

Energy Levels of Light Nuclei $A = 20$

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Abstract: An evaluation of $A = 18-20$ was published in *Nuclear Physics A392* (1983), p. 1. This version of $A = 20$ differs from the published version in that we have corrected some errors discovered after the article went to press. Figures and introductory tables have been omitted from this manuscript. [Reference](#) key numbers have been changed to the NNDC/TUNL format.

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²⁰n
(Not illustrated)

²⁰n has not been observed. See (1978SA1E; theor.).

²⁰B
(Not illustrated)

²⁰B has not been observed. The mass excess is predicted to be 69.08 MeV (1974TH01). ²⁰B is then unstable with respect to breakup into ¹⁹B + n by 0.9 MeV [see ¹⁹B]. See also (1978AJ03).

²⁰C
(Not illustrated)

²⁰C has been observed in the fragmentation of 213 MeV/nucleon ⁴⁸Ca by Be: it is particle stable (1981ST23). Assuming the mass excess of ²⁰C to be 37.3 MeV [see (1978AJ03)], ²⁰C is then stable with respect to ¹⁹C + n and ¹⁸C + 2n by 3.2 and 3.75 MeV, respectively [see ¹⁸C and ¹⁹C]. See also (1978AJ03) and (1978NA07, 1981KI04; theor.).

²⁰N
(Not illustrated)

²⁰N is particle stable: see (1972AJ02). Assuming that the atomic mass excess is 22.0 MeV, ²⁰N is then stable with respect to ¹⁹N + n by 1.94 MeV (see ¹⁹N). See also (1978AJ03).

²⁰O
(Figs. 9 and 13)

GENERAL: (See also (1978AJ03).)

Model calculations: (1977GR16).

Special states: (1977GR16).

Astrophysical questions: (1978WO1E).

Other topics: (1977GR16, 1978RA1J, 1979BE1H).

1. ²⁰O(β^-)²⁰F $Q_m = 3.816$

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 $g = -0.352 \pm 0.015$	γ	2, 3, 4
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
8.962 ± 21	(0^+)			2
9.770 ± 8	0^+			2
10.125 ± 11	2^+			2, 3

^{20}O decays to $^{20}\text{F}^*(1.06)$ [$J^\pi = 1^+$] with a half-life of 13.51 ± 0.05 sec (weighted mean of (1970MA42, 1974AL09)), $\log ft = 3.75 \pm 0.01$. Upper limits for the branching to other states of ^{20}F are shown in Table 20.2 of (1978AJ03) and in Table IV of (1974AL09). See also (1981KA32; theor.).

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

Observed proton groups are displayed in Table 20.2. The first excited state, $^{20}\text{O}^*(1.67)$ has $\tau_m = 10.7 \pm 0.4$ psec (1980RU01) [$M^2|E2| = 1.76 \pm 0.07$ W.u.], 9.8 ± 0.7 psec (1977HE12); $g = -0.352 \pm 0.015$ [(1980RU01) and see (1978AJ03)]. $^{20}\text{O}^*(4.07)$ decays to $^{20}\text{O}^*(0, 1.67)$ with branchings of 26 ± 4 and 74 ± 4 %. The $p\text{-}\gamma$ 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]. $^{20}\text{O}^*(4.46)$ and $^{20}\text{O}^*(5.39)$ decay primarily via $^{20}\text{O}^*(1.67)$; 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 $^{20}\text{O}^*(5.39 \rightarrow 4.07)$ is not observed: the upper limit is 8% (1981YO03).

$$3. \ ^{18}\text{O}(\alpha, 2p)^{20}\text{O} \quad Q_m = -16.735$$

At $E_\alpha = 65$ MeV the population of $^{20}\text{O}^*(0, 1.67, 3.57)$ and of states at 7.78, 8.78 and 10.2 [± 0.1] MeV are reported (1978JA10). See also (1978BI1N).

$$4. \ ^{18}\text{O}(^{18}\text{O}, ^{16}\text{O})^{20}\text{O}^\dagger \quad Q_m = -0.628$$

Angular distributions have been measured to $^{20}\text{O}^*(0, 1.67)$ at $E(^{18}\text{O}) = 24$ to 36 MeV (1977KA21) and to $^{20}\text{O}^*(0, 1.67, 3.57, 4.07, 4.46)$ (1979KU01). A FRDWBA analysis shows $L = 0$ for the transitions to $^{20}\text{O}^*(0, 4.46)$ but underestimates the absolute cross sections by an order of magnitude (1979KU01).

[†] For other reactions leading to ^{20}O see (1978AJ03).

Table 20.2: Energy levels of ^{20}O from $^{18}\text{O}(t, p)^{20}\text{O}$ ^a

E_x (keV)	L	J^π
0.0	0	0^+
1674 ± 3 ^b	2	2^+
3570 ± 7	4	4^+
4072 ± 4	2	2^+
4456 ± 5 ^c	0	0^+
4850 ± 15	4	4^+
5002 ± 6		
5234 ± 5	2	2^+
5304 ± 6 ^c	2	2^+
5387 ± 6	0	0^+
5614 ± 3	(3)	(3^-)
6555 ± 8		(2)
7252 ± 8	5	5^-
7622 ± 7	3 + 4	$3^- + 4^+$
7754 ± 5	4	4^+
7855 ± 6	(5)	(5^-)
8554 ± 8	4	4^+
8804 ± 9	3	3^-
8962 ± 21	(0)	(0^+)
9770 ± 8 ^d	0	0^+
10125 ± 11	2	2^+

^a (1979LA18): $E_t = 15$ MeV. See also Table 20.3 in (1978AJ03) and (1979FO17, 1979PI01).

^b E_γ leads to $E_x = 1673.68 \pm 0.15$ keV (1973WA19).

^c 6p-2h structure: see (1979LA04, 1979LA18).

^d This strong state suggests that $(fp)^2$ excitations are important (1979LA18).

²⁰F
(Figs. 10 and 13)

GENERAL: (See also (1978AJ03).)

Shell model: (1978MA2H, 1981EL1D, 1982KI02).

Electromagnetic transitions: (1976MC1G).

Special states: (1978MA2H, 1981EL1D, 1982KI02).

Complex reactions involving ²⁰F: (1978SH18, 1982FR03).

Astrophysical questions: (1978WO1E).

Muon and pion capture and reactions: (1979KN1G, 1980TR1A).

Other topics: (1977GR16, 1978MA2H, 1978RA1J, 1979BE1H, 1981EL1D, 1982KI02, 1982QUZY).

Ground state of ²⁰F: (1976MC1G).

$$\mu = +2.094 (2) \text{ nm (1978LEZA);}$$

$$Q = 0.070 (13) \text{ b (1978LEZA).}$$

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

The half-life of ²⁰F is 11.00 ± 0.02 sec: see (1978AJ03). See also (1975SA1D, 1978CA02). ²⁰F decays principally to ²⁰Ne*(1.63): see ²⁰Ne, reaction 42.

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

At $E(^9\text{Be}) = 12$ to 27 MeV angular distributions are reported (1979JA22, 1981JA09: $p_0, p_{1+2+3+4}$). See also (1978AJ03).

3. $^{13}\text{C}(^7\text{Li}, ^7\text{Li})^{13}\text{C}$ $E_b = 18.050$

See (1976PO02, 1978DR07) and ¹³C in (1981AJ01). For fusion cross sections see (1981DE1H, 1981DE2K).

4. $^{13}\text{C}(^9\text{Be}, \text{d})^{20}\text{F}$ $Q_m = 1.3543$

At $E(^{13}\text{C}) = 27.9$ MeV angular distributions are reported by (1980BO21: $d_0, d_{1+2+3+4}$).

Table 20.3: Energy levels of ^{20}F ^a

E_x (MeV \pm keV)	$J^\pi; T$	τ	Decay	Reactions
0	$2^+; 1$	$\tau_{1/2} = 11.0 \pm 0.02$ sec	β^-	1, 2, 4, 6, 7, 13, 14, 21, 22, 25, 26, 27, 28, 29
0.65594 ± 0.15	3^+	$\tau_m = 0.39 \pm 0.03$ psec	γ	2, 4, 6, 7, 12, 13, 14, 22, 23, 26, 28
0.82288 ± 0.20	4^+	79 ± 6 psec	γ	2, 4, 5, 6, 7, 12, 13, 14, 22, 26, 28
0.98371 ± 0.20	1^-	2.0 ± 0.2 psec	γ	2, 4, 6, 7, 12, 13, 14, 22, 26, 28
1.05693 ± 0.20	1^+	45 ± 13 fsec	γ	2, 4, 6, 7, 13, 14, 22, 24, 25, 26, 28
1.30923 ± 0.20	2^-	1.6 ± 0.3 psec	γ	6, 7, 12, 13, 14, 22, 25, 26, 28
1.8244 ± 1.2	5^+	≤ 65 fsec	γ	5, 6, 12, 13, 22, 28
1.84337 ± 0.30	2^-	30 ± 20 fsec	γ	7, 13, 14, 22, 25, 26, 28
1.9707 ± 0.4	(3^-)		γ	6, 7, 12, 13, 14, 22, 28
2.04400 ± 0.30	2^+	37 ± 16 fsec	γ	6, 7, 13, 14, 22, 23, 26, 28
2.1948 ± 0.4	(3^+)	< 12 fsec	γ	6, 7, 13, 14, 22, 26, 28
2.8649 ± 1.5	(3^-)		γ	6, 7, 13, 22, 28
2.9661 ± 0.4	3^+	60 ± 40 fsec	γ	6, 7, 13, 14, 22, 28
2.968 ± 1.5	(4^-)		γ	5, 6, 7
3.1740 ± 1.5	1^+		γ	6, 7, 13, 22, 28
3.48843 ± 0.25	1^+	44 ± 11 fsec	γ	13, 14, 22, 28
3.5260 ± 0.4	0^+	30 ± 15 fsec	γ	6, 7, 13, 14, 22
3.5871 ± 0.3	$(1, 2, 3)^+$	≤ 60 fsec	γ	6, 7, 13, 14, 22, 28
3.6810 ± 0.4	$(1, 2, 3)^+$		γ	6, 7, 13, 14, 22, 28
3.7611 ± 1.9	$(2^-, 3^+)$		γ	6, 7, 13, 22, 28
3.9660 ± 1.5	1^+		γ	6, 7, 13, 14, 22, 28
4.0823 ± 0.4	$(1)^+$		γ	6, 7, 13, 14, 22, 28
4.1989 ± 2.7			(γ)	6, 7, 22, 28
4.2077 ± 2.6			(γ)	6, 7, 22, 28
4.2766 ± 0.5	$(1, 2, 3)^+$		γ	6, 7, 14, 22, 28
4.3154 ± 2.0	$(0, 1)^+$		(γ)	6, 7, 22, 28
4.3745 ± 2.0	$0^{(-)}$		(γ)	6, 7, 22, 28
4.5105 ± 2.0	$(6^+, 4^-)$		(γ)	6, 7, 22, 28

Table 20.3: Energy levels of ^{20}F ^a (continued)

E_x (MeV \pm keV)	$J^\pi; T$	τ	Decay	Reactions
4.5808 \pm 1.8			(γ)	6, 7, 22, 28
4.5922 \pm 2.9			(γ)	6, 7, 22, 28
4.7310 \pm 2.0	(5 ⁺ , 6 ⁺ , 4 ⁻)		(γ)	6, 7, 22, 28
4.7656 \pm 2.0	(5 ⁺ , 6 ⁺ , 4 ⁻)		(γ)	6, 7, 22, 28
4.8916 \pm 2.8			(γ)	22, 28
4.8982 \pm 2.8			(γ)	22, 28
5.0402 \pm 3.1	(0, 1, 2) ⁻		(γ)	7, 22, 28
5.0655 \pm 3.1			(γ)	7, 22, 28
5.135 \pm 4			(γ)	7, 22, 28
5.2240 \pm 2.8	(0, 1, 2) ⁻		(γ)	7, 22, 28
5.284 \pm 3	(1, 0) ⁺		(γ)	22, 28
5.318 \pm 3			(γ)	7, 22, 28
5.349 \pm 4	(1, 2, 3) ⁺		(γ)	7, 22, 28
5.4131 \pm 0.6			γ	7, 14, 22, 28
5.4503 \pm 3.8			(γ)	22, 28
5.4554 \pm 3.2			(γ)	22, 28
5.463 \pm 3	(1, 2, 3) ⁺		(γ)	7, 22
5.5629 \pm 2.0	(0, 1, 2) ⁻		γ	7, 14, 22, 28
5.5881 \pm 1.5			(γ)	7, 22, 28
5.620 \pm 3			(γ)	7, 22, 28
5.713 \pm 2			γ	14, 22, 28
5.7640 \pm 2.5	(1, 2, 3) ⁺		(γ)	7, 22, 28
5.8104 \pm 2.5	(2 ⁻ , 1 ⁺)		(γ)	7, 22, 28
5.9361 \pm 0.3	(1 ⁻ , 2 ⁻)		γ	7, 14, 22, 28
6.0174 \pm 0.3	(2 ⁻)		γ	7, 14, 22, 28
6.0446 \pm 0.4			γ	7, 14, 22, 28
6.163 \pm 6			(γ)	7, 28
6.205 \pm 6			(γ)	7, 28
6.240 \pm 7			(γ)	28
6.300 \pm 5			(γ)	28
6.337 \pm 5			(γ)	28
6.370 \pm 6			(γ)	28
6.407 \pm 12			(γ)	28

Table 20.3: Energy levels of ^{20}F ^a (continued)

E_x (MeV \pm keV)	$J^\pi; T$	τ	Decay	Reactions
6.441 \pm 9			(γ)	28
6.480 \pm 5			(γ)	28
6.519 \pm 3	$0^+; 2$		γ	13, 27
6.588 \pm 5			(γ)	28
6.6269 \pm 0.6	2^-	0.310 ± 0.020	γ, n	14, 15
6.6425 \pm 0.6	(3, 4)	< 0.08	γ, n	14, 28
6.6474 \pm 0.7	1^-	1.59 ± 0.10	γ, n	14, 15, 28
6.6933 \pm 0.8	1^-	13.8 ± 0.8	γ, n	14, 15, 28
6.7660 \pm 1.1		≤ 0.6	γ, n	14, 28
6.829			n	16
6.8566 \pm 1.2	2	10 ± 2	γ, n	14, 16, 28
(6.858 \pm 8)	1		γ, n	14
6.905 \pm 8				28
6.9677 \pm 1.2	1^-	5 ± 1	γ, n	14, 16
(7.0670 \pm 1.2)	0^-	(2.4 ± 0.6)	γ, n	14, 16
7.076	(1^+)	24	n	15
7.166 \pm 2	$2^{(+)}$	8 ± 1	γ, n	14, 15, 16
7.311	(1)	33	γ, n	14, 15
7.361	(1)	19	n	15, 16
7.410	(2^+)	10	γ, n	14, 15, 16
7.50	(2)	80	γ, n	14, 15
7.67	(2^+)	65	γ, n	14, 15, 16
7.79		140	n	15, 16
(7.831 \pm 12)	1^-	(50 ± 10)	γ, n	14
7.988 \pm 3	1	14 ± 2	γ, n	14
8.05 \pm 100	$2^+; 2$			27
8.13		195	γ, n	14, 15, 16
8.163		15	n	16
8.421		27	n	16
8.50		140	n	15
8.728		≤ 30	n	15, 16
8.77		76	n	15
8.942		73	n	15, 16

Table 20.3: Energy levels of ^{20}F ^a (continued)

E_x (MeV \pm keV)	$J^\pi; T$	τ	Decay	Reactions
9.165			n	16
9.521		110	n	16
9.654		100	n	15, 16
9.830		33	n	16
9.85		120	n	15
(9.886 \pm 10)			n	15
9.901		≤ 30	n	16
(9.929 \pm 10)			n	15
(9.981 \pm 10)			n	15
10.024 \pm 10		150	n, α	15, 26, 20
10.10 \pm 50			n, α	20
10.228 \pm 10	$0^-, 1$	≈ 200	n, α	15, 20
10.480 \pm 10		≈ 10	n, α	15, 20
10.641 \pm 10	1, 2	70	n	15, 16
10.807 \pm 10	$0^-, 1$	≈ 310	n, α	15, 20
10.988		190	n	16
(11.045 \pm 10)		≈ 30	n	15
(11.130 \pm 10)		< 25	n	15
(11.244 \pm 10)		< 25	n	15, 16
(11.287 \pm 10)			n	15
11.49 \pm 50			n, α	20
12.0			n, α	20
12.2 \pm 100			n, α	20
12.39			n, α	20
12.82			n, α	20
13.2			n, α	20
13.66			n, α	16, 20
14.0			n, α	20

^a See also Tables [20.4](#) and [20.5](#).

Table 20.4: 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	41 ± 4	
		0.66	59 ± 5	
0.98 ^c	1^-	0	≥ 96	b
1.06 ^c	1^+	0	≥ 96	
1.31 ^c	2^-	0	100	b
1.82 ^c	5^+	0.82	≥ 95	-0.03 ± 0.07
1.84 ^c	2^-	0	≥ 94	
1.97 ^c	(3^-)	0	16 ± 4	-0.06 ± 0.14
		0.82	55 ± 3	$+0.27 \pm 0.30$
		1.31	29 ± 3	
2.04 ^c	2^+	0	8 ± 4	
		0.66	92 ± 4	$0.08_{-0.1}^{+0.06}$
2.19 ^c	(3^+)	0	58 ± 4	0 ± 0.09
		0.82	42 ± 4	$+0.07 \pm 0.10$
2.86		0	(100)	
2.966	3^+	0	19 ± 5	
		0.66	17 ± 5	
		0.82	35 ± 4	
		1.97	29 ± 4	
2.968 ^d	(4^-)	0.82	39 ± 4	
		1.97	61 ± 4	
3.17 ^c	(1^+)	0.98	> 95	
3.49	1^+	0	68 ± 4	
		0.98	7 ± 1	
		1.06	7 ± 1	
		1.31	10 ± 2	
		1.84	8 ± 2	
3.53	0^+	1.06	100	
3.59	$(1, 2, 3)^+$	0	63	
		2.04	37	

Table 20.4: Radiative transitions in ^{20}F ^a (continued)

E_i (MeV)	J_i^π	E_f (MeV)	Branching (%)	δ
3.68	(1, 2, 3) ⁺	0	33	
		0.66	67	
3.76	1 ⁺	0.66	observed	
3.97		0.98	22 ± 7	
		1.31	78 ± 7	
4.08	(1) ⁺	0	45 ± 7	
		1.06	55 ± 7	
e				

^a For references see Table 20.5 in (1978AJ03).

^b Pure E1.

^c For upper limits for transitions to other states of ^{20}F see Table 20.5 in (1978AJ03).

^d (1978LE19).

^e For the decays of higher states see Table 20.5 in (1978AJ03), and Tables 20.8 and 20.9 here.

5. $^{13}\text{C}(^{11}\text{B}, \alpha)^{20}\text{F}$ $Q_m = 9.3851$

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 $^{20}\text{F}^*(1.97, 0.82)$ [$J^\pi = (3^-), 4^+$]: this is consistent with $J^\pi = (4^-)$ for $^{20}\text{F}^*(2.968)$ (1978LE19).

6. $^{14}\text{N}(^7\text{Li}, \text{p})^{20}\text{F}$ $Q_m = 12.054$

The ^{20}F states observed in this reaction at $E(^7\text{Li}) = 16$ MeV are displayed in Table 20.7. The cross sections for forming states of known J^π are proportional to $2J_f + 1$ with slopes which are different for the even- and the odd-parity states. Extrapolation of these relationships to states of unknown J^π leads to the assignments shown in Table 20.6 (1977FO11).

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

Angular distributions have been measured at $E(^7\text{Li}) = 24$ MeV for the ^3He groups corresponding to the states shown in Table 20.7. It is suggested that the states at $E_x = 4.20, 4.52, 4.58$ and 5.41 MeV have high spin and (sd)⁴ configurations (1978FO14).

Table 20.5: Lifetime measurements of some ^{20}F states ^a

$^{20}\text{F}^*$ (MeV)	τ_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 ^c
1.06	45 ± 13 fsec
1.31	1.16 ± 0.20 psec ^a
	1.9 ± 0.3 psec ^b
	1.6 ± 0.3 psec ^c
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 For references see Table 20.6 in (1978AJ03).

^b (1980KO1H; abstract) and R.L. Kozub (private communication).

^c “Best” value.

Table 20.6: States of ^{20}F from $^{14}\text{N}(^7\text{Li}, \text{p})$ and $^{16}\text{O}(^7\text{Li}, ^3\text{He})$

E_x (keV) ^a	E_x (keV) ^b	J^π ^{a,b}
0	0	2^+
657 ± 6	654 ± 4	3^+
820 ± 5	819 ± 3	4^+
984 ± 5	974 ± 6	1^-
1049 ± 5	1044 ± 6	1^+
1310 ± 6	1310 ± 2	2^-
1826 ± 4 ^c		5^+
	1824 ± 2 ^c	(2^-)
1969 ± 5	1973 ± 3	(3^-)
2040 ± 3	2043 ± 3	2^+
2194 ± 6	2197 ± 3	3^+
2863 ± 5	2866 ± 2	(3^-)
2962 ± 3 ^c	2968 ± 3	
3171 ± 4	3176 ± 3	1^+
3491 ± 3 ^c	3491 ± 4 ^c	0^+
3578 ± 5 ^d	3593 ± 3	
3674.2 ± 2.8 ^d	3680 ± 5	
3756.5 ± 2.3	3760 ± 2	$(2^-, 3^+)$ ^e
3967 ± 5	3972 ± 4	1^+
4080 ± 4 ^d	4082 ± 10	
4198 ± 3 ^c	4205 ± 3 ^c	
4274 ± 3 ^c	4285 ± 5 ^c	
4366 ± 8	4372 ± 12	$0^{(-)}$
4508 ± 4	4513 ± 3	$(6^+, 4^-)$ ^e
4576.8 ± 2.6 ^c	4583 ± 3 ^c	
4736 ± 4	4729 ± 3	$(5^+, 6^+, 4^-)$
4768 ± 4	4767 ± 4	$(5^+, 6^+, 4^-)$
4887.9 ± 2.9 ^c	4901 ± 4 ^c	
	5057 ± 7 ^c	
	5144 ± 6	
	5236 ± 7	

Table 20.6: States of ^{20}F from $^{14}\text{N}(^7\text{Li}, \text{p})$ and $^{16}\text{O}(^7\text{Li}, ^3\text{He})$ (continued)

E_x (keV) ^a	E_x (keV) ^b	J^π ^{a,b}
	5326 ± 3 ^c	
	5414 ± 3	
	5470 ± 4 ^c	
	5554 ± 9 ^c	
	5608 ± 12	
	5776 ± 5 ^c	
	5951 ± 4	
	6033 ± 4 ^c	
	6199 ± 10 ^c	

^a (1977FO11): $E(^7\text{Li}) = 16$ MeV. Some E_x values have been rounded off.

^b (1978FO14): $E(^7\text{Li}) = 24$ MeV.

^c Unresolved.

^d Possible doublet.

^e If single state.

$$8. \ ^{17}\text{O}(\text{t}, \text{p})^{19}\text{O}^\dagger \qquad Q_m = 3.520 \qquad E_b = 14.157$$

See ^{19}O .

$$9. \ ^{17}\text{O}(^{13}\text{C}, ^{10}\text{B})^{20}\text{F} \qquad Q_m = -9.719$$

See (1979GO17).

$$10. \ (a) \ ^{18}\text{O}(\text{d}, \text{n})^{19}\text{F} \qquad Q_m = 5.7685 \qquad E_b = 12.3699$$

$$(b) \ ^{18}\text{O}(\text{d}, \text{p})^{19}\text{O} \qquad Q_m = 1.732$$

Vector analyzing power measurements [reaction (b)] have been carried out at $E_d = 10$ MeV (1979ST21; p_0, p_2, p_3, p_4) and at 14 MeV: see (1978AJ03). See also (1981NE1B; theor.). See also ^{19}O . For reaction (a) see ^{19}F .

[†] Additional reactions on which no new work is reported are listed in (1978AJ03).

Table 20.7: States in ^{20}F for $^{18}\text{O}(^3\text{He}, \text{p})^{19}\text{F}$ ^a

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

^a For a complete listing of references see reaction 13 and Table 20.8 in (1978AJ03).

^b $E(^3\text{He}) = 18$ MeV (1974CR04): predominant L -values.

^c From L -values, γ -ray polarization data and branching ratio and lifetime measurements: see also Tables 20.4 and 20.5.

^d $E_x = 1824.4 \pm 2.1$ and 1843.0 ± 2.2 keV (1967QU01).

^e $E_x = 3765 \pm 6$ keV, based on $E_x = 657 \pm 1$ keV (1973PR01).

^f Decays principally ($> 90\%$) to $^{20}\text{F}^*(1.06)$: the γ -rays are isotopic [$\Gamma_\gamma = 3.6 \pm 0.6$ eV, based on the analog decay in ^{20}Ne]. $^{20}\text{F}^*(6.52)$ is the 0^+ , $T = 2$ analog of the ground states of ^{20}O and ^{20}Mg (1976MI01, 1977BA50).

^g Weakly populated.

11. $^{18}\text{O}(\text{d}, \text{d})^{18}\text{O}$

$$E_b = 12.3699$$

VAP measurements involving the elastic group have been carried out at $E_{\bar{d}} = 10$ MeV (1979ST21) and at 14.8 MeV: see (1978AJ03).

12. (a) $^{18}\text{O}(\text{d}, ^3\text{He})^{17}\text{N}$

$$Q_m = -10.449$$

$$E_b = 12.3699$$

(b) $^{18}\text{O}(\text{d}, \alpha)^{16}\text{N}$

$$Q_m = 4.246$$

VAP measurements are reported at $E_{\bar{d}} = 52$ MeV for reaction (a) (1981MA14: to $^{17}\text{N}^*(0, 1.37, 1.85, 2.53, 5.51, 6.99)$) and (b) (1982MA25: to $^{16}\text{N}^*(0, 0.30, 3.36, 3.96, 4.32, 6.17)$). TAP measurements are reported to reaction (b) at $E_{\bar{d}} = 8.5$ to 11.3 MeV (1978BA43). For excitation functions see (1972AJ02). See also ^{16}N , ^{17}N in (1982AJ01) and (1979SE04).

12. $^{18}\text{O}(\text{t}, \text{n})^{20}\text{F}$

$$Q_m = 6.1126$$

See (1978AJ03).

13. $^{18}\text{O}(^3\text{He}, \text{p})^{20}\text{F}$

$$Q_m = 6.8764$$

States of ^{20}F observed in this reaction are displayed in Table 20.7. For a complete listing of the references see (1978AJ03).

14. $^{19}\text{F}(\text{n}, \gamma)^{20}\text{F}$

$$Q_m = 6.6012$$

The thermal capture cross section is 9.8 ± 0.7 mb (1974SH1E). A number of resonances have been observed: see Table 20.8. See also (1981MUZQ). The primary γ -rays resulting from capture at thermal energies ($^{20}\text{F}^*(6.60)$; $J^\pi = 0^+, 1^+$) and at $E_n = 27, 44$ and 49 keV ($^{20}\text{F}^*(6.63, 6.643, 6.647)$; $J^\pi = 2^-, (3, 4)$ and 1^-) have been studied by several groups: see (1972AJ02) and Table 20.9 here. It appears that the thermal capture [$^{20}\text{F}^*(6.60)$] is dominated by two intense transitions (probably E1) to $^{20}\text{F}^*(5.94, 6.02)$ [thus $J^\pi = 1^-, 2^-$]. If the ground-state transition is mainly M1, these two E1 transitions are (in terms of W.u.) about 150 times stronger than the M1 transition (1968SP01). It appears also that at $^{20}\text{F}^*(6.63, 6.64, 6.65)$ [$J^\pi = 2^-, (3, 4)$ and 1^-] the E1 transitions to the ground state are very weak, even though other E1 transitions in the decay of these two states have approximately normal strengths (1967BE36, 1974KE18). The strongest transitions from the 27 keV resonance appear to be M1. On the basis of the J^π of the final states involved in

Table 20.8: Resonances in $^{19}\text{F}(n, \gamma)^{20}\text{F}$ ^a

E_n (keV)	J^π ^b	Γ_γ (eV)	$\Gamma_{\text{c.m.}}$ (keV)	E_x in ^{20}F (MeV)
27.07 ± 0.05	2^-	1.4 ± 0.3	0.355 ± 0.03	6.6269
43.5 ± 0.1	(3, 4)	^c	< 0.08	6.6425
48.7 ± 0.3	1^-	1.6 ± 0.3	1.96 ± 0.3	6.6474
97.0 ± 0.5	1^-	6.0 ± 1.8 ^d	13.5 ± 1.5	6.6933
173.5 ± 0.9		^e	≤ 0.6	6.7660
269 ± 1	2	3.5 ± 0.8	10 ± 2	6.8566
(270 ± 8)	1	≤ 4.4		(6.858)
386 ± 1	1^-	2.4 ± 0.8	5 ± 1	6.9677
(490.5 ± 1)	0^-	($\geq 10 \pm 3$)	(2.4 ± 0.6)	(7.0670)
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: (1973MA14).

^c $g\Gamma_n = 0.086 \pm 0.02$ eV (1973MA14).

^d May be two resonances.

^e $g\Gamma_n = 0.35 \pm 0.1$ eV (1973MA14).

Table 20.9: Primary capture transitions in $^{19}\text{F}(n, \gamma)^{20}\text{F}$ ^a

Final state $^{20}\text{F}^*$ (MeV)	I_γ ^b from			
	$^{20}\text{F}^*(6.60)$ ^c	$^{20}\text{F}^*(6.63)$	$^{20}\text{F}^*(6.64)$	$^{20}\text{F}^*(6.65)$
0	10	2.0 ± 0.5		
0.66		6 ± 1	42 ± 7	
0.82			23 ± 7	
0.98				18 ± 4
1.06	6			9 ± 4
1.31		31 ± 2		
1.84		8 ± 2		
1.97		46 ± 4		
2.04	6	1.5 ± 1		59 ± 6
2.97			35 ± 9	
3.49		3 ± 1		14 ± 5
3.53		8 ± 1		
4.08		2.5 ± 1		
5.94	15			
6.02	43			

^a For complete references see Table 20.10 in (1978AJ03). See also Tables 20.4 and 20.8 here.

^b In units of photons/100 captures.

^c $I_\gamma < 5$ not shown: see Table 20.10 in (1978AJ03). Transitions from thermal energy capture.

Table 20.10: States of ^{20}F involved in $^{19}\text{F}(\text{n}, \gamma)^{20}\text{F}$ ^a

E_x (keV)	
0	3526.0 ± 0.5
656.3 ± 0.3 ^b	3587.3 ± 0.3
822.9 ± 0.3	3681.0 ± 0.4
983.8 ± 0.3 ^b	3967 ± 2 ^c
1057.2 ± 0.3	4082.2 ± 0.5
1309.1 ± 0.3	4276.7 ± 0.5
1843.4 ± 0.3	5413.1 ± 0.6
1970.6 ± 0.3	5554.7 ± 0.6
2044.2 ± 0.4	5713 ± 2 ^c
2194.5 ± 0.6	5936.0 ± 0.3
2965.8 ± 0.5	6017.3 ± 0.3
3488.3 ± 0.3	6044.6 ± 0.4
	6601.1 ± 0.3 ^d

^a (1968SP01).

^b 656.1 ± 0.3 and 983.4 ± 0.4 keV (1972OP01).

^c (1969HA04).

^d 6602.0 ± 0.6 keV (1969HA04).

the decay of the 44 keV resonance $J = 3$ or 4, assuming dipole transitions (1974KE18). Branching ratios for other ^{20}F states involved in this reaction are shown in Table 20.4.

Table 20.10 displays excitation energies for ^{20}F states involved in cascade and in primary γ -transitions.

15. $^{19}\text{F}(\text{n}, \text{n})^{19}\text{F}$

$$E_b = 6.6012$$

The scattering amplitude (bound) $a = 5.654 \pm 0.010$ fm, $\sigma_{\text{free}} = 3.641 \pm 0.010$ b (1979KO26). See also (1981MUZQ).

The total cross section has been measured for $E_n = 0.5$ to 29.1 MeV: see (1978AJ03). Observed resonances are displayed in Table 20.11. See also ^{19}F .

16. $^{19}\text{F}(\text{n}, \text{n}')^{19}\text{F}^*$

$$E_b = 6.6012$$

Observed resonances in the excitation functions involving $^{19}\text{F}^*(0.11, 1.5 \text{ [u]})$ are displayed in Table 20.12. See also (1978CO18, 1980CO1U) and (1978AJ03).

$$17. \text{}^{19}\text{F}(\text{n}, 2\text{n})^{18}\text{F} \qquad Q_{\text{m}} = -10.4313 \qquad E_{\text{b}} = 6.6012$$

Cross sections have been measured for $E_{\text{n}} = 10$ to 37 MeV [see (1978AJ03)] and at $E_{\text{n}} = 14.7$ –19.0 MeV (1978RY02) and 16.2–21.8 MeV (1978CO18, 1980CO1U). See also (1979HA60).

$$18. \text{}^{19}\text{F}(\text{n}, \text{p})^{19}\text{O} \qquad Q_{\text{m}} = -4.036 \qquad E_{\text{b}} = 6.6012$$

The differential cross section at 92° for production of the 96 keV γ -ray has been studied by (1976MO13: $E_{\text{n}} = 4.0$ to 18.6 MeV): the cross section increases sharply at $E_{\text{n}} = 6$ MeV and then gradually decreases beyond $E_{\text{n}} = 12$ MeV. Cross sections have also been measured for $E_{\text{n}} = 12.6$ to 21 MeV: see (1972AJ02) and the summary in (1976GAYV). See also (1978SM1E, 1979BR08, 1979HA60).

$$19. \text{(a) } ^{19}\text{F}(\text{n}, \text{d})^{18}\text{O} \qquad Q_{\text{m}} = -5.7688 \qquad E_{\text{b}} = 6.6012$$

$$\text{(b) } ^{19}\text{F}(\text{n}, \text{t})^{17}\text{O} \qquad Q_{\text{m}} = -7.556$$

For reaction (a) see (1978CO18, 1980CO1U). For reaction (b) see (1978QA01). For both see also (1978AJ03).

$$20. \text{}^{19}\text{F}(\text{n}, \alpha)^{16}\text{N} \qquad Q_{\text{m}} = -1.522 \qquad E_{\text{b}} = 6.6012$$

Reported resonances are shown in Table 20.13: see graph in (1976GAYV). See also (1978SM1E, 1979BR08).

$$21. \text{}^{19}\text{F}(\text{p}, \pi^+)^{20}\text{F} \qquad Q_{\text{m}} = -133.748$$

Cross sections at 5.3 and 10.4 MeV above threshold are reported by (1979MA39).

$$22. \text{}^{19}\text{F}(\text{d}, \text{p})^{20}\text{F} \qquad Q_{\text{m}} = 4.3765$$

Table 20.11: Resonances in $^{19}\text{F}(n, n)^{19}\text{F}$ ^a

E_n (keV)	Γ_{lab} (keV)	J^π	$^{20}\text{F}^*$ (MeV)
26.99	0.325 ± 0.020	2^-	6.6268
48.78	1.67 ± 0.10	1^-	6.6475
97.50	14.5 ± 0.8	1^-	6.6938
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 $^{20}\text{F}^*(7.08, 7.17, 7.31, 7.41)$ (1973MU14).

Table 20.12: States of ^{20}F from resonances in $^{19}\text{F}(\text{n}, \text{n}'\gamma)^{19}\text{F}$

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 $\theta = 92^\circ$: values for E_n read by reviewer from differential cross section tables ([1976MO13](#)).

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

^c Appears to be unresolved.

Table 20.13: Resonances in $^{19}\text{F}(n, \alpha)^{16}\text{N}$ ^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).

^b Not resolved.

States of ^{20}F observed in this reaction are displayed in Table 20.14. Angular distributions have been measured at $E_d = 0.6$ to 16 MeV [see (1978AJ03)] and at 12 MeV (1977MO16). See (1978AJ03) for a discussion of the earlier work. See also (1980HU1D, 1980HU1J).

23. $^{19}\text{F}(^{13}\text{C}, ^{12}\text{C})^{20}\text{F}$ $Q_m = 1.6548$

See (1978AJ03).

24. $^{20}\text{O}(\beta^-)^{20}\text{F}$ $Q_m = 3.816$

See ^{20}O .

Table 20.14: States in ^{20}F from $^{19}\text{F}(\text{d}, \text{p})^{20}\text{F}$ ^a

E_x (keV) ^b	l_n ^c	J^π	$(2J + 1)S$ ^c	n, l, j ^c
0	2	2^+	0.054	$1\text{d}_{5/2}$
655.9 ± 0.2	2	3^+	2.32	$1\text{d}_{5/2}$
823.0 ± 0.3	d	4^+	0.32	$1\text{g}_{9/2}$
983.9 ± 0.3	d	1^-	0.014	$1\text{p}_{1/2}$
1057.0 ± 0.2	$0 + 2$	1^+	0.013	$2\text{s}_{1/2}$
1309.3 ± 0.2	d	2^-	0.017	$1\text{p}_{3/2}$
1820 ± 10	d	(5^+)	0.35	$1\text{g}_{9/2}$
1843.5 ± 0.7	d	2^-	0.007	$2\text{p}_{3/2}$
1970 ± 10	d	(3^-)	0.038	$1\text{f}_{7/2}$
2043.7 ± 0.5	2	2^+	2.32	$1\text{d}_{5/2}$
2194.5 ± 0.6	2	3^+	0.55	$1\text{d}_{5/2}$
2863.7 ± 1.6	d		0.044	$1\text{f}_{7/2}$
2966.8 ± 0.6	2	3^+	0.38	$1\text{d}_{3/2}$
3175.6 ± 1.3	d		0.019	$1\text{d}_{5/2}$
3488.5 ± 0.3	0	1^+	1.20^e	$2\text{s}_{1/2}$
3525.9 ± 0.5	0	0^+	0.28^e	$2\text{s}_{1/2}$
3586.5 ± 0.6	2	$\pi = +$	0.038	$1\text{d}_{3/2}$
3681.0 ± 2.5	2	$\pi = +$	0.031	$1\text{d}_{5/2}$
3760.8 ± 2.7	d		^c	
3964.5 ± 2.5	2	$\pi = +$	0.036	$1\text{d}_{5/2}$
4082.5 ± 0.8	$0 + 2$	$\pi = +$	0.13	$1\text{s}_{1/2}$
4198.9 ± 2.7	d		0.083	$1\text{d}_{3/2}$
4207.7 ± 2.6				
4279.0 ± 2.0	2	$\pi = +$	0.087	$1\text{d}_{5/2}$
4315.4 ± 2.0	0	$(0, 1)^+$	0.20	$2\text{s}_{1/2}$
4374.5 ± 2.0			f	
4509.5 ± 3.0			f	
4583.8 ± 3.0			0.02	$2\text{p}_{3/2}$
	1	$(0 - 2)^-$		
4592.2 ± 2.9			(< 0.05)	$(1\text{f}_{7/2})$

Table 20.14: States in ^{20}F from $^{19}\text{F}(\text{d}, \text{p})^{20}\text{F}$ ^a (continued)

E_x (keV) ^b	l_n ^c	J^π	$(2J + 1)S$ ^c	n, l, j ^c
4730.2 ± 2.9	2, 3		f	
4763.8 ± 2.7	2, 3		f	
4891.6 ± 2.8			f	
4898.2 ± 2.8			f	
5048.7 ± 1.5			f	
5069.0 ± 3	2	(1, 2, 3) ⁺	0.09	1d _{5/2}
5132.4 ± 3.5			f	
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			f	
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			f	
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 ⁺)	f	
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).

^b Best values from data for proton groups and γ -rays taken from data shown in the (1978AJ03) table and in (1977MO16).

^c See (1974FO21, 1977MO16): $E_d = 12$ MeV; assumed in analysis.

^d Weak groups.

^e At $E_d = 16$ MeV.

^f See (1977MO16).

Table 20.15: Analog states of $A = 20$ observed in $^{21}\text{Ne}(d, ^3\text{He})^{20}\text{F}$ and $^{21}\text{Ne}(d, t)^{20}\text{Ne}$ ^a

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

^a (1974MI13): $E_d = 26$ MeV: DWBA analysis of angular distributions. See Table 20.34 for $T = 0$ states in ^{20}Ne observed in the (d, t) reaction.

^b E_x are nominal.

$$25. \ ^{20}\text{Ne}(\pi^-, \gamma)^{20}\text{F} \quad Q_m = 132.541$$

The branching ratio to $^{20}\text{F}^*(1.06)$ [$J^\pi = 1^+$] is compared to the analogous M1 decay width $^{20}\text{Ne}^*(11.24)$ [$J^\pi = 1^+$] \rightarrow $^{20}\text{Ne}_{\text{g.s.}}$. The M1 amplitude contains $(47 \pm 16)\%$ spin flip, in agreement with shell-model calculations. The population of $^{20}\text{F}^*(0, 1.31, 1.84)$ [$J^\pi = 2^+, 2^-, 2^-$] is also reported (1981MA04). See also (1979TR1B, 1982RI1B).

$$26. \ ^{21}\text{Ne}(d, ^3\text{He})^{20}\text{F} \quad Q_m = -7.511$$

The ^{20}F states observed at $E_d = 26$ MeV in this reaction and analog [$T = 1$] states observed in ^{20}Ne in the (d, t) reaction are displayed in Table 20.15. The spectroscopic factors of analog states are consistent to within 20% for states excited by a single l -transfer (1974MI13).

$$27. \ ^{22}\text{Ne}(p, ^3\text{He})^{20}\text{F} \quad Q_m = -15.6513$$

Table 20.16: States of ^{20}F from $^{22}\text{Ne}(\text{d}, \alpha)^{20}\text{F}$ ^a

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

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

^b Unresolved.

At $E_p = 43.7$ to 45.0 MeV analog states have been studied in ^{20}F and ^{20}Ne [the latter via $^{22}\text{Ne}(\text{p}, \text{t})^{20}\text{Ne}$]. Angular distributions for the ^3He ions and the tritons corresponding to the first $T = 2$ states ($J^\pi = 0^+$) [$^{20}\text{Ne}^*(16.722 \pm 0.025)$ and $^{20}\text{F}^*(6.513 \pm 0.033)$] 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 errors ± 0.1 MeV)] (1964CE05, 1969HA38).

$$28. \ ^{22}\text{Ne}(\text{d}, \alpha)^{20}\text{F} \quad Q_m = 2.7019$$

Angular distributions have been obtained at $E_d = 10$ MeV to all ^{20}F states with $E_x < 4.4$ MeV: they are generally featureless. Observed states of ^{20}F are displayed in Table 20.16. See also (1978AJ03).

$$29. \ ^{23}\text{Na}(\text{n}, \alpha)^{20}\text{F} \quad Q_m = -3.866$$

See (1978AJ03).

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

GENERAL: (See also (1978AJ03).)

Shell model: (1977GR16, 1977HA1Z, 1977SC27, 1978AR1H, 1978CH26, 1978HA2C, 1978HE04, 1978MA2H, 1978RA1B, 1978TO07, 1979DA15, 1979EL04, 1979HA50, 1979HA59, 1979SI12, 1979WU06, 1980CA12, 1980MC1D, 1980RO11, 1980TE02, 1981ER03, 1981GR06, 1981KR1G, 1981SC12, 1982KA1K, 1982KI02).

Collective, deformed and rotational models: (1977FO1E, 1977HA1Z, 1978HO1E, 1978PE09, 1978PI08, 1978TO07, 1979EL04, 1979FU06, 1979FU08, 1979FU09, 1979KO38, 1979MA01, 1979MA1J, 1980CA12, 1980FU1H, 1980LE26, 1980RO11, 1981KR1G, 1981MC1C, 1981MI13, 1981RA14).

Cluster and α -particle models: (1977BA30, 1977BU22, 1977FO1E, 1977SA1C, 1978AR1H, 1978CH26, 1978HE04, 1978HO1E, 1978IS04, 1978KA22, 1978PI06, 1978TA1A, 1978TH1A, 1978TO07, 1979FU06, 1979FU08, 1979FU09, 1979GO24, 1980FU1G, 1980FU1H, 1980IK1B, 1981FU1F, 1981KN12, 1981WI01).

Electromagnetic transitions: (1976MC1G, 1977MA1Y, 1978GO1K, 1978GR06, 1978HA2C, 1978RO07, 1978SC19, 1978SI11, 1978TO07, 1979FU06, 1979FU08, 1979FU09, 1979KA40, 1979SI12, 1980BR09, 1980KO1L, 1981CO04, 1981KH04, 1981KN06, 1981MC1C, 1981SC12, 1982HA07, 1982HA15, 1982HA10, 1982LA26, 1982RI1B).

Special states: (1977BA30, 1977FO1E, 1977SC27, 1977SH18, 1978AL1T, 1978GO1K, 1978GR06, 1978HO1E, 1978KA22, 1978MA2H, 1978MC04, 1978PE09, 1978PI06, 1978PI08, 1978RA1B, 1978RO07, 1978SC19, 1978SI11, 1978TA1A, 1978TO07, 1978ZA04, 1979DA15, 1979FU06, 1979FU08, 1979FU09, 1979IN07, 1979KA40, 1979KO2L, 1979MI1L, 1979SI12, 1979WI1Q, 1980BI05, 1980BR21, 1980CA12, 1980FO02, 1980FU1H, 1980KL1B, 1980KO29, 1981CO04, 1981ER03, 1981RA14, 1981SC12, 1981WI01, 1981WI1K, 1982AO1B, 1982KI02, 1982MI1B).

Giant resonance (See also reactions 43 and 45.): (1978HE04, 1980SP1E, 1980WI1J, 1981KN12, 1981SP1D).

Astrophysical questions: (1977AL2C, 1977FR1K, 1978BU1H, 1978CL1F, 1978DI1D, 1978DW1B, 1978ME1D, 1978OR1A, 1978PO1B, 1978TR1D, 1978WO1E, 1979CH1T, 1979DI1B, 1979GA1M, 1979LA1H, 1979LE1F, 1979MA2D, 1979ME1L, 1979RA1C, 1979SI1D, 1980BH1B, 1980CO1R, 1980FR1C, 1980MO1L, 1980SC1L, 1981WI1D, 1981AU1D, 1981DU1E, 1981SH1J, 1981WE1F, 1981WO1B).

Applied topics: (1979KU20).

Complex reactions involving ^{20}Ne : (1978CA1N, 1978HE18, 1978KA1Y, 1978OB01, 1978SA33, 1978SH18, 1978VO1D, 1978WI1G, 1978YO01, 1979AL1H, 1979BE31, 1979CE1B, 1979DA1F, 1979GA04, 1979GA1L, 1979GO11, 1979HA07, 1979HE1D, 1979KN1H, 1979MC1D, 1979MO17,

1979NA1F, 1979SA1W, 1979ST1R, 1979SY01, 1979TA19, 1980AK1C, 1980CH1G, 1980EV1A, 1980GR10, 1980NA1C, 1980RA1G, 1981CE1D, 1981EG01, 1981GR08, 1981HI1C, 1981LO1F, 1981MA1G, 1981NA1E, 1981SC03, 1981TA02, 1982ME1C, 1982SU01, 1982TA02).

Table 20.17: Energy levels of ^{20}Ne ^a

E_x (MeV \pm keV)	$J^\pi; T$	K^π	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
0	$0^+; 0$	0_1^+		stable	2, 3, 7, 8, 9, 13, 17, 18, 22, 23, 24, 25, 30, 31, 32, 33, 38, 39, 40, 41, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 57, 58, 62, 63, 64, 67, 68, 69, 70, 71, 72, 77
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, 10, 13, 17, 18, 21, 22, 23, 24, 25, 27, 29, 30, 31, 32, 33, 38, 39, 40, 41, 42, 45, 47, 48, 50, 51, 52, 55, 62, 63, 64, 67, 68, 69, 70, 71, 72, 77
4.2477 ± 1.1	$4^+; 0$	0_1^+	$\tau_m = 93 \pm 9$ fsec $g = -0.01 \pm 0.14$	γ	2, 3, 7, 8, 9, 13, 17, 18, 21, 22, 23, 24, 25, 27, 29, 30, 31, 32, 38, 39, 40, 41, 47, 48, 50, 51, 55, 64, 67, 68, 69, 70, 71, 72
4.96651 ± 0.20	$2^-; 0$	2^-	$\tau_m = 4.8 \pm 0.5$ psec	γ	2, 3, 7, 8, 9, 13, 17, 30, 33, 38, 39, 40, 41, 42, 47, 64, 67, 68, 71, 72
5.6214 ± 1.7	$3^-; 0$	2^-	200 ± 50 fsec	γ, α	2, 3, 7, 8, 13, 17, 27, 38, 40, 41, 47, 65, 67, 70, 71, 72
5.785 ± 2.3	$1^-; 0$	0^-		γ, α	2, 3, 7, 8, 13, 14, 17, 18, 27, 31, 39, 40, 41, 47, 65, 67, 70, 71
6.724 ± 5	$0^+; 0$	0_2^+	$\Gamma = 15 \pm 7$ keV	γ, α	8, 13, 17, 30, 38, 39, 41, 45, 47, 67, 71
7.004 ± 3.6	$4^-; 0$	2^-	$\tau_m = 440 \pm 90$ fsec	γ	2, 7, 8, 17, 39, 47, 71
7.1563 ± 0.5	$3^-; 0$	0^-	$\Gamma = 8.1 \pm 0.3$ keV	γ, α	2, 4, 7, 8, 13, 14, 17, 18, 20, 23, 29, 30, 31, 38, 39, 47, 71
7.191 ± 3	$0^+; 0$	0_3^+	4	γ, α	5, 6, 7, 13, 14, 45, 47, 71
7.4214 ± 1.0	$2^+; 0$	0_2^+	8	γ, α	2, 5, 6, 7, 13, 14, 17, 39, 41, 45, 47, 63, 65, 71
7.8290 ± 2.0	$2^+; 0$	0_3^+	2.4	γ, α	2, 6, 7, 13, 14, 30, 38, 39, 45, 47, 63, 65, 71
≈ 8.3	$0^+; 0$	0_4^+	≈ 800	α	14, 39
8.4486 ± 2.3	$5^-; 0$	2^-	0.013 ± 0.004	γ, α	2, 6, 7, 13, 14, 17, 23, 39, 47, 71

Table 20.17: Energy levels of ^{20}Ne ^a (continued)

E_x (MeV \pm keV)	$J^\pi; T$	K^π	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
8.699 ± 5	$1^-; 0$	(1^-)	2.1 ± 0.8	γ, α	7, 13, 39, 47, 71
8.7767 ± 2.3	$6^+; 0$	0_1^+	< 3	γ, α	2, 4, 6, 7, 13, 14, 17, 18, 20, 21, 23, 29, 30, 38, 39, 47, 71
≈ 8.8	$2^+; 0$	0_4^+	> 800	α	14
8.848 ± 5	$1^-; 0$	1^-	19	α	7, 13, 14, 39, 65, 71
9.030 ± 4	$4^+; 0$	0_3^+	3.2	γ, α	2, 6, 7, 13, 14, 39, 47, 71
9.1124 ± 2.4	$3^-; 0$		3.2	γ, α	2, 7, 13, 14, 38, 39, 47, 71
9.310 ± 6	$(1, 2, 3)^+$				7, 39, 47, 71
9.466 ± 7					71
9.508 ± 12	$2^+; 0$		29 ± 15	γ, α	13, 14, 38, 39, 47, 63
9.873 ± 4	$3^+; 0$			γ	7, 39, 63
9.935 ± 12	$(1^+); 0$		$\tau_m < 35$ fsec	γ	39, 71
10.005 ± 17	$4^+; 0$	0_2^+	$\Gamma = 155 \pm 30$	γ, α	2, 13, 14, 30, 38, 39, 71
10.261 ± 4	$5^-; 0$	0^-	145 ± 40	α	2, 4, 7, 14, 17, 18, 20, 23, 29
10.2724 ± 2.0	$2^+; 1$		0.4 ± 0.2	γ, α	13, 14, 30, 39, 63, 65, 71
10.403 ± 5	$3^-; 0$	1^-	80	α	7, 14, 31, 39, 65, 71
10.548 ± 5	$4^+; 0$		16	α	7, 14, 39
10.583 ± 6	$2^+; 0$		24	α	14, 39, 63, 71
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
10.79 ± 100	$4^+; 0$	0_4^+	$\Gamma = 350$	α	14
10.837 ± 5	$2^+; 0$		13	α	14, 39, 63
10.840 ± 6	(3^-)	(1^-)	45	α	7, 14
10.89 ± 10	$3^+; 1$		$\tau_m < 30$ fsec	γ	7, 39, 63, 65
10.97 ± 150	$0^+; 0$		$\Gamma = 580$	α	14
11.015 ± 6	$4^+; 0$		24	α	6, 7, 14, 71
11.087 ± 3	$4^+; 1$		≤ 0.5	γ, α	13, 14, 39, 65
11.23 ± 10	$1^+; 1$			γ	38, 45, 63, 65
11.261 ± 5	$1^-; 0$		170	α	14
11.268 ± 4	$1^-; 1$		≤ 0.3	γ, α	13, 14, 39, 63, 65
11.322 ± 7	$2^+; 0$		40 ± 10	α	14, 63
11.528 ± 6	$3^+, 4^-; 0$		$\tau_m \leq 30$ fsec	γ	7
11.555 ± 6	$1^+, 2^-, 3^+$			γ	7, 39
11.556 ± 6	$(2^+, 0^+)$		$\Gamma = 1.1 \pm 0.5$	γ, α	13, 14
11.601 ± 10	$2^-; 1$				65
11.66	$(3^+); 0$			γ	6, 7
11.866 ± 9	$2^+; 0$		46	α	7, 14, 39, 63, 71

Table 20.17: Energy levels of ^{20}Ne ^a (continued)

E_x (MeV \pm keV)	$J^\pi; T$	K^π	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
11.925 \pm 4	4 ⁺ ; 0		0.44 \pm 0.15	γ, α	13, 14, 71
11.950 \pm 4	8 ⁺ ; 0	0 ₁ ⁺	(3.5 \pm 1.0) $\times 10^{-2}$	γ, α	4, 6, 7, 8, 13, 14, 17, 18, 20, 21, 23, 71
11.962 \pm 8	1 ⁻ ; 0		30 \pm 5	α	14, 71
12.100 \pm 10	2 ⁻ ; 1				65
12.136 \pm 4	6 ⁺ ; 0	0 ₃ ⁺	0.13 \pm 0.07	α	5, 6, 7, 8, 14, 17
12.218 \pm 4	2 ⁺ ; 1		< 0.1	γ, α	13, 30, 38, 39
12.24 \pm 30	4 ⁺ ; 0		148 \pm 20	α	14
12.253 \pm 3	3 ⁻ ; 1		< 1	γ, α	13, 14
(12.35 \pm 100)	(2 ⁺)		\approx 500	α	14
12.394 \pm 4	3 ⁻ ; (1)		37.3 \pm 0.9	γ, α	6, 7, 13, 14, 39, 71
12.436 \pm 4	0 ⁺ ; 0	0 ₆ ⁺	24.4 \pm 0.5	γ, α	7, 13, 14, 30, 39, 71
12.582 \pm 12	6 ⁺ ; 0	0 ₄ ⁺	70 \pm 20	α	6, 7, 14, 17, 18, 20, 21, 71
12.600 \pm 10	6 ⁺ ; 0		130 \pm 20	α	6, 7, 14, 17, 18, 20, 21, 71
12.683 \pm 15	5 ⁻ ; 0	1 ⁻	97	α	14
12.730 \pm 10	4 ⁺ ; 0		100	α	6, 7, 14
12.83 \pm 30			55	α	14, 30, 39
12.919 \pm 10					7, 71
13.010 \pm 10	(4 ⁺ ; 0)		60	α	7, 14
13.049 \pm 10	(4 ⁺ ; 0)		70	α	6, 7, 14, 39
13.060 \pm 3.5	2 ⁻		1.0	p, α	36, 38, 39
13.1680 \pm 0.6	1 ⁺ ; (1)		2.3 \pm 0.2	γ, p, α	33, 34, 36, 38
13.190 \pm 10	(4 ⁺ ; 0)		60	α	6, 7, 14
13.225	1 ⁻		95	p, α	36
13.225	0 ⁺		95	p, α	36
13.3038 \pm 0.7	1 ⁺		0.9 \pm 0.1	γ, p, α	33, 34, 36
13.334 \pm 6	7 ⁻ ; 0	2 ⁻	(8 \pm 3) $\times 10^{-2}$	α	6, 7, 8, 14
13.343 \pm 6	4 ⁺ ; 0		20 \pm 5	α	14
13.412 \pm 1	2 ⁻		26 \pm 3	γ, p, α	14, 33, 34, 36
(13.42 \pm 140)	(4 ⁺ ; 0)		110	α	14
13.462 \pm 20	1 ⁻		190	p, α	36
13.482 \pm 1	1 ⁺ ; 1		6.4 \pm 0.3	γ, p, α	33, 34, 36, 38
13.519	(1 ⁻)		33	p, α	34, 36
13.569 \pm 15	2 ⁺		63	p, α	7, 36
13.583 \pm 2	2 ⁺		9 \pm 1	p, α	30, 34, 36
13.644 \pm 2	0 ⁺ ; 1		17 \pm 1	p, α	7, 34, 36, 38
(13.66)	(1 ⁻)		110	p, α	7, 36
13.6729 \pm 0.7	(2 ⁻)		4.5 \pm 0.2	γ, p, α	33, 34, 36

Table 20.17: Energy levels of ^{20}Ne ^a (continued)

E_x (MeV \pm keV)	$J^\pi; T$	K^π	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
13.7 \pm 400	(3, 7) ⁻		320	α	14
(13.73)	(0 ⁺)		\approx 170	p, α	36
13.733 \pm 1.4	1 ⁺		7.7 \pm 0.5	γ , p, α	33, 34, 36
13.845 \pm 15	(1 ⁻)		\approx 190	p, α	7, 36
13.878 \pm 1	2 ⁺ ; 1		0.14 \pm 0.05	γ , p, α	7, 8, 33, 34, 36, 38
13.904	2 ⁺		47	p, α	30, 36
13.923 \pm 1	0 ⁺		\approx 70	p, α	36
13.926 \pm 9	6 ⁺	0 ₂ ⁺	113 \pm 7	α	6, 7, 17, 18
14.017	1 ⁻		\approx 70	p, α	36
14.060 \pm 1	2 ⁺		\approx 140	p, α	34, 36
14.124 \pm 1	2 ⁻		4.7 \pm 0.7	γ , p, α	33, 34, 36
14.127 \pm 3	2 ⁺		34 \pm 1	p, α	7, 14, 36
14.147 \pm 1	2 ⁻		11.8 \pm 1.0	γ , p, α	33, 34, 36
14.195	1 ⁺		14 \pm 1	γ , p	30, 33, 34
14.298 \pm 12	6 ⁺		100 \pm 20		6, 7, 14, 17, 18
14.311 \pm 10	6 ⁺		< 50	α	7
14.367 \pm 1	0 ⁺		86 \pm 5	p, α	7, 34, 36
14.451 \pm 2			33 \pm 3	p, α	34, 36
14.471 \pm 6	0 ⁺		68 \pm 2	p, α	36
14.594 \pm 7	1 ⁻		116 \pm 5	p, α	36
14.6 \pm 300	(4 ⁺)		240	α	14
14.650 \pm 10				p, α	36
14.695 \pm 2.5	(0 ⁺ , 1 ⁺)		36 \pm 10	p, α	34, 36
14.772 \pm 3.0			110 \pm 20	p, α	34, 36
14.812 \pm 15	(2 ⁺ , 4 ⁺)		\approx 100	p, α	6, 7, 14, 36
15.034 \pm 15	(2 ⁺)		\approx 100	p, α	7, 14, 36
15.159 \pm 5	6 ⁺	(0 ₆ ⁺)	60 \pm 15	α	6, 7
15.23			28	p, α	36
15.27	(1 ⁻)		285	p, α	36
15.30	(0 ⁺)		285	p, α	14, 36
15.336 \pm 15	7 ⁻	0 ⁻	380 \pm 60	α	4, 6, 7, 17, 18, 20, 21, 29
15.438 \pm 10			100 \pm 20	p, α	7, 36
15.47			55	p, α	36
b					
15.70 \pm 15	(6 ⁺)			α	6, 7, 14
15.874 \pm 9	8 ⁺	0 ₃ ⁺	100 \pm 15	α	5, 6, 7, 21, 29
(15.97)	(6 ⁺)			α	14
16.01 \pm 25	(2 ⁺ ; 1)		100	p, α	30, 36

Table 20.17: Energy levels of ^{20}Ne ^a (continued)

E_x (MeV \pm keV)	$J^\pi; T$	K^π	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
16.139 \pm 15			38	p, α	6, 7, 14, 36
16.25				α	6, 14
16.326 \pm 15	4 ⁺		43	p, α	14, 36
16.434 \pm 15	(0, 2, 4) ⁺		34	α	14
16.506 \pm 11	6 ⁺		25 \pm 3	α	6, 14
16.579 \pm 8	7 ⁻	1 ⁻	86 \pm 6	α	7, 14, 17, 18, 20
16.600 \pm 15	7 ⁻	1 ⁻	160 \pm 30	α	7
16.634 \pm 14	3 ⁻		51 \pm 14	α	14
16.671 \pm 12	4 ⁺		79 \pm 11	α	14
16.716 \pm 8	(5, 3) ⁻		14 \pm 7	α	6, 7, 14
16.730 \pm 3	0 ⁺ ; 2		2.0 \pm 0.5	γ , p, α	30, 33, 34, 36
16.8	7 ⁻			α	7
16.850 \pm 11	5 ⁻		16 \pm 5	α	14
16.98			100	p, α	36
17.156 \pm 11	5 ⁻		33 \pm 3	α	14
17.205 \pm 12	4 ⁺		142 \pm 9	α	14
17.259 \pm 11	7 ⁻ (9 ⁻)		162 \pm 20	α	7
17.301 \pm 14	8 ⁺	0 ₄ ⁺	52 \pm 10	α	4, 14, 17, 18, 20, 21, 29
17.394 \pm 14	9 ⁻	2 ⁻	241 \pm 13	α	6, 7, 8, 14
17.542 \pm 15	6 ⁺		136	α	14
17.55 \pm 10	(2 ⁺ ; 1)		19	n, p, α	30, 35, 36
17.752 \pm 15	4 ⁻ , (0 ⁺)		36	p, α	14, 36
17.91 \pm 20	(0 ⁺)			n, p	30, 35
18.002 \pm 15	7 ⁻		< 10	α	14
18.024 \pm 8	5 ⁻		35 \pm 3	α	14
18.119 \pm 8	7 ⁻		29 \pm 3	α	6, 7, 8, 14
18.32 \pm 20	(6 ⁺)		240	α	6, 14
18.427 \pm 7	2 ⁺ ; 2		9.5 \pm 3	γ , n, p, α	33, 34, 35, 36
18.538 \pm 7	8 ⁺	(0 ₆ ⁺)	138 \pm 13	α	7
18.7 \pm 100	(6 ⁺ , 7 ⁻)		600	α	14, 17
19.113 \pm 10	6 ⁺		149 \pm 18	α	8, 14
19.322 \pm 9	6 ⁺		123 \pm 10	α	14, 30
19.437 \pm 10	6 ⁺		102 \pm 7	α	14
19.648 \pm 10	6 ⁺		89 \pm 8	α	14
19.914 \pm 12	5 ⁻		203 \pm 19	α	14
20.130 \pm 17	7 ⁻		156 \pm 21	α	14, 17
20.317 \pm 12	7 ⁻		203 \pm 19	α	14
20.433 \pm 16	6 ⁺		346 \pm 32	α	14

Table 20.17: Energy levels of ^{20}Ne ^a (continued)

E_x (MeV \pm keV)	$J^\pi; T$	K^π	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
20.478 \pm 11	8 ⁺	0 ₂ ⁺	250 \pm 30	α	7
20.683 \pm 9	(9 ⁻)		75 \pm 9	α	7, 14, 18
20.782 \pm 11	7 ⁻		122 \pm 13	α	14, 17
20.920 \pm 12	7 ⁻		181 \pm 22	α	7, 14
21.056 \pm 26	9 ⁻	(1 ⁻)	120 \pm 50	α	4, 7, 18, 20, 29
21.3 \pm 100	7 ⁻ , 8 ⁺		300	α	14, 17
21.65 \pm 100	(7 ⁻ , 9 ⁻)		240 \pm 50	α	7, 14, 17
22.03 \pm 100	(8 ⁺)		630 \pm 80	α	7, 14, 17
22.7 \pm 100	9 ⁻		500 \pm 150	α	7, 14
22.87 \pm 40	9 ⁻	0 ⁻	225 \pm 40	α	4, 7, 14, 18, 20
23.70 \pm 30	9 ⁻ , (8 ⁺)		230 \pm 100	α	7, 14, 17, 18
24.21 \pm 25	8 ⁺		\approx 500	α	14, 18
24.374 \pm 30	7 ⁻ , (5 ⁻)		200 \pm 50	α	7
25.10 \pm 50	8 ⁺		\leq 200	α	14, 18
25.67 \pm 50			\approx 500	α	14, 18
27.1 \pm 100	(9 ⁻)		700	α	14, 17
28	8 ⁺		1600	α	14, 26
28.1 \pm 100	(10 ⁺)		700	α	14, 17

^a See also Table 20.18.

^b For other states with $E_x > 15.5$ MeV see Tables 20.27, 20.28, 20.29 and 20.30 and reactions 1, 43 and 45. 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 .

Muon and neutrino capture and reactions: (1978IT1A, 1979YU02, 1980GA10, 1981PA1D).

Pion and kaon capture and reactions: (1977BA1Q, 1977NO1G, 1977ST1G, 1977YE1B, 1978AN20, 1978AT01, 1978BE1X, 1978YU1B, 1979AK02, 1979AL1V, 1979BA2V, 1979BE31, 1979HA07, 1979JA11, 1979KN1G, 1979MI1G, 1979NA1F, 1979NA12, 1979SA1W, 1979TA19, 1979TR1B, 1980OT1A, 1980ST25, 1980TR1A, 1981AN1H, 1981AS01, 1981GY1B, 1981MA04, 1982BIIH, 1982MU1C, 1982OS01, 1982RA1C).

Other topics: (1977BO33, 1977GR16, 1977SA2C, 1977SH18, 1978AN15, 1978FI1C, 1978MA2H, 1978MC04, 1978RA1J, 1978RO17, 1978SA1R, 1978TA1Y, 1979BE1H, 1979BO17, 1979BR30, 1979CH2E, 1979CO10, 1979CO09, 1979EL04, 1979GO24, 1979HA50, 1979HA59, 1979HE1F, 1979KA40, 1979ST1V, 1979WI1Q, 1979WU06, 1980BR21, 1980DI06, 1980KO29, 1980RO11, 1980TE02, 1980ZO1A, 1981AR1D, 1981CA1H, 1981ER03, 1982IS1B, 1982KI02).

Ground state of ^{20}Ne : (1976MC1G, 1977BO33, 1977HA1Z, 1977MA1Y, 1977ZA1D, 1978AN07, 1978AR1R, 1978CH26, 1978FI1C, 1978GO1K, 1978HE1D, 1978RO17, 1978SM02, 1978SV01,

1978DE1V, 1978TA1Y, 1978ZA1D, 1979BO17, 1979BR30, 1979CH2E, 1979HA50, 1979HA59, 1979IN07, 1979KA40, 1979MA01, 1979SI12, 1979WU06, 1980BR09, 1980BR13, 1980DI06, 1980LE26, 1980MO05, 1980TE02, 1981AR1D, 1981HA46, 1981SC12, 1982DE1N).

$$Q_{1.63} = -0.27 \pm 0.03 e \cdot b \text{ (1978GR06)}. \text{ See also (1978AJ03, 1981SP07);}$$

$$g_{1.63} = +0.54 \pm 0.04 \text{ (1975HO15)}. \text{ See also (1982SP02);}$$

$$B(E2) \uparrow [0 \rightarrow 1.63] = 0.0330 \pm 0.0015 e^2 \cdot b^2 \text{ (1978GR06)}. \text{ See also (1978AJ03);}$$

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

$$g_{4.25} = -0.10 \pm 0.19 \text{ (1980SP02)}, +0.08 \pm 0.20 \text{ (1982SP02):}$$

$$\text{weighted mean} = -0.01 \pm 0.14 \text{ (1982SP02)}.$$

1. (a) $^{10}\text{B}(^{10}\text{B}, ^{10}\text{B})^{10}\text{B}$ $E_b = 31.1464$
 (b) $^{10}\text{B}(^{10}\text{B}, \alpha)^{16}\text{O}$ $Q_m = 26.4155$

Excitation functions for reactions (a) and (b) have been measured for $E_{c.m.} = 3$ to 10 MeV: large resonant structures are observed in reaction (b). Particularly pronounced structures [≈ 0.6 MeV] corresponding to $E_x \approx 38$ MeV (α_0) and 38.6 MeV (α to $^{16}\text{O}^*(7.0, 10.3, 16.2 \text{ [u]})$) are reported (1978MA07). The elastic excitation function has also been studied for $E(^{10}\text{B}) = 8$ to 30 MeV by (1975DI08). See also (1978AJ03), ^{10}B in (1979AJ01) and ^{16}O in (1982AJ01).

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

At $E(^{14}\text{N}) = 25$ and 35 MeV angular distributions of the α -particles to $^{20}\text{Ne}^*(0, 1.63, 4.25, 4.97, 5.62, 5.78, 7.00, 7.17, 7.42, 7.83, 8.45, 8.78, 9.03 + 9.12, 9.99, 10.26, 10.61)$ have been measured by (1974MA38, 1975LE23). The average behavior of the cross section is generally well described by a statistical mechanism but the reaction mechanism is not purely statistical (1975LE23). Angular distributions are also reported at $E(^{14}\text{N}) = 23.5$ MeV (1978DU08: $\alpha_0, \alpha_1, \alpha_2, \alpha_{4+5}$). For experiments relating to the compound nucleus see (1978AJ03) and (1977MA33, 1978DU08, 1978DU23, 1978WU1C, 1981BA26). See also (1976KL1B, 1978HO1C).

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

At $E(^{16}\text{O}) = 19.5, 24.3, 31.5, 35.9$ and 42 MeV angular distributions have been measured for the ^6Li ions corresponding to transitions to $^{20}\text{Ne}^*(0, 1.63, 4.25, 4.97, 5.62 + 5.78, 6.7 - 7.2)$. Hauser-Feshbach calculations are generally in good agreement with the data (1976LO03). See also (1977MO1A) and (1978AJ03).

Table 20.18: Radiative decays in ^{20}Ne ^a

E_i (MeV)	$J_i^\pi; T$	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
				$\delta(M2/E1) = 0.076 \pm 0.011$
				$\delta(E3/E1) = 0.043 \pm 0.016$
5.62	$3^-; 0$	0	7.6 ± 1.0	0.018 ± 0.006^n
		1.63	87.6 ± 1.0	0.21 ± 0.06^n
		4.97	4.8 ± 1.6	0.012 ± 0.005^n
5.79	$1^-; 0$	0	18 ± 5	0.8 ± 0.3^o
		1.63	82 ± 5	3.8 ± 0.8^o
6.72	$0^+; 0$	0		$ M ^2 = 7.4 \pm 2.0 \text{ fm}^2{}^i$
		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 ^c	$3^-; 0$	4.25	60 ± 5	0.97 ± 0.11
		5.79	40 ± 5	0.64 ± 0.10
7.19	$0^+; 0$	0		$\Gamma_\pi = 3.9 \times 10^{-2}$
				$6.9 \pm 1.4 \text{ fm}^2{}^i$
		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	$\geq 90.6 \pm 1.4^m$	29 ± 4
		4.25	≤ 7.6	
7.83	$2^+; 0$	0	83 ± 1	57 ± 7
		1.63	17 ± 1	11.7 ± 1.6
		4.25	< 3	< 2
8.45	$5^-; 0$	5.62	100	13 ± 3
8.70 ^d	$1^-; 0$	0	87 ± 8	61 ± 16
		1.63	13 ± 8	9 ± 6
8.78	$6^+; 0$	4.25	100	100 ± 15

Table 20.18: Radiative decays in ^{20}Ne ^a (continued)

E_i (MeV)	$J_i^\pi; T$	E_f (MeV)	Branch (%)	Γ_γ (meV)
9.03	$4^+; 0$	1.63	100	340 ± 42
		4.25	< 2	< 6.8
9.11 ^d	$3^-; 0$	1.63	50 ± 5	13 ± 2
		4.97	33 ± 5	8.6 ± 1.7
		5.62	17 ± 4	4.4 ± 1.1
9.51	$2^+; 0$	0		$\lesssim 60$
		1.63	(100)	260 ± 100
9.87	$3^+; 0$	0	< 0.5	
		1.63	78	k
		4.25	12 ± 3	
		4.97	≤ 5	
		5.62	≈ 7	
		7.42	≈ 3	
9.94	$(1^+); 0$	1.63	78 ± 5	
		4.97	22 ± 5	
10.01	$4^+; 0$	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
		7.42	6.9 ± 0.4	310 ± 40
		7.83	0.22 ± 0.06	8 ± 2
10.61	$6^-; 0$	7.00	95.5 ± 1.2	29 ± 9 ^b
		8.45	4.5 ± 1.2	1.3 ± 0.4 ^o
10.69	$4^-, 3^+; 0$	4.25	25 ± 4	
		4.97	75 ± 4	
10.89	$3^+; 1$	1.63	26 ± 3	
		4.25	74 ± 3	l
11.09 ^{d,e}	$4^+; 1$	1.63	0.5 ± 0.25	2 ± 1
		4.25 ^p	99.5 ± 0.25	338 ± 40
11.27 ^{d,e}	$1^-; 1$	0	55 ± 2	390 ± 47

Table 20.18: Radiative decays in ^{20}Ne ^a (continued)

E_i (MeV)	$J_i^\pi; T$	E_f (MeV)	Branch (%)	Γ_γ (meV)
11.53	$3^+, 4^-; 0$	1.63	2.5 ± 1	18 ± 7
		4.97	6.5 ± 1	46 ± 9
		8.85	27 ± 1.5	189 ± 24
		9.31	9 ± 1	63 ± 10
		4.25	30 ± 3	
		4.97	70 ± 3	
11.555 ^f	$1^+, 2^-, 3^+; 0$	7.00	^f	
		1.63		
11.556 ^d	$(0^+, 2^+); 0$	7.00		
		1.63	100	
11.66	(3^+)	4.25	< 8	
		1.63	14 ± 3	
11.93 ^d	$4^+; 0$	4.25	86 ± 3	
		1.63	21 ± 11	5.5 ± 3.0
11.95 ^g	$8^+; 0$	4.25	79 ± 11	20.5 ± 5.5
		8.78	100	7.7 ± 1.1
12.25 ^d	$3^-; 1$	1.63	63 ± 1.5	
		5.62	37 ± 1.5	
12.39 ^h	$3^-; (1)$	0	≈ 1	
		1.63	≈ 29	80
		4.25	≈ 70	200
12.44 ^h	$0^+; 0$	1.63	100	170 ± 50
13.48	$1^+; 1$	1.63	95	
		4.97	5	
13.88		1.63	20	
		4.97	80	
16.73	$0^+; 2$	1.63	^j	
		5.79	^j	
		11.23	(100)	≈ 5000 ^j
18.43	$2^+; 2$	12.22	(100)	≈ 300

^a For earlier references see Table 20.19 in (1978AJ03). See also Tables 20.21 and 20.25 here.

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

^c (1980MA27).

^d (1980FI01).

^e See also Table 20.19 in (1978AJ03).

^f See discussion in (1976FI10).

^g (1980HU08).

^h (1978ST08).

ⁱ Monopole matrix element.

^j See footnote ^a in Table 2 of (1976MA01).

^k $\Gamma_\gamma(\text{total})/\Gamma = 0.82 \pm 0.27$.

^l $\Gamma_\gamma(\text{total})/\Gamma < 0.3$.

^m $\delta(\text{E2/M1}) = -8.36^{+1.0}_{-1.5}$.

ⁿ $\Gamma_\gamma(\text{total}) = 240 \pm 64 \mu\text{eV}$: see Table 20.20 (P.M. Endt, private communication).

^o P.M. Endt, private communication.

^p $\delta = +0.01 \pm 0.06$ (1980FI01).

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

At $E(^{11}\text{B}) = 115$ MeV, angular distributions are reported to $^{20}\text{Ne}^*(7.17, 8.78, 10.25, 11.95, 15.4)$. $^{20}\text{Ne}^*(8.78, 15.4, 17.3, 21.0 \pm 0.07, 22.78 \pm 0.06)$ are particularly strongly populated. It is suggested that these five states have $J^\pi = 6^+, 7^-, (8^+), 9^-$ and 9^- (1979BR03, 1979RA10). See also (1978AJ03).

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

At $E(^9\text{Be}) = 16$ and 24 MeV angular distributions have been measured for $^{20}\text{Ne}^*(7.3 \pm 0.4, 9.2 \pm 0.4, 10.9 \pm 0.3, 12.2 \pm 0.3, 15.7 \pm 0.3)$. It is suggested that $^{20}\text{Ne}^*(7.3, 9.2, 12.2, 15.7)$ correspond to the $0^+ + 2^+, 4^+, 6^+$ and 8^+ members of the $K^\pi = 0_3^+$ band (1981SU01).

6. (a) $^{12}\text{C}(^{10}\text{B}, d)^{20}\text{Ne}$ $Q_m = 5.9589$

(b) $^{12}\text{C}(^{11}\text{B}, t)^{20}\text{Ne}$ $Q_m = 0.7610$

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

on basis of Hauser-Feshbach calculations. The states in italics are well resolved: the authors indicate ± 20 keV for such states.] The relative intensities of the groups to $^{20}\text{Ne}^*(17.39, 15.38)$ [$J^\pi = 9^-, 7^-$] argue against the existence of a superband (1976KL03). At $E(^{10}\text{B}) = 20.0$ and 20.5 MeV angular distributions are reported to the 2^+ states $^{20}\text{Ne}^*(7.42, 7.83)$. $^{20}\text{Ne}^*(7.83)$ is more strongly populated than $^{20}\text{Ne}^*(7.42)$, and it, and $^{20}\text{Ne}^*(7.19)$, have integrated cross sections which deviate from the $(2J + 1)$ “rule” by a factor of about two (1978FO01). See also (1978AJ03) and (1976KL1B, 1978HO1C).

$$7. \text{}^{12}\text{C}(\text{}^{12}\text{C}, \alpha)\text{}^{20}\text{Ne} \quad Q_m = 4.6181$$

Double and triple (α, α, γ) correlations and γ -ray branching measurements [see Table 20.18] lead to the J^π assignments shown in Table 20.19, which also shows level assignments to rotational bands. Angular distributions have been reported at $E(^{12}\text{C}) = 4.9$ to 51 MeV [see (1978AJ03)] and at $E(^{12}\text{C}) = 6.3$ to 6.6 MeV (1980IS1B; α_0, α_1), 10 MeV (1981BE60; α_0), 12 MeV (1981BE60; α_1), 19.3 MeV (1980AN08; α_0) and 33 to 40 MeV (1982FO03; α_0). τ_m for $^{20}\text{Ne}^*(4.25)$ is 95 ± 13 fsec (1982SP02) [see also for g-value, the “Ground state of ^{20}Ne ” section here].

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) for the earlier work and (1977CI1E, 1977CO25, 1977PA1G, 1978TR06, 1979DE08, 1980AN08, 1980CO03, 1980ER06, 1980IS1B, 1980KO02, 1981BE60, 1982FO03). See also (1978MA2J), (1978SC1G, 1979GO1C), (1978RO1D, 1978RO1L, 1981BE60, 1982IB1A; astrophys.) and (1977AB1E, 1978BR12, 1978MA1G, 1978TO12, 1980GA18, 1981NO1J, 1981SU1J; theor.).

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

Angular distributions of the ^6Li 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. Compound nucleus formation appears to be dominant. In the latter work (1973BE11) $^{20}\text{Ne}^*(16.67, 17.38, 18.11, 19.16, 19.6)$ are particularly strongly populated. For complete references see (1978AJ03). See also (1977ST34) and (1976KL1B, 1978HO1C).

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

$$\text{(b) } \text{}^{12}\text{C}(\text{}^{19}\text{F}, \text{}^{11}\text{B})\text{}^{20}\text{Ne} \quad Q_m = -3.1122$$

See (1978AJ03). See also (1981YO05; theor.).

$$10. \text{}^{13}\text{C}(\text{}^{13}\text{C}, \alpha 2n)\text{}^{20}\text{Ne} \quad Q_m = -5.2747$$

See (1982CH05).

Table 20.19: Excited states of ^{20}Ne from $^{12}\text{C}(^{12}\text{C}, \alpha)^{20}\text{Ne}$ ^a

E_x ^c (MeV \pm keV)	J^π ^b	$\Gamma_{\text{c.m.}}$ (keV)	K^π ^b	θ_α^2
1.6329 \pm 1.0	2 ⁺		0 ₁ ⁺	
4.2456 \pm 2.5	4 ⁺		0 ₁ ⁺	
4.9663 \pm 2.5	2 ⁻		2 ⁻	
5.618 \pm 4	3 ⁻		2 ⁻	
5.774 \pm 6	1 ⁻		0 ⁻	
6.725 \pm 6	0 ⁺		0 ₂ ⁺	
7.004 \pm 4	4 ⁻		2 ⁻	
7.169 \pm 6	3 ⁻		0 ⁻	
7.196 \pm 6	0 ⁺		0 ₃ ⁺	0.026 ^p
7.435 \pm 6	2 ⁺		0 ₂ ⁺	
7.835 \pm 6	2 ⁺		0 ₃ ⁺	0.015 ^p
8.449 \pm 6	5 ⁻		2 ⁻	(1.6 \pm 0.5) $\times 10^{-3}$ ^q
8.694 \pm 6	1 ⁻		(1 ₂ ⁻)	0.0027 ^p
8.779 \pm 6	6 ⁺		0 ₁ ⁺	
8.85	1 ⁻		(1 ₁ ⁻)	0.0179 ^p
9.033 \pm 6	4 ⁺		0 ₃ ⁺ ^a	0.033 ^p , 0.022 ^q
9.110 \pm 6	^a			
9.318 \pm 6	^a			
9.533 \pm 6				
9.872 \pm 6	1 ⁺ , 2 ⁻ , 3 ⁺ ^a			
9.950 \pm 6	1 ⁺ , 2 ⁻ , 3 ⁺ ^a			
10.024 \pm 6				
10.264 \pm 6	5 ⁻		0 ⁻	
10.407 \pm 6	(3 ⁻)		(1 ₁ ⁻)	0.078 ^p
10.545 \pm 6				
10.609 \pm 5	6 ⁻		2 ⁻	
10.694 \pm 6	4 ⁻ , 3 ⁺ ^a			
10.840 \pm 6	(3 ⁻)		(1 ₂ ⁻)	0.0099 ^p
10.917 \pm 6	3 ⁺ ^a			
11.013 \pm 6				

Table 20.19: Excited states of ^{20}Ne from $^{12}\text{C}(^{12}\text{C}, \alpha)^{20}\text{Ne}$ ^a (continued)

E_x ^c (MeV \pm keV)	J^π ^b	$\Gamma_{\text{c.m.}}$ (keV)	K^π ^b	θ_α^2
11.528 \pm 6				
11.555 \pm 6	$1^+, 2^-, 3^+$ ^a			
11.656 \pm 6	(3^+) ^a			
11.871 \pm 6	^a			
11.949 \pm 6	8^+		0_1^+	$(7.6 \pm 2.2) \times 10^{-3}$ ^q
12.135 \pm 5 ^d	6^+		0_3^+	$(4.9 \pm 2.6) \times 10^{-4}$ ^{q,s}
12.381 \pm 6				
12.436 \pm 5 ^e	0^+ ^r	15 ± 1	^r	^{q,r}
12.600 \pm 10 ^{aa}	6^+	50 ± 10		0.09 ± 0.02
12.730 \pm 6	(5^-)		(1^-)	0.129 ^p
12.919 \pm 6				
13.010 \pm 6				
13.049 \pm 6				
13.190 \pm 6				
13.277 \pm 6				
13.335 \pm 6	7^-		2^-	$(2.4 \pm 1.0) \times 10^{-4}$ ^{q,t}
13.441 \pm 6	(5^-)		(1_2^-)	≤ 0.023 ^p
13.569 \pm 15				
13.631 \pm 15				
13.679 \pm 15				
13.845 \pm 15				
13.886 \pm 15				
13.927 \pm 5	6^+	113 ± 7	0_2^+	0.10 ± 0.01 ^q
14.144 \pm 15				
14.311 \pm 15 ^{bb}	6^+	< 50		$\lesssim 0.45$
14.60				
14.812 \pm 15				
15.034 \pm 15	^a			
15.159 \pm 5 ^e	6^+	60 ± 15	(0_6^+)	$< 8 \times 10^{-4}$ ^{q,u}
15.359 \pm 15 ^f	7^-	410 ± 30	0^-	

Table 20.19: Excited states of ^{20}Ne from $^{12}\text{C}(^{12}\text{C}, \alpha)^{20}\text{Ne}$ ^a (continued)

E_x ^c (MeV \pm keV)	J^π ^b	$\Gamma_{\text{c.m.}}$ (keV)	K^π ^b	θ_α^2
15.438 \pm 10 ^g		100 \pm 20		
15.691 \pm 15				
15.874 \pm 9 ^h	8 ⁺	100 \pm 15	0 ₃ ⁺	0.047 \pm 0.013 ^{q,v}
16.139 \pm 15				
16.600 \pm 15 ^{cc}	7 ⁻	160 \pm 30		cc
16.717 \pm 10		37 \pm 10		
17.259 \pm 11 ^k	7 ⁻ (9 ⁻)	162 \pm 20	2 ⁻	0.019 \pm 0.004 ^{q,x}
18.153 \pm 10 ^{l,q}	7 ⁻			
18.538 \pm 7 ^m	8 ⁺	138 \pm 13	0 ₆ ⁺	(3.2 \pm 1.5) \times 10 ⁻³ ^{q,y}
20.478 \pm 11 ⁿ	8 ⁺	250 \pm 30	0 ₂ ⁺	0.11 \pm 0.04 ^{q,z}
20.704 \pm 11 ^o	8 ⁺ (10 ⁺)	\approx 120		^q
20.89 \pm 30				
21.05 \pm 20		140 \pm 50		
21.65 \pm 100	(7 ⁻ , 9 ⁻)	240 \pm 50		
22.03 \pm 100	(8 ⁺)	630 \pm 80		
22.7 \pm 100		500 \pm 150		
23.2 \pm 100		300 \pm 100		
23.74 \pm 100		230 \pm 100		
24.374 \pm 30	7 ⁻ (5 ⁻)	200 \pm 50		

^a For complete references see Table 20.21 in (1978AJ03).

^b See discussion in (1975ME04).

^c Uncertainties shown for $E_x > 5.7$ MeV are approximate: see footnote ^c in Table 20.21 (1978AJ03).

^d Alpha decay is by α_2 to $^{16}\text{O}^*(6.13)$: $\Gamma_{\alpha'}/\Gamma = (6.0 \pm 0.15)\%$: assuming $\Gamma_\alpha \Gamma_{\alpha'}/\Gamma = 7.7 \pm 3.8$ eV this leads to $\Gamma_\alpha = 0.128 \pm 0.072$ keV for this 6⁺ state (1972BA97). See also (1982HI1K).

^e Alpha decay is (2 \pm 2)% by α_0 , (46 \pm 2)% via α_{1+2} (mainly α_2) and (52 \pm 2)% via α_{3+4} (mainly α_3) (1979YO04).

^f Alpha decay is (32 \pm 2)% by α_0 , (58 \pm 2)% via α_{1+2} (mainly α_2) and (10 \pm 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).

^g Alpha decay is (20 \pm 5)% by α_0 , (57 \pm 7)% by α_{1+2} and (23 \pm 4)% by α_{3+4} (1982HI1K).

^h Alpha decay is (9 \pm 2)% by α_0 , (79 \pm 2)% via α_{1+2} (mainly α_2) and (12 \pm 4)% via α_{3+4} (mainly α_3) (1979YO04); (24 \pm 5)% via α_0 , (51 \pm 7)% via α_{1+2} , (25 \pm 5)% via α_{3+4} (1982HI1K).

ⁱ Alpha decay is $(72 \pm 3)\%$ via α_0 , $(20 \pm 3)\%$ via α_{1+2} (mainly α_2) and $(8 \pm 3)\%$ via α_{3+4} (mainly α_3) (1979YO04).

^j Alpha decay is $(5 \pm 2)\%$ via α_0 , $(52 \pm 2)\%$ via α_{1+2} (mainly α_2) and $(43 \pm 2)\%$ via α_{3+4} (mainly α_3) (1979YO04); $(60 \pm 5)\%$ via α_0 , $(20 \pm 5)\%$ via α_{1+2} , $(20 \pm 5)\%$ via α_{3+4} (1982HI1K).

^k Alpha decay is $(15 \pm 2)\%$ via α_0 , $(50 \pm 6)\%$ via α_{1+2} and $(35 \pm 7)\%$ via α_{3+4} (1982HI1K). See also (1979YO04).

^l Alpha decay is $(71 \pm 6)\%$ via α_0 and $(29 \pm 6)\%$ via α_{1+2} (mainly α_2) (1979YO04).

^m Alpha decay is $(1.8 \pm 0.9)\%$ via α_0 , $(60 \pm 8)\%$ via α_{1+2} and $(26 \pm 4)\%$ via α_{3+4} . Decay to $^{12}\text{C}_{\text{g.s.}} + ^8\text{Be}_{\text{g.s.}}$ is also observed: the branching ratio is 12%. This state may be a member of an excited $8\text{p-}4\text{h}$ ($K^\pi = 0_6^+$) band of which $^{20}\text{Ne}^*(12.44)$ is the 0^+ band head (1981HI02, 1982HI1K).

ⁿ Decay is $(66 \pm 26)\%$ via α_0 , $(14 \pm 7)\%$ via α_{1+2} and $(13.2 \pm 2.5)\%$ via $^{12}\text{C} + ^8\text{Be}$ (1982HI1K).

^o Decay is $\lesssim 14\%$ via α_0 , $(25 \pm 15)\%$ via α_{1+2} , $(46 \pm 22)\%$ via α_{3+4} and $(4.5 \pm 0.9)\%$ via $^{12}\text{C} + ^8\text{Be}$ (1982HI1K). See also (1979YO04).

^p (1979YO04).

^q (1981HI02, 1982HI1K). θ_α^2 shown are $\theta_{\alpha_0}^2$ (1982HI1K) and P.D. Parker, private communication.

^r See footnote ^f in Table 20.21 (1981GA35).

^s $\theta_{\alpha_2}^2 = 0.66 \pm 0.36$ (1982HI1K).

^t $\theta_{\alpha_2}^2 = 0.025 \pm 0.010$ (1982HI1K).

^u $\theta_{\alpha_2}^2 = 0.05 \pm 0.013$, $\theta_{\alpha_3}^2 = 0.91 \pm 0.23$ (1982HI1K).

^v $\theta_{\alpha_2}^2 = 0.94 \pm 0.14$, $\theta_{\alpha_3}^2 = 4.2 \pm 0.9$ (1982HI1K).

^w $\theta_{\alpha_2}^2 = 0.048 \pm 0.013$, $\theta_{\alpha_3}^2 = 0.44 \pm 0.12$ (1982HI1K).

^x $\theta_{\alpha_2}^2 = 0.071 \pm 0.013$, $\theta_{\alpha_3}^2 = 0.32 \pm 0.08$ [all θ_α^2 assume $J^\pi = 7^-$] (1982HI1K).

^y $\theta_{\alpha_2}^2 = 0.085 \pm 0.014$, $\theta_{\alpha_3}^2 = 0.24 \pm 0.04$, $\theta_{^{12}\text{C}}^2 = 1.50 \pm 0.21$ (1982HI1K).

^z $\theta_{\alpha_2}^2 = 0.016 \pm 0.008$, $\theta_{^{12}\text{C}}^2 = 0.24 \pm 0.05$ (1982HI1K).

^{aa} For the new level at 12.600 ± 10 see (1983HI06).

^{bb} For the new level at 14.311 ± 15 see (1983HI06).

^{cc} For the new level at 16.600 ± 15 see (1983HI06).

11. (a) $^{14}\text{N}(^6\text{Li}, \text{p})^{19}\text{F}$	$Q_{\text{m}} = 11.1491$	$E_{\text{b}} = 23.994$
(b) $^{14}\text{N}(^6\text{Li}, \text{d})^{18}\text{F}$	$Q_{\text{m}} = 2.942$	
(c) $^{14}\text{N}(^6\text{Li}, \alpha)^{16}\text{O}$	$Q_{\text{m}} = 19.2628$	

Yield curves for $E(^6\text{Li}) = 4.1$ to 9.2 MeV do not show any structure: see (1978AJ03).

12. (a) $^{14}\text{N}(^{12}\text{C}, ^6\text{Li})^{20}\text{Ne}$	$Q_{\text{m}} = -4.181$
(b) $^{15}\text{N}(^{12}\text{C}, ^7\text{Li})^{20}\text{Ne}$	$Q_{\text{m}} = -7.764$

For reaction (a) see (1979GO1C). For reaction (b) see (1979RA10).

Table 20.20: Resonances in $^{16}\text{O}(\alpha, \gamma)^{20}\text{Ne}$ ^a

E_α (MeV \pm keV)	$\Gamma_{\text{c.m.}}$ (keV)	$\omega\gamma$ ^b (eV)	E_x (MeV \pm keV)	$J^\pi; T$	K^π
1.116 \pm 4	2.6×10^{-6} ^c	$(1.7 \pm 0.3) \times 10^{-3}$	5.624	$3^-; 0$	2^-
1.3174 \pm 2.2 ^d	$(2.8 \pm 0.3) \times 10^{-2}$ ^c	$(1.4 \pm 0.3) \times 10^{-2}$	5.785	$1^-; 0$	0^-
2.490 \pm 8	15 ± 7 ^c	$(3.8 \pm 1.0) \times 10^{-2}$	6.722	$0^+; 0$	
3035.9 \pm 2.3 ^d	8.1 ± 0.3		7.1563 \pm 0.5	$3^-; 0$	0^-
3.074	4	$(4.4 \pm 0.8) \times 10^{-3}$	7.189 \pm 3	$0^+; 0$	
3.363	8	0.146 ± 0.019	7.421 \pm 1	$2^+; 0$	
3.872	2.4	0.343 ± 0.035	7.828 \pm 3	$2^+; 0$	
(4.647 \pm 3)			(8.447)	$(5^-; 0)$	
4.969 \pm 9 ^e	2.1 ± 0.8	0.21 ± 0.05	8.705 \pm 7	$1^-; 0$	
5.06	< 3	1.35 ± 0.15	8.776 \pm 3.2	$6^+; 0$	
5.368	3.2	3.05 ± 0.38	9.024 \pm 3	$4^+; 0$	
5.477 \pm 4 ^e	< 4	0.18 ± 0.02	9.111 \pm 3	$3^-; 0$	
5.94 \pm 30	29 ± 15	1.3 ± 0.5	9.48	$2^+; 0$	
6.61 \pm 30	155 ± 30	8 ± 3	10.02	$(4^+); 0$	
6.924 \pm 7 ^{f,g}	≤ 1	19.5 ± 1.5 ^h	10.271 \pm 7 ⁱ	$2^+; 1$	
7.948 \pm 4 ^{e,g}	< 1	30.2 ± 3.5	11.087 \pm 3	$4^+; 1$	
8.180 \pm 5 ^{e,g,j}	< 1	2.06 ± 0.25 ^k	11.272 \pm 4	$1^-; 1$	
8.535 \pm 6 ^{e,g}	1.3 ± 0.8	0.41 ± 0.05	11.556 \pm 6	$(0^+, 2^+); 0$	
8.994 \pm 8 ^e	< 1	0.23 ± 0.05 ^l	11.923 \pm 6	$4^+; 0$	
9.02 ^m		0.131 ± 0.018	11.950 \pm 4	$8^+; 0$	
(9.05 \pm 50) ^g	< 40		(11.97)		
(9.15 \pm 50) ^g	< 40		(12.05)		
9.362 \pm 5 ^e	< 1	1.41 ± 0.23	12.218 \pm 4	$2^+; 1$	
9.406 \pm 4 ^e	< 1	6.6 ± 0.8 ⁿ	12.253 \pm 3	$3^-; 1$	
9.57 \pm 10 ^g	33 ± 4	1.94 ± 0.15	12.38	$3^-; (1)$	
9.70 \pm 30 ^g	≤ 10	0.17 ± 0.05	12.49		

^a For complete references see Table 20.22 in (1978AJ03).

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

^c This is also Γ_α .

^d (1980MA27). The strength of the γ -decay of $^{20}\text{Ne}^*(7.16)$ to $^{20}\text{Ne}^*(5.78)$ (see Table 20.18) is strong evidence that these two states are members of the $K^\pi = 0^-$ band.

^e (1980FI01). See also Table 20.18.

^f See also (1978SN1B).

^g (1978ST08).

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

ⁱ From E_γ measurements (1977FI08). The measurements of the decay of this state leads to $E_x = 4247.9 \pm 1.3, 4966.0 \pm 1.9, 5621.0 \pm 3.5, 7423.1 \pm 3.0, 7828.1 \pm 3.8$ and 8776.7 ± 2.3 keV (1977FI08).

^j (1978DA19) find $E_x = 11.278 \pm 0.004$ MeV, $\omega\gamma_0 = 1.0 \pm 0.3$ eV.

^k The γ -decay is partly (see Table 20.18) to a state at $E_x = 9318 \pm 2$ keV. The strength of this transition and the subsequent decay to $^{20}\text{Ne}^*(1.63)$ (and not to the ground state) favor 2^- for $^{20}\text{Ne}^*(9.32)$. The other M1 transition [$11.27 \rightarrow 8.85$] is also strong suggesting similar structures for $^{20}\text{Ne}^*(8.85, 9.32)$ (1980FI01).

^l 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).

^m (1980HU08).

ⁿ (1980FI01): see also for a discussion of the decay of the 18.43 MeV, $J^\pi = 2^+, T = 2$ state.

13. $^{16}\text{O}(\alpha, \gamma)^{20}\text{Ne}$ $Q_m = 4.7309$

Observed resonances in the yield of capture γ -rays over the range $E_\alpha = 0.8$ to 10 MeV are displayed in Table 20.20. Information on the character of the radiative decay is shown in Table 20.18. $^{20}\text{Ne}^*(11.261)$ [$J^\pi = 1^+; T = 1$] is not observed: $\Gamma_\alpha < 3 \times 10^{-5}$ eV, leading to $|\langle 1^+V_{\text{PNC}}1^- \rangle| < 1.2$ eV (1980FI1C). $^{20}\text{Ne}^*(12.25)$ is the $3^-; T = 1$ analog of $^{20}\text{F}^*(1.97)$ (1980FI01). See also (1978AJ03, 1979NO1H), (1982IB1A; astrophys.) and (1982DU1A; theor.).

14. (a) $^{16}\text{O}(\alpha, \alpha)^{16}\text{O}$ $E_b = 4.7309$

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

Excitation functions have been measured over a wide range for elastically and inelastically scattered α -particles, and γ -rays from the decay of $^{16}\text{O}^*(6.13, 6.92, 7.12)$: see (1978AJ03) and (1981GA35; 9.5 to 9.8 MeV; α_1), (1979BI10; 14.6 to 20.4 MeV; $\alpha_0 \rightarrow \alpha_5$), (1979AR05; 17.5 to 22.7 MeV; α_0) and (1978CO10; 27 to 33.6 MeV; α_0).

A number of anomalies are observed: they are displayed in Table 20.21: see, in particular, (1972HA07, 1973HA63, 1979BI10). (1979AR05) report structures in the range $E_x = 18.7 - 22.9$

MeV which are similar to those observed in $^{16}\text{O}(^6\text{Li}, \text{d})^{20}\text{Ne}^* \rightarrow \alpha + ^{16}\text{O}_{\text{g.s.}}$. The excitation function for α_0 at 178.1° shows a very strong structure at $E_\alpha \approx 29.5$ MeV as does the excitation function for deuterons to $^{18}\text{F}^*(1.13) [J^\pi = 5^+]$ (1978CO10, 1979CO1P): this anomalous scattering is correlated with a large variation in the degree of forward peaking of the (α, d) process.

Table 20.21: Resonances in $^{16}\text{O}(\alpha, \alpha)^a$

E_α (MeV \pm keV)	$\Gamma_{\text{c.m.}}$ (keV)	Outgoing particles	θ^2 (%)	E_x (MeV \pm keV)	J^π	K^π
1.3174 ± 2.2^b	$(2.8 \pm 0.3) \times 10^{-2}^b$	α_0		5.785	1^-	0^-
2.490 ± 10	19	α_0	22	6.722	0^+	0_2^+
3.0359 ± 2.3^b	8.1 ± 0.3^b	α_0	36	7.1563 ± 0.5	3^-	0^-
3.090 ± 10	4	α_0	1.1	7.202	0^+	0_3^+
3.380 ± 10	8	α_0	4.7	7.434	2^+	0_2^+
3.885 ± 10	2	α_0	0.6	7.838	2^+	0_3^+
4.653 ± 5	0.013 ± 0.004	α_0	0.07	8.452	5^-	2^-
≈ 4.9	> 800	α_0	≈ 70	≈ 8.6	0^+	0_4^+
5.002	2.5	α_0	0.23	8.731	1^-	
5.058 ± 3	0.11 ± 0.02	α_0	8.5 ± 1.5	8.776	6^+	0_1^+
≈ 5.1	> 800	α_0	≈ 95	≈ 8.8	2^+	0_4^+
5.11	< 1	α_0		8.82	(5^-)	
5.152 ± 5	19	α_0	1.1	8.851	1^-	
5.395 ± 5	3	α_0	3.9	9.046	4^+	0_3^+
5.486 ± 5	3.2	α_0	0.49	9.118	3^-	
5.955 ± 10	24	α_0	1.4	9.493	2^+	
6.569 ± 10	97	α_0	17	9.984	4^+	0_2^+
6.912 ± 5	141	α_0	66	10.259	5^-	0^-
6.92 ± 10^c	≤ 0.3	α_0	$\leq 1.3 \times 10^{-3}$	10.27	(2^+)	
7.092 ± 5	81	α_0	4.8	10.403	3^-	
7.276 ± 5	16	α_0	1.8	10.550	4^+	
7.314 ± 10	24	α_0	0.85	10.580	2^+	
7.580 ± 100	349	α_0	33	10.79	4^+	0_4^+
7.635 ± 5	13	α_0	0.42	10.837	2^+	
7.636	45	α_0	2.1	10.838	3^-	
(7.75)	80	α_0		(10.93)		
7.80 ± 150	576	α_0	14	10.97	0^+	
7.860 ± 10	24	α_0	2.0	11.017	4^+	
7.93 ± 10^c	≤ 0.5	α_0	≤ 0.05	11.07	(4^+)	
8.132 ± 30	172	α_0	4.2	11.234	1^-	
8.16 ± 10^c	≤ 0.3	α_0	≤ 0.009	11.26	(1^-)	
8.24 ± 10^c	40 ± 10	α_0	1.4	11.32	2^+	
8.528 ± 10^c	1.0 ± 0.5	α_0	0.03, 0.02	11.551	$(2^+, 0^+)$	

Table 20.21: Resonances in $^{16}\text{O}(\alpha, \alpha)^a$ (continued)

(≈ 8.6)	≈ 500	α_0		(≈ 11.6)	(2^+)	
8.930 ± 20	46	α_0	1.1	11.872	2^+	
8.997 ± 5	0.44 ± 0.15	$\alpha_0, \gamma_{6.13}$	0.04 ± 0.01	11.926	4^+	
9.026 ± 5	$(35 \pm 10) \times 10^{-3}$	α_0	1.0 ± 0.3	11.949	8^+	0_1^+
9.043 ± 10^c	30 ± 5	α_0	0.72	11.962	1^-	
9.26		$\gamma_{6.13}$	d	12.137 ± 5	6^+	0_3^+
9.39 ± 30^c	148 ± 20	α_0	7.7	12.24	4^+	
9.406 ± 4	< 1	$\gamma_{6.13}$	d	12.253 ± 3	$3^-; 1$	
9.53 ± 100^c	≈ 500	α_0	≈ 13	12.35	2^+	
9.58 ^{c,e}	37.3 ± 0.9	$\alpha_0, \gamma_{6.13}$		12.394 ± 4	3^-	
9.64 ^f	24.4 ± 0.5	α_0, α_1	f	12.436 ± 4	0^+	
9.790 ± 10^c	88 ± 10	α_0	28	12.560	6^+	0_4^+
(9.860 ± 100)		α_0		(12.62)		
9.944 ± 15	97	α_0	7.3	12.683	5^-	
10.050 ± 100	100	α_0		12.77	4^+	
10.14 ± 70	55	$\alpha_0, \gamma_{6.13}$		12.84		
10.32 ± 75^g	60	$\alpha_0, \gamma_{6.13}$		12.98	(4^+)	
10.43 ± 90	70	$\alpha_0, \gamma_{6.13}$		13.07	(4^+)	
10.57 ± 75	60	$\alpha_0, \gamma_{6.13}$		13.18	(4^+)	
10.759 ± 6	$(80 \pm 30) \times 10^{-3}$	α_0	0.08 ± 0.03	13.334	7^-	2^-
10.770 ± 6	20 ± 5	$\alpha_0, \gamma_{6.13}$	0.7 ± 0.2	13.343	4^+	
10.83 ± 50	40	$\gamma_{6.13}$		13.39		
10.87 ± 140	110	$\alpha_0, \gamma_{6.13}$		13.42	(4^+)	
11.20 ± 400	320	$\alpha_0, \gamma_{6.13}$		13.7	($3, 7$) ⁻	
(11.51 ± 125) ^g	(400)	($\alpha_0, \gamma_{6.13}$)		13.93	(6^+)	
11.77		$\alpha_0, \gamma_{6.9+7.1}$		14.14		
E_α (MeV \pm keV)	$\Gamma_{\text{c.m.}}$ (keV)	Outgoing particles	Γ_{α_0}/Γ	E_x (MeV \pm keV)	J^π	K^π
11.97 ± 300 (12.06)	240	$\alpha_0, \gamma_{6.13}, \gamma_{6.9+7.1}$ $\alpha_0, \gamma_{6.9+7.1}$		14.3 (14.37)	6^+	
12.31 ± 300	240	$\alpha_0, \gamma_{6.9+7.1}$		14.6	(4^+)	
12.66 ± 150	120	$\alpha_0, \gamma_{6.13}, \gamma_{6.9+7.1}$		14.85		
12.86 ± 150	120	$\alpha_0, \gamma_{6.13}, \gamma_{6.9+7.1}$		15.01		
13.165 ± 150	120	$\alpha_0, \gamma_{6.13}$		15.26		
13.22		α_0		15.30		
13.37 ± 470	380	$\alpha_0, \gamma_{6.13}, \gamma_{6.9+7.1}$		15.4	7^-	0^-
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 20.21: Resonances in $^{16}\text{O}(\alpha, \alpha)^a$ (continued)

14.26		$\gamma_{6.13}, \gamma_{6.9+7.1}$		16.13	
14.40		$\gamma_{6.13}$		16.25	
14.501 \pm 15	43	α_0, α_{1+2}		16.326	4 ⁺
14.636 \pm 15	34	α_0, α_{1+2}		16.434	(0, 2, 4) ⁺
14.726 \pm 11 ^h	25 \pm 3	α_0, α_{1+2}	0.473 \pm 0.024	16.506	6 ⁺
14.815 \pm 15 ^h	86 \pm 6	α_0	0.446 \pm 0.019	16.577 \pm 12	7 ⁻
14.886 \pm 17 ^h	51 \pm 14	α_0	0.173 \pm 0.014	16.634 \pm 14	3 ⁻
14.932 \pm 12 ^h	79 \pm 11	α_0	0.259 \pm 0.025	16.671	4 ⁺
14.988 \pm 12 ^h	14 \pm 7	α_0, α_{1+2}	0.062 \pm 0.026	16.715	(5, 3) ⁻
15.156 \pm 11 ^h	16 \pm 5	α_0, α_{1+2}	0.126 \pm 0.021	16.850	5 ⁻
15.540 \pm 11 ^h	33 \pm 3	α_0, α_{1+2}	0.291 \pm 0.019	17.156	5 ⁻
15.601 \pm 15 ^h	142 \pm 9	α_0	0.460 \pm 0.019	17.205 \pm 12	4 ⁺
15.691 \pm 12 ^h	52 \pm 10	α_0	0.155 \pm 0.019	17.277	4 ⁺
15.721 \pm 17 ^h	213 \pm 12	α_0	0.237 \pm 0.013	17.301 \pm 14	8 ⁺
15.828 \pm 15	< 10	α_{1+2}		17.387	
15.837 \pm 17 ^h	241 \pm 13	α_0	0.209 \pm 0.012	17.394 \pm 14	9 ⁻
16.023 \pm 15	136	α_0, α_{1+2}		17.542	6 ⁺
16.285 \pm 15	36	α_0, α_{1+2}		17.752	(4, 0) ⁺
16.598 \pm 15	< 10	α_0, α_{1+2}		18.002	7 ⁻
16.625 \pm 10 ^h	35 \pm 3	α_0, α_{1+2}	0.372 \pm 0.018	18.024 \pm 8	5 ⁻
16.744 \pm 9 ^h	29 \pm 3	α_0, α_{1+2}	0.420 \pm 0.024	18.119 \pm 8	7 ⁻
16.98 \pm 300	240	$\alpha_0, \gamma_{6.13}, \gamma_{6.9+7.1}$		18.31	(6 ⁺)
17.45	600	$\alpha_0, \gamma_{6.13}$		18.7	(6 ⁺)
17.988 \pm 12 ^h	149 \pm 18	α_1	0.420 \pm 0.012 ⁱ	19.113 \pm 10	6 ⁺
18.250 \pm 11 ^h	123 \pm 10	α_1	0.272 \pm 0.014 ⁱ	19.322 \pm 9	6 ⁺
18.393 \pm 12 ^h	102 \pm 7	α_1	0.466 \pm 0.012 ⁱ	19.437 \pm 10	6 ⁺
18.658 \pm 12 ^h	89 \pm 8	α_1	0.332 \pm 0.012 ⁱ	19.648 \pm 10	6 ⁺
18.990 \pm 15 ^h	203 \pm 19	α_1	0.379 \pm 0.017 ⁱ	19.914 \pm 12	5 ⁻
19.261 \pm 21 ^h	156 \pm 21	α_1	0.301 \pm 0.020 ⁱ	20.130 \pm 17	7 ⁻
19.495 \pm 15 ^h	203 \pm 19	α_1	0.343 \pm 0.021 ⁱ	20.317 \pm 12	7 ⁻
19.640 \pm 20 ^h	346 \pm 32	α_1	0.444 \pm 0.020 ⁱ	20.433 \pm 16	6 ⁺
19.953 \pm 11 ^h	75 \pm 9	α_0	0.247 \pm 0.018	20.683 \pm 9	9 ⁻
20.076 \pm 14	122 \pm 13	α_1	0.395 \pm 0.020	20.782 \pm 11	7 ⁻
20.249 \pm 15	181 \pm 22	α_1	0.339 \pm 0.017	20.920 \pm 12	7 ⁻
20.45 \pm 40	80	α_0		21.08	9 ⁻
20.70	300	α_0		21.3	7 ⁻
21.3 \pm 200	300	α_0		21.8	7 ⁻
22.0 \pm 200	500	α_0		22.3	7 ⁻
22.5 \pm 250	500	α_0		22.7	9 ⁻

Table 20.21: Resonances in $^{16}\text{O}(\alpha, \alpha)$ ^a (continued)

22.65 ± 125	250	α_0		22.84	9^-	
23.3 ± 250	500	α_0		23.4	8^+	
24.24 ± 150	350	α_0		24.11	8^+	
25.4 ± 300	600	α_0		25.0	8^+	
26.2 ± 200	400	α_0		25.7		
28.1 ± 350	700	α_0		27.2		
29	1600	α_0		28	8^+	
29.4 ± 350	700	α_0		28.2		

^a See also Table 20.20, and Table 2 in (1973HA63). For a complete listing of references see Table 20.23 in (1978AJ03).

^b (1980MA27): $\Gamma_{\text{c.m.}} = \Gamma_{\alpha}$.

^c (1978ST08).

^d $(2J + 1)\Gamma_{\alpha_0}\Gamma_{\alpha_2}/\Gamma = 81 \pm 12$ eV and 14 ± 2 eV, respectively, for $^{20}\text{Ne}^*(12.14, 12.25)$ (1980FI01).

^e (1981GA35): $\omega\gamma_{\text{c.m.}} = 3.3 \pm 0.3$ keV. See also (1978ST08).

^f $\omega\gamma_{\text{c.m.}} = 2.82 \pm 0.29$, $\Gamma_{\alpha_1} = 20.8 \pm 0.4$ keV, $\Gamma_{\alpha_0} = 3.2 \pm 0.4$ keV. The spectroscopic factors are ≈ 1 and 0.001 for the α_1 and α_0 decays suggesting that the wave function of $^{20}\text{Ne}^*(12.44)$ contains a large amount of 8p-4h configuration (1981GA35). See also (1980CA1K).

^g (1981CA1J; abstract) suggest 8p-4h 2^+ and 4^+ states at $E_x = 12.95$ and 13.96 MeV; $\theta^2 = 0.004$ and 0.001, respectively. (1982HIZY; abstract) find $\Gamma_{\alpha_1}/\Gamma < 0.6\%$ [$^{16}\text{O}^*(12.98)$], $\Gamma_{\alpha_3}/\Gamma < 0.1\%$ [$^{16}\text{O}^*(13.34)$] and $\Gamma_{\alpha_1}/\Gamma = (0.7 \pm 0.5)$, $\Gamma_{\alpha_{3+4}}/\Gamma = (1.0 \pm 0.4)$ [$^{16}\text{O}^*(13.93)$]. The corresponding reduced widths are very small and indicate that these states are not the 8p-4h 2^+ and 4^+ states suggested by (1981CA1J).

^h (1979BI10). The state at $E_x = 19.577$ MeV has been withdrawn. The quoted errors in the branching ratios reported by (1979BI10) correspond to a χ^2 doubling as the parameter is varied. However because of correlations in the fitting program, the uncertainties may well be as large as ± 0.1 . The uncertainties in the quoted widths may be appreciably larger than shown (H.T. Richards and S. Riedhauser, private communication).

ⁱ $(\Gamma_{\alpha_0}\Gamma_{\alpha_1})^{1/2}/\Gamma$.

^j Preliminary work by G. Caskey indicates that the resonance at $E_{\alpha} = 11183 \pm 5$ keV corresponds to a state at $E_x = 13672 \pm 4$ keV [$\Gamma_{\text{c.m.}} = 15 \pm 6$ keV] with $J^{\pi} = 5^-$ (H.T. Richards, private communication).

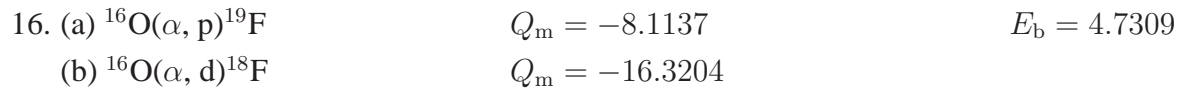
For reaction (b) see (1980AJ01). For spallation reactions see (1978AJ03) and (1979VI05, 1980GO1E, 1980RE1B, 1981GO1E). See also (1981BE2D), (1979RA1C; astrophys.), (1977ST1X, 1982FI1C) and (1976PA20, 1977BA1N, 1977BA30, 1977IK1A, 1977TO1K, 1978FL1D, 1978KA22, 1978NO1B, 1978TA1A, 1978TH1A, 1978TO07, 1979AR05, 1979LE1B, 1979LE11, 1979VE09, 1979VE1C, 1980BA2K, 1980FL1C, 1980FU1F, 1980LE26, 1980TO1D, 1981AO01, 1981FI1B, 1981GY01, 1981WI01, 1982AO1B, 1982BI1D, 1982FL1A, 1982LA04; theor.).

15. $^{16}\text{O}(\alpha, n)^{19}\text{Ne}$

$Q_m = -12.1344$

$E_b = 4.7309$

The excitation function (activation measurements) has been measured from threshold to $E_\alpha = 26.8$ MeV (1973GR29). See also ^{19}Ne , (1979BA48), (1979BU19; applied) and (1977GR18).



For reaction (a) see ^{19}F . For reaction (b) see (1978CO10, 1979CO1P) and reaction 14.



Deuteron groups have been observed to many states of ^{20}Ne : see Table 20.22. Angular distributions have been measured for $E(^6\text{Li}) = 5.5$ to 45 MeV [see (1978AJ03)] and at 20 and 38 MeV (1979AN01; d_0, d_1, d_2), 32 MeV (1979AN01; to all states shown in Table 20.23 with $E_x < 12.2$ MeV, except $^{20}\text{Ne}^*(10.7)$), 42 MeV (1978BE43; d_0, d_1) and 75.4 MeV (1981TA06, 1981TA23; d to $^{20}\text{Ne}^*(0, 1.63, 4.25, 5.78, 7.17, 8.78, 10.26, 11.95)$; $S_\alpha = 1.0, 0.96, 1.0, < 0.93, 0.49, 0.98, 0.88, 0.65$, respectively; $^{20}\text{Ne}^*(12.59, 13.90, 15.34, 17.30)$ were also populated. Reaction processes are discussed by (1979AN01). See also reaction 14 (1979AR05) and (1979ES01; d- γ involving $^{20}\text{Ne}^*(1.63, 4.25)$). For excitation functions see (1978HO01). See also (1980MA1N), (1977ST1X, 1979FU1N, 1980AN16) and (1981GY01, 1981LE10, 1981MA26, 1981XE01, 1982SE1E; theor.).



States observed in this reaction are displayed in Table 20.22. Angular distributions are reported at $E(^7\text{Li}) = 15$ to 38 MeV [see (1978AJ03)] and at 50 and 68 MeV (1979BR03; to $^{20}\text{Ne}^*(1.63, 4.25, 7.17, 8.78, 10.25, 15.4)$; see also for C^2S). See also (1978AJ03).



See (1979CH12, 1979CU1A).

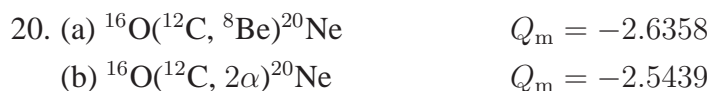


Table 20.22: States of ^{20}Ne from $^{16}\text{O}(^6\text{Li}, \text{d})$, $^{16}\text{O}(^7\text{Li}, \text{t})$ and $^{16}\text{O}(^{12}\text{C}, ^8\text{Be})$ ^a

	E_x (MeV \pm keV)			$\Gamma_{\text{c.m.}}$ (keV)	Γ_{α_0}/Γ ^b	S ^c	J^π	K^π ^{a,b,c}
	($^6\text{Li}, \text{d}$)	($^7\text{Li}, \text{t}$)	($^{12}\text{C}, ^8\text{Be}$) ^b					
0	0	0				1.00	0^+	0_1^+
1	1.63	1.63				0.41	2^+	0_1^+
2	4.25	4.25				0.22	4^+	0_1^+
3	4.97						2^-	2^-
4	5.62					0.06	3^-	2^-
5	5.78	5.78				0.54	1^-	0^-
6	6.72					0.56	0^+	
7	7.00						4^-	2^-
8	7.16	7.16	7.16			0.26	3^-	0^-
9	7.42					0.13	2^+	
10	8.45					0.04	5^-	0^-
11	8.78	8.78	8.78			0.20	6^+	0_1^+
12	10.3 ± 100	10.26	10.26	145 ± 40	1	0.15	5^-	0^-
13	10.7 ± 100						4^+	(0_2^+)
14	11.95	11.95	11.95		0.85 ± 0.15	0.51	8^+	0_1^+
15	12.15					0.05	6^+	
16	12.6 ± 100	12.591 ± 10	12.59	110 ± 40	0.80 ± 0.10		6^+	0_2^+
17	13.9	13.904 ± 20		≈ 100			6^+	
18	14.3	14.310 ± 20		< 100			6^+	
19	15.35 ± 100	15.336 ± 15	15.34	380 ± 60	0.90 ± 0.10		7^-	0^-
20	15.9 ± 100			< 250			7^-	
21	16.7 ± 100	16.63 ± 20	16.63	190 ± 40	0.90 ± 0.10		7^- ^e	0^-

Table 20.22: States of ^{20}Ne from $^{16}\text{O}(^6\text{Li}, \text{d})$, $^{16}\text{O}(^7\text{Li}, \text{t})$ and $^{16}\text{O}(^{12}\text{C}, ^8\text{Be})$ ^a
(continued)

	E_x (MeV \pm keV)			$\Gamma_{\text{c.m.}}$ (keV)	$\Gamma_{\alpha_0}/\Gamma^{\text{b}}$	S^{c}	J^π	K^π ^{a,b,c}
	($^6\text{Li}, \text{d}$)	($^7\text{Li}, \text{t}$)	($^{12}\text{C}, ^8\text{Be}$) ^b					
22	17.35 \pm 100	17.30 \pm 20	17.30	220 \pm 40	$\geq 0.40 \pm 0.10$		8 ⁺ ^e	0 ₂ ⁺
23	18.7 \pm 100						7 ⁻	
24	19.4 \pm 100			400			7 ⁻	
25	19.9 \pm 100			400			7 ⁻	
26		20.67 \pm 40						
27	20.8 \pm 100						7 ⁻ (6 ⁺)	
28		21.08 \pm 30	21.08	100 \pm 50	0.65 \pm 0.15		9 ⁻	0 ⁻
29	21.3 \pm 100			300			8 ⁺	
30	21.8 \pm 100			300			8 ⁺	
31	22.3 \pm 100			300			8 ⁺	
32		22.87 \pm 40	22.87	225 \pm 40	0.90 \pm 0.10		9 ⁻	0 ⁻
33	23.5 \pm 100	23.70 \pm 30		≤ 200			9 ⁻ (8 ⁺)	
34		24.21 \pm 25		≈ 500				
35		25.10 \pm 50		≤ 200				
36		25.67 \pm 50 ^f		≈ 500				
37	27.1 \pm 100 ^d						9 ⁻	
38	28.1 \pm 100 ^d						10 ⁺	
39	(29.4) ^d						(10 ⁺)	
40	((33.4)) ^d						((10 ⁺))	

^a For complete references see Table 20.24 in (1978AJ03).

^b (1979SA29): $E(^{12}\text{C}) = 78 \text{ MeV}$.

^c Relative α -particle spectroscopic factors (1979AN01): $E(^6\text{Li}) = 32 \text{ MeV}$ (DWBA). S_α values are reported by (1981TA06, 1981TA23: $E(^6\text{Li}) = 75.4 \text{ MeV}$). See also Table 20.24 in (1978AJ03), (1978BE43) and (1979BR03).

^d (1977AR18): $E(^6\text{Li}) = 57.8 \text{ MeV}$.

^e (1979FO20) suggest an admixture of 6^+ or 8^+ in the d- α angular correlation involving $^{20}\text{Ne}^*(16.6)$ and a doublet ($8^+ + 7^-$) at $E_x = 17.4 \text{ MeV}$.

Angular distributions in reaction (a) have been measured for $E(^{16}\text{O}) = 27.1$ to 46.4 MeV [see (1978AJ03)] and 28.5 to 35.2 MeV (1979VI08; g.s.), 43.2 to 53.0 MeV (1979JA19; g.s.) and 43.9 MeV (1979EB01; g.s.), and at $E(^{12}\text{C}) = 56$ MeV (1976MA12), 22.7 to 32.4 MeV (1980HU07; g.s.) and 78 MeV (1979SA29; see Table 20.23). Γ_{α_0}/Γ measurements derived from $^8\text{Be}-\alpha$ correlations are listed in Table 20.22 (1979SA29). For reaction (b) see (1978AJ03). For yield and cross-section measurements see (1977BR38, 1978CH15, 1978DI1F, 1978KA1L, 1978TA11, 1979EB01, 1979FL1J, 1979JA19, 1979KO03, 1979VI08, 1980HA1L, 1980HU07, 1980SI15). See also (1979GO1C, 1981RA1G) and (1981SA1J; theor.).

$$21. \ ^{16}\text{O}(^{13}\text{C}, ^9\text{Be})^{20}\text{Ne} \quad Q_m = -5.9170$$

At $E(^{13}\text{C}) = 105$ MeV angular distributions to $^{20}\text{Ne}^*(1.63, 4.25, 8.78, 11.95, 15.34, 21.0)$ have been studied by (1979BR03): the first four states are the 2^+ , 4^+ , 6^+ and 8^+ members of the 0^+ band; the two higher states [$J^\pi = 7^-, 9^-$] belong to the 0^- band whose band head is $^{20}\text{Ne}^*(5.79)$. In addition distributions are reported to $^{20}\text{Ne}^*(12.56, 15.9, 17.3)$ [$J^\pi = 6^+, 8^+, 8^+$] (1979BR03). See also (1977FO1E, 1978AJ03).

$$22. \ ^{16}\text{O}(^{14}\text{N}, ^{10}\text{B})^{20}\text{Ne} \quad Q_m = -6.8823$$

Angular distributions are reported at $E(^{14}\text{N}) = 76.2$ MeV to $^{20}\text{Ne}^*(0, 1.63, 4.25)$ (1977MO1A, 1979MO14). See also (1977FO1E, 1978AJ03).

$$23. \ ^{16}\text{O}(^{16}\text{O}, ^{12}\text{C})^{20}\text{Ne} \quad Q_m = -2.4310$$

Angular distributions have been reported at $E(^{16}\text{O}) = 23.9$ to 51.5 MeV [see (1978AJ03)] and at 35 MeV (1977KA26; $^{20}\text{Ne}^*(0, 1.63)$), 68 and 90 MeV (1977PO14, 1979PO14; $^{20}\text{Ne}^*(0, 1.63, 4.25, 7.16, 8.45, 8.78, 10.26, 11.95)$) and 95.2 MeV (1977MO1A, 1979MO14; $^{20}\text{Ne}^*(0, 1.63)$). (1979PO14, 1981PO1A) report that $^{20}\text{Ne}^*(7.17, 8.45, 8.78)$ are strongly aligned and polarized along an axis perpendicular to the reaction plane. See also (1977PO14) and (1980BO1K; theor.). For partial fusion excitation functions see (1978FE04, 1978TS04, 1979KO15). See also (1978AJ03, 1978FI1E, 1979GO1C, 1981BR1P) and (1981KR09, 1982KO07; theor.).

$$24. \ (a) \ ^{16}\text{O}(^{17}\text{O}, ^{13}\text{C})^{20}\text{Ne} \quad Q_m = -1.629$$

$$(b) \ ^{16}\text{O}(^{18}\text{O}, ^{14}\text{C})^{20}\text{Ne} \quad Q_m = -1.4970$$

Angular distributions are reported at $E(^{17}\text{O}) = 35$ MeV to $^{20}\text{Ne}^*(0, 1.63)$ and at $E(^{18}\text{O}) = 36.1$ MeV to $^{20}\text{Ne}^*(0, 1.63, 4.25)$ (1977KA26). See also (1978AJ03).

Table 20.23: States of ^{20}Ne from $^{18}\text{O}(^3\text{He}, n)$ ^a

E_x (MeV \pm keV)	L	$J^\pi; T$
0	0	0^+
1.65 ± 15	2	2^+
4.21 ± 30	4	4^+
4.96 ± 150		
5.71 ± 30		
6.72 ± 70		
7.15 ± 20		
7.86 ± 100		
8.79 ± 60		
9.05 ± 60		
9.98 ± 50		
10.24 ± 30	2	$2^+; (1)$
10.88 ± 50		
11.27 ± 50		
11.48 ± 60	(0)	(0^+)
11.59 ± 40		
12.21 ± 15	2	2^+
12.41 ± 30	0	0^+
12.83 ± 30		
13.10 ± 30	0	0^+
13.34 ± 30		
13.48 ± 30		
13.59 ± 20	(2)	(2^+)
13.90 ± 25	(2)	(2^+)
14.22 ± 30		
15.52 ± 15	(2)	$(2^+; 1)$
16.01 ± 25	(2)	$(2^+; 1)$
16.730 ± 6 ^b	0	$0^+; T = 2$
17.55 ± 10	(2)	$(2^+; 1)$
17.91 ± 20	(0)	(0^+)
19.33 ± 15		

^a For references see Table 20.25 in (1978AJ03).

^b $\Gamma < 20$ keV.

$$25. \text{}^{16}\text{O}(\text{}^{19}\text{F}, \text{}^{15}\text{N})\text{}^{20}\text{Ne} \quad Q_m = 0.7171$$

Angular distributions involving $^{20}\text{Ne}^*(0, 1.63)$ have been studied at $E(^{19}\text{F}) = 36$ MeV and $E(^{16}\text{O}) = 46, 58$ and 68 MeV: see (1978AJ03) and (1980TA1K; theor.).

$$26. \begin{array}{lll} \text{(a) } ^{17}\text{O}(\text{}^3\text{He}, \text{n})\text{}^{19}\text{Ne} & Q_m = 4.299 & E_b = 21.164 \\ \text{(b) } ^{17}\text{O}(\text{}^3\text{He}, \text{t})\text{}^{17}\text{F} & Q_m = -2.780 & \\ \text{(c) } ^{17}\text{O}(\text{}^3\text{He}, \text{}^3\text{He})\text{}^{17}\text{O} & & \\ \text{(d) } ^{17}\text{O}(\text{}^3\text{He}, \alpha)\text{}^{16}\text{O} & Q_m = 16.4335 & \end{array}$$

For reaction (a) see ^{19}Ne . The excitation function for α_0 [$E(^3\text{He}) = 7.0$ to 10.0 MeV] shows a resonance corresponding to $^{20}\text{Ne}^*(28.)$: see (1978AJ03). Polarization measurements are reported at $E(^3\text{He}) = 33$ MeV for the t_0 group [reaction (b)], the ^3He groups to $^{17}\text{O}^*(0, 0.87)$ [reaction (c)] and the α -groups to $^{16}\text{O}^*(12.97, 13.26)$ [reaction (d)] (1981BA1G, 1981KA1L, 1981LE1H). See also (1981RO1H).

$$27. \text{}^{17}\text{O}(\alpha, \text{n})\text{}^{20}\text{Ne} \quad Q_m = 0.587$$

Angular distributions have been measured at $E_\alpha = 9.8$ to 12.3 MeV for the n_1, n_2 and n_{4+5} groups: see (1978AJ03). See also (1979BU19; applied) and (1981CH1K; astrophys.).

$$28. \text{}^{17}\text{O}(\text{}^6\text{Li}, \text{t})\text{}^{20}\text{Ne} \quad Q_m = 5.370$$

See (1978AJ03).

$$29. \begin{array}{ll} \text{(a) } ^{17}\text{O}(\text{}^{11}\text{B}, \text{}^8\text{Li})\text{}^{20}\text{Ne} & Q_m = -6.046 \\ \text{(b) } ^{17}\text{O}(\text{}^{12}\text{C}, \text{}^9\text{Be})\text{}^{20}\text{Ne} & Q_m = -5.115 \end{array}$$

At $E = 115$ MeV the 8^+ state at $E_x = 11.95$ MeV is particularly strongly populated in both reactions. $^{20}\text{Ne}^*(1.63, 4.25, 7.16, 8.78, 10.3, 15.3, 15.9, 17.3, 21.1)$ are also observed (1979GO17).

$$30. \text{}^{18}\text{O}(\text{}^3\text{He}, \text{n})\text{}^{20}\text{Ne} \quad Q_m = 13.1199$$

Angular distributions have been measured for $E(^3\text{He}) = 2.8$ to 18.3 MeV. States of ^{20}Ne observed in this reaction are displayed in Table 20.23. See also (1978AJ03).

$$31. \text{}^{18}\text{O}(^{11}\text{B}, \text{}^9\text{Li})^{20}\text{Ne} \quad Q_{\text{m}} = -10.027$$

At $E(^{11}\text{B}) = 114$ MeV, $^{20}\text{Ne}^*(4.25, 8.9, 10.39, 15.43)$ are relatively strongly populated: see (1978AJ03).

$$32. \text{}^{18}\text{O}(^{12}\text{C}, \text{}^{10}\text{Be})^{20}\text{Ne} \quad Q_{\text{m}} = -4.7816$$

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

$$33. \text{}^{19}\text{F}(\text{p}, \gamma)^{20}\text{Ne} \quad Q_{\text{m}} = 12.8447$$

Over the range $E_{\text{p}} = 2.9$ 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 (1967SE02). The 90° γ_0 yield for E_{p} and $E_{\text{p}} = 3.5$ to 10 MeV has been measured: the results are interpreted in terms of four primary doorway states at $E_{\text{x}} = 16.7, 17.8, 19.1$ and 20.2 MeV (1980CA11).

The yield curve for 11.2 MeV γ -rays [from the decay of $^{20}\text{Ne}^*(11.23)$, $J^\pi = 1^+$, $T = 1$, to the ground state] displays a resonance at $E_{\text{p}} = 4.090 \pm 0.005$ MeV [$^{20}\text{Ne}^*(16.73)$]. 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 : $\Gamma_{\text{p}}\Gamma_{\gamma}/\Gamma \approx 0.5$ eV. Since Γ_{p}/Γ (from the elastic scattering) is ≈ 0.1 , $\Gamma_{\gamma} \approx 5$ eV (1967KU06). For $E_{\text{p}} = 5.65$ 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 [$\Gamma_{\text{c.m.}} = 9.5 \pm 3$ keV, $\Gamma_{\text{p}_0}\Gamma_{\gamma}/\Gamma \approx 0.05$ eV; $\Gamma_{\gamma} \approx 0.3$ eV]. The 10.6 MeV γ -ray is due to the cascade decay of $^{20}\text{Ne}^*(18.43)$, $J^\pi = 2^+$; $T = 2$ via $^{20}\text{Ne}^*(12.22)$ to the 2^+ state at 1.63 MeV (1972KU24). (1976MA01) have determined the upper limits to the strengths of the transitions to various states of ^{20}Ne from the 0^+ and 2^+ $T = 2$ states: these are displayed in Table 20.18. No evidence is found for an isotensor transition amplitude (1976MA01). Resonances observed in this capture reaction are displayed in Table 20.24. See also (1979HA1G) and (1978SC19, 1980SC1M; theor.).

$$34. \text{(a) } ^{19}\text{F}(\text{p}, \text{p})^{19}\text{F} \quad E_{\text{b}} = 12.8447$$

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

Table 20.24: Resonances in $^{19}\text{F}(p, \gamma)^{20}\text{Ne}$ ^a

E_p (keV)	Γ_{lab} (keV)	Γ_{γ_0} (eV)	Γ_{γ_1} (eV)	$^{20}\text{Ne}^*$ (MeV)	$J^\pi; T$
340 ^b		< 0.07	0.28 ± 0.06	13.168	
484 ^b		≈ 0.05	0.42	13.304	
597 ± 1 ^b	30 ± 3	< 0.6	12	13.412	
671 ± 1 ^{b,c}	6.0 ± 0.7	1.0×10^{-2}	2.2	13.482	1^+
874 ^b				13.675	
935 ^b				13.733	
980				13.775	
1091 ^b	0.8		1.1	13.881	$2^+; 1$
1280				14.060	
1320	4.0			14.098	
1350				14.127	
1370				14.146	
1420	15.7			14.193	
4090 ± 5		$\Gamma_\gamma \approx 5 \text{ eV}$		16.728	$0^+; 2$
5879 ± 7	10 ± 3	$\Gamma_\gamma \approx 0.3 \text{ eV}$		18.427	$2^+; 2$

^a For earlier references see Table 20.26 in (1978AJ03). See also Table 20.18 and the text of reaction 33.

^b See (1979SU13).

^c See also (1980BI05).

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). The observed anomalies are displayed in Table 20.25.

Resonances for inelastic scattering [p_1 and p_2] are listed in Table 20.26. In general the resonances observed are identical with those reported from other $^{19}\text{F} + p$ reactions, although the relative intensities differ greatly. For reduced widths see Table 20.28 in (1978AJ03). See also (1981KE1E; thick target yields; $E_p = 1.75$ to 2.75 MeV), (1980CU09, 1982FI1C) and (1977PH02; theor.).

35. $^{19}\text{F}(p, n)^{19}\text{Ne}$

$$Q_m = -4.0207$$

$$E_b = 12.8447$$

Observed resonances are displayed in Table 20.27. See also (1980HU1D, 1980HU1J).

Table 20.25: Levels of ^{20}Ne from $^{19}\text{F}(p, p_0)$ ^a

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

^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 Resonance also observed in p_1, p_3, p_4 and p_5 yields.

Table 20.26: Resonances in $^{19}\text{F}(p, p')^{19}\text{F}^*$ ^a

E_p (keV)	J^π	Γ_{lab} (keV)	Γ_{p_1} (eV)	Γ_{p_2} (eV)	$\theta_{p_1}^2$ (%)	$\theta_{p_2}^2$ (%)	E_x in ^{20}Ne (MeV)
340	1^+	2.9	< 0.5	< 0.1	< 15		13.168
483	1^+	2.2	< 1.3	< 1.2			13.303
598	2^-	37	< 100	< 60	< 28	< 145	13.413
669	1^+	7.5	46	< 0.5	0.6	< 0.4	13.480
720		≈ 30	< 10000	< 10000			13.528
780		≈ 10	< 400	≈ 9000			13.585
831		8.3	< 6	≈ 2300			13.634
845	0^+	23	≈ 50	< 10	≈ 0.14	< 0.92	13.647
873	2^-	5.2	< 2	570	< 0.07	2.7	13.674
900		4.8	< 30	≈ 2200			13.699
935	1^+	8.0	3000	< 20	5.0	< 0.8	13.733
1092 ^b	2^+	0.8	173	592			13.882
1137		3.7	< 40	≈ 2100			13.924
≈ 1250		≈ 80	≈ 70000	< 4000			14.03
1290		19	< 600	≈ 900			14.070
1346	2^-	4.5	300	600	0.92	0.24	14.123
1372	2^-	15	700	1400	1.93	0.56	14.148
1422	1^+	14.6 ± 1	2200	≤ 35	0.56	≤ 0.11	14.195
1610		≈ 5					14.374
1660							14.421
1700							14.459
5879 ^c	$2^+; 2$		r				18.427

r = resonant.

^a For references see Table 20.29 in (1978AJ03).

^b (1979SU13): $\Gamma_{p_0} = 29$ eV.

^c Resonance also observed in p_3 , p_4 and p_5 yields.

Table 20.27: Resonances in $^{19}\text{F}(p, n)^{19}\text{Ne}$ ^a

E_p (MeV) ^b	Γ_{lab} (keV)	$^{20}\text{Ne}^*$ (MeV)
4.30	45	16.93
4.46	80	17.08
4.52	20	17.14
4.61	60	17.22
4.72	25	17.33
4.75	45	17.35
4.87		17.47
4.95	20	17.55
5.03		17.62
5.11		17.70
5.23		17.81
5.25		17.84
5.37		17.94
(5.44)		(18.01)
5.50		18.07
5.57		18.13
(5.62)		(18.18)
(5.69)		(18.25)
5.72		18.28
5.77		18.32
5.84		18.39
5.879 ± 0.007 ^c	10 ± 3	18.427
5.90		18.45
6.00		18.54
6.15		18.68
6.35		18.87
6.53		19.04
6.81		19.31
7.14		19.62
7.27		19.75
7.41		19.88

Table 20.27: Resonances in $^{19}\text{F}(\text{p}, \text{n})^{19}\text{Ne}$ ^a (continued)

E_{p} (MeV) ^b	Γ_{lab} (keV)	$^{20}\text{Ne}^*$ (MeV)
7.52		19.98
7.74		20.19
8.02		20.46
8.15		20.58
8.28		20.71
8.37		20.79
8.70		21.10
8.82		21.22
9.08		21.47
9.2		21.6
9.5		21.9
9.8		22.1
10.2		22.5

^a For references see Table 20.30 in (1978AJ03).

^b ± 5 keV for $E_{\text{x}} < 6.1$ MeV; ± 20 keV for $E_{\text{x}} < 9.1$ MeV.

^c Anomaly in n_0 and n_{1+2} yields: 2^+ ; $T = 2$.

36. $^{19}\text{F}(\text{p}, \alpha)^{16}\text{O}$

$Q_{\text{m}} = 8.1137$

$E_{\text{b}} = 12.8447$

Many resonances occur in this reaction. They are displayed in Tables 20.28, 20.29 and 20.30 depending on whether they are observed in the α_0 yield [Table 20.28], in the α_1 [or α_{π}] yield to $^{16}\text{O}^*(6.05)$ [Table 20.29] or in the α_2 , α_3 and α_4 yields [or in the yield of the γ -rays from $^{16}\text{O}^*(6.13, 6.92, 7.12)$] [Table 20.30]. 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). 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 (1978DE1D, 1980CU09; 0.70 to 2.68 MeV; α_0 , α_{π} , α_2 , α_3 , α_4), (1980DI03; 0.4 to 2.0 MeV; α_0 , $\alpha\gamma$) and (1977ST03; 12.4 to 18.0 MeV; α_0). In the latter work resonant structures with $\Gamma \approx 0.5$ to 1 MeV are reported at $E_{\text{p}} = 13.0, 14.3, 15.3, 16.5, (17.5)$, corresponding to $^{20}\text{Ne}^*(25.2, 26.4, 27.4, 28.5, (29.5))$ (1977ST03).

Table 20.28: Resonances for ground-state α -particles (α_0) in $^{19}\text{F}(p, \alpha_0)^a$

E_p (keV)	Γ_{lab} (keV)	θ_α^2 (%) ^a	$J\pi$	$^{20}\text{Ne}^*$ (MeV)
400	100		1^-	13.225
400	100		0^+	13.225
650 ± 20^b	200		1^-	13.462^h
710	35	0.6	(1^-)	13.519
733	66	1.0	2^+	13.541
777 ± 2^b	9 ± 1	0.02	2^+	13.583
842 ± 2^b	18 ± 1	0.16^c	$(2^+)^d$	13.644
≈ 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^+	13.904
1160	≈ 70	1.1	0^+	13.946
1235	≈ 70	1.2	1^-	14.017
≈ 1250	≈ 150	2.7	2^+	14.03
1350 ± 3^b	36 ± 1		2^+	14.127
1652 ± 5^b	90 ± 5			14.413
$1713 \pm 6^{b,e}$	72 ± 2		0^+	14.471
$1842 \pm 7^{b,e}$	122 ± 5		1^-	14.594
1901 ± 10^b				14.650
2110 ^f	75		$(2^+, 4^+)$	14.85
2310 ^f	90		(2^+)	15.04
2550	300		(1^-)	15.27
2590 ^f	300		(0^+)	15.30
2680	80			15.39
2730	60			15.44
2820	160			15.52
2940				(15.64)
3120	170			(15.81)
3340	105			16.02
3680	(100)			16.34
3860				16.51

Table 20.28: Resonances for ground-state α -particles (α_0) in $^{19}\text{F}(\text{p}, \alpha_0)$ ^a
(continued)

E_p (keV)	Γ_{lab} (keV)	θ_α^2 (%) ^a	J^π	$^{20}\text{Ne}^*$ (MeV)
3980	135			16.62
4130	100			16.77
4360	100			16.98
4460	95			17.08
4690	65			17.30
4900	90			17.50
4990	40			17.58
5879 ± 7	10 ± 3	g	$2^+; T = 2$	18.427

^a For earlier references and additional comments see Table 20.31 in (1978AJ03).

^b (1980DI03).

^c $\Gamma_{\alpha_0} \approx 0.06$ keV.

^d $J = 0$ from $^{19}\text{F}(\text{p}, \text{p})$; possibly $T = 0$.

^e See also (1978DE1D).

^f See also (1980CU09).

^g $\Gamma_{\alpha_0} \approx 0.3$ keV.

^h (1981OH04) find a weak resonance corresponding to the parity forbidden $J^\pi = 1^+$; $T = 1$ state $^{20}\text{Ne}^*(13.48)$: see text.

Longitudinally polarized protons with $E_p \approx 0.67$ MeV have been used to study $^{20}\text{Ne}^*(13.48)$ [$J^\pi = 1^+; T = 1$]: the maximum of the analyzing power was found to be $(6.6 \pm 2.4) \times 10^{-3}$. The parity mixing of the 670 keV resonance appears to be caused by the $T = 0$ continuum as well as by the 1^- state at $E_x = 13.46$ MeV (1981OH04). Anomalies are observed in $\alpha_0, \alpha_1, \alpha_2, \alpha_4$ and α_8 but not in $\alpha_3, \alpha_5, \alpha_7$ and α_9 corresponding to the formation of the $2^+; T = 2$ state at 18.43 MeV [$E_p = 5.88$ MeV] (1972KU24). See also (1979SU13, 1979TR1G, 1981KE1E), (1978ZI1A, 1980DI03; applications) and (1977GA1H, 1980BI05; theor.).

37. $^{19}\text{F}(\text{p}, ^8\text{Be})^{12}\text{C}$

$$Q_m = 0.8599$$

$$E_b = 12.8447$$

See (1978AJ03).

38. $^{19}\text{F}(\text{d}, \text{n})^{20}\text{Ne}$

$$Q_m = 10.6200$$

Table 20.29: Nuclear pair resonances (α_π) in $^{19}\text{F}(\text{p}, \alpha_\pi)$ ^a

E_p (keV)	Γ_{lab} (keV)	σ (mb)	θ_α^2 (%)	J^π	$^{20}\text{Ne}^*$ (MeV)
710	35	≈ 0.2	2	1^-	13.519
780	≈ 10	≈ 0.2	0.15	2^+	13.585
842	23	3.4	0.27	2^+ ^d	13.644
1115	50	1.5	3.6	2^+	13.904
1236	≈ 70	3	1.0	1^-	14.018
1367	30	6.0	0.29	2^+	14.143
1630 ^b	60				14.39
1720 ^b	95	≈ 18			14.48
1880 ^b	170				14.63
2080 ^c	60	12.1		(2^+)	14.82
2170 ^c	70	12.2		(0^+)	14.91
2330 ^c	70	17.0		(2^+)	15.06
2600	100				15.31
2680	100				15.39
2820	125				15.52
3120	145				15.81
3340	100				16.02
(3500)	(80)				(16.17)
(3590)	(115)				(16.25)
3960	200				16.60
4360	95				16.98
4690	< 150				17.30
4900	115				17.50
4990	40				17.58
5170	220				17.75

^a For references see Table 20.32 in (1978AJ03).

^b See also (1978DE1D).

^c (1980CU09): see also for partial widths.

^d See footnote ^d in Table 20.28.

Table 20.30: Resonances for 6 – 7 MeV γ -rays ($\alpha_2, \alpha_3, \alpha_4$) in $^{19}\text{F}(p, \alpha)$ ^a

E_p (keV)	Γ_{lab} (keV)	Γ_{α_2} (eV)	Γ_{α_3} (eV)	Γ_{α_4} (eV)	$J\pi$	$^{20}\text{Ne}^*$ (MeV)
226.9 ± 3.4	1.0	1000	< 2.5	< 2.5	2^-	13.060
340.46 ± 0.04	2.4 ± 0.2	2800	16	75	1^+	13.1680
483.8 ± 0.3^b	0.9 ± 0.1	700	19	190	1^+	13.3038
594 ± 3^b	25 ± 3					13.409
667.5 ± 2^b	6.7 ± 0.3					13.479
832.1 ± 1^b						13.635
872.11 ± 0.20^b	4.7 ± 0.2	2200	620	180	2^-^d	13.6729
935.4 ± 1.3^b	8.1 ± 0.5	2900	110	720	1^+	13.733
1087.7 ± 1^b	0.15 ± 0.05					13.878
1135.6 ± 1^b						13.923
1280 ± 1^b						14.060
1347.7 ± 1^b	4.9 ± 0.7	2250	650	1200	2^-	14.124
1371.0 ± 1^b	12.4 ± 1.0	6650	700	300	2^-	14.147
1603 ± 2^b						14.367
1692 ± 2^b	35 ± 3					14.451
1949 ± 2.5^b	40 ± 10					14.695
2030 ± 3.0^b	120 ± 20					14.722
2320	85					15.05
2510	30					15.23
2630	90					15.34
2800	60					15.50
3020	30					15.71
3190	80					15.87
3490	40					16.16
3920	30					16.57
4000	110					16.64
4090 ^c					$0^+; T = 2$	16.73
4290	50					16.92
4490	30					17.11
4570	30					17.18
4710	30					17.32

Table 20.30: Resonances for 6 – 7 MeV γ -rays ($\alpha_2, \alpha_3, \alpha_4$) in $^{19}\text{F}(\text{p}, \alpha)$ ^a
(continued)

E_p (keV)	Γ_{lab} (keV)	Γ_{α_2} (eV)	Γ_{α_3} (eV)	Γ_{α_4} (eV)	J^π	$^{20}\text{Ne}^*$ (MeV)
4780	35					17.38
4990	20					17.58
5070	35					17.66
5200	70					17.78

^a See Table 20.33 in (1978AJ03) for earlier references and for additional comments.

^b (1980DI03).

^c See (1972AJ02).

^d See, however, footnote ^j in Table 20.21.

Levels of ^{20}Ne derived from reported neutron groups are displayed in Table 20.31. Angular distributions have been measured for $E_d = 0.5$ to 6.1 MeV: see (1972AJ02). See also (1978AJ03).

$$39. \ ^{19}\text{F}(^3\text{He}, \text{d})^{20}\text{Ne} \quad Q_m = 7.3511$$

Levels of ^{20}Ne observed in this reaction are displayed in Table 20.32. Deuteron angular distributions have been studied at $E(^3\text{He}) = 9.5$ to 21 MeV: see (1978AJ03). See also (1979GR11, 1980MU13; theor.).

$$40. \ ^{19}\text{F}(\alpha, \text{t})^{20}\text{Ne} \quad Q_m = -6.9694$$

Angular distributions have been measured at $E_\alpha = 18.5$ and 28.5 MeV [see (1972AJ02, 1978AJ03)] and at 25.0 MeV (1978LE08; t_0, t_1, t_2). The distributions of the tritons to $^{20}\text{Ne}^*(0, 1.63, 4.25)$ have been analyzed by (1974OB02): $C^2S = 0.08, 0.16$ and 0.0 (CCBA) [the DWBA results are nearly the same]. Agreement with the values obtained in the (d, n) and ($^3\text{He}, \text{d}$) reactions is poor (1974OB02). See also (1979BA2W).

$$41. \ ^{19}\text{F}(^7\text{Li}, ^6\text{He})^{20}\text{Ne} \quad Q_m = 2.867$$

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

Table 20.31: Neutron groups from $^{19}\text{F}(d, n)^{20}\text{Ne}$ ^a

E_x (MeV \pm keV)	l_p	$J^\pi; T$
0	0	0^+
1.74 ± 30	2	2^+
4.20 ± 40		
4.96 ± 50		
5.62 ± 40		
6.80 ± 10	0	0^+
7.16 ± 90		
7.41 ± 50		
7.90 ± 40		
(8.71 ± 10)		
9.15 ± 40		
(9.50 ± 40)		
10.01 ± 30		
10.32 ± 50		
10.59		
10.879 ± 40	2	$T = 1$
11.03 ± 80 ^b		
11.26 ± 40	0	$1^+; (1)$
11.568 ± 35	2	$(T = 1)$
11.915 ± 30		
(12.09 ± 10)	^c	$(T = 1)$
(12.15 ± 10)	^c	$(T = 0)$
12.179 ± 25		
(12.20 ± 10)	^c	$(T = 1)$
12.25 ± 10	2	$T = 1$
12.397 ± 20	0	$T = 0$
13.086 ± 15		
13.170 ± 15	0	$1^+; (1)$
13.481 ± 15	0	$1^+; 1$
13.650 ± 15	0	$(0^+); 1$
13.882 ± 15		

^a For references and additional comments see Tables 20.34 in (1978AJ03) and 20.31 and 20.32 in (1972AJ02).

^b This state decays to $^{20}\text{Ne}^*(1.63)$.

^c Weak group.

Table 20.32: States of ^{20}Ne from $^{19}\text{F}(^3\text{He}, d)^{20}\text{Ne}$ ^a

E_x (MeV \pm keV)	Γ (keV)	nlj ^b	$J^\pi; T$	K^π	$(2J + 1)C^2S$	
					DWBA	CCBA ^c
0		$2s_{1/2}$	0^+	0_1^+		0.37
1.6353 ± 1.8		$1d_{5/2}$	2^+	0_1^+		1.7
4.249 ± 2.5		n.s.	4^+	0_1^+		0.08
4.968 ± 3		$1p_{3/2}$	2^-	2^-	(0.03)	0.03
5.623 ± 3		$1f_{7/2}$	3^-	2^-	(0.09)	0.06
5.785 ± 3		$2p_{3/2}$	1^-	0^-	0.16	0.11
6.722 ± 3		$2s_{1/2}$	0^+	0_2^+	0.52	0.30
7.00		$1f_{7/2}$	4^-	2^-		0.12
7.156 ± 8		$1f_{7/2}$	3^-	0^-	0.42	0.12
7.422 ± 3		$1d_{5/2}$	2^+	0_2^+	0.79	0.50
7.829 ± 10		$1d_{5/2}$	2^+	0_3^+	0.06	0.046
≈ 8.3	≈ 800	$2s_{1/2}$	0^+	0_4^+	0.13	
8.45		n.s.	5^-	2^-		
8.70		n.s.	1^-			
8.769 ± 10		n.s.	6^+	0_1^+		
8.8	broad	$1d_{5/2}$	2^+		0.21	
8.841 ± 10		$2p_{3/2}$	1^-		(0.01)	
9.03		n.s.	4^+	0_3^+		
9.12		n.s.	3^-			
9.305 ± 10		$1d_{5/2}$	$(1, 2, 3)^+$		0.04	
9.469 ± 10		$1d_{5/2}$	2^+		0.03	
9.859 ± 3		$1d_{5/2}$	3^+ ^e		2.37	
9.92		n.s.	(1^+)			
9.99		n.s.	4^+	0_2^+		
10.257 ± 15		$1d_{5/2}$	$2^+; 1$		0.07	
10.40						
10.55						
10.568 ± 15	27	$1d_{5/2}$	2^+		0.05	
10.815 ± 15	12	$1d_{5/2}$	2^+		0.05	
10.860 ± 15		$1d_{5/2}$	$3^+; 1 \text{ }^e$		2.82	

Table 20.32: States of ^{20}Ne from $^{19}\text{F}(^3\text{He}, d)^{20}\text{Ne}$ ^a (continued)

E_x (MeV \pm keV)	Γ (keV)	nlj ^b	$J^\pi; T$	K^π	$(2J + 1)C^2S$	
					DWBA	CCBA ^c
10.951 \pm 15						
11.067 \pm 15		n.s.	(4 ⁺ ; 1)			
11.239 \pm 15					see ^a	
11.27 \pm 15	73	n.s.				
11.549 \pm 15		1d _{5/2}	3 ⁺ ^e		1.00	
11.83 \pm 15	81	1d _{5/2}			0.10	
11.992 \pm 15		n.s.	(8 ⁺)	0 ₁ ⁺		
12.082 \pm 15		1d _{5/2}			0.35	
12.190 \pm 15	< 0.1	1d _{5/2}	(1, 2, 3) ^e		2.10	
12.367 \pm 15 ^d	< 200		3 ⁻ ^e		see ^{a,e}	
12.423 \pm 15	160	1d _{5/2}	(2 ⁺)		0.19	
12.503 \pm 15		1d _{5/2}			0.02	
12.823 \pm 15		2s _{1/2}			0.15	
13.037 \pm 15		1d _{5/2}				
13.135 \pm 15						
13.270 \pm 15						

n.s. = not stripping.

^a For complete references see Table 20.35 in (1978AJ03).

^b Orbital for direct transfer.

^c Average of values displayed in Table 20.35 (1978AJ03).

^d α -decays to $^{16}\text{O}^*(6.13)$ (1977MA07).

^e Gamma-ray measurements (1977MA07): $E_x = 9.88 \pm 0.03, 10.89 \pm 0.03, 11.59 \pm 0.03, 12.22, 12.40 \pm 0.04$ MeV. The E_x measured by (1975BE02) appear to be systematically low by 14 – 30 keV: see (1977MA07).

42. $^{20}\text{F}(\beta^-)^{20}\text{Ne}$

$$Q_m = 7.0259$$

The decay is principally to $^{20}\text{Ne}^*(1.63)$ with a half-life of 11.00 ± 0.02 sec: see reaction 1 in ^{20}F . Besides the principal decay to $^{20}\text{Ne}^*(1.63)$ [$\log f_0t = 4.97$], ^{20}F also decays to $^{20}\text{Ne}^*(4.97)$ [$J^\pi = 2^-$] with a branching ratio of $0.0090 \pm 0.0004\%$ [$\log f_0t = 7.16 \pm 0.02$; however the

transition is first-forbidden] (1981AL13). The upper limit for the ground-state decay is 0.001% [$\log f_0 t > 10.5$] (1978CA02). For other values see Table 20.36 in (1978AJ03). The energy of the γ -ray from $^{20}\text{Ne}^*(1.63)$ is 1633.602 ± 0.015 keV (1981WA06). 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 (1981AL13). The shape of the β -spectrum has been measured by (1978CA02) and compared with predictions of the CVC theory: the results are not inconsistent with the predictions of CVC. β - γ correlation measurements lead to an upper limit for the second-class current contribution to the correlation which is consistent with zero (1978DU14, 1978TR07). For the earlier work see (1978AJ03). See also (1982QUZY), (1976BE1E, 1977DE1W, 1978CA1H) and (1976KI1N, 1977OK1A, 1978BE58, 1978CA1H, 1981HO06, 1981KA32; theor.).

- | | |
|---|------------------|
| 43. (a) $^{20}\text{Ne}(\gamma, n)^{19}\text{Ne}$ | $Q_m = -16.8653$ |
| (b) $^{20}\text{Ne}(\gamma, 2n)^{18}\text{Ne}$ | $Q_m = -14.419$ |
| (c) $^{20}\text{Ne}(\gamma, p)^{19}\text{F}$ | $Q_m = -12.8447$ |
| (d) $^{20}\text{Ne}(\gamma, \alpha)^{16}\text{O}$ | $Q_m = -4.7309$ |

The photoneutron cross section (bremsstrahlung photons) shows peaks at $E_x = 17.78 \pm 0.05$, 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 \cdot mb [exhausting $\approx 20\%$ of the dipole sum] (1981AL05). The cross section for (γ, Tn) using monoenergetic photons shows a structure at 18 MeV and some fluctuations atop the broad giant resonance, $\sigma_{\text{max}} \approx 7$ mb. The double photoneutron cross section, $\sigma(\gamma, 2n)$, is dominated by a single peak at ≈ 20.5 MeV, $\sigma_{\text{max}} \approx 1.1$ mb (1974VE06). For reactions (c) and (d) see (1978AJ03) and reaction 45. See also (1980FL1C; theor.).

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

See (1980AC1A, 1981WI1E).

- | | |
|---|------------------|
| 45. (a) $^{20}\text{Ne}(e, e)^{20}\text{Ne}$ | |
| (b) $^{20}\text{Ne}(e, ep)^{19}\text{F}$ | $Q_m = -12.8447$ |
| (c) $^{20}\text{Ne}(e, e\alpha)^{16}\text{O}$ | $Q_m = -4.7309$ |

The ^{20}Ne charge radius, $\langle r^2 \rangle^{1/2} = 3.004 \pm 0.025$ fm (1981KN07). Form factors for many excited states of ^{20}Ne with $E_x < 8$ MeV have been reported: see (1978AJ03).

At $E_e = 39$ and 56 MeV, the 180° inelastic scattering is dominated by the transition to a $J^\pi = 1^+$, $T = 1$ state at $E_x = 11.22 \pm 0.05$ MeV with $\Gamma_{\gamma_0} = 11.2_{-1.8}^{+2.1}$ eV. A subsidiary peak is observed

corresponding to a state at an $E_x = 0.35 \pm 0.03$ MeV higher [if $J^\pi = 1^+$ or 2^+ , $\Gamma_{\gamma_0} = 0.65 \pm 0.18$ or 0.40 ± 0.13 eV]. A number of small peaks are also reported corresponding to $E_x \approx 12.0, 12.9, 13.9, 15.8, 16.9, 18.0$ and 19.0 MeV (1971BE18, and W.L. Bendel, private communication). Prominent electric dipole peaks are reported at $E_x = 17.7, 19.1, 20.2$ and 23 MeV, in addition to weaker structures between 12.5 and 15 MeV; and prominent electric-quadrupole peaks are observed at $E_x = 13.0, 13.7, 14.5, 15.0, 15.4$ and 16.2 MeV and there is a broad quadrupole excitation between 16 and 25 MeV (1978SZ02; $E_e = 59.5$ to 119.7 MeV): the GDR cross section 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 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 $E_x = 15$ to 24 MeV is dominated by an E1 resonance [1^- ; $T = 1$, with an admixture of $T = 0$ which permits the α_0 decay] at $E_x = 20$ MeV; lesser E1 structures are reported at $E_x = 16.7, 17.1, 21$ and 22 MeV. A relatively strong 2^+ ; $T = 0$ resonance appears at $E_x = 18.5$ MeV, and evidence is reported for increasing E2 strength below 16 MeV (1975SK06).

See also (1978GU13, 1978HA43, 1978SI11, 1979CH2E, 1979IN06, 1979SI12, 1981ST1B; theor.).

46. $^{20}\text{Ne}(n, n)^{20}\text{Ne}$

See (1978AJ03).

47. (a) $^{20}\text{Ne}(p, p)^{20}\text{Ne}$

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

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

Angular distributions of elastically scattered protons and of a number of inelastic groups have been measured for $E_p = 2.15$ to 41.8 MeV [see (1978AJ03)] and at $E_p = 4.5$ to 7.9 MeV (1981FE05; p_0), 35.2 MeV (1980FA07; p_0) and $E_p = 65$ MeV (1979SA38; p_0).

Angular distributions at $E_p = 24.5$ and 30 MeV for the 0^+ , 2^+ and 4^+ members of the ground-state $K^\pi = 0^+$ band are well fitted using coupled-channels calculations and deformation parameters of $\beta_2 = +0.47 \pm 0.04$ and $\beta_4 = +0.28 \pm 0.05$. When the 6^+ state is included [$^{20}\text{Ne}^*(8.78)$], the fit is improved if $\beta_6 = -0.10$ is included: see (1978AJ03).

For yield measurements [p_0, p_1] see (1981FE05). See (1981CA02) for reaction (b). For reaction (c) see (1978AJ03). See also (1981AZ1A), (1979RA1C; astrophys.) and (1977PH02, 1978MA2K, 1979MA01, 1981SM1B; theor.).

48. $^{20}\text{Ne}(d, d)^{20}\text{Ne}$

Angular distributions have been reported at $E_d = 10.0$ to 52 MeV [see (1978AJ03)] and at $E_d = 10 - 12$ MeV (1979DA17; d_0, d_1) and 52 MeV (1980MA10; d_0). See also (1979GR11; theor.).

49. $^{20}\text{Ne}(t, t)^{20}\text{Ne}$

See (1978AJ03).

50. $^{20}\text{Ne}(^3\text{He}, ^3\text{He})^{20}\text{Ne}$

Angular distributions have been measured at $E(^3\text{He}) = 10$ to 35 MeV and at 68 MeV: see (1978AJ03). See also (1975AU01: S_α) and (1977MA1Y; theor.).

51. (a) $^{20}\text{Ne}(\alpha, \alpha)^{20}\text{Ne}$

(b) $^{20}\text{Ne}(\alpha, 2\alpha)^{16}\text{O} \quad Q_m = -4.7309$

Angular distributions have been measured at $E_\alpha = 3.8$ to 155 MeV [see (1978AJ03)], at 21.7 to 23.7 MeV (1982PE1C) and at $25.8, 27.0$ and 31.1 MeV (1978CO11; α_0). A coupled-channel analysis of angular distributions at $E_\alpha = 104$ MeV leads to $\beta_2 = +0.35 \pm 0.01, \beta_4 = +0.11 \pm 0.01, Q_{20} = +0.46 \pm 0.02$ b and $Q_{40} = +0.026 \pm 0.002$ b² (1972RE05). At $E_\alpha = 155$ MeV (1976KN05) find that the strength concentrated in the giant quadrupole resonance exhausts more than 30% of the isoscalar energy-weighted sum rule. See also (1979KN1F).

For yield measurements see (1978AJ03) and (1981DA1G). For reaction (b) see (1978AJ03) and (1980WA07; 140 MeV: $S_\alpha = 0.202 \pm 0.029$). See also (1981AN1K), (1979RA1C; astro-phs.), (1977MA2E, 1980SPIE, 1980ST1J) and (1978AN20, 1978YO1F, 1979CO15, 1979GO24, 1982BU1D; theor.).

52. $^{20}\text{Ne}(^7\text{Li}, ^7\text{Li})^{20}\text{Ne}$

Angular distributions have been reported at $E(^7\text{Li}) = 36$ MeV (1976CO23; g.s.) and 68 and 89 MeV (1979BR03; $^{20}\text{Ne}^*(0, 1.63)$). see also (1979VA1B).

53. (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 scattering angular distributions have been measured at $E(^{10}\text{B}) = 65.9$ MeV (1979MO14) and $E(^{11}\text{B}) = 115$ MeV (1981GO11).

54. (a) $^{20}\text{Ne}(^{12}\text{C}, ^{12}\text{C})^{20}\text{Ne}$
 (b) $^{20}\text{Ne}(^{12}\text{C}, \alpha^8\text{Be})^{20}\text{Ne}$ $Q_m = -7.3667$

Elastic angular distributions have been obtained at $E(^{12}\text{C}) = 22.2$ to 42.7 MeV [see (1978AJ03)] and 77.4 MeV (1979MO14) and at $E(^{20}\text{Ne}) = 65.9$ MeV (1978DO01) and 74 and 75.2 MeV (1979FO22, 1979SH18; back angles). See also (1980RI1D, 1980SH1T). For yield and fusion measurements see (1978DO01, 1979FO22, 1979SA26, 1979SH18, 1980CO08, 1980HU12, 1980RI1D, 1980SK1A, 1980TS03, 1981DE20, 1981SH1R, 1982DE10). See also (1981VA1E; theor.). For pion production see (1979NA12). For reaction (b) see (1981OS07, 1982DE10). See also (1980MA1T, 1981ST20), (1978RO1L, 1981RO1W; astrophys.), (1979GO1C, 1981SC1J) and (1978TR08, 1978VO06, 1978VO13, 1980OH05, 1981AB1A, 1981AN1D, 1982RA1D; theor.).

55. $^{20}\text{Ne}(^{16}\text{O}, ^{16}\text{O})^{20}\text{Ne}$

Angular distributions have been studied at $E(^{20}\text{Ne}) = 50$ MeV (1976ST18) and 94.8 MeV (1977MO1A, 1979MO14) involving $^{16}\text{O}_{\text{g.s.}}$ and $^{20}\text{Ne}^*(0, 1.63, 4.25)$. Yield and fusion measurements are reported by (1978GA1G, 1978SH1P, 1979GA1K, 1979GA1F, 1979KO2H, 1979RE1E, 1980DI1B, 1980GA1F, 1981GA1D). For pion production see (1981GA1F). See also (1979VA1B, 1981BR1P) and (1979JA11, 1979LE1B, 1980OH05, 1981AN1D, 1982SM1D; theor.).

56. $^{20}\text{Ne}(^{19}\text{F}, ^{19}\text{F})^{20}\text{Ne}$

See (1979SI1K; theor.).

57. $^{20}\text{Ne}(^{20}\text{Ne}, ^{20}\text{Ne})^{20}\text{Ne}$

For yield and fusion measurements see (1978SH1P, 1980DI1B). See also (1979SH22) and (1979CA11, 1979CU1C, 1979PI03, 1979RA06, 1979YA12, 1980BO1J, 1980CU1D, 1981BO11, 1981CU1G, 1981CU1K, 1981JE1B, 1982SM1D; theor.).

58. $^{20}\text{Ne}(^{24}\text{Mg}, ^{24}\text{Mg})^{20}\text{Ne}$

Elastic angular distributions have been measured at $E(^{20}\text{Ne}) = 50, 60, 80, 90$ and 100 MeV (1981BE22). For yield and fusion cross sections see (1981BE22, 1981GR08). See also (1980KO46; theor.).

59. $^{20}\text{Ne}(^{27}\text{Al}, ^{27}\text{Al})^{20}\text{Ne}$

For yield measurements see (1978OB1B, 1979OB1A, 1980OB1A, 1981NA07). See also (1978GE08, 1980MA1T, 1981WE1E), (1977SC1G, 1979BE16) and (1979SA10, 1979YA1F; theor.).

60. $^{20}\text{Ne}(^{28}\text{Si}, ^{28}\text{Si})^{20}\text{Ne}$

See (1978SA1T, 1979SA10, 1979YA1F; theor.).

61. $^{20}\text{Ne}(^{32}\text{S}, ^{32}\text{S})^{20}\text{Ne}$

See (1978AJ03).

62. $^{20}\text{Ne}(^{40}\text{Ca}, ^{40}\text{Ca})^{20}\text{Ne}$

Elastic angular distributions are reported at $E(^{20}\text{Ne}) = 44.1$ to 70.4 MeV (1979NG02), 54 and 60.5 MeV (1978NG01; also to $^{20}\text{Ne}^*(1.63)$) and 151 MeV (1980SE06). For yield and fusion measurements see (1978TR1H, 1978NG01, 1979NG02, 1980SE06, 1981KO1N). See also (1979UD02, 1980MA34; theor.).

63. $^{20}\text{Na}(\beta^+)^{20}\text{Ne} \quad Q_m = 13.887$

^{20}Na has a half-life of 446 ± 3 msec: see reaction 1 in ^{20}Na . It decays to a number of states of ^{20}Ne , principally $^{20}\text{Ne}^*(1.63)$: see Table 20.33. The ratio of the mirror decays $^{20}\text{Na} \xrightarrow{\beta^+} ^{20}\text{Ne}^*(1.63)$ and $^{20}\text{F} \xrightarrow{\beta^-} ^{20}\text{Ne}^*(1.63)$, $(ft)^+/(ft)^- = 1.026 \pm 0.024$ (1973TO08), 1.033 ± 0.022 (1976IN06). β - γ 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 (1978DU14, 1981TR04). See also (1981CL1D), (1977DE1W, 1977GA1E, 1978AJ03, 1978RA2A) and (1978BE58, 1978CA1H, 1980OK01, 1981HO06; theor.).

Table 20.33: Decay of ^{20}Na ^a

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

^a For additional comments and references see Table 20.37 in (1978AJ03).

^b 10.278 \pm 5 (1973TO08).

^c Electron capture + β^+ .

^d Includes radiative, nuclear size, lepton wavelength, electron screening and electron capture corrections (1976IN06).

64. $^{21}\text{Ne}(p, d)^{20}\text{Ne}$ $Q_m = -4.537$

Angular distributions have been measured for $d_0 \rightarrow d_3$ at $E_p = 14.1$ and 20 MeV: see (1978AJ03).

65. $^{21}\text{Ne}(d, t)^{20}\text{Ne}$ $Q_m = -0.504$

The $T = 1$ states observed in this reaction, and the analog states observed in ^{20}F in the (d, ^3He) reaction, are displayed in Table 20.15. $T = 0$ states are presented in Table 20.34.

66. $^{21}\text{Ne}(^3\text{He}, \alpha)^{20}\text{Ne}$ $Q_m = 13.816$

Table 20.34: $T = 0$ states of ^{20}Ne from $^{21}\text{Ne}(d, t)^{20}\text{Ne}$ (1974MI13) ^a

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

^a For $T = 1$ states see Table 20.15.

^b Values used in DWBA calculations.

^c From Table 20.17.

^d Unresolved.

^e $K^\pi = (1^-)$.

^f See, however, discussion in (1974MI13).

See (1978AJ03) and (1979CO15; theor.).

67. $^{22}\text{Ne}(p, t)^{20}\text{Ne}$

$$Q_m = -8.644$$

Angular distributions have been reported at $E_p = 26.9$ to 43.7 MeV [see (1978AJ03)] and at $E_p = 23$ MeV (1980AN21; t_0). The angular distributions of the tritons to the ground state of ^{20}Ne and to the first 0^+ , $T = 2$ state [$E_x = 16.722 \pm 0.025$ MeV (1969HA38)] have been fitted by $L = 0$ and the tritons to $^{20}\text{Ne}^*(18.5)$ by $L = 2$. The latter is the first 2^+ , $T = 2$ state. The 0^+ , $T = 2$ state [$^{20}\text{Ne}^*(16.73)$] decays by α_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 (1970MC04). The ratios of the cross section for formation of the analog states $^{20}\text{Ne}^*(10.27)/^{20}\text{F}^*(0)$ and $^{20}\text{Ne}^*(12.25 \pm 0.03)/^{20}\text{F}^*(1.85)$ are 2.00 ± 0.20 and 1.40 ± 0.15 , respectively, at $E_p = 45$ MeV (1969HA19).

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

$$68. \ ^{23}\text{Na}(p, \alpha)^{20}\text{Ne} \quad Q_m = 2.377$$

Angular distributions have been measured at $E_p = 10.0$ and 45.5 MeV: see (1972AJ02). For yield measurements see (1978AJ03) and (1979KU06). See also (1966YO1A, 1979CH2D) and (1975ZI1A, 1981ZY04; astrophys.).

$$69. \ ^{23}\text{Na}(^3\text{He}, ^6\text{Li})^{20}\text{Ne} \quad Q_m = -1.643$$

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

$$\begin{aligned} 70. \text{ (a) } & \ ^{24}\text{Mg}(\gamma, \alpha)^{20}\text{Ne} & Q_m &= -9.3125 \\ \text{ (b) } & \ ^{24}\text{Mg}(p, p\alpha)^{20}\text{Ne} & Q_m &= -9.3125 \\ \text{ (c) } & \ ^{24}\text{Mg}(\alpha, 2\alpha)^{20}\text{Ne} & Q_m &= -9.3125 \end{aligned}$$

See (1978AJ03). For reaction (b) see also (1981CA02).

$$71. \ ^{24}\text{Mg}(d, ^6\text{Li})^{20}\text{Ne} \quad Q_m = -7.839$$

Angular distributions have been studied to many states of ^{20}Ne at $E_d = 28$ and 35 MeV [see (1978AJ03)] and at $E_d = 28$ MeV (1978FO08), 54.25 MeV (1980YA02), 55 MeV (1981VE05) and at 80 MeV (1979OE02, 1980OE01): see Table 20.35. See also (1978BE1H) and (1978TA1F; theor.).

$$72. \ ^{24}\text{Mg}(^3\text{He}, ^7\text{Be})^{20}\text{Ne} \quad Q_m = -7.726$$

Angular distributions have been studied at $E(^3\text{He}) = 25.5$ and 70 MeV: see (1978AJ03). For polarization measurements see (1980LE1J, 1981LE1F).

Table 20.35: States of ^{20}Ne from $^{24}\text{Mg}(d, ^6\text{Li})^{20}\text{Ne}$

E_x (MeV \pm keV) ^a	L ^a	$J\pi$ ^a	S_α ^{a,b}	S_α ^c	S_α ^d
0	0	0 ⁺	1.00	\equiv 1.00	\equiv 1.00
1.632	2	2 ⁺	0.80	0.79	0.31
4.248	4	4 ⁺	0.91	see ^c	0.85
4.963 \pm 7					
5.619	3	3 ⁻	3.02	8.15	3.1
5.786 \pm 7	1	1 ⁻	0.24	1.6	0.42 ^d
6.715 \pm 10	0	0 ⁺	0.04	see ^c	
7.004 \pm 7					
7.180 \pm 7	see ^a		see ^a	1.1	0.67 ^d
7.416 \pm 7	2	2 ⁺	0.19	see ^c	0.67
7.829	2	2 ⁺	see ^a	see ^c	5.9 ^d
8.449	5	5 ⁻	1.02	\approx 1	2.0
8.704 \pm 15	1	1 ⁻		see ^c	
8.777	6	6 ⁺	1.64	1.2	7.0
8.86 \pm 20	1	1 ⁻	0.07	see ^c	
9.026 \pm 7	4	4 ⁺	see ^a		14 ^d
9.100 \pm 15	3	3 ⁻	0.30		
9.300 \pm 7					
9.466 \pm 7					
9.943 \pm 15					
10.04 \pm 30	4		0.34	0.70	
10.27 ^c				0.34	
10.40 ^c				0.66	
10.572 \pm 7	2		0.16		
10.848 \pm 7	2 + 3		see ^a	0.32	
10.90 \pm 20					
11.00 \pm 20	4		0.27	0.32	
11.22 \pm 20	1		0.12		
11.30 \pm 20	2		0.08		
11.56 \pm 20					
11.85 \pm 20	2		0.13		

Table 20.35: States of ^{20}Ne from $^{24}\text{Mg}(d, ^6\text{Li})^{20}\text{Ne}$ (continued)

E_x (MeV \pm keV) ^a	L ^a	J^π ^a	S_α ^{a,b}	S_α ^c	S_α ^d
11.92 \pm 20	4		0.32	0.13	
11.95 ^c				1.2	
11.96 ^c				0.32	
12.39 \pm 20	0 + 3		see ^a	see ^c	
12.54 \pm 20					
12.95 \pm 20					
13.34 \pm 20					
13.68 \pm 20					
13.91 \pm 20					

^a (1981VE05): $E_d = 55$ MeV. E_x values without uncertainties were used for calibration. L -values shown are the dominant ones.

^b Average of values from ZRDWBA and FRDWBA analyses. K^π assignments are also discussed by (1981VE05). See also (1976CO23, 1980YA02) for S_α .

^c (1980OE01): $E_d = 80$ MeV; DWUCK 5 analysis; values recalculated relative to unity for the ground state.

^d (1978FO08): $E_d = 28$ MeV; DWBA analysis; values recalculated relative to unity for the ground state. K^π assignments are also discussed.

$$73. \ ^{24}\text{Mg}(\alpha, \ ^8\text{Be})^{20}\text{Ne} \quad Q_m = -9.404$$

See (1980WO1C, 1981WO1A) and (1982SH02; theor.).

$$74. \text{ (a) } \ ^{24}\text{Mg}(^{12}\text{C}, \ ^{16}\text{O})^{20}\text{Ne} \quad Q_m = -2.151$$

$$\text{ (b) } \ ^{24}\text{Mg}(^{16}\text{O}, \ ^{20}\text{Ne})^{20}\text{Ne} \quad Q_m = -4.582$$

$$\text{ (c) } \ ^{24}\text{Mg}(^{18}\text{O}, \ ^{22}\text{Ne})^{20}\text{Ne} \quad Q_m = 0.355$$

For reaction (a) see (1978NO02). See also (1980LE21; theor.). For reaction (b) see (1979LA07; theor.). For reaction (c) see (1980MO1F).

$$75. \ ^{27}\text{Al}(^{16}\text{O}, \ \alpha)^{20}\text{Ne} \quad Q_m = -17.313$$

See (1980SA1H).

$$76. \text{}^{28}\text{Si}(\alpha, \text{}^{12}\text{C})\text{}^{20}\text{Ne} \quad Q_m = -16.873$$

See (1980BE04, 1980BE15: $E_\alpha = 90.3$ MeV).

$$77. \text{}^{28}\text{Si}(\text{}^{18}\text{O}, \text{}^{26}\text{Mg})\text{}^{20}\text{Ne} \quad Q_m = 0.981$$

See (1979ME12).

^{20}Na
(Figs. 11, 12 and 13)

GENERAL: (See also (1978AJ03).)

(1977SI1D, 1978WO1E, 1979BE1H, 1980OK01, 1981AY01).

$$J = 2 \text{ (1975SC20);}$$

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

1. $^{20}\text{Na}(\beta^+)^{20}\text{Ne}$ $Q_m = 13.887$

^{20}Na decays by positron emission to $^{20}\text{Ne}^*(1.63)$ and to a number of other excited states of ^{20}Ne : see Table 20.33 and reaction 63 in ^{20}Ne . The half-life of ^{20}Na is 446 ± 3 msec; $J^\pi = 2^+$: see (1978AJ03).

2. $^{16}\text{O}(^{12}\text{C}, ^8\text{Li})^{20}\text{Na}$ $Q_m = -32.528$

See (1979RA10).

3. $^{20}\text{Ne}(p, n)^{20}\text{Na}$ $Q_m = -14.669$

Neutron groups have been observed at $E_p = 22.9$ MeV to states with $E_x < 1.4$ MeV: see Table 20.40 in (1978AJ03).

4. $^{20}\text{Ne}(^3\text{He}, t)^{20}\text{Na}$ $Q_m = -13.906$

Triton groups have been observed at $E(^3\text{He}) = 32$ MeV to nine states of ^{20}Na : see Table 20.40 in (1978AJ03).

5. $^{20}\text{Mg}(\beta^+)^{20}\text{Na}$ $Q_m = 10.724$

The first 0^+ ; $T = 2$ state in ^{20}Na is reported at $E_x = 6.57 \pm 0.05$ MeV. It decays by proton emission: see ^{20}Mg .

Table 20.36: Energy levels of ^{20}Na

E_x (MeV \pm keV)	$J^\pi; T$	$\tau_{1/2}$ or $\Gamma_{\text{c.m.}}$	Decay	Reactions
0	$2^+; 1$	$\tau_{1/2} = 446 \pm 3$ msec	β^-	1, 3, 4
0.591 ± 12			(γ)	3, 4
0.768 ± 8			(γ)	3, 4
(0.85 ± 50)			(γ)	4
0.958 ± 8			(γ)	3, 4
(1.010 ± 14)			(γ)	3
1.310 ± 10			(γ)	3, 4
1.92 ± 40				4
2.89 ± 50		a		4
4.33 ± 100		a		4
6.57 ± 50	$0^+; 2$		p	5

^a Broad or unresolved.

^{20}Mg

(Figs. 12 and 13)

^{20}Mg has been populated in the $^{24}\text{Mg}(\alpha, ^8\text{He})$ reaction [see (1978AJ03)], and in the $^{20}\text{Ne}(^3\text{He}, 3n)$ reaction at 70 MeV (1981AY01, 1979MO02). The super-allowed decay of ^{20}Mg to the first $T = 2$ ($J^\pi = 0^+$) state of ^{20}Na [$E_x = 6.57 \pm 0.05$ 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_{-50}^{+80} msec leading to a branching ratio of $(3 \pm 2)\%$ for the super-allowed decay; $\log ft = 3.18$. The results for $A = 20$ are in agreement with the quadratic form of the IMME (1981AY01). See also (1978AJ03) and (1979BE1H, 1980TR1E, 1981HA2C).

^{20}Al

(Not illustrated)

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

References

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References are arranged and designated by the year of publication followed by the first two letters of the first-mentioned author's name and then by two additional characters. Most of the references appear in the National Nuclear Data Center files (Nuclear Science References Database) and have NNDC key numbers. Otherwise, TUNL key numbers were assigned with the last two characters of the form 1A, 1B, etc. In response to many requests for more informative citations, we have, when possible, included up to ten authors per paper and added the authors' initials.

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