table 20.14 here.
[d] (1987FI01). ^{20}Ne*(11.89, 12.38) also decay via α_2.
[e] See also (1984LE19).
[f] 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: see (1978AJ03). (1983HI06) report an α_0 branching ratio of (90 ± 6)%.
[g] Alpha decay is (2 ± 2)% by α_0, (46 ± 2)% via α_{1+2} (mainly α_2) and (52 ± 2)% via α_{3+4} (mainly α_3) (1979YO04).
[h] Alpha decay is (32 ± 2)% by α_0, (58 ± 2)% via α_{1+2} (mainly α_2) and (10 ± 2)% via α_{3+4} (mainly α_3); $\Gamma_{\alpha_0}/\Gamma = 0.3 \pm 0.02$, assuming a single state. The state may correspond to a doublet (1979YO04). See also (1983HI06).
[i] Alpha decay is (20 ± 5)% by α_0, (57 ± 7)% by α_{1+2} and (23 ± 4)% by α_{3+4} (1983HI06).
[j] Alpha decay is (9 ± 2)% by α_0, (79 ± 2)% via α_{1+2} (mainly α_2) and (12 ± 4)% via α_{3+4} (mainly α_3) (1979YO04); (24 ± 5)% via α_0, (51 ± 7)% via α_{1+2}, (25 ± 5)% via α_{3+4} (1983HI06).
[k] Alpha decay is (72 ± 3)% via α_0, (20 ± 3)% via α_{1+2} (mainly α_2) and (8 ± 3)% via α_{3+4} (mainly α_3) (1979YO04); (60 ± 5)% via α_0, (20 ± 5)% via α_{1+2} and (20 ± 5)% via α_{3+4} (1983HI06).
[l] Alpha decay is (15 ± 2)% via α_0, (50 ± 6)% via α_{1+2} and (35 ± 7)% via α_{3+4} (1983HI06). See also (1979YO04).
[m] Alpha decay is (71 ± 6)% via α_0 and (29 ± 6)% via α_{1+2} (mainly α_2) (1979YO04).
[n] Alpha decay is (1.8 ± 0.9)% via α_0, (60 ± 8)% via α_{1+2} and (26 ± 4)% via α_{3+4}. Decay to $^{12}C_{g.s.} + {}^8Be_{g.s.}$ is also observed: the branching ratio is (12 ± 1.2)%. This state may be a member of an excited 8p-4h $(K^\pi = 0^+_6)$ band of which ^{20}Ne*(12.44) is the 0^+ band head (1983HI06).
[o] Deacy is (66 ± 26)% via α_0, (14 ± 7)% via α_{1+2}, (13.2 ± 2.5)% via $^{12}C + {}^8Be$ (1983HI06).
[p] Decay is $\lesssim 14$% via α_0, (25 ± 15)% via α_{1+2}, (46 ± 22)% via α_{3+4} and (4.5 ± 0.9)% via $^{12}C + {}^8Be$ (1983HI06). See also (1979YO04).
[q] (1979YO04).
[r] θ^2_α shown are $\theta^2_{\alpha_0}$ (1983HI06). See also (1987FI01).
[s] See footnote [f] in Table 20.21 in (1978AJ03).
[t] $\theta^2_{\alpha_2} = 0.66 \pm 0.36$ (1983HI06).
[u] $\theta^2_{\alpha_2} = 0.025 \pm 0.010$ (1983HI06).
[v] $\theta^2_{\alpha_2} = 0.05 \pm 0.013$, $\theta^2_{\alpha_3} = 0.91 \pm 0.23$ (1983HI06).
[w] $\theta^2_{\alpha_2} = 0.94 \pm 0.14$, $\theta^2_{\alpha_3} = 4.2 \pm 0.9$ (1983HI06).
[x] $\theta^2_{\alpha_2} = 0.048 \pm 0.013$, $\theta^2_{\alpha_3} = 0.44 \pm 0.12$ (1983HI06).
[y] $\theta^2_{\alpha_2} = 0.071 \pm 0.013$, $\theta^2_{\alpha_3} = 0.32 \pm 0.08$ [all θ^2_α assume $J^\pi = 7^-$] (1983HI06).
[z] $\theta^2_{\alpha_2} = 0.085 \pm 0.014$, $\theta^2_{\alpha_3} = 0.24 \pm 0.04$, $\theta^2(^{12}C) = 1.50 \pm 0.21$ (1983HI06).
[aa] $\theta^2_{\alpha_2} = 0.016 \pm 0.008$, $\theta^2(^{12}C) = 0.24 \pm 0.05$ (1983HI06).

9. $^{13}C(^9Be, 2n)^{20}Ne$ $Q_m = 5.376$

For cross sections see (1986CU02).

10. ^{14}N(^{12}C, ^{6}Li)^{20}Ne $Q_{\rm m} = -4.176$

See reaction 8.

11. ^{14}N(^{14}N, 2α)^{20}Ne $Q_{\rm m} = 7.923$

For yields of 1.63 MeV γ-rays see (1982DE39).

12. ^{16}O(α, γ)^{20}Ne $Q_{\rm m} = 4.734$

Observed resonances in the yield of capture γ-rays over the range $E_\alpha = 0.8$ to 10 MeV are displayed in Table 20.17. For a discussion of ^{20}Ne*(11.28) [$J^\pi = 1^+$; $T = 1$] whose excitation is parity forbidden see (1983FI02). See also (1984BU01). Total cross sections have been measured in the range $E_{\rm c.m.} = 1.7$ to 2.35 MeV. Assuming that S does not vary with energy over that interval, the astrophysical factor for non-resonant capture to ^{20}Ne$_{\rm g.s.}$ is 0.26 ± 0.07 MeV · b. An estimate of 0.7 ± 0.3 MeV · b for S at 300 keV is deduced (1987HA24). See also Table 20.17. For other papers on astrophysical considerations see (1982BA1D, 1982SA1A, 1984LA18, 1984NO1B, 1984TR1C, 1985AR1A, 1985TA1A, 1986DE27, 1986FI15, 1986KH1J). See also (1981KH1H, 1983BA50, 1983DE32, 1983LA25, 1984LA18, 1985BA2W, 1985BA1Q, 1986DE27; theor.).

13. ^{16}O(α, d)^{18}F $Q_{\rm m} = -16.3211$ $E_{\rm b} = 4.734$

See (1986KA36).

14. (a) ^{16}O(α, α)^{16}O $E_{\rm b} = 4.734$
(b) ^{16}O(α, 2α)^{12}C $Q_{\rm m} = -7.16195$

Excitation functions have been measured over a wide range of energies for elastically and inelastically scattered α-particles and γ-rays from the decay of ^{16}O*(6.13, 6.92, 7.13) [see (1978AJ03, 1983AJ01)] and (1986LE23; 1.8 to 4.8 MeV; α_0), (1985JA17; 2.0 to 3.6 MeV; α_0), (1983CA1F, 1985CA09; 9.2 to 13.5 MeV; α_0), (1984LA1N, 1986LAZZ; 10.8 to 18 MeV; α_1; prelim.) and (1979BI10, 1984RI06; 14.6 to 20.4 MeV; $\alpha_0 \to \alpha_5$). See also (1983FR14, 1985ISZU) and ^{16}O in (1986AJ04).

Table 20.17: Resonances in $^{16}O(\alpha,\gamma)^{20}Ne$ [a]

E_α (MeV $\pm$ keV)	$\Gamma_{c.m.}$ (keV)	$\omega\gamma$ [b] (eV)	E_x (MeV $\pm$ keV)	$J^\pi; T$
1.116 ± 4	2.6×10^{-6} [d]	$(1.7 \pm 0.3) \times 10^{-3}$	5.627 ± 4	3^-; 0
1.3174 ± 2.2 [c]	$(2.8 \pm 0.3) \times 10^{-2}$ [d]	$(1.7 \pm 0.3) \times 10^{-2}$ [l]	5.7877 ± 3.0	1^-; 0
2.490 ± 8	20 ± 3 [d,m]	$(7.1 \pm 1.2) \times 10^{-2}$ [m]	6.726 ± 6	0^+; 0
3.0359 ± 2.3 [c]	8.2 ± 0.3 [l]		7.1563 ± 0.5	3^-; 0
3.069	4	$(4.4 \pm 0.8) \times 10^{-3}$	7.189 ± 3	0^+; 0
3.359	8	0.146 ± 0.019	7.421 ± 1	2^+; 0
3.868	2.4	0.343 ± 0.035	7.828 ± 3	2^+; 0
(4.647 ± 3)			(8.451 ± 3)	(5^-; 0)
4.969 ± 9	2.1 ± 0.8	0.21 ± 0.05	8.708 ± 7	1^-; 0
5.05	< 3	1.35 ± 0.15	8.776 ± 3.2	6^+; 0
5.364	3.2	3.05 ± 0.38	9.024 ± 3	4^+; 0
5.477 ± 4	< 4	0.18 ± 0.02	9.114 ± 3	3^-; 0
5.94 ± 30	29 ± 15	1.3 ± 0.5	9.48 ± 24	2^+; 0
6.61 ± 30	155 ± 30	8 ± 3	10.02 ± 24	(4^+); 0
6.924 ± 7 [k]	≤ 1	19.5 ± 1.5 [e]	10.271 ± 7 [f]	2^+; 1
7.948 ± 4	< 1	30.2 ± 3.5	11.090 ± 3	4^+; 1
8.180 ± 5 [g]	< 1	2.06 ± 0.25 [h]	11.276 ± 4	1^-; 1
8.535 ± 6	1.3 ± 0.8	0.41 ± 0.05	11.559 ± 6	0^+; 0 [j]
8.994 ± 8	< 1	0.23 ± 0.05 [i]	11.926 ± 6	4^+; 0
9.02		0.131 ± 0.018	11.950 ± 4	8^+; 0
(9.05 ± 50)	< 40		(11.97)	
(9.15 ± 50)	< 40		(12.05)	
9.362 ± 5	< 1	1.41 ± 0.23	12.221 ± 4	2^+; 1
9.406 ± 4	< 1	6.6 ± 0.8 [g]	12.256 ± 3	3^-; 1
9.57 ± 10	33 ± 4	1.94 ± 0.15	12.39	3^-; (1)
9.70 ± 30	≤ 10	0.17 ± 0.05	12.49	

[a] For complete references see Tables 20.22 in (1978AJ03) and 20.20 in (1983AJ01). See also Table 20.18 here.

[b] $\omega\gamma = (2J + 1)\Gamma_\alpha\Gamma_\gamma/\Gamma$.

[c] The strength of the γ-decay of ^{20}Ne*(7.16) to ^{20}Ne*(5.79) (see Table 20.14) is strong evidence that these two states are members of the $K^\pi = 0^-$ band.

[d] This is also Γ_α.

[e] Other values are $\omega\gamma = 19.2 \pm 1.9$ eV; $\Gamma_\alpha = 116 \pm 20$ eV; $\Gamma_\gamma = 4.26 \pm 0.23$ eV: see (1983AJ01).

[f] The measurements of the decay of this state lead to $E_x = 4247.9 \pm 1.3$, 4966.0 ± 1.9, 5621.0 ± 3.5, 7423.1 ± 3.0, 7828.1 ± 3.8 and 8776.7 ± 2.3 keV.

[g] See also Table 20.20 in (1983AJ01).

[h] The γ-decay is partly (see Table 20.14) to a state at $E_x = 9318 \pm 2$ keV. The strength of this transition and the subsequent decay to ^{20}Ne*(1.63) (and not to the ground state) favor 2^- for ^{20}Ne*(9.32). The other M1 transition $[11.27 \rightarrow 8.85]$ is also strong suggesting similar structures for ^{20}Ne*(8.85, 9.32) (1980FI01).

[i] Also observed as a resonance in the yield of 6.13 MeV γ-rays with $(2J + 1)\Gamma_{\alpha_0}\Gamma_{\alpha_2}/\Gamma = 5.2 \pm 0.9$ eV (1980FI01).

[j] From (α, α_0): see (1984RI07).

[k] See also (1984RO04).

[l] Best value including the recent work by (1987HA24).

[m] (1987HA24).

A number of anomalies are observed: see Table 20.18. K^π parameter assignments derived from this and other work are displayed in Table 20.15 (1984RI07). See also (1983MI22). For reaction (b) see ^{12}C in (1985AJ01). For cross sections of relevance to astrophysics for both reactions see (1985DY05; $E_\alpha = 10$ to 26 MeV). For other channels see (1983AJ01). See also (1981BU27, 1983SA07, 1984BUZO, 1984SA28), (1984RE14), (1982WA1K, 1985ME1N; applications) and (1981SH1A, 1982AO06, 1982LE23, 1982SC16, 1983AO03, 1983BI1F, 1983BR1V, 1983CS02, 1983HO1D, 1983HO1F, 1983MA29, 1983MA68, 1983SM1B, 1983WA04, 1984BY02, 1984GO04, 1984OK04, 1984PR09, 1984SE20, 1984SU02, 1985MI11, 1985WA08, 1986ALZZ, 1986CEZW, 1986DE31, 1986HO33, 1986MA35, 1986SH07, 1986SU06, 1987HO1B, 1987PR01, 1987WA1B; theor.).

15. ^{16}O(^{6}Li, d)^{20}Ne $\qquad Q_m = 3.259$

Deuteron groups have been observed to many states of ^{20}Ne: see Table 20.19. Angular distributions have been measured for $E(^6\text{Li}) = 5.5$ to 75.4 MeV: see (1978AJ03, 1983AJ01). See also (1984MO08). Angular correlations [(d, α_0) to ^{16}O$_{\text{g.s.}}$] have been measured at $E(^6\text{Li}) = 60$, 75 and 95 MeV (1982AR20). See also (1986BE1D) and (1980GR1L, 1982ES1A, 1982GY02, 1983COZV, 1983OS03, 1983SU11, 1984GR29, 1986GR1R; theor.).

16. ^{16}O(^{7}Li, t)^{20}Ne $\qquad Q_m = 2.266$

Table 20.18: Resonances in ^{16}O(α, α) [a]

E_α (MeV ± keV)	$\Gamma_{\rm c.m.}$ (keV)	Outgoing particles	Γ_{α_0}/Γ	θ^2 (%)	$E_{\rm x}$ (MeV ± keV)	J^π
1.3174 ± 2.2	$(2.8 \pm 0.3) \times 10^{-2}$ [b]	α_0			5.7877 ± 2.6	1^-
2.522 ± 2.5 [c]	19.0 ± 0.9	α_0		22	6.751 ± 3	0^+
3.0382 ± 2.0 [a,c]	8.1 ± 0.3 [b]	α_0		36	7.164	3^-
3.082 ± 3.1 [c]	3.4 ± 0.2 [c]	α_0		1.1	7.199 ± 3	0^+
3.372 ± 3.4 [c]	15.1 ± 0.7 [c]	α_0		4.7	7.431 ± 3	2^+
3.885 ± 10	2	α_0		0.6	7.841 ± 8	2^+
4.653 ± 5	0.013 ± 0.004	α_0		0.07	8.455 ± 5	5^-
≈ 4.9	> 800	α_0		≈ 70	≈ 8.7	0^+
5.002	2.5	α_0		0.23	8.734	1^-
5.058 ± 3	0.11 ± 0.02	α_0		8.5 ± 1.5	8.779 ± 3	6^+
≈ 5.1	> 800	α_0		≈ 95	≈ 8.8	2^+
5.11	< 1	α_0			8.82	(5^-)
5.152 ± 5	19	α_0		1.1	8.854 ± 5	1^-
5.395 ± 5	3	α_0		3.9	9.049 ± 5	4^+
5.486 ± 5	3.2	α_0		0.49	9.121 ± 5	3^-
5.955 ± 10	24	α_0		1.4	9.496 ± 8	2^+
6.569 ± 10	97	α_0		17	9.987 ± 8	4^+
6.912 ± 5	141	α_0		66	10.262 ± 5	5^-
6.92 ± 10	≤ 0.3	α_0		$\leq 1.3 \times 10^{-3}$	10.27 ± 10	(2^+)
7.092 ± 5	81	α_0		4.8	10.406 ± 5	3^-
7.276 ± 5	16	α_0		1.8	10.553 ± 5	4^+
7.314 ± 10	24	α_0		0.85	10.583 ± 8	2^+

Table 20.18: Resonances in ^{16}O(α, α) [a] (continued)

E_α (MeV ± keV)	$\Gamma_{\mathrm{c.m.}}$ (keV)	Outgoing particles	Γ_{α_0}/Γ	θ^2 (%)	E_x (MeV ± keV)	J^π
7.580 ± 100	349	α_0		33	10.80 ± 75	4^+
7.635 ± 5	13	α_0		0.42	10.840 ± 5	2^+
7.636	45	α_0		2.1	10.841	3^-
(7.75)	80	α_0			(10.93)	
7.80 ± 150	576	α_0		14	10.97 ± 113	0^+
7.860 ± 10	24	α_0		2.0	11.020 ± 8	4^+
7.93 ± 10	≤ 0.5	α_0		≤ 0.05	11.08 ± 10	(4^+)
8.132 ± 30	172	α_0		4.2	11.24 ± 23	1^-
8.16 ± 10	≤ 0.3	α_0		≤ 0.009	11.26 ± 10	(1^-)
8.24 ± 10	40 ± 10	α_0		1.4	11.32 ± 10	2^+
8.528 ± 10	1.0 ± 0.5	α_0		0.03	11.551 ± 8	0^+ [i]
(≈ 8.6)	≈ 500	α_0			(≈ 11.6)	(2^+)
8.930 ± 20	46	α_0		1.1	11.875 ± 15	2^+
8.997 ± 5	0.44 ± 0.15	α_0, $\gamma_{6.13}$		0.04 ± 0.01	11.929 ± 5	4^+
9.026 ± 5	$(35 \pm 10) \times 10^{-3}$	α_0		1.0 ± 0.3	11.952 ± 5	8^+
9.043 ± 10	30 ± 5	α_0		0.72	11.966 ± 8	1^-
9.25 [d]		α_0, $\gamma_{6.13}$		[e]	12.137 ± 5	6^+
9.403 ± 9	155 ± 15	α_0	0.89 ± 0.05	6.8	12.253 ± 10	4^+
9.406 ± 4 [f]	< 1	$\gamma_{6.13}$		[e]	12.256 ± 4	3^-; 1
9.495 ± 13	390 ± 50	α_0	0.92 ± 0.04	8	12.327 ± 10	2^+
9.587 ± 2	37.3 ± 0.9	α_0 $\gamma_{6.13}$	1.00 ± 0.04	1.2	12.401 ± 5	3^-
9.628 ± 5	24.4 ± 0.5	α_0, α_1	0.62 ± 0.15	0.3	12.433 ± 5	0^+

Table 20.18: Resonances in ^{16}O(α, α) [a] (continued)

E_α (MeV ± keV)	$\Gamma_{\mathrm{c.m.}}$ (keV)	Outgoing particles	Γ_{α_0}/Γ	θ^2 (%)	E_x (MeV ± keV)	J^π
9.677 ± 8	124 ± 6	α_0	0.88 ± 0.05	2.4	12.472 ± 10	(2^+)
9.818 ± 6	72 ± 9	α_0	0.68 ± 0.05	14	12.585 ± 5	6^+
9.827 ± 14	145 ± 25	α_0	0.78 ± 0.09	2.5	12.592 ± 15	(2^+)
9.978 ± 6	84 ± 8	α_0	1.00 ± 0.05	7.3	12.713 ± 5	5^-
10.015 ± 7	61 ± 12	α_0	0.72 ± 0.09	0.9	12.743 ± 10	(2^+)
10.132 ± 2	30 ± 5	α_0, $\gamma_{6.13}$	0.83 ± 0.09	0.45	12.836 ± 5	1^-
(10.27)	(580)	(α_0)	(0.92)	(21)	(12.95)	(4^+)
10.283 ± 2	38 ± 4	α_0, $\gamma_{6.13}$	1.00 ± 0.08	0.8	12.957 ± 5	2^+
10.397 ± 1	18 ± 3	α_0, $\gamma_{6.13}$	0.55 ± 0.05	0.4	13.048 ± 5	4^+
(10.419 ± 15)	(305 ± 55)	(α_0)	(0.42 ± 0.03)	(3.2)	(13.066 ± 15)	$(3^-, 5^-)$
10.461 ± 12	53 ± 24	α_0	0.22 ± 0.07	0.5	13.099 ± 10	(0^+)
10.468 ± 5	102 ± 5	α_0	0.52 ± 0.04	11	13.105 ± 5	6^+
10.508 ± 2	48 ± 4	α_0	1.00 ± 0.05	1.2	13.137 ± 5	3^-
10.614 ± 7	40 ± 13	α_0	0.55 ± 0.13	0.4	13.222 ± 10	0^+
10.617 ± 19	≈ 80	α_0	0.22 ± 0.07	0.3	13.224 ± 15	1^-
10.620 ± 2	53 ± 4	α_0	1.00 ± 0.04	1.3	13.226 ± 5	3^-
10.759 ± 6 [f]	$(8 \pm 3) \times 10^{-2}$	α_0		0.08 ± 0.03	13.338 ± 5	7^-
10.763 ± 1	26 ± 3	α_0, $\gamma_{6.13}$	0.70 ± 0.05	0.6	13.341 ± 5	4^+
10.854 ± 3	34 ± 5	α_0, $\gamma_{6.13}$	0.46 ± 0.05	0.4	13.414 ± 5	3^-
10.857 ± 4	≈ 16	α_0	0.16 ± 0.06	0.06	13.416 ± 5	(3^-)
10.870 ± 4	49 ± 7	α_0	0.38 ± 0.04		13.426 ± 5	(5^-)
10.913 ± 8	195 ± 25	α_0	0.99 ± 0.05	3.2	13.461 ± 10	1^-

Table 20.18: Resonances in ^{16}O(α, α) [a] (continued)

E_α (MeV $\pm$ keV)	$\Gamma_{\text{c.m.}}$ (keV)	Outgoing particles	Γ_{α_0}/Γ	θ^2 (%)	E_x (MeV $\pm$ keV)	J^π
10.971 ± 4	24 ± 8	α_0	0.36 ± 0.07	0.15	13.507 ± 5	1^-
10.999 ± 4	61 ± 8	α_0	0.72 ± 0.05	0.8	13.529 ± 5	2^+
11.000 ± 15	76 ± 32	α_0	0.52 ± 0.13	0.6	13.530 ± 15	(0^+)
11.054 ± 3	12 ± 5	α_0	0.19 ± 0.06	0.04	13.573 ± 5	2^+
11.183 ± 1	11 ± 2	α_0	0.33 ± 0.05	0.2	13.677 ± 5	5^-
11.202 ± 12	310 ± 30	α_0, $\gamma_{6.13}$	0.51 ± 0.03	84	13.692 ± 10	7^-
11.267 ± 26	≈ 80	α_0	0.33 ± 0.12	0.4	13.744 ± 20	0^+
11.371 ± 9	136 ± 15	α_0	0.73 ± 0.04	2.1	13.827 ± 10	3^-
11.420 ± 34	≈ 175	α_0	0.21 ± 0.06	0.6	13.866 ± 30	1^-
11.473 ± 5	74 ± 10	α_0	0.75 ± 0.06	1.0	13.908 ± 5	2^+
11.498 ± 5	65 ± 3	α_0	0.86 ± 0.04	6.9	13.928 ± 5	6^+
11.522 ± 7	79 ± 15	α_0	1.0 ± 0.1	1.3	13.948 ± 10	0^+
11.544 ± 2	8.1 ± 1	α_0	0.46 ± 0.05	0.11	13.965 ± 5	4^+
(11.607 ± 19)	(≈ 80)	(α_0)	(0.19 ± 0.05)	(0.25)	(14.015 ± 15)	(1^-)
(11.663 ± 19)	(150 ± 50)	(α_0)	(0.24 ± 0.05)	(0.6)	(14.060 ± 15)	(2^+)
11.732 ± 4	42 ± 6	α_0, $\gamma_{6.9+7.1}$	0.71 ± 0.06	0.5	14.115 ± 5	2^+
11.925 ± 7	92 ± 9	α_0	0.64 ± 0.04	1.6	14.270 ± 10	4^+
11.968 ± 8	60 ± 13	α_0, $\gamma_{6.13}$, $\gamma_{6.9+7.1}$	0.31 ± 0.05	1.9	14.304 ± 10	(6^+)
11.977 ± 6	117 ± 8	α_0	0.82 ± 0.04	9.6	14.311 ± 5	6^+
11.979 ± 15	≈ 45	α_0	0.13 ± 0.06	0.1	14.313 ± 15	(3^-)
12.148 ± 28	≈ 95	α_0	0.18 ± 0.06 [e]	0.3	14.448 ± 25	$(0^+, 2^+)$
12.156 ± 4	≈ 15	α_0	0.09 ± 0.04	0.05	14.454 ± 5	5^-

Table 20.18: Resonances in ^{16}O(α, α) [a] (continued)

E_α (MeV $\pm$ keV)	$\Gamma_{c.m.}$ (keV)	Outgoing particles	Γ_{α_0}/Γ	θ^2 (%)	E_x (MeV $\pm$ keV)	J^π
12.322 ± 25	140 ± 50	α_0	0.45 ± 0.08	0.9	14.587 ± 20	1^-
12.329 ± 13	260 ± 25	$\alpha_0, \gamma_{6.9+7.1}$	0.79 ± 0.04	5.3	14.593 ± 10	4^+
12.447 ± 11	90 ± 30	α_0	0.35 ± 0.06	0.6	14.687 ± 10	(3^-)
12.502 ± 10	60 ± 25	α_0	0.25 ± 0.06	0.4	14.731 ± 10	(4^+)
12.539 ± 2	7.3 ± 4.8	α_0	0.18 ± 0.05	0.1	14.761 ± 5	6^+
12.597 ± 4	86 ± 7	α_0	0.95 ± 0.04	6.5	14.807 ± 5	6^+
12.608 ± 5	117 ± 13	α_0	0.69 ± 0.04	3.1	14.816 ± 5	5^-
12.637 ± 8	79 ± 15	α_0	0.45 ± 0.05	0.9	14.839 ± 10	(4^-)
12.699 ± 12	100 ± 30	α_0	0.44 ± 0.06	0.7	14.888 ± 10	2^+
12.897 ± 10	66 ± 20	α_0	0.31 ± 0.06	0.3	15.047 ± 10	2^+
12.930 ± 12	160 ± 25	α_0	0.40 ± 0.04	2.3	15.073 ± 10	5^-
13.016 ± 20	≈ 60	α_0	≈ 0.12	0.11	15.142 ± 15	(2^+)
13.056 ± 10	230 ± 25	α_0	0.70 ± 0.04	5.5	15.174 ± 10	5^-
(13.238 ± 10)	(130 ± 20)	(α_0)	(0.99 ± 0.08)		(15.319 ± 10)	(1^-)
(13.266 ± 12)	(50 ± 25)	(α_0)	(0.69 ± 0.17)		(15.342 ± 10)	(0^+)
13.237 ± 29	280 ± 40	α_0	0.39 ± 0.04	20	15.319 ± 25	7^-
13.251 ± 6	34 ± 10	α_0	0.29 ± 0.05	0.2	15.330 ± 5	4^+
13.296 ± 5	110 ± 10	$\alpha_0, \gamma_{6.13}, \gamma_{6.9+7.1}$	0.71 ± 0.04	14	15.366 ± 5	7^-
13.384 ± 15 [d]	85 ± 35	α_0	0.26 ± 0.05	0.4	15.436 ± 15	(3^-)
13.58		$\alpha_0, \gamma_{6.13}, \gamma_{6.9+7.1}$			15.59	
13.73		$\alpha_0, \gamma_{6.13}, \gamma_{6.9+7.1}$			15.71	(6^+)
14.05		$\alpha_0, \gamma_{6.13}, \gamma_{6.9+7.1}$			15.97	(6^+)

Table 20.18: Resonances in ^{16}O(α, α) [a] (continued)

E_α (MeV ± keV)	$\Gamma_{\text{c.m.}}$ (keV)	Outgoing particles	Γ_{α_0}/Γ	θ^2 (%)	E_x (MeV ± keV)	J^π
14.26		$\gamma_{6.13}$, $\gamma_{6.9+7.1}$			16.14	
14.40		$\gamma_{6.13}$			16.25	
14.501 ± 15	45	α_0, α_{1+2}			16.329 ± 11	4^+
14.636 ± 15 [g]	35	α_0, α_{1+2}, α_3			16.437 ± 11	$(0, 2, 4)^+$
14.721 ± 15	24 ± 4	α_0, α_{1+2}, α_3, α_4	0.36 ± 0.03	0.38 ± 0.07	16.505 ± 15	6^+
14.789 ± 18	90 ± 30	α_0	0.16 ± 0.03	0.37 ± 0.13	16.559 ± 15	5^-
14.816 ± 15	92 ± 8	α_0, α_3	0.45 ± 0.03	4.1 ± 0.5	16.581 ± 15	7^-
14.875 ± 22	80 ± 25	α_0	0.18 ± 0.04	0.22 ± 0.08	16.628 ± 20	3^-
14.924 ± 20	100 ± 25	α_0, (α_3)	0.23 ± 0.03	0.42 ± 0.11	16.667 ± 15	4^+
14.987 ± 18	≈ 25	α_0, α_{1+2}, α_3, α_4	0.08 ± 0.03	≈ 0.05	16.717 ± 15	5^-
15.023 ± 33	160 ± 50	α_0	0.10 ± 0.02	4.8 ± 1.9	16.746 ± 25	8^+
15.149 ± 16	16 ± 8	α_0, α_{1+2}, α_3, α_4	0.11 ± 0.02	0.04 ± 0.02	16.847 ± 15	5^-
15.179 ± 25	350 ± 50	α_0	0.28 ± 0.03	3.9 ± 0.7	16.871 ± 20	6^+
15.430 ± 21	180 ± 30	α_0	0.32 ± 0.03	1.0 ± 0.2	17.072 ± 20	4^+
15.535 ± 15	26 ± 5	α_0, α_{1+2}, α_3, α_4	0.22 ± 0.02	0.13 ± 0.03	17.155 ± 15	5^-
15.607 ± 19	225 ± 30	α_0	0.32 ± 0.02	1.2 ± 0.2	17.213 ± 15	4^+
15.696 ± 20	86 ± 25	α_0, α_{1+2}, α_3, α_4	0.16 ± 0.03	0.20 ± 0.07	17.284 ± 15	3^-
15.710 ± 17	200 ± 25	α_0	0.26 ± 0.02	11.6 ± 1.4	17.295 ± 15	8^+
15.828 ± 15 [f]	< 10	α_{1+2}			17.390 ± 15	
15.878 ± 18	220 ± 25	α_0	0.24 ± 0.01	48 ± 6	17.430 ± 15	9^-
16.017 ± 16	86 ± 9	α_0, α_{1+2}, α_3, α_4	0.45 ± 0.03	1.3 ± 0.2	17.541 ± 15	6^+
16.099 ± 17	140 ± 20	α_0, α_4	0.36 ± 0.03	1.05 ± 0.15	17.606 ± 15	5^-

Table 20.18: Resonances in ^{16}O(α, α) [a] (continued)

E_α (MeV $\pm$ keV)	$\Gamma_{\rm c.m.}$ (keV)	Outgoing particles	Γ_{α_0}/Γ	θ^2 (%)	$E_{\rm x}$ (MeV $\pm$ keV)	J^π
16.302 ± 23	≈ 125	α_0	0.13 ± 0.03	≈ 0.3	17.769 ± 20	4^+
16.405 ± 17	200 ± 30	α_0	0.38 ± 0.03	1.6 ± 0.3	17.851 ± 15	5^-
16.598 ± 15 [f]	< 10	α_0, α_{1+2}			18.005 ± 15	7^-
16.622 ± 6	34 ± 7	α_0, α_{1+2}, α_3, α_4	0.34 ± 0.04	0.23 ± 0.06	18.024 ± 5	5^-
16.695 ± 30	140 ± 60	α_0	0.20 ± 0.05	0.4 ± 0.2	18.083 ± 25	4^+
16.748 ± 6	29 ± 6	α_0, α_{1+2}, α_3, α_4	0.46 ± 0.06	0.8 ± 0.2	18.125 ± 5	7^-
16.949 ± 13	190 ± 30	α_0, α_4	0.32 ± 0.02	1.7 ± 0.3	18.286 ± 10	6^+
17.129 ± 24	185 ± 40	α_0, (α_{1+2}), α_3, α_4	0.19 ± 0.02	1.8 ± 0.4	18.430 ± 20	7^-
17.210 ± 21	130 ± 30	α_0, α_3	0.21 ± 0.03	0.5	18.494 ± 20	5^-
17.368 ± 23	185 ± 30	α_0, α_4	0.24 ± 0.03	5.5 ± 1.1	18.621 ± 20	8^+
17.524 ± 29	140 ± 50	α_0, α_{1+2}	0.17 ± 0.04	0.6 ± 0.3	18.745 ± 25	6^+
17.552 ± 24	140 ± 35	α_0	0.22 ± 0.03	1.5 ± 0.4	18.768 ± 20	7^-
17.793 ± 29	200 ± 60	α_0	0.15 ± 0.02	3.2 ± 1.1	18.960 ± 25	8^+
17.906 ± 18	≈ 90	α_0, α_{1+2}	0.18 ± 0.03	≈ 0.3	19.051 ± 15	5^-
18.03 ± 20	200 ± 50	α_0, α_1, (α_2), α_4, α_5	0.38 ± 0.04 [d]	≈ 2	19.15 ± 20	6^+
18.198 ± 17	140 ± 25	α_1, (α_5)	0.12 ± 0.02 [h]		19.284 ± 15	6^+
18.216 ± 30	430 ± 60	α_0	0.36 ± 0.03	6.4 ± 1.1	19.298 ± 25	7^-
18.397 ± 11	130 ± 15	α_0, α_3, α_4	0.38 ± 0.01 [h]		19.443 ± 10	6^+
18.514 ± 29	250 ± 60	α_0, α_2, α_3	0.27 ± 0.04	1.6 ± 0.4	19.536 ± 25	6^+
(18.563 ± 25)	(140 ± 50)	(α_1)	(0.09 ± 0.02) [h]		(19.576 ± 20)	(7^-)
18.662 ± 23	140 ± 35	α_1	0.14 ± 0.02 [h]		19.655 ± 20	6^+
18.757 ± 28	330 ± 60	α_0, (α_2), α_3	0.23 ± 0.02	6.3 ± 1.2	19.731 ± 20	8^+

Table 20.18: Resonances in $^{16}O(\alpha, \alpha)$ [a] (continued)

E_α (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	Outgoing particles	Γ_{α_0}/Γ	θ^2 (%)	E_x (MeV ± keV)	J^π
18.900 ± 48	360 ± 120	α_0	0.18 ± 0.03	1.4 ± 0.5	19.845 ± 40	6^+
18.918 ± 11	170 ± 25	α_1	0.26 ± 0.02 [h]		19.859 ± 10	5^-
18.949 ± 52	≈ 120	α_0	0.08 ± 0.03	≈ 0.35	19.884 ± 40	7^-
19.083 ± 39	130 ± 100	$\alpha_0, \alpha_2, (\alpha_5)$	0.11 ± 0.04	0.19 ± 0.04	19.991 ± 30	4^+
19.128 ± 16	80 ± 35	α_1, α_4	0.10 ± 0.04 [h]		20.027 ± 15	6^+
19.227 ± 28	190 ± 35	α_1	0.29 ± 0.03 [h]		20.106 ± 25	7^-
19.304 ± 47	285 ± 100	α_0, α_3	0.18 ± 0.04	1.1 ± 0.4	20.168 ± 35	6^+
19.464 ± 19	255 ± 40	α_1, α_5	0.28 ± 0.03 [h]		20.296 ± 15	7^-
19.521 ± 22	190 ± 40	α_1	0.26 ± 0.03 [h]		20.341 ± 20	5^-
19.524 ± 16	135 ± 35	α_0, α_3	0.25 ± 0.04	1.1 ± 0.3	20.344 ± 15	7^-
19.618 ± 39	215 ± 90	α_0	0.14 ± 0.03	0.6 ± 0.3	20.419 ± 30	6^+
19.651 ± 32	370 ± 55	α_1	0.32 ± 0.03 [h]		20.445 ± 25	6^+
19.679 ± 35	280 ± 70	α_0, α_2	0.20 ± 0.03	0.86 ± 0.25	20.468 ± 30	5^-
19.952 ± 8	78 ± 11	$\alpha_0, \alpha_1, \alpha_2, \alpha_3$	0.33 ± 0.03 [j]	4.5 ± 0.8	20.686 ± 6	9^-
20.04	240 ± 50	$\alpha_0, \alpha_1, \alpha_4$	0.2 [j]	1.8 ± 0.5	20.76 ± 30	7^-
20.095 ± 32	170 ± 60	α_1	0.11 ± 0.02 [h]		20.800 ± 25	5^-
20.28	300 ± 50	α_0, α_1	0.23 ± 0.03 [j]	2.1 ± 0.6	20.95 ± 40	7^-
20.423 ± 8 [g]	60 ± 6	α_0, α_3	0.46 ± 0.03	4.1 ± 0.5	21.062 ± 6	9^-
20.7	300	α_0			21.3	7^-
21.3 ± 200	300	α_0			21.8 ± 150	7^-
22.0 ± 200	500	α_0			22.3 ± 150	7^-
22.5 ± 250	500	α_0			22.7 ± 200	9^-

Table 20.18: Resonances in $^{16}O(\alpha, \alpha)$ [a] (continued)

E_α (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	Outgoing particles	Γ_{α_0}/Γ	θ^2 (%)	E_x (MeV ± keV)	J^π
22.65 ± 125	250	α_0			22.84 ± 100	9^-
23.3 ± 250	500	α_0			23.4 ± 200	8^+
24.24 ± 150	350	α_0			24.11 ± 100	8^+
25.4 ± 300	600	α_0			25.0 ± 250	8^+
26.2 ± 200	400	α_0			25.7 ± 150	
28.1 ± 350	700	α_0			27.2 ± 300	
29	1600	α_0			28	8^+
29.4 ± 350	700	α_0			28.2 ± 300	

[a] For earlier references see Tables 20.23 in (1978AJ03) and 20.21 in (1983AJ01). For K^π assignments see Table 20.15 here. The uncertainties in the excitation energies are calculated by taking the uncertainty in the E_α in the c.m. [$\frac{3}{4} \times$ uncertainty in the lab] and adding the uncertainty in E_b [2 keV], in quadrature, rounding upwards. I am indebted to Prof. H.T. Richards for many very useful comments.

[b] $\Gamma_{c.m.} = \Gamma_\alpha$.

[c] (1985JA17).

[d] Resonances with $9.25 \leq E_\alpha \leq 13.39$ MeV are from (1985CA09), except for the states labelled [f]. Certain values are rounded upwards. See also (1983CA1F) and Table 20.21 in (1983AJ01).

[e] $(2J+1)\Gamma_{\alpha_0}\Gamma_{\alpha_2}/\Gamma_g = 81 \pm 12$ eV and 14 ± 2 eV, respectively, for ^{20}N*(12.14, 12.25) [for the latter see Table 20.17] (1980FI01).

[f] See Table 20.21 in (1983AJ01).

[g] Resonances with $14.6 < E_\alpha < 20.4$ MeV are from the re-analysis of the data of (1979BI10) by (1984RI06). Certain values are rounded upwards.

[h] $(\Gamma_{\alpha_0}\Gamma_{\alpha_1})^{1/2}/\Gamma$.

[i] (1984RI07).

[j] For information on the α_1 strength see (1984RI06).

Table 20.19: States of ^{20}Ne from ^{16}O(^{6}Li, d), ^{16}O(^{7}Li, t) and ^{16}O(^{12}C, ^{8}Be) [a]

E_x (MeV ± keV)			$\Gamma_{c.m.}$ (keV)	Γ_{α_0}/Γ	S [b]	J^π
(^{6}Li, d)	(^{7}Li, t)	(^{12}C, ^{8}Be)				
0	0	0			1.00	0^+
1.63	1.63	1.63			0.41	2^+
4.25	4.25	4.25			0.22	4^+
4.97						2^-
5.62					0.06	3^-
5.79	5.79	5.79			0.54	1^-
6.73					0.56	0^+
7.00						4^-
7.16	7.16	7.16			0.26	3^-
7.43					0.13	2^+
8.46					0.04	5^-
8.78	8.78	8.78			0.20	6^+
10.3 ± 100	10.26	10.26	145 ± 40	1	0.15	5^-
10.7 ± 100						4^+
11.95	11.95	11.95		0.85 ± 0.15	0.51	8^+
12.14					0.05	6^+
12.6 ± 100	12.591 ± 10	12.59	110 ± 40	0.80 ± 0.10		6^+
13.9	13.904 ± 20		≈ 100			6^+
14.3	14.310 ± 20	14.3 [d]	< 100			6^+
15.35 ± 100	15.336 ± 15	15.34	380 ± 60	0.90 ± 0.10		7^-
15.9 ± 100		15.87	< 250			7^-
16.7 ± 100	16.63 ± 20	16.63	190 ± 40	0.90 ± 0.10		7^- [e]
17.35 ± 100	17.30 ± 20	17.30	220 ± 40	$\geq 0.40 \pm 0.10$		8^+ [e]
18.7 ± 100						7^-
19.4 ± 100			400			7^-
19.9 ± 100			400			7^-
	20.67 ± 40	20.5 [d]				
20.8 ± 100						$7^-(6^+)$
	21.08 ± 30	21.08	100 ± 50	0.65 ± 0.15		9^-

Table 20.19: States of ^{20}Ne from ^{16}O(^{6}Li, d), ^{16}O(^{7}Li, t) and ^{16}O(^{12}C, ^{8}Be) [a] (continued)

E_x (MeV ± keV)			$\Gamma_{c.m.}$ (keV)	Γ_{α_0}/Γ	S [b]	J^π
(^{6}Li, d)	(^{7}Li, t)	(^{12}C, ^{8}Be)				
21.3 ± 100			300			8^+
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		≤ 200			$9^-(8^+)$
	24.21 ± 25		≈ 500			
	25.10 ± 50		≤ 200			
	25.67 ± 50		≈ 500			
27.1 ± 100 [c]		27.0 [d]				9^-
28.1 ± 100 [c]						10^+
(29.4) [c]						(10^+)
((33.4))						$((10^+))$

[a] For complete references see Tables 20.24 in (1978AJ03) and 20.22 in (1983AJ01).

[b] Relative α-particle spectroscopic factors (DWBA). Other S_α values have also been reported.

[c] (1982AR20).

[d] (1983SH26).

[e] An admixture of 6^+ or 8^+ in the d-α angular correlation involving ^{20}Ne*(16.6) and a doublet $(8^+ + 7^-)$ at $E_x = 17.4$ MeV have been suggested. See also Table 20.18.

States observed in this reaction are displayed in Table 20.19. Angular distributions have been measured at $E(^{7}\text{Li}) = 15$ to 68 MeV: see (1978AJ03, 1983AJ01). See also (1986CO15; theor.).

17. ^{16}O(^{9}Be, ^{5}He)^{20}Ne $\qquad Q_m = 2.27$

See (1985CU1A).

18. (a) ^{16}O(^{12}C, ^{8}Be)^{20}Ne $\qquad Q_m = -2.633$

(b) ^{16}O(^{12}C, 2α)^{20}Ne $\qquad Q_m = -2.541$

(c) ^{16}O(^{12}C, α^{12}C)^{12}C $\qquad Q_m = -7.16195$

Angular distributions in reaction (a) have been measured for $E(^{16}\text{O}) = 27.1$ to 46.4 MeV and for $E(^{12}\text{C}) = 22.7$ to 78 MeV [see (1978AJ03, 1985AJ01)] as well as at $E(^{12}\text{C}) = 109$ MeV (1984MU04, 1985MU14; ^{20}Ne*(1.63, 4.25, 5.79, 7.16, 8.78, 10.26, 11.95, 12.59, 15.34, 15.87, 17.30, 21.08, 22.87); $\sigma(\theta)$ at several angles; EFR-DWBA analysis). Γ_{α_0}/Γ are displayed in Table 20.19: see (1983AJ01) and (1983SH26). Preliminary evidence for 10^+ strength at $E_x \approx 28$ MeV is reported by (1986ALZN). See also (1983DEZW). For reaction (b) see (1978AJ03) and (1986CA19). For reaction (c) and for a discussion of ^{24}Mg states reached in this reaction see (1983SH26, 1984MU04). See also (1985BE37, 1987SU03) and (1986BE19; theor.).

19. ^{16}O(^{13}C, ^{9}Be)^{20}Ne $\qquad Q_m = -5.914$

At $E(^{13}\text{C}) = 105$ MeV angular distributions to ^{20}Ne*(1.63, 4.25, 8.78, 11.95, 15.34, 21.0) have been studied by (1979BR03): the first four states are the 2^+, 4^+, 6^+ and 8^+ members of the 0_1^+ band; the two higher states [$J^\pi = 7^-, 9^-$] belong to the 0^- band whose band head is ^{20}Ne*(5.79). In addition distributions are reported to ^{20}Ne*(12.59, 15.9, 17.3) [$J^\pi = 6^+, 8^+, 8^+$] (1979BR03). See also (1985MU14). For fusion cross sections see (1986PA10).

20. ^{16}O(^{16}O, ^{12}C)^{20}Ne $\qquad Q_m = -2.428$

Angular distributions have been reported to a number of states of ^{20}Ne at $E(^{16}\text{O}) = 23.9$ to 95.2 MeV [see (1978AJ03, 1983AJ01)] and recently at $E(^{16}\text{O}) = 26$, 28 and 30 MeV (1986CA24). (1983ME13) have studied the quasi-elastic spectrum at $E(^{16}\text{O}) = 50$, 60, 68 and 72 MeV. For excitation functions see (1986CA24; ^{20}Ne*(0, 1.63)). See also (1982KO1C, 1984ME10, 1985ST1B) and (1982KO1D, 1984AP03, 1984KO13; theor.).

21. (a) ^{17}O(^{3}He, ^{3}He)^{17}O $\qquad E_b = 21.168$
(b) ^{17}O(^{3}He, α)^{16}O $\qquad Q_m = 16.4341$

The excitation function for α_0 shows a resonance corresponding to ^{20}Ne*(28.): see (1978AJ03). At $E(^3\vec{\text{He}}) = 33$ MeV A_y measurements have been reported for the elastic scattering [reaction (a)] (1983LE03) and for many α-groups [see ^{16}O in (1986AJ04)] (1982KA12). For the earlier work and for other channels see (1983AJ01). See also (1985HA11, 1987CO07; theor.).

22. ^{17}O(α, n)^{20}Ne $\qquad Q_m = 0.590$

See (1978AJ03).

23. (a) ^{17}O(^{11}B, ^{8}Li)^{20}Ne $\quad Q_{\rm m} = -6.041$

(b) ^{17}O(^{12}C, ^{9}Be)^{20}Ne $\quad Q_{\rm m} = -5.111$

At $E = 115$ MeV the 8^{+} state at $E_{\rm x} = 11.95$ MeV is particularly strongly populated in both reactions: see (1983AJ01).

24. ^{18}O(^{3}He, n)^{20}Ne $\quad Q_{\rm m} = 13.124$

Angular distributions have been measured for $E(^{3}$He$) = 2.8$ to 18.3 MeV. States of ^{20}Ne observed in this reaction are displayed in Table 20.23 of (1983AJ01). These include a state at $E_{\rm x} = 16.730 \pm 0.006$ MeV, $\Gamma < 20$ keV: $J^{\pi} = 0^{+}$, $T = 2$.

25. ^{19}F(p, γ)^{20}Ne $\quad Q_{\rm m} = 12.848$

Over the range $E_{\rm p} = 2.9$ 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 displaced 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. The 90° γ_0 yield for $E_{\vec{\rm p}}$ and $E_{\rm p} = 3.5$ to 10 MeV has been measured: the results are interpreted in terms of four primary doorway states at $E_{\rm x} = 16.7$, 17.8, 19.1 and 20.2 MeV. See also (1985WAZV; $E_{\vec{\rm p}} = 5.9$ to 10.3 MeV; E2 strength; prelim.). See also (1986OUZZ).

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 $E_{\rm p} = 4.090 \pm 0.005$ 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: $\Gamma_{\rm p}\Gamma_{\gamma}/\Gamma \approx 0.5$ eV. Since $\Gamma_{\rm p}/\Gamma$ (from the elastic scattering) is ≈ 0.1, $\Gamma_{\gamma} \approx 5$ eV. For $E_{\rm p} = 5.65$ 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 [$\Gamma_{\rm c.m.} = 9.5 \pm 3$ keV, $\Gamma_{\rm p_0}\Gamma_{\gamma}/\Gamma \approx 0.05$ 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. For the upper limits to the strengths of the transitions to various states of ^{20}Ne from the 0^{+} and 2^{+} $T = 2$ states, see (1983AJ01). Resonances observed in this capture reaction are displayed in Table 20.20. For references see (1978AJ03, 1983AJ01). See also (1987RO25; astrophysics).

26. (a) ^{19}F(p, p)^{19}F $\quad E_{\rm b} = 12.848$

(b) ^{19}F(p, p$'$)^{19}F*

(c) ^{19}F(p, d)^{18}F $\quad Q_{\rm m} = -8.2074$

Table 20.20: Resonances in ^{19}F(p, γ)^{20}Ne [a]

E_p (keV)	Γ_{lab} (keV)	Γ_{γ_0} (eV)	Γ_{γ_1} (eV)	^{20}Ne* (MeV)	$J^\pi; T$
340		< 0.07	0.28 ± 0.06	13.171	
484		≈ 0.05	0.42	13.308	
597 ± 1	30 ± 3	< 0.6	12	13.415	
671 ± 1	6.0 ± 0.7	1.0×10^{-2}	2.2	13.485	1^+
874				13.678	
935				13.736	
980				13.779	
1091	0.8		1.1	13.884	$2^+; 1$
1280				14.063	
1320	4.0			14.101	
1350				14.130	
1370				14.149	
1420	15.7			14.196	
4090 ± 5		$\Gamma_\gamma \approx 5$ eV		16.732	$0^+; 2$
5879 ± 7	10 ± 3	$\Gamma_\gamma \approx 0.3$ eV		18.430	$2^+; 2$

[a] For earlier references see Table 20.26 in (1978AJ03) and 20.24 in (1983AJ01). See also Table 20.14 here.

The elastic scattering has been studied in the range $E_p = 0.5$ to 7.5 MeV and 24.9 to 46.3 MeV [see (1978AJ03)] and at $E_p = 1.5$ to 3.5 MeV (1985OU01, 1986OUZZ, 1986OU01). The observed anomalies are displayed in Table 20.21.

Resonances for inelastic scattering [p_1 and p_2] are listed in Table 20.22. In general the resonances observed are identical with those reported from other ^{19}F+p reactions, although the relative intensities differ greatly. Cross sections for production of 110 and 197 keV γ-rays are reported for $E_p = 0.5$ to 4.3 MeV by (1986CHYY). See also (1983LE28; astrophysics) and (1986BA88). For reaction (c) see (1986KA1U; applied) and ^{18}F.

27. ^{19}F(p, n)^{19}Ne $\qquad Q_m = -4.0207 \qquad E_b = 12.848$

Observed resonances are displayed in Table 20.30 of (1978AJ03). See also (1984BA1R).

28. ^{19}F(p, α)^{16}O $\qquad Q_m = 8.1137 \qquad E_b = 12.848$

Many resonances occur in this reaction. They are displayed in Tables 20.23, 20.24 and 20.25 depending on whether they are observed in the α_0 yield [20.23], in the α_1 [or α_π] yield to ^{16}O*(6.05) [20.24] 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) [20.25]]. 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.

Listings of the earlier yield studies are given in (1972AJ02, 1978AJ03, 1983AJ01). A detailed discussion of the evidence leading to many of the J^π assignments is given in (1959AJ76). For values of θ^2 see Table 20.28 in (1978AJ03). Recent measurements are reported by (1985OU01; 1.15 to 2.1 MeV; $\alpha_0 \rightarrow \alpha_3$) and (1984IN04; 4.15 to 13 MeV; $\alpha_0 \rightarrow \alpha_5$). In the latter work there are no marked correlations between the different channels.

Longitudinally and transversely polarized protons with $E_{\vec{p}} \approx 0.67$ MeV have been used to study ^{20}Ne*(13.48) [$J^\pi = 1^+$; $T = 1$] via a parity (and isospin) forbidden α-transition. The state is not excited. The upper limits for the process, and their significance in the determination of f_π, the weak pion-nucleon coupling constant, are discussed by (1983KN01, 1986KN1C). See also (1983AJ01, 1984KN1A).

See also (1985ISZU), (1982MA1Q, 1982MA1V, 1983DE2J, 1986SI1L; applications), (1987RO25; astrophysics), (1986SI1D; computing) and (1983IN1B, 1985LO1C, 1986LO1E, 1986SI1K; theor.).

29. ^{19}F(d, n)^{20}Ne $\qquad Q_m = 10.623$

Levels of ^{20}Ne derived from this reaction are displayed in Tables 20.31 in (1972AJ02) and 20.34 in (1978AJ03). See also (1983LIZW).

Table 20.21: Levels of ^{20}Ne from ^{19}F(p, p_0) [a]

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	13.171
483			1^+			13.307
598	37	1	2^-	0.0012	0.38	13.416
669	7.5	0	1^+	0.98	9.6	13.483
843	23	0	0^+	0.996	10.8	13.649
873	5.2	1	2^- [b]	0.21	1.5	13.677
935	8.0	0	1^+	0.17	0.44	13.736
1346	4.5	1	2^- [b]	0.067	0.07	14.126
1372	15	1	2^- [b]	0.17	0.52	14.151
1422	14.6	0	1^+	0.85	0.92	14.198
1710 [c]	90	0	0^+	0.8		14.472
1896 [c]	25	0	0^+	0.3		14.648
1943 [c]	40	0	(1^+)	0.5		14.693
2030 [c]	70	1	(1^-)	0.75		14.776
2.763 [c]		2				15.472
2.970 [c]		2				15.668
4094 ± 3	2.1 ± 0.5	0	$0^+; 2$	0.062 ± 0.004		16.735
5879 ± 7 [d]	10 ± 3	2	$2^+; 2$	≈ 0.2		18.430

[a] For references see Table 20.27 in (1978AJ03). For θ^2 see Table 20.28 in (1978AJ03).

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

[c] (1985OU01, 1986OU01; R-matrix analysis). Weak resonances at $E_p = 1.75$ and 1.78 MeV are also suggested.

[d] Resonance also observed in p_1, p_3, p_4 and p_5 yields.

Table 20.22: Resonances in $^{19}F(p, p')^{19}F^*$ [a]

E_p (keV)	J^π	Γ_{lab} (keV)	Γ_{p_1} (eV)	Γ_{p_2} (eV)	$\theta^2_{p_1}$ (%)	$\theta^2_{p_2}$ (%)	E_x in ^{20}Ne (MeV)
340	1^+	2.9	< 0.5	< 0.1	< 15		13.171
483	1^+	2.2	< 1.3	< 1.2			13.307
598	2^-	37	< 100	< 60	< 28	< 145	13.416
669	1^+	7.5	46	< 0.5	0.6	< 0.4	13.483
720		≈ 30	< 10000	< 10000			13.532
780		≈ 10	< 400	≈ 9000			13.589
831		8.3	< 6	≈ 2300			13.637
845	0^+	23	≈ 50	< 10	≈ 0.14	< 0.92	13.650
873	2^-	5.2	< 2	570	< 0.07	2.7	13.677
900		4.8	< 30	≈ 2200			13.703
935	1^+	8.0	3000	< 20	5.0	< 0.8	13.736
1092 [b]	2^+	0.8	173	592			13.885
1137		3.7	< 40	≈ 2100			13.928
≈ 1250		≈ 80	≈ 70000	< 4000			14.03
1290		19	< 600	≈ 900			14.073
1346	2^-	4.5	300	600	0.92	0.24	14.126
1372	2^-	15	700	1400	1.93	0.56	14.151
1422	1^+	14.6 ± 1	2200	≤ 35	0.56	≤ 0.11	14.198
1610		≈ 5					14.377
1660							14.424
1700							14.462
2763 [c]							15.472
2970 [c]							15.668
5879 [d]	2^+; 2		r				18.430

r = resonant.

[a] For references see Tables 20.29 in (1978AJ03) and 20.26 in (1983AJ01).

[b] $\Gamma_{p_0} = 29$ eV.

[c] Reported in $p_{1\to4}$ yield (1986OU01).

[d] Resonance also observed in p_3, p_4 and p_5 yields.

Table 20.23: Resonances for ground-state α-particles (α_0) in ^{19}F(p, α_0) [a]

E_p (keV)	Γ_{lab} (keV)	θ_α^2 (%) [a]	J^π	^{20}Ne* (MeV)
400	100		1^-	13.228
400	100		0^+	13.228
650 ± 20	200		1^-	13.465
710	35	0.6	(1^-)	13.522
733	66	1.0	2^+	13.544
777 ± 2	9 ± 1	0.02	2^+	13.586
842 ± 2	18 ± 1	0.16 [b]	(2^+) [c]	13.648
≈ 860	120	2.1	1^-	13.66
≈ 930	≈ 180	2.9	0^+	13.73
≈ 1080	≈ 200	3.4	1^-	13.87
1115	50	0.55	2^+	13.907
1160	≈ 70	1.1	0^+	13.950
1235	≈ 70	1.2	1^-	14.021
≈ 1250	≈ 150	2.7	2^+	14.03
1350 ± 3	36 ± 1		2^+	14.130
1652 ± 5	90 ± 5		1^-	14.417
1713 ± 6	72 ± 2		0^+	14.475
1842 ± 7	122 ± 5		1^-	14.597
1901 ± 10	25 [d]		0^+	14.653
2110	75		$(2^+, 4^+)$	14.85
2310	90		(2^+)	15.04
2550	300		(1^-)	15.27
2590	300		(0^+)	15.31
2680	80			15.39
2730	60			15.44
2820	160			15.53
2940				(15.64)
3120	170			(15.81)
3340	105			16.02
3680	(100)			16.34
3860				16.51

Table 20.23: Resonances for ground-state α-particles (α_0) in ^{19}F(p, α_0) [a] (continued)

E_p (keV)	Γ_{lab} (keV)	θ^2_α (%) [a]	J^π	^{20}Ne* (MeV)
3980	135			16.63
4130	100			16.77
4360	100			16.99
4460	95			17.08
4690	65			17.30
4900	90			17.50
4990	40			17.59
5879 ± 7	10 ± 3	[d]	$2^+; T = 2$	18.430

[a] For earlier references and additional comments see Tables 20.31 in (1978AJ03) and 20.28 in (1983AJ01). See also (1985OU01, 1986OU01).
[b] $\Gamma_{\alpha_0} \approx 0.06$ keV.
[c] $J = 0$ from ^{19}F(p, p); possibly $T = 0$.
[d] $\Gamma_{\alpha_0} \approx 0.3$ keV.

30. ^{19}F(^{3}He, d)^{20}Ne $\qquad Q_m = 7.354$

Levels of ^{20}Ne observed in this reaction are displayed in Table 20.35 of (1978AJ03). Deuteron angular distributions have been studied at $E(^3\text{He}) = 9.5$ to 21 MeV: see (1978AJ03).

The ΔE_x between the 1^+ and 1^-, $T = 1$ states ^{20}Ne*(11.26, 11.27) is 11.1 ± 0.7 keV (1983FI02). $\Gamma_\gamma/\Gamma_\alpha = 0.88 \pm 0.05$ for ^{20}Ne*(12.22) [2^+; $T = 1$] (1984CA08). Using $(2J + 1)$ $\Gamma_\alpha\Gamma_\gamma/\Gamma = 1.41 \pm 0.23$ eV (1980FI01), $\Gamma_\alpha = 0.32 \pm 0.06$ eV for ^{20}Ne*(12.22) (1984CA08). The Γ_γ/Γ of ^{20}Ne*(12.22) implies B(M1) $= 0.07$ W.u. for the transition from ^{20}Ne*(18.43) [2^+; $T = 2$]. This is much weaker than other isovector M1 transitions in ^{20}Ne and a factor of five lower than predicted by shell model calculations: see (1984CA08).

31. ^{19}F(α, t)^{20}Ne $\qquad Q_m = -6.966$

Angular distributions have been measured at $E_\alpha = 18.5$ and 28.5 MeV: see (1978AJ03, 1983AJ01).

Table 20.24: Nuclear pair resonances (α_π) in ^{19}F(p, α_π) [a]

E_p (keV)	Γ_{lab} (keV)	σ (mb)	θ^2_α (%)	J^π	^{20}Ne* (MeV)
710	35	≈ 0.2	2	1^-	13.522
780	≈ 10	≈ 0.2	0.15	2^+	13.589
842	23	3.4	0.27	2^+ [c]	13.648
1115	50	1.5	3.6	2^+	13.907
1236	≈ 70	3	1.0	1^-	14.022
1367	30	6.0	0.29	2^+	14.146
1640	60			1^-	14.41
1720	95	≈ 18		0^+	14.48
1850	170			1^-	14.60
1896	25			0^+	14.65
2080 [b]	60	12.1		(2^+)	14.82
2170 [b]	70	12.2		(0^+)	14.91
2330 [b]	70	17.0		(2^+)	15.06
2600	100				15.32
2680	100				15.39
2820	125				15.53
3120	145				15.81
3340	100				16.02
(3500)	(80)				(16.17)
(3590)	(115)				(16.26)
3960	200				16.61
4360	95				16.99
4690	< 150				17.30
4900	115				17.50
4990	40				17.59
5170	220				17.76

[a] For references see Tables 20.32 in (1978AJ03) and 20.29 in (1983AJ01). See also (1985OU01, 1986OU01).
[b] (1980CU09): see also for partial widths.
[c] See footnote [c] in Table 20.23.

Table 20.25: Resonances for $6-7$ MeV γ-rays (α_2, α_3, α_4) in ^{19}F(p, α) [a]

E_p (keV)	Γ_{lab} (keV)	Γ_{α_2} (eV)	Γ_{α_3} (eV)	Γ_{α_4} (eV)	J^π	^{20}Ne* (MeV)
223.99 ± 0.07 [b]	0.99 ± 0.02	1000	< 2.5	< 2.5	2^-	13.0607
340.46 ± 0.04 [b,c]	2.34 ± 0.04	2800	16	75	1^+	13.1713
483.91 ± 0.10 [b]	0.90 ± 0.03	700	19	190	1^+	13.3075
594 ± 3	25 ± 3					13.412
667.5 ± 2	6.7 ± 0.3					13.482
832.1 ± 1						13.638
872.11 ± 0.20 [d]	4.53 ± 0.16	2200	620	180	2^-	13.6762
935.4 ± 1.3	8.1 ± 0.5	2900	110	720	1^+	13.736
1087.7 ± 1	0.15 ± 0.05					13.881
1135.6 ± 1						13.926
1280 ± 1						14.063
1347.7 ± 1	4.9 ± 0.7	2250	650	1200	2^-	14.128
1371.0 ± 1	12.4 ± 1.0	6650	700	300	2^-	14.150
1603 ± 2						14.370
1692 ± 2	35 ± 3				$(1, 2)^-$	14.455
1949 ± 2.5	40 ± 10				$(0, 1)^+$	14.699
2030 ± 3.0	120 ± 20					14.776
2320	85					15.05
2510	30					15.23
2630	90					15.35
2800	60					15.51
3020	30					15.72
3190	80					15.88
3490	40					16.16
3920	30					16.57
4000	110					16.65
4090					$0^+; T=2$	16.73
4290	50					16.92
4490	30					17.11
4570	30					17.19
4710	30					17.32

Table 20.25: Resonances for $6-7$ MeV γ-rays (α_2, α_3, α_4) in ^{19}F(p, α) [a] (continued)

E_p (keV)	Γ_{lab} (keV)	Γ_{α_2} (eV)	Γ_{α_3} (eV)	Γ_{α_4} (eV)	J^π	^{20}Ne* (MeV)
4780	35					17.39
4990	20					17.59
5070	35					17.66
5200	70					17.79

[a] See Tables 20.33 in (1978AJ03) and 20.30 in (1983AJ01) for earlier references and for additional comments. See also (1985OU01, 1986OU01).
[b] (1985UH01). See also (1977FR20).
[c] (1982BE29): $\sigma = 88 \pm 3$ mb, $\omega\gamma = 22.3 \pm 0.8$ eV.
[d] (1982BE29): $\sigma = 440 \pm 13$ mb, $\omega\gamma = 570 \pm 30$ eV.

32. ^{19}F(^{7}Li, ^{6}He)^{20}Ne $\qquad Q_m = 2.873$

Angular distributions have been studied at $E(^7\text{Li}) = 34$ MeV to a number of states of ^{20}Ne. C^2S values are consistent with those reported in the (d, n) and (^{3}He, d) reactions: see (1978AJ03).

33. ^{20}F(β^-)^{20}Ne $\qquad Q_m = 7.029$

The decay is primarily to ^{20}Ne*(1.63) with a half-life of 11.00 ± 0.02 sec: see reaction 1 in ^{20}F. Besides the principal decay to ^{20}Ne*(1.63) [log $f_0t = 4.97$], ^{20}F also decays to ^{20}Ne*(4.97) [$J^\pi = 2^-$] with a branching ratio of (0.0082 ± 0.0006)% (1987AL06) [log $f_0t = 7.20 \pm 0.03$; D.E. Alburger and E.K. Warburton, private communication]. The upper limit for the ground-state decay is 0.001% [log $f_0t > 10.5$]. For other values and earlier references see Table 20.36 in (1978AJ03). The energy of the γ-ray from ^{20}Ne*(1.63) is 1633.602 ± 0.015 keV. E_γ for the $4.97 \rightarrow 1.63$ transition is 3332.54 (19) keV which gives $E_x = 4966.51$ (20) keV based on $E_x = 1633.674$ (15) keV for the first excited state. The shape of the β-spectrum is not inconsistent with the predictions of CVC. $\beta - \gamma$ correlation measurements lead to an upper limit for the second-class current contribution to the correlation which is consistent with zero. For references see (1983AJ01); for the earlier work see (1978AJ03). See also (1985BR29, 1985GR1A) and (1983KA32, 1985YA1J; theor.).

34. (a) ^{20}Ne(γ, n)^{19}Ne $\qquad Q_m = -16.869$
(b) ^{20}Ne(γ, 2n)^{18}Ne $\qquad Q_m = -28.508$
(c) ^{20}Ne(γ, α)^{16}O $\qquad Q_m = -4.734$

The photoneutron cross section (bremsstrahlung photons) shows peaks at $E_{\rm x} = 17.78 \pm 0.05$, 19.00 ± 0.05, 20.15 ± 0.15 [main peak of the GDR], 22.6 ± 0.3, 24.9 ± 0.5 and 27.5 MeV [the latter three states are broad]: the integrated cross section to 28.5 MeV is 58 ± 6 MeV · mb [exhausting $\approx 20\%$ of the dipole sum]. The cross section for (γ, Tn) using monoenergetic photons shows a structure at 18 MeV and some fluctuations atop the broad giant resonance, $\sigma_{\rm max} \approx 7$ mb. The double photo-neutron cross section, $\sigma(\gamma$, 2n), is dominated by a single peak at ≈ 20.5 MeV, $\sigma_{\rm max} \approx 1.1$ mb. For references see (1978AJ03, 1983AJ01). The significance of reaction (c) to astrophysics is discussed by (1982SA1A, 1984FO1A).

35. ^{20}Ne(γ, γ)^{20}Ne

$E_{\rm x} = 11262.3 \pm 1.9$ keV for ^{20}Ne*(11.26), the first 1^+; $T = 1$ state. The branchings to ^{20}Ne*(0, 1.63) are (84 ± 5) and (16 ± 5)%, respectively (1983BE19). See also (1984BE26).

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

(b) ^{20}Ne(e, ep)^{19}F $\quad Q_{\rm m} = -12.848$

(c) ^{20}Ne(e, eα)^{16}O $\quad Q_{\rm m} = -4.734$

The ^{20}Ne charge radius, $\langle r^2 \rangle^{1/2} = 3.004 \pm 0.025$ fm. Form factors for many excited states of ^{20}Ne with $E_{\rm x} < 8$ MeV have been reported: see (1978AJ03).

At $E_{\rm e} = 39$ and 56 MeV, the $180°$ inelastic scattering is dominated by the transition to a $J^\pi = 1^+$, $T = 1$ state at $E_{\rm x} = 11.22 \pm 0.05$ MeV with $\Gamma_{\gamma_0} = 11.2^{+2.1}_{-1.8}$ eV. A subsidiary peak is observed corresponding to a state 0.35 ± 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 $E_{\rm x} \approx 12.0$, 12.9, 13.9, 15.8, 16.9, 18.0 and 19.0 MeV. Prominent electric dipole peaks are reported at $E_{\rm x} = 17.7$, 19.1, 20.2 and 23 MeV, in addition to weaker structures between 12.5 and 15 MeV; and prominent electric-quadrupole peaks are observed at $E_{\rm x} = 13.0$, 13.7, 14.5, 15.0, 15.4 and 16.2 MeV and there is a broad quadrupole excitation between 16 and 25 MeV. The GDR cross scetion integrated from 11 to 25 MeV contains about 65% of the dipole EWSR while over 90% of the isoscalar quadrupole EWSR is exhausted by the strength in the region $10 - 25$ MeV.

For $11 < E_{\rm x} < 24$ MeV only two isovector M2 transitions appear: These are to ^{20}Ne*(11.62, 12.10) with B(M2, $k) \uparrow\, = 64 \pm 13$ and 56 ± 13 $\mu_{\rm N}^2$fm^2 [orbital contributions are non-negligible]. The M1 transition to ^{20}Ne*(11.26) is also observed but that to ^{20}Ne*(13.48) is not: it is < 0.2 $\mu_{\rm N}^2$ (1985RA08). For reaction (b) see (1978AJ03).

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 $E_{\rm x} = 15$ 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 $E_{\rm x} = 20$ MeV; lesser E1 structures are reported at $E_{\rm x} = 16.7$, 17.1, 21 and 22 MeV. A relatively strong 2^+; $T = 0$ resonance appears at $E_{\rm x} = 18.5$ MeV, and evidence is reported for increasing E2 strength below 16 MeV.

For references see (1978AJ03). See also (1987DE43) and (1978WI1B, 1982RU05, 1983BR1P, 1983KN05, 1984AM03, 1984AM07, 1985LE1H, 1985LE14, 1985ST23, 1986BR1X, 1986KA17, 1986SH16, 1986TA1W, 1986VA12, 1987VA12; theor.).

37. ^{20}Ne(n, n)^{20}Ne

See (1978AJ03).

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

(b) ^{20}Ne(p, pα)^{16}O $\qquad Q_{\rm m} = -4.734$

Angular distributions of elastically scattered protons and of a number of inelastic groups have been measured for $E_{\rm p} = 2.15$ to 65 MeV [see (1978AJ03, 1983AJ01)] and at $E_{\vec{\rm p}} = 0.8$ GeV (1984BL14; to ^{20}Ne*(0, 1.63, 4.25, 8.7(u); also $A_{\rm y}$). The latter work confirms the large hexadecapole deformation of ^{20}Ne. At $E_{\rm p} = 201$ MeV, probable 1^+ states at $E_{\rm x} = 11.25 \pm 0.01$, 13.51 ± 0.03 and 15.72 ± 0.05 MeV are reported by (1987WI03): There does not appear to be any quenching of the M1 strength. In addition 2^- states are observed at 11.58 and 12.08 MeV with B(M2) $= 64 \pm 13$ and 56 ± 13 $\mu_{\rm N}^2$ as is a state of unknown J^π at $E_{\rm x} \approx 17$ MeV (1987WI03). See also the earlier work in (1978AJ03). For reaction (b) see (1984CA09; $E_{\rm p} = 101.5$ MeV). See also (1983CE1A, 1986BA2U), (1986BA88) and (1982SC20, 1983SM04, 1984AM03, 1984AM07, 1985KN04; theor.).

39. ^{20}Ne($\overline{\rm p}$, $\overline{\rm p}$)^{20}Ne

For a study of antiproton interactions see (1986BA22).

40. (a) ^{20}Ne(d, d)^{20}Ne

(b) ^{20}Ne(t, t)^{20}Ne

Angular distributions of deuterons have been reported at $E_{\rm d} = 10.0$ to 52 MeV [see (1978AJ03, 1983AJ01)] and at $E_{\vec{\rm d}} = 52$ MeV (1987NU01). For reaction (b) see (1978AJ03).

41. ^{20}Ne(^{3}He, ^{3}He)^{20}Ne

Angular distributions have been measured at $E(^3\text{He}) = 10$ to 35 MeV and at 68 MeV: see (1978AJ03). See also (1987TR01; theor.).

42. (a) $^{20}\text{Ne}(\alpha, \alpha)^{20}\text{Ne}$
(b) $^{20}\text{Ne}(\alpha, 2\alpha)^{16}\text{O}$ $\qquad Q_\text{m} = -4.734$

Angular distributions have been measured at $E_\alpha = 3.8$ to 155 MeV [see (1978AJ03, 1983AJ01)] and at 54.1 MeV (1987AB03; g.s.). See also (1986BU1L; $E_\alpha = 50.5$ MeV). For a spallation study see (1984AN1H); for cross sections of astrophysical interest see (1984SE02). For reaction (b) see (1983AJ01). See also (1984SA28, 1986TR08), (1982VO04, 1983CH1B) and (1982JA07, 1982WA13, 1984BU1R, 1984SR01, 1985UM01, 1986GA1N, 1986KA17; theor.).

43. $^{20}\text{Ne}(^7\text{Li}, ^7\text{Li})^{20}\text{Ne}$

Angular distributions have been studied at $E(^7\text{Li}) = 36$, 68 and 89 MeV: see (1983AJ01).

44. $^{20}\text{Ne}(^9\text{Be}, ^9\text{Be})^{20}\text{Ne}$

For pion production see (1985FR13).

45. (a) $^{20}\text{Ne}(^{10}\text{B}, ^{10}\text{B})^{20}\text{Ne}$
(b) $^{20}\text{Ne}(^{11}\text{B}, ^{11}\text{B})^{20}\text{Ne}$

Elastic angular distributions have been measured at $E(^{10}\text{B}) = 65.9$ and $E(^{11}\text{B}) = 115$ MeV: see (1983AJ01).

46. (a) $^{20}\text{Ne}(^{12}\text{C}, ^{12}\text{C})^{20}\text{Ne}$
(b) $^{20}\text{Ne}(^{12}\text{C}, \alpha^8\text{Be})^{20}\text{Ne}$ $\qquad Q_\text{m} = -7.3665$

Elastic angular distributions have been obtained at $E(^{12}\text{C}) = 22.2$ to 42.7 MeV and 77.4 MeV and at $E(^{20}\text{Ne}) = 65.9$, 74 and 75.2 MeV [see (1978AJ03, 1983AJ01)] as well as at $E(^{20}\text{Ne}) = 72.6$, 74.0 and 75.2 MeV (1982SH29). For yield, fusion, total reaction cross section and fragmentation studies see (1982KO29, 1982MO15, 1982SH29, 1984AN1H, 1984KO12, 1985FL1B, 1985OS05, 1986BL1K, 1987KO12) and (1983AJ01). For pion production see (1982AN1H, 1983AN1L).

For reaction (b) see (1983AJ01), (1984RA10, 1987SI06) and ^{12}C in (1985AJ01). See also (1985MU18), (1983HE1B, 1984FR1A, 1984HA53, 1984NA1D, 1984ST1B, 1985BE1A, 1985CU1A, 1985ST1B, 1986IK03, 1986ST1J, 1987LA05, 1987SC1D) and (1982LO13, 1983CI08, 1983TO1L, 1984HA43, 1984IN03, 1984MAZT, 1984SH1T, 1985CH11, 1985GA1G, 1985GU1J, 1985HU04, 1985KO1J, 1986GA1F, 1986GI03, 1986HA13, 1986HE1A; theor.).

47. ^{20}Ne(^{16}O, ^{16}O)^{20}Ne

Angular distributions have been studied at $E(^{20}\mathrm{Ne}) = 50$ and 94.8 MeV involving $^{16}\mathrm{O}_{\mathrm{g.s.}}$ and ^{20}Ne*(0, 1.63, 4.25) [see (1983AJ01)], at $E(^{16}\mathrm{O}) = 25.6$ to 44.5 MeV (1984GA22; elastic; also to ^{20}Ne*(1.63) at 31.3, 33.3 and 44.5 MeV)) and at $E(^{20}\mathrm{Ne}) = 66.8$, 115, 137 and 156 MeV (1983SH25; elastic). Yield and fusion cross section measurements are reported by (1982SC13, 1982SH1N, 1983BR1R, 1983SH25, 1984GA22) and in (1983AJ01). See also (1983DU13, 1986BA69, 1986ST1J, 1987SC1D) and (1983KO31, 1983MA29, 1984NI1D, 1985CH11, 1985GU1J, 1985IC01, 1985KO43, 1985KO38, 1986GA1F, 1986HE1A, 1986KO1C, 1986TA1A; theor.).

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

Elastic angular distributions are reported at $E(^{20}\mathrm{Ne}) = 68$, 117, 140 and 156 MeV (1983SH25). For yield and fusion measurements see (1983PO09, 1983SH25) and (1983AJ01). See also (1983RA1J, 1987SC1D) and (1983AB1G, 1983GO13, 1983SI01, 1984TO02, 1985GA1T, 1985IV1C, 1985IV1B, 1987BA1V; theor.).

49. (a) ^{20}Ne(^{24}Mg, ^{24}Mg)^{20}Ne
(b) ^{20}Ne(^{26}Mg, ^{26}Mg)^{20}Ne

Elastic angular distributions for reaction (a) have been measured at $E(^{20}\mathrm{Ne}) = 50$, 60, 80, 90 and 100 MeV [see (1983AJ01)] and at 40 MeV (1983NA04; S_α for the system $^{20}\mathrm{Ne} + {}^{24}\mathrm{Mg} = 0.08 \pm 0.02$). For yield and fusion cross sections see (1982GR1T, 1983AL01, 1984CHZU [also reaction (b)], 1984LE06) and (1983AJ01). See also (1983BI13, 1983DU13, 1984FR1A, 1986BL08) and (1982LO13, 1983OH1C, 1985NI1C, 1987BA01; theor.).

50. ^{20}Ne(^{27}Al, ^{27}Al)^{20}Ne

Elastic angular distributions are reported at $E(^{20}\mathrm{Ne}) = 55.7$, 63, 125 and 151 MeV (1983NG01). For yield, fusion and evaporation residue studies see (1982MO15, 1983MO13, 1983NG01, 1985MO08, 1986GRZK, 1987JA06) and (1983AJ01). See also (1983BI13, 1983HE1B, 1984FR1A, 1984HA53, 1985ST1B, 1985TU01) and (1982LO13, 1983CI08, 1983GO13, 1983OH1B, 1984BI06, 1985HU04; theor.).

51. (a) ^{20}Ne(^{28}Si, ^{28}Si)^{20}Ne
(b) ^{20}Ne(^{29}Si, ^{29}Si)^{20}Ne

See (1983DU13).

52. ^{20}Ne(^{40}Ca, ^{40}Ca)^{20}Ne

Angular distributions have been studied at $E(^{20}\text{Ne}) = 44.1$ to 70.4 MeV and at 151 MeV: see (1983AJ01). For an evaporation residue study see (1982MO15). For yield and fusion measurements see (1983AJ01). The breakup of ^{20}Ne at $E(^{20}\text{Ne}) = 92$, 149 and 213 MeV involves ^{20}Ne*(5.79, 6.73, 7.16, 8.78, 10.26, 11.95) (1986SH30). See also (1983BI13, 1983HE1B, 1984FR1A) and (1982ST08, 1983SI01, 1984GU09, 1984SH2D, 1985AN16, 1985GU08; theor.).

53. ^{20}Na(β^+)^{20}Ne $\qquad Q_{\text{m}} = 13.887$

^{20}Na has a half-life of 447.9 ± 2.3 msec: see reaction 1 in ^{20}Na. It decays to a number of states of ^{20}Ne, principally ^{20}Ne*(1.63): see Table 20.26. The ratio of the mirror decays $^{20}\text{Na} \xrightarrow{\beta^+} {}^{20}\text{Ne*}(1.63)$ and $^{20}\text{F} \xrightarrow{\beta^-} {}^{20}\text{Ne*}(1.63)$, $(ft)^+/(ft)^- = 1.03 \pm 0.02$. $\beta - \gamma$ correlation measurements, as in the decay of ^{20}F, lead to an upper limit for the second-class contribution to the correlation which is consistent with zero: see (1983AJ01). $\beta - \nu - \alpha$ triple correlation coefficient measurements for the transitions via the α-unstable 2^+ states shown in Table 20.26 lead to values of the isospin mixing amplitudes [and to a determination of the vector weak coupling constant] (1983CL01). See also (1987ROZZ) and (1983HA1V, 1985BR29, 1985GR1A, 1985HA1T).

54. ^{21}Ne(p, d)^{20}Ne $\qquad Q_{\text{m}} = -4.536$

See (1978AJ03).

55. ^{21}Ne(d, t)^{20}Ne $\qquad Q_{\text{m}} = -0.503$

Table 20.26: Decay of ^{20}Na [a]

Decay to ^{20}Ne* (MeV ± keV)	$J^{\pi}; T$	Branching ratio (%)	log ft
1.633 ± 2	$2^+; 0$	79.33 ± 1.11	4.988 ± 0.009
7.415 ± 5	$2^+; 0$	16.37 ± 1.28	4.19 ± 0.05
7.826 ± 7	$2^+; 0$	0.674 ± 0.055	5.417 ± 0.033
8.82 ± 10		0.034 ± 0.007	6.27 ± 0.08
9.481 ± 7	$2^+; 0$	0.247 ± 0.020	5.064 ± 0.034
9.873 ± 5	$3^+; 0$	0.0272 ± 0.0138	5.78 ± 0.18
10.275 ± 3	$2^+; 1$	2.868 ± 0.039 [b]	3.476 ± 0.009 [b]
10.584 ± 7	$2^+; 0$	0.087 ± 0.009	4.76 ± 0.05
10.848 ± 7	$2^+; 0$	0.193 ± 0.016	4.179 ± 0.035
10.884 ± 3	$3^+; 1$	0.0392 ± 0.0139	4.84 ± 0.13
11.261 ± 5	$1^+; 1$	0.203 ± 0.026	3.73 ± 0.05
11.320 ± 15	$2^+; 0$	0.036 ± 0.004	4.41 ± 0.05
11.856 ± 20	$2^+; 0$	0.0016 ± 0.0004	4.98 ± 0.10

[a] For additional comments and references see Table 20.37 in (1978AJ03).
[b] (1983CL01).

The $T = 1$ states observed in this reaction, and ther analog states observed in ^{20}F in the (d, ^{3}He) reaction, are displayed in Table 20.16 of (1978AJ03). $T = 0$ states are presented in Table 20.38 of (1978AJ03).

56. ^{22}Ne(p, t)^{20}Ne $\qquad Q_{\rm m} = -8.641$

Angular distributions have been reported at $E_{\rm p} = 26.9$ to 43.7 MeV: see (1978AJ03, 1983AJ01). The angular distributions of the tritons to the ground state of ^{20}Ne and to the first 0^{+}, $T = 2$ state [$E_{\rm x} = 16.722 \pm 0.025$ MeV] have been fitted by $L = 0$ and the tritons to ^{20}Ne*(18.4) by $L = 2$. The latter is the first 2^{+}, $T = 2$ state. The 0^{+}, $T = 2$ state [^{20}Ne*(16.73)] decays by $\alpha_0[(-6 \pm 5)\%]$, $\alpha_1 + \alpha_2[(35 \pm 12)\%]$, $\alpha_3 + \alpha_4[(29 \pm 12)\%]$, $p_0 + p_1 + p_2[(14 \pm 9)\%]$ and $p_3 + p_4 + p_5[(13 \pm 8)\%]$ [measured branching ratios in percent are given in the brackets] to final states in ^{16}O and ^{19}F. See (1978AJ03) for references and additional information.

57. ^{23}Na(p, α)^{20}Ne $\qquad Q_{\rm m} = 2.379$

Angular distributions have been measured at $E_{\rm p} = 10.0$ and 45.5 MeV: see (1972AJ02). For astrophysical considerations see (1982SA1A, 1984FO1A, 1985AR1A) and (1983AJ01). See also (1985RH1A) and (1986TU1B; applied).

58. ^{23}Na(^{3}He, ^{6}Li)^{20}Ne $\qquad Q_{\rm m} = -1.639$

See (1978AJ03).

59. ^{24}Mg(p, pα)^{20}Ne $\qquad Q_{\rm m} = -9.312$

See (1984CA09). See also (1978AJ03).

60. ^{24}Mg(d, ^{6}Li)^{20}Ne $\qquad Q_{\rm m} = -7.837$

Angular distributions have been studied to many states of ^{20}Ne at $E_{\rm d} = 28$ to 80 MeV [see (1978AJ03, 1983AJ01)] and at $E_{\rm d} = 54.2$ MeV (1984UM04; to ^{20}Ne*(0, 1.63, 4.25, 5.62)). Table 20.35 in (1983AJ01) displays the observed states and S_α obtained from several analyses. For newer values of S_α see (1984UM04, 1986OE01). See also (1984PA18, 1986PAZJ; theor.).

61. ^{24}Mg(^{3}He, ^{7}Be)^{20}Ne $\qquad Q_{\rm m} = -7.724$

Angular distributions have been studied at $E(^{3}{\rm He}) = 25.5$ and 70 MeV: see (1978AJ03). See also (1983AJ01) and (1986RA15; theor.).

62. ^{24}Mg(α, ^{8}Be)^{20}Ne $\qquad Q_{\rm m} = -9.404$

See (1983AJ01).

63. ^{24}Mg(^{12}C, ^{16}O)^{20}Ne $\qquad Q_{\rm m} = -2.150$

The angular distribution for the ground state transition has been measured at $E(^{12}{\rm C}) = 40$ MeV (1982LI16). See also (1983AJ01).

64. ^{28}Si(α, ^{12}C)^{20}Ne $\qquad Q_{\rm m} = -12.021$

See (1983AJ01).

^{20}Na

(Figs. 11, 12 and 13)

GENERAL: (See also (1983AJ01).)

(1981WA1Q, 1983ANZQ, 1983BR29, 1985AN28, 1985HA1N, 1985RO1N, 1986AN07, 1986GA1P).

1. ^{20}Na(β^+)^{20}Ne $Q_m = 13.887$

^{20}Na decays by positron emission to ^{20}Ne*(1.63) and to a number of other excited states of ^{20}Ne: see Table 20.26 and reaction 53 in ^{20}Ne. The half-life of ^{20}Na is 447.9 ± 2.3 msec [weighted mean of values quoted in (1978AJ03) and in (1983CL01)]; $J^\pi = 2^+$: see (1978AJ03). See also (1986HO35).

2. ^{19}F(p, π^-)^{20}Na $Q_m = -140.608$

Angular distributions and A_y have been studied at $E_{\vec{p}} = 199.6$ MeV to ^{20}Na*(0.74, 1.85, 3.01, 4.11) [probably unresolved]: it is suggested that the latter two have $J = 6$ or 7 (1987CA05).

3. ^{19}Ne(p, γ)^{20}Na $Q_m = 2.199$

(1986LA07) have calculated the reaction rates at stellar energies. They are higher than those previously estimated. The higher rate implies a greater production of intermediate A elements in the r-p process in stellar evolution. See also (1987LA14).

4. ^{20}Ne(p, n)^{20}Na $Q_m = -14.670$

For observed neutron groups see Tables 20.40 in (1978AJ03) and 20.27 here. For preliminary work at $E_p = 120$ MeV see (1983DEZT). See also (1986BA16) and (1983KN05; theor.).

5. ^{20}Ne(^{3}He, t)^{20}Na $Q_m = -13.906$

States derived from triton groups listed in Tables 20.40 in (1978AJ03) and 20.27 here: see, in particular, (1987LA14). [I am grateful to Professor M. Wiescher for communicating these results to me].

Table 20.27: Energy levels of ^{20}Na

E_x (MeV ± keV)	$J^\pi; T$	$\tau_{1/2}$ or $\Gamma_{c.m.}$	Decay	Reactions
0	$2^+; 1$	$\tau_{1/2} = 447.9 \pm 2.3$ msec	β^-	1, 4, 5
0.591 ± 12			(γ)	4, 5
0.768 ± 8			(γ)	2, 4, 5
(0.85 ± 50)			(γ)	5
0.958 ± 8			(γ)	4, 5
(1.010 ± 14)			(γ)	4
1.310 ± 10			(γ)	4, 5
1.82 ± 20				5
1.91 ± 20				2, 5
1.98 ± 20				5
2.57 ± 20				5
2.66 ± 20				5
2.88 ± 40				2, 5
2.96 ± 40				5
3.06 ± 40				5
3.16 ± 40				5
4.33 ± 100		[a]		2, 5
6.57 ± 50	$0^+; 2$		p	6

[a] Broad or unresolved. See also reaction 2.

6. ^{20}Mg(β^+)^{20}Na $\qquad Q_{\rm m} = 10.731$

^{20}Mg decays to ^{20}Na*(6.57 ± 0.05) [$J^\pi = 0^+; T = 2$]. That state decays by proton emission: see ^{20}Mg.

7. ^{27}Al(^{20}Ne, ^{27}Mg)^{20}Na $\qquad Q_{\rm m} = -16.498$

The Δ resonance is very strongly excited in this reaction at E(^{20}Ne) $= 950$ MeV/A (1986BA16).

^{20}Mg

(Figs. 12 and 13)

^{20}Mg has been populated in the ^{24}Mg(α, ^{8}He) reaction at $E_\alpha = 127$ and 156 MeV and in the ^{20}Ne(^{3}He, 3n) reaction at E(^{3}He) $= 70$ MeV. The super-allowed decay of ^{20}Mg to the first $T = 2$ ($J^\pi = 0^+$) state of ^{20}Na [$E_{\rm x} = 6.57 \pm 0.05$ MeV] has been reported from observations of the subsequent decay of that state by proton emission [see Fig. 12]. The partial half-life is 95^{+80}_{-50} msec leading to a branching ratio of (3 ± 2)% for the super-allowed decay; $\log ft = 3.18$. The results for $A = 20$ are in agreement with the quadratic form of the IMME: see (1978AJ03, 1983AJ01). See also (1985AN28, 1986AN07) and (1983ANZQ; theor.).

^{20}Al, etc.

(Not observed)

See (1972AJ02, 1986AN07) and (1983ANZQ; theor.).

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