Energy Levels of Light Nuclei
$A = 17$

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Abstract: An evaluation of $A = 16$–17 was published in *Nuclear Physics A*564 (1993), 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. The introduction 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 of Contents for $A = 17$

Below is a list of links for items found within the PDF document. The introductory Table 2 *is available on this website via the link.*

Because much of the theoretical work reported in the literature for $A = 17$ is relevant to more than one of the $A = 17$ nuclides, the following general theoretical discussion for this mass system is provided here. Some of this work is also referenced in later sections of this compilation.

Ground state properties of ^{17}O and ^{17}F are calculated by (1989FU05) with the use of self-consistent relativistic mean field models of baryon-meson dynamics, including contributions from ρ, ω, and σ mesons. They calculate binding energies, rms radii, magnetic and quadrupole moments, and elastic magnetic scattering form factors and compare to experimental data. Work reported in (1990LO11) revisits previous calculations based on the density functional method. Binding energies of ^{17}O and ^{17}F as well as proton and neutron radii are calculated and compared to experimental data. Calculations of Coulomb excitation of the first excited state of ^{17}O due to virtual E1 transitions through intermediate states are reported in (1989BA60). They use shell-model wavefunctions including single-particle harmonic oscillator and higher configurations. The work in (1986PO06, 1987RI03, 1989VOZM) deals with $A = 17$ nuclei as reaction products in heavy ion reactions. (1989WA06) reports shell model calculations which use a modification of the Millener-Kurath interaction (MK3), including energy spectra and wavefunctions of ^{17}C and ^{17}N. The half-life and decay modes of both the allowed and first-forbidden β-decays of ^{17}C are predicted, as are the spectroscopic factors and electromagnetic transition rates of ^{17}N. They find generally good agreement with experimental results.

Analog correspondences and structure of states in ^{17}N and ^{17}O are covered in Table 17.3. A relativistic Hartree calculation was performed by (1991ZH06). The effect of tensor coupling of the pion is found to be important in calculating the magnetic moments. Results are presented for binding energies, quadrupole moments, magnetic moments, and single particle energies. (1988BR11) analyze ground state binding energies and excited-state energies using several two-body interactions. They develop a semi-empirical "best fit" based on a 14-parameter density-dependent two-body potential. (1988MI1J) discuss features of an effective interaction used to calculate cross-shell matrix elements. They apply shell-model transition densities to the $1\hbar\omega$ excitation of non-normal-parity states in electron, nucleon, and pion scattering. (1986YA1B) obtain an effective shell-model interaction by starting with a bare Hamiltonian of kinetic energy and the Reid soft-core pair potential, and folding this with pair correlation operators not represented by configuration mixing in a given shell model space. In (1987BR30), calculations based on the full-basis sd-shell wave function are used to analyze M1 transition data and magnetic moment data. The parameters of an effective M1 operator are obtained. Differences in effective operators are used to evaluate the importance of meson exchange currents, Δ-isobar effects and other mesonic exchange currents. The authors of (1986ED03) apply the particle-hole model to the study of E1 states below the GDR using the WMBH residual interaction and compare the results to experimental data. The elastic magnetic form factor is calculated with the inclusion of both the $2\hbar\omega$ particle-hole excitations and the Zuker-type multi-particle-multi-hole configuration mixing, the latter of which helps explain the M3 suppression, but produces magnetic moments which are too small (1992ZH07). The low-energy spectra were investigated by (1990LI1Q), who included 2h-1p multiple scattering and PH TDA self-screening in their Paris-potential-based Green's function calculation. Two- and three-fragment clustering of 1p-shell nuclei is studied in the framework of the intermediate-coupling shell model (1992KW01). (1991SK02) use matrix inversion techniques to determine effective matrix elements for E2 and M1 transitions for $A = 17$ nuclei. A compilation of calculated mass excesses and binding energies of members of $T \leq 6$ isospin multiplets for $9 \leq A \leq 60$ is presented in (1986AN07). The production of nuclei far from stability via multinucleon transfer reactions is reviewed in (1989VOZM).

^{17}He, ^{17}Li
(not illustrated)

Not observed: see (1986AJ04, 1988POZS).

^{17}Be
(not illustrated)

This nucleus has not been observed. Its atomic mass excess is calculated to be 70.67 MeV: see (1977AJ02). It is then unstable with respect to breakup into ^{16}Be + n and ^{15}Be + 2n by 3.38 and 3.35 MeV, respectively. See also (1983ANZQ).

^{17}B
(not illustrated)

^{17}B was observed in the 4.8 GeV proton bombardment of Uranium: it is particle stable and its ground state probably has $J^\pi = \frac{3}{2}^-$ (1974BO05, 1986AJ04) in agreement with the shell model (1992WA22). It has been observed in several heavy ion reactions (1987GI05, 1988DU09, 1988SA04, 1988TA1N, 1988WO09, 1989LE16). The atomic mass was measured to be 42.82 ± 0.80 MeV (1987GI05), 43.62 ± 0.17 MeV (1988WO09), and 43.90 ± 0.23 MeV (1991OR01), which compare well with the predicted mass of 43.31 ± 0.50 MeV (1988WA18). See also (1986AN07). The half life has been measured to be $T_{1/2} = 5.3 \pm 0.6$ msec (1988SA04), 5.08 ± 0.05 msec (1988DU09), and 5.9 ± 3.0 msec (1991RE02). Beta-delayed multi-neutron emission has been observed and branching ratios have been measured (1988DU09, 1989LE16, 1991RE02).

A model of ^{17}B considered as a three-body system composed of a ^{15}B core and two outside neutrons was studied by (1990RE16). The binding energy and radius were calculated. Shell model interactions in the cross-shell model space connecting the 0p and 1s0d shells were applied in the $A = 15$–20 Boron isotopes by (1992WA22).

^{17}C
(Fig. 4)

The atomic mass excess given by (1988WA18) for ^{17}C is 21035 ± 17 keV. See also (1986AN07). ^{17}C is then stable with respect to ^{16}C + n by 0.73 MeV. E_{β^-}(max) to ^{17}N$_{\rm g.s.}$ $= 13.16$ MeV. See also (1986BI1A). The half-life of ^{17}C has been measured to be 202 ± 17 msec (1986CU01), 220 ± 80 msec (1986DU07), 180 ± 31 msec (1988SA04), and 174 ± 31 msec (1991RE02). Relative intensities of β-delayed gammas were measured by (1986DU07, 1986HU1A, 1986JEZY) [see Table 17.1]. Observation of β-delayed neutron emission has been reported and the probability measured to be (32.0 ± 2.7)% by (1991RE02). See also (1988MU08). Total cross sections induced by ^{17}C on Cu were measured by (1989SA10). See also (1987SA25). An excited state of ^{17}C is reported at $E_{\rm x} = 292 \pm 20$ keV [see (1982AJ01)] and at 295 ± 10 keV (1982FI10). Three closely

Table 17.1: Beta decay of ^{17}C [a]

^{17}N state		
J^{π}_{n}	$E_{\rm x}$ (keV)	Branch(%) [b]
$\frac{3}{2}^-$	1374	21(10)
$\frac{1}{2}^+$	1850	40(7)
$\frac{5}{2}^-$	1907	20(8)
$\frac{5}{2}^+$	2526	19(9)

[a] (1986DU07). See also (1989WA06).

[b] These intensities are relative ones for decay to bound states. To obtain absolute intensities, one would scale by a factor $(1 - P_{\rm n})$ where the fraction of decays leading to neutron-unstable states $P_{\rm n} = 0.320 \pm 0.027$ (1991RE02).

spaced low-lying states are expected $[J^{\pi} = \frac{5}{2}^+, \frac{3}{2}^+, \frac{1}{2}^+]$ (1982CUZZ, 1989WA06): it is not clear which is the ground state. See also (1986AJ04).

Shell-model calculations of energy spectra and wave functions and predictions of half lives and β-decay modes are described in (1989WA06). Hartree-Fock calculations of light neutron-rich nuclei including ^{17}C are discussed in (1987SA15). See also the study of partitioning of a two component particle system in (1987SN01).

^{17}N

(Figs. 1 and 4)

GENERAL:

Theoretical papers and reviews: Energy spectra and wave functions of ^{17}N are calculated and the results used to predict ^{18}O(d, ^{3}He)^{17}N spectroscopic factors and electromagnetic transition rates (1989WA06). Self-consistent calculations of light nuclei including ^{17}N are reviewed in (1990LO11). Production of ^{17}N in heavy ion collisions is discussed in (1986HA1B, 1987RI03, 1987YA16, 1989VOZM). See also (1986AN07, 1986PO06, 1991SK02, 1992KW01, 1992WA22).

Experimental papers: Production of ^{17}N in heavy ion collisions or multinucleon transfer in collisions of light nuclei are discussed in (1986BI1A, 1987AN1A, 1987AV1B, 1987SA25, 1987VI02, 1989CA25, 1989SA10, 1989YO02).

1. (a) ^{17}N(β^-)^{17}O$^* \rightarrow$ ^{16}O + n $\qquad Q_{\rm m} = 4.537$

   (b) ^{17}N(β^-)^{17}O $\qquad Q_{\rm m} = 8.680$

The half-life of ^{17}N is 4.173 ± 0.004 sec. The decay is principally [see Table 17.5] to the neutron unbound states ^{17}O*(4.55, 5.38, 5.94) $[J^\pi = \frac{3}{2}^-, \frac{3}{2}^-, \frac{1}{2}^-]$. The nature of the decay is in agreement with $J^\pi = \frac{1}{2}^-$ for ^{17}N$_{\rm g.s.}$: see (1982AJ01). For a comparison of the ^{17}N and ^{17}Ne decays see Table 17.6. For GT transition rates see (1983SN03) and (1983RA29) and references in (1986AJ04). See also the recent analysis of GT beta decay rates of (1993CH06).

2. ^{9}Be(^{9}Be, p)^{17}N $\qquad Q_{\rm m} = 7.534$

See (1988LA25).

3. ^{11}B(^{7}Li, p)^{17}N $\qquad Q_{\rm m} = 8.415$

Observed proton groups and γ-rays are displayed in Table 17.7. Table 17.4 shows branching ratio and lifetime measurements. Recent measurements of the cross section at $E_{\rm c.m.} = 1.45$–6.10 are reported in (1990DA03).

4. ^{14}C(^{6}Li, ^{3}He)^{17}N $\qquad Q_{\rm m} = -5.697$

Angular distributions have been studied to ^{17}N*(1.91, 2.53, 3.63, 4.01, 5.17) at $E(^6{\rm Li}) = 34$ MeV and the results compared with those for the analog reaction to ^{17}O (reaction 20) (1983CU04).

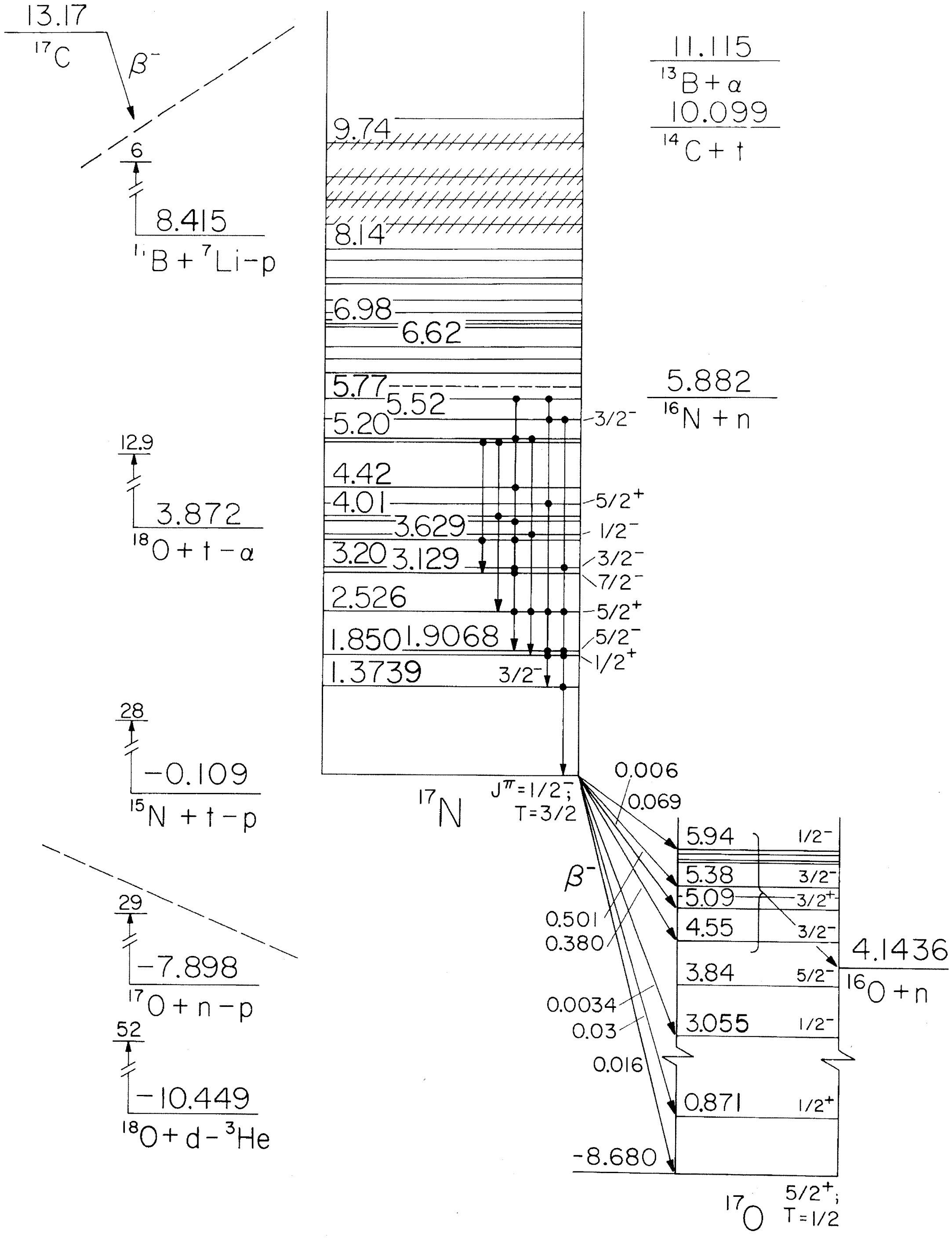

Fig. 1: Energy levels of ^{17}N. For notation see Fig. 2.

Table 17.2: Energy levels of ^{17}N [a]

E_x in ^{17}N (MeV $\pm$ keV)	$J^\pi; T$	τ or Γ	Decay	Reactions
0	$\frac{1}{2}^-; \frac{3}{2}$	$\tau_{1/2} = 4.173 \pm 0.004$ sec	β^- [b]	1, 2, 3, 4, 5, 6, 7, 8
1.3739 ± 0.3	$\frac{3}{2}^-$	$\tau_m = 93 \pm 35$ fsec	γ	3, 5, 6, 7, 8
1.8496 ± 0.3	$\frac{1}{2}^+$	41^{+20}_{-9} psec	γ	3, 5, 6, 7, 8
1.9068 ± 0.3	$\frac{5}{2}^-$	11 ± 2 psec	γ	3, 4, 5, 6, 7, 8
2.5260 ± 0.5	$\frac{5}{2}^+$	33 ± 3 psec	γ	3, 4, 5, 7, 8
3.1289 ± 0.5	$\frac{7}{2}^-$	275 ± 80 psec	γ	3, 5, 7, 8
3.2042 ± 0.9	$\frac{3}{2}^-$	< 30 fsec	γ	3, 5, 7, 8
3.6287 ± 0.7	$(\frac{7}{2}, \frac{9}{2})^-$ [c]	12 ± 2 psec	γ	3, 4, 5
3.663 ± 4	$\frac{1}{2}^-$	< 350 fsec	γ	3, 5
3.9060 ± 2.0	$(\frac{3}{2}, \frac{5}{2})^-$ [c]	52 ± 22 fsec	γ	3, 5
4.0064 ± 2.0	$\frac{3}{2}^{(+)}$ [c]	< 15 fsec	γ	3, 4, 5, 7
4.209 ± 3	$\frac{5}{2}^+$	< 70 fsec	γ	3, 5
4.415 ± 3	$(\frac{3}{2}, \frac{5}{2})^-$ [c]	$(< 60$ fsec)	γ	3, 5
5.170 ± 2	$(\frac{9}{2}^+)$ [c]	< 60 fsec	γ	3, 4, 5, 7
5.195 ± 3	$\frac{3}{2}^+$ [c]	< 95 fsec	γ	3, 5
5.515 ± 3	$\frac{3}{2}^-$	< 100 fsec	γ	3, 5, 7
5.772 ± 3	$\frac{1}{2}, \frac{3}{2}^+$ [c]	< 120 fsec	γ	3, 5
(6.08 ± 30)				3
6.233 ± 8				3, 5
6.449 ± 3				3, 5
6.615 ± 19				3, 5
6.938 ± 15				5
6.981 ± 20	$\frac{3}{2}^-$ [c]			3, 5, 7
7.013 ± 22				3, 5, 7
7.17 ± 40				3
7.37 ± 40				3
7.63 ± 40				3
7.73 ± 40				3
8.00 ± 25				3
8.14 ± 40				3
8.55 ± 40		broad		3

Table 17.2: Energy levels of ^{17}N [a] (continued)

E_x in ^{17}N (MeV ± keV)	$J^\pi; T$	τ or Γ	Decay	Reactions
8.93 ± 40		broad		3
9.26 ± 40		broad		3
9.74 ± 40		broad		3
10.14	$(\frac{1}{2}, \frac{3}{2})^-$			7

[a] See also (1984BA24) and Table 17.3.

[b] See also Tables 17.4 and 17.5.

[c] Arguments presented in the appendix of (1989WA06) favor assigments (E_x(MeV), J^π) = (3.629, $\frac{9}{2}^-$; 3.906, $\frac{5}{2}^-$; 4.006, $\frac{3}{2}^+$; 4.415, $\frac{5}{2}^-$; 5.170, $\frac{9}{2}^+$; 5.195, $\frac{3}{2}^+$; 5.772, $\frac{3}{2}^+$).

5. ^{15}N(t, p)^{17}N $\qquad Q_m = -0.109$

Observed proton groups are displayed in Table 17.8.

6. ^{18}O(γ, p)^{17}N $\qquad Q_m = -15.942$

The giant resonance at $E_x = 23.5$ MeV decays to ^{17}N$_{\rm g.s.}$ and to the first three excited states of ^{17}N (1982BA03). See also ^{18}O in (1983AJ01).

7. ^{18}O(d, ^{3}He)^{17}N $\qquad Q_m = -10.448$

Observed groups of ^{3}He ions are displayed in Table 17.7. See also (1982AJ01) and ^{20}F in (1983AJ01).

Shell-model calculations of energy spectra and wave functions for ^{17}C and ^{17}N are presented in (1989WA06), and the results are used to predict spectroscopic factors for this reaction. Arguments are given for J^π assignments for states in ^{16}N below neutron threshold.

8. ^{18}O(t, α)^{17}N $\qquad Q_m = 3.873$

See Tables 17.4 and 17.7.

Table 17.3: Analog correspondences and structure of states in ^{17}N and ^{17}O [a]

J^π	$E_x(^{17}\text{N})$	$E_x(^{17}\text{O})$	Configuration
$\frac{1}{2}^-$	0.000	11.078	$p_{1/2}^{-1} \otimes (sd)^2; 0_1^+$
$\frac{3}{2}^-$	1.374	12.466	$p_{1/2}^{-1} \otimes (sd)^2; 2_1^+$
$\frac{5}{2}^-$	1.907	12.998	$p_{1/2}^{-1} \otimes (sd)^2; 2_1^+$
$\frac{7}{2}^-$	3.129	14.230	$p_{1/2}^{-1} \otimes (sd)^2; 4_1^+$
$\frac{9}{2}^-$	3.629	14.760	$p_{1/2}^{-1} \otimes (sd)^2; 4_1^+$
$\frac{3}{2}^-$	3.663	14.791	$p_{1/2}^{-1} \otimes (sd)^2; 0_2^+$
$\frac{3}{2}^-$	3.204	14.286	$p_{1/2}^{-1} \otimes (sd)^2; 2_2^+$
$\frac{5}{2}^-$	3.906	[b]	$p_{1/2}^{-1} \otimes (sd)^2; 2_2^+$
$\frac{5}{2}^-$	4.415	[b]	$p_{1/2}^{-1} \otimes (sd)^2; 3_1^+$
$\frac{7}{2}^-$	[b]	[b]	$p_{1/2}^{-1} \otimes (sd)^2; 3_1^+$
$\frac{3}{2}^-$	5.515	16.580	$p_{1/2}^{-1} \otimes (sd)^2; 0_1^+$
$\frac{1}{2}^+$	1.850	12.944	$^{14}\text{C(gs)} \otimes {}^{19}\text{F(gs)}$
$\frac{5}{2}^+$	2.526	13.635	$^{14}\text{C(gs)} \otimes {}^{19}\text{F}(0.197)$
$\frac{3}{2}^+$	4.006	15.199	$^{14}\text{C(gs)} \otimes {}^{19}\text{F}(1.554)$
$\frac{5}{2}^+$	4.209	15.368	
$\frac{9}{2}^+$	5.170	16.243	$^{14}\text{C(gs)} \otimes {}^{19}\text{F}(2.780)$
$\frac{3}{2}^+$	5.195	[b]	

[a] This information was provided by D.J. Millener in a private communication.

[b] Uncertain.

Table 17.4: Radiative transitions and lifetimes of ^{17}N states [a]

E_i (MeV)	E_f (MeV)	Mtpl.	Branch (%)	$\Gamma_\gamma/\Gamma_\omega$ [b] (W.u.)	τ_m
1.37	0	M1	100	0.13 ± 0.05	95 ± 35 fsec
1.85	0	E1	86.5 ± 2.5		41^{+20}_{-9} psec
	1.37	E1	13.5 ± 2.5	$(3.2 \pm 1.5) \times 10^{-5}$	
1.91	0	E2	77.0 ± 2.5	0.9 ± 0.2	11 ± 2 psec
	1.37	M1	23.0 ± 2.5	$(5 \pm 1) \times 10^{-3}$ [c]	
2.53	0	M2	11 ± 1	0.22 ± 0.04	33 ± 3 psec
	1.37	E1	34 ± 3	$(1.0 \pm 0.2) \times 10^{-5}$	
	1.85	E2	12.0 ± 1.5	8.1 ± 1.6	
	1.91	E1	41.0 ± 2.5		
3.13 [d]	1.91	M1	100	0.06 ± 0.02	275 ± 80 fsec
3.20 [e]	0	M1	88 ± 4	> 0.025 [f]	< 30 fsec
	1.91	M1	12 ± 4	> 0.05	
3.63 [g]	1.91	E2	47 ± 10	0.8 ± 0.2	12 ± 2 psec
	3.13	M1	53 ± 10	0.010 ± 0.03	
3.66	1.85	E1	100	$> 7 \times 10^{-4}$	< 350 fsec
3.91	1.91	M1	100	$(8^{+5}_{-3}) \times 10^{-2}$ [h]	52 ± 22 fsec
4.01	1.85		$\geq 15 \pm 5$ [i]		
	2.53	(M1)	85 ± 5	0.55	< 15 fsec
4.21	1.37		100		< 70 fsec
4.42	1.91		100		(< 60 fsec)
5.17	2.53	E2	37 ± 7	> 15	< 60 fsec
	3.13		63 ± 7		
5.20	1.85		≈ 42		< 95 fsec
	1.91		≈ 58		
5.52	0		≈ 50		< 100 fsec
	1.37		≈ 50		
5.77	1.37		≈ 25		< 120 fsec
	1.91		≈ 25		
	4.01		≈ 50 [i]		

[a] See Tables 17.5 in (1977AJ02, 1982AJ01) for references and additional detail.
[b] Assuming pure multipole transitions and J^π from Table 17.2: see also Table 2.
[c] $\Gamma_\gamma/\Gamma_\omega = 0.4^{-0.4}_{+1.3}$ (E2).
[d] Branches to ^{17}N*(0, 1.37, 1.85, 2.53) are, respectively, < 2, < 5, < 2 and < 3%.
[e] Branches to ^{17}N*(1.37, 1.85, 2.53) are, respectively, < 5, < 6 and < 3%.
[f] $\delta = -0.06 \pm 0.08$ or 2.1 ± 0.4. All other δ are consistent with 0.
[g] Branches to ^{17}N*(0, 1.37, 1.85, 2.53, 3.20) are, respectively, < 10, < 10, < 7, < 3, < 2%.
[h] This number appears to be in error: see Table 2.
[i] This branch is uncertain.

Table 17.5: Beta decay of ^{17}N [a]

Decay to ^{17}O*(keV)	J^π	Branch(%)	log ft
0	$\frac{5}{2}^+$	1.6 ± 0.5	7.29 ± 0.11 [f]
871	$\frac{1}{2}^+$	3.0 ± 0.5	6.80 ± 0.07
3055.2 ± 0.3 [b]	$\frac{1}{2}^-$	0.34 ± 0.06	7.08 ± 0.08
3841	$\frac{5}{2}^-$	$< 7 \times 10^{-3}$	> 8.5
4551.2 ± 1.3 [c]	$\frac{3}{2}^-$	38.0 ± 1.3 [e]	4.41 ± 0.02
5083 ± 21 [c]	$\frac{3}{2}^+$	0.6 ± 0.4	5.9 ± 0.5
5389.0 ± 1.2 [c, d]	$\frac{3}{2}^-$	50.1 ± 1.3 [e]	3.86 ± 0.02
5738	$(\frac{1}{2}^+)$	< 0.23	> 6.0
5868	$\frac{3}{2}^+$	< 0.15	> 6.0
5951.8 ± 1.9 [c, d]	$\frac{1}{2}^-$	6.9 ± 0.5 [e]	4.35 ± 0.03
6356	$\frac{1}{2}^+$	< 0.08	> 6.0

[a] See Table 17.3 in (1986AJ04) and Table 17.2 in (1982AJ01) for references and additional information.

[b] Direct ground state decay < 1.5%.

[c] From neutron groups. [The E_x were calculated on the basis of 4144.3 ± 0.8 keV for E_b for a neutron in ^{17}O.] Γ_n for ^{17}O*(4.55, 5.08, 5.38, 5.94) are, respectively, 54.8 ± 0.4, 113 ± 55, 63.2 ± 1.1 and 60.5 ± 3.2 keV. See also Table 17.17.

[d] See, however, Tables 17.17 and 17.10.

[e] Calculated to lead to a total neutron emission probability of (95 ± 1)% [100% less the branches to ^{17}O*(0, 0.87, 3.06)].

[f] $\log f_1 t = 9.56 \pm 0.13$ (1971TO08).

Table 17.6: Comparison of ^{17}N and ^{17}Ne β-decay [a]

Final state in		J^{π}	Γ_{n} [b, c] (keV)	Γ_{p} [b] (keV)	$(ft)^{-}$ [d, e]	$(ft)^{+}$ [d]	δ [f]
^{17}O	^{17}F						
3.06	3.10	$\frac{1}{2}^{-}$	0	19	$(1.2 \pm 0.2) \times 10^{7}$	$(1.3^{+0.2}_{-0.3}) \times 10^{7}$	0.1 ± 0.3
4.55	4.70	$\frac{3}{2}^{-}$	55	230	$(2.57 \pm 0.13) \times 10^{4}$	$(3.79 \pm 0.07) \times 10^{4}$	0.47 ± 0.08
5.38	5.52	$\frac{3}{2}^{-}$	63	69	$(7.2 \pm 0.3) \times 10^{3}$	$(6.51 \pm 0.12) \times 10^{3}$	-0.10 ± 0.04
5.94	6.04	$\frac{1}{2}^{-}$	61	28	$(2.24 \pm 0.16) \times 10^{4}$	$(3.53 \pm 0.11) \times 10^{4}$	0.58 ± 0.12

[a] (1988BO39). See also Table 17.4 in (1986AJ04) and see Table 17.3 in (1982AJ01) for references.
[b] Γ_{n} and Γ_{p} are the neutron and proton widths of the ^{17}O and ^{17}F states, respectively.
[c] Γ_{n} for ^{17}O*(4.55, 5.08, 5.38, 5.94) are reported to be, respectively, 54.8 ± 0.4, 113 ± 55, 63.2 ± 1.1 and 60.5 ± 3.2 keV.
[d] $(ft)^{-}$ and $(ft)^{+}$ are for the ^{17}N and ^{17}Ne decays, respectively.
[e] See Tables 17.5 and 17.27.
[f] $\delta \equiv [(ft)^{+}/(ft)^{-}] - 1$.

Table 17.7: Excited states of ^{17}N from ^{11}B(^{7}Li, p), ^{18}O(d, ^{3}He) and ^{18}O(t, α) [a]

E_{x} (keV)		l	J^{π}	C^2S
^{11}B(^{7}Li, p)	^{18}O(t, α)^{17}N and ^{18}O(d, ^{3}He)^{17}N			
	0	1	$\frac{1}{2}$	2.02
1373.7 ± 0.5	1374.1 ± 0.4	1	$\frac{3}{2}^{-}$	0.38
1850.0 ± 0.5	1849.5 ± 0.3	0	$\frac{1}{2}^{+}$	0.41 ± 0.14
1906.8 ± 0.4	1906.9 ± 0.5		$\frac{5}{2}^{-}$	
2526.3 ± 1.0	2525.9 ± 0.6	2	$\frac{5}{2}^{+}$	0.53 ± 0.17
3128.7 ± 0.6	3129.2 ± 0.6		$\frac{7}{2}^{(-)}$	
3203 ± 2	3204.4 ± 0.9	1	$\frac{3}{2}^{-}$	0.05
3628.7 ± 0.7			$> \frac{3}{2}$ [d]	
3663 ± 4			$(\frac{1}{2}, \frac{3}{2})^{-}$	
3906.0 ± 2.0			$\leq \frac{7}{2}$	
4006.4 ± 2.0	4000	(1)	$\frac{3}{2}^{(-)}$	0.04
4208 ± 3			$\leq \frac{5}{2}$	
4415 ± 3			$\leq \frac{7}{2}$	
5170 ± 2	5170	(2)	$\frac{3}{2} \leq J \leq \frac{9}{2}$ [e]	0.08

Table 17.7: Excited states of ^{17}N from ^{11}B(^{7}Li, p), ^{18}O(d, ^{3}He) and ^{18}O(t, α) [a] (continued)

E_x (keV)		l	J^π	C^2S
^{11}B(^{7}Li, p)	^{18}O(t, α)^{17}N and ^{18}O(d, ^{3}He)^{17}N			
5195 ± 3			$(\frac{1}{2}, \frac{3}{2}, \frac{5}{2})^+$	
5514 ± 3	$\equiv 5523$	1	$\frac{3}{2}^-$	1.83
5770 ± 3			$\leq \frac{7}{2}$	
6080 ± 30				
6240 ± 25				
6430 ± 30				
6610 ± 25				
6990 ± 20	6990 [c]	1	$\frac{3}{2}^-$ [f]	0.32
7170 ± 40				
7370 ± 40				
	7510	(1)	$(\frac{1}{2}, \frac{3}{2})^-$	0.09
7630 ± 40				
7730 ± 40				
8000 ± 25				
8140 ± 40				
8000 ± 25				
8140 ± 40				
8550 ± 40 [b]				
8930 ± 40				
9260 ± 40				
9740 ± 40				
	10140	(1)	$(\frac{1}{2}, \frac{3}{2})^-$	0.5

A: ^{11}B(^{7}Li, p)^{17}N
B: ^{18}O(t, α)^{17}N and ^{18}O(d, ^{3}He)^{17}N

[a] See also Tables 17.4 in (1977AJ02, 1982AJ01) for references and additional information. See also (1981MA14).
[b] This state and the ones below are broad.
[c] Unresolved.
[d] Probably $(\frac{7}{2}, \frac{9}{2})^-$.
[e] Probably $(\frac{7}{2}, \frac{9}{2})^+$.
[f] See (1981MA14) for confirmation of $J^\pi = \frac{3}{2}^-$ for $E_x = 1.37, 5.51, 6.99$ MeV.

Table 17.8: States of ^{17}N from ^{15}N(t, p) [a]

E_x (keV)	L	J^π	E_x (keV)	L	J^π
0 [b]	0	$\frac{1}{2}^-$	4420 ± 7 [b]	2	$(\frac{3}{2}, \frac{5}{2})^-$
1372 ± 6 [b]	2	$(\frac{3}{2}, \frac{5}{2})^-$		5	$(\frac{9}{2}^+)$
			5179 ± 4 [c]		
1851 ± 4	1	$(\frac{1}{2}, \frac{3}{2})^+$		1	$((\frac{1}{2}, \frac{3}{2})^+)$
1909 ± 3 [b]	2	$(\frac{3}{2}, \frac{5}{2})^-$	5517 ± 6	(2)	
2524 ± 4	3	$(\frac{5}{2}, \frac{7}{2})^+$	5780 ± 6	(1)	
3127 ± 6 [b]	4	$(\frac{7}{2}, \frac{9}{2})^-$	6233 ± 8 [d]	(2)	
3201 ± 5 [b]	2	$(\frac{3}{2}, \frac{5}{2})^-$	6449 ± 3	(4, 5)	
3625 ± 6 [b]	4	$(\frac{7}{2}, \frac{9}{2})^-$	6627 ± 30	weak	
3664 ± 6 [b]	0	$\frac{1}{2}^-$	6938 ± 15		
3906 ± 5 [b]	2	$(\frac{3}{2}, \frac{5}{2})^-$	6981 ± 20	(3, 4)	
4011 ± 6	(1)		7013 ± 22		
4213 ± 6	3	$\frac{5}{2}^+$ [e]			

[a] (1979FO14): $E_t = 15.0$ MeV; DWBA analysis.
[b] Predominantly 2p-1h states.
[c] Unresolved states.
[d] ^{17}N*(6.08) is not observed.
[e] The $\frac{7}{2}^+$ possibility can be eliminated because the $4.21 \rightarrow 1.37$ MeV transition would then have too large an M2 strength (> 500 W.u.). See (1986AJ04).

^{17}O

(Figs. 2 and 4)

GENERAL: See Table 17.9.

$\mu = -1.89379(9)$ n.m. [see (1989RA17)].
$Q = -25.78$ mb [see (1989RA17)].
Isotopic abundance $= (0.038 \pm 0.003)$% (1984DE53).
For Coulomb excitation of ^{17}O*(0.87) see (1982KU14).

1. ^{7}Li(^{14}N, α)^{17}O $\quad Q_{\rm m} = 16.155$

See (1977AJ02, 1987SHZS).

2. ^{9}Be(^{16}O, ^{8}Be)^{17}O $\quad Q_{\rm m} = 2.478$

See (1982AJ01).

3. (a) ^{10}B(^{7}Li, p)^{16}N $\quad Q_{\rm m} = 13.986$ $\quad E_{\rm b} = 27.766$
(b) ^{10}B(^{7}Li, d)^{15}N $\quad Q_{\rm m} = 13.720$
(c) ^{10}B(^{7}Li, t)^{14}N $\quad Q_{\rm m} = 9.144$
(d) ^{10}B(^{7}Li, α)^{13}C $\quad Q_{\rm m} = 21.408$

See (1977AJ02).

Figure 2: Energy levels of ^{17}O. In these diagrams, energy values are plotted vertically in MeV, based on the ground state as zero. Uncertain levels or transitions are indicated by dashed lines; levels which are known to be particularly broad are cross-hatched. Values of total angular momentum J, parity, and isobaric spin T which appear to be reasonably well established are indicated on the levels; less certain assignments are enclosed in parentheses. For reactions in which ^{17}O is the compound nucleus, some typical thin-target excitation functions are shown schematically, with the yield plotted horizontally and the bombarding energy vertically. Bombarding energies are indicated in laboratory coordinates and plotted to scale in cm coordinates. Excited states of the residual nuclei involved in these reactions have generally not been shown; where transitions to such excited states are known to occur, a brace is sometimes used to suggest reference to another diagram. For reactions in which the present nucleus occurs as a residual product, excitation functions have not been shown; a vertical arrow with a number indicating some bombarding energy, usually the highest, at which the reaction has been studied, is used instead. Further information on the levels illustrated, including a listing of the reactions in which each has been observed, is contained in the master table, entitled “Energy levels of ^{17}O”.

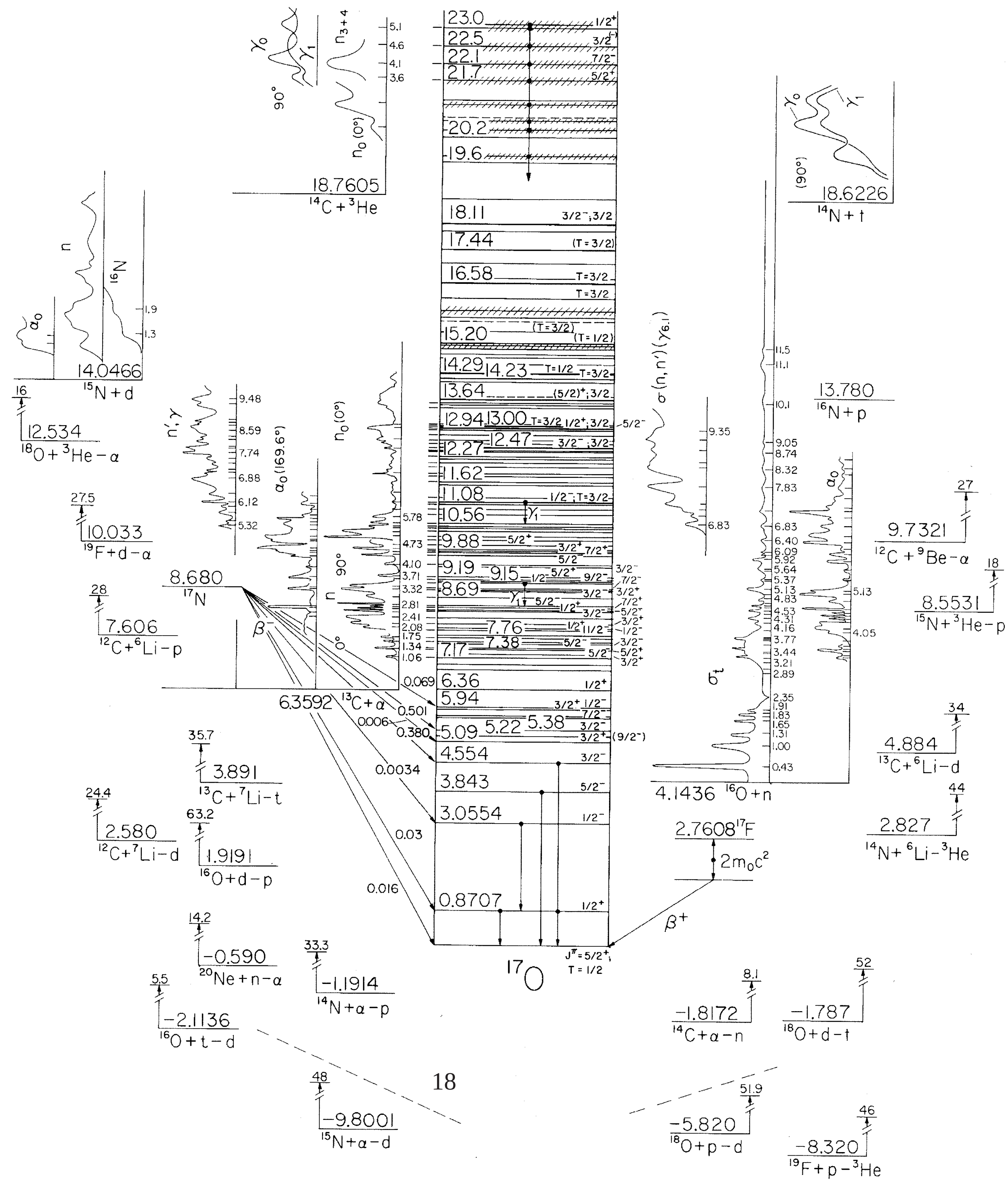

Table 17.9: ^{17}O – General

Reference	Description
	Shell Model
1986BO1C	Argument for modification of the accepted values for single-particle energies in ^{17}O
1986ED03	Particle-hole description of dipole states in ^{17}O
1986YA1B	Effective shell-model operators; calculated D-shell splitting
1987BR30	Empirically optimum M1 operator for sd-shell nuclei
1987LI1F	Double delta & surface delta interactions & spectra of O isotopes in the (s-d) shell (A)
1988BR11	Semi-empirical effective interactions for the 1s-0d shell
1988MI1J	Shell model transition densities for electron & pion scattering
1989OR02	Empirical isospin-nonconserving hamiltonians for shell-model calculations
1989WU1C	Contribution of the 2p-1h multiple scattering correlation to spectra of ^{17}O & ^{15}O (A)
1990LI1Q	Contrib. of 2h-1p multiple scat. correl. & self-screening effect to spectra of ^{17}O & ^{15}O
1991SK02	Effective transition operators in the sd shell
1992JA13	Kinetic-energy operator in the effective shell-model interaction applied to ^{16}O & ^{17}O
1992KW01	Clustering of 1p-shell nuclei in the framework of the shell model
1992WA22	Effective interactions for the 0p1s0d nuclear shell-model space
1992ZH07	Magnetic moments & form factors of ^{17}O and ^{41}Ca
	Collective and Cluster Models
1991LI41	Equilibrium deformation & pairing force calculated for $A = 17$–29 nuclei (Nilsson levels)
1992BA50	Vertex constants & the nucleon-nucleon potential in the generator coordinate method
1992JA13	Kinetic-energy operator in the effective shell-model interaction applied to ^{16}O & ^{17}O
1992KW01	Clustering of 1p-shell nuclei in the framework of the shell model
1992NA04	Shell-model operator for K(j)-band splitting in odd-A nuclei
	Special States
1986AN07	Predicted masses and excitation energies in higher isospin multiplets for $9 \leq A \leq 60$
1986BO1C	Argument for modification of the accepted values for single-particle energies in ^{17}O
1986CA27	Quadrupole moments of sd-shell nuclei
1986ED03	Particle-hole description of dipole states in ^{17}O
1987LI1F	Double delta & surface delta interactions & spectra of O isotopes in the (s-d) shell (A)
1988MI1J	Shell model transition densities for electron & pion scattering
1989BA60	Investigation of E1 strength in Coulomb excitation of light nuclei

Reference	Description

Special States – continued

1989JI1D	Strength of tensor force and s-d-shell effective interactions
1989OR02	Empirical isospin nonconserving hamiltonians for shell-model calculations
1989WU1C	Contribution of the 2p-1h multiple scattering correlation to the spectra of ^{17}O & ^{15}O (A)

Electromagnetic transitions and giant resonances

1986CA27	Quadrupole moments of sd-shell nuclei
1986ED03	Particle-hole description of dipole states in ^{17}O
1986TO13	Isovector magnetic quadrupole strengths in ^{17}O; microscopic 2p-1h model
1987BR30	Empirically optimum M1 operator for sd-shell nuclei
1989BA60	Investigation of E1 strength in Coulomb excitation of light nuclei
1991SK02	Effective transition operators in the sd shell
1992ZU01	Giant dipole resonance in ^{17}O observed with the (γ, p) reaction

Astrophysical questions

1986LA1C	Chemical composition (including O) of 30 cool carbon stars in the galactic disk
1987DO1A	^{12}C/^{13}C & ^{16}O/^{17}O isotopic ratios in seven evolved stars (types MS, S & SC)
1987HA1D	Oxygen isotopic abundances in 26 evolved Carbon stars
1987MC1A	Oxygen isotopes in refractory stratospheric dust particles: proof of extraterrestrial origin
1987WA1F	Abundances in red giant stars: C & O isotopes in C-rich molecular envelopes
1988DU1B	Spectrophotometry & chemical composition of the O-poor bipolar nebula NGC 6164-5
1989BO01	Accurate energy deter. of 5673-keV state in ^{18}F & implications in ^{17}O nucleosynthesis
1989JI1A	Nucleosynthesis inside thick accretion disks around massive black holes
1989LA19	^{17}O(^{3}He, d)^{18}F reaction & its implication in ^{17}O destruction in the CNO cycle in stars
1989ME1C	Isotope abundances of solar coronal material derived from solar energetic particle meas.
1990LA1J	Revised reaction rates for H-burning of ^{17}O & oxygen isotopic abundances in red giants
1991PA1C	Extremum problem treatment of C, N & O abundances in late-type star atmospheres (A)
1991SA1F	Extragalactic ^{18}O/^{17}O ratios imply high-mass stars preferred in starburst systems

Applications

1989TA1Y	Separation of nitrogen & oxygen isotopes by liquid chromatography

Reference	Description
	Applications – continued
1992LA08	Ion beam analysis of laser-irradiated borosilicate glass
	Complex reactions involving ^{17}O
Review:	
1988BE14	Heavy ion excitation of giant resonances
Other Articles:	
1986BA13	Electromagnetic decay of giant quadrupole resonances of ^{208}Pb via inelastic ^{17}O scat.
1986MA1O	Study of breakup for light neutron rich projectiles (A)
1986ME06	Quasi-elastic, deep-inelastic, quasi-compound nucleus mechanisms from ^{89}Y + ^{19}F
1986SC29	Partition of excitation energy in peripheral heavy-ion reactions
1987BE02	Excitation of the high energy nuclear continuum in ^{208}Pb by 22 MeV/u ^{17}O & ^{32}S
1987LI04	Multistep effects in ^{17}O + ^{208}Pb near the Coulomb barrier
1987NA01	Linear momentum & angular momentum transfer in ^{154}Sm + ^{16}O
1987RI03	Isotopic distributions of fragments from ^{40}Ar + ^{68}An at $E = 27.6$ MeV/u
1988AN1C	Multiple angular scattering of ^{16,17}O, ^{40}Ar, ^{86}Kr & ^{100}Mo at 20–90 MeV/u
1988BA39	Coulomb excitation of giant resonances in ^{208}Pb by $E = 84$ MeV/u ^{17}O projectiles
1988BE15	γ-decay of isoscalar & isovector giant resonances following heavy ion inelastic scat.
1988BE56	Formation of light nuclei in ^{11}B & ^{20}Ne induced reactions at energies of 18–20 MeV/u
1988GA11	Neutron pickup & 4-body processes in reactions of ^{16}O + ^{197}Au at 26.5 & 32.5 MeV/u
1988HO04	Characterization of GQR in ^{208}Pb as reported from π^-/π^+ vs. ^{16}O/^{17}O scat.
1989SA10	Total cross sections of reactions induced by neutron-rich light nuclei
1989TE02	Dissipative mechanisms in the 120 MeV ^{19}F + ^{64}Ni reaction
1989YO02	Quasi-elastic & deep inelastic transfer in ^{16}O + ^{197}Au for $E < 10$ MeV/u
	Hypernuclei
1986MO1A	The ΛN interaction & structures of the ^{16,17,18}O hypernuclei
1987CO1E	Hypernuclear currents in a relativistic mean-field theory
1988IT02	Pi-mesonic decay of hypernuclei & pion wavefunction
1988MA58	Pions in nuclear interior: sensitive test by hypernuclear decay
1989BA93	Production of hypernuclei in relativistic ion beams
1989BA92	Strangeness production by heavy ions
1989MA30	Λ-hyperon(s) in the nuclear medium; relativistic mean field theory analysis

Reference	Description

Hypernuclei – continued

1991KO1C	Calculation of low-excited states of $^{13}_{\Lambda}$C & $^{17}_{\Lambda}$O lambda hypernuclei

Antiproton interactions

Reviews:

1987GR1I	Low energy antiproton physics in the early LEAR era

Other Articles:

1986DU10	Microscopic calculation of antiproton atomic-like bound states in light nuclei
1986KO1E	Search for p-atomic X-rays; observed spin-dependence of p-nucleus interaction (LEAR)
1986RO23	Meas. of the $4f$ strong interaction level width in light antiprotonic atoms (LEAR)
1987GR20	Widths of $4f$ antiprotonic levels in the O region & Dover-Richard potential shell model
1987HA1J	Widths of $4f$ antiprotonic levels in the O region using realistic wavefunctions
1987SP05	Spin & isospin efcts. in a relativ. impulse approx. treatment of p-atom shifts & widths
1992PY1A	High-precision calculations of nuclear quadrupole moments for light nuclei

Ground-state properties

1986CA27	Quadrupole moments of sd-shell nuclei
1986MC13	Resolution of the magnetic moment problem in relativistic theories
1986TO1A	Weak interaction probes of light nuclei
1986WUZX	Charge dependence of Brueckner's G-matrix & Nolen-Schiffer-Okamoto anomaly (A)
1987AB03	Measurement & folding-potential analysis of the elastic α-scattering on light nuclei
1987BR30	Empirically optimum M1 operator for sd-shell nuclei
1987CH02	Nuclear binding & quark confinement; calculated Nolen-Schiffer anomaly
1987FU06	Nuclear currents in a relativistic mean-field theory
1987IC02	Isoscalar currents & nuclear magnetic moments
1988AR1I	Relativistic & quark contributions to nuclear magnetic moments
1988CH1T	Microscopic calculation of ^{15}O-^{15}N, ^{17}F-^{17}O Coulomb displacement energies (A)
1988FU04	Convection currents in nuclei in a relativistic mean-field theory
1988NI05	Nuclear magnetic moments & spin-orbit current in the relativistic mean field theory
1988SH07	Magnetic response of closed-shell $\pm$ 1 nuclei in Dirac-Hartree approximation
1989CH24	Medium induced magnetization current & nuclear magnetic moments
1989NE02	Magnetic moments of closed-shell $\pm$ 1 nuclei in the relativistic shell model
1989SA10	Total cross sections of reactions induced by neutron-rich light nuclei
1990MO36	Meson exchange current corrections to magnetic moments in quantum hadro-dynamics
1991CO12	Wave function effects & the elastic magnetic form factor of ^{17}O
1991HA15	QCD sum rules in a nuclear medium & the Okamoto-Nolen-Schiffer anomaly

Reference	Description
	Antiproton interactions – continued
1991ZH06	Relativistic Hartree study of deformed sd-shell nuclei
1992MA45	Coulomb displacement energies in relativistic & non-relativistic self-consistent models
1992SU02	Nolen-Schiffer anomaly of mirror nucl: effects of valence nucleon orbits & CSB
1992ZH07	Magnetic moments & form factors of ^{17}O & ^{41}Ca

4. ^{10}B(^{9}Be, d)^{17}O $\quad Q_{\rm m} = 11.070$

Cross sections for populating ^{17}O*(0.87) were measured at $E_{\rm cm} = 2.38$, 2.89, 3.16 MeV by (1986CU02).

5. (a) ^{11}B(^{6}Li, p)^{16}N $\quad Q_{\rm m} = 9.782 \quad E_{\rm b} = 23.562$
   (b) ^{11}B(^{6}Li, d)^{15}N $\quad Q_{\rm m} = 9.516$
   (c) ^{11}B(^{6}Li, t)^{14}N $\quad Q_{\rm m} = 4.940$
   (d) ^{11}B(^{6}Li, α)^{13}C $\quad Q_{\rm m} = 17.204$

See (1977AJ02).

6. ^{11}B(^{11}B, X)^{17}O

Cross sections for populating ^{17}O*(0.87, 3.06, 3.84) were measured at $E_{\rm cm} = 2.22$–3.23 MeV by (1986CU02).

7. ^{12}C(^{6}Li, p)^{17}O $\quad Q_{\rm m} = 7.605$

Table 17.10: Energy levels of ^{17}O

E_x in ^{17}O (MeV $\pm$ keV)	$J^\pi; T$	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
0	$\frac{5}{2}^+; \frac{1}{2}$		stable	1, 2, 7, 8, 9, 13, 14, 17, 18, 20, 21, 22, 23, 28, 29, 30, 31, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60
0.87073 ± 0.10 [a]	$\frac{1}{2}^+$	$\tau_m = 258.6 \pm 2.6$ psec	γ	1, 2, 7, 8, 9, 10, 11, 13, 14, 17, 18, 20, 21, 22, 23, 28, 29, 30, 31, 36, 37, 38, 39, 40, 42, 45, 46, 48, 50, 53, 54, 55, 57, 58, 59
3.05536 ± 0.16	$\frac{1}{2}^-$	$\tau_m = 120^{+80}_{-60}$ fsec	γ	7, 8, 9, 13, 14, 20, 22, 23, 28, 30, 31, 36, 37, 38, 39, 40, 42, 45, 53, 54, 58
3.84276 ± 42 [a]	$\frac{5}{2}^-$	$\tau_m \leq 25$ fsec	γ	7, 8, 9, 13, 14, 15, 16, 20, 22, 23, 28, 29, 37, 38, 42, 43, 53, 54, 58
4.5538 ± 1.6 [a]	$\frac{3}{2}^-$	$\Gamma = 40 \pm 5$	γ, n	7, 9, 13, 14, 20, 22, 23, 28, 29, 32, 37, 38, 40, 41, 42, 43, 53, 54, 58
5.0848 ± 0.9 [a]	$\frac{3}{2}^+$	96 ± 5	γ, n	2, 8, 9, 13, 14, 22, 23, 28, 32, 37, 40, 41, 42, 53, 54
5.21577 ± 0.45 [a]	$\frac{9}{2}^-$	< 0.1	γ, n	8, 9, 13, 14, 15, 16, 22, 23, 28, 29, 30, 32, 37, 42, 43, 53, 58

Table 17.10: Energy levels of ^{17}O (continued)

E_x in ^{17}O (MeV $\pm$ keV)	$J^\pi; T$	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
5.3792 ± 1.4 [a]	$\frac{3}{2}^-$	28 ± 7	γ, n	9, 22, 23, 28, 32, 37, 38, 40, 41, 42, 53, 54, 58
5.69726 ± 0.33 [a]	$\frac{7}{2}^-$	3.4 ± 0.3	γ, n	2, 4, 13, 14, 20, 22, 23, 28, 29, 32, 37, 41, 42, 43, 54
5.73279 ± 0.52 [a]	$(\frac{5}{2}^-)$	< 1	n	2, 7, 8, 13, 14, 20, 22, 23, 32, 37, 58
5.86907 ± 0.55 [a]	$\frac{3}{2}^+$	6.6 ± 0.7	n	8, 9, 13, 14, 22, 23, 28, 32, 37, 58
5.939 ± 4	$\frac{1}{2}^-$	32 ± 3	γ, n	7, 8, 13, 14, 22, 23, 28, 32, 37, 40, 42, 54, 58
6.356 ± 8	$\frac{1}{2}^+$	124 ± 12	γ, n	7, 9, 20, 22, 28, 32, 41, 42
6.862 ± 2	$(\frac{5}{2}^+)$	< 1	γ, n	7, 8, 9, 13, 14, 22, 23, 28, 32, 37, 42, 54, 58
6.972 ± 2	$(\frac{7}{2}^-)$	< 1	γ, n	8, 9, 13, 14, 22, 23, 28, 32, 42, 58
7.1657 ± 0.8	$\frac{5}{2}^-$	1.38 ± 0.05	n, α	7, 8, 9, 12, 13, 14, 22, 28, 32, 35
7.202 ± 10	$\frac{3}{2}^+$	280 ± 30	n, α	13, 14, 22, 32, 35
7.3792 ± 1.0	$\frac{5}{2}^+$	0.64 ± 0.23	γ, n, α	7, 8, 9, 9, 10, 11, 28, 29, 32, 35, 42, 54, 58
7.3822 ± 1.0	$\frac{5}{2}^-$	0.96 ± 0.20	γ, n, α	6, 9, 12, 13, 14, 22, 29, 32, 35, 41, 42, 54, 58
7.559 ± 20	$\frac{3}{2}^-$	500 ± 50	n, α	32, 35, 37
7.576 ± 2	$(\frac{7}{2}^+)$ [e]	< 0.1	γ, n, α	7, 8, 12, 13, 14, 22, 28, 32, 42
7.6882 ± 0.9	$\frac{7}{2}^-$	14.4 ± 0.3	γ, n, α	7, 8, 12, 13, 14, 28, 32, 35, 41

Table 17.10: Energy levels of ^{17}O (continued)

E_x in ^{17}O (MeV ± keV)	$J^\pi; T$	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
7.757 ± 9	$\frac{11}{2}^-$		γ	20, 28, 29, 30, 42, 43
7.956 ± 6	$\frac{1}{2}^+$	90 ± 9	n, α	12, 28, 32, 35
7.99 ± 50	$\frac{1}{2}^-$	270 ± 30	n, α	32, 35
8.070 ± 10	$\frac{3}{2}^+$	85 ± 9	n, α	12, 28, 32, 35
8.200 ± 7	$\frac{3}{2}^-$	60	γ, n, α	12, 20, 28, 32, 35, 41, 54
8.3424 ± 0.9	$\frac{1}{2}^+$	11.4 ± 0.5	γ, n, α	12, 28, 32, 35, 42
8.4023 ± 0.8	$\frac{5}{2}^+$	6.17 ± 0.13	γ, n, α	8, 12, 13, 14, 28, 32, 35, 42
8.4660 ± 0.8	$(\frac{9}{2}^+)$ [f]	2.13 ± 0.11	(γ), n, α	7, 8, 12, 13, 14, 28, 32, 35, 42, 54
8.5007 ± 0.8	$\frac{5}{2}^-$	6.89 ± 0.22	γ, n, α	8, 12, 13, 14, 28, 32, 35, 41, 42
8.6870 ± 1.0	$\frac{3}{2}^-$	55.3 ± 0.6	γ, n, α	12, 28, 32, 35, 41, 54
8.885 ± 14 [b]	$\frac{7}{2}^-, \frac{9}{2}^-$	6	γ	42
8.897 ± 8	$\frac{3}{2}^+$	101 ± 3	n, α	8, 12, 13, 14, 28, 29, 32, 35, 42
8.9672 ± 1.7	$\frac{7}{2}^-$	26 ± 2	γ, n, α	8, 12, 13, 14, 28, 32, 35, 41, 42
9.147 ± 4	$\frac{1}{2}^-$	4 ± 3	γ, n, α	8, 11, 12, 13, 14, 54
9.15 ± 20	$\frac{9}{2}^-$		γ	28, 29, 30, 32
9.18	$\frac{7}{2}^-$	3	α	12, 13, 14
9.1939 ± 0.8	$\frac{5}{2}^+$	3.53 ± 0.13	n, α	12, 13, 14, 32
9.42	$\frac{3}{2}^-$	120	n	32
9.492 ± 4	$\frac{5}{2}^-$	15 ± 1	n, α	7, 11, 14, 28, 32, 54
9.7119 ± 0.9	$\frac{7}{2}^+$	23.1 ± 0.3	n, α	12, 14, 20, 28, 32
9.7833 ± 0.9	$\frac{3}{2}^+$	11.7 ± 0.3	n, α	12, 14, 32
9.8589 ± 0.9	$(\frac{5}{2}^-)$	4.01 ± 0.23	n, α	12, 14, 28, 32
9.8765 ± 1.3	$(\frac{1}{2}^-)$	16.7 ± 1.7	n, α	12, 14, 28, 32

Table 17.10: Energy levels of ^{17}O (continued)

E_x in ^{17}O (MeV $\pm$ keV)	$J^\pi; T$	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
9.976 ± 20	$\frac{5}{2}^+$	≈ 80	n, α	12
10.045 ± 20		≈ 100	n, α	12
10.1678 ± 1.0	$\frac{7}{2}^-$	49.1 ± 0.8	n, α	12, 32
10.336 ± 15	$\frac{5}{2}^+, \frac{7}{2}^-$	150	n, α	12, 28
10.423 ± 3		14 ± 3	n, α	12, 20
10.49	$\frac{5}{2}^+, \frac{7}{2}^-$	75 ± 30	n, α	12
10.5591 ± 1.0	$(\frac{7}{2}^-)$	42.5 ± 1.1	n, α	12, 16, 28, 32, 33
10.777 ± 3	$\frac{1}{2}^+, \frac{7}{2}^-$	74 ± 3	n, α	12, 14, 23, 28, 33
10.9129 ± 2.8	$(\frac{5}{2}^+)$	41.7 ± 1.4	n, α	12, 28, 32, 33
11.036 ± 3	$T = \frac{1}{2}$	31 ± 3	n, α	12, 28
11.0787 ± 0.8 [c]	$\frac{1}{2}^-; \frac{3}{2}$	2.4 ± 0.3	γ, n, α	11, 12, 28, 32, 42, 54, 55
11.238		80 ± 3	n, α	7, 12, 20
11.51	$\geq \frac{3}{2}$	190	n	32, 33
11.622		65 ± 2	n, α	12
11.750 ± 10		40 ± 25	γ, n, α	12, 42
11.815 ± 15		12 ± 3	n, α	12, 20
12.005 ± 15	$\geq \frac{3}{2}$	270	γ, n, α	12, 20, 23, 32, 33, 42
12.11 ± 20		150 ± 50	n, α	12, 16, 33
12.22 ± 20		≤ 20	γ	42
12.274 ± 15		100 ± 30	n, α	12, 20
12.38 ± 20			n, α	12, 32
12.420 ± 15			n, α	12
12.4660 ± 1.0	$\frac{3}{2}^-; \frac{3}{2}$	6.9 ± 1.1	γ, n, α	12, 32, 33, 42, 54, 55
12.595 ± 15		75 ± 30	n, α	12
12.669 ± 15		≈ 5	γ, n, α	12, 32, 33, 42
12.81 ± 25			n, α	12
12.93 ± 20		≥ 150	n, α	12
12.944 ± 5	$\frac{1}{2}^+; \frac{3}{2}$	6 ± 2	n, α	12, 32, 33, 54, 55

Table 17.10: Energy levels of ^{17}O (continued)

E_x in ^{17}O (MeV ± keV)	$J^\pi; T$	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
12.9982 ± 1.0	$\frac{5}{2}^-; \frac{3}{2}$	2.5 ± 1.0	γ, n, α	12, 32, 42, 55
13.076 ± 15		16 ± 4	n, α	12
13.484 ± 15		≈ 120	n, α	12
13.58 ± 20	$(\frac{11}{2}^-, \frac{13}{2}^-)$	68 ± 19	(γ)	13, 14, 42
13.609 ± 15		250 ± 100	n, α	12
13.6353 ± 2.5	$(\frac{5}{2})^+; \frac{3}{2}$	9 ± 5	n, α	32, 54, 55
(13.67)		400	n	32
14.15 ± 100	$(\frac{9}{2}^+, \frac{11}{2}^+)$	≈ 100		13
14.2303 ± 1.7	$\frac{7}{2}^-; \frac{3}{2}$	20.5 ± 1.6	γ, n, α	32, 42, 55
14.286 ± 3	$T = \frac{1}{2}$ $^{\rm d}$	7.5 ± 4	n, α	32, 55
14.451 ± 3		40 ± 6	γ, n, α	32
14.72	$\frac{9}{2}^-; \frac{3}{2}$	35 ± 11		
14.76 ± 100	$(\geq \frac{3}{2})$	340	γ, n	32, 42
14.791 ± 3	$(\frac{1}{2}^-; \frac{3}{2})$	36 ± 13	(γ), n, α	32, 41
15.00		180	n, d, α	27, 32
15.1 ± 100	$(\frac{9}{2}^+, \frac{11}{2}^+)$	≈ 500		13
15.199 ± 3	$T = \frac{1}{2}$ $^{\rm d}$	52 ± 14	γ, n, d, α	20, 27, 32, 42
15.368 ± 3	$(\frac{5}{2}^+; \frac{3}{2})$	40 ± 6	n, d, α	26, 32
(15.6)	$T = \frac{1}{2}$ $^{\rm d}$	≈ 300	p, d, α	25, 26, 27
15.78 ± 20	$(\frac{13}{2}^-; \frac{3}{2})$ $^{\rm e}$	≤ 30	γ	42
15.95 ± 150	$(\frac{9}{2}^+, \frac{11}{2}^+)$	≈ 700		13
16.243 ± 4	$(\frac{9}{2}^+; \frac{3}{2})$	21 ± 10	n, p, d, α	25, 32
16.58 ± 10	$(\frac{1}{2}, \frac{3}{2})^-; \frac{3}{2}$	≈ 300	γ	42, 54
16.6 ± 150	$(\frac{11}{2}^-, \frac{13}{2}^-)$			13
17.06 ± 20	$\frac{11}{2}^-; \frac{1}{2}$ $^{\rm e}$	≤ 20	γ	13, 42, 43
17.436 ± 11	$(T = \frac{3}{2})$	66 ± 20	n, α	32
17.92 ± 20		98 ± 16	γ	42
18.110 ± 4	$\frac{3}{2}^-; \frac{3}{2}$	46 ± 12	n, α	32, 54
18.72 ± 20		87 ± 33		42
19.6 ± 150	$(\frac{13}{2}^+, \frac{15}{2}^+)$	≈ 250		13
19.82 ± 40	$\frac{3}{2}$	550 ± 50	γ, t	21, 42

Table 17.10: Energy levels of ^{17}O (continued)

E_x in ^{17}O (MeV ± keV)	$J^\pi; T$	τ_m or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
20.14 ± 20	$\frac{11}{2}^-; \frac{1}{2}$ [e]	31 ± 5	γ	42
20.2 ± 150	$(\frac{13}{2}^+, \frac{15}{2}^+)$	≈ 250		13
20.39 ± 50	$\frac{5}{2}, \frac{7}{2}^-$	660 ± 70	γ, t	21
20.58 ± 50	$\frac{1}{2}$	570 ± 80	γ, t	21
20.70 ± 20	$(\frac{9}{2}^-; \frac{3}{2})$ [e]	≤ 20	γ	42
21.05 ± 50	$\frac{3}{2}$	470 ± 60	γ, t	21
21.2	$(\frac{13}{2}^+, \frac{15}{2}+)$			13
21.7 ± 100	$\frac{5}{2}^+$	≈ 750	γ, ^{3}He, α	18, 19
22.1 ± 100	$\frac{7}{2}^-$	≈ 750	γ, n, ^{3}He, α	13, 18, 19
22.5 ± 200	$\frac{3}{2}^{(-)}$	≈ 1000	γ, ^{3}He	18
23		≈ 6000	γ, n	41, 42
23.0	$\frac{1}{2}^+$	≈ 400	γ, ^{3}He	18, 19
23.5			γ, ^{3}He	18
24.4			γ, ^{3}He	18

[a] (1990PI05).
[b] See also (1971AJ02).
[c] See also Tables 17.16 and 17.19, and see Table 17.6 in (1977AJ02).
[d] $T = \frac{1}{2}$ assignments based on evidence of excitation in ^{17}O(γ, n_0) reported in (1990MC06).
[e] (1987MI25) and private communication from D.M. Manley.
[f] (1987MA52) and private communication from D.J. Millener.

Angular distributions have been studied for $E(^6\text{Li}) = 3$–28 MeV [See (1982AJ01, 1986AJ04)]. More recently, differential cross sections at $E(^6\text{Li}) = 28$ MeV were measured by (1986SM10). Many of the known levels in ^{17}O were populated. See Table 17.11. Hauser-Feshbach calculations and DWBA analyses were carried out for the data.

8. ^{12}C(^{7}Li, d)^{17}O $\qquad Q_m = 2.580$

See Table 17.6 in (1977AJ02) and ^{19}F in (1983AJ01).

9. ^{12}C(^{9}Be, α)^{17}O $\qquad Q_m = 9.732$

Table 17.11: ^{17}O states from ^{12}C(^{6}Li, p)^{17}O [a]

Level	Excitation energy (MeV $\pm$ keV)	$\sigma_{\rm tot}$ (μb)	Level	Excitation energy (MeV $\pm$ keV)
0	0	110 ± 2	18	8.40
1	0.869 ± 10	36 ± 1	19	8.476 ± 12
2	3.056 ± 8	60 ± 1	20	8.702 ± 12
3	3.844 ± 7	138 ± 2	21	8.905 ± 8
4	4.555 ± 8	141 ± 2	22	8.966 ± 15
5	5.079 ± 15	55 ± 1	23	9.181 ± 9
6	5.217 ± 8	285 ± 4	24	9.487 ± 8
7	5.380 ± 9	79 ± 1	25	9.719 ± 15
8	5.719 ± 12	222 ± 3	26	9.866 ± 11
9	5.877 ± 14	202 ± 3	27	10.426 ± 8
10	6.861 ± 2	370 ± 5	28	10.549 ± 9
11	6.974 ± 5	176 ± 2	29	10.694 ± 8
12	7.175 ± 14	146 ± 2	30	10.92
13	7.388 ± 14	391 ± 5	31	11.03
14	7.580 ± 16	404 ± 5	32	11.815 ± 20
15	7.690 ± 15	186 ± 3	33	12.02 ± 20
16	7.773 ± 16	439 ± 5	34	12.25 ± 20
17	8.210 ± 25		35	12.430 ± 15

[a] (1986SM10).

Angular distributions have been reported at $E(^9\text{Be}) = 16.1$–20 MeV [see (1982AJ01)] and at $E(^9\text{Be}) = 12.0$–27.0 MeV (1981JA09; α_0, α_2). For excitation functions see (1982AJ01, 1986AJ04), and see (1988GO1G).

10. ^{12}C(^{13}C, ^{8}Be)^{17}O $\qquad Q_{\rm m} = -1.007$

Excitation functions at $E_{\rm cm} = 13.4$–16.8 MeV and angular distributions at $E_{\rm cm} = 13.8$ and 16.38 MeV have been measured by (1988JA14).

11. ^{13}C(α, γ)^{17}O $\qquad Q_{\rm m} = 6.358$

Table 17.12: Resonances in ^{13}C(α, n) and ^{13}C(α, α) [a]

$E_{\rm res}$ (MeV $\pm$ keV)	$\Gamma_{\rm c.m.}$ (keV)	Γ_α/Γ	J^π	$E_{\rm x}$ (MeV)
1.0563 ± 1.5	1.5 ± 0.2		$\frac{5}{2}$	7.1669
1.3367 ± 1.5	$0.6^{+0.2}_{-0.1}$			7.3813
1.3406 ± 1.5	$0.8^{+0.3}_{-0.2}$			7.3842
1.590 ± 2	≤ 1		$\frac{7}{2}^-$	7.575
1.745 ± 6	≤ 15		$\frac{5}{2}^+$	7.693
2.083 ± 8	75	0.03	$\frac{1}{2}^-$	7.952
2.250 ± 8	110	0.05	$\frac{3}{2}^+$	8.080
2.407 ± 8	70	0.11	$\frac{3}{2}^-$	8.200
2.604 ± 4	9 ± 3	0.44	$\frac{1}{2}^+$	8.350
2.680 ± 3	4 ± 3	0.08	$\frac{5}{2}^+$	8.408
2.763 ± 3	7 ± 3	0.97	$\frac{7}{2}^+$	8.472
2.808 ± 3	5 ± 3	0.26	$\frac{5}{2}^-$	8.506
3.059 ± 5	50 ± 3	0.06	$\frac{3}{2}^-$	8.698
(3.1)	broad		$\frac{1}{2}^-$	(8.7)
3.318 ± 8	101 ± 3	0.50	$\frac{3}{2}^+$	8.896
3.415 ± 4	21 ± 3	0.04	$\frac{7}{2}^-$	8.970
3.645 ± 4	4 ± 3	0.45	$\frac{1}{2}^-$	9.146
(3.69)	3	1.00	$\frac{7}{2}^-$	(9.18)
3.714 ± 4	5.5 ± 1	0.20	$\frac{5}{2}^+$	9.199
4.096 ± 4	15 ± 1	0.85	$\frac{5}{2}^-$	9.491
(4.3)			$\frac{3}{2}^-$	(9.6)
4.394 ± 5	16 ± 1	0.70	$\frac{7}{2}^+$	9.719
4.465 ± 15	≈ 25	0.90	$\frac{3}{2}^+$	9.773
4.583 ± 5	14			9.863
4.600 ± 15	≈ 10			9.876
4.730 ± 20	≈ 80	0.78	$\frac{5}{2}^+$	9.976
4.820 ± 20	≈ 100			10.044
(4.94)	138	0.85	$\frac{5}{2}+$	(10.14)
4.993 ± 5	45	0.15	$\frac{7}{2}-$	10.177
(5.08)	122	0.60	$\frac{7}{2}^+$	(10.2)
5.200 ± 15	150		$\frac{5}{2}^+$, $\frac{7}{2}^-$	10.335

Table 17.12: Resonances in ^{13}C(α, n) and ^{13}C(α, α) [a] (continued)

E_{res} (MeV $\pm$ keV)	$\Gamma_{\text{c.m.}}$ (keV)	Γ_α/Γ	J^π	E_x (MeV)
5.315 ± 3	14 ± 3			(10.423)
5.40	75 ± 30		$\frac{5}{2}^+, \frac{7}{2}^-$	10.49
5.492 ± 3	51 ± 2		$\frac{7}{2}^-, \frac{9}{2}^+$	(10.558)
(5.68)	≤ 25	1.00	$(\frac{7}{2}^+)$	(10.70)
5.778 ± 3	74 ± 3		$\frac{1}{2}^+, \frac{7}{2}^-$	(10.777)
5.945 ± 3	46 ± 2		$\frac{5}{2}$	(10.904)
6.117 ± 3	31 ± 3			(11.036)
6.168	5.0 ± 1.1		$\frac{1}{2}^-; T = \frac{3}{2}$	(11.075 ± 0.005)
6.380 ± 3	80 ± 3			(11.237)
6.883 ± 3	65 ± 2			(11.621)
7.051 ± 10	40 ± 25			11.750
7.136 ± 15	12 ± 3			11.815
7.384 ± 15				12.004
7.52 ± 20	150 ± 50			12.11
7.736 ± 15	100 ± 30			12.273
7.88 ± 20				12.38
7.927 ± 15				12.419
7.976	8 ± 2		$\frac{3}{2}^-; T = \frac{3}{2}$	12.457 ± 0.005
8.156 ± 15	75 ± 30		12.594	
8.253 ± 15	≈ 5			12.668
8.44 ± 25				12.81
8.59 ± 20	≥ 150			12.93
8.612	6 ± 2		$\frac{1}{2}^+; T = \frac{3}{2}$	12.943 ± 0.006
8.676	≤ 3		$\frac{5}{2}^-; T = \frac{3}{2}$	12.992 ± 0.006
8.72 ± 20				13.03
8.785 ± 15	16 ± 4			13.075
9.319 ± 15	≈ 120			13.483
9.483 ± 15	250 ± 100			13.609

[a] See references listed in Tables 17.8 of (1977AJ02, 1982AJ01). See also Table 17.17 here.

At $E_\alpha = 3.65$ and 6.17 MeV [^{17}O*(9.15, 11.08)] $\Gamma_\alpha\Gamma_{\gamma 1}/\Gamma = 0.65 \pm 0.07$ and 1.46 ± 0.13 eV, respectively. Assuming $\Gamma_\alpha/\Gamma = 0.45$ for the lower resonance, $\Gamma_{\gamma 1}$ for the E1 transition from ^{17}O*(9.15) $[J^\pi = \frac{1}{2}^-]$ to ^{17}O*(0.87) $[\frac{1}{2}^+]$ is 1.44 ± 0.26 eV. The parameters of ^{17}O*(11.08) are discussed in Table 17.16. See (1986AJ04).

12. (a) ^{13}C(α, n)^{16}O $\quad Q_{\rm m} = 2.215 \quad E_{\rm b} = 6.358$
(b) ^{13}C(α, α)^{13}C $\quad Q_{\rm m} = 2.215$

The yield of neutrons increases monotonically for $E_\alpha = 0.475$ to 1 MeV: for $S(E)$ see (1977AJ02, 1982AJ01). Resonances observed in the yield of neutrons and through the anomalies in the elastic scattering are displayed in Table 17.12. See also (1986AJ04). Cross sections for reaction (a) at $E_\alpha = 0.40$–1.20 MeV were measured by (1989KEZZ). Distributions of alpha particle strength were obtained by (1988LE05). See also (1985CA41, 1987BU27).

A microscopic analysis of reactions (a) and (b) with the generator-coordinate method was carried out by (1987DE38).

13. ^{13}C(^{6}Li, d)^{17}O $\quad Q_{\rm m} = 4.883$

Angular distributions are reported at $E(^6{\rm Li}) = 35.5$ MeV to ^{17}O*(13.58 ± 0.02), which is strongly populated. Comparisons with ^{12}C(^{6}Li, d)^{16}O*(16.29) and with the results of reaction 14 below suggest that the peak corresponding to ^{17}O*(13.58) contains a state or states of spin $\frac{11}{2}^-$, $\frac{13}{2}^-$, or both, based on ^{16}O*(16.29) (1978CL08). (d, α) angular correlations [$E(^6{\rm Li}) = 26$, 29 and 34 MeV] indicate the involvement of ^{17}O states at 13.6 ± 0.1 [$l = 6$], 14.15 ± 0.1 [5], 15.1 ± 0.1 [5], 15.95 ± 0.15 [5], 16.6 ± 0.15 [6], 17.1 ± 0.15 [6], 19.6 ± 0.15 [7], 20.2 ± 0.15 [7], 21.2 [7], and 22.1 MeV, $\Gamma \approx 0.1$, 0.5, 0.7, and 0.25 MeV for ^{17}O*(14.2, 15.1, 16.0, 19.6, 20.2) (1978AR15). See, however, (1984CA39). For the earlier work see Table 17.7 in (1977AJ02).

Measurements and analysis by (1987CA30) of data at $E(^6{\rm Li}) = 34$ MeV for deuteron peaks corresponding to ^{16}O*(16.1, 13.6) indicated that the reaction proceeds by a direct alpha transfer process which populates doublets of interfering ^{17}O levels.

14. ^{13}C(^{7}Li, t)^{17}O $\quad Q_{\rm m} = 3.891$

Angular distributions are reported to ^{17}O*(3.06) and to ^{17}O*(13.58), which is preferentially populated (see discussion in reaction 13), at $E(^7{\rm Li}) = 35.7$ MeV. Narrow states at $E_{\rm x} = 14.86$, 18.17 and 19.24 MeV are also strongly excited (1978CL08). See (1986AJ04) and for the earlier work see Table 17.6 in (1977AJ02). Recent measurements of the cross section for $E_{\rm c.m.} = 1.46$–6.48 MeV are reported in (1990DA03).

Table 17.13: States of ^{17}O from ^{14}C + ^{3}He [a]

E_{res} (MeV)	Resonant for	$\Gamma_{c.m.}$ (MeV)	E_x (MeV)	J^π
3.6 ± 0.1	γ_0, (γ_1), α_0, α_1	0.75	21.7	$\frac{5}{2}^+$
4.1 ± 0.1	γ_0, n_0, n_{3+4}, α_0, α_1	0.75	22.1	$\frac{7}{2}^-$
4.6 ± 0.2	γ_1	≈ 1	22.5	$\frac{3}{2}^{(-)}$
5.1 ± 0.1	γ_0, ^{3}He	≈ 0.4	23.0	$\frac{1}{2}^+$
5.7 ± 0.1	γ_1		23.5	
6.9 ± 0.1	γ_1		24.4	

[a] For references see Table 17.9 in (1977AJ02).

15. ^{13}C(^{9}Be, αn)^{17}O $\qquad Q_m = 4.786$

Cross sections for population of ^{17}O*(0.87, 3.06, 3.84) were measured at $E_{cm} = 2.76$–4.82 MeV by (1986CU02).

16. ^{13}C(^{13}C, ^{9}Be)^{17}O $\qquad Q_m = -4.288$

States of ^{17}O with $E_x = 3.9$, 5.2, 5.8 ± 0.1, 7.2, 7.6, 8.4 ± 0.06, 8.9, 9.8 ± 0.07, 10.55 ± 0.06, 12.1 ± 0.06, 13.3, 14.6 and 18.9 ± 0.14 MeV have been reported (1979BR04) at $E(^{13}\text{C}) = 105$ MeV.

17. ^{13}C(^{16}O, ^{12}C)^{17}O $\qquad Q_m = -0.803$

Angular distributions involving ^{17}O*(0, 0.87) have been studied for $E(^{16}\text{O}) = 12$–25 MeV: see (1977AJ02, 1982AJ01, 1986AJ04). See also (1989FR04). More recently, cross sections were measured for $E_{c.m.} = 4.8$–9.8 MeV by (1991DA05). A calculation involving application of the nuclear molecular-orbital model and Landau-Zener coupling effects is discussed in (1990IM01).

18. ^{14}C(^{3}He, γ)^{17}O $\qquad Q_m = 18.760$

The capture cross sections at $90°$ for γ_0 and for γ_1 have been studied for $E(^3\text{He}) = 3.2$ to 7.5 MeV and angular distributions of the γ-rays have been studied at the six observed resonances: see Table 17.13.

Table 17.14: States of ^{17}O from ^{14}N(t, γ)^{17}O [a]

J^{π}	E_x (MeV)	Γ (MeV)	$\Gamma_t\Gamma_{\gamma_0}$ (keV)^2	$\Gamma_t\Gamma_{\gamma_1}$ (keV)^2	Lower limit	
					Γ_{γ_0} (eV)	Γ_{γ_1} (eV)
$\frac{3}{2}^{\mp}$	19.76 ± 0.06	0.55 ± 0.05	0.54 ± 0.1	1.25 ± 0.15	1.0	2.3
$\frac{5}{2}^{\mp}, \frac{7}{2}^{-}$	20.39 ± 0.05	0.66 ± 0.07	2.9 ± 0.3		4.3	
$\frac{1}{2}^{\pm}$	20.58 ± 0.05	0.57 ± 0.08		2.9 ± 0.5		5.1
$\frac{3}{2}^{\mp}$	21.05 ± 0.05	0.47 ± 0.06	2.7 ± 0.4	3.0 ± 0.4	5.8	6.5

[a] (1980LI05).

19. (a) ^{14}C(^{3}He, n)^{16}O $\qquad Q_m = 14.617 \qquad E_b = 18.76$

(b) ^{14}C(^{3}He, ^{3}He)^{14}C

(c) ^{14}C(^{3}He, α)^{13}C $\qquad Q_m = 12.402$

See Table 17.13. See also (1977AJ02), ^{13}C and ^{14}C in (1986AJ01) and ^{16}O here.

20. ^{14}C(^{6}Li, t)^{17}O $\qquad Q_m = 2.964$

At $E(^6\text{Li}) = 34$ MeV angular distributions have been reported (1986AJ04) to ^{17}O*(0,0.87, 3.06, 3.84, 4.55, 5.70, 6.36, 7.17 (u), 7.38 (u), 7.76, 8.20, 8.47 (u), 9.18 (u), 9.71, 9.87 (u), 10.42, 11.24, 11.82, 12.01, 12.27, 13.00 (u), 13.6 (u), 14.76 (u), 15.20, 16.3 (u)) (1981CU11, 1983CU02, 1983CU04; u = unresolved). (1983CU02) suggests evidence for two 3p-2h bands in ^{17}O and (1983CU04) for analog states in ^{17}N–^{17}O. See these two papers for spectroscopic factors.

21. ^{14}N(t, γ)^{17}O $\qquad Q_m = 18.622$

The excitation functions for γ_0 and γ_1 have been measured for $E_t = 0.8$ to 3.3 MeV: broad resonances are observed at 2.2 and 2.8 MeV in the γ_0 cross section, and at 2.4 and 2.8 MeV in the γ_1 cross section. Both also exhibit a structure at 1.5 MeV. The data are consistent with the states in Table 17.14 and possibly with a state at ≈ 19.3 MeV (1980LI05). For the charged particle channels see (1977AJ02).

22. (a) ^{14}N(α, p)^{17}O $\qquad Q_m = -1.193$

(b) ^{14}N(α, αp)^{13}C $\qquad Q_m = -7.551$

Angular distributions have been measured for ^{17}O states with $E_x < 7.6$ MeV in the range $E_\alpha = 8.1 \rightarrow 33.3$ MeV: see a listing of the references in (1971AJ02). The sequential decay (reaction (b)) appears to take place via ^{17}O states with $8.46 \leq E_x \leq 13.57$ MeV. Those involved are believed to have $J \geq \frac{5}{2}$, $\Gamma_\alpha/\Gamma \geq 0.6$. See also the measurements at $E_\alpha = 48$ MeV of (1987MIZY, 1988BRZY).

23. (a) ^{14}N(^{6}Li, ^{3}He)^{17}O $\quad Q_m = 2.826$
(b) ^{14}N(^{6}Li, ^{3}Heα)^{13}C $\quad Q_m = -3.532$

Angular distributions (a) and angular correlations (b) have been measured at $E(^6\text{Li}) = 36$ MeV involving ^{17}O*(8.48, 10.7, 12.0, 13.53, 14.88). Comparisons are made with the results in the analog reaction (^{6}Li, t) involving states in ^{17}F. See (1982AJ01, 1986AJ04).

24. ^{14}N(^{7}Li, α)^{17}O $\quad Q_m = 16.155$

See (1986NE1A).

25. (a) ^{15}N(d, γ)^{17}O $\quad Q_m = 14.046 \quad E_b = 14.046$
(b) ^{15}N(d, n)^{16}O $\quad Q_m = 9.903$
(c) ^{15}N(d, p)^{16}N $\quad Q_m = 0.266$

Radiative capture cross sections (reaction (a)) have been measured for $E_x = 25$–40 MeV by (1986ANZL, 1988CO1D). Excitation functions have been measured for $E_d = 0.5$–5.9 MeV (b) and 0.3–6.3 MeV (reaction (c)): see (1977AJ02). Unresolved structures are observed in the neutron data. There is some evidence for structures at $E_d = 1.8$ MeV [p_0, p_1, p_3] and 2.4 MeV [p_2] [^{17}O*(15.6, 16.2)]: see (1982AJ01). See also (1986AJ04) and ^{16}N, ^{16}O here.

26. ^{15}N(d, d)^{15}N $\quad E_b = 14.046$

Excitation functions for have been measured for $E_d = 1.4$ to 6.25 MeV. Structures are reported at ≈ 1.4 and 1.8 MeV: see (1982AJ01, 1986AJ04).

Table 17.15: Levels of ^{17}O from ^{15}N(^{3}He, p)^{17}O [a]

E_x (MeV) [b]	L [c]	E_x (MeV) [b]	L [c]
0	$(1+3)$	8.192	0
0.874	1	8.322	
3.053	0	8.390	
3.845	2	8.492	(2)
4.549	0	8.682	
5.081	(1)	8.900	
5.215	(4)	8.955	
5.381	0	9.16	(4)
5.698	2	9.495	
5.873	(1)	9.712	
5.938	0	9.856	
6.37		(10.24)	
6.861	(0)	10.33	
6.973	$(1+3)$	10.57	
7.162	2	10.782	
7.382	2	10.913	
7.561		11.032 ± 0.004 [d]	
7.687		11.075 ± 0.004 [e]	
7.761	4		
7.938			
8.054	(1)		

[a] For references see Table 17.10 in (1982AJ01).

[b] ± 10 keV, except where shown otherwise.

[c] $E(^{3}\text{He}) = 18$ MeV.

[d] $T = \frac{1}{2}$.

[e] $J^{\pi} = \frac{1}{2}^{-}$; $T = \frac{3}{2}$: see Table 17.16.

Table 17.16: Decay properties of the lowest $T = \frac{3}{2}$ states in $A = 17$ [a]

		^{17}O*(11.0787 ± 0.0008) [b]		^{17}F*(11.1928 ± 0.0021) [c]	
	J^π:	$\frac{1}{2}^-$		$\frac{1}{2}^-$	
	$\Gamma_{\text{c.m.}}$ (keV):	2.4 ± 0.3 [b]		0.18 ± 0.03 [d]	
p- or n-decay to states in		Branching ratio (%)	Partial Widths	Branching ratio (%) [e]	Partial Widths
^{16}O*	J^π				
0	0^+	81 ± 6	1.88 ± 0.12 keV	10.7 ± 0.6	19 ± 3 eV [f]
6.05	0^+			11 ± 3	20 ± 7 eV [e]
6.13	3^-	5 ± 2	0.12 ± 0.05 keV	25 ± 2	45 ± 9 eV [e]
6.92	2^+			< 4	< 8 eV [e]
7.12	1^-			18 ± 3	32 ± 8 eV [e]
θ^2(g.s.)/θ^2(6.13):			0.31 ± 0.14 [g]		0.065 ± 0.019 [g]
α-decay to ^{13}C or ^{13}N:		7 ± 1 [h]	$\Gamma_{\alpha_0} = 0.34 \pm 0.09$ keV [i]	^{13}N*(0): 1.1 ± 0.5	2.1 ± 1 eV [e]
				^{13}N*(2.36): 29 ± 9	52 ± 19 eV [e]
γ-decay:			$\Gamma_{\gamma_1} = 10 \pm 3$ eV [i]		$\Gamma_{\gamma_1} = 6.0 \pm 2.5$ eV [j]

[a] See also Table 2 in (1973AD02) and reaction 11, and see Table 17.11 in (1986AJ04).
[b] (1981HI01) [see for IMME parameters for six $T = \frac{3}{2}$ states].
[c] (1971HA05, 1973AD02, 1976HI09, 1988BO39) and see references in Table 17.11 in (1982AJ01).
[d] Calculated from direct measurement of $\Gamma_{\text{p}_0} = 19 \pm 3$ eV (1976HI09) and weighted mean of $\Gamma_{\text{p}_0}/\Gamma = 0.104 \pm 0.006$ obtained from measurements of (1971HA05, 1973AD02, 1988BO39).
[e] Branching ratios measured by (1988BO39). Partial widths obtained using total width of 180 ± 30 eV and these branching ratios.
[f] (1976HI09).
[g] (1973AD02).
[h] (1976MC11).
[i] Using $\Gamma_{\alpha_0}\Gamma_{\gamma_1}/\Gamma_{\text{tot}} = 1.46 \pm 0.13$ eV and $\Gamma_{\alpha_0}\Gamma_{\text{n}_0}/\Gamma_{\text{tot}} = 0.27$ keV $\pm$ 20% [see footnote [f]) in Table 17.11 0f (1986AJ04)] and the Γ_{n_0} and Γ_{tot} values shown above, these values are calculated for Γ_{α_0} and Γ_{γ_1}.
[j] (1975HA06).

27. (a) ^{15}N(d, t)^{14}N $\quad Q_m = -4.576$

(b) ^{15}N(d, α)^{13}C $\quad Q_m = 7.688 \quad E_b = 14.046$

Differential cross sections and analyzing powers for reaction (a) were measured for $E_d = 88, 89$ MeV by (1988SA19, 1988SAZY). Yield curves for reaction (b) have been measured for $E_d = 0.8$ to 2.7 MeV. Structures are reported at $E_d = 1.06$, 1.25 and ≈ 1.8 MeV. The latter has $\Gamma \approx 300$ keV: see (1982AJ01).

28. ^{15}N(^{3}He, p)^{17}O $\quad Q_m = 8.552$

Table 17.17: Resonances in ^{16}O(n, n) and ^{16}O(n, α) [a]

E_n (keV)	$\Gamma_{c.m.}$ (keV)	Γ_n (keV)	Γ_α (keV)	J^π	E_x (keV)
433 ± 2 [b]	45	45		$\frac{3}{2}^-$	4551
1000 ± 2	96	96		$\frac{3}{2}^+$	5084
1140 [c]	≤ 0.1				5216
1312 ± 2	42	41.5		$\frac{3}{2}^-$	5378
1651 ± 2	3.4 ± 0.3	3.4		$\frac{7}{2}^-$	5697
1689 ± 2	≤ 1			d	5732
1833 ± 2	6.6 ± 0.7	6.6		$\frac{3}{2}^+$	5868
1908 ± 4	32 ± 3	31.5		$\frac{1}{2}^-$	5938
2351 ± 8 [i]	124 ± 12	124		$\frac{1}{2}^+$	6355
2889 ± 2	≤ 1			d	6861
3006 ± 2	≤ 1			d	6971
3211.70 ± 0.17	1.38 ± 0.05	1.38 ± 0.05 [e]	0.0033	$\frac{5}{2}^-$	7164.5
3250 ± 10	280 ± 30	280	0.07	$\frac{3}{2}^+$	7201
3438.38 ± 0.19	0.64 ± 0.23	0.64 ± 0.23 [e]	0.01	$\frac{5}{2}^+$	7377.7
3441.73 ± 0.14	0.96 ± 0.20	0.96 ± 0.20 [e]	0.003	$\frac{5}{2}^-$	7380.8
3630 ± 20	500 ± 50	500	0.08	$\frac{3}{2}^-$	7558
3647 [c]	≤ 0.1				7574
3767.76 ± 0.22	14.4 ± 0.3	13.0 ± 0.6 [e]	0.01	$\frac{7}{2}^-$	7687.5
4053 ± 8	90 ± 9	84	6.7	$\frac{1}{2}^+$	7956
4090 ± 50	270 ± 30	250	16	$\frac{1}{2}^-$	7991

Table 17.17: Resonances in ^{16}O(n, n) and ^{16}O(n, α) [a] (continued)

E_n (keV)	$\Gamma_\mathrm{c.m.}$ (keV)	Γ_n (keV)	Γ_α (keV)	J^π	E_x (keV)
4162 ± 8	85 ± 9	71	15	$\frac{3}{2}^+$	8058
4290 ± 20	69 ± 7	68	0.8	$\frac{1}{2}^-$	(8179)
4310 ± 10	52	48	4.0	$(\frac{3}{2}^-)$	8197
4463.41 ± 0.26	11.4 ± 0.5	8.1 ± 0.3	2.2	$\frac{1}{2}^+$	8341.7
4527.12 ± 0.07	6.17 ± 0.13	4.75 ± 0.11	0.54	$\frac{5}{2}^+$	8401.6
4594.83 ± 0.09	2.13 ± 0.11	1.18 ± 0.04	(7.6)	$\frac{7}{2}^+$	8465.3
4631.78 ± 0.12	6.89 ± 0.22	2.86 ± 0.08	1.9	$\frac{5}{2}^-$	8500.0
4829.9 ± 0.4	55.3 ± 0.6	48.9 ± 1.1	1.8	$\frac{3}{2}^-$	8686.3
5050	78	68	9.5	$\frac{3}{2}^+$	8893
5127.0 ± 1.6	26.3 ± 1.9	23.5 ± 1.9		$\frac{7}{2}^-$	8965.7
5368.90 ± 0.09	3.53 ± 0.13	2.37 ± 0.08		$\frac{5}{2}^+$	9193.2
5610	120	120		$\frac{3}{2}^-$	9420
5640	140			$\geq \frac{3}{2}$	9448
5919.67 ± 0.14	23.1 ± 0.3	18.0 ± 0.6		$\frac{7}{2}^+$	9711.1
5995.68 ± 0.15	11.7 ± 0.3	10.3 ± 0.3		$\frac{3}{2}^+$	9782.6
6076.08 ± 0.15	4.01 ± 0.23	3.37 ± 0.23		$(\frac{5}{2}^-)$	9858.2
6094.8 ± 1.0	16.7 ± 1.7	10.9 ± 1.2		$(\frac{1}{2}^-)$	9875.8
6404.6 ± 0.5	49.1 ± 0.8	22.3 ± 0.6		$(\frac{7}{2}^-)$	10167.1
6820.7 ± 0.6	42.5 ± 1.1	17.2 ± 0.7 [e]		$(\frac{7}{2}^-)$	10558.4
7199.3 ± 1.3	41.7 ± 1.4	26.4 ± 0.9 [e]		$(\frac{5}{2}^+)$	10914.4
7373.31 ± 0.18	2.4 ± 0.3	1.88 ± 0.12 [e]		$\frac{1}{2}^-$ [f]	11078.0
7830	190			$\geq \frac{3}{2}$	11507
8320	270			$\geq \frac{3}{2}$	11968
8740	130				12363
8848.8 ± 0.6	6.9 ± 1.1	1.27 ± 0.14 [e]		$\frac{3}{2}^-$ [f]	12465.3
9050	95				12654
9353 ± 6	6 ± 2	0.21 ± 0.14 [e]		$\frac{1}{2}^+$ [f]	12939
9414.9 ± 0.6	2.5 ± 1.0	0.40 ± 0.06 [e]		$\frac{5}{2}^-$ [f]	12997.5
10092.5 ± 2.4	9 ± 5	0.24 ± 0.09 [e]		$(\frac{5}{2}^+)$ [f]	13634.6
10130	400				13670
10725.5 ± 1.5	20.5 ± 1.6	2.07 ± 0.16 [e]		$(\frac{7}{2}^-)$ [f]	14229.6

Table 17.17: Resonances in ^{16}O(n, n) and ^{16}O(n, α) [a] (continued)

E_n (keV)	$\Gamma_{c.m.}$ (keV)	Γ_n (keV)	Γ_α (keV)	J^π	E_x (keV)
10785 ± 3	7.5 ± 4	0.80 ± 0.16 [g]		[j]	14286
10960 ± 3	40 ± 6	13 ± 6 [g]			14450
11140	340			$(\geq \frac{3}{2})$	14619
11322 ± 3	36 ± 13	3.2 ± 1.0 [g]		$(\frac{1}{2})$ [h]	14790
11540	180				14995
11756 ± 3	52 ± 14	11 ± 3 [g]		[j]	15198
11936 ± 3	40 ± 6	7 ± 1 [g]		$(\frac{5}{2}^+)$ [h]	15368
12867 ± 4	21 ± 10	2 ± 0.5 [g]		$(\frac{9}{2}^+)$ [h]	16243
14136 ± 11	66 ± 20	8.0 ± 2.4 [g]		[f]	17435
14853 ± 4	43 ± 12	1.0 ± 0.3 [e]		$\frac{3}{2}^-$	18109

[a] See Tables 17.12 in (1977AJ02) and (1982AJ01).
[b] $\Gamma_{\gamma_0} = (1.80 \pm 0.35)$ eV, $\Gamma_{\gamma_1} = (1.85 \pm 0.35)$ eV (1992IG01).
[c] Not observed in σ_t.
[d] Not $\frac{1}{2}^+$.
[e] Γ_{n_0}.
[f] $T = \frac{3}{2}$.
[g] $(J \pm \frac{1}{2})\Gamma_{n_0}$ (1981HI01).
[h] J^π assignment by comparison with ^{17}N states presumed to be analogs; then $T = \frac{3}{2}$ (1981HI01).
[i] See also (1980JO1A).
[j] $T = \frac{1}{2}$ based on evidence of excitation in ^{16}O(γ, n$_0$) reported in (1990MC06).

Observed proton groups are displayed in Table 17.15. For the parameters of the first $T = \frac{3}{2}$ state see Table 17.16.

29. ^{15}N(α, d)^{17}O $\qquad Q_m = -9.802$

At $E_\alpha = 45.4$ MeV, the deuteron spectrum is dominated by the groups corresponding to states with $E_x = 7.742 \pm 0.020$ and 9.137 ± 0.030 MeV. These states are assigned $J^\pi = (\frac{11}{2}^-)$ and $(\frac{9}{2}^-)$ and arise from a dominant $(\mathrm{d}_{5/2})^2_5\mathrm{p}^{-1}_{1/2}$ configuration: see (1977AJ02).

30. ^{15}N(^{11}B, ^{9}Be)^{17}O $\qquad Q_m = -1.769$

See (1982AJ01).

31. ^{16}O(n, γ)^{17}O $\qquad Q_{\rm m} = 4.143$

The capture cross section for thermal neutrons is $\sigma_{\rm capt.} = 202 \pm 28$ μb (1977MC05). See also (1981MUZQ). At thermal energies the branchings via ^{17}O*(0.87, 3.05) are (18 ± 3) and (82 ± 3)%; $E_\gamma = 870.89 \pm 0.22$ and 2184.47 ± 0.12 keV [the latter leads to $E_{\rm x} = 3055.43 \pm 0.19$ keV for ^{17}O*(3.09); [see (1986AJ04)]. The cross section for two-photon emission $\sigma_{2\gamma} < 3 \pm 19$ μb for $1200 < E_\gamma < 2943$ keV. The two-photon branching ratio is $(1.6 \pm 10) \times 10^{-2}$ (1977MC05). The mechanism of p-wave neutron resonance capture was studied by measurements of gamma spectra from the $E_{\rm n} = 434$ keV resonance ($E_{\rm x} = 4552$ keV) by (1988KI02, 1992IG01). Partial radiative widths and off-resonance capture cross sections were obtained. See footnote $^{\rm b}$) in Table 17.17 and see Table 2.

32. ^{16}O(n, n)^{16}O $\qquad E_{\rm b} = 4.143$

The scattering length (bound) $a = 5.805 \pm 0.005$ fm, $\sigma_{\rm free} = 3.761 \pm 0.007$ b (1979KO26). See also (1981MUZQ). Resonances observed in the elastic scattering and in the (n, α) reaction are displayed in Table 17.17. A two-channel R-matrix analysis finds that five states contain nearly 100% of the $1{\rm d}_{3/2}$ strength and have their eigenenergy at $E_{\rm x} \approx 5.7$ MeV [the dominant state is ^{17}O*(5.08)]. Spectroscopic factors are deduced for 26 states in ^{17}O for $4.5 < E_{\rm x} < 9.5$ MeV [see Table 17.12 in (1977AJ02)]: the sum of these factors is 1% for $J^\pi = \frac{1}{2}^+$, 5% for $\frac{1}{2}^-$, 12% for $\frac{3}{2}^-$, 99% for $\frac{3}{2}^+$, 0.1% for $\frac{5}{2}^+$, 1% for $\frac{5}{2}^-$ and 14% for $\frac{7}{2}^-$. $T = \frac{3}{2}$ resonances are discussed by (1981HI01): see Tables 17.16 and 17.17. See also the review of neutron resonance spectroscopy by (1986WE1B).

Cross-section measurements are listed in Table 17.10 of (1971AJ02) and in (1977AJ02, 1982AJ01). An optical model analysis of angular distributions leads to predictions of $\sigma_{\rm R}$ and $\sigma_{\rm T}$ for $E_{\rm n} = 6$ to 19 MeV (1983DA22). Analyzing power measurements for ${\rm n}_0$ have been carried out at $E_{\rm n} = $ 5–23 MeV (1986AJ04). More recently scattering cross sections have been reported for $E_{\rm n} = 14.1$ MeV (1986BAYL) and $E_{\rm n} = 21.6$ MeV (1990OL01). Optical model parameters were deduced. Small angle scattering cross sections at $E_{\rm n} = 14.8$ MeV are reported by (1992QI02). Neutron total cross section measurements from 160 to 575 MeV are reported by (1988FR23) from an experiment which included a test of charge symmetry. An experimental study of p-wave strength functions is described in (1988KO18).

A cascade statistical-model study of nucleon induced reactions in the range 50 MeV–1 GeV is reported in (1990TA21). A resonating group study of the ^{16}O+single nucleon problem is discussed in (1990HA38). See also the analyses reported in (1992KA21) and (1992KA41).

Neutron elastic-scattering observables were calculated on the basis of the relativistic impulse approximation by (1991KA22).

33. ^{16}O(n, n′)^{16}O* $E_b = 4.143$

A number of resonances have been observed in the cross sections for production of 6.13 and $(6.92 + 7.12)$ MeV γ-rays: see Table 17.13 in (1977AJ02) and (1982AJ01). For cross-section measurements see Table 17.10 in (1971AJ02) and (1977AJ02, 1982AJ01). Studies of circular polarization of gamma rays from inelastic scattering of partially polarized neutrons from a nuclear reactor are reported by (1988LI34). See also the measurements at $E_n = 21.6$ MeV and DWBA coupled channels analysis reported in (1990OL01).

34. (a) ^{16}O(n, p)^{16}N $Q_m = -9.637$ $E_b = 4.143$
(b) ^{16}O(n, d)^{15}N $Q_m = -9.903$
(c) ^{16}O(n, t)^{14}N $Q_m = -14.479$
(d) ^{16}O(n, ^{3}He)^{14}C $Q_m = -14.617$

See (1982AJ01). See also (1981HAZJ, 1982HA1A). Differential cross sections for neutron-induced reactions (a, b, c, d) have been measured for incident neutron energies of 27.4, 39.7, and 60.7 MeV by (1986RO1F, 1986SU15).

In a recent measurement of reaction (a) at $E_n = 298$ MeV, the Gamow-Teller and spin dipole strength functions were extracted (1991HI05).

35. ^{16}O(n, α)^{13}C $Q_m = -2.215$ $E_b = 4.143$

Table 17.17 displays the results from a multilevel two-channel R-matrix analysis of the data from this reaction and from the elastic scattering of neutrons: see (1982AJ01). See also (1981HAZJ, 1982HA1A). More recently differential cross sections were measured for incident neutron energies of 27.4, 39.7, and 60.7 MeV by (1986RO1F, 1986SU15).

36. ^{16}O(p, π^+)^{17}O $Q_m = -136.207$

Angular distributions have been measured at $E_p = 185$ and 800 MeV [to ^{17}O*(0, 0.87, 3.05)] [see (1982AJ01)], as well as at $E_p = 154$ to 185 MeV [for π^+ to ^{17}O*(0, 0.87)]. See (1986AJ04). More recently angular distributions and analyzing powers at $E_p = 250$, 354, 489 MeV were measured to ^{17}O*(0, 5.22, 7.76, 15.78) by (1988HU02) and to ^{17}O*(0, 5.22, 7.76, 14.20, 14.60) at $E_p = 200$ MeV by (1987AZZZ, 1988AZZZ). Studies of (p, π^+) reactions to the Δ_{1232} region are described in (1988HU06).

A relativistic stripping model is applied to the ^{16}O(p, π^+)^{17}O reaction and discussed in (1986CO20).

37. $^{16}O(d, p)^{17}O$ $Q_m = 1.919$

Observed proton groups are displayed in Table 17.14 of (1977AJ02). Angular distributions have been measured at many energies in the range $E_d = 0.3$–698 MeV [see (1982AJ01, 1986AJ04)] and at $E_d = 12.3$ MeV (1990PI05). Reported level parameters are $\tau_m = 258.6 \pm 2.6$ psec [see Table 17.7 in (1971AJ02)] and $E_x = 870.749 \pm 0.020$ keV [$E_\gamma = 870.725 \pm 0.020$ keV] for ^{17}O*(0.87) and $\Gamma_n = 97 \pm 5$ keV for ^{17}O*(5.09): see (1982AJ01), and see (1988GU1E). Recent measurements at $E_d = 12.3$ MeV (1990PI05) determined high precision excitation energies for the first ten levels of ^{17}O (see Table 17.10). For applications, see (1990CA32, 1992LA08).

Theoretical studies of breakup and rearrangement reactions including $^{16}O(d, p)^{17}O$ carried out by means of a coupled-channels variational method are discussed in (1986KA1A, 1986KA1B).

See also ^{18}F in (1983AJ01, 1987AJ02).

38. (a) $^{16}O(^7Li, ^6Li)^{17}O$ $Q_m = -3.106$

(b) $^{16}O(^9Be, ^8Be)^{17}O$ $Q_m = 2.478$

(c) $^{16}O(^{11}B, ^{10}B)^{17}O$ $Q_m = -7.310$

Reaction (a) has been studied at $E(^7Li) = 36$ MeV [see (1982AJ01, 1986AJ04) and more recently at $E(^7Li) = 34$ MeV (1988KE07). For reaction (b) see (1979CU1A, 1985CU1A) and the measurements at $E_{cm} = 10.3$, 12.8 MeV reported by (1988JA14). See also (1988WE17). For reaction (c) see (1982AJ01).

39. (a) $^{16}O(^{13}C, ^{12}C)^{17}O$ $Q_m = -0.803$

(b) $^{16}O(^{14}N, ^{13}N)^{17}O$ $Q_m = -6.410$

For reaction (a) see (1982AJ01, 1986AJ04) and the cross section measurements at $E_{cm} = 7.8$, 14.6 MeV of (1986PA10). For reaction (b) see (1982AJ01).

40. $^{17}N(\beta^-)^{17}O$ $Q_m = 8.680$

The decay is principally to ^{17}O*(4.55, 5.38, 5.94): see Table 17.5.

41. (a) $^{17}O(\gamma, n)^{16}O$ $Q_m = -4.413$

(b) $^{17}O(\gamma, 2n)^{15}O$ $Q_m = -19.806$

(c) $^{17}O(\gamma, p)^{16}N$ $Q_m = -13.780$

Table 17.18: Transition properties and ground state relative widths from ^{17}O(e, e) [a]

E_x (MeV)	J^π	Mtpl.	Γ (keV)	B(E$\lambda\uparrow$) (e$^2\cdot$ fm$^{2\lambda}$)	Mtpl. [b]	Γ_{γ_0} (Mλ) [b] (eV)	B(M$\lambda\uparrow$) [b] (e$^2\cdot$ fm$^{2\lambda}$)
0.87	$\frac{1}{2}^+$	E2		2.18 ± 0.16			
3.06	$\frac{1}{2}^-$	E3		14.1 ± 3.9			
3.84	$\frac{5}{2}^-$	E3		93.0 ± 8.3	M2	$(4.6 \pm 1.8) \times 10^{-3}$	$(5 \pm 2) \times 10^{-2}$
4.55	$\frac{3}{2}^-$	E3		20 ± 12	M2	$(1.8 \pm 0.7) \times 10^{-2}$	$(5.4 \pm 2.1) \times 10^{-2}$
5.09	$\frac{3}{2}^+$	E2		2.05 ± 0.20			
5.22	$\frac{9}{2}^-$	E3		319 ± 13	M2	$< 1 \times 10^{-2}$	$< 4 \times 10^{-2}$
5.38	$\frac{3}{2}^-$	E3		47.9 ± 4.3	M2	$(4.5 \pm 2.2) \times 10^{-2}$	$(6 \pm 3) \times 10^{-2}$
5.70	$\frac{7}{2}^-$	E3		97.0 ± 6.5	M2	0.15 ± 0.10	0.3 ± 0.2
5.73	$(\frac{5}{2}^-)$	E3		134 ± 21			
5.87	$\frac{3}{2}^+$	E2		2.13 ± 0.22			
5.94	$\frac{1}{2}^-$	E3		25.3 ± 5.1			
6.36	$\frac{1}{2}^+$	E2		1.43 ± 0.21			
6.86	$\frac{5}{2}^+$	E2		0.83 ± 0.25			
6.97	$(\frac{7}{2}^-)$	E3		75.5 ± 5.6			
7.17	$\frac{5}{2}^-$	E3		11.1 ± 2.9			
7.20	$\frac{3}{2}^+$	E2		1.79 ± 0.25			
7.38	$\frac{5}{2}^+$	E2		< 0.8			
7.38	$\frac{5}{2}^-$	E3		36.9 ± 2.4			
7.56	$\frac{3}{2}^-$	E3		< 15			
7.58	$\frac{7}{2}^+$	E2		4.20 ± 0.51			
7.69	$\frac{7}{2}^-$	E3		33.9 ± 4.9			
7.76	$\frac{11}{2}^-$	E3		287 ± 14			
7.96	$\frac{1}{2}^+$	E2		2.00 ± 0.38			
8.20	$\frac{3}{2}^-$	E3		11.0 ± 1.3			
8.34	$\frac{1}{2}^+$	E2		0.48 ± 0.07			
8.40	$\frac{5}{2}^+$	E2		2.10 ± 0.34			
8.47	$\frac{9}{2}^+$	E2		10.05 ± 1.19			
8.50	$\frac{5}{2}^-$	E3		< 7			
8.69	$\frac{3}{2}^-$	E3		5.2 ± 1.2			
8.90	$(\frac{9}{2}^-)$	E3		13.3 ± 2.3			
8.97	$\frac{7}{2}^-$	E3		36.3 ± 4.1			
9.15	$(\frac{1}{2}^-, \frac{9}{2}^-)$	E3		< 2.3			
9.18	$\frac{7}{2}^-$	E3		2.4 ± 1.0			
9.19	$\frac{5}{2}^+$	E2		0.48 ± 0.16			
9.42	$\frac{3}{2}^-$	E3		17.6 ± 4.8			
9.49	$\frac{5}{2}^-$	E3		6.5 ± 1.0			

Table 17.18: Transition properties and ground state relative widths from ^{17}O(e, e) [a] (continued)

E_x (MeV)	J^π	Mtpl.	Γ (keV)	B(E$\lambda\uparrow$) ($e^2\cdot fm^{2\lambda}$)	Mtpl. [b]	Γ_{γ_0} (Mλ) [b] (eV)	B(M$\lambda\uparrow$) [b] ($e^2\cdot fm^{2\lambda}$)
9.71	$\frac{7}{2}^+$						
9.86 [c]	$(\frac{5}{2}^-)$						
9.88 [c]	$(\frac{1}{2}^-)$						
11.04 [d]							
11.08 [d]	$\frac{1}{2}^-$				M2		$(6.7 \pm 2.1) \times 10^{-2}$
12.22							
12.47	$\frac{3}{2}^-$				M2		$(7 \pm 3) \times 10^{-2}$
12.94 [e]	$\frac{1}{2}^+$						
13.00 [e]	$\frac{5}{2}^-$				M2		$(7 \pm 3) \times 10^{-2}$
13.58	$(\frac{11}{2}^-)$		68 ± 19				
14.23	$\frac{7}{2}^-$				M2		$(51 \pm 8) \times 10^{-2}$
14.45							
14.72	$\frac{9}{2}^-$				M2		$(30 \pm 10) \times 10^{-2}$
15.78 ± 0.02 [f]			< 30		M4		177 ± 17
16.50 ± 0.02 [f, g]			≤ 20				
17.06 ± 0.02 [f]			< 20		M4		76 ± 6
17.92 ± 0.02 [f]			98 ± 16				
18.72 ± 0.02 [f]			87 ± 33				
18.83 ± 0.02 [f, g]			≤ 20				
19.85 ± 0.04 [f]			530 ± 150				
20.14 ± 0.02 [f]			31 ± 5		M4		349 ± 18
20.70 ± 0.02 [f]			< 20		M4		177 ± 10

[a] (1987MA52) except where footnote is shown. See also Table 17.19 and see Tables 17.13, 17.14 in (1986AJ04) for earlier work.
[b] These data are from (1978KI01) for the levels at $E_x = 3.84 - 5.70$ MeV, from (1983RA27) for $E_x = 11.08 - 14.72$ MeV, and from (1986MA48) for levels at $E_x = 15.78 - 20.20$ MeV. See also Table 17.13 in (1986AJ04).
[c] Unresolved doublet.
[d] Unresolved doublet.
[e] Unresolved doublet.
[f] (1986MA48).
[g] Weakly excited.

Monoenergetic photons with $E_\gamma = 8.5$ to 39.7 MeV have been used to measure the (γ, n) and the (γ, 2n) [above 10 MeV] cross sections. The giant dipole resonance, 6 MeV broad, is centered at 23 MeV; a pigmy resonance is also observed at 13 MeV. The pigmy resonance $[J^\pi = \frac{3}{2}^-]$ decays primarily to ^{16}O$_{g.s.}$, (1986AJ04), and the work of (1985JU02) indicates that above $E_x \approx$ 17 MeV nearly all of the decay is to excited states of ^{16}O. See, however, the experimental results of (1989OR07), which determine that the neutron emission from the ^{17}O GDR to ^{16}O is primarily to the ground state with ≈ 4% going to the 6.13 MeV 3^- level. Four resonances have been inferred at $E_x = 10.5$, 14.0, 16.6 and 21.0 MeV with $J^\pi = \frac{5}{2}^-, \frac{3}{2}^-, \frac{7}{2}^-$, and $\frac{7}{2}^-$ respectively (1985JU02). Recent work of (1990MC06) reanalyzes earlier data and reports that the ^{17}O levels at $E_x = 14.4$, 15.2 and 15.6 MeV should be assigned $T = \frac{1}{2}$. Most of the GDR strength decays to $T = 1$ states in ^{16}O: this implies a $T = \frac{3}{2}$ assignment for the main part of the GDR (1986AJ04). A broad structure, of $T = \frac{1}{2}$ nature, with $28 < E_x < 36$ MeV is also reported (1980JU01). For radiative widths see Table 17.13 in (1982AJ01). Measurements of bremsstrahlung-weighted integral cross sections for reaction (c) carried out by (1989OR07) indicated that 90% of the photoproton emission to ^{16}N populates the ground state (2^-) and the 0.298 MeV (3^-) levels. More recently, the GDR was studied with reaction (c) using quasimonoenergetic photons from $E_\gamma = 13.5$ to 43.15 MeV (1992ZU01). Major peaks were observed at $E_\gamma = 15.1$, 18.1, 19.3, 20.3, 22.2, 23.1, 24.4 and ≈ 26.5 MeV.

Comparisons of ^{17}O photonuclear data with shell model and continuum shell model calculations are discussed in (1987KI1C).

42. ^{17}O(e, e)^{17}O

The ^{17}O charge radius is reported to be $\langle r^2 \rangle_{1/2} = 2.710 \pm 0.015$ fm (1978KI01). The r.m.s. radius of the 1d$_{5/2}$ neutron orbit deduced from the data is 3.56 ± 0.09 fm (1982HI01). The elastic magnetic form factor was measured for $2.47 \leq q_{\rm eff} \leq 3.65$ fm^{-1} by (1988KA08). Inelastic scattering is reported to a number of ^{17}O states: see Tables 17.18 and 17.19. Excited states in ^{16}O up to $E_x = 15$ MeV were studied in high resolution at q $= 0.8$–2.6 fm^{-1} by (1987MA52). Recent form-factor measurements for momentum transfers q $= 1.4$–1.9 fm^{-1} at $90°$ and q $=$ 1.7 fm^{-1} at $160°$, for levels between $E_x = 15$ and 27 MeV, were reported by (1986MA48). See also footnote ^{e}) in Table 17.10. Note, however, the comments by (1987MI25) and reply by (1987MA40) concerning the spin assignments of (1986MA48). See also (1986AJ04) and reaction 50.

Calculations of charge and magnetic form factors in a consistent relativistic formalism are described in (1986KI10, 1986WA1D, 1991BL14). See also (1989FU05). Excitation energies, magnetic moments and M2 magnetic ground state transitions for five $T = \frac{3}{2}$ excited states were calculated in a microscopic 2p-1h model by (1986TO13). Nuclear currents and amplitudes for elastic magnetic scattering in a relativistic mean-field theory were studied by (1987FU06, 1988FU04). A relativistic direct-interaction-based impulse approximation model is discussed in (1989GA04).

Model dependence of *rms* radii as determined from elastic magnetic form factors was studied by (1991CO12). See also (1991GO1F, 1991GO1G, 1992GO07). See also the study by (1992BO07) of ^{17}O(e, e′n)^{16}O as a tool for investigation of the role of two-body currents in quasi-free electron scattering.

43. ^{17}O($\pi^\pm$, $\pi^\pm$)^{17}O

Table 17.19: Some inelastic groups observed in ^{17}O(e, e) [a]

E_x (MeV)	Γ (keV)	E_x (MeV)	Γ (keV)
11.71 ± 0.05 [b]	narrow	14.76 ± 0.10 [b]	> 300
11.95 ± 0.05 [b]	≈ 250	15.24 ± 0.10 [b]	≈ 200
12.22 ± 0.02 [c]	≤ 20	16.52 ± 0.05 [b]	≈ 300
12.66 ± 0.05 [b]	≈ 90	17.92 ± 0.02 [c]	98 ± 16
12.96 ± 0.05 [b]	≈ 200	18.72 ± 0.02 [c]	87 ± 33
13.56 ± 0.05 [b]	≈ 150	22.0 [b, d]	
14.14 ± 0.10 [b]	≈ 100	23.0 [b, d]	
14.72 ± 0.02 [c]	35 ± 11		

[a] See also Table 17.18 for other inelastic groups and more recent data, and see (1986AJ04).
[b] (1977NO06).
[c] See references and comments in Table 17.14 of (1986AJ04).
[d] C1.

At $E_{\pi^\pm} = 164$ MeV angular distributions to ^{17}O*(3.85, 4.55, 5.22, 5.69, 7.76, 8.1, 8.4, 15.7, 17.1) have been analyzed by DWBA. Evidence is suggested for E2 strength near 8 MeV and for M4 strength to the two states at $E_x = 15.7$ and 17.1 MeV (1984BL17). [See, however, caveat on p. 1990 of that reference, and the density of states above $E_x = 5$ MeV in Table 17.10.]

44. ^{17}O(n, α)^{14}C $\qquad\qquad Q_m = 1.818$

Cross sections were measured for thermal energies to $E_n \approx 1$ MeV by (1991KO31). This reaction plays a role in the nucleosynthesis of heavy elements in nonstandard big-bang models. See also (1991KO1P).

45. (a) ^{17}O(p, p)^{17}O
(b) ^{17}O(d, d)^{17}O

Angular distributions for the elastic scattering have been reported for $E_p = 8.6$ to 65.8 MeV and $E_d = 18$ MeV: see (1982AJ01). Analyzing power measurements for $E_p = 89.7$ MeV are reported in (1985VO12). For reaction (a) see also ^{18}F in (1983AJ01, 1987AJ02).

A coupled-channels variational-method calculation has been applied to reaction (a) and is discussed in (1986KA1A).

46. (a) ^{17}O(^{3}He, ^{3}He)^{17}O
(b) ^{17}O(α, α)^{17}O

Elastic angular distributions have been measured at $E(^{3}\text{He}) = 11.0$ and 17.3 MeV [see (1977AJ02)], and at 14 MeV (1982AB04). Analyzing powers were measured at $E(^{3}\text{He}) = 33.3$ MeV [see (1986AJ04) ; also A_{y} to ^{17}O*(0.87)]. For reaction (b) see (1982AJ01, 1986AJ04). More recently, differential cross sections were measured at $E_{\alpha} = 54.1$ MeV (1987AB03).

Microscopic spin-orbit potentials for polarized ^{3}He scattering on ^{17}O have been calculated (1987CO07) by a double folding model.

47. (a) ^{17}O(^{9}Be, ^{9}Be)^{17}O
(b) ^{17}O(^{10}B, ^{10}B)^{17}O

Fusion cross section measurements for reaction (b) are reported by (1982CH07). See also (1982AJ01, 1986AJ04).

48. (a) ^{17}O(^{12}C, ^{12}C)^{17}O
(b) ^{17}O(^{13}C, ^{13}C)^{17}O
(c) ^{17}O(^{14}C, ^{14}C)^{17}O

Elastic angular distributions (reactions (a) and (b)) have been reported at $E(^{17}\text{O}) = 30.5$ to 33.8 MeV [see (1982AJ01)] and at $E(^{17}\text{O}) = 40$ to 70 MeV (1986FR04; also ^{17}O*(0.87)) and 85.4, 120 and 140 MeV (1982HE07). See also the comparison of reaction (a) with $^{16}\text{O} + {}^{13}\text{C}$ by (1989FR04). For fusion cross section and yield measurements see (1982AJ01, 1986AJ04).

Results of a barrier-penetration calculation for these reactions is discussed in (1986HA13). The energy dependence of nucleus-nucleus potentials is explored in (1987BA01). Molecular single-particle effects are studied in an asymmetric two-center shell model in (1987MO27). See also (1988MI25). The origin of the resonant structure in reaction (b) is treated in (1988FR15). The nuclear Landau-Zener effect in reaction (a) is discussed in (1988TH02, 1988THZZ). Some features in inelastic scattering angular distributions that had been attributed to the existence of nucleon promotion are explained in terms of DWBA calculations by (1987VO05).

See also (1991TA11, 1991TH04).

49. ^{17}O(^{15}N, ^{15}N)^{17}O

See (1986AJ04).

50. (a) ^{17}O(^{16}O, ^{16}O)^{17}O
(b) ^{17}O(^{18}O, ^{18}O)^{17}O

Angular distributions involving ^{17}O*(0, 0.87) in reaction (a) have been studied at $E(^{16}\mathrm{O}) = 22$ to 32 MeV and $E(^{17}\mathrm{O}) = 25.7$ to 32.0 MeV [see (1977AJ02)] as well as at $E(^{17}\mathrm{O}) = 22$ MeV [see (1986AJ04)]. A model independent value of 0.82 ± 0.07 is obtained for the coupling constant of the 1d$_{5/2}$ neutron in ^{17}O. A review of magnetic electron scattering on ^{17}O then leads to a spectroscopic factor $S = 1.03 \pm 0.07$. This corresponds to (91 ± 7)% of the single-particle value [see (1982AJ01, 1986AJ04)]. For fusion cross sections see (1982AJ01) and (1986TH01). The elastic scattering angular distribution in reaction (b) has been reported at $E(^{17}\mathrm{O}) = 36$ MeV: see (1982AJ01, 1986AJ04).

Rotational coupling effects on nucleon molecular orbits in reaction (a) are studied in (1987IMZY, 1988IM02). See also (1987IMZZ). Subbarrier interactions are discussed in (1987PO11, 1988BE1W). Calculations of Gamow states in a realistic two-center potential are described in (1986MI22). Two-particle transfer is studied with a semiclassical approach in (1987MA22). Parity dependence in heavy ion collisions is discussed in (1986BA69).

51. (a) ^{17}O(^{22}Ne, ^{22}Ne)^{17}O
(b) ^{17}O(^{24}Mg, ^{24}Mg)^{17}O
(c) ^{17}O(^{27}Al, ^{27}Al)^{17}O
(d) ^{17}O(^{40}Ca, ^{40}Ca)^{17}O

See (1982AJ01, 1986AJ04). Reaction (d) has been described in a two-center shell model (1989TH1B). See also (1989TH1D).

52. ^{17}F(β^+)^{17}O $\qquad Q_\mathrm{m} = 2.760$

See ^{17}F.

53. ^{18}O(p, d)^{17}O $\qquad Q_\mathrm{m} = -5.820$

Angular distributions have been measured at a number of energies for $E_{\rm p} = 17.6$ to 51.9 MeV: see (1977AJ02, 1982AJ01).

54. ^{18}O(d, t)^{17}O $\qquad Q_{\rm m} = -1.787$

See Table 17.20. See also reaction 7 in ^{17}N.

55. ^{18}O(^{3}He, α)^{17}O $\qquad Q_{\rm m} = 12.534$

See Tables 17.16 and 17.21. See also (1982AJ01).

56. (a) ^{18}O(^{10}B, ^{11}B)^{17}O $\qquad Q_{\rm m} = 3.409$
(b) ^{18}O(^{11}B, ^{12}B)^{17}O $\qquad Q_{\rm m} = -4.674$

Angular distributions (reaction (a)) have been measured at $E(^{18}{\rm O}) = 20$ and 24 MeV: see (1977AJ02). For S-factor measurements see (1977AJ02). Cross sections for reaction (b) are several orders of magnitude less than those for reaction (a) for $E(^{18}{\rm O})_{\rm c.m.} = 3$–7.7 MeV: see (1977AJ02).

57. (a) ^{19}F(n, t)^{17}O $\qquad Q_{\rm m} = -7.557$
(b) ^{19}F(p, ^{3}He)^{17}O $\qquad Q_{\rm m} = -8.320$

See (1977AJ02).

58. ^{19}F(d, α)^{17}O $\qquad Q_{\rm m} = 10.034$

Observed α-groups are displayed in Table 17.14 of (1977AJ02). Angular distributions have been measured at many energies in the range $E_{\rm d} = 0.3$ to 27.5 MeV [see (1977AJ02)] and at $E_{\rm d} = 2.75$ MeV [see (1986AJ04)].

59. (a) ^{19}F(α, ^{6}Li)^{17}O $\qquad Q_{\rm m} = -12.339$
(b) ^{20}Ne(n, α)^{17}O $\qquad Q_{\rm m} = -0.591$

Table 17.20: States of ^{17}O from ^{18}O(d, t) [a]

E_x [b] (MeV)	$J^\pi; T$ [b]	l	C^2S
0	$\frac{5}{2}^+; \frac{1}{2}$	2	1.53
0.87	$\frac{1}{2}^+; \frac{1}{2}$	0	0.21
3.06	$\frac{1}{2}^-; \frac{1}{2}$	1	1.08
3.84	$\frac{5}{2}^-; \frac{1}{2}$	> 2	
4.55	$\frac{3}{2}^-; \frac{1}{2}$	1	0.12
5.09	$\frac{3}{2}^+; \frac{1}{2}$	2	0.10
5.38	$\frac{3}{2}^-; \frac{1}{2}$	1	0.53
5.70	$\frac{7}{2}^-; \frac{1}{2}$		
5.94	$\frac{1}{2}^-; \frac{1}{2}$	1	0.06
6.86		$\neq 1$	
7.38 [c]	$\frac{5}{2}^+; \frac{5}{2}^-$	$\neq 2$	
8.20	$\frac{3}{2}^-; \frac{1}{2}$	1	0.15
8.47	$\frac{7}{2}^+; \frac{1}{2}$		
8.69	$\frac{3}{2}^-; \frac{1}{2}$	1	0.10
9.15	$\frac{1}{2}^-; \frac{1}{2}$	1	0.10
9.49	$\frac{5}{2}^-; \frac{1}{2}$		
11.08	$\frac{1}{2}^-; \frac{3}{2}$	1	0.96
11.41 ± 0.01 [a]	$T = \frac{1}{2}$ [a]	(1)	0.04
12.12 ± 0.01 [a]	$T = \frac{1}{2}$ [a]	(1)	0.24
12.47	$\frac{3}{2}^-; \frac{3}{2}$ [d]	1	0.24
12.76 ± 0.01 [a]	$T = \frac{1}{2}$ [a]	(1)	0.17
12.94	$\frac{1}{2}^+; \frac{3}{2}$ [d]	0	0.19 ± 0.05
13.64	$\frac{5}{2}^+; \frac{3}{2}$ [d]	2	0.29 ± 0.12
16.58 ± 0.01 [a]	$\frac{3}{2}^-; \frac{3}{2}$ [d]	1	0.93
18.14 ± 0.01 [a]	$\frac{3}{2}^-; \frac{3}{2}$ [d]	1	0.17

[a] (1977MA10): $E_d = 52$ MeV; DWBA analysis. See also Table 17.16 in (1982AJ01). Comparisons of the (d, t) and (d, ^{3}He) reactions to analog states of ^{17}N and ^{17}O have been made by (1977MA10).

[b] From Table 17.10, unless footnote is shown.

[c] Unresolved.

[d] See also (1981MA14).

Table 17.21: $T = \frac{3}{2}$ states of ^{17}O from ^{18}O(^{3}He, α)^{17}O [a]

E_x (MeV $\pm$ keV)	l_n	J^π	C^2S [b]
11.082 ± 6	1	$(\frac{1}{2})^-$	0.49
12.471 ± 5	1	$(\frac{3}{2})^-$	0.27
12.950 ± 8	0	$\frac{1}{2}^+$	0.096
12.994 ± 8			
13.640 ± 5	2	$(\frac{5}{2})^+$	0.39
14.219 ± 8			
14.282 ± 12			
15.101 ± 8			

[a] See also Table 17.16, and Table 17.17 in (1982AJ01).
[b] Calculated assuming $C^2S = 4$ for ^{15}O*(6.18) in ^{16}O(^{3}He, α)^{15}O.

See (1977AJ02). See also (1988SH1E).

60. ^{23}Na(d, ^{8}Be)^{17}O $\qquad Q_m = -0.528$

See (1984NE1A).

^{17}F
(Figs. 3 and 4)

GENERAL: See Table 17.22.

$$\mu = 4.72130 \pm 0.00025 \text{ n.m. (1992MI13)},$$
$$Q = 0.10 \pm 0.02 \text{ b (1974MI21)}.$$

1. ^{17}F(β^+)^{17}O $\quad Q_{\rm m} = 2.760$

The half-life of ^{17}F is 64.49 ± 0.16 sec; $\log ft = 3.358 \pm 0.002$. The $\log ft$ value for the transition to ^{17}O*(0.87) is > 5.6: see (1982AJ01, 1986AJ04). The β anisotropy has been measured with on-line isotope separation and low-temperature nuclear orientation (1988SE11, 1988VAZP, 1989SE07). See also (1988TA1N).

Gamow-Teller matrix elements were calculated for the ^{17}F β^+ decay in the relativistic scalar-vector shell model by (1990NE12). The effect of exchange currents arising from quark degrees of freedom was studied by (1988TA09). A relativistic analysis of semileptonic weak interactions is described in (1987KI22). See also (1987BA89, 1988BA1Y, 1988BA55, 1991NA05).

2. ^{12}C(^{14}N, ^{9}Be)^{17}F $\quad Q_{\rm m} = -10.435$

See (1982AJ01).

3. ^{14}N(^{3}He, γ)^{17}F $\quad Q_{\rm m} = 15.843$

Excitation functions for γ_{0+1}, γ_2 and γ_3 have been studied for $E(^3\text{He}) \approx$ 3–18 MeV. Resonances are reported corresponding to ^{17}F states at 20.1 ± 0.2 (γ_2) [$\Gamma = 1.07 \pm 0.16$ MeV], 20.4 ± 0.1 (γ_1) [$\Gamma = 0.7 \pm 0.1$] and 21.3 ± 0.1 MeV (γ_1) [$\Gamma = 0.9 \pm 0.1$] (1983WA05): see Table 17.19 in (1982AJ01).

4. ^{14}O(α, p)^{17}F $\quad Q_{\rm m} = 1.190$

This reaction is important in astrophysical processes. Analytic expressions for reaction rates are given in (1988CA26). The rates are calculated on the basis of $T = 1$ analog structure in ^{18}O and ^{18}Ne by (1987WI11). See also the studies of this reaction in the framework of the generator coordinate method by (1988FU02, 1989FU01).

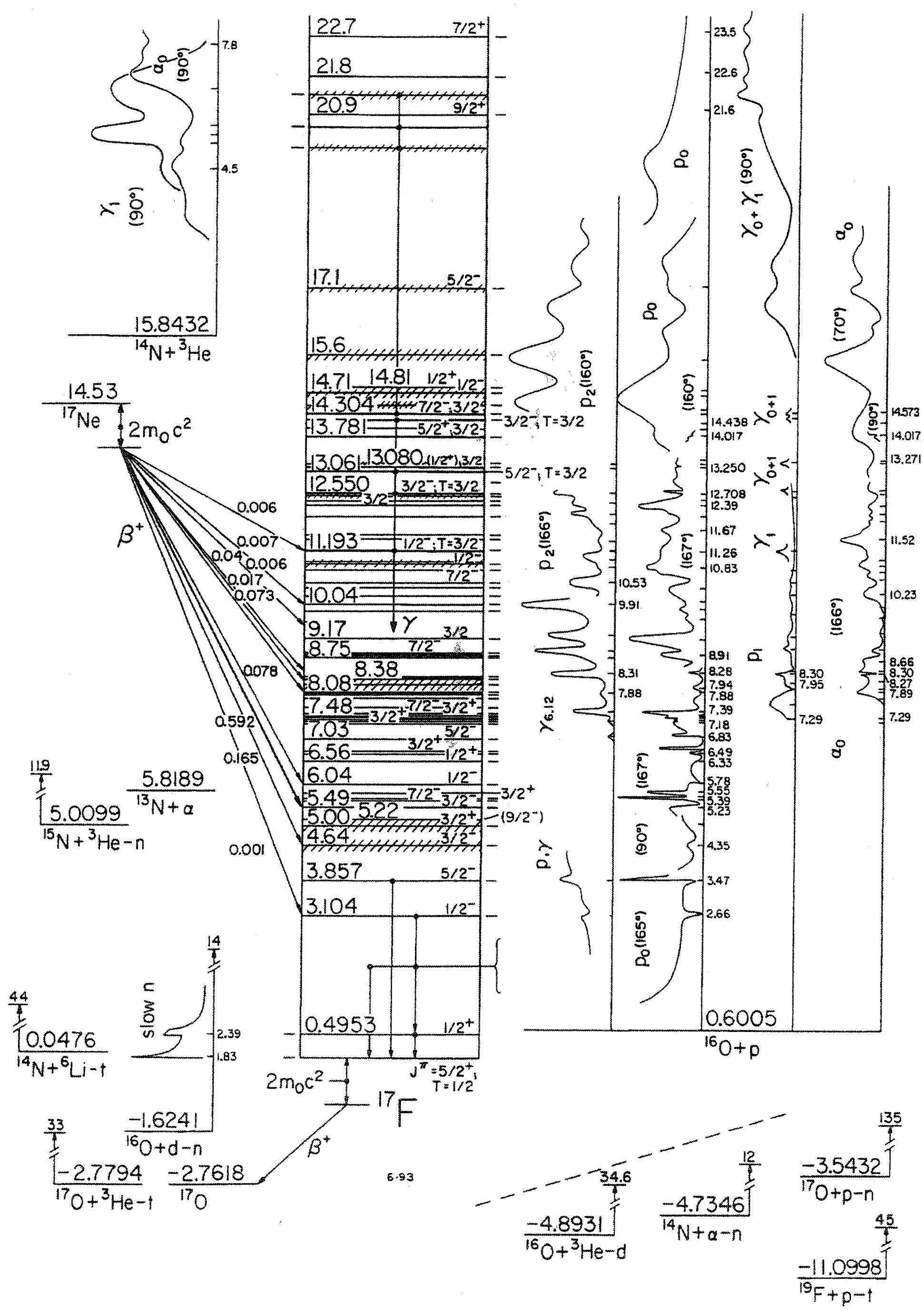

Fig. 3: Energy levels of ^{17}F. For notation see Fig. 2.

Table 17.22: ^{17}F – General

Reference	Description
	Ground State Properties
Review:	
1989RA17	Table of nuclear moments
Other Articles:	
1986CA27	Shell-model calculations of quadrupole moments of sd-shell nuclei
1986MC13	Resolution of the magnetic moment problem in relativistic theories
1986WUZX	Charge dependence of Brueckner's G-matrix & the Nolen-Schiffer-Okamoto anomaly
1987BR30	Empirically optimum M1 operator for sd-shell nuclei
1987DE03	Compared mag. moments from non-relativistic HF mean-fields & relativistic approach
1987FU06	Nuclear currents in a relativistic mean-field theory
1988CH1T	Microscopic calculation of ^{15}O-^{15}N, ^{17}F-^{17}O Coulomb displacement energies (A)
1988FU04	Convection currents in nuclei in a relativistic mean-field theory
1988NI05	Nuclear magnetic moments & spin-orbit current in the relativistic mean field theory
1988SH07	Magnetic response of closed-shell $\pm$ 1 nuclei in Dirac-Hartree approximation
1989CH24	Medium induced magnetization current & nuclear magnetic moments
1989FU05	Relativistic Hartree calculations of odd-A nuclei
1989NE02	Magnetic moments of closed-shell $\pm$ 1 nuclei in the relativistic shell model
1991HA15	QCD sum rules in a nuclear medium & the Okamoto-Nolen-Schiffer anomaly
1991ZH06	Relativistic Hartree study of deformed sd-shell nuclei
1992AV03	Proton-neutron interaction used to help calculate masses of $Z > N$ nuclei
1992MA45	Coulomb displacement energies in relativistic & non-relativistic self-consistent models
1992SU02	Nolen-Schiffer anomaly of mirror nuclei: valence nucleon orbits & chrg. sym. breaking
	Other topics
1986AN07	Predicted masses and excitation energies in higher isospin multiplets for $9 \leq A \leq 60$
1986CA27	Shell-model calculations of quadrupole moments of sd-shell nuclei
1986YA1B	Effective shell-model operators; calculated spin-orbit splitting
1987BR30	Empirically optimum M1 operator for sd-shell nuclei
1987BU07	Projectile-like fragments from ^{20}Ne + ^{197}Au - counting simultaneously emitted neutrons
1987RI03	Isotopic distributions of fragments produced in ^{40}Ar + ^{68}Zn at 27.6 MeV/u
1989BA92	Strangeness production by heavy ions
1989BA93	Production of hypernuclei in relativistic ion beams
1991NI02	Production of pionic atoms with the (e, e$'$) reaction
1991SK02	Effective transition operators in the sd shell

Reference	Description
	Other Topics — continued
1991ZH06	Relativistic Hartree study of deformed sd-shell nuclei
1992BE21	Search for the 70 keV resonance in ^{17}O(p, α)^{14}N
1992KW01	Clustering of 1p-shell nuclei in the framework of the shell model

5. (a) ^{14}N(^{6}Li, t)^{17}F $\quad Q_{\rm m} = 0.047$
   (b) ^{14}N(^{6}Li, tα)^{13}N $\quad Q_{\rm m} = -5.771$

Angular distributions for reaction (a) involving ^{17}F*(8.43, 10.7, 11.9, 13.51, 14.84) have been measured at $E(^{6}{\rm Li}) = 36$ MeV. For comparisons with the results in the analog reaction ^{14}N(^{6}Li, ^{3}He)^{17}O see (1986AJ04). For the earlier work see (1982AJ01).

6. ^{15}N(^{3}He, n)^{17}F $\quad Q_{\rm m} = 5.010$

Angular distributions have been reported to most of the states of ^{17}F with $E_{\rm x} < 8.1$ MeV at $E(^{3}{\rm He}) = 3.8$ and 4.8 MeV. Neutron groups have also been reported to ^{17}F states at $E_{\rm x} = 11.195 \pm 0.007$, 12.540 ± 0.010 and 13.059 MeV, with $\Gamma < 20$, < 25 and < 25 keV, respectively. Angular distributions at $E(^{3}{\rm He}) = 10.36$ and 11.88 MeV lead to $J^{\pi} = \frac{1}{2}^{-}$ for ^{17}F*(11.20) [L=0], $\frac{3}{2}^{-}$ or $\frac{5}{2}^{-}$ for ^{17}F*(12.54) and $\frac{3}{2}^{-}$, $\frac{5}{2}^{-}$ for ^{17}F*(13.06). These three states are probably the first three $T = \frac{3}{2}$ states in ^{17}F (1969AD02). The branching ratios for transitions to ^{16}O*(0, 6.05, 6.13) for ^{17}F*(11.20) and for the analog $T = \frac{3}{2}$ state in ^{17}O are displayed in Table 17.16: the ratios of the reduced widths are quite different in the two mirror nuclei. See (1977AJ02) for the references.

7. ^{16}O(p, γ)^{17}F $\quad Q_{\rm m} = 0.601$

At low energies the direct capture to ^{17}F*(0, 0.50) is observed. Extrapolation of cross-section data leads to S$(0) \approx 8$ keV·b: see (1977AJ02). In addition to two $T = \frac{1}{2}$ resonances, five resonances corresponding to $T = \frac{3}{2}$ states are observed in the γ_1 and $\gamma_0 + \gamma_1$ yields: see Table 17.24 for the reported parameters. The lowest $T = \frac{3}{2}$ states of even parity at $E_{\rm x} = 13.27$ and 14.02 MeV

$[J^\pi = (\frac{1}{2}^+)$ and $\frac{5}{2}^+]$ (see Table 17.24) are not observed here: $\Gamma_\gamma \leq 7$ and ≤ 11.8 eV, respectively (1975HA06).

The $(\gamma_0 + \gamma_1)$ yield at $90°$ has been studied for $E_p = 15.75$ to 31.66 MeV: it shows the giant dipole resonance centered at $E_x = 22$ MeV with a width of ≈ 5 MeV and a pigmy resonance centered at 17.5 MeV. The integrated strength of the mainly $T = \frac{1}{2}$ giant resonance is 10 MeV·mb; the observed strength distribution is in good agreement with odd parity 2p-1h, 1p shell excitation

Table 17.23: Energy levels of ^{17}F [a]

E_x in ^{17}F (MeV $\pm$ keV)	$J^\pi; T$	τ or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
0	$\frac{5}{2}^+; \frac{1}{2}$	$\tau_{1/2} = 64.49 \pm 0.16$ sec	β^+	1, 2, 3, 4, 5, 6, 7, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24
0.49533 ± 0.10	$\frac{1}{2}^+$	$\tau_m = 412 \pm 9$ psec	γ	2, 3, 4, 5, 6, 7, 13, 14, 15, 16, 17, 18, 19, 20, 22
3.104 ± 3	$\frac{1}{2}^-$	$\Gamma = 19 \pm 1$	γ, p	3, 4, 5, 6, 7, 8, 13, 14, 20, 22
3.857 ± 4	$\frac{5}{2}^-$	1.5 ± 0.2	γ, p	3, 4, 5, 6, 7, 8, 13, 14, 22
4.64 ± 20	$\frac{3}{2}^-$	225	p	5, 6, 8, 13, 17, 20
5.00 ± 20	$\frac{3}{2}^+$	1530	p	8
5.220 ± 10	$\frac{9}{2}^-$			5, 6, 16
5.488 ± 11	$\frac{3}{2}^-$	68	p	5, 6, 8, 20
5.672 ± 20	$\frac{7}{2}^-$	40	p	5, 6, 8
5.682 ± 20	$(\frac{5}{2}^-)$ [b]	< 0.6	p	5, 6, 8
5.82 ± 20	$\frac{3}{2}^+$	180	p	5, 8, 17
6.037 ± 9	$\frac{1}{2}^-$	30	p	5, 6, 8, 20
6.56 ± 20	$\frac{1}{2}^+$	200	p	8
6.697 ± 7	$\frac{5}{2}^+$	$\leq 1.6 \pm 0.2$	p	5, 6, 8
6.774 ± 20	$(\frac{3}{2}^+)$	4.5	p	8
7.027 ± 20	$\frac{5}{2}^-$	3.8	p	6, 8
7.356 ± 20	$(\frac{3}{2}^+)$	10 ± 2	p, α	6, 8, 12
7.448 ± 20		≤ 5	p	8
7.454 ± 20		7 ± 2	p, α	8, 12
7.471 ± 20		5 ± 2	p	8

Table 17.23: Energy levels of ^{17}F [a] (continued)

E_x in ^{17}F (MeV ± keV)	$J^\pi; T$	τ or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
7.479 ± 20	$\frac{3}{2}^+$	795	p	8
7.546 ± 20	$\frac{7}{2}^-$	30	p	8
7.75 ± 40	$(\frac{1}{2}^+)$	179 ± 30	p, α	8, 12
7.95 ± 30		10 ± 3	p	8
8.01 ± 40		50 ± 20	p, α	7, 11
8.07 ± 30	$\frac{5}{2}^{(+)}$	100 ± 20	p, α	6, 8, 12
8.075 ± 10	$(\frac{1}{2}, \frac{3}{2})^-$		p	6, 20
8.2	$\frac{3}{2}^{(-)}$	700 ± 250	p, α	8, 12
8.383 ± 10	$\frac{5}{2}^{(-)}$	11 ± 5	p, α	8, 12
8.416 ± 20	$(\frac{7}{2}^+)$	45 ± 10	p, α	8, 12
8.436 ± 10	$(\frac{1}{2}, \frac{3}{2})^-$		p	20
8.75 ± 60	$\frac{5}{2}^{(+)}$	170 ± 30	p, α	8, 12
8.76	$\frac{3}{2}^+$	90 ± 20	p	8
8.825 ± 25	$(\frac{1}{2}, \frac{3}{2})^-$		p	20
8.98 ± 20	$\frac{7}{2}^-$	165 ± 30	p, α	8, 12
9.17 ± 60	$\frac{3}{2}^{(+)}$	140 ± 30	p, α	8, 12, 17
9.450 ± 50		200 ± 40	p	20
9.92	$\frac{9}{2}^+$	90 ± 30	p, α	8, 12
10.030 ± 60		170 ± 40	p	20
10.04 ± 40	$\frac{7}{2}$	280 ± 100	p	8
10.22 ± 40		250 ± 80	α	12
10.40 ± 40	$\frac{5}{2}^{(+)}$	160 ± 40	p	8
10.499 ± 30	$\frac{7}{2}^-$	165 ± 25	p, α	8, 12
10.660 ± 20		90 ± 60	p	20
10.79 ± 40		120 ± 40	p, (α)	8, 12
10.91 ± 100	$\frac{1}{2}^-$	560 ± 100	p	8
10.95 ± 40		190 ± 50	p, (α)	8, 12
11.1929 ± 2.3	$\frac{1}{2}^-; \frac{3}{2}$	0.18 ± 0.03	γ, p, α	6, 7, 8, 12, 20
11.43 ± 40		240 ± 50	p, α	8, 12
11.58 ± 50		160 ± 30	p	8
12.00 ± 40		120 ± 40	p, α	8, 12

Table 17.23: Energy levels of ^{17}F [a] (continued)

E_x in ^{17}F (MeV ± keV)	$J^\pi; T$	τ or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
12.25 ± 40	$\frac{3}{2}^-$	300 ± 30	p	8
12.355 ± 20	$\frac{1}{2}^-$	190 ± 20	p	8
≈ 12.50	$\frac{7}{2}^-$	≈ 600	p	8
12.5501 ± 0.9	$\frac{3}{2}^-; \frac{3}{2}$	2.83 ± 0.12	γ, p, α	6, 7, 8, 12
13.061 ± 4	$\frac{5}{2}^-; \frac{3}{2}$	2 ± 1	γ, p, α	6, 7, 8, 12
13.080 ± 4	$(\frac{1}{2}^+); \frac{3}{2}$	2 ± 1	p, α	8, 12
13.13 ± 100	$\frac{5}{2}^-$	520 ± 50	p	8
13.781 ± 4	$\frac{5}{2}^+; \frac{3}{2}$	12 ± 5	p, α	8, 12
14.00 ± 50	$\frac{7}{2}^-$	260 ± 30	p	8
14.176 ± 6	$\frac{3}{2}^-; \frac{3}{2}$	30 ± 5	γ, p	7, 8
14.3038 ± 3.1	$\frac{7}{2}^-; \frac{3}{2}$	19.3 ± 1.6	γ, p, α	7, 8, 12
14.38 ± 50	$\frac{5}{2}^-$	610 ± 50	p	8, 17
14.71 ± 100	$\frac{1}{2}^-$	470 ± 100	p	8
14.809 ± 20	$\frac{1}{2}^+$	190 ± 25	p	8
15.6		≈ 550	p	8
17.1	$\frac{5}{2}^-$	1500	p	8
20.1 ± 200		1070 ± 60	γ, ^{3}He	3
20.4 ± 100		700 ± 100	γ, ^{3}He	3
20.9	$\frac{9}{2}^+$	600	p	8
21.3 ± 100		900 ± 100	γ, ^{3}He	3
21.8	$(\frac{9}{2}^+)$	400	p	8
22.7	$\frac{7}{2}^+$	600	p	8
23.8	$\frac{7}{2}^+$	600	p	8
25.4	$\frac{7}{2}^-$	1500	p	8
27.2	$\frac{5}{2}^-$	1500	p	8
28.9	$\frac{5}{2}^+$	2000	p	8

[a] See also Table 17.25, and see (1986AJ04).

[b] Appears to be analog of ^{17}O*(5.733) (D.J. Millener, private communication).

calculations. The pigmy resonance is due to $f_{7/2} \approx d_{5/2}$. The main $f_{7/2}$ strength lies in two states at $E_x = 16.9$ and 18.0 MeV (1975HA07). The γ_0 yield at 60° for $E_p = 20$ to 100 MeV

Table 17.24: Resonances in ^{16}O(p, γ)^{17}F [a]

E_p (MeV $\pm$ keV)	Resonant in [b]	Γ_γ (eV)	Γ (keV)	E_x (MeV)	$J^\pi; T$
2.66	γ_1	$(12 \pm 2) \times 10^{-3}$		3.11	$\frac{1}{2}^-; \frac{1}{2}$
3.47	γ_0	0.11 ± 0.02	< 1.5	3.86	$\frac{5}{2}^-; \frac{1}{2}$
11.275 ± 6	γ_1	6.0 ± 2.5 [c]	≤ 1.6	11.204	$\frac{1}{2}^-; \frac{3}{2}$
12.707 ± 1	$\gamma_0 + \gamma_1$	11.3 ± 3.4 [c]	1.8 ± 0.5	12.550	$\frac{3}{2}^-; \frac{3}{2}$
13.255 ± 6	$\gamma_0 + \gamma_1$	2.8 ± 1.8 [c]	5.0 ± 1.5	13.065	$\frac{5}{2}^-; \frac{3}{2}$
14.435 ± 10	γ_0	72 ± 37 [e]	41 ± 10	14.174	$\frac{3}{2}^-; \frac{3}{2}$
14.583 ± 6 [d]	$\gamma_0 + \gamma_1$	13.4 ± 7.0 [c]	28 ± 5	14.313	$\frac{7}{2}^-; \frac{3}{2}$

[a] See also Table 17.25 and Table 17.20 in (1982AJ01).

[b] γ_0 and γ_1 correspond to transitions to ^{17}F*(0, 0.50), respectively.

[c] These Γ_γ are based on J^π and Γ_{p_0}/Γ determinations quoted by (1975HA06). The B(E1) values for these four states are 4.7 ± 2.0, 5.4 ± 1.6, 1.2 ± 0.8 and 4.4 ± 2.3 $[\times 10^{-3}]$ $e^2 \cdot \mathrm{fm}^2$.

[d] See the text of reaction 7 for discussion of the observed pigmy and giant resonances (1975HA07).

[e] See also Table 17.18 in (1977AJ02).

and differential cross sections at $E_p = 20.8$, 28.35, 49.2 and 49.69 MeV have been measured (1988HA04). Differential cross sections have been measured for ^{17}O excitation energies $E_x = 20$–40 MeV by (1986ANZL, 1988CO10), and it is reported that the (p, γ_0) data indicate a direct capture term and the excitation of giant dipole resonances based on excited states having a probable 2p-1h structure. See also (1986PO1D, 1987PO09, 1988PO1G). The ^{16}O + p bremsstrahlung cross sections have been measured at $E_p = 2.74$ MeV at $155°$ by (1988PE12). For discussions of the ^{16}O(p, γ)^{17}F reaction in astrophysical processes see the reviews of (1985CA41, 1987RO25, 1988CA26), and see (1991RA1C).

8. (a) ^{16}O(p, p)^{16}O $E_b = 0.601$
   (b) ^{16}O(p, 2p)^{15}N $Q_m = -12.127$
   (c) ^{16}O(p, pn)^{15}O $Q_m = -15.663$
   (d) ^{16}O(p, pα)^{12}C $Q_m = -7.161$

Yield curves for elastic protons, protons scattered to ^{16}O*(6.05, 6.13, 6.92, 7.12, 8.87) and for γ-rays from ^{16}O*(6.13, 6.92) have been studied at many energies up to $E_p = 46$ MeV: see (1971AJ02, 1977AJ02, 1982AJ01). The observed resonances are displayed in Table 17.25. Absolute $\sigma(\theta)$ [$\theta = 110°$ to $160°$] have been measured for $E_p = 0.60$ to 2.00 MeV to ± 5% (1983BR11). Cross sections for bremsstrahlung emission are reported in the vicinity of the $E_p = 2.66$ MeV resonance by (1983TRZZ, 1988PE12, 1992DA19). A measurement of the lifetime of the state at

$E_x = 3.105$ MeV in ^{17}F is reported in (1990GOZN). The cross sections of the 6.13 MeV γ-ray at $E_p = 23.7$ and 44.6 MeV have been measured by (1981NA14), and (1979SC07) report the σ_t for $E_p = 190$ to 558 MeV. See also (1982AJ01).

Table 17.25: Resonances in ^{16}O(p, p)^{16}O and ^{16}O(p, α)^{13}N [a]

E_p (MeV $\pm$ keV)	$\Gamma_{c.m.}$ (keV)	Particles out	Γ_{p_0}/Γ	^{17}F*(MeV)	$J^\pi; T$
2.663 ± 7	19 ± 1	p_0		3.105	$\frac{1}{2}^-$
3.47	1.53 ± 0.2	p_0		3.86	$\frac{5}{2}^-$
4.304 ± 20 [b]	225	p_0		4.649	$\frac{3}{2}^-$
4.672 ± 20 [b]	1530	p_0		4.995	$\frac{3}{2}^+$
5.231 ± 20	68	p_0		5.521	$\frac{3}{2}^-$
5.392 ± 20	40	p_0		5.672	$\frac{7}{2}^-$
5.402 ± 20	< 0.6	p_0		5.682	$\frac{1}{2}^+$
5.546 ± 20	180	p_0		5.817	$\frac{3}{2}^+$
5.779 ± 20	30	p_0		6.036	$\frac{1}{2}^-$
6.332 ± 20	200	p_0		6.556	$\frac{1}{2}^+$
6.482 ± 7 [c]	$\leq 1.6 \pm 0.2$	p_0	$\geq 0.25 \pm 0.04$	6.697	$\frac{5}{2}^+$
6.564 ± 20	4.5	p_0		6.774	$\frac{3}{2}^+$
6.833 ± 20	3.8	p_0, $\gamma_{6.13}$		7.027	$\frac{5}{2}^-$
7.183 ± 20	10 ± 2	p_0, p_2, α_0		7.356	$\frac{3}{2}^+$
7.280 ± 20	≤ 5	p_0		7.448	
7.287 ± 20	7 ± 2	p_0, p_1, p_2, α		7.454	
7.305 ± 20	5 ± 2	p_0, p_2		7.471	
7.313 ± 20	795	p_0		7.479	$\frac{3}{2}^+$
7.385 ± 20	30	p_0, p_2, $\gamma_{6.13}$		7.546	$\frac{7}{2}^-$
7.60 ± 40	179 ± 30	p_0, p_1, α_0		7.75	$\frac{1}{2}^+$
7.81 ± 30	10 ± 3	p_2		7.95	$(\frac{11}{2}^-)$
7.88 ± 40	50 ± 20	p_0, $\gamma_{6.13}$, $\gamma_{6.92}$, α_0		8.01	
7.94 ± 30	100 ± 20	p_0, p_1, α_0		8.07	$\frac{5}{2}^{(+)}$
8.1	700 ± 250	(p_0), p_1, α_0		8.2	$\frac{3}{2}^{(-)}$
8.275 ± 10	11 ± 5	p_0-p_3, α_0		8.383	$\frac{5}{2}^{(-)}$
8.310 ± 20	45 ± 10	p_0-p_3, $\gamma_{6.13}$, $\gamma_{6.92}$, α_0		8.416	$(\frac{7}{2}^+)$
8.66 ± 60	170 ± 30	p_2, p_3, p_4, α_0		8.75	$\frac{5}{2}^{(+)}$
8.68	90 ± 20	p_0	0.2	8.76	$\frac{3}{2}^+$

Table 17.25: Resonances in ^{16}O(p, p)^{16}O and ^{16}O(p, α)^{13}N [a] (continued)

E_p (MeV $\pm$ keV)	$\Gamma_{c.m.}$ (keV)	Particles out	Γ_{p_0}/Γ	^{17}F*(MeV)	$J^\pi; T$
8.91	165 ± 30	p_0-p_4, $\gamma_{6.13}$, $\gamma_{6.92}$, α_0	0.34 ± 0.05	8.98 ± 0.02	$\frac{7}{2}^-$
9.11	140 ± 30	p_0-p_4, $\gamma_{6.13}$, $\gamma_{6.92}$, α_0	0.55 ± 0.05	9.17 ± 0.06	$\frac{3}{2}^{(+)}$
9.91	90 ± 30	p_0, p_2, α_0	0.095 ± 0.005	9.92	$\frac{9}{2}^+$
10.04 ± 40	280 ± 100	p_0, p_1		10.04	$\frac{7}{2}$
10.23 ± 40	250 ± 80	α_0		10.22	
10.42 ± 40	160 ± 40	p_0, p_1, p_3		10.40	$(\frac{5}{2}^+)$
10.525 ± 30	165 ± 25	p_0, p_2, α_0	0.28 ± 0.03	10.499	$\frac{7}{2}^-$
(10.75 ± 50)		p_0, p_1, α_0		(10.71)	$(\frac{7}{2}^-)$
10.83 ± 40	120 ± 40	p_0, p_2, (p_3), (α_0)		10.79	
10.96 ± 100	560 ± 100	p_0	0.25 ± 0.07	10.91	$\frac{1}{2}^-$
11.00 ± 40	190 ± 50	(p_2), p_3, (α_0)		10.95	
11.2636 ± 2.0 [d]	0.20 ± 0.04	p_0, p_2, p_4, α_0	0.093 ± 0.013	11.1929 ± 2.1	$\frac{1}{2}^-; \frac{3}{2}$
11.52 ± 40	240 ± 50	p_2, α_0		11.43	
11.67 ± 50	160 ± 30	p_0, p_3		11.58	
12.12 ± 40	120 ± 40	p_2, α_0		12.00	
12.39 ± 40	300 ± 30	p_0, p_2	0.26 ± 0.03	12.25	$\frac{3}{2}^-$
12.500 ± 20	190 ± 20	p_0, p_1, p_4	0.31 ± 0.03	12.355	$\frac{1}{2}^-$
≈ 12.65	≈ 600	p_0	≈ 0.09	≈ 12.50	$\frac{7}{2}^-$
12.7077 ± 2.0 [e]	2.83 ± 0.12	p_0, p_2, p_4, p_5, α_0, α_1	0.332 ± 0.018	12.5505 ± 2.3	$\frac{3}{2}^-; \frac{3}{2}$
(13.06 ± 100)		p_0		(12.88)	$(\frac{7}{2}^-)$
(13.06 ± 50)		p_0		(12.88)	$(\frac{1}{2}^+)$
13.250 ± 4	2 ± 1	p_0, p_{1+2}, p_{3+4}, p_5, α_0	0.15 ± 0.04	13.060	$\frac{5}{2}^-; \frac{3}{2}$
13.271 ± 4	2 ± 1	p_0-p_4	0.04 ± 0.02	13.080	$(\frac{1}{2}^+); \frac{3}{2}$
13.32 ± 100	520 ± 50	p_0	0.163 ± 0.016	13.13	$\frac{5}{2}^-$
14.017 ± 4	12 ± 5	p_0, p_{1+2}, p_{3+4}, α_0	0.02 ± 0.01	13.781	$\frac{5}{2}^+; \frac{3}{2}$
(14.20 ± 50)		p_0		(13.95)	$(\frac{1}{2}^+)$
14.25 ± 50	260 ± 30	p_0	0.08 ± 0.01	14.00	$\frac{7}{2}^-$
14.438 ± 6	27 ± 5	p_0, p_{3+4}	0.04 ± 0.02	14.177	$\frac{3}{2}^-; \frac{3}{2}^+$
14.5730 ± 3.0 [f]	19.3 ± 1.6	p_0, p_{1+2}, p_{3+4}, p_5, α_0	0.085 ± 0.008	14.3038 ± 3.1	$\frac{7}{2}^-; \frac{3}{2}$
14.65 ± 50	610 ± 50	p_0	0.10 ± 0.01	14.38	$\frac{5}{2}^-$
(14.94 ± 100)		p_0			$(\frac{3}{2}^-)$

Table 17.25: Resonances in ^{16}O(p, p)^{16}O and ^{16}O(p, α)^{13}N [a] (continued)

E_p (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	Particles out	Γ_{p_0}/Γ	^{17}F*(MeV)	$J^\pi; T$
15.00 ± 100	470 ± 100	p_0	0.25 ± 0.03	14.71	$\frac{1}{2}^-$
15.110 ± 20	190 ± 25	p_0	0.150 ± 0.015	14.809	$\frac{1}{2}^+$
(15.245 ± 100)		p_0		(14.94)	$(\frac{5}{2}^+)$
(15.30 ± 50)		p_0		(14.98)	$(\frac{3}{2}^+)$
(15.37 ± 100)		p_0		(15.05)	$(\frac{3}{2}^-)$
(15.545 ± 100)		p_0		(15.22)	$(\frac{7}{2}^-)$
15.9 [g]	≈ 550	p_0, p_{1+2}		15.6	
17.6	1500	p_0, p_{3+4}		17.1	$\frac{5}{2}^-$
20.4	600	p_0		19.8	$\frac{3}{2}^+$
21.6	600	p_0, (α)		20.9	$\frac{9}{2}^+$
22.6	400	p_0, (α)		21.8	$(\frac{9}{2}^+)$
23.5	600	p_0, p_5		22.7	$\frac{7}{2}^+$
24.7	600	p_0, (α)		23.8	$\frac{7}{2}^+$
26.4	1500	p_0, (α)		25.4	$\frac{7}{2}^-$
28.3	1500	p_0		27.2	$\frac{5}{2}^-$
30.1	2000	p_0		28.9	$\frac{5}{2}^+$

[a] See earlier references and comments in Tables 17.20 (1971AJ02), 17.19 (1977AJ02) and 17.21 (1982AJ01). See also Table 17.24 here. Uncertainties in E_p (below 12.7 MeV) have been increased because of a possible error in calibrating the magnet used in many of the measurements reported in (1971AJ02). See also (1964DA02), and see comments in (1986AJ04).

[b] E_r, not E_λ, is used for calculating E_x.

[c] (1982SE01). Uncertainty in E_p estimated by reviewer (1986AJ04). See also (1982AJ01).

[d] $\Gamma_{p_0} = 19 \pm 3$ eV (1976HI09).

[e] $\Gamma_{p_0} = 0.94 \pm 0.06$ keV, $\Gamma_{\alpha_0} = 62 \pm 16$ eV, $\Gamma_{\alpha_1} = 53 \pm 22$ eV (1976HI09). See also (1986AJ04).

[f] $\Gamma_{p_0} = 1.65 \pm 0.12$ keV, $\Gamma_{\alpha_0} = 2.6 \pm 0.7$ keV (1976HI09).

[g] See also Table 17.20 of (1971AJ02) for possible other resonances.

A_y measurements have been made for inelastic scattering to many excited states of ^{16}O for E_p = 35–200 MeV. A_y and spin transfer observables for p_0, p_2, p_3, and p_4 groups have been measured at $E_p = 35$–200 MeV and polarization transfer-coefficients have been studied at $E_p =$ 200 MeV to 4^- states of ^{16}O. The spin rotation parameter Q has been measured for the elastic scattering at $E_p = 65$ MeV and 200 MeV. [See references in (1986AJ04).] In more recent work, differential cross sections and analyzing powers have been measured at $E_p = 6.4$–7.7 MeV

(1992WI13), at $E_p = 13.5$ MeV for all narrow states below $E_x = 12.1$ MeV up to a momentum transfer of 3.2 fm^{-1} (1989KE03), at $E_p = 35$ MeV (1990OH04), and at $E_p = 318$ MeV for states with $E_x < 14$ MeV (1991KE02), and at $E_p = 400$ MeV for excitation of the $E_x = 10.957$ MeV 0^-, $T = 0$ state (1991KI08). See also (1987KE1A, 1988SEZU). Quasielastic spin observables for elastic scattering are reported for $E_p = 320$, 400, 500, 650, and 800 MeV. Cross sections and analyzing powers for $0^+ \approx 0^-$ excitations in ^{16}O with $E_p = 200$ MeV are reported in (1989SAZZ). See also (1986GA31, 1987PI02). Cross section measurements for gamma ray production relevant to astrophysics are discussed in (1987LA11, 1988LE08). See also (1988SA1B). For earlier work see (1982AJ01, 1986AJ04), and see the compilation of cross sections in (1986BA88), and the reviews of (1985KI1A, 1988ZA06). See also the conference reports (1986VDZY, 1986YE1B, 1987RO1F, 1989PLZU).

For reaction (b) see (1982REZZ, 1985BO1A, 1986CH1J, 1986KU15, 1986SA24, 1991CO13). For reaction (c) and for fragmentation see (1986AJ04) and see ^{16}O.

In recent theoretical work, a resonating group method study of ^{16}O+p is discussed in (1990HA38), the alpha particle model is used to calculate elastic scattering observables in (1988BE57, 1992LI1D), and a Skyrme force approach to intermediate energy proton scattering is presented in (1988CH08). A Dirac coupled-channels analysis for (p, p′) at $E_p = 800$ MeV is described in (1988DE35). See also (1988DE31, 1991PH01). Off-shell effects from meson exchange in the nuclear optical potential are studied in (1989EL02). See also the non-relativistic full-folding model descriptions of (1990AR03, 1990AR11, 1990CR02, 1990EL01, 1991AR1K). Dirac optical potentials are obtained in (1988HA08, 1990PH02). A comparison of Dirac and Schrödinger descriptions is made in (1990CO19). A relativistic microscopic optical potential is derived from the relativistic Brueckner-Bethe-Goldstone equation in (1992CH1E). Relativistic effects on quasielastic spin observables are discussed in (1988HO1K). Non relativistic multiple scattering theory is used for elastic scattering at $E_p = 800$ MeV in (1987LU04). See also (1992BE03). Effective interactions for elastic scattering above 300 MeV are discussed in (1990RA12). A second-order relativistic impulse approximation model is used for $E_p = 500$ and 800 MeV in (1988LU03). See also (1988OT04). An empirical effective interaction for excitation of ^{16}O by 135 MeV protons is discussed in (1989KE05). The excitation of the 7.12 dipole state in ^{16}O is shown to be non-collective (1988AM03). Effects of vacuum polarization and Pauli blocking are treated in (1988OT05). A review of relativistic theory of nuclear matter is presented in (1988MA1X). Spin-independent isoscalar response functions and interpretation of polarization-transfer measurements are discussed in (1986OR03). Recoil effects in the coordinate space Dirac equation have been studied (1987OT02). Effects of short range correlations on the self energy in the optical model are studied by (1992BO04). See also the calculation of (1992OL02) concerning resonance shapes and the $A = 17$ Theoretical discussion at the beginning of this compilation.

9. ^{16}O(p, n)^{16}F $\qquad Q_m = -16.199 \qquad E_b = 0.6005$

The analyzing power for the transition to the 4^- state ^{16}F*(6.37) has been measured at $E_p = 135$ MeV (1982MA11). See also (1983WA29). More recently, polarization observables have been measured at $E_p = 135$ MeV by (1989WAZZ). See also ^{16}F.

10. ^{16}O(p, d)^{15}O $\quad Q_m = -13.439 \quad E_b = 0.601$

The excitation function for d_0 at $\theta = 70°$ has been measured for $E_p = 21$ to 38.5 MeV. A strong resonance is observed at $E_p = 24$ MeV: see Table 17.25. The analyzing power has been measured for the d_0 group at $E_p = 65$ MeV (1980HO18). Cross sections and analyzing powers have been measured at $E_p = 200$ MeV for the $\frac{1}{2}^-$ (ground state) and $\frac{3}{2}^-$ (6.18 MeV) levels in ^{15}O. See also (1989WA16) and see (1982AJ01) for the earlier work.

11. (a) ^{16}O(p, t)^{14}O $\quad Q_m = -20.404 \quad E_b = 0.601$
(b) ^{16}O(p, ^{3}He)^{14}N $\quad Q_m = -15.242$

See (1982AJ01) and ^{14}N, ^{14}O in (1986AJ01).

12. ^{16}O(p, α)^{13}N $\quad Q_m = -5.217 \quad E_b = 0.601$

Observed resonances are displayed in Table 17.25. Some broad structures have been reported above $E_p \approx 15$ MeV; particularly strong peaks appear at $E_p \approx 22$ and 25.5 MeV: see (1977AJ02). Total cross sections were measured by the activation method up to $E_p = 30$ MeV by (1989WA16).

This reaction is involved in explosive burning in stars. Numerical values of thermonuclear reaction rates are tabulated in (1985CA41). See (1977AJ02, 1982AJ01) for the earlier work and see (1979MO04).

13. ^{16}O(d, n)^{17}F $\quad Q_m = -1.623$

Parameters of the first excited state of ^{17}F are $E_x = 495.33 \pm 0.10$ keV, $\tau_m = 407 \pm 9$ psec: see (1971AJ02). See also Table 17.21 in (1971AJ02). For polarization measurements see (1981LI23) and ^{18}F in (1983AJ01). See also (1986AJ04, 1989VI1E). This reaction has been used in analysis of Oxygen in Flouride glasses (1990BA1M).

14. ^{16}O(^{3}He, d)^{17}F $\quad Q_m = -4.893$

At $E(^3\text{He}) = 18$ MeV, angular distributions of the deuterons to ^{17}F*(0, 0.50,3.104 ± 0.003, 3.857 ± 0.004) have been measured. The spectroscopic factors for ^{17}F*(0, 0.50) are 0.94 and 0.83. Two-step processes appear to be involved in the excitation of ^{17}F*(3.10, 3.86). Angular distributions have also been measured at $E(^3\text{He}) = 30$ MeV (to ^{17}F*(5.1, 5.7)) and at $E(^3\text{He}) = 33$ MeV (d_0, d_1): see (1982AJ01) for references.

15. ^{16}O(^{7}Li, ^{6}He)^{17}F $\quad Q_\text{m} = -9.733$

Angular distributions for ^{6}He leading to the ^{17}F $\frac{5}{2}^+$ ground state were measured at $E_\text{lab} = 34$ MeV (1988KE07). The data are structureless and are neither described by finite range DWBA nor by coupled-channels Born approximation calculations.

16. (a) ^{16}O(^{10}B, ^{9}Be)^{17}F $\quad Q_\text{m} = -5.985$
(b) ^{16}O(^{11}B, ^{10}Be)^{17}F $\quad Q_\text{m} = -10.627$
(c) ^{16}O(^{12}C, ^{11}B)^{17}F $\quad Q_\text{m} = -15.356$
(d) ^{16}O(^{13}C, ^{12}B)^{17}F $\quad Q_\text{m} = -16.932$
(e) ^{16}O(^{14}N, ^{13}C)^{17}F $\quad Q_\text{m} = -6.950$
(f) ^{16}O(^{16}O, ^{15}N)^{17}F $\quad Q_\text{m} = -11.526$

See (1982AJ01, 1986AJ04). Measurements of $\sigma(\theta)$ vs. Q-value for reaction (f) were made at $E_\text{lab} = 72$ MeV by (1988AU03). Results were not compatible with a low-ℓ fusion window.

17. ^{17}O(p, n)^{17}F $\quad Q_\text{m} = -3.542$

At $E_\text{p} = 135.2$ MeV differential cross sections are reported for the transitions to ^{17}F*(0, 0.5 ± 0.05, 4.84 ± 0.1, 5.89 ± 0.2, 6.34 ± 0.2, 7.26 ± 0.2, 7.64 ± 0.2, 9.3 ± 0.1, 14.3 ± 0.1). [Note known density of states.] The group to ^{17}F*(4.84) has $\Gamma = 1.8 \pm 0.05$ MeV (1985PU1A). For a discussion of Gamow-Teller transition probabilities see (1985WA24). For A_y measurements see (1983PUZZ, 1985PU1A). For the earlier work see (1982AJ01).

18. ^{17}O(^{3}He, t)^{17}F $\quad Q_\text{m} = -2.779$

Angular distributions have been studied at $E(^3\text{He}) = 17.3$ MeV [t_0, t_1]. Angular distributions and analyzing powers were measured at $E(^3\text{He}) = 33$ MeV $[\text{t}_0]$: see (1982AJ01).

19. ^{17}F(p, γ)^{18}Ne $Q_m = 3.921$

A $J^\pi = 3^+$ level in ^{18}Ne at $E_x = 4.561 \pm 0.009$ MeV is reported in (1991GA03), and the effects of this result on the ^{17}F(p, γ) thermonuclear reaction rate as well as astrophysical consequences are discussed.

20. ^{17}Ne(β^+)^{17}F $Q_m = 14.529$

See ^{17}Ne and Table 17.27.

21. ^{18}O(^{18}O, ^{19}N)^{17}F $Q_m = -19.386$

See (1983DE1A).

22. ^{19}F(p, t)^{17}F $Q_m = -11.099$

See (1977AJ02).

23. ^{20}Ne(p, α)^{17}F $Q_m = -4.133$

Thermonuclear reaction rates for this reaction and other astrophysically important thermonuclear reactions are tabulated in (1985CA41). Analytic expressions for the reaction rates are given in (1988CA26). See also the study of processes and effects in (1989GU28), and see (1977AJ02) for earlier work.

24. ^{26}Mg(^{18}O, ^{27}Na)^{17}F $Q_m = -13.347$

See (1985FI08).

Table 17.26: Energy levels of ^{17}Ne [a]

E_x (MeV)	$J^\pi; T$	$\tau_{1/2}$ (msec)	Decay	Reaction
0	$\frac{1}{2}^-; \frac{3}{2}$	109.2 ± 0.6	β^+ [b]	1

[a] The evidence for excited states of ^{17}Ne has not been published: see (1977AJ02).

[b] See also Tables 17.5, 17.6 and 17.5.

^{17}Ne
(Fig. 4)

1. (a) ^{17}Ne(β^+)^{17}F* $\rightarrow$ ^{16}O + p $\quad Q_m = 13.928$
   (b) ^{17}Ne(β^+)^{17}F $\rightarrow$ ^{13}N + α $\quad Q_m = 8.711$
   (c) ^{17}Ne(β^+)^{17}F $\quad Q_m = 14.529$

The half-life of ^{17}Ne has been reported as 109.0 ± 1.0 msec (1971HA05) and 109.3 ± 0.6 msec (1988BO39): the weighted mean is 109.2 ± 0.6 and we adopt it. The decay is primarily to the proton unstable states of ^{17}F at 4.65, 5.49, 6.04 and 8.08 MeV with $J^\pi = \frac{3}{2}^-, \frac{3}{2}^-, \frac{1}{2}^-$ and $\frac{3}{2}^-$, but decay to alpha unstable states has also been observed: see Table 17.27. The super-allowed decay to the analog state [^{17}F*(11.20)] has $\log ft = 3.29^{+0.04}_{-0.07}$. The character of the decay leads to $J^\pi = \frac{1}{2}^-$ for ^{17}Ne$_{\rm g.s.}$ (1971HA05). See Table 17.6 for a comparison of the mirror ^{17}N and ^{17}Ne decays and Table 17.16 for the decay of ^{17}F*(11.20). See also (1986AJ04), and see the recent analysis of GT beta-decay rates of (1993CH06).

^{17}Na
(not illustrated)

^{17}Na has not been observed: its mass excess is predicted to be 35.61 MeV by (1966KE16). It is then unbound with respect to breakup into ^{16}Ne + p by 4.3 MeV and with respect to breakup into ^{14}O + 3p by 5.7 MeV. See also (1983ANZQ, 1985AN28, 1988WA18, 1992AV03).

^{17}Mg, ^{17}Al, ^{17}Si, ^{17}P

(Not observed)

See (1983ANZQ, 1988WA18, 1992AV03).

Table 17.27: β^+ decay of ^{17}Ne [a]

Decay to ^{17}F* (MeV)	J^π	Total branching ratio (%)		log ft [c]	Decay branches [d]
		Ref. [a]	Ref. [b]		
0.0	$\frac{5}{2}^+$	0.55 ± 0.17 [e]		$9.56^{1u}{}^{+0.16}_{-0.12}$ [f]	
0.495	$\frac{1}{2}^+$	0.61 ± 0.10 [e]		$6.80^{+0.08}_{-0.06}$ [f]	
3.10	$\frac{1}{2}^-$	$0.10^{+0.03}_{-0.01}$	0.48 ± 0.07	$7.12^{+0.05}_{-0.11}$	p_0
4.65	$\frac{3}{2}^-$	16.54 ± 0.14	16.2 ± 0.7	4.57 ± 0.05	p_0
5.49	$\frac{3}{2}^-$	59.16 ± 0.4	54.4 ± 0.7 [g]	3.811 ± 0.015	p_0
6.04	$\frac{1}{2}^-$	7.8 ± 0.2	10.6 ± 0.2	4.545 ± 0.018	p_0
8.08	$\frac{3}{2}^-$	7.3 ± 0.9	6.83 ± 0.11	3.93 ± 0.06	p_0, p_1, α_0
8.2	$\frac{3}{2}^-$	1.7 ± 0.3	2.08 ± 0.08 [g]	4.51 ± 0.09	p_0
8.43	$\frac{1}{2}^-$	4.0 ± 0.9	6.51 ± 0.26	4.05 ± 0.10	p_0, p_1, p_3, α_0
9.4 [h]		0.6 ± 0.2		$4.43^{+0.19}_{-0.13}$	p_0, p_1/p_2, α_0
10.0 [h]		0.7 ± 0.3		$4.05^{+0.26}_{-0.16}$	p_0, p_4, α_0
10.66 [h]		0.007 ± 0.004		$5.7^{+0.4}_{-0.2}$	p_0, α_0
10.9	$\frac{1}{2}^-$	0.016 ± 0.006		$5.14^{+0.22}_{-0.17}$	p_0, α_0
11.193	$\frac{1}{2}^-$	0.64 ± 0.14	$0.71^{+0.1}_{-0.05}$	3.31 ± 0.11	p_0, p_1, p_2, p_4, α_0, α_1
12.23		0.001 ± 0.0006		$4.98^{+0.41}_{-0.23}$	p_0

[a] (1988BO39). See also Table 17.21 in (1986AJ04).

[b] (1971HA05).

[c] We are grateful to Dr. M. Martin for providing these log ft values calculated for the branchings measured in (1988BO39).

[d] Proton decay to states ^{16}O*(0.0, 6.05, 6.13, 6.92, 7.16) are indicated by p_0, p_1, p_2, p_3, p_4, respectively. Alpha decay to ^{13}N*(0.0, 2.36) are indicated by α_0, α_1 respectively.

[e] Based on assumption that log ft values are the same as for the ^{17}N mirror decays.

[f] From ^{17}N β^- decay.

[g] Obtained by (1988BO39) from addition of several of the peaks in (1971HA05).

[h] New levels observed by (1988BO39) with measured energies, $E_x = 9.450 \pm 0.050$, 10.030 ± 0.060, 10.660 ± 0.020 MeV and widths $\Gamma = 200 \pm 40$, 170 ± 40, 90 ± 60 keV, respectively.

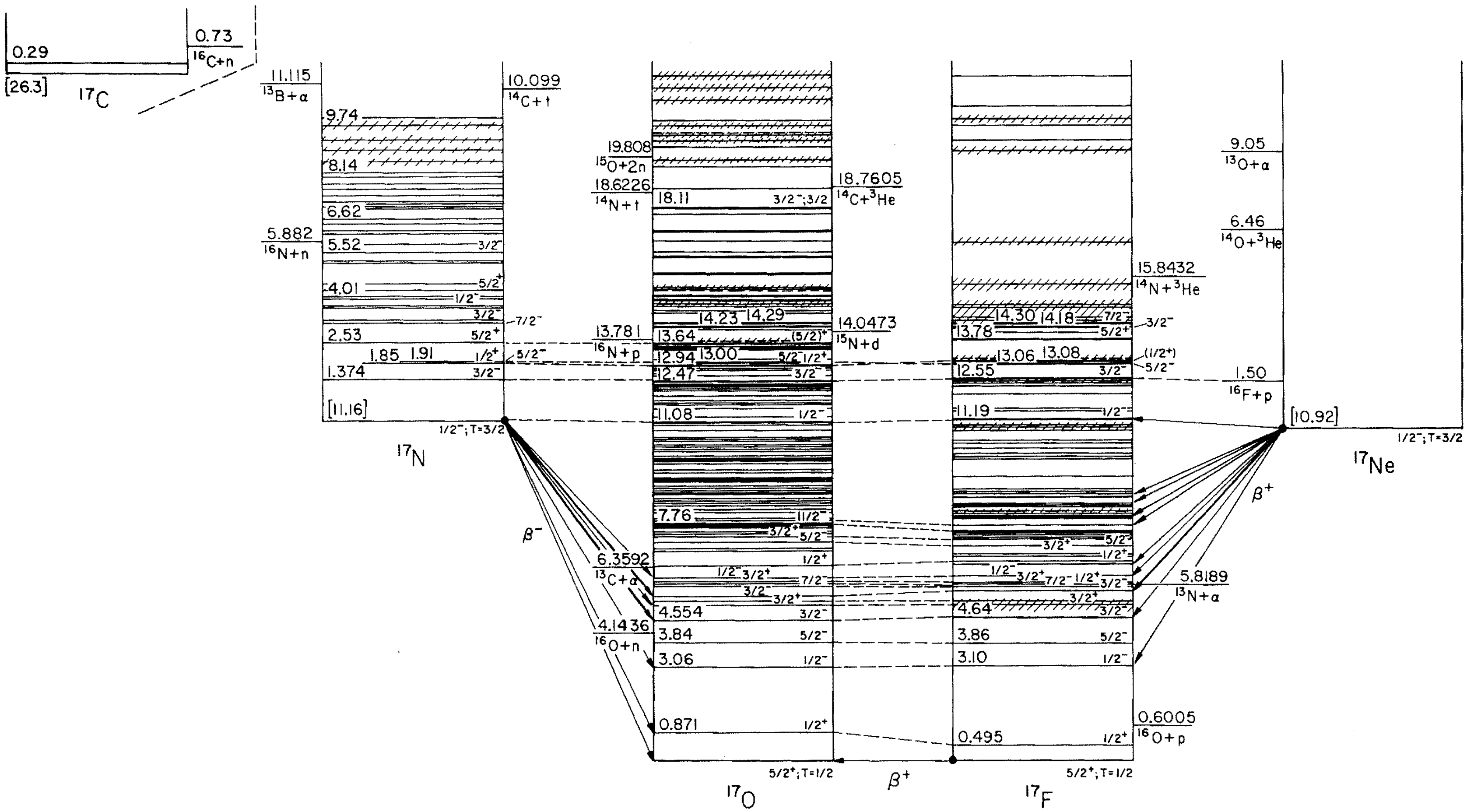

Fig. 4: Isobar diagram, $A = 17$. The diagrams for individual isobars have been shifted vertically to eliminate the neutron-proton mass difference and the Coulomb energy, taken as $E_C = 0.60Z(Z-1)/A^{1/3}$. Energies in square brackets represent the (approximate) nuclear energy, $E_N = M(Z,A) - ZM(H) - NM(n) - E_C$, minus the corresponding quantity for ^{17}O: here M represents the atomic mass excess in MeV. Levels which are presumed to be isospin multiplets are connected by dashed lines.

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