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Energy Levels of Light Nuclei $A = 19$

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Abstract: An evaluation of $A = 5$–24 was published in *Nuclear Physics* 11 (1959), p. 1. This version of $A = 19$ 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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Table 19.1: Energy levels of ^{19}O

E_x (MeV $\pm$ keV)	J^π	τ (sec)	Decay	Reactions
0	$\frac{5}{2}^+, (\frac{3}{2}^+)$	$\tau_{1/2} = 29$	β^-	1, 3, 4, 7
0.096 ± 11	$\frac{3}{2}^\pm, \frac{5}{2}^+$	$\tau_m = (1.75 \pm 0.3) \times 10^{-9}$	γ	4
1.469 ± 11	$\frac{1}{2}^+$		γ	4

^{19}O

(Fig. 40)

GENERAL:

Theory: See (1955EL1A, 1955EL1B, 1955RE1D, 1955RE1E, 1957RA1C, 1958RE1B).

1. ^{19}O(β^-)^{19}F $\quad Q_m = 4.789$

The decay is complex: see ^{19}F, (1958ST50).

2. ^{17}O(t, p)^{19}O $\quad Q_m = 3.542$

Not reported.

3. ^{18}O(n, γ)^{19}O $\quad Q_m = 3.958$

The thermal cross section is 0.21 ± 0.04 mb (1958HU18).

4. ^{18}O(d, p)^{19}O $\quad Q_m = 1.731$

Observed proton groups are exhibited in Table 19.2. Angular distributions of p_0, p_1 have been measured at $E_d = 0.8$ MeV by (1956AH1A: see (1956PO1B)), of p_2 at $E_d = 3.0$ MeV by (1955ST1A) and of p_0, p_1, p_2 at $E_d = 1.2$ to 2.5 MeV by (1959ZI16). The p_0 and p_2 groups show clear stripping distributions (1955ST1A, 1959ZI16), corresponding to $l_n = 2$ and 0, respectively: $J_0 = \frac{3}{2}^+$ or $\frac{5}{2}^+$ and $J_2 = \frac{1}{2}^+$. The p_1 group is almost isotropic at $E_d = 2.5$ MeV, indicating a small reduced width (1959ZI16).

Table 19.2: Proton groups from ^{18}O(d, p)^{19}O

Q (keV)				E_x (keV)	l_n	J^π
(1954AH1C, 1954MI89)	(1954TH30)	(1955HO28)	(1957AH19)			
1730 ± 8	1732 ± 8	1735 ± 8	1734 ± 5	0	2 [a]	$\frac{3}{2}^+, \frac{5}{2}^+$
1636 ± 8	1632 ± 8	1641 ± 8		96 ± 11		$\frac{3}{2}^\pm, \frac{5}{2}^+$
262 ± 6	263 ± 10	264 ± 13		1469 ± 11	0 [b]	$\frac{1}{2}^+$

[a] (1959ZI16).
[b] (1955ST1A, 1959ZI16).

The 1.47 MeV state decays almost entirely to ^{19}O*(0.096) in preference to the ground state, suggesting $J = \frac{1}{2}^\pm, \frac{3}{2}^\pm$ for ^{19}O*(0.096), with $\frac{5}{2}^+$ a less likely possibility. The lifetime of ^{19}O*(0.096) is $\tau_m = (1.75 \pm 0.3) \times 10^{-9}$ sec, consistent with a slow E1 or M1 transition. If the ground state is $\frac{5}{2}^+$, the 0.096 MeV state is $\frac{3}{2}^\pm$ or $\frac{5}{2}^+$ (1959ZI16). No other proton groups are observed at $E_d = 2.18$ MeV, $\theta = 140°$, corresponding to states in ^{19}O below 2.4 MeV (1954TH30).

5. ^{18}O(t, d)^{19}O $\qquad Q_m = -2.301$

Not reported.

6. ^{18}O(α, ^{3}He)^{19}O $\qquad Q_m = -16.620$

Not reported.

7. ^{19}F(n, p)^{19}O $\qquad Q_m = -4.006$

See ^{20}F and (1950JE1A, 1955RI1C, 1956JO35, 1956PH30).

8. ^{19}F(t, ^{3}He)^{19}O $\qquad Q_m = -4.771$

Not reported.

9. $^{21}Ne(n, ^{3}He)^{19}O$ $Q_{\mathrm{m}} = -15.916$

Not reported.

10. $^{22}Ne(n, \alpha)^{19}O$ $Q_{\mathrm{m}} = -5.704$

Not reported.

^{19}F
(Fig. 41)

GENERAL:

Theory: See (1955EL1A, 1955EL1B, 1955RE1D, 1955RE1E, 1956BA1J, 1956PA23, 1957PA1C, 1957RA1C, 1958AB1A, 1958KU1C, 1958RE1B).

1. ^{9}Be(^{14}N, α)^{19}F $\qquad Q_{\rm m} = 13.263$

See (1958GO71).

2. ^{15}N(α, γ)^{19}F $\qquad Q_{\rm m} = 3.993$

Three resonances are observed (1957PR1A): see Table 19.4. The γ-transition strengths indicate that all three yield dipole or E2 radiation. The indicated assignments are derived from branching ratios and angular distributions. Nether the 1.34 or the 2.8 MeV level may have $J = \frac{1}{2}$ (1957PR1A).

3. ^{15}N(α, α)^{15}N $\qquad E_{\rm b} = 3.993$

Differential cross sections for elastic scattering at several angles have been measured for $E_\alpha = 1.7$ to 5.4 MeV. Over twenty resonances have been observed: below $E_{\rm x} = 7$ MeV the levels are narrow (≈ 10 keV); above this energy they are much broader (1958SM05: see (1958BU12)).

4. ^{16}O(t, n)^{18}F $\qquad Q_{\rm m} = 1.280 \qquad E_{\rm b} = 11.693$

The excitation function has been measured for $E_{\rm t} = 0.68$ to 2.13 MeV; at the latter energy the cross section is 100 ± 20 mb (1955JA1A). See also (1950HO80).

5. ^{16}O(α, p)^{19}F $\qquad Q_{\rm m} = -8.119$

At $E_\alpha = 20.6$ MeV, proton groups are observed corresponding to excited states at 1.36 ± 0.05, 2.67 ± 0.05 and 3.92 ± 0.05 MeV (1951BU1E).

6. ^{17}O(d, n)^{18}F $\qquad Q_{\rm m} = 3.392 \qquad E_{\rm b} = 13.806$

Table 19.3: Energy levels of ^{19}F

E_x (MeV $\pm$ keV)	J^π	τ_m (sec) or Γ (keV)	Decay	Reactions
0	$\frac{1}{2}^+$	–	stable	1, 2, 5, 17, 20, 26, 27, 28, 29, 30, 31, 37
0.10987 ± 0.04	$\frac{1}{2}^-$	$\tau_m = (1.0 \pm 0.25) \times 10^{-9}$	γ	2, 20, 26, 27, 29, 30, 37
0.198 ± 1	$\frac{5}{2}^+$	$\tau_m = (1.25 \pm 0.025) \times 10^{-7}$	γ	2, 17, 20, 26, 27, 29, 30, 37
1.347 ± 3	$\frac{3}{2}, (\frac{5}{2})$		γ	2, 5, 17, 26, 27
1.460 ± 3	$\frac{1}{2}, \frac{3}{2}$		γ	17, 26, 27
1.556 ± 3	$\frac{3}{2}^+$		γ	17, 20, 26, 27, 28
2.784 ± 8	$(\frac{7}{2}, \frac{9}{2})$		γ	2, 5, 12, 17, 26, 27, 28
3.912 ± 10				5, 17, 27
4.002 ± 10				27
4.036 ± 10				27
(4.41)				27
(4.48)				17, 27
4.57 ± 20				27
4.76 ± 50				17, 27
(4.95 ± 20)				27
5.320 ± 10	$\frac{1}{2}, (\frac{3}{2}^-)$		α, γ	2, 17, 27
5.455 ± 10	$> \frac{1}{2}$		α, γ	2, 17, (27)
5.480 ± 10	$(\frac{3}{2}^+)$		α, γ	2, 15, (27)
6.048 ± 14			γ	17
(6.07 ± 20)				17, 27
6.210 ± 14	$(\frac{1}{2}^+, \frac{3}{2}^+)$		γ	17
6.262 ± 15			γ	17
(6.50 ± 90)				27
7.40 ± 50	$(T = \frac{3}{2})$		γ	17
7.67 ± 50			γ	17
8.11 ± 50			γ	17
8.49 ± 15			p, α, γ	12, 16, 17
8.564 ± 10	$\frac{3}{2}$	2.5	p, α, γ, n, d	12, 16, 17
$\downarrow$	Thirty nine levels observed in ^{18}O + p: see Table 19.5			
14.28			p, n	16
15.3			γ, n	21
22.2		5600	γ, n	21

Table 19.4: Resonances in $^{15}N(\alpha, \gamma)^{19}F$ (1957PR1A)

E_α (keV)	Γ (keV)	E_x (MeV)	E_γ (keV)	$\omega\Gamma_s$ [a] (eV)	J^π
1681 ± 5	< 2	5.320	5.2	6.6	$\frac{1}{2}, (\frac{3}{2}^-)$
			0.11		
1852 ± 3	< 1	5.455	4.0	3.8	$\frac{3}{2}, \frac{5}{2}, \frac{7}{2}$ $(> \frac{7}{2})$
			2.6	7.0	
			1.3		
			0.20		
			0.11		
1883 ± 3	4 ± 1	5.480	5.2	5.2	$\frac{3}{2}^+, (\frac{3}{2}^-, \frac{5}{2}^+, \frac{7}{2})$
			4.0	3.3	
			1.3		
			0.19		
			0.11		

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

See (1955BU1C) and (1950HO80).

7. $^{17}O(d, p)^{18}O$ $\quad Q_m = 5.842$ $\quad E_b = 13.806$

See ^{18}O.

8. $^{17}O(d, \alpha)^{15}N$ $\quad Q_m = 9.812$ $\quad E_b = 13.806$

See ^{15}N.

9. $^{17}O(t, n)^{19}F$ $\quad Q_m = 7.548$

Not reported.

Table 19.5: Resonances in $^{18}O(p, \gamma)^{19}F$, $^{18}O(p, n)^{18}F$ and $^{18}O(p, \alpha)^{15}N$

E_p (keV)	Γ (keV)	Particle out	J^π	E_x (MeV)	References
560		γ, α		8.495	(1953CO1F, 1955HU1D)
633 ± 4	2.6	γ, α	$\frac{3}{2}$	8.564	(1951SE1C, 1953CO1F, 1955BU1D)
846 ± 5	40	γ, α	$\frac{1}{2}$	8.765	(1951SE1C, 1953CO1F, 1955BU1D, 1955HU1D, 1956HI35)
980 ± 4		α		8.892	(1956HI35)
1169 ± 2 [a]	< 0.9	γ		9.071	(1955BU1D)
1271 ± 10		α		9.168	(1956HI35)
1403 ± 4	< 15	γ, α		9.292	(1955BU1D, 1956HI35)
1621 ± 4		α		9.500	(1956HI35)
1687 ± 4	< 15	γ, α		9.562	(1955BU1D, 1956HI35)
1736 ± 5		α		9.609	(1956HI35)
1765 ± 3	4.0	γ, α		9.636	(1955BU1D, 1955HU1D, 1956HI35)
1932 ± 2	1.5	γ, α		9.794	(1955BU1D, 1955HU1D, 1956HI35)
2007 ± 4		α		9.865	(1956HI35)
2175 ± 4		α, γ		10.025	(1955HU1D, 1956HI35)
2232 ± 5		α		10.079	(1956HI35)
2258 ± 5		α		10.103	(1956HI35)
2291 ± 5		α, γ		10.134	(1955HU1D, 1956HI35)
2378 ± 5		α, γ		10.217	(1955HU1D, 1956HI35)
2450 ± 5		α, γ		10.285	(1955HU1D, 1956HI35)
2635 ± 5		α		10.460	(1956HI35)
2655 ± 5	10 ± 3	n		10.479	(1950RI59, 1956HI35 , 1956MA18, 1956NA1B)
2712 ± 5		α		10.533	(1956HI35)
2729 ± 5		n		10.549	(1956HI35 , 1956MA18, 1956NA1B)
2773 ± 5	< 20	n, α		10.591	(1950RI59, 1956HI35 , 1956MA18, 1956NA1B)
2798 ± 6		α		10.615	(1956HI35)
2929 ± 5		α		10.739	(1956HI35)
3037 ± 7	33 ± 3	n, α	$\frac{3}{2}$	10.841	(1950RI59, 1956HI35 , 1956MA18, 1956NA1B)

Table 19.5: Resonances in ^{18}O(p, γ)^{19}F, ^{18}O(p, n)^{18}F and ^{18}O(p, α)^{15}N (continued)

E_p (keV)	Γ (keV)	Particle out	J^π	E_x (MeV)	References
3064 ± 6		α		10.867	(1956HI35)
3165 ± 5		n, α	$(\frac{1}{2})$	10.962	(1956HI35 , 1956MA18, 1956NA1B)
3266 ± 4	29 ± 3	n, α	$\frac{3}{2}$	11.058	(1950RI59, 1956HI35 , 1956MA18, 1956NA1B, 1957SZ1A)
3386 ± 4	15 ± 3	n	$(\frac{1}{2})$	11.172	(1950RI59, 1956HI35 , 1956MA18, 1956NA1B, 1957SZ1A)
3483 ± 6		n, α		11.264	(1950RI59, 1956HI35 , 1956MA18, 1956NA1B)
3600 ± 20	85 ± 20	n		11.38	(1956MA18)
3685		n, α		11.46	(1956NA1B, 1957SZ1A)
3755 ± 20 [a]		n(α)		11.52	(1956MA18, 1956NA1B, 1957SZ1A)
3901		n, α		11.66	(1956NA1B, 1957SZ1A)
4018		n		11.77	(1956NA1B)
4250		n		11.99	(1951BL1A)
5080		n		12.78	(1951BL1A)
5630		n		13.30	(1951BL1A)
6200		n		13.84	(1951BL1A)
6670		n		14.28	(1951BL1A)

[a] $(T = \frac{3}{2})$.

10. ^{17}O(^{3}He, p)^{19}F $\qquad Q_m = 8.313$

Not reported.

11. ^{17}O(α, d)^{19}F $\qquad Q_m = -10.038$

Not reported.

12. ^{18}O(p, γ)^{19}F $\quad Q_{\rm m} = 7.964$

Resonances for capture radiation observed for $E_{\rm p} = 0.3$ to 2.6 MeV are displayed in Table 19.5 (1955BU1D, 1955HU1D, 1956HI35). The 9.07 MeV level ($E_{\rm p} = 1.169$ MeV) decays preferentially through the 2.8 MeV level. Its small width and the absence of α-decay may indicate a $T = \frac{3}{2}$ character; the position is close to that expected for the analogue of the 1.47 MeV state of ^{19}O (1955BU1D).

13. ^{18}O(p, n)^{18}F $\quad Q_{\rm m} = -2.450 \quad E_{\rm b} = 7.964$

Observed resonances in the neutron yield are listed in Table 19.5 (1950RI59, 1951BL1A, 1956HI35 , 1956MA18, 1956NA1B). The relative weakness of (p, α) at $E_{\rm p} = 3.8$ MeV suggests $T = \frac{3}{2}$ for ^{19}F*(11.5) (1957SZ1A). See also (1956TS1A).

14. ^{18}O(p, p)^{18}O $\quad E_{\rm b} = 7.964$

See ^{18}O.

15. ^{18}O(p, d)^{17}O $\quad Q_{\rm m} = -5.842 \quad E_{\rm b} = 7.964$

See (1956TS1A).

16. ^{18}O(p, α)^{15}N $\quad Q_{\rm m} = 3.970 \quad E_{\rm b} = 7.964$

Observed resonances are exhibited in Table 19.5 (1951SE1C, 1953CO1F, 1956HI35 , 1957SZ1A). The sharp resonances at $E_{\rm p} = 633$ and 846 keV are superposed on what may be one or more broad resonances: see (1953CO1F).

17. ^{18}O(d, n)^{19}F $\quad Q_{\rm m} = 5.737$

Neutron groups corresponding to 12 levels of ^{19}F are reported by (1953SE1B). Two thresholds for slow neutron production are observed (1956HA1A): see Table 19.6. Both are quite sharp, suggesting s-wave neutron emission; the lower is probably formed by s-wave deuterons, $J = \frac{1}{2}^{+}$, $\frac{3}{2}^{+}$ (1956HA1A). Seven thresholds for γ-ray production are reported. Of these one, at $E_{\rm d} = 1.85$ MeV (^{19}F*(7.40)), dose not appear in ^{15}N(α, α)^{15}N; it is suggested that this may be the first $T = \frac{3}{2}$ level of ^{19}F. Gamma-spectra are reported for several levels (1958BU12, 1959BU81).

Table 19.6: Thresholds in the ^{18}O(d, n)^{19}F reaction

E_d (keV)		E_x	Gamma decay to
(1956HA1A) [a]	(1958BU12, 1959BU81) [b]	(MeV)	^{19}F* (MeV)
	346 ± 8	6.048 ± 0.014	0, 1.57
	(370)	(6.07)	
497 ± 15	525 ± 8	6.210 ± 0.014	0, 1.57
	584 ± 10	6.262 ± 0.015	0.20
	1850 ± 50	7.40 [c]	
	2150 ± 50	7.67	
	2640 ± 50	8.11	
3050 ± 20		8.48 ± 0.02	
	3160 ± 30	8.58	

[a] Slow neutron thresholds.
[b] Thresholds for γ-rays.
[c] $(T = \frac{3}{2})$.

18. ^{18}O(^{3}He, d)^{19}F $\qquad Q_m = 2.470$

Not reported.

19. ^{18}O(α, t)^{19}F $\qquad Q_m = -11.849$

Not reported.

20. ^{19}O(β^-)^{19}F $\qquad Q_m = 4.789$

The decay branches 30 ± 10 % to the 198 keV state ($E_\beta = 4.5 \pm 0.3$ MeV) and 70% to a state at 1.57 MeV ($E_\beta = 2.9 \pm 0.3$ MeV) (1947BL33, 1954JO21). With a half-life of 29 sec (see (1954AH1C, 1954MI89, 1958ST50)), $\log ft = 5.55$ and 4.33, respectively (1951FE1A). Gamma rays of energy $\gamma_1 = 1366 \pm 8$ keV, $\gamma_2 = 199.6 \pm 1.5$ keV, and $\gamma_3 = 111.5 \pm 1.5$ keV with relative intensities 0.67 : 1.00 : 0.04 are reported, as is the transition, γ_4, from the 1570 keV level to the 0.110 keV level. The γ_1-γ_2 coincidences indicate that γ_1 arises from the transition $1570 \rightarrow 197$: see Fig. 42. The transition $197 \rightarrow 110$ has an intensity $< 0.5\%$ and the transitions $1570 \rightarrow 0$

and $1570 \rightarrow 1350$ are ≤ 3 and ≤ 4%, respectively. The mean lifetime of the 197 keV state is $(1.0 \pm 0.2) \times 10^{-7}$ sec (1954JO21), $(1.25 \pm 0.025) \times 10^{-7}$ sec (1956JO35) while that of the 110 keV state is $\ll 10^{-6}$ sec (compare ^{19}F(p, p′)^{19}F*) (1954JO21). The magnetic moment of the 197 keV state is 3.50 ± 0.24 nuclear magnetons (1956PH30) (compare ^{19}F(p, p′)^{19}F*). Lower limits on $\log ft$ for β transitions to the ground state and those at 110 and 1350 keV are 6.5, 7.3, and 5.3 (1954JO21).

The present observations, together with Coulomb excitation data (^{19}F(α, α')^{19}F*) require $J = \frac{1}{2}^-$ and $\frac{5}{2}^+$ for the 110 keV and 197 keV levels (see also ^{19}F(p, p′)^{19}F*). The assignment $J = \frac{3}{2}^+$ for the 1570 keV state is obtained from the ^{19}O beta decay, from the γ_1-γ_2 angular correlation, and a study of γ_4. If the beta transitions to the 1570 and 197 keV states are allowed and that to the ground state is forbidden, it follows that ^{19}O has $J = \frac{5}{2}^+$ (1954JO21). See also (1956TO1B) and (1957RA1C, 1958RE1B; theor.).

21. ^{19}F(γ, n)^{18}F $\qquad Q_{\rm m} = -10.414$

Discontinuities in the activation curve are reported at 70 ± 20 keV above threshold (1958BE74) and at 10.6, 11.0, 11.2, 11.5, 11.9, 12.2, and 15.3 MeV (1954GO39, 1954TA1B). The “giant” resonance appears at $E_\gamma = 22.2$ MeV, $\Gamma = 5.6$ MeV (1954FE16: see also (1952HO1B)). See also (1955AJ61).

22. ^{19}F(γ, 2n)^{17}F $\qquad Q_{\rm m} = -19.582$

See (1952HO1B, 1958MA1L).

23. ^{19}F(γ, p)^{18}O $\qquad Q_{\rm m} = -7.964$

See (1955LA1E, 1956WH1A, 1958JO1C).

24. ^{19}F(p, d)^{18}F $\qquad Q_{\rm m} = -8.187$

At $E_{\rm p} = 18$ MeV, the ground-state reduced width, $\theta_{\rm n}^2 = 0.009$ (1956RE04).

25. ^{19}F(p, α)^{16}O $\qquad Q_{\rm m} = 8.119$

Table 19.7: Gamma rays from ^{19}F(n, n′γ)^{19}F

A		B	
E_γ (keV)	σ (mb)	E_γ (keV)	Assignment
110 ± 1	193	111 ± 1.5	$111 \rightarrow 0$
197 ± 2	537	196 ± 2	$196 \rightarrow 0$
1234 ± 20	50	1236 ± 12	$1346 \rightarrow 111$
1358 ± 30	307	1358 ± 12	{ $1466 \rightarrow 111$ $1557 \rightarrow 196$
1460 ± 30	57	1472 ± 16	$1466 \rightarrow 0$
(1560 ± 30)	21		
		2594 ± 15	$2791 \rightarrow 197$

A: (1956DA23); $E_n = 2.6$ MeV.
B: (1955FR1B, 1956FR1D, 1957FR57): $E_n = 0.5$ to 3.7 MeV.

At $E_p = 18.5$ MeV, the angular distribution shows strong maxima and minima, indicative of triton pickup. The triton reduced width for ^{19}F(0) is $\theta^2 = 0.1 - 0.15$ (1956LI37).

26. ^{19}F(n, n′)^{19}F*

At $E_n = 540$ keV, only two γ-ray lines appear, at $E_\gamma = 111 \pm 1.5$ keV and 196 ± 2 keV. At $E_n = 1.50$ MeV, a threshold occurs for a further line, at $E_\gamma = 1.24$ MeV. At $E_n = 1.6$ MeV, lines with $E_\gamma = 1.24$, 1.36, and 1.47 MeV are observed: see Table 19.7 and Fig. 42. The level assignments indicated in the table derive from coincidence studies. Upper limits on other γ-lines are about 10% (1956FR1D). At $E_n = 3.7$ MeV, a line at $E_\gamma = 2.594$ MeV is observed, attributed to a level at 2.791 MeV (cascade to ^{19}F*(0.197)). The excitation function suggests $J = \frac{7}{2}$ or $\frac{9}{2}$ (1957FR57). (1956VA29) find the threshold for 1.37 MeV radiation at $E_n = 1.55 \pm 0.2$ MeV. (1956DA23) reports the relative intensity of the cascade ^{19}F*($0.197 \rightarrow 0.111$) as $< 6 \times 10^{-3}$ of $(0.197 \rightarrow 0)$. See also (1955FR1B, 1955GR18, 1955VA1B, 1956CR31).

27. ^{19}F(p, p′)^{19}F*

Observed proton groups are listed in Table 19.8 (1952AR29, 1954PE1C, 1955GO1F, 1956SQ1A, 1957HO1J, 1957YO04). At $E_p = 7.3$ MeV, no other groups appear for $E_x < 4.05$ MeV with intensity > 2% of the $Q = -1.558$ MeV group (1956SQ1A).

Table 19.8: Proton groups from ^{19}F(p, p′)^{19}F*

Level energies (MeV ± keV)					
A	B	C	D	E	F
0.111 ± 2			0.1104 ± 0.6	0.1088 ± 0.8	
0.197 ± 2			0.1978 ± 1.2	0.1960 ± 1.4	
1.350 ± 5	1.37	1.36 ± 20			1.344 ± 5
1.462 ± 5					1.458 ± 5
1.558 ± 5	1.59	1.55 ± 10			1.554 ± 5
2.784 ± 8	2.82	2.83 ± 20			
3.912 ± 10	3.94	3.92 ± 40			
4.002 ± 10					
4.036 ± 10	4.06	4.06 ± 50			
	4.41				
	4.48				
	4.59	4.57 ± 20			
	4.76	4.76 ± 50			
		(4.95 ± 20)			
		5.27 ± 20			
		5.53 ± 30			
		6.07 ± 20			
		(6.50 ± 90)			

A: (1956SQ1A: $E_{\rm p} = 7.0$ to 7.3 MeV).
B: (1952AR29: $E_{\rm p} = 8$ MeV).
C: (1957HO1J: $E_{\rm p} = 9.5$ MeV).
D: (1955GO1F: $E_{\rm p} = 2.1$ to 4.5 MeV).
E: (1954PE1C: $E_{\rm p} = 0.3$ to 1.5 MeV).
F: (1957YO04: $E_{\rm p} = 5.2$ MeV).

The energy of the first excited state is given as 109.87 ± 0.04 keV from the energy of the γ-decay (1958CH34: see also Table III (19) in (1955AJ61)). The lifetime of the state is $(1.0 \pm 0.25) \times 10^{-9}$ sec (1954TH41). The internal conversion coefficient indicates E1 and therefore $J = \frac{1}{2}^{-}$ or $\frac{3}{2}^{-}$ for the 0.11 MeV state (1955MI1B). Since the cascade transition from the 0.2 $(J = \frac{5}{2}^{+})$ to the 0.1 MeV state is not observed, $J = \frac{1}{2}^{-}$ is indicated (1954SH1B, 1955BA94).

The lifetime of the 198 keV state is 0.8×10^{-7} sec (1954TH41), $(1.23 \pm 0.07) \times 10^{-7}$ sec (1955FI38, 1956LE1F): see also ^{19}O(β^-)^{19}F. The lifetime requires E2 or faster radiation; the internal conversion coefficient indicates E2 (1955MI1B). Angular distributions at various $J = 2^-$ resonances in ^{20}Ne* confirm the assignment $J^\pi = \frac{5}{2}^{+}$ for ^{19}F*(0.197) (1954CH27, 1954PE1C, 1954SH1B, 1955BA94). The Coulomb excitation also requires an E2 transition (1956TE1A). The magnetic moment is 3.70 ± 0.45 n.m. (1955LE1C, 1956LE1F, 1956LE22), 3.0 ± 0.7 n.m. (1956SU1C), 4.5 ± 1.0 n.m. (1955TR1C, 1956TR1A), 3.5 ± 0.5 n.m. (1958MA38): the value predicted by (1955EL1B) is 3.3 n.m.; compare ^{19}O(β^-)^{19}F. The static electric quadrupole moment is 0.13×10^{-24} cm^2 (1958SU58). See also (1956BA1J, 1957RA1C, 1957TR1A, 1957TR1B).

The γ-decay of higher excited states has been studied by (1956TO1B: $E_p = 2.4$ to 4.1 MeV): see Fig. 42. Gamma rays with $E_\gamma = 1.238 \pm 0.010$, 1.350 ± 0.010 and 1.449 ± 0.010 MeV are observed in addition to the two low energy γ's. The 1.24 and 1.35 MeV γ-rays are in prompt coincidence with 0.11 MeV radiation, indicating cascade decay of states at 1.342 ± 0.010 MeV and 1.452 ± 0.010 MeV through the 0.11 MeV state. A (1.354 ± 0.010) MeV γ-ray is found to be in delayed coincidence with 197 keV radiation, indicating the cascade decay of a level at 1.551 ± 0.010 MeV through the $J = \frac{5}{2}^{+}$ second excited state. The 1.34 MeV state does not appear to decay to the 0.198 MeV state ($< 8\%$); it decays almost entirely to the $J = \frac{1}{2}^{-}$ first excited state. This observation suggests $J = \frac{1}{2}$ or $\frac{3}{2}$, with $J = \frac{5}{2}$ not excluded; the observed anisotropy excludes $J = \frac{1}{2}$. Similarly, the γ-decay of the 1.46 MeV state suggests $J = \frac{1}{2}$ or $\frac{3}{2}$. The assignment $J = \frac{3}{2}^{+}$ for ^{19}F*(1.56) follows from ^{19}O(β^-)^{19}F (1956TO1B). (1958RA26) find gamma-ray energies of 1236 ± 10, 1358 ± 8 and 1460 ± 30 keV, not corrected for Doppler shift. Relative intensities for $E_p = 3.2$ to 4.7 MeV are given. See also (1958RA15) and ^{19}F(n, n′)^{19}F*.

For elastic and inelastic scattering at high energies, see (1956BU95, 1956DA03, 1956KL55, 1956ST30, 1957GI14, 1958TY47).

28. ^{19}F(d, d′)^{19}F*

At $E_d = 8.9$ MeV, deuteron groups are observed to states at 1.60 ± 0.02 and 2.83 ± 0.02 MeV (1956EL1A). See also (1954TH1B).

29. ^{19}F(α, α')^{19}F*

Gamma radiation of energy 110 keV and 197 keV (See Table III (19) of (1955AJ61)) is observed for $E_\alpha = 0.6$ to 3.5 MeV. The shape of the rise, the absolute cross sections at low energies, and the γ-ray angular distributions agree well with E1 and E2 Coulomb excitation, respectively, of the first two excited states (see (1954HE22, 1954JO1G, 1954SH1B, 1954TE1B, 1956TE1A)).

30. ^{19}F(^{14}N, ^{14}N$'\gamma$)^{19}F

At $E(^{14}\text{N}) = 15.6$ MeV, γ-rays are observed from the Coulomb excitation of the first two excited states (1956AL1D, 1956AL36, 1956AL55).

31. ^{19}Ne(β^+)^{19}F $\quad Q_{\rm m} = 3.256$

See ^{19}Ne.

32. ^{20}Ne(n, d)^{19}F $\quad Q_{\rm m} = -10.646$

Not reported.

33. ^{20}Ne(d, ^{3}He)^{19}F $\quad Q_{\rm m} = -7.379$

Not reported.

34. ^{20}Ne(t, α)^{19}F $\quad Q_{\rm m} = 6.940$

Not reported.

35. ^{21}Ne(n, t)^{19}F $\quad Q_{\rm m} = -11.145$

Not reported.

36. ^{21}Ne(p, ^{3}He)^{19}F $\quad Q_{\rm m} = -11.910$

Not reported.

37. ^{21}Ne(d, α)^{19}F $\quad Q_{\rm m} = 6.441$

At $E_{\rm d} = 2.1$ MeV, α-particle groups are observed to ^{19}F*(0, 113 ± 8, and 192 ± 12 keV) (1952MI54).

38. ^{22}Ne(p, α)^{19}F $\quad Q_{\rm m} = -1.698$

Not reported.

Table 19.9: Energy levels of ^{19}Ne

E_x (MeV ± keV)	J^π	$\tau_{1/2}$ or τ_m (sec)	Decay	Reactions
0	$\frac{1}{2}^+$	$\tau_{1/2} = 17.8 \pm 0.1$	β^+	1, 5, 7
0.241 ± 4	$(\frac{5}{2}^+)$	$\tau_m = (1.8 \pm 0.2) \times 10^{-8}$	γ	5
0.280 ± 4	$(\frac{1}{2}^-)$	$\tau_m < 5 \times 10^{-9}$	γ	5
≈ 10.48			p, α, ^{3}He	3

^{19}Ne
(Fig. 43)

GENERAL:

Theory: See (1955EL1B, 1955RE1D, 1955RE1E, 1957RA1C, 1958RE1B).

1. ^{19}Ne(β^+)^{19}F $\qquad Q_m = 3.256$

The positron end point is 2.18 ± 0.03 (1952SC15), 2.23 ± 0.05 (1957AL29), 2.24 ± 0.01 MeV (1958WE25). The half-life is 17.4 ± 0.2 sec (1959HE1E), 17.7 ± 0.1 (1957PE12), 18.3 ± 0.5 (1957AL29), 18.5 ± 0.5 (1952SC15), 19 ± 1 (1954NA29), 19.5 ± 1.0 (1958WE25), 20.3 ± 0.5 sec (1939WH02). The absence of low-energy γ-rays (see ^{19}F) indicates that the transition takes place to the ground state, $J = \frac{1}{2}^+$, of ^{19}F: $\log ft = 3.30$, $\log ft$ for a transition to the 0.11 MeV, $J = \frac{1}{2}^-$, state of ^{19}F is ≥ 6.0, $\log ft$ to the 0.20 MeV, $J = \frac{5}{2}^+$, state is ≥ 5.5. It follows that the ground state of ^{19}Ne is $J = \frac{1}{2}^+$ (1954JO21). The Kurie plot is linear from the end point to 0.7 MeV (1957AL29).

The electron-neutrino angular correlation has been studied by (1955MA1M, 1957AL29, 1957GO1J, 1958HE1J, 1959HE1E). See also (1954AL29, 1959LA01) and (1958RE1B; theor.).

2. ^{16}O(α, n)^{19}Ne $\qquad Q_m = -12.158$

See (1947TE01).

3. (a) ^{16}O(^{3}He, p)^{18}F $\qquad Q_m = 2.045 \qquad E_b = 8.419$

(b) ^{16}O(^{3}He, α)^{15}O $\qquad Q_m = 4.923$

Yield curves for the ground-state alpha-particle group and for proton groups to the first six states of ^{18}F have been obtained for $E(^3\text{He}) = 2.0$ to 5.4 MeV. All curves show pronounced resonance structure; in particular, all groups appear to be resonant at $E(^3\text{He}) \approx 2.45$ MeV, corresponding to ^{19}Ne* ≈ 10.48 MeV. Angular distributions have also been measured at several energies (1958BR86).

4. ^{17}O(^{3}He, n)^{19}Ne $\quad Q_\text{m} = 4.274$

Not reported.

5. ^{19}F(p, n)^{19}Ne $\quad Q_\text{m} = -4.039$

The ground-state threshold is $E_\text{thresh.} = 4240 \pm 8$ keV (1955KI28), 4235 ± 5 keV (1955MA84). Two additional thresholds are observed, corresponding to excited states of ^{19}Ne at 241 ± 4 and 280 ± 4 keV. No other excited states appear with $E_\text{x} < 1.5$ MeV (1955MA84). The two excited states radiate to the ground state with $E_\gamma = 242 \pm 5$ and 281 ± 8 keV and with lifetimes of $(1.8 \pm 0.2) \times 10^{-8}$ sec and $< 5 \times 10^{-9}$ sec (1957BA09). It appears from these results that the position of the first two excited states in the $A = 19$ pair is reversed in ^{19}F and ^{19}Ne: the sequence in ^{19}F is $\frac{1}{2}^+$, $\frac{1}{2}^-$, $\frac{5}{2}^+$, in ^{19}Ne it appears from the lifetimes to be $\frac{1}{2}^+$, $\frac{5}{2}^+$, $\frac{1}{2}^-$. See also (1958BI1B).

6. ^{19}F(^{3}He, t)^{19}Ne $\quad Q_\text{m} = -3.274$

Not reported.

7. ^{20}Ne(γ, n)^{19}Ne $\quad Q_\text{m} = -16.912$

See ^{20}Ne.

8. ^{20}Ne(p, d)^{19}Ne $\quad Q_\text{m} = -14.685$

Not reported.

9. ^{20}Ne(d, t)^{19}Ne $\quad Q_\text{m} = -10.653$

Not reported.

10. ^{20}Ne(^{3}He, α)^{19}Ne $Q_{\mathrm{m}} = 3.666$

Not reported.

11. ^{21}Ne(p, t)^{19}Ne $Q_{\mathrm{m}} = -15.184$

Not reported.

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(Closed 01 December 1958)

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