Energy Levels of Light Nuclei
$A = 17$

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Abstract: An evaluation of $A = 5$–24 was published in *Nuclear Physics* 11 (1959), p. 1. This version of $A = 17$ 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 17.1: Energy levels of ^{17}N

E_x (MeV)	$J^\pi; T$	$\tau_{1/2}$ (sec)	Decay	Reactions
0	$; \frac{3}{2}$	4.14 ± 0.04	β^-	1, 2, 3, 4, 5, 6, 9, 11
1.32 ± 0.08				2
1.89 ± 0.08				2
2.50 ± 0.08				2
2.82 ± 0.08				2
(3.27 ± 0.09)				2
(3.57 ± 0.09)				2
(3.86 ± 0.09)				2
(4.18 ± 0.09)				2

^{17}N

(Fig. 34)

GENERAL:

Mass of ^{17}*N:* From the Q_0 of the ^{11}B(^{7}Li, p)^{17}N reaction and the Wapstra masses (1955WA1A) for ^{11}B, ^{7}Li and ^{1}H, the mass excess $(M - A)$ of ^{17}N is 12.93 ± 0.06 MeV.

1. ^{17}N(β^-)^{17}O* $\rightarrow$ ^{16}O + n $\qquad Q_m = 4.57$

The decay is complex. See ^{17}O.

2. ^{11}B(^{7}Li, p)^{17}N $\qquad Q_m = 8.38$

$Q_0 = 8.38 \pm 0.06$ (C. Littlejohn, private communication).

At $E(^7\text{Li}) = 2$ MeV, proton groups are observed corresponding to the ground state of ^{17}N and to excited states at 1.32 ± 0.08, 1.89 ± 0.08, 2.50 ± 0.08, 2.82 ± 0.08, 3.27 ± 0.09, 3.57 ± 0.09, 3.86 ± 0.09, and 4.18 ± 0.09 MeV. The data on the four highest levels are preliminary (C. Littlejohn, private communication).

3. ^{14}C(α, p)^{17}N $\qquad Q_m = -9.75$

See ^{18}O.

4. ^{15}N(t, p)^{17}N $Q_{\rm m} = -0.15$

See (1956SH1A).

5. ^{17}O(n, p)^{17}N $Q_{\rm m} = -7.93$

See (1956FA1C).

6. ^{18}O(γ, p)^{17}N $Q_{\rm m} = -15.99$

See (1955RE1C).

7. ^{18}O(n, d)^{17}N $Q_{\rm m} = -13.77$

Not reported.

8. ^{18}O(d, ^{3}He)^{17}N $Q_{\rm m} = -10.50$

Not reported.

9. ^{18}O(t, α)^{17}N $Q_{\rm m} = 3.82$

See (1956SH1A).

10. ^{19}F(n, ^{3}He)^{17}N $Q_{\rm m} = -16.24$

Not reported.

11. Photospallation reactions.

A number of spallation reactions yielding ^{17}N have been observed by (1955RE1C) and (1955CH1C). See also (1958BA60).

^{17}O
(Fig. 35)

GENERAL:

Theory: (1956BA1J, 1956KA1C, 1956KI1C, 1956LE1C, 1956SC1E, 1956VI1A, 1957AM1B, 1957AM1C, 1957FA1B, 1957FE1A, 1957PE1D, 1957RA1B, 1957TA1C, 1958BA32, 1958NI1D).

1. ^{13}C(α, n)^{16}O $\qquad Q_{\rm m} = 2.203 \qquad E_{\rm b} = 6.348$

Observed resonances for $E_\alpha = 1$ to 5 MeV are listed in Table 17.3 (1953JO1A, 1954TR09, 1956BE98, 1956BO61, 1956RU1A, 1957WA46), together with those observed in ^{16}O(n, α)^{13}C. The observed cross section of ^{13}C(α, n)^{16}O is closely matched by that calculated from the inverse reaction, for $E_\alpha = 4.0$ to 5.2 MeV (1957WA46). Assignments for J^π in the range ^{16}O*(7.1 to 9.0 MeV) are derived from angular distributions (1956SC1C, 1957WA46). The existence of additional broad states underlying this region is indicated by the analysis (1956RU1A, 1957WA46). Reduced widths have been tabulated for a number of levels by (1957WA46); it is of interest that $\theta^2_{\rm n}$ and θ^2_α generally differ by less than one order of magnitude (1957WA46). The implications of the present reaction for element synthesis in stars are discussed by (1955FO1C, 1957BU66, 1957SA1B). See also (1954NA1B, 1956BA1K).

2. ^{14}C(α, n)^{17}O $\qquad Q_{\rm m} = -1.825$

$Q_0 = -1.820 \pm 0.002$ (1956SA06).

3. ^{14}N(α, p)^{17}O $\qquad Q_{\rm m} = -1.197$

Proton groups have been observed to the ground and first excited states of ^{17}O (1951RO1D, 1953HJ1A, 1953HJ1B).

4. ^{15}N(d, n)^{16}O $\qquad Q_{\rm m} = 9.886 \qquad E_{\rm b} = 14.032$

The excitation function has been measured from 0.5 to 5.3 MeV. Above $E_{\rm d} = 1.0$ MeV pronounced peaks are observed, presumably to be ascribed to numerous overlapping resonances. Angular distributions are generally well accounted for by the exchange stripping theory of (1957OW03), with an admixture of heavy-particle stripping which is almost constant for $E_{\rm d} > 1$ MeV (1958WE31).

Table 17.2: Energy levels of ^{17}O

E_x in ^{17}O (MeV $\pm$ keV)	J^π	τ_m or Γ (keV)	Decay	Reactions
0	$\frac{5}{2}^+$		stable	2, 3, 17, 21, 22, 23, 28, 29
0.871 ± 4	$\frac{1}{2}^+$	$\tau_m = (2.5 \pm 1) \times 10^{-10}$ sec	γ	3, 17, 28, 29
3.058 ± 6	$(\frac{1}{2}^-)$		γ	17, 28
3.846 ± 5	$(\frac{7}{2}^-)$		γ	17, 28
4.555 ± 5	$\frac{3}{2}^-$	$\Gamma = 40 \pm 3$	n	11, 17, 28
5.083 ± 5	$\frac{3}{2}^+$	90 ± 5	n	11, 17, 28
5.217 ± 5		< 8		17, 28
5.378 ± 7	$\frac{3}{2}^-$	31 ± 4	n	11, 17, 28
5.697 ± 4	$\frac{7}{2}^-$	≤ 7	n	11, 17
5.729 ± 5		< 8		17, 28
5.866 ± 5	$\geq \frac{3}{2}$	≤ 8	n	11, 17, 28
5.940 ± 10	$\frac{1}{2}^-$	26 ± 5	n	11, 17, 28
6.24 ± 20				17, 28
6.38 ± 30	$\frac{1}{2}^+$	130	n	11
6.87 ± 20				17, 28
(6.99 ± 20)				28
7.161 ± 6	$\frac{5}{2}$	2.7 ± 1	n, α	1
7.28 ± 30	$\frac{3}{2}^+$	210	n	11
7.373 ± 6	$\frac{5}{2}$	≤ 2	n, α	1, 28
7.560 ± 10	$\geq \frac{7}{2}$	≤ 4	n, α	1, 17, 28
7.676 ± 7	$\geq \frac{5}{2}$	22	n, α	1
(7.72 ± 80)	$(\frac{3}{2}^-)$	750	n	11
7.94 ± 20	$\frac{1}{2}$	90	n, α	1, 16
8.07 ± 20	$\frac{3}{2}$	75	n, α	1, 11, 16
8.20 ± 20	$\frac{3}{2}$	60	n, α	1, 11, 16
8.27 ± 40				28
8.340 ± 7	$\frac{1}{2}$	≤ 5	n, α	1, 11, 16, 28
8.390 ± 7	$\frac{5}{2}$	8	n, α	1, 11, 16
8.460 ± 7	$\frac{7}{2}$	9	n, α	1, 11, 16
8.493 ± 7	$(\frac{3}{2})$	≤ 6	n, α	1, 11, 16

Table 17.2: Energy levels of ^{17}O (continued)

E_x in ^{17}O (MeV $\pm$ keV)	J^π	τ_m or Γ (keV)	Decay	Reactions
(8.59 ± 40)				28
8.70 ± 20	$\frac{3}{2}$	70	n, α	1, 11, 16
8.89 ± 20	$\frac{3}{2}$	110	n, α	1, 11, 16
8.96 ± 20	$\frac{7}{2}$	30	n, α	1, 11, 16
9.06 ± 40				28
9.15 ± 20		≤ 6	n, α	1, 11
9.20	$\frac{5}{2}$	≤ 4	n, α	1
9.50	$\frac{7}{2}$	11	n, α	1, 11
9.73	$\frac{7}{2}$	19	n, α	1, 11
9.78		55	n, α	1
9.89	$\frac{9}{2}$	12	n, α	1
9.98	$(\frac{5}{2}, \frac{7}{2})$	150	n, α	1
10.21		50	n, α	1, 11
10.5			n	11, 12
10.9			n	11, 12
11.5			n	11, 12
12.1			n	11, 12
15.2			d, p	5
15.8			d, p	5

5. ^{15}N(d, p)^{16}N $\quad Q_m = 0.267 \quad E_b = 14.032$

The excitation curve has been obtained for $E_d = 0.3$ to 2.7 MeV. There is some resonance structure at $E_d = 1.3$ and 1.9 MeV corresponding to ^{17}O*(15.2 and 15.8 MeV) (1957BO04). See also ^{16}N.

6. ^{15}N(d, α)^{13}C $\quad Q_m = 7.683 \quad E_b = 14.032$

See (1940HO1A).

Table 17.3: Resonances in ^{13}C(α, n)^{16}O and ^{16}O(n, α)^{13}C

E_{α} (MeV $\pm$ keV)	$E_{\rm n}$	$\Gamma_{\rm c.m.}$ (keV)	l_{α}	$l_{\rm n}$	J^{π}	$E_{\rm x}$ in ^{17}O (MeV)	Refs.
1.063 ± 4		2.7 ± 1	3, 2	2, 3	$\frac{5}{2}$	7.161	a
1.340 ± 4		≤ 2	3, 2	2, 3	$\frac{5}{2}$	7.373	a
1.585 ± 7		≤ 4			$\geq \frac{7}{2}$	7.560	b
1.736 ± 5		22			$\geq \frac{5}{2}$	7.676	b
2.080 ± 20	4.0	90	1, 0		$\frac{1}{2}^{\pm}$	7.94	c
2.250 ± 20	4.15	75	2, 1		$\frac{3}{2}^{\mp}$	8.07	d
2.420 ± 20	4.25	60	1, 2	2, 1	$\frac{3}{2}^{\pm}$	8.20	d
2.603 ± 5	4.46	≤ 5	1, 0		$\frac{1}{2}$	8.34	e
2.675 ± 5	4.53	8	3, 2		$\frac{5}{2}$	8.39	f
2.760 ± 5	4.59	9	3, 4		$\frac{7}{2}^{\pm}$	8.46	f
2.805 ± 5	4.62	≤ 6	1, 2		$(\frac{3}{2}^{\mp})$	8.493	e
3.08 ± 15	4.85	70	1, 2		$\frac{3}{2}^{\pm}$	8.70	e
3.33 ± 15	5.05	110	2, 1		$\frac{3}{2}^{\mp}$	8.89	f
3.42 ± 15	5.13	30	3, 4		$\frac{7}{2}^{\pm}$	8.96	f
3.67 ± 15		≤ 6				9.15	g
3.73		≤ 4			$\frac{5}{2}$	9.20	h
4.125		11			$\frac{7}{2}$	9.502	h
4.42		19			$\frac{7}{2}$	9.73	h
(4.50)		55				9.78	h
4.63		12			$\frac{9}{2}$	9.89	h
4.75		150			$\frac{5}{2}, \frac{7}{2}$	9.98	h
5.05		50				10.21	h

[a] (1953JO1A, 1956RU1A, 1957WA46).
[b] (1956RU1A, 1957WA46).
[c] (1955SE1A, 1956BO61, 1956RU1A, 1956SC1C, 1957WA46).
[d] (1954TR09, 1955SE1A, 1956BE98, 1956BO61, 1956RU1A, 1956SC1C, 1957WA46).
[e] (1956BE98, 1956BO61, 1956SC1C, 1957WA46).
[f] (1954TR09, 1956BE98, 1956BO61, 1956SC1C, 1957WA46).
[g] (1956BO61).
[h] (1956BO61, 1956SC1C).

7. ^{15}N(t, n)^{17}O $Q_m = 7.774$

Not reported.

8. ^{15}N(^{3}He, p)^{17}O $Q_m = 8.539$

Not reported.

9. ^{15}N(α, d)^{17}O $Q_m = -9.812$

Not reported.

10. ^{16}O(n, γ)^{17}O $Q_m = 4.146$

$\sigma_{capt.} < 0.2$ mb (1955HU1B).

11. ^{16}O(n, n)^{16}O $E_b = 4.146$

The cross section is almost constant at 3.76 b from thermal energies to $E_n = 0.3$ MeV (1958HU18). Observed resonances are indicated in Table 17.4 (1952BA1D, 1955OK01, 1956BE98, 1957WA46, 1958HU18, 1958LA09, 1958ST28). (1958FO67) have measured angular distributions at six energies in the range $E_n = 0.7$ to 2.2 MeV and have derived the phase shifts up to 2.4 MeV. From measurements in the range $E_n = 0.1$ to 1.7 MeV, (1958LA09) find that the $E_n = 1.65$ MeV resonance is due to a $\frac{7}{2}^-$ state. Phase shifts for $E_n = 0.2$ to 1.4 MeV derived by (1958ST28) from total cross section measurements are in good agreement with those of (1958FO67) except for a $5°$ discrepancy in $\delta_{\frac{3}{2}+}$ at $E_n = 0.73$ MeV. According to (1958ST28), the s-wave shifts from 0.2 to 2.3 MeV fit hard-sphere scattering with $R = 5.6 \times 10^{-13}$ cm. (1958FO67) find that the s- and d-wave phase shifts and the locations of ^{17}O(g.s.; d$_{\frac{5}{2}}$), ^{17}O*(0.87; s$_{\frac{1}{2}}$) and ^{17}O*(5.08; d$_{\frac{3}{2}}$) can be adequately described by a potential well $40 - 45$ MeV deep, with a diffuse boundary. See also (1956VI1A).

The angular distribution has also been measured at $E_n = 5$ MeV (1958HI68). Polarization studies have been carried out for $E_n = 0.25$ to 0.6 MeV by (1954WI42, 1955OK01) and for $E_n = 0.7$ to 1.4 MeV by (1958ST28). Cross sections at $E_n = 14$ MeV are tabulated by (1958HU18). See also (1956BA1K, 1956FL1B, 1957MC1B) and (1955AJ61).

12. ^{16}O(n, n′)^{16}O* $E_b = 4.146$

Table 17.4: Resonances in ^{16}O(n, n)^{16}O

$E_{\rm n}$ (MeV $\pm$ keV)	$\Gamma_{\rm lab}$ (keV)	$l_{\rm n}$	J^{π}	$E_{\rm x}$ in ^{17}O (MeV)	Refs.
0.433 ± 4	41 ± 3	1	$\frac{3}{2}^{-}$	4.554	(1955OK01, 1958HU18)
0.998 ± 8	96 ± 5	2	$\frac{3}{2}^{+}$	5.085	(1958HU18, 1958LA09, 1958ST28)
1.310 ± 8	33 ± 4	1	$\frac{3}{2}^{-}$	5.379	(1958HU18, 1958ST28)
1.651 ± 6	≤ 7	≥ 1	$\frac{7}{2}^{-}$	5.700	(1958HU18, 1958LA09)
1.830 ± 6	≤ 8	≥ 1	$\geq \frac{3}{2}$	5.868	(1958HU18)
1.903 ± 11	28 ± 5	1	$\frac{1}{2}^{-}$	5.937	(1952BA1D, 1958HU18)
2.370 ± 20	140	0	$\frac{1}{2}^{+}$	6.377	(1952BA1D, 1958HU18)
3.330 ± 30	220	2	$\frac{3}{2}^{+}$	7.28	(1952BA1D, 1958HU18)
3.750 ± 20	< 100			7.68	(1957WA46, 1958HU18)
(3.800)	800	1	$(\frac{3}{2}^{-})$	(7.72)	(1952BA1D, 1958HU18)
4.190 ± 20	< 100			8.09	(1957WA46, 1958HU18)
4.320 ± 20	< 100			8.21	(1952BA1D, 1957WA46, 1958HU18)
4.440 ± 20	< 100			8.32	(1956BE98, 1957WA46, 1958HU18)
4.53			$\geq \frac{3}{2}$	8.41	(1956BE98)
4.59				8.47	(1956BE98)
4.62			$\geq \frac{3}{2}$	8.49	(1956BE98)
4.85				8.71	(1956BE98)
5.08				8.93	(1956BE98)
5.13				8.97	(1956BE98)
5.37				9.20	(1956BE98)
5.7				9.5	(1958HU18)
5.9				9.7	(1958HU18)
6.4				10.2	(1958HU18)
6.8				10.5	(1958HU18)
7.2				10.9	(1958HU18)
7.8				11.5	(1956BE98, 1958HU18)
8.4				12.1	(1956BE98, 1958HU18)

The yield of γ-rays shows marked structure in the range $E_n = 7 - 10$ MeV (1958HU18). At $E_n = 14.1$ MeV, the inelastic scattering cross section is 0.5 b (1953CO67).

13. $^{16}O(n, 2n)^{15}O$ $\quad Q_m = -15.655$ $\quad E_b = 4.146$

See (1955AJ61).

14. $^{16}O(n, p)^{16}N$ $\quad Q_m = -9.619$ $\quad E_b = 4.146$

The cross section rises from threshold to a peak of 89 ± 30 mb at $E_n = 14$ MeV, falling to ≈ 60 mb at 18 MeV (1954MA97). See also (1955AJ61) and (1953KI1A, 1956FA1C, 1958HU18).

15. $^{16}O(n, d)^{15}N$ $\quad Q_m = -9.884$ $\quad E_b = 4.146$

See (1953KI1A, 1955HU1B).

16. $^{16}O(n, \alpha)^{13}C$ $\quad Q_m = -2.203$ $\quad E_b = 4.146$

The cross section has been measured from threshold to 4.2 MeV by (1955SE1A) and from 4.0 to 5.2 MeV by (1957WA46). All of the ^{16}O levels observed in $^{13}C(\alpha, n)^{16}O$ from ^{17}O*(7.92 to 8.96 MeV) are also observed in this reaction, with good agreement in level position: see Table 17.3. Observed cross sections correspond closely to those calculated from the inverse reaction (1957WA46). At higher energies, using continuous fast neutrons, (1956KI1B) report 18 levels in ^{17}O in the range $E_x = 6.8$ to 9.7 MeV, and (1953GI1B) reports 32 levels in the range $E_x = 6.8$ to 12.8 MeV. See also (1953KI1A, 1955HU1B, 1955HU1C, 1956BA1K).

17. $^{16}O(d, p)^{17}O$ $\quad Q_m = 1.919$
$Q_0 = 1.918 \pm 0.004$ (1957BR82);
$Q_0 = 1.915 \pm 0.010$ (1954SP01);
$Q_0 = 1.885$ (1955KH35).

^{17}O levels derived from observed proton groups are listed in Table 17.5 (1951BU1A, 1957BR82: see also (1953KH1A, 1954SP01, 1955KH35)), together with those from the α-groups from $^{19}F(d, \alpha)^{17}O$. The J^π assignments are derived from stripping analysis: see (1955AJ61, 1956GR37,

Table 17.5: States of ^{17}O from ^{16}O(d, p)^{17}O and ^{19}F(d, α)^{17}O

E_x [a] (MeV ± keV)	$\Gamma_{c.m.}$ [a] (keV)	l_n [b]	J^π [b]	$\frac{\Lambda}{2J+1}$ [c]	E_x [d] (MeV ± keV)	E_x [e] (MeV ± keV)
0	< 8	2	$\frac{5}{2}^+$	72	0	0
0.871 ± 4	< 8	0	$\frac{1}{2}^+$	68	0.870 ± 20	0.883 ± 11
3.055 ± 4	< 8	iso.	$(\frac{1}{2}^-)$		3.060 ± 30	3.069 ± 10
3.846 ± 5	< 8	3	$(\frac{7}{2}^-)$	15	3.850 ± 30	3.856 ± 11
4.553 ± 6	40 ± 5	1	$\frac{3}{2}^-$	2.2	4.580 ± 20	4.567 ± 14
5.083 ± 10	95 ± 5	2	$\frac{3}{2}^+$	25	5.070 ± 20	
5.215 ± 5	< 8					5.229 ± 13
5.378 ± 7	28 ± 7				5.310 ± 20	5.397 ± 14
5.695 ± 5	< 8					
5.731 ± 5	< 8				5.760 ± 20	5.723 ± 14
5.866 ± 5	< 8					5.875 ± 15
5.940 ± 15	23 ± 10					5.947 ± 15
					6.240 ± 20	
					6.890 ± 30	6.869 ± 14
						(6.986 ± 15)
						(7.371 ± 15)
					7.510 ± 30	
					8.270 ± 40	
					(8.590 ± 40)	
					9.060 ± 40	

[a] ^{16}O(d, p)^{17}O: (1957BR82); $E_d = 6.5$ to 7.5 MeV. No other proton groups appear with intensities greater than 0.1 of 4.55 MeV group.
[b] ^{16}O(d, p)^{17}O: (1956GR37); $E_d = 9$ MeV.
[c] (1956GR37); relative capture probabilities.
[d] ^{16}O(d, p)^{17}O and ^{19}F(d, α)^{17}O: (1951BU1A); $E_d = 7.9$ MeV.
[e] ^{19}F(d, α)^{17}O: (1952WA1A); $E_d = 1.8$ MeV.

1958RI1A). It is noted that the relatively large capture probabilities corresponding to ^{17}O*(0, 0.87, 3.8, 5.08) are consistent with the assumption that these are relatively pure single particle states formed from an ^{16}O core with 1d, 2s, 1f and 1d neutrons, respectively. The states at $E_x = 3.06$ and 4.55 MeV must be presumed to arise from more complicated configurations (1956GR37).

An earlier report that the 871 keV level might be a close doublet (1956DO41) is not confirmed by (1957BR82, 1957MA1C, 1957MO1B). Q for this level is 1049.0 ± 2.2 keV (1957MO1B), 1048 ± 2 keV (1956DO41), 1047 ± 4 keV (1957BR82). The γ-ray energy is 870.5 ± 2.0 keV (1952TH24), 869 ± 3 keV (1955MA36); the internal conversion coefficient is consistent with E2 (1952TH24). The lifetime is $\tau_m = (2.5 \pm 1) \times 10^{-10}$ sec (1953TH14): this value indicates a considerable enhancement of the single particle transition rate. Possible models are discussed by (1956BA1J, 1956KA1D, 1956SC1E, 1957AM1B, 1957AM1C, 1957FA1B, 1957RA1B, 1958BA32).

Observed widths and shapes of ^{17}O*(4.55 and 5.08 MeV) are in good accord with ^{16}O(n, n)^{16}O results (1957BR82). The ratio of ground state reduced widths is 1.30 (1956CA1D). See also (1955AJ61, 1955AL1D, 1955KH31, 1956EL1A), (1956IV1A; theor.) and ^{18}F.

18. ^{16}O(t, d)^{17}O $\qquad Q_m = -2.113$

Not reported.

19. ^{16}O(α, ^{3}He)^{17}O $\qquad Q_m = -16.436$

Not reported.

20. ^{17}N(β^-)^{17}O* $\rightarrow$ ^{16}O + n $\qquad Q_m = 4.57$

The half-life is 4.14 ± 0.04 sec (1948KN24), 4.15 ± 0.1 sec (1951ST1E), 4.16 ± 0.15 sec (1956FA1C). E_β(max) $= 3.7 \pm 0.2$ MeV (1949AL04): $\log ft = 3.8$. The β-decay proceeds to an excited state or states of ^{17}O which in turn decay to ^{16}O by neutron emission: the neutron spectrum has a maximum at 0.92 ± 0.07 MeV (1949AL04, 1949HA55) and a half-width < 0.5 MeV. See also (1957JO1D; theor.).

21. ^{17}O(p, p$'$)^{17}O*

See (1954WA1A).

22. ^{17}F(β^+)^{17}O $Q_{\rm m} = 2.767$

See ^{17}F.

23. ^{18}O(p, d)^{17}O $Q_{\rm m} = -5.842$

See (1956TS1A).

24. ^{18}O(d, t)^{17}O $Q_{\rm m} = -1.810$

Not reported.

25. ^{18}O(^{3}He, α)^{17}O $Q_{\rm m} = 12.509$

Not reported.

26. ^{19}F(n, t)^{17}O $Q_{\rm m} = -7.548$

Not reported.

27. ^{19}F(p, ^{3}He)^{17}O $Q_{\rm m} = -8.313$

Not reported.

28. ^{19}F(d, α)^{17}O $Q_{\rm m} = 10.038$

Observed alpha groups are displayed in Table 17.5 (1951BU1A, 1952WA1A). At $E_{\rm d} = 1.2$ MeV, two γ-rays are observed with $E_\gamma = 2.2$ MeV ($3.06 \rightarrow 0.87$) and 3.81 MeV. The absence of the direct ground state decay of the 3.06 MeV state is consistent with $J = \frac{1}{2}$ (1956GO1Q, 1957MU1A).

29. ^{20}Ne(n, α)^{17}O $Q_{\rm m} = -0.608$

See ^{21}Ne.

^{17}F
(Fig. 36)

GENERAL:

Theory: See (1956KA1C, 1958BA32).

1. ^{17}F(β^+)^{17}O $\quad Q_{\rm m} = 2.767$

The decay proceeds to the ground state of ^{17}O: E_{β^+}(max) $= 1.748 \pm 0.006$ MeV. The spectrum has the allowed shape down to 570 keV, and an upper limit of 1% is placed on possible transitions to the 875 keV state of ^{17}O (1954WO20). The weighted mean value of the half-life from the determinations of (1949BR27, 1951LA15, 1954KO54, 1954WA1A, 1954WO20, 1958AR15) is 66.0 ± 0.3 sec. Log $ft = 3.38$. See also (1958BE1G; theor.).

2. ^{14}N(α, n)^{17}F $\quad Q_{\rm m} = -4.747$
$Q_0 = -4.76 \pm 0.07$ (1956DO1C).

Slow neutron threshold and proton recoil measurements indicate an excited state at 0.53 ± 0.04 MeV (1956DO1C).

3. ^{15}N(^{3}He, n)^{17}F $\quad Q_{\rm m} = 4.989$

Not observed.

4. ^{16}O(p, γ)^{17}F $\quad Q_{\rm m} = 0.596$

Non-resonant capture has been studied for $E_{\rm p} = 0.8$ to 2.1 MeV. This work indicates, in addition to the direct ground-state transition (γ_1), a transition (γ_2) to a state of ^{17}F at 487 ± 10 keV which then radiates (γ_3) to the ground state. The ratio of γ_2 to γ_1 is ≈ 10 over the energy region studied. The γ_1 and γ_3 radiations are approximately isotropic, while γ_2 has an almost pure ($\sin^2\theta$) distribution ($E_{\rm p} = 1.0$ to 1.9 MeV). At $E_{\rm p} = 1.35$ MeV, the cross section for production of γ_2 radiation is 6 ± 3 μb. The fact that most transitions involve the 0.50 MeV state (γ_2) indicates

Table 17.6: Energy levels of ^{17}F

E_x (MeV)	J^π	τ (sec) or Γ (keV)	Decay	Reactions
0	$(\frac{5}{2}^+)$	$\tau_{1/2} = 66.0 \pm 0.3$	β^+	1, 2, 4, 8, 13
0.500 ± 0.003	$\frac{1}{2}^+$	$\tau_m = (2.9 \pm 0.7) \times 10^{-10}$	γ	2, 4, 8
3.10	$\frac{1}{2}^-$	18.7	p	6, 8
3.86	$\frac{7}{2}^-$	< 3.3	p, γ	4, 6
4.4	$(\frac{3}{2}^-)$	≈ 400	p	6
4.7	$(\frac{3}{2}^+)$	(300)	p	6, 8
(5.1)	$(\frac{1}{2}^+)$	190	p	6
5.45		≈ 40	p	6
5.66		≈ 40	p	6
5.83		≈ 40	p	6
(6.15)		< 25	p	6
(6.6)	$(\frac{1}{2}^+)$	140	p	6
(6.75)		< 25	p	6
(6.90)		< 25	p	6

that the non-resonant yield is not to be attributed to this state; it is suggested that direct, one-stage capture is involved (1954WA1A).

The relative ^{17}F activity has been measured from $E_p = 1.1$ to 4.1 MeV by (1951LA15). The cross section increases almost linearly with proton energy from 1.1 to 3.75 MeV, except for a sharp resonance at 3.47 MeV. There is some indication of a broad resonance at 3.99 MeV (1951LA15, 1951LA1B).

For $E_p = 140$ to 170 keV, the cross section varies from 0.46 to 2.34×10^{-10} b (1958HE57). At $E_p = 616$ keV, $\sigma = 0.29 \pm 0.03$ μb; both the magnitude of the cross section and the character of the excitation function from $E_p = 275$ to 616 keV are consistent with a direct capture process (1959TA03). See also (1953WI1A, 1957BU66, 1958LI1A, 1959CH1F).

The excitation energy of the first level of ^{17}F is 495 ± 15 keV (1958HO97), 505 ± 10 keV (1957LE28). The lifetime of ^{17}F*(0.5) is $\tau_m = (2.5 \pm 0.7) \times 10^{-10}$ sec (1957LE28), $(3.5 \pm 1.5) \times 10^{-10}$ sec (1958HO97). Using the weighted mean, 2.9×10^{-10} sec, the ration τ_m ^{17}F*(0.5)/τ_m ^{17}O*(0.87) $= 1.2$ (1958HO97): see ^{16}O(d, p)^{17}O and (1958BA32).

5. ^{16}O(p, n)^{16}F $\qquad Q_m = -16.41 \qquad E_b = 0.596$

See (1958TA03).

6. ^{16}O(p, p)^{16}O $E_b = 0.596$

Observed anomalies in the scattering are exhibited in Table 17.7. The low energy scattering data require a large s-wave phase shift, probably reflecting the bound level at ^{17}F*(0.55), and a relatively large d-wave shift (1951LA1B, 1953EP1A). A study of proton polarization for $E_p = 2.5$ to 3.0 MeV confirms the assignment $J = \frac{1}{2}^-$ to ^{17}F*(3.10) and excludes $\frac{1}{2}^+$, $\frac{3}{2}^-$ (1957SO1B). A phase shift analysis for $E_p = 3$ to 7 MeV requires four broad resonances corresponding to ^{17}F*(4.5) ($P_{\frac{3}{2}}$), *(4.6) ($D_{\frac{3}{2}}$), *(5.15) ($S_{\frac{1}{2}}$) and *(6.65) MeV ($S_{\frac{1}{2}}$). Eight additional sharp resonances are found in this region (1954SE1B: see Table 17.7): however, the curves of (1956HE1B) show no evidence of fine structure from $E_p = 2.5$ to 5.5 MeV beyond that indicated in column A of Table 17.7. See also ^{16}O(d, n)^{17}F.

Table 17.7: Levels of ^{17}F from ^{16}O(p, p)^{16}O

A			B				^{17}F*
E_p (MeV)	Γ (keV)	J^π	E_p (MeV)	Γ (keV)	J^π	θ_p^2 (%)	(MeV)
2.66	19.9	$\frac{1}{2}^-$					3.10
3.47	< 3.5	$\frac{7}{2}^-$	3.50	< 25			3.86
(3.99)	≈ 500	$(\frac{3}{2}^+)$	4.1	400	$\frac{3}{2}^-$	20	4.4
(4.39)	240	$(\frac{3}{2}^-)$	4.2	350	$\frac{3}{2}^+$	32	4.7
			4.70	< 25			(5.05)
			4.8	200	$\frac{1}{2}^+$	5.5	5.1
			4.95	< 25			(5.30)
5.16	60		5.20	< 25			5.45
5.38	50		5.40	< 25			5.66
5.56	60		5.60	< 25			5.83
			5.85	< 25			(6.15)
			6.50	< 25			(6.75)
			6.4	150	$\frac{1}{2}^+$	3.7	(6.6)
			6.65	< 25			(6.90)

A: (1951LA15, 1951LA1B, 1953EP1A, 1956HE1B).

B: (1954SE1A, 1954SE1B).

Scattering at $E_p > 10$ MeV appears to be dominated by optical model effects: see ^{16}O.

7. ^{16}O(p, α)^{13}N $Q_m = -5.208$ $E_b = 0.596$

See (1958WH34).

8. ^{16}O(d, n)^{17}F $Q_{\rm m} = -1.631$

$E_{\rm thresh.} = 1.830 \pm 0.004$; $Q_0 = -1.626 \pm 0.004$ (1955MA85).

Neutron groups have been observed corresponding to ^{17}F*(0, 0.536 ± 0.010 (1951AJ1B), 0.53 ± 0.06 (1951EL1A, 1953MI10), 3.03 ± 0.06, and 4.74 ± 0.07 MeV (1957GR1A)). Angular distributions of the n_0 and n_1 groups, analyzed by stripping theory, indicate $J = \frac{3}{2}^+$ or $\frac{5}{2}^+$ for the ground state and $J = \frac{1}{2}^+$ for the first excited state (1951AJ1B, 1951EL1A, 1953MI10). The ratio of the reduced widths of the ^{17}F and ^{17}O ground states is 1.30 (1956CA1D). The width of the neutron group corresponding to ^{17}F*(4.74) is < 90 keV, considerably smaller than is reported in ^{16}O(p, p)^{16}O (1957GR1A).

Slow neutron thresholds have been observed corresponding to the ground and first excited states of ^{17}F: $Q_1 = -2.125 \pm 0.004$ MeV corresponding to ^{17}F*(499 ± 3 keV) (1955MA85). See also (1958BE03, 1958GO77).

9. ^{16}O(^{3}He, d)^{17}F $Q_{\rm m} = -4.898$

Not reported.

10. ^{16}O(α, t)^{17}F $Q_{\rm m} = -19.217$

Not reported.

11. ^{17}O(p, n)^{17}F $Q_{\rm m} = -3.550$

Not reported.

12. ^{17}O(^{3}He, t)^{17}F $Q_{\rm m} = -2.785$

Not reported.

13. ^{19}F(γ, 2n)^{17}F $Q_{\rm m} = -19.582$

See ^{19}F.

14. $^{19}F(p, t)^{17}F$ $Q_{\rm m} = -11.098$

Not reported.

15. $^{20}Ne(p, \alpha)^{17}F$ $Q_{\rm m} = -4.158$

Not reported.

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(Closed 01 December 1958)

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