Energy Levels of Light Nuclei
$A = 18$

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Abstract: Our evaluation of $A = 18$–19 was published in *Nuclear Physics* A595 (1995), p. 1. This version of $A = 18$ differs from the published version in that we have corrected some errors discovered after the article went to press. Figures and introductory tables have been omitted from this manuscript. References, figures, and the $A = 19$ evaluation are available elsewhere on this web site.

(References closed as of October 31, 1994)

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^{18}He

Not observed: See (82AV1A, 83ANZQ).

^{18}Li

^{18}Li has not been observed. Shell model calculations described in (88PO1E) predict the ground state magnetic dipole moment and charge and matter radii.

^{18}Be

^{18}Be has not been observed. It is predicted to have a mass excess of 78.43 MeV: see (78AJ03). ^{18}Be is then unstable with respect to breakup into ^{16}Be+2n, ^{15}Be+3n, ^{14}Be+4n, ^{13}Be + 5n, ^{12}Be + 6n, ^{11}Be + 7n and ^{10}Be + 8n by, respectively 3.01, 3.04, 6.26, 2.92, 4.93, 1.76, and 1.26 MeV, using the masses for the residual nuclei adopted by (91AJ01, 93AU05, 93TI07). See also (83ANZQ, 89OG1B).

^{18}B

^{18}B has not been observed in the bombardment of Ta by 44 MeV/A Ar ions (85DE1A, 85LA03, 86PO13) or in the bombardment of Be by 12 MeV/A ^{56}Fe ions (84MU27). ^{18}B has been predicted to have a mass excess of 52.3 MeV (93AU05). It would then be unstable with respect to ^{17}B + n by 0.5 MeV: see (78AJ03, 93AU05). ^{18}B is calculated to have $J^\pi = 4^-$ and to have excited states at 0.62, 0.86 and 1.59 MeV with $J^\pi = 1^-$, 2^- and 2^- (85PO10). The shell model calculations of (92WA22) predict $J^\pi = 2^-$ for the ground state with the first three excited states at 0.45, 0.52 and 0.839 MeV with $J^\pi = 4^-$, 2^-, 3^-. See also (87AJ02, 88GU1A).

^{18}C

GENERAL: See Table 18.1.

Mass of ^{18}C: The atomic mass excess of ^{18}C adopted by (93AU05) is 24.920±0.030 MeV, based on the Q-value of the ^{48}Ca(^{18}O, ^{18}C)^{48}Ti reaction. ^{18}C is then bound by 4.188 MeV with respect to breakup into ^{17}C + n. See (82FI10, 87AJ02, 92WA22).

Table 18.1
^{18}C – General

Reference	Description
Reviews:	
87GI1C	Pion-nucleus interactions
89AJ1A	Summary of recent work involving light nuclei (Sec. 4.2 covers ^{18}C)
89DE1X	Exotic light nuclei: production, mass meas., decay, & complex reactions
89VO1F	History of & future prospects for production of nuclei far from stability
94BO1H	Summary of recent research employing radioactive nuclear beams
Other Articles:	
87BL18	Gogny's effective interaction used to calc. ground & excited states of light nuclei
87SN1A	Partitioning of 2 component particle syst. & isotope distrib. in nucl. fragmentation
88PO1E	Shell-model calcs. of exotic light nucl. ground state props. compared to exp. data
89RA16	Predxns. from systematics & tabulation of B(E2; $0^+_1 \rightarrow 2^+_1$) values for even-even nucl.
89SA10	Total cross sections of reactions induced by neutron-rich light nuclei
90LO11	Self-consistent calcs. of light neutron-rich nuclei using density-functional method
90ST08	2nd-generation microscopic predictions of β-decay half-lives of neutron-rich nuclei
91RE02	Meas. half-lives & neutron emission probabilities of neutron-rich Li-Al nuclei
92LA13	Influence of separation energy on the radius of neutron-rich nuclei
92WA22	Effective interactions for the 0p1s0d nuclear shell-model space
93PA14	Relativistic mean field theory; calc. binding energy, rms radii, deformation parameters

Table 18.2
Energy Levels of ^{18}C

E_x in ^{18}C (MeV ± keV)	$J^\pi; T$	$\tau_{1/2}$ (msec)	Decay	Reactions
0	(0^+); 3	95 ± 10	(β^-)	2, 3
1.62 ± 20	(2^+); 3			2, 3

1. ^{18}C(β^-)^{18}N $\qquad$ $Q_m = 11.807$

The half-life of ^{18}C has been measured to be 66^{+25}_{-18} ms (88MU08), 78^{+20}_{-15} ms (89LE16), 94 ± 27 ms (91RE02), (95 ± 10) ms (91PR03).

Branching to states in ^{18}N has been measured by (91PR03) and is presented here in Table 18.6. These authors also measured the total branching probability to gamma emitting states plus the ground state of ^{18}N to be $P_\gamma = (81 \pm 5)\%$. The β-delayed neutron emission probability is $P_n = 1 - P_\gamma = (19 \pm 5)\%$. Other values reported for P_n are $(25\pm4.5)\%$ (88MU08), $(50\pm10)\%$ (89LE16), $(43.3\pm6.5)\%$ (91RE02). The ^{18}C(β^-) decay is also discussed in the analysis of Gamow-Teller rates presented in (93CH06). Experimental Gamow-Teller matrix elements are compared with results of shell-model calculations.

2. ^{18}O(π^-, π^+)^{18}C $\qquad$ $Q_m = -25.706$

The angular distribution of the π^+ to the ground state of ^{18}C has been measured at $E_{\pi^-} = 164$ MeV by (84GI10) [see also for excitation function at $\theta = 5°$ for $E_{\pi^-} \approx 140$ to 240 MeV]. There is also some indication of the population of an excited state at $E_x = 1.55$ MeV (84GI10). See also (83AJ01).

3. ^{48}Ca(^{18}O, ^{18}C)^{48}Ti $\qquad$ $Q_m = -21.434$

At $E(^{18}\mathrm{O}) = 112$ MeV the ground state and an excited state at 1.62 ± 0.024 MeV are observed by (82FI10). See also (83AJ01).

^{18}N

GENERAL: See Table 18.3.

Mass of ^{18}*N:* The atomic mass excess derived from the Q-value of the ^{18}O(^{7}Li, ^{7}Be)^{18}N reaction and adopted by (93AU05) is 13.117 ± 0.020 MeV (83PU01). ^{18}N is then stable with respect to breakup into $^{17}\mathrm{N} + \mathrm{n}$ by 2.825 MeV. See (83AJ01) for the earlier work.

1. ^{18}N(β^-)^{18}O $\qquad$ $Q_m = 13.899$

The half-life of ^{18}N is 0.624 ± 0.012 sec (82OL01). The decay branches are displayed in Table 18.18. The nature of the decay leads to $J^\pi = 1^-$ for the ^{18}N ground state (82OL01). See also (83SN03), and see the measurements on beta branching reported in

Table 18.3
^{18}N – General

Reference	Description
Reviews:	
88MI1J	Shell model transition densities for electron and pion scattering
90TH1E	Summary of topics presented at Workshop on Primordial Nucleosynthesis
94BO1H	Summary of recent research employing radioactive nuclear beams
Other Articles:	
87AN1A	Use of LISE spectrometer at GANIL for identification of exotic light nuclei
87RI03	Isotopic distributions of fragments in ^{40}Ar + ^{68}Zn at 27.6 MeV/nucleon
87SA25	LISE spectrometer at GANIL: results of search for new exotic nuclei
89SA10	Total cross sections of reactions induced by neutron-rich light nuclei
91RE02	Meas. half-lives & neutron emission probabilities of neutron-rich Li-Al nuclei
93PA14	Relativistic mean field theory; calc. binding energy, rms radii, deformation parameters

Table 18.4
Energy Levels of ^{18}N

E_x(MeV ± keV)	$J^\pi; T$	$\tau_{1/2}$ (msec)	Decay	Reactions
0	$1^-; 2$	624 ± 12	β^-	1, 3, 5, 6, 7
0.11490 ± 0.18 [a])	(2^-) [b])		γ	3, 4, 5, 7
0.58756 ± 0.24	(2^-) [b])		γ	3, 4, 7, 8
0.747 ± 10	(3^-) [b])			7
[c])				
1.73485 ± 0.22 [a])	(2^+) [d])		γ	4
2.21				7
2.42				7
2.61445 ± 0.23 [a])	1^+ [a,d])		γ	4

[a]) Level energies determined from γ energies reported in (91PR03).
[b]) Suggested by (84BA24). See also (82OL01).
[c]) See (84BA24) for a calculation suggesting additional states in this energy region.
[d]) (93CH06).

Table 18.5
Radiative decays in ^{18}N [a]

E_i (MeV)	J_i^π	E_f (MeV)	Branch (%)
0.115	(2$^-$)	0	100
0.587	(2$^-$)	0.115	100 ± 16
1.735	(2$^+$)	0	33 ± 8
		0.115	38 ± 9
		0.587	29 ± 10
2.614	1$^+$	0	49 ± 8
		0.115	22 ± 6
		0.587	3 ± 2
		1.735	26 ± 6

[a]) (91PR03).

(89ZH04) which indicate a total branching ratio to alpha-particle-emitting states in ^{18}O of at least 12.2%. A delayed-neutron emission probability $P_n = (14.3 \pm 2.0)\%$ was measured by (91RE02). More recently a study reported by (94SC01) gave $P_n = (2.2 \pm 0.4)\%$ for transitions to neutron unstable states in ^{18}O above $E_x = 9.0$ MeV. See also reaction 22 under ^{18}O.

2. ^{14}C(^{7}Li, ^{3}He)^{18}N $\qquad Q_m = -10.121$

The preliminary work described in (83AJ01) has not been published.

3. ^{14}C(^{18}O, ^{14}N)^{18}N $\qquad Q_m = -13.740$

At $E(^{18}\text{O}) = 92.2$ MeV groups are observed to the ground state of ^{18}N (unresolved) and to an excited state at $E_x = 575 \pm 25$ keV (80NA14).

4. ^{18}C(β^-)^{18}N $\qquad Q_m = 11.807$

See reaction 1 under ^{18}C. Branching to states in ^{18}N was measured by (91PR03) and is presented here in Table 18.6. These authors measured the total branching probability to gamma emitting states of ^{18}N to be $P_\gamma = 81 \pm 5$ %. Measurements of γ-ray energies and branching lead to the level energies displayed in Table 18.4 and ^{18}N radiative decays in Table 18.5.

Table 18.6
Branchings in $^{18}C(\beta^-)^{18}N$

Decay to $^{18}N^*$ (MeV)	Branch [a]) (%)	$\log ft$ [b])
0.115		
0.587	≤ 1	≥ 6.4
1.735	9 ± 7	5.2 ± 0.4
2.614	72 ± 10	4.08 ± 0.08

[a]) (91PR03), calculated with the hypothesis that there is no direct β-feeding of the 0.115 MeV level. The total probability of β decay to gamma emitting states plus to the ground state is $P_\gamma = (81 \pm 5)\%$. The β-delayed neutron probability is $P_n = 1 - P_\gamma$.
[b]) $\log ft$'s were recalculated by evaluators and are slightly different from those in (91PR03) due to use of level energies from Table 18.4 and Q-values from (93AU05).

Table 18.7
γ-ray intensities in $^{18}C(\beta^-)^{18}N$ [a])

E_γ (keV)	E_i (keV)	E_f (keV)	I_γ [b])
114.9 ± 0.2	115	0	36.5 ± 7.5
472.7 ± 0.2	587	115	10.2 ± 4.0
879.7 ± 0.2	2614	1735	18.7 ± 5.0
1147.8 ± 0.4	1735	587	8.0 ± 3.7
1619.9 ± 0.3	1735	115	10.5 ± 4.1
1734.8 ± 0.4	1735	0	9.1 ± 3.6
2025.3 ± 0.8	2614	587	2.2 ± 1.5
2499.3 ± 0.4	2614	115	15.8 ± 4.8
2614.2 ± 0.4	2614	0	35.3 ± 7.6

[a]) (91PR03).
[b]) γ-ray intensities are per 100 parent decays.

5. $^{18}O(\pi^-, \pi^0)^{18}N$ $Q_m = -9.305$

See (83AS01, 84AS05).

6. $^{18}O(t, ^3He)^{18}N$ $Q_m = -13.880$

See (83AJ01).

7. $^{18}O(^7Li, ^7Be)^{18}N$ $Q_m = -14.761$

$Q_0 = -14761 \pm 20$ keV (83PU01)

At $E(^7Li) = 52$ MeV, ^7Be groups are observed corresponding to the excitation of the states displayed in Table 18.4 (83PU01).

8. $^{18}O(^{11}B, ^{11}C)^{18}N$ $Q_m = -15.881$

See (83PU01).

^{18}O

GENERAL: See Table 18.8.

Isotopic abundance = $(0.200 \pm 0.012)\%$ (84DE1A).

$\langle r^2 \rangle^{1/2} = 2.784 \pm 0.020$ fm: see reaction 25.

$^{18}O^*(1.98)$

g $= -0.287 \pm 0.015$ [see (83AJ01)]

$Q = -0.042 \pm 0.008$ b. [weighted mean of -0.036 ± 0.009 and -0.058 ± 0.015 b: see (83GR28); see also (83AJ01)].

$$\begin{aligned} B(E2; 0^+ \rightarrow 2^+) &= 39.0 \pm 1.8\ e^2 \cdot \text{fm}^4\ [\text{(79FE06, 83GR10); see also (83AJ01)}]; \\ &= 44.8 \pm 1.3\ e^2 \cdot \text{fm}^4\ \text{(82NO04)}; \\ &= 47.6 \pm 1.0\ e^2 \cdot \text{fm}^4\ \text{(82BA06); see also (87RA01).} \end{aligned}$$

For a discussion of the hexadecapole deformation see (83GR10). See also (87RA01).

Table 18.8
^{18}O – General

Reference	Description
	Shell Model
Review:	
88BR1P	Status of the nuclear shell model
Other Articles:	
87CH1J	Nucl. struc. calcs. using mixed-config. shell model: effective & surface δ-interactions
87LE1L	Low-lying non-normal parity states of ^{18}O & ^{18}F calculated in shell model + tensor force
87MU16	Relativistic effects in the low-energy spectra of 1s0d-shell nuclei
87SH1O	Validity of M-3Y force equivalent G-matrix element for sd-shell nucl. struc. calcs.
88BR11	Semi-empirical effective interactions for the 1s-0d shell
88FI01	Effective interactions for sd-shell-model calculations
88HI05	Effect on Gamow-Teller strength of config. mixing and p-n correl. in e-e sd-shell nucl.
89GU06	Hartree-Fock & shell-model charge densities calc. for ^{16,18}O, ^{32,34}S, ^{40,48}Ca
89HJ03	Effective interactions through 3rd order for $A = 18$ nuclei with the Paris potential
89OR02	Empirical isospin-nonconserving Hamiltonians for shell-model calculations
90HJ01	3rd order number-conserving sets & effective interactions calc. with Bonn-Jülich potential
90HJ03	Choice of single-particle potential & the convergence of the effective interaction
90MI01	Shell model states in the ^{18}O three-body wave function from Faddeev formalism
90SK04	Study of $A = 18$ nuclei and the effective interaction in the sd shell
92FR01	Nuclear charge radii systematics in the sd shell from muonic atom measurements
92HJ01	Folded-diagram effective interactions with the Bonn meson-exchange potential model
92JI04	Bonn potential used to evaluate energy spectra of some light sd-shell nuclei
92OS01	Spin-tensor analysis of realistic shell model interactions
94VE04	Exp. meas. & calc. of spectroscopic factors from one-proton stripping rxns. on sd-shell nucl.
	Cluster models
88KU17	Microscopic boson descrip. of p-n systems applied to electron scat. from ^{18}O, ^{20}Ne
89FU08	Microscopic multichannel calc. of the molecular dipole degree of freedom in ^{18}O
89TR18	2-nucleon and 4-nucleon clusters in light & heavy nuclei
90OS03	Cluster-stripping reactions in the heavy-ion collisions (includes ^{14}C(^{6}Li, d)^{18}O)
	Special States
Review:	
88BR1P	Status of the nuclear shell model
89RA17	Compilation of exp. data on nuclear moments for ground & excited states of nucl.
Other articles:	
87BL18	Gogny's effective inter. used to calc. gnd. & excited states of specific spin-isospin order
87CH1J	Nucl. struc. calcs. using mixed-config. shell model: effective & surface δ-interactions
87LE1L	Non-normal parity states of ^{18}O & ^{18}F calculated in shell model + tensor force
87LI1F	Double delta & surface delta interactions used to calc. low-lying spectra of $^{17-22}$O
87MU16	Relativistic effects in the low-energy spectra of 1s0d-shell nuclei
87SH1O	Validity of M-3Y force equivalent G-matrix element for sd-shell nucl. struc. calcs.
87VA19	Microscopic analysis of excitation of first 2^+ state of ^{18}O on ^{64}Ni
88KU17	Microscopic boson descrip. of p-n systems applied to electron scat. from ^{18}O & ^{20}Ne

Table 18.8 (continued)
^{18}O – General

Reference	Description
	Special States (continued)
89FU08	Microscopic multichannel calculation of the molecular dipole degree of freedom in ^{18}O
89HJ03	Effective interactions through 3rd order for $A = 18$ nuclei with the Paris potential
89OR02	Empirical isospin-nonconserving Hamiltonians for shell-model calculations
90MI01	Shell model states in the ^{18}O three-body wave function from Faddeev formation
90SK04	Study of $A = 18$ nuclei and the effective interaction in the sd shell
	Electromagnetic
Review:	
89RA17	Compilation of exp. data on nuclear moments for ground & excited states of nucl.
93EN03	Strengths of γ-ray transitions in $A = 5$–44 nuclei
Other articles:	
87CH1J	Nucl. struc. calcs. using mixed-config. shell model: effective & surface δ-interactions
89FU08	Microscopic multichannel calc. of the molecular dipole degree of freedom in ^{18}O
89RA16	Predxns. from systematics & tabulation of B($E2$; $0_1^+ \rightarrow 2_1^+$) values for even-even nucl.
89SP01	Reduced electric-octupole transition probabilities, B($E3$; $0_1^+ \rightarrow 3_1^-$), for even-even nucl.
90NO1A	Calcs. of electric quadrupole excitations in relativistic nucleus-nucleus collisions
93EG04	Calc. transition probs. with angular-momentum-projected wave functions & realistic forces
	Astrophysics
Reviews:	
88HU1E	Chrondrules: chemical, mineralogical & isotopic constraints on theories of their origin
89GU1L	Chemical analyses of cool stars (includes isotopic abundance ratios)
89WH1B	Abundance ratios as a function of metallicity
90AR10	Nuclear reactions in astrophysics
90TH1E	Summary of topics presented at Workshop on Primordial Nucleosynthesis
93MA1M	Review of primordial nucleosynthesis beyond the standard big bang
Other Articles:	
87BE1H	^{12}C/^{13}C & ^{16}O/^{18}O ratios in Venus' atmosphere from high-res. 10-μm spectroscopy
87FA1C	^{16}O excess in hibonites discredits late supernova injection origin of isotopic anomalies
87SO1E	Interstellar shock waves related to high ^{10}Be & ^{18}O concentrations in ice cores
87WA1F	Abundances in red giant stars: C & O isotopes in carbon-rich molecular envelopes
88BE1B	Past solar activity & geomagnetism info. from ^{10}Be & ^{18}O concentrations in ice cores
88BU01	Stellar reaction rates of α capture on light $N \neq Z$ nuclei & astrophysical implications
88CA1N	Analytic expressions for thermonuclear reaction rates involving $Z \leq 14$ nucl.
89JI1A	Nucleosynthesis inside thick accretion disks around massive black holes
89ME1C	Isotope abundances of solar coronal material derived from solar energetic particle meas.
90MA1Z	Nuclear reaction uncertainties in standard & non-standard cosmologies
90ST1G	High spatial resolution isotopic CO & CS observations of M17 SW
90TO1F	C^{18}O in the Chameleon 1 dark cloud (a nearby site of low-mass star formation)
91KO31	^{17}O(n, α)^{14}C cross section measured from 25 meV to approximately 1 MeV
91SA1F	Extragalactic ^{18}O/^{17}O ratios imply high-mass stars preferred in starburst systems
92GA11	Implications of the ^{14}C(α, γ)^{18}O reaction for nonstandard big bang nucleosynthesis

Table 18.8 (continued)
^{18}O – General

Reference	Description
	Astrophysics (continued)
92GO14	Alpha capture on ^{14}C from $E_\alpha = 1.14$ to 2.33 MeV and its astrophysical implications
93GA1G	Secondary radioactive beams used to measure cross sections of astrophysical importance
94BE29	Neutron capture rates of light isotopes for inhomogeneous Big Bang nucleosythesis
	Applications
Reviews:	
87SE1D	Progress in the field of accelerator mass spectrometry (1977–1987)
89KU1P	Production and application of stable enriched isotopes in the USSR
Other articles:	
87MC1A	O isotopes in refractory stratospheric dust particles: proof of extraterrestrial origin
87ZU1A	Oxygen isotope effect in high-temperature oxide superconductors
88FA1A	Extreme ^{18}O depletion in calcite & chert clasts from Elephant Moraine (in Antarctica)
88FI1C	Assessment of ^{18}O enriched water as a marker of total body water (A)
88HI1F	Design & uses of target systems used to produce positron emitters (A)
88HI1G	The oxygen isotope effect in $Ba_{0.625}K_{0.375}BiO_3$ (a high-temp. superconducting oxide)
88KH06	Threshold track detectors used to study interaction of ^{18}O ions w/ light & heavy targets
88MI1B	O-isotope analyses & deep-sea temp. changes: implications for rates of oceanic mixing
88NW1A	Measurement of oil reservoir rock dispersivity by nuclear reaction analysis (A)
89GR1F	Brachiopod calcite record of oceanic C & O isotope shifts at Permian/Triassic transition
89NW1A	Assessment of ^{18}O enriched water as a marker of total body water
89TA1Y	Separation of N & O isotopes by liquid chromatography
90CH1I	^{18}O isotope studies on redistribution of O obtained in O ion implantation
90CO1K	Determination of ^{18}O concentrations in microsamples of biological fluids
90MI15	Determination of absolute oxygen coverage by nuclear reaction analysis
90SA1J	O isotope evidence for a stronger winter monsoon current during the last glaciation
	Complex Reactions
86MA13	Experimental search for nonfusion yield in heavy residues emitted from ^{11}B + ^{12}C
87BE1I	Search for a nucleon-participant multiplicity effect on anomalous fragment production
87BU07	Projectile-like fragments from ^{20}Ne + ^{197}Au — counting simultaneously emitted neutrons
87HE1H	Search for anomalously heavy isotopes of low Z nuclei
87VA19	Microscopic analysis of excitation of first 2^+ state of ^{18}O on ^{64}Ni
88BE56	Light nuclei formation in reactions of B & Ne ions with Ta & Th at $E = 18$–20 MeV/A
88BL11	Systematics of cluster-radioactivity-decay constants as suggested by microscopic calcs.
88KH06	Threshold track detectors used to study interaction of ^{18}O ions w/ light & heavy targets
88PR1C	Target & projectile mass dependence of charge pickup reactions by $\approx$ GeV/N nuclei (A)
88UT02	Extended Serber model applied to quasi-free stripping reactions
89GE1A	Complex fragments emitted in excited states
89SA10	Total cross sections of reactions induced by neutron-rich light nuclei
89TE02	Dissipative mechanisms in the 120 MeV ^{19}F + ^{64}Ni reaction
89YO02	Quasi-elastic & deep inelastic transfer in ^{16}O + ^{197}Au for $E < 10$ MeV/u
90LE08	Statistical equilibrium in the ^{40}Ar + ^{12}C system at $E/A = 8$ MeV
90LI1J	Z dependence of Coulomb dissociation cross sections in heavy ion reactions

Table 18.8 (continued)
^{18}O – General

Reference	Description
	Antimatter
Reviews:	
86KO1E	Search for p̄-atomic X-rays at LEAR
87GR1I	Low energy antiproton physics in the early LEAR era
87VO1B	Interaction and annihilation of anitprotons and nuclei
87YA1E	Summary of scattering results at LEAR & unique features of the (p̄, n̄) reaction
Other articles:	
87AD04	Microscopic analysis of antiproton-nucleus elastic scattering
87GR20	Widths of $4f$ antiprotonic levels in the oxygen region
87HA1J	Widths of $4f$ antiprotonic levels in the O region using realistic nucl. wavefunctions
88LI1O	Optical model analysis of antiproton-nucleus elastic scattering (in Chinese)
89CH13	Phenomenological model analysis of scattering of ≈ 180 MeV antiprotons from nuclei
89HE21	Microscopic analysis of antiproton elastic scattering on even-even nuclei
89MA24	Microscopic analysis of antiproton-nucleus inelastic scattering at 600 MeV/c
92TA08	Eikonal and Glauber calculations of scattering of antiprotons on ^{18}O at 180 MeV
	Other Topics
Review:	
88BA82	Use of reactions involving pions & kaons in the study of heavy hypernuclei
93PE19	Overview of new experimental results in meson-nucleus interactions & future opportunities
Other Articles:	
87BL18	Gogny's effective interaction used to calc. ground & excited states of light nuclei
88HI05	Effect on Gamow-Teller strength of config. mixing & p-n correl. in e-e sd-shell nucl.
88KA39	Coulomb effects in the 4-body model of simultaneous 2n transfer induced by heavy ions
88TR02	Interacting boson scheme for light nuclei
89BA2N	Evaluation of hypernucleus production cross-sections in relativistic heavy-ion collisions
89OR02	Empirical isospin nonconserving Hamiltonians for shell-model calculations
89TA1T	Schmidt diagrams & configuration mixing effects on hypernuclear magnetic moments
90BR13	Empir. p-n interactions: global trends, configuration sensitivity & $N = Z$ enhancements
90HJ01	3rd order number-conserving sets & effective interactions calc. with Bonn-Jülich potential
90KA1F	Theoretical aspects of nuclear parity violation
90SK04	Study of the $A = 18$ nuclei and the effective interaction in the sd shell
94CI02	Specific heat and shape transitions in light sd nuclei
94LU01	Deep pionic bound states in a nonlocal optical potential
	Ground State Properties
Review:	
89RA17	Compilation of exp. data on nuclear moments for ground & excited states of nucl.
Other articles:	
87BL18	Gogny's effective inter. used to calc. gnd. & excited states of specific spin-isospin order
88GU03	Charge-density distribution of 1s-1p & 1d-2s shell nuclei & filling numbers of the states
89CH1P	1s-0d effective interxns. of isospin triplet & ^{18}Ne-^{18}O Coulomb displacmt. energ. (in Chin.)

Table 18.8 (continued)
^{18}O – General

Reference	Description
	Ground State Properties (continued)
89GU06	Hartree-Fock & shell-model charge densities calc. for ^{16,18}O, ^{32,34}S, ^{40,48}Ca
89SA10	Total cross sections of reactions induced by neutron-rich light nuclei
89TR18	2-nucleon & 4-nucleon clusters in nuclei
90GU10	Charge densities of sp- and sd-shell nuclei & occupation numbers of 2s states
90LO11	Self-consistent calcs. of light neutron-rich nuclei using density-functional method
92FR01	Behavior of nuclear charge radii systematics in the sd shell from muonic atom meas.
93PA14	Relativistic mean field theory; calc. binding energy, rms radii, deformation parameters
93PA19	Continuation of 93PA14: effects of pairing correlations

(A) denotes that only an abstract is available for this reference.

Table 18.9
Energy Levels of ^{18}O [a])

E_x (MeV $\pm$ keV)	$J^\pi; T$	τ [b]) or $\Gamma_{c.m.}$	Decay	Reactions
0	$0^+; 1$		stable	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 15, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52
1.98207 ± 0.09	2^+	$\tau_m = 2.80 \pm 0.07$ ps (g $= -0.287 \pm 0.015$) ($Q = -0.042 \pm 0.008$ b)	γ	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 15, 17, 19, 20, 21, 22, 25, 26, 27, 28, 29, 30, 32, 33, 39, 40, 42, 44, 45, 47, 48, 49, 50, 51, 52
3.55484 ± 0.40	4^+	$\tau_m = 24.8 \pm 1.2$ ps (g $= -0.62 \pm 0.10$)	γ	3, 4, 7, 9, 10, 15, 16, 17, 19, 20, 21, 22, 25, 28, 33, 39, 40, 51, 52
3.63376 ± 0.11	0^+	$\tau_m = 1.38 \pm 0.16$ ps	γ	3, 4, 7, 9, 10, 15, 19, 22, 25, 28, 33, 39, 40, 50, 51, 52
3.92044 ± 0.14	2^+	$\tau_m = 26.5 \pm 2.9$ fs	γ	3, 4, 7, 9, 10, 15, 19, 22, 25, 28, 33, 39, 51
4.45554 ± 0.10	1^-	$\tau_m = 65 \pm 15$ fs	γ	3, 4, 7, 9, 10, 15, 19, 22, 25, 28, 33, 39, 40, 50, 51
5.09778 ± 0.54	3^-	$\tau_m = 62 \pm 25$ fs	γ	3, 4, 7, 9, 10, 15, 19, 22, 25, 26, 27, 28, 33, 39, 40, 45, 51, 52
5.2548 ± 0.9	2^+	$\tau_m = 10.1 \pm 0.5$ fs	γ	3, 4, 7, 9, 10, 15, 17, 19, 25, 28, 33, 50, 51
5.3364 ± 0.6	0^+	$\tau_m = 200 \pm 40$ fs	γ	3, 4, 9, 15, 19, 25, 33, 51

Table 18.9 (continued)
Energy Levels of ^{18}O [a])

E_x (MeV ± keV)	$J^\pi; T$	τ [b]) or $\Gamma_{c.m.}$	Decay	Reactions
5.3778 ± 1.2	3^+	$\tau_m < 30$ fs	γ	3, 4, 15, 19, 20, 51
5.53024 ± 0.29	2^-	$\tau_m < 25$ fs $\Gamma < 50$ keV	γ	3, 4, 15, 22, 25, 28, 33, 51
6.19822 ± 0.40	1^-	$\tau_m = 3.7 \pm 0.6$ fs	γ	3, 4, 9, 15, 19, 22, 24, 25, 33, 51
6.3513 ± 0.6	(2^-)	$\tau_m < 35$ fs $\Gamma < 50$ keV	γ	3, 4, 15, 19, 22, 25, 33, 51, 52
6.4044 ± 1.2	3^-	$\tau_m = 30 \pm 15$ fs	γ	3, 4, 15, 33, 51
6.88045 ± 0.27	0^-	$\tau_m < 25$ fs	γ	3, 4, 15, 22, 33, 50, 51
7.1169 ± 1.2	4^+	$\tau_m < 25$ fs	γ, α	3, 4, 7, 9, 10, 15, 17, 19, 20, 25, 28, 33, 37, 39, 40, 51
7.6159 ± 0.7	1^-	$\Gamma < 2.5$ keV	γ, α	3, 4, 7, 9, 15, 22, 25, 33, 37, 39, 40, 51
7.77107 ± 0.50	2^-	$\Gamma < 50$ keV	γ	3, 4, 15, 22, 25, 51
7.864 ± 5	5^-		γ	3, 4, 7, 9, 10, 15, 19, 20, 25, 33, 37, 39, 40, 51, 52
7.977 ± 4	$(3^+, 4^-)$		γ	3, 4, 15, 19, 51
8.0378 ± 0.7	1^-	$\Gamma < 2.5$ keV	γ, α	3, 4, 7, 8, 15, 16, 17, 22, 25, 37, 39, 40, 51
8.125 ± 2	5^-		γ, α	3, 4, 7, 9, 10, 15, 25, 51
8.213 ± 4	2^+	$\Gamma = 1.0 \pm 0.8$ keV	γ, n, α	3, 4, 7, 8, 15, 25, 28, 33, 37, 39, 40, 51
8.282 ± 3	3^-	$\Gamma = 8 \pm 1$ keV	γ, n, α	3, 4, 7, 8, 9, 10, 15, 25, 33, 51
8.410 ± 8	(2^-)	$\Gamma = 8 \pm 6$ keV	γ, n, α	8, 15, 25, 51
8.521 ± 6	(4^-)	$\Gamma < 50$ keV	γ	15, 25, 51
8.660 ± 6				15, 51
8.817 ± 12	(1^+)	$\Gamma = 70 \pm 12$ keV	n, α	8, 20, 28, 33
8.955 ± 4	(4^+)	$\Gamma = 43 \pm 3$ keV	γ, n, α	8, 15, 25, 33
(9.0 ± 200) [d])	(1^-)		α	22
9.03				15, 19, 33
(9.10)				33
9.27 ± 20 [d])	$(0, 1, 2)^-$		n	22
9.361 ± 6	2^+	$\Gamma = 27 \pm 15$ keV	γ, n, α	8, 10, 15, 25, 33, 37, 39, 40
9.414 ± 18		$\Gamma \approx 120$ keV	n, α	8, 10, 15, 33
9.48 ± 24		$\Gamma \approx 65$ keV	n, α	8, 15
9.672 ± 7	(3^-)	$\Gamma = 60 \pm 30$ keV	n, α	8, 15, 33, 37, 39, 40
9.713 ± 7	(5^-)	$\Gamma < 50$ keV	γ	15, 25, 33

Table 18.9 (continued)
Energy Levels of ^{18}O [a]

E_x (MeV ± keV)	$J^\pi; T$	τ [b] or $\Gamma_{c.m.}$	Decay	Reactions
9.890 ± 11		$\Gamma \approx 150$ keV	n, α	8, 15, 33
10.118 ± 10	3^-	$\Gamma = 16 \pm 4$ keV	n, α	8, 9, 15, 33
10.24 ± 20 [d]	$(0, 1, 2)^-$		n	22
10.295 ± 14	4^+	$\Gamma < 50$ keV	γ, n, α	8, 9, 10, 15, 16, 25, 33, 37, 39, 40
10.396 ± 9	3^-		n, α	8, 15, 33
10.43 ± 40	(2^-)	$\Gamma < 50$ keV	γ	25
10.595 ± 15			n, α	8, 15
10.67 ± 20	(2^-)	$\Gamma < 50$ keV	γ	25
10.82 ± 20			n, α	8
10.91 ± 20			n, α	8, 10
10.99 ± 20	(2^-)	$\Gamma < 50$ keV	γ, n, α	8, 25
11.06	(6^-)			20
11.13 ± 20			n, α	8, 10, 50
11.39 ± 20	(2^+)		n, α	8, 9
11.41 ± 20	(4^+)		n, α	8, 9
11.49 ± 30 [d]	$(0, 1, 2)^-$		n	22
11.52 ± 50	(2^-)	$\Gamma < 50$ keV	γ	25
11.62 ± 20	5^-		n, α	8, 9, 10, 33, 37, 39, 40
11.67 ± 20	(3^-)	$\Gamma = 112 \pm 0.02$ keV		25
11.69 ± 20	6^+		n, α	8, 9, 10, 33
11.82 ± 20	(3^-)		n, α	8
11.90 ± 30	(2^-)	$\Gamma < 50$ keV	γ	25
12.04 ± 20	(2^+)		n, α	8, 9
12.09 ± 20	$(1^-, 2^+)$	$\Gamma < 50$ keV		25
12.25 ± 20	(1^-)		n, α	8, 9
12.33 ± 20	5^-		n, α	8, 9, 10
12.41 ± 20	(3^-)	$\Gamma = 143 \pm 24$ keV	γ	25
12.50 ± 20	4^+		n, α	8, 37, 39, 40
12.52 ± 20		$\Gamma < 50$ keV	γ	25
12.53 ± 20	6^+		n, α	8, 9, 10, 37, 39, 40
12.66 ± 20	(2^-)	$\Gamma < 50$ keV	γ	25
12.99 ± 20	(4^-)	$\Gamma = 68 \pm 18$ keV	γ	25
13.1 [c]	1^-	$\Gamma = 700$ keV	γ, n	23
13.40 ± 20	(2^-)	$\Gamma = 108 \pm 20$ keV	γ	25
13.8	1^-	$\Gamma = 600$ keV	γ, n	23

Table 18.9 (continued)
Energy Levels of ^{18}O [a])

E_x (MeV ± keV)	J^π; T	τ [b]) or $\Gamma_{c.m.}$	Decay	Reactions
13.85 ± 13	(6$^-$)	Γ ≈ 200 keV	γ	20, 25
14.17 ± 40	(6$^-$)	Γ = 140 ± 50 keV	γ	20, 25
14.45 ± 50		Γ ≈ 1070 keV	γ	25
14.7	1$^-$	Γ = 800 keV	γ, n	23
15.23 ± 40		Γ ≈ 300 keV	γ	25
15.8	1$^-$	Γ = 700 keV	γ, n	23
15.95 ± 30		Γ < 50 keV	γ	25
16.210 ± 10	1$^{(-)}$		γ	25
16.315 ± 10	$(3, 2)^-$		γ	25
16.399 ± 5	2$^-$; 2	Γ < 20 keV	γ	25, 28
16.88 ± 30	(4$^-$, 2$^-$); (1)	Γ < 50 keV	γ	25
16.948 ± 10	$(3, 2)^-$		γ	25
17.025 ± 10	(3$^-$); 2	Γ = 20 ± 6 keV	γ	25
17.05	(7$^-$)	Γ ≈ 350 keV		9
17.398 ± 10	1$^-$; (2)	Γ = 600 keV	γ, n, p	23, 25
17.450 ± 10	$(2, 1, 3)^-$		γ	25
17.46 ± 30	(4$^-$); 1	Γ ≈ 600 keV	γ	25
17.5		Γ ≈ 150 keV	γ	25
17.502 ± 10	$(1, 2, 3)^-$		γ	25
(17.6 ± 200)	(8$^+$)			9
17.635 ± 10			γ	25
18.049 ± 10			γ	25
18.2		Γ ≈ 150 keV	γ	25
18.45 ± 20	(3$^-$); (1)	Γ = 75 ± 27 keV	γ	25
18.5		Γ ≈ 4300 keV	γ	25
18.70 ± 20	(4$^-$); 2	Γ < 20 keV	γ	25
18.871 ± 5	1$^+$; 2		γ	25
18.927 ± 10	(1, 2$^+$)		γ	25
18.95	(7$^-$)	Γ ≈ 350 keV		9
19.027 ± 10	$(1, 3)^-$		γ	25
19.150 ± 10	$(1^-, 2^+, 3^-)$		γ	25
19.24 ± 20	(> 2); 2	Γ < 20 keV	γ	25
19.4	1$^-$; (2)	Γ = 900 keV	γ, p	23
19.7		Γ ≈ 200 keV	γ	25
20.2		Γ ≈ 180 keV	γ	25
20.36 ± 20	(4$^-$); 2	Γ < 20 keV	γ	25
20.86 ± 20		Γ = 97 ± 41 keV	γ	25

Table 18.9 (continued)
Energy Levels of ^{18}O [a]

E_x (MeV ± keV)	$J^\pi; T$	τ [b] or $\Gamma_{c.m.}$	Decay	Reactions
21.0	1^-; (1)	$\Gamma \approx 150$ keV	γ, n, p	23, 25
21.42 ± 20	(4^-); (2)	$\Gamma < 50$ keV	γ	25
22.40 ± 20	4^-; 2	$\Gamma = 91 \pm 8$ keV	γ	25
22.7	1^-		γ, n, p	23
23.10 ± 20		$\Gamma = 49 \pm 24$ keV	γ	25
23.8	1^-; (1)	$\Gamma \approx 1500$ keV	γ, n, p	23, 25
27	1^-; (2)		γ, n, p	23
30			γ, n	23
36			γ	23

[a]) See also Tables 18.10 and 18.21 here and 18.12 in (83AJ01).
[b]) See Table 18.14 in (78AJ03) for a display of τ_m measurements.
[c]) For additional states with $12.9 \leq E_x \leq 23.1$ MeV see (83CU03) [reaction 9].
[d]) See reaction 22 in ^{18}O and Table 18.18 for discussion of this level.

Table 18.10
Radiative decays in ^{18}O [a]

E_i (MeV)	J_i^π	E_f (MeV)	Branch (%)	δ
1.98	2^+	0	100	
3.55	4^+	1.98	100	
3.63	0^+	0	0.30 ± 0.06 [b])	
		1.98	99.70 ± 0.06	
3.92	2^+	0	12.4 ± 0.7	
		1.98	87.6 ± 0.7	[c])
4.46	1^-	1.98	27.1 ± 2.6	[c])
		3.63	70.4 ± 1.7	
		3.92	2.5 ± 0.9	
5.10	3^-	1.98	76.1 ± 0.8	[c])
		3.55	6.3 ± 0.8	[c])
		3.92	17.6 ± 0.7	[c])
5.26	2^+	0	30.3 ± 0.9	
		1.98	55.9 ± 1.0	0.15 ± 0.04
		3.55	1.1 ± 0.6	
		3.63	1.0 ± 0.6	

Table 18.10 – continued
Radiative decays in ^{18}O [a])

E_i (MeV)	J^π_i	E_f (MeV)	Branch (%)	δ
		3.92	8.7 ± 0.4	
		4.46	3.0 ± 0.3	
5.34	0^+	0	[d])	
		1.98	58 ± 2	
		4.46	42 ± 2	
5.38	3^+	1.98	86.5 ± 2.2	[c])
		3.92	13.5 ± 2.2	[c])
5.53	2^-	1.98	49 ± 2	[c])
		3.92	24 ± 2	
		4.46	27 ± 2	[c])
6.20	1^-	0	88.7 ± 0.9	
		3.63	2.5 ± 0.3	
		4.46	4.1 ± 0.4	
		5.26	3.6 ± 0.4	
		5.34	1.1 ± 0.3	
6.35	(2^-)	1.98	32 ± 2	[c])
		3.92	55 ± 2	[c])
		4.46	12 ± 2	[c])
6.40	3^-	1.98	68.1 ± 1.8	[c])
		3.55	7.4 ± 1.2	
		3.92	6.3 ± 1.0	[c])
		4.46	2.8 ± 1.0	
		5.10	9.8 ± 0.9	
		5.26	5.6 ± 0.9	
6.88	0^-	4.46	100	[c])
7.12 [e])	4^+	1.98	27.1 ± 0.4	$-(0.052 \pm 0.035)$
		3.55	69.2 ± 0.7	
		3.92	2.1 ± 0.2	
		5.10	1.3 ± 0.2	
		5.26	0.30 ± 0.06	
7.62	1^-	0	23 ± 2	
		1.98	62 ± 3 [f])	$-(0.027 \pm 0.008)$
		4.46	8 ± 1	$-(0.21 \pm 0.03)$
		5.34	6 ± 1	
		6.20	1 ± 1	
7.77	2^-	1.98	53 ± 3	
		4.46	11 ± 2	
		5.10	36 ± 3	
7.86	5^-	3.55	> 75	

Table 18.10 – continued
Radiative decays in ^{18}O [a])

E_i (MeV)	J_i^π	E_f (MeV)	Branch (%)	δ
7.98	$(3^+, 4^-)$	3.55	67 ± 2	
		5.10	12 ± 2	
		5.38	21 ± 2	
8.04	1^-	0	16 ± 1	
		1.98	70 ± 2 [g])	
		3.63	10 ± 1	
		5.26	4 ± 1	
8.13	5^-	3.55	99 ± 1 [h])	
		5.10	1 ± 1	
8.21	2^+	0	19 ± 4	
		1.98	29 ± 3	
		3.55	3 ± 1	
		3.92	3 ± 1	
		4.46	29 ± 3	
		5.10	17 ± 1	
8.28	3^-	3.55	61 ± 3	
		4.46	3 ± 3	
		5.26	36 ± 3	

[a]) For references and additional information see Tables 18.3 in (78AJ03, 83AJ01). Upper limits for other transitions are not shown.
[b]) $\Gamma_\pi/\Gamma = (3.0 \pm 0.6) \times 10^{-3}$ (75SO05).
[c]) δ is consistent with 0.
[d]) $\Gamma_\pi/\Gamma \leq 2.3 \times 10^{-3}$.
[e]) $\Gamma_\gamma/\Gamma = 0.561 \pm 0.013$ (94ME02).
[f]) $\Gamma_\alpha\Gamma_\gamma/\Gamma = 0.34$ eV.
[g]) $\Gamma_\alpha\Gamma_\gamma/\Gamma = 0.89$ eV.
[h]) $\Gamma_\alpha\Gamma_\gamma/\Gamma = 0.22$ eV.

1. (a) ^{7}Li(^{11}B, nn)^{16}O $\qquad Q_m = 12.171$
   (b) ^{9}Be(^{9}Be, nn)^{16}O $\qquad Q_m = 11.291$

Reactions (a) and (b) have been studied by (93CU01, 93DA17) in low energy heavy-ion fusion reactions. It is reported that the ≈ 3 MeV wide resonance observed at $E_x(^{18}\text{O}) \approx 28$ MeV in the $^7\text{Li} + {}^{11}\text{B} \to {}^{18}\text{O} \to {}^{16}\text{O} + \text{nn}$ and $^9\text{Be} + {}^9\text{Be} \to {}^{18}\text{O} \to {}^{16}\text{O} + \text{nn}$ reactions overlaps with the higher part of the $T_< = 1$, ^{18}O GDR observed in photonuclear excitation.

2. (a) ^{10}B(^{9}Be, p)^{18}O $\qquad Q_m = 16.892$
   (b) ^{11}B(^{9}Be, d)^{18}O $\qquad Q_m = 7.662$

See (86CU02) for production cross sections of 1.98 MeV γ-rays.

3. $^{12}C(^{7}Li, p)^{18}O$ $\qquad Q_m = 8.401$

Observed proton groups are displayed in Table 18.5 of (87AJ02).

In a recent experiment, the 4^+ state at 7117 keV in ^{18}O was studied by (94ME02) and an E2 strength for the 7117–5060 branches of $B(E2) = 6.4 \pm 1.6$ W.u. was deduced in agreement with results of (89GA01). It was concluded that it is highly improbable that the 7117 keV state is energetically degenerate with a state of different decay properties.

4. $^{13}C(^{6}Li, p)^{18}O$ $\qquad Q_m = 10.704$

See (86SM01) and Table 18.5 in (87AJ02). It is noted there that existing data indicate that when σ_{tot} to a particular state in ^{18}O is large in this reaction, it is also large in the $^{12}C(^{7}Li, p)$ reaction. More recent data are reported in (88SM01). (See Table 18.11 here). Differential cross sections were measured and compared with results of Hauser-Feshbach calculations. The results suggest the presence of an additional non-statistical mechanism.

5. $^{13}C(^{9}Be, \alpha)^{18}O$ $\qquad Q_m = 12.830$

See (83AJ01, 87AJ02).

6. $^{13}C(^{17}O, ^{12}C)^{18}O$ $\qquad Q_m = 3.098$

See (83AJ01, 87AJ02).

7. $^{14}C(\alpha, \gamma)^{18}O$ $\qquad Q_m = 6.227$

Resonances in the yield of capture γ-rays are observed at $E_\alpha = 1.14$, 1.79, 2.09, 2.33, 2.44, 2.55, and 2.64 MeV: see Tables 18.12 here and 18.5 in (78AJ03). Gamma-ray angular distribution and correlation measurements lead to $J^\pi = 4^+$, 1^-, 1^-, and 5^- for $^{18}O^*$(7.11, 7.62, 8.04, 8.13), as well as to J^π assignments for lower states involved in the cascade decay. See also references in (87AJ02) and see the cross section measurements of (93DA17). The speculated presence of enhanced E1 γ de-excitation in ^{18}O (83GA02) was followed by further experimental and theoretical investigations of collective band structure in ^{18}O (89FU08, 93RE03). See however (86HA1J). See also (89FU1H, 89KAZH). The $4^+_2 \rightarrow 2^+_2$ ($7117 \rightarrow 5260$) keV γ branching ratio of $0.30 \pm 0.08\%$ was measured by (89GA01) and

Table 18.11
States of ^{18}O from ^{13}C(^{6}Li, p) [a]

E_x [a] (MeV ± keV)	σ_{tot} [a,b] (μb)	E_x [a] (MeV ± keV)	σ_{max} [a] (μb/sr)
0	6.1 ± 0.3	8.667 ± 13	20.8 ± 1.0
1.987 ± 8	39 ± 1	8.82 ± 20	13.0 ± 0.9
3.555 ± 10	56 ± 1	8.96 ± 20	16.3 ± 1.0
3.632 ± 15	13 ± 1	9.72 ± 30	26.3 ± 1.3
3.926 ± 6	36 ± 1	10.09 ± 30	30.6 ± 1.5
4.455 ± 8	46 ± 1	10.28 ± 30	100 ± 5
5.095 ± 11	74 ± 1	10.63 ± 30	31.3 ± 1.6
5.256 ± 9	44 ± 1	10.90 ± 30	42.7 ± 2.1
5.374 ± 8	35 ± 1	10.99 ± 20	84.8 ± 4.2
5.532 ± 8	45 ± 1	11.12 ± 20	17.7 ± 0.9
6.199 ± 8	37 ± 1	11.26 ± 20	33.9 ± 1.7
6.383 ± 11 [c]	131 ± 2	11.42 ± 30	46.6 ± 2.3
6.882 ± 19	5.3 ± 0.4	11.61 ± 30	34.1 ± 1.7
7.117 ± 5 [d]	208 ± 2	11.70 ± 30	75.4 ± 3.8
7.618 ± 10	33 ± 1	11.85 ± 30	81.9 ± 4.1
7.764 ± 14	37 ± 1	12.07 ± 30	34.2 ± 1.7
7.850 ± 13	101 ± 1	12.23 ± 30	32.1 ± 1.6
7.962 ± 12	84 ± 1	12.33 ± 30	50.4 ± 2.5
8.026 ± 14	19 ± 1	12.44 ± 30	96.0 ± 4.8
8.120 ± 12	140 ± 2	12.54 ± 30	90.2 ± 4.5
8.200 ± 17	48 ± 1	13.08 ± 30	48.4 ± 2.4
8.274 ± 15	103 ± 2	13.23 ± 30	99.3 ± 5.0
8.401 ± 12	45 ± 1	13.48 ± 30	24.6 ± 1.2
8.496 ± 15	75 ± 1	13.60 ± 30	29.0 ± 1.5
		13.81 ± 30	159 ± 8
		14.14 ± 30	92.7 ± 4.6
		15.80 ± 30	136 ± 7

[a]) (88SM01). The maximum value of the differential cross section results were compared with a Hauser-Feshbach calculation. The comparison suggests the presence of an additional nonstatistical mechanism.
[b]) See Table 18.5 in (87AJ02), which shows a comparison with σ_{tot} from ^{12}C(^{7}Li, p) for $E_x \leq 8.3$ MeV.
[c]) Unresolved doublet (88SM01).
[d]) See discussion of Γ_γ/Γ results from (94ME02) under reaction 3 here.

Table 18.12
Resonances in $^{14}C(\alpha, \gamma)^{18}O$, $^{14}C(\alpha, n)^{17}O$ and $^{14}C(\alpha, \alpha)^{14}C$ [a])

E_α (MeV ± keV)	Γ_{lab} (keV)	Particles out	$E_x(^{18}O)$ (MeV)	J^π
1.140 ± 2 [b])		γ	7.114	4^+
1.790 ± 2 [b])	< 3	γ	7.619 [h])	1^-
2.10 [b])		γ	7.86	5^-
2.330 ± 2 [b])	< 3	γ, α_0	8.039 [b,h])	1^-
2.440 ± 2 [b])		γ	8.125	5^-
2.554 ± 4 [b])	1.3 ± 1	γ, n, α_0	8.213	2^+
2.643 ± 3 [b])	10 ± 1	γ, n, α_0	8.282	3^-
2.800 ± 7	10 ± 7	n	8.404	
3.330 ± 12	90 ± 15	n, α_0	8.817	
3.508 ± 4	55 ± 3	n, α_0	8.955	
4.030 ± 15	35 ± 20	n, (α_0)	9.361	
4.07 ± 40	≈ 150	n, (α_0)	9.39	
4.17 ± 40	≈ 70	n, (α_0)	9.47	
4.434 ± 10	80 ± 40	n, (α_0)	9.675	
4.70 ± 40	≈ 200	n, (α_0)	9.88	
5.004 ± 10	21 ± 5	n, α_0	10.118	3^-
5.23 [c])	[d])	n, α_0	10.29	4^+
5.34	[d])	n, α_0	10.38	3^-
5.60	[e])	n, α_0	10.58	
5.90	[f])	n, α_0	10.82	
6.02	[f])	n, α_0	10.91	
6.13	[f])	n, α_0	10.99	
6.30	[e])	n, α_0	11.13	
6.64	[d])	n, α_0	11.39	(2^+)
6.67	[d])	n, α_0	11.41	(4^+)
6.93	[d])	n, α_0	11.62	5^-
7.03	[d])	n, α_0	11.69	6^+
7.19	[f])	n, α_0	11.82	(3^-)
7.47	[f])	n, α_0	12.04	(2^+)
7.75	[g])	n, α_0	12.25	$(0^+, 1^-)$
7.85	[d])	n, α_0	12.33	5^-
8.06	[d])	n, α_0	12.50	4^+
8.10	[d])	n, α_0	12.53	6^+

[a]) See also Table 18.10. For references see Table 18.5 in (78AJ03).
[b]) (87GA15): $\Gamma_\gamma = 0.095 \pm 0.020$, 0.41 ± 0.08, 0.043 ± 0.009, 1.07 ± 0.22, 0.27 ± 0.05, 0.41 ± 0.09, and 0.49 ± 0.13 eV, respectively for $^{18}O^*$ (7.11, 7.62, 7.86, 8.04, 8.13, 8.21, 8.28 MeV).
[c]) ± 10–20 keV for this and all higher resonances (G.E. Mitchell, private comm.).
[d]) Γ_α, large; Γ_n, large.
[e]) Γ_α, small; Γ_n, small.

Table 18.12 (continued)
Resonances in $^{14}C(\alpha, \gamma)^{18}O$, $^{14}C(\alpha, n)^{17}O$ and $^{14}C(\alpha, \alpha)^{14}C$ [a])

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[f]) Γ_α, small; Γ_n, large.
[g]) Γ_α, large; Γ_n, small.
[h]) Recent $^{14}C(\alpha, \gamma)$ measurements for these two 1^- states by (93HA17) gave $E_x = 7.6159 \pm 0.0007$ and 8.0378 ± 0.0007 keV.

Table 18.13
Gamma-ray branching ratios in $^{14}C(\alpha, \gamma)^{18}O$ [a])

E_i (MeV)	J_i^π	E_f (MeV)	J_f^π	Branching ratio (%)
7.620 ± 0.002	1^-	0	0^+	23 ± 2
		1.98	2^+	62 ± 3
		3.63	0^+	< 1
		3.92	2^+	< 3
		4.46	1^-	8 ± 2
		5.26	2^+	< 3
		5.34	0^+	6 ± 1
		5.53	2^-	< 5
		6.20	1^-	1 ± 1
7.859 ± 0.005	5^-	3.56	4^+	> 75
8.040 ± 0.002	1^-	0	0^+	17 ± 1
		1.98	2^+	71 ± 2
		3.63	0^+	9 ± 1
		3.92	2^+	< 1
		4.46	1^-	< 1.5
		5.10	3^-	< 1
		5.26	2^+	3.2 ± 0.9
		5.34	0^+	< 1
		5.53	2^-	< 2
		6.20	1^-	< 2
8.125 ± 0.002	5^-	3.55	4^+	99 ± 1
		5.10	3^-	1 ± 1
		7.12	4^+	< 2
8.214 ± 0.004	2^+	0	0^+	19 ± 4
		1.98	2^+	29 ± 3
		3.55	4^+	3 ± 1
		3.63	0^+	< 3
		3.92	2^+	3 ± 1
		4.46	1^-	29 ± 3

Table 18.13 (continued)
Gamma-ray branching ratios in $^{14}C(\alpha,\ \gamma)^{18}O$ [a]

E_i (MeV)	J_i^π	E_f (MeV)	J_f^π	Branching ratio (%)
		5.10	3^-	17 ± 1
		5.26	2^+	< 3
		5.34 – 6.35		< 1
8.283 ± 0.003	3^-	0	0^+	< 7
		1.98	2^+	< 3
		3.55	4^+	61 ± 3
		3.92	2^+	< 3
		4.46	1^-	3 ± 3
		5.10	3^-	< 8
		5.26	2^+	36 ± 3
		5.38	3^+	< 4
		5.53	2^-	< 8
		6.40	3^-	< 5

[a]) 87GA15. See also table 18.12 for measured Γ_γ for these levels.

an E2 transition strength B(E2) $= 5.7 \pm 1.9$ W.u. was deduced. This result is confirmed by the $(\Gamma_{\alpha x}\Gamma_\gamma)/(\Gamma_\alpha + \Gamma_\gamma)$ and (7117 → 5260) keV γ branching ($0.24 \pm 0.08\%$) measurements of (92GO14) and the $\Gamma_\gamma/\Gamma_\alpha$ measurement of (94ME02).

The $^{14}C(\alpha,\ \gamma)$ reaction is important in astrophysical processes and the details of the cross section are relevant to the process of heavy element formation in inhomogeneous big bang nucleosynthesis (88AP1A, 89FU06, 90WIZP, 92GA11, 92GO14). See also (88BU01, 88MA1U, 89KA1K, 89NO1A, 89TH1C) and the review of thermonuclear reaction rates in (88CA1N).

8. (a) $^{14}C(\alpha,\ \alpha')^{14}C$ $\qquad E_b = 6.227$
   (b) $^{14}C(\alpha,\ n)^{17}O$ $\qquad Q_m = -1.817$

Observed anomalies in the scattering [reaction (a)] for $E_\alpha = 2$ to 8.2 MeV and the resonances in the relative neutron yield [reaction (b)] for $E_\alpha = 2.3$ MeV are displayed in Table 18.12. See also (78AJ03).

The α-cluster structure of ^{18}O has been investigated in the theoretical work of (89FU08, 93RE03) based on $^{14}C(\alpha,\ \alpha)$ scattering, and the results do not support the existence of proposed negative-parity molecular dipole states. See (89GA01).

9. (a) $^{14}C(^6Li,\ d)^{18}O$ $\qquad Q_m = 4.752$
   (b) $^{14}C(^6Li,\ d\alpha)^{14}C$ $\qquad Q_m = -1.475$

At $E(^6\text{Li}) = 34$ MeV angular distributions have been measured for the deuteron groups to many states of ^{18}O (81CU07) [see also (83AJ01)] including ^{18}O*(17.6 ± 0.2) (82CU01). $J^\pi = 4^+, 2^+, 2^+, (4^+)$, and (4^+) are suggested for ^{18}O*(7.86, 8.9, 12.04, 14.6, 17.0) (81CU07). The 2^+, 4^+, 6^+ and 8^+ members of the $K^\pi = 0_2^+$ rotational band based on ^{18}O* (3.62) are ^{18}O* (5.26, 7.12, 11.69, 17.6) (82CU01).

Angular correlations have been measured at $E(^6\text{Li}) = 34$ MeV; these lead to the assignment of $J^\pi = 8^+$ to ^{18}O* (17.6) (82CU01) and to the assignment of $J^\pi = 4^+, 5^-, 6^+, 7^-$ and 8^+ to sixteen states in ^{18}O with $11.4 \leq E_x \leq 23.1$ MeV (83CU03) [also see (83CU03) for assignment of ^{18}O states to bands]. At $E(^6\text{Li}) = 32$ MeV (83AR1B) find that the strongest groups are those to (unresolved) structures at $E_x = 17.05$ and 18.95 MeV [each $\Gamma \approx 0.35$ MeV] dominated by $J^\pi = 7^-$. ^{18}O* (11.6, 12.6) with $J^\pi = (6^+, 5^-)$ and 5^- are also observed (83AR1B). [See, however, the density of states]. See also (87AJ02, 90OS03).

10. ^{14}C(^{7}Li, t)^{18}O $\qquad Q_\text{m} = 3.760$

At $E(^7\text{Li}) = 20.4$ MeV, triton groups are observed corresponding to a number of states of ^{18}O with $E_\text{x} < 12.6$ MeV. Angular distributions were obtained for some of these, including ^{18}O* (0, 1.98, 7.12, 11.69) with $J^\pi = 0^+, 2^+, 4^+, 6^+$. The latter two are the most strongly populated in this reaction: they appear to be part of the ground-state rotational band: see (72AJ02). See also (87AJ02).

In more recent work at $E(^7\text{Li}) = 15$ MeV, ^{18}O gamma de-excitation modes for all natural parity states up to the alpha-particle threshold at $E_x = 6.227$ MeV were studied (91GA08). See Table 18.14.

11. ^{14}C(^{14}C, ^{10}Be)^{18}O $\qquad Q_\text{m} = -5.785$

See (85KO04).

12. ^{14}C(^{16}O, ^{12}C)^{18}O $\qquad Q_\text{m} = -0.935$

See (78AJ03).

13. ^{15}N(α, p)^{18}O $\qquad Q_\text{m} = -3.980$

Several states in ^{18}O at $E_x = 10$–25 MeV were observed in ^{15}N(α, p) experiments reported in (87MI1C, 88BRZY, 89BR1J).

14. ^{15}N(^{13}C, ^{10}B)^{18}O $\qquad Q_\text{m} = -8.042$

Table 18.14
Gamma decay branching ratios for ^{18}O from ^{14}C(^{7}Li, tγ)^{18}O [a])

$E_{\rm i}$ (MeV)	$J^{\pi}_{\rm i}$	$E_{\rm f}$ (MeV)	$J^{\pi}_{\rm f}$	Branching ratio (%)
1.98	2^+_1	0.00	0^+	100
3.55	4^+_1	1.98	2^+	100
3.63	0^+_2	1.98	2^+	100
3.92	2^+_2	0.00	0^+	11.1 ± 1.0
		1.98	2^+	88.9 ± 1.0
4.45	1^-_1	0.00	0^+	< 0.2
		1.98	2^+	29.5 ± 1.0
		3.63	0^+_2	68.9 ± 1.0
		3.92	2^+_2	1.6 ± 0.2
5.10	3^-_1	1.98	2^+	76.5 ± 1.0
		3.55	4^+	5.6 ± 1.0
		3.92	2^+_2	17.9 ± 0.8
		4.45	1^-	< 0.14
5.26	2^+_3	0.00	0^+	30.3 ± 0.9
		1.98	2^+	55.9 ± 1.0
		3.55	4^+	1.1 ± 0.6
		3.63	0^+_2	1.0 ± 0.6
		3.92	2^+_2	8.7 ± 0.4
		4.45	1^-	3.0 ± 0.3
5.34	0^+_3	1.98	2^+	45.2 ± 5.0
		3.92	2^+_2	< 12.0
		4.45	1^-	54.8 ± 5.0
6.20	1^-_2	0.00	0^+	88.7 ± 0.9
		1.98	2^+	< 1.3
		3.63	0^+_2	2.5 ± 0.3
		3.92	2^+_2	< 0.9
		4.45	1^-	4.1 ± 0.4
		5.09	3^-	< 0.7
		5.26	2^+_3	3.6 ± 0.4
		5.34	0^+_3	1.1 ± 0.3
6.40	3^-_2	1.98	2^+	68.1 ± 1.8
		3.55	4^+	7.4 ± 1.2
		3.92	2^+_2	6.3 ± 1.0
		4.45	1^-	2.8 ± 1.0
		5.09	3^-	9.8 ± 0.9
		5.26	2^+_3	5.6 ± 0.9
7.12	4^+_2	1.98	2^+	27.0 ± 0.5
		3.55	4^+	70.0 ± 1.0
		3.92	2^+_2	1.8 ± 0.4

Table 18.14
Gamma decay branching ratios for ^{18}O from ^{14}C(^{7}Li, tγ)^{18}O [a]

E_i (MeV)	J_i^π	E_f (MeV)	J_f^π	Branching ratio (%)
		5.09	3^-	1.2 ± 0.3
		5.26	2_3^+	< 0.6
		6.40	3_2^-	< 0.2

[a]) (91GA08). See Table 1 of (91GA08) for additional information including transition strengths. See also Table 18.10 here.

See (83AJ01).

15. ^{16}O(t, p)^{18}O $\qquad Q_m = 3.706$

Proton groups corresponding to states of ^{18}O are displayed in Table 18.15 (81CO13). See (76LA13) for a general discussion of the properties of the states of ^{18}O. Lifetime measurements are reported in Table 18.4 of (78AJ03). See also reaction 19 and (82AN12, 85AN17, 85BA1A).

16. ^{16}O(α, 2p)^{18}O $\qquad Q_m = -16.108$

At $E_\alpha = 65$ MeV, the angular distribution to ^{18}O*(3.55) [$J^\pi = 4^+$] has been studied. ^{18}O* (8.04, 9.15, 10.3) are also populated: see (83AJ01).

17. (a) ^{16}O(^{10}B, ^{8}B)^{18}O $\qquad Q_m = -14.825$
(b) ^{16}O(^{13}C, ^{11}C)^{18}O $\qquad Q_m = -11.480$

At $E(^{10}\text{B}) = 100$ MeV, ^{18}O*(3.55) [first $(\text{d}_{5/2})^2_{4^+}$ state] is preferentially populated. ^{18}O*(1.98, 5.26, 7.12, 8.0, 8.3, 9.1) are also observed. The angular distribution to ^{18}O*(3.55) has been measured at $E(^{13}\text{C}) = 105$ MeV. See (83AJ01, 83OS07).

18. (a) ^{17}O(n, γ)^{18}O $\qquad Q_m = 8.044$
(b) ^{17}O(n, n$'$)^{17}O $\qquad E_b = 8.044$
(c) ^{17}O(n, α)^{14}C $\qquad Q_m = 1.817$

Table 18.15
States in ^{18}O from ^{16}O(t, p) [a]

E_x (keV)	L	J^π	E_x (keV)	E_x (keV)
0	0	0^+	7623 ± 18	9713 ± 7
1986 ± 4	2	2^+	7782 ± 6	9890 ± 11
3556 ± 2	4	4^+	7871 ± 2 [d]	10120 ± 40
3634 [b]	0	0^+	7983 ± 3 [d]	10300 ± 20
3915 ± 2	2	2^+	8046 ± 7	10400 ± 10
4458 ± 3	1	1^-	8140 ± 10	10610 ± 20
5105 ± 2	3	3^-	8233 ± 9	
5258 ± 6	2	2^+	8294 ± 5 [d]	
5340 ± 4	0	0^+	8430 ± 12	
5382 ± 4			8521 ± 3 [d]	
5530 ± 4			8660 ± 6	
6197 ± 3	1	1^-	9030 ± 15 [e]	
6356 ± 7	1, 2	$(1^-,\ 2^+)$ [c]	9362 ± 5 [d]	
6399 ± 3	3	3^-	9420 ± 20	
6885 ± 9			9480 ± 30	
7123 ± 7	4	4^+	9671 ± 8	

[a]) (81CO13): $E_t = 15$ MeV; DWBA analysis. See also Table 18.6 in (78AJ03).
[b]) Nominal energy.
[c]) See, however, Table 18.18.
[d]) Comparisons of E_x shown here with those displayed in Table 18.9 for ^{18}O* (3.92, 5.10, 6.40, 7.77) suggest that the uncertainty shown may be low: $\pm$ 6 keV was arbitrarily used in calculating the best value for E_x for this state in Table 18.3 of (87AJ02).
[e]) This is the "average" of several unresolved levels. (85FO11) states that the main components are at 8.96 and 9.03 MeV. [Comment: It is not clear whether these states are actually resolved (87AJ02).]

Table 18.16
States of ^{18}O from ^{17}O(d, p) [a]

E_x (MeV ± keV) [b]	l_n [b]	J^π [b]	S [b]
0	2	0^+	1.22
1.982 ± 10	0 + 2	2^+	0.21 + 0.83
3.552 ± 10	2	4^+	1.57
3.63	2	0^+	0.28
3.92	0 + 2	2^+	0.35 + 0.66
4.46	1	1^-	0.03
5.10	3	3^-	0.03
5.255 ± 10	0	2^+	0.35
5.34	2	0^+	0.16
5.375 ± 10	0	3^+	1.01
6.20	1	1^-	0.03
6.35	1	(2^-)	0.03
7.110 ± 15	2	4^+	
7.855 ± 20			
7.962 ± 20			
9.0 [c]			

[a]) See references in Tables 18.7 of (72AJ02, 78AJ03).
[b]) E_x values without uncertainties are nominal. J are consistent with l_n and are used to calculate S.
[c]) (85FO11). See text.

For reaction (a) see (83AJ01). [The work reported there has not been published.] The scattering amplitude (bound) $a = 5.62 \pm 0.45$ fm; $\sigma_{\text{free}} = 3.55 \pm 0.25$ b. The thermal cross section for reaction (c) is 235 ± 10 mb. See (83AJ01) for references. See also (88MCZT).

In more recent work, the cross section for ^{17}O(n, α) has been measured from $E_n = 25 \times 10^{-3}$ eV to 1 MeV (91KO31). An evaluation of the cross sections from $E_n = 10^{-5}$ eV to 20 MeV has been carried out by (91HI15). Results are given in tabular and graphical form. See also (91KO1P).

19. ^{17}O(d, p)^{18}O $\qquad Q_m = 5.820$

Observed proton groups are displayed in Table 18.16. A strong asymmetric peak is observed at $E_d = 12$ MeV corresponding to $E_x = 9.0$ MeV. On the basis of this work and the measurement of the cross section at a peak at about the same energy observed in the ^{16}O(t, p) reaction, (85FO11) assign $J^\pi = 4^+$ and a $(1d_{5/2})$ $(1d_{3/2})$ configuration to ^{18}O*(9.0). Proton-γ coincidence measurements are shown in Table 18.10.

20. ^{17}O(α, ^{3}He)^{18}O $\qquad Q_m = -12.533$

Table 18.17
Some states in ^{18}O from ^{17}O(α, ^{3}He) [a]

E_x (MeV) [b]	J^π [b]	σ_{int} (mb) [c]
0.0	0^+	0.22
1.98	2^+	0.64
3.55	4^+	1.59
5.38	3^+	0.12
7.12	4^+	0.09
7.86	5^-	0.14
8.12	5^-	0.06
8.82	(1^+)	0.04
11.06 [a]	(6^-) [a]	0.18
13.85	(6^-) [d]	0.02
14.17	(6^-) [d]	0.01

[a]) (92YA08); $E_\alpha = 65$ MeV.
[b]) E_x and J^π values from Table 18.9.
[c]) Integrated cross section. See Tables III and IV in (92YA08) for spectroscopic factors.
[d]) (90SEZZ).

Differential cross sections were measured at $E_\alpha = 65$ MeV (92YA08) for ^{18}O states up to $E_x = 15$ MeV. DWBA analysis led to proposed spin, parity and isospin assignments, and spectroscopic factors. See Table 18.17.

21. ^{17}O(^{12}C, ^{11}C)^{18}O $\qquad Q_m = -10.677$

Angular distributions involving ^{18}O*(0, 1.98, 3.55) have been studied at $E(^{12}\text{C}) =$ 115 MeV: see (83AJ01).

22. ^{18}N(β^-)^{18}O $\qquad Q_m = 13.899$

The transitions observed in the β^- decay are displayed in Table 18.18. The γ-decaying states were measured by (82OL01) and an estimated $15 \pm 6\%$ branching to non-γ-decaying states in ^{18}O was assumed. At least $12.2 \pm 0.6\%$ of the β-decay branching ratio has been measured to feed 1^- alpha-particle emitting states (89ZH04). See also the measurements of (87GA1G, 87ZH1F, 88MI1G). A β-delayed neutron emission probability of $14.3 \pm 2.0\%$ has been measured (91RE02). The β^- branchings to γ-emitting states of (82OL01) has been renormalized to take in account the $26.5 \pm 2.1\%$ branches to particle emitting states. The γ-ray intensities of (82OL01) also need to be renormalized by this factor, see Table

Table 18.18
Branching in ^{18}N(β^-)^{18}O [a]

Decay to ^{18}O* (keV)	Decay Mode	J^π	Branch [b] (%)	log ft
1982.05 ± 0.09 [c]	γ	2^+	3.4 ± 1.3	6.79 ± 0.17
3554.13 ± 0.80	γ	4^+	< 0.5	> 7.3
3633.70 ± 0.11	γ	0^+	< 0.3	> 7.5
3920.42 ± 0.14	γ	2^+	< 0.4	> 7.4
4455.52 ± 0.10	γ	1^-	47.2 ± 0.9	5.167 ± 0.013
5097.60 ± 0.60	γ	3^-	< 0.4	> 7.1
5530.17 ± 0.32	γ	2^-	2.7 ± 0.3	6.16 ± 0.05
6198.22 ± 0.40	γ	1^-	1.2 ± 0.2	6.34 ± 0.08
6349.76 ± 1.0	γ	(2^-)	1.9 ± 0.2	6.10 ± 0.05
6880.45 ± 0.27	γ	0^- [d]	12.8 ± 0.7	5.13 ± 0.03
7620	α	1^-	6.8 ± 0.5	5.17 ± 0.04
7771.07 ± 0.50	γ	2^- [d]	4.3 ± 0.4	5.32 ± 0.05
8040	α	1^-	1.8 ± 0.2	5.61 ± 0.05
9000 [e]	α	(1^-)	$\geq 3.6 \pm 0.2$	≤ 5.0
(9090 ± 30)	n	$(0-2)^-$	0.16 ± 0.03	6.27 ± 0.09
9270 ± 20	n	$(0-2)^-$	0.39 ± 0.09	5.80 ± 0.11
9470 ± 20	n	$(0-2)^-$	0.47 ± 0.09	5.64 ± 0.09
9690 ± 20	n	$(0-2)^-$	0.14 ± 0.03	6.06 ± 0.10
9910 ± 20	n	$(0-2)^-$	0.17 ± 0.03	5.87 ± 0.08
10240 ± 30	n	$(0-2)^-$	0.16 ± 0.03	5.73 ± 0.09
10650 ± 30	n	$(0-2)^-$	0.43 ± 0.09	5.07 ± 0.10
10990 ± 30	n	$(0-2)^-$	0.13 ± 0.03	5.38 ± 0.11
11490 ± 30	n	$(0-2)^-$	0.19 ± 0.04	4.85 ± 0.10

[a]) Branchings to γ-decaying levels (82OL01), branchings to α-decaying levels (89ZH04), and branchings to n-decaying levels (94SC01).
[b]) 12.2 ± 0.6% of the β-decay branching ratio has been measured to feed α-emitting states (89ZH04). 14.3 ± 2.0% has been measured to feed n-decaying states (91RE02). The branching ratios of γ-decaying states (82OL01) have been renormalized to take these values into account. See reaction 22 of ^{18}O. Branchings in this table do not add up to 100% since n-decaying levels below 9.00 MeV were not measured by (94SC01) and there is a missing 12.1% branching to n-decaying levels not listed.
[c]) $E_\gamma = 1981.933 \pm 0.09$ keV is adopted by (82OL01).
[d]) See (82OL01).
[e]) Found as a broad bump at 3 MeV in β-delayed alpha spectrum. Could be several unresolved 1^- states or a new broad 1^- state in ^{18}O (89ZH04).

Table 18.19
γ-ray intensities observed in $^{18}N(\beta^-)^{18}O$ [a])

E_γ (keV) [b])	E_i (keV)	E_f (keV)	I_γ [c])
535.24 ± 0.05	4456	3920	2.85 ± 0.14
821.71 ± 0.09	4456	3634	60.6 ± 1.8
1074.8 ± 0.6	5530	4456	0.80 ± 0.12
1177.3 ± 0.9	5098	3920	0.42 ± 0.13
1572.0 ± 0.8	3554	1982	0.64 ± 0.13
1609.6 ± 0.9	5530	3920	0.85 ± 0.34
1651.56 ± 0.07	3634	1982	60.5 ± 1.8
1893.9 ± 0.9	6350	4456	0.37 ± 0.06
1938.2 ± 0.2	3920	1982	4.49 ± 0.14
1981.93 ± 0.09	1982	0	98.0 ± 2.0
2424.8 ± 0.3	6880	4456	17.53 ± 0.70
2429.7 ± 0.8	6350	3920	1.41 ± 0.14
2473.0 ± 0.3	4456	1982	20.4 ± 1.0
2673.0 ± 0.5	7771	5098	1.63 ± 0.16
3114.5 ± 0.6	5098	1982	0.92 ± 0.14
3315.1 ± 0.9	7771	4456	0.63 ± 0.25
3547.7 ± 0.4	5530	1982	2.01 ± 0.14
3920.1 ± 0.9	3920	0	0.65 ± 0.07
4366.0 ± 0.8	6350	1982	0.84 ± 0.21
5788.5 ± 0.7	7771	1982	3.58 ± 0.32
6197.1 ± 0.4	6198	0	1.40 ± 0.14

[a]) (82OL01).
[b]) γ-ray energies have not been corrected for nuclear recoil.
[c]) γ-ray intensities are normalized such that the flux into the ground state is 100. To obtain γ-ray intensities per 100 parent decays multiply by 0.735 ± 0.021 (see reaction 22 under ^{18}O for discussion of this normalization).

18.19. (94SC01) has measured β decay branching ratios to 9 neutron emitting states in ^{18}O listed in Table 18.18 for a total of $2.2 \pm 0.4\%$.

23. (a) ^{18}O(γ, n)^{17}O $Q_m = -8.044$
(b) ^{18}O(γ, 2n)^{16}O $Q_m = -12.187$
(c) ^{18}O(γ, p)^{17}N $Q_m = -15.942$
(d) ^{18}O(γ, t)^{15}N $Q_m = -15.834$
(e) ^{18}O(γ, pn + np)^{14}C $Q_m = -34.522$
(f) ^{18}O(γ, α)^{14}C $Q_m = -6.227$

The cross sections for the (γ, p), (γ, n), (γ, 2n) and (γ, tot) [tot = total absorption] have been measured with monoenergetic photons to 42 MeV: observed resonances are displayed in Table 18.20. All three of the partial cross sections have substantial strength in the giant resonance region; the (γ, 2n) cross section is a significant fraction of $\sigma(\gamma$, tot) and is even larger than $\sigma(\gamma$, p). Above the GDR the partial cross sections decrease. The integrated $\sigma(\gamma$, tot) between 29 and 42 MeV is about one-third of the value integrated from threshold to 42 MeV. The relative strengths of partial cross sections leads to the T assignments shown in Table 18.20. The $T_<$ and $T_>$ components of the ^{18}O photo absorption cross section are also derived (79WO04).

In a related, but more recent, experiment the cross section for reaction (e) was measured (91MC01) and it was determined that the cross section rises to a maximum of 1.2 mb at 27.5 MeV, approximately one-tenth of the total (γ, n) cross section there. The cross section, integrated to 43 MeV, is only 11.8 mb-MeV, and as a result the isospin assignments of (79WO04) are unaffected by neglect of this channel. A recent extensive study of isospin effects in the photodisintegration of light nuclei (93MC02) used a collection of data on (γ, p), (γ, n), (γ, 2n) and (γ, n_0) cross sections and separated the $T_>$ and $T_<$ isospin components of the GDR in several light nuclei including ^{18}O. The relative strengths were extracted. See also the atlas of photoneutron cross sections with monoenergetic photons (88DI02), and see (88BE1T, 89NO1C). Structures in the (γ, α_0) cross section are reported at E_x = 18.2, 20.9, 22.1, and 24.2 MeV (82BA03; $E_{\rm brems.}$). The decay of the GDR to ^{14}C, ^{15}N, ^{16}O, ^{17}N and ^{17}O states has been studied: see (83AJ01). Less than 20% of the decay of states with $14.5 < E_x < 20$ MeV goes via the n_0 channel (87JU07). See (78AJ03, 87AJ02) for the earlier work.

24. ^{18}O(γ, γ)^{18}O

For ^{18}O*(6.20) $\Gamma_{\gamma_0} = 0.18 \pm 0.03$ eV, assuming $\Gamma_{\gamma_0}/\Gamma = 0.88$; $E_x = 6202.7 \pm 0.8$ keV: see (78AJ03).

25. ^{18}O(e, e$'$)^{18}O

Table 18.20
Resonances in $^{18}O + \gamma$

E_x (MeV) [a]				σ (mb)	Γ (MeV)
(γ, tot)	(γ, n)	(γ, 2n)	(γ, p)		
9.1	9.1			1.1 [b]	0.6
10.3	10.3			5.3 [b]	0.9
11.4	11.4			9.0 [b]	0.7
13.1	13.1	13.2		8.6 [b]	0.7
13.8	13.8	13.9		6.9 [b]	0.6
14.7	14.7	14.8		13.1 [b]	0.8
15.8	15.7	15.8		10.9 [b]	0.7
17.3 [c]	17.1		17.5	10.1 [b], 1.2 [e]	0.6
19.4 [c]		(19.1)	19.4	10.0 [b], 1.8 [e]	0.9
21.1 [d]		21.1	21.0	9.7 [b], 1.2 [e]	
22.6	(22.6)	22.7	22.7		
23.7 [d]	23.7	23.5	23.7	17.7 [b], 6.1 [e]	1.6
27 [c]	27		27–28		
30 [f]	30				
36 [f]					

[a]) (79WO04). See also (87JU07, 93MC02) and Table 18.9 in (83AJ01).
[b]) $\sigma(\gamma,\ n) + 2\sigma(\gamma,\ 2n)$.
[c]) $T = 2$: see (79WO04).
[d]) $T = 1$: see (79WO04).
[e]) $\sigma(\gamma,\ p)$.
[f]) Weak and broad resonances: may indicate the presence of particle-hole states at these high energies.

Table 18.21
Some states of ^{18}O from ^{18}O(e, e′) [a]

E_x (MeV)	Γ (keV)	$J^\pi; T$	Mult.	Transition probability (in $e^2 \cdot \mathrm{fm}^{2\lambda}$)
1.98 [b]		$2^+; 1$	C2	44.8 ± 1.3
3.55 [b]		$4^+; 1$	C4	$(9.04 \pm 0.90) \times 10^2$
3.92 [b]		$2^+; 1$	C2	22.2 ± 1.0
4.46 [c]		1^-		
5.10 [c]		3^-	C3	1301 ± 39
5.26 [b]		$2^+; 1$	C2	28.3 ± 1.5
5.53 ± 0.01 [e]	< 50	$2^-; 1$		
6.20 [c]		1^-		
6.35 ± 0.01 [e]	< 50	$(2^-); 1$		
6.40 [c]		3^-	C3	40 ± 9
7.12 [b]		$4^+; 1$	C4	$(1.31 \pm 0.06) \times 10^4$
7.62 [c]		1^-		
7.77 ± 0.01 [e]	< 50	$2^-; 1$		
7.86 [c]		5^-	C5	$(3.54 \pm 0.64) \times 10^4$
8.04 [c]		1^-		
8.13 [c]		5^-	C5	$(1.88 \pm 0.35) \times 10^4$
8.21 [d]		$2^+; (1)$	C2	7.3 ± 4.2
8.29 [c]		3^-	C3	≤ 19
8.41 ± 0.01 [e]	< 50	$(2^-); 1$		
8.52 ± 0.01 [e]	< 50	$(4^-); 1$		
8.82 ± 0.01 [e]	70 ± 12	$(1^+); 1$		
8.96 ± 0.01 [e]	43 ± 3	$(4^+); 1$		
9.36 ± 0.01 [d,e]	≤ 20	$(2^+); 1$		
9.71 ± 0.01 [e]	< 50	$(5^-); 1$		
10.31 ± 0.02 [e]	< 50	$(4^+); 1$		
10.43 ± 0.04 [e]	< 50	$(2^-); 1$		
10.67 ± 0.02 [e]	< 50	$(2^-); 1$		
10.99 ± 0.02 [e]	< 50	$(2^-); 1$		
11.52 ± 0.05 [e]	< 50	$(2^-); 1$		
11.67 ± 0.02 [e]	112 ± 7	$(3^-); 1$		
11.90 ± 0.03 [e]	< 50	$(2^-); 1$		
12.09 ± 0.02 [e]	< 50	$(1^-,\ 2^+); 1$		
12.41 ± 0.02 [e]	143 ± 24	$(3^-); 1$		
12.52 ± 0.02 [e]	< 50			
12.66 ± 0.02 [e]	< 50	$(2^-); 1$		
12.99 ± 0.02 [e]	68 ± 18	$(4^-); 1$		
13.40 ± 0.02 [e]	108 ± 26	$(2^-); 1$		
13.85 ± 0.13 [e]	~ 200	$(6^-); 1$		

Table 18.21 (continued)
Some states of ^{18}O from ^{18}O(e, e′) [a])

E_x (MeV)	Γ (keV)	J^π; T	Mult.	Transition probability (in $e^2 \cdot fm^{2\lambda}$)
14.17 ± 0.04 [e])	140 ± 50	(6^-); 1		
14.45 ± 0.05 [e])	~ 1070			
15.23 ± 0.04 [e])	~ 300			
15.95 ± 0.03 [e])	< 50			
16.210 ± 0.01 [f,g])		$1^{(-)}$		
16.315 ± 0.01 [f,g])		$(3,\ 2)^-$		
16.399 ± 0.005 [f,h])	< 20	2^-; 2 [i])	M2	$(64 \pm 8) \times 10^{-2}$
16.40 ± 0.02 [e])	< 50	(2^-); 2		
16.88 ± 0.03 [e])	< 50	$(4^-,\ 2^-;\ 1)$		
16.948 ± 0.01 [f,g])		$(3,\ 2)^-$		
17.025 ± 0.01 [e,f,g,h])	20 ± 6	(3^-); 2		
17.398 ± 0.01 [f,g])		$(2,\ 1,\ 3)^-$		
17.450 ± 0.01 [f,g])		$(2,\ 1,\ 3)^-$		
17.46 ± 0.03 [e])	~ 600	(4^-); 1		
17.5 [f])	≈ 150			
17.502 ± 0.01 [f,g])		$(1,\ 2,\ 3)^-$		
17.635 ± 0.01 [f,g])				
18.049 ± 0.01 [f,g])		[d])		
18.2 [f])	≈ 150			
18.45 ± 0.02 [e])	75 ± 27	$(3^-;\ 1)$		
18.5 [f])	≈ 4300			
18.68 ± 0.02 [e,h])	< 50	$(4^-;\ 2)$		63 ± 8 [h])
18.871 ± 0.005 [f])		1^+; 2	M1	$(3.1 \pm 0.4) \times 10^{-2}$
18.927 [f,g])		$1\ (2^+)$		
19.027 ± 0.01 [f,g])		$(1,\ 3)^-$		
19.150 ± 0.01 [f,g])		$1^-\ (2^+,\ 3^-)$		
19.22 ± 0.02 [e])	< 50	$(3^-;\ 2)$		
19.7 [f])	≈ 200			
20.2 [f])	≈ 180			
20.36 ± 0.02 [e,h])	< 20	(4^-); 2	M4	66 ± 6
20.86 ± 0.02 [e])	97 ± 41			
21.0 [f])	≈ 150			
21.42 ± 0.02 [e,h])	49 ± 37	$(4^-;\ 2)$		
22.40 ± 0.02 [e,f,h])	91 ± 8 [e])	$4^-;\ 2$ [e])	M4	400 ± 32
23.10 ± 0.02 [e])	49 ± 24			
23.8 [f])	~ 1300			

Table 18.21 (continued)
Some states of ^{18}O from ^{18}O(e, e′) [a]

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[a]) Additional states have been excited: see reaction 28 in (83AJ01). For ground state see reaction 25 here.
[b]) (82NO04).
[c]) (91MA14).
[d]) (90MA06).
[e]) (95SE1A).
[f]) (83BE36).
[g]) Weakly excited.
[h]) (86MA48).
[i]) See fig. 5 for missing $T = 2$ strength.

The ^{18}O charge radius, $\langle r^2\rangle^{1/2} = 2.784 \pm 0.020$ fm, based on studies of the elastic charge form factors for $E_e = 70$ to 370 MeV, the resulting determinations of the difference in the ^{18}O and ^{16}O radii, and the rms radius of ^{16}O: see (83AJ01).

Inelastic scattering has been reported to many states of ^{18}O: see (83AJ01, 87AJ02) and Table 18.21 here, which also includes the very recent work reported in (95SE1A). See also the comment (87MI25) and reply (87MA40) on the work reported in (86MA48). Recent measurements are reported for 4^- and 6^- states at $E_e = 140$–275 MeV (90SEZZ), and for 1^-, 3^-, 5^- states (91MA14). Form factor measurements for the 2^+ level at $E_x = 8.21$ MeV and the (2^+) level at $E_x = 9.3$ MeV at momentum transfer $0.9 < q < 2.1$ fm^{-1} (90MA06) and for the 1^-, 3^- and 5^- levels at $0.6 < q < 2.7$ fm^{-1} (91MA14) are reported.

Several theoretical studies of inelastic electron scattering to states of ^{18}O have been carried out. A microscopic calculation for scattering to 2^+ states is reported in (88HAZZ) and to 0^+ and 2^+ states in (88KU17). See also the calculations of transition charge densities described in (88GU03, 88GU12, 92GU11) and see (87GU1D, 88GU1B, 89AJ1A).

26. (a) ^{18}O($\pi^\pm$, $\pi^\pm$)^{18}O
(b) ^{18}O($\pi^\pm$, $\pi^\pm$p)^{17}N $Q_m = -15.942$
(c) ^{18}O(π^-, π^-n)^{17}O $Q_m = -8.044$

Angular distributions for the scattering to ^{18}O* (0, 1.98, 5.10) have been reported at $E_{\pi^\pm} = 29.2$ to 230 MeV [see (83AJ01)] and at 50 MeV (84TA1A; ^{18}O*(0, 1.98)) at 140, 180, and 220 MeV (84SE1A; ^{18}O*(1.98)), and at 164 MeV (87CH14; ^{18}O*(0, 1.98, 4.46, 5.10)) and (88SE04; ^{18}O*(1.98, 3.92, 5.26 MeV)). See also (89GR1M, 90WI1K). Measurements and analysis work reported in (83AJ01) determine $\langle r_n^2\rangle^{1/2} = 2.81 \pm 0.03$ fm, $\langle r_n^2\rangle^{1/2} - \langle r_p^2\rangle^{1/2} = 0.03 \pm 0.03$ fm. For a discussion of proton matter distribution in ^{18}O see (85BA27). Total reaction cross sections at $E_\pi = 50$ MeV have been determined by (87ME12). At $E = 165$ MeV, the cross section for reaction (c) is larger for ^{18}O than for ^{16}O while reaction (b) has a lower cross section (82PI06). For the (π^+, 2p), (π^+, pn) and (π^-, pn) reactions at $E_\pi = 165$ MeV see (84AL20, 86AL22).

Results of Glauber model calculations of pion scattering from ^{18}O at energies above the Δ_{33} resonance are presented in (91OS01). A microscopic study of inelastic scattering to the 2^+ states in ^{18}O is reported in (88HAZZ). See also the review of pion-nucleus physics in (91MO13).

27. ^{18}O(n, n′)^{18}O

Angular distributions have been measured for E_n = 2.9 to 24 MeV [see (72AJ02, 83AJ01)] and at E_n = 5.0 to 7.5 MeV (86KO10; n_0, n_1).

28. ^{18}O(p, p′)^{18}O

Angular distributions have been measured for E_p = 0.84 to 135 MeV [see (78AJ03, 83AJ01)], at E_p = 135 MeV (86KE05; p_1) and at E_p = 800 MeV (82GL08; p to ^{18}O*(0, 1.98, 7.12).) At E_p = 24.5 MeV (74ES02) have studied the angular distributions of the proton groups to ^{18}O*(1.98, 3.55, 3.63, 3.92, 4.46, 5.10, 5.26, 5.53, 7.12): a modified DWBA analysis leads to J^π = 2^+, 4^+, 0^+, 2^+, 1^-, 3^-, 2^+, 2^- and 4^+ for these states. A coupled-channels calculation suggests $\beta_2 = 0.37 \pm 0.03$, 0.56 ± 0.06 and 0.18 ± 0.04 for ^{18}O*(1.98, 5.10, 7.12). Such calculations also support evidence for a rotational band involving ^{18}O*(0, 1.98, 7.12). The 3^- state at 5.10 MeV is strongly excited and collective in nature: $B(E3) = 1120\ e^2 \cdot fm^6$. For ^{18}O*(1.98, 3.92, 5.26), $B(E2)$ = 45, 8.3 and 24 $e^2 \cdot fm^4$ (74ES02). The 800-MeV data indicates that ^{18}O*(7.12) can be described only if a large hexadecapole deformation is assumed (82GL08). At E_p = 201 MeV, $\sigma(\theta)$ at forward angles has been measured to ^{18}O*(8.21, 8.82, 16.40): it is proposed that ^{18}O*(8.82) has $J^\pi = 1^+$ and that additional 1^+ strength is located in a group centered at $E_x \approx 10.1$ MeV as well as in the region E_x = 12.4 to 15 MeV. The 1^+; $T = 2$ state ^{18}O*(18.87), reported in (e, e′), is not observed (87DJ01). See also (88CR1B).

^{18}O*(1.98) has $|g| = 0.287 \pm 0.015$ [$\tau_m = 2.99 \pm 0.12$ psec]. ^{18}O*(3.55) has $|g| = 0.62 \pm 0.10$ suggesting a mainly $(d_{5/2})^2$ configuration for this state: see (83AJ01). See also ^{19}F and (87AJ02).

A Dirac optical model analysis of ^{18}O(p, p) cross section and analyzing power at 800 MeV is described in (90PH02). A coupled-channels analysis was presented in (88DE31). The intrinsic radial sensitivity of nucleon inelastic scattering was studied by (88KE01) and a comparison of electromagnetic and hadronic probes of nuclear structure is described in (86KE1C).

29. ^{18}O($\bar{p}$, $\bar{p}'$)^{18}O

Angular distributions are reported with 178.4 MeV antiprotons to ^{18}O*(0, 1.98) (86BR04, 86LE13). For atomic effects see (86KO22). See also (87AJ02).

Differential cross sections for elastic and inelastic scattering of 180-MeV antiprotons by ^{18}O were calculated in the eikonal and Glauber approaches by (92TA08).

30. ^{18}O(d, d′)^{18}O

Angular distributions have been reported at $E_{\rm d}$ = 7.0 to 15.0 MeV: see (72AJ02, 83AJ01). See also ^{20}F of (87AJ02).

31. ^{18}O(t, t′)^{18}O

See (72AJ02).

32. ^{18}O(^{3}He, ^{3}He′)^{18}O

The elastic scattering has been studied at $E(^3{\rm He})$ = 11.0 to 41 MeV [see (72AJ02, 83AJ01)] and at 14 MeV (82AB04), at 25 MeV (82VE13) [the matter radius, $\langle r^2\rangle_{\rm m}^{1/2} = 2.59 \pm 0.12$ fm] and at 33 MeV (83LE03; also A_γ; and also to ^{18}O*(1.98)). A strong-absorption model analysis of angular distributions at 2.5 and 41 MeV is described in (87RA36). See also (85HA11, 87CO07).

33. ^{18}O(α, α′)^{18}O

Recent elastic scattering cross sections at E_α = 44.8 MeV were reported by (92AR18). Angular distributions of many α-groups have been measured in the range E_α = 21 to 40.5 MeV [see (78AJ03)], at 23.5 MeV (84SA28; to ^{18}O*(1.98, 3.56 + 3.63, 3.92, 4.45, 5.1–5.53)) and at 54.1 MeV (87AB03; g.s.). The transitions to ^{18}O*(4.46, 5.10) are $L = 1$ and 3, respectively, fixing $J^\pi = 1^-$ and 3^- for these states. Measurements of α-groups near 180° for E_α = 20.0 to 23.4 MeV confirm assignments of natural parity for ^{18}O*(1.98, 3.55, 3.63, 3.92, 4.46, 5.10, 5.26, 5.34, 6.20, 6.40, 7.12, 7.62, 7.86, 8.22, 8.29, 8.82, 8.96, 9.03, 9.10, 9.36, 9.41, 9.67, 9.72 ± 0.03, 9.88, 10.12, 10.30, 10.40, 11.62, 11.69). [See, however, Table 18.9.] Levels at $E_{\rm x}$ = 5.38, 8.48 and 8.64 MeV were not observed, and those at 5.53, 6.35 and 6.88 MeV were populated weakly indicating unnatural parity; $J^\pi = 3^+$ and 2^- respectively for ^{18}O*(5.38, 5.53).

Alpha-gamma correlation measurements involving ^{18}O states below $E_{\rm x}$ = 6.4 MeV [see Table 18.10] lead to $J^\pi = 1^-$ and 3^- for ^{18}O*(6.20, 6.40). Other J^π values agree with previous assignments. The transitions 3.92 → 1.98 and 5.26 → 1.98 are almost pure M1. For $\tau_{\rm m}$ measurements, see Table 18.4 in (78AJ03). For references see (83AJ01, 87AJ02). A microscopic investigation of the $\alpha + {}^{18}$O system in a three-cluster model is discussed in (88DE37).

34. (a) ^{18}O(^{6}Li, ^{6}Li$'$)^{18}O
    (b) ^{18}O(^{7}Li, ^{7}Li$'$)^{18}O

See (72AJ02, 83AJ01).

35. (a) ^{18}O(^{9}Be, ^{9}Be$'$)^{18}O
    (b) ^{18}O(^{9}Be, π^{-}n)X (not observed)

A recent search for a bound system of π^{-} and neutrons in the fragmentation region of ^{18}O + ^{9}Be collisions at 100 A MeV is reported in (93SU08). Upper limits were obtained.

See also (72AJ02, 87AJ02).

36. (a) ^{18}O(^{10}B, ^{10}B$'$)^{18}O
    (b) ^{18}O(^{11}B, ^{11}B$'$)^{18}O

An elastic angular distribution has been reported at $E(^{11}\text{B}) = 115$ MeV: see (83AJ01). For reaction (a) see (74AJ01).

A recent measurement of ^{18}O on ^{10,11}B targets at $E_{\text{lab}} \approx 55$ MeV is described in (93AN08) and evidence for fusion-fission rather than orbiting is reported. See also (90SZ1C).

37. (a) ^{18}O(^{12}C, ^{12}C$'$)^{18}O
    (b) ^{18}O(^{13}C, ^{13}C$'$)^{18}O
    (c) ^{18}O(^{14}C, ^{14}C$'$)^{18}O
    (d) ^{18}O(^{12}C, α^{12}C)^{14}C $Q_{\text{m}} = -6.227$

Elastic angular distributions have been studied at $E(^{18}\text{O}) = 32.3$ to 57.5 MeV for reaction (a) [as well as at $E(^{18}\text{O}) = 70$, 100, and 140 MeV (82HE07)] and at $E(^{18}\text{O}) = 31$ MeV for reaction (b). Yields and fusion cross sections are reported by (82BA49, 82HE07, 85BE40, 85CA01, 86GA13). For reaction (c) see (86ST1C). See also (83AJ01, 87AJ02).

Angular correlations (reaction (d)) have been studied at $E(^{18}\text{O}) = 82$ MeV. ^{18}O*(7.10, 7.62, 7.86, 8.04, 8.22, 10.30, 11.59, 12.55) are observed: the first seven of these have $J^{\pi} = 4^{+}, 1^{-}, 5^{-}, 1^{-}, 2^{+}, 4^{+}, 5^{-}$ (84BH01, 84RA07). In addition ^{18}O*(9.33, 9.65) are also populated [$\Gamma \approx 0.3$ MeV]: a possible interpretation of the data is that these two are 3^{-} states and that there is in addition a very wide (>1 MeV) 2^{+} state at ≈ 9.5 MeV (84RA17). See also (87AJ02).

Giant dipole decays in nuclei excited by ^{18}O+^{12}C collisions were discussed in (89BEZC, 90SN1A). Competition between p2n, dn and t emissions in the ^{12}C + ^{18}O reaction was studied in an experiment reported in (90XE01).

Predictions of possible resonant behavior in medium-mass colliding systems are discussed in (89CI1C). Molecular single particle effects for $^{12}C + ^{18}O$ are explored in calculations described in (87MO27).

38. $^{18}O(^{15}N, ^{15}N')^{18}O$

See (83DU13).

39. $^{18}O(^{16}O, ^{16}O')^{18}O$

Angular distributions have been measured at many energies for $E(^{16}O) = 24$ to 54.5 MeV and $E(^{18}O) = 25$ to 52 MeV, involving besides $^{18}O_{g.s.}$, $^{18}O^*(1.98, 3.55 + 3.63, 3.92, 4.46, 5.10, 7.12)$. At $E(^{18}O) = 126$ MeV, $^{18}O^*(9.0)$ is relatively strongly populated. See (83AJ01). For yields and fusion cross sections, including the effect of $^{18}O^*(1.98)$, see (85TH03, 85WU03, 86GA13, 86TH01). See also (87AJ02). Competition between p2n, dn and t emissions in $^{18}O + ^{16}O$ reactions was studied in an experiment reported in (90XE01).

A unified description of sub-barrier interactions of oxygen isotopes is discussed in (87PO11); see the coupled-channels calculations reported in (92LI1K). See also the review of sub-barrier fusion in (88BE1W). A semi-classical analysis of two particle transfer in $^{16}O + ^{18}O$ reactions is discussed in (87MA22).

40. (a) $^{18}O(^{17}O, ^{17}O')^{18}O$
(b) $^{18}O(^{18}O, ^{18}O')^{18}O$

Angular distributions involving $^{18}O^*(0, 1.98)$ are reported at $E(^{17}O) = 36$ MeV. Angular distributions [reaction (b)] have been studied at $E(^{18}O) = 20$ to 52 MeV. $^{18}O^*(3.55 + 3.63, 4.46, 5.10, 7.12)$ are also populated; see (78AJ03, 83AJ01). See also (87AJ02) and see (90XE01) reporting on p2n, dn and t emissions in $^{18}O + ^{18}O$ reactions.

The effect of high spin states on fusion in $^{18}O + ^{18}O$ systems has been studied in the framework of a statistical theory (87RA28).

41. $^{18}O(^{19}F, ^{19}F')^{18}O$

The elastic scattering has been studied at $E(^{19}F) = 27$, 30, and 33 MeV: see (83AJ01). See also (87AJ02). An experiment reported in (90XE01) studied p2n, dn and t emission in $^{18}O + ^{19}F$ reactions.

42. (a) ^{18}O(^{24}Mg, ^{24}Mg$'$)^{18}O
(b) ^{18}O(^{26}Mg, ^{26}Mg)^{18}O

Angular distributions are reported for reaction (a) at $E(^{18}\text{O}) = 29$ and 35 MeV to ^{18}O*(0, 1.98). See (87AJ02).

43. ^{18}O(^{27}Al, ^{27}Al$'$)^{18}O

The elastic angular distribution has been studied at $E(^{18}\text{O}) = 100$ MeV (81ME13). See also (83AJ01, 87AJ02).

44. ^{18}O(^{28}Si, ^{28}Si$'$)^{18}O

Elastic angular distributions are reported at $E(^{18}\text{O}) = 36$ to 56 MeV [see (83AJ01)] and at 351.7 MeV (84BU1A, 88BU15; also to ^{18}O*(1.98)). See also (87AJ02).

Ambiguities in optical-model potentials for describing $^{18}\text{O} + {}^{28}\text{Si}$ and other heavy-ion reactions are discussed in (87HO18). See also (89NA1M).

45. (a) ^{18}O(^{40}Ca, ^{40}Ca$'$)^{18}O
(b) ^{18}O(^{44}Ca, ^{44}Ca$'$)^{18}O
(c) ^{18}O(^{48}Ca, ^{48}Ca$'$)^{18}O

Angular distributions have been measured at $E(^{18}\text{O}) = 62.1$ MeV [reaction (a)] for the transitions to ^{18}O*(0, 1.98, 5.10) (82RE14). For a fusion study [reaction (b)] see (84DE1B). See also (87AJ02, 87SC34).

46. ^{18}F(β^+)^{18}O $\qquad Q_{\text{m}} = 1.655$

See ^{18}F, reaction 1.

47. ^{19}F(γ, p)^{18}O $\qquad Q_{\text{m}} = -7.994$

(85KE03) have measured the yields of proton groups to ^{18}O*(0, 1.98) [and to unresolved states] for E_{bs} in the GDR range. See also (78AJ03) and ^{19}F, reaction 36.

Table 18.22
^{18}O states from ^{19}F(t, $\alpha\gamma$) [a])

E_x (keV)	J^π	E_x (keV)	J^π
1982.16 ± 0.20		5530.5 ± 0.6	1, 2
3555.07 ± 0.45		6196.3 ± 1.2	1
3634.50 ± 0.40		6351.3 ± 0.6	1, 2
3920.6 ± 0.4		6404.4 ± 1.2	
4456.1 ± 0.5		6881.6 ± 1.2	0, (1)
5098.5 ± 1.2		7116.9 ± 1.2	
5260.4 ± 1.2		7750	1–4
5336.4 ± 0.6		7980	1–5
5377.8 ± 1.2		[b])	

[a]) (73OL02): See Table 18.10 for branching ratios and Table 18.9 for τ_m. See also Table 18.10 in (83AJ01).
[b]) Alpha groups are also reported to ^{18}O states with E_x = 7.60, 7.75, 7.84, 7.96, 8.02, 8.11, 8.19, 8.26, 8.39, 8.48, 8.64 MeV (± 20 keV) (62HI06).

48. ^{19}F(n, d)^{18}O $\qquad Q_m = -5.770$

Angular distributions have been measured at E_n = 14 to 14.4 MeV: see (72AJ02). See also (78AJ03) and ^{20}F of (87AJ02). Nuclear model calculations for E_n = 2–20 MeV are described in (92ZH15).

49. ^{19}F(p, pp)^{18}O $\qquad Q_m = -7.994$

Experimental and theoretical studies of knockout reactions are reviewed in (87VD1A).

50. ^{19}F(d, ^{3}He)^{18}O $\qquad Q_m = -2.500$

Many states of ^{18}O (E_x < 14.6 MeV) have been populated in this reaction: see Table 18.8 in (78AJ03). [Comment: Note, however, density of states.] Analyzing powers for the ground-state transition are reported at E_d = 12.4 MeV (83EN02). See also (83KI13).

51. ^{19}F(t, α)^{18}O $\qquad Q_m = 11.820$

See Table 18.22.

52. ^{22}Ne(d, ^{6}Li)^{18}O $\qquad Q_{\rm m} = -8.192$

At $E_{\rm d} = 80$ MeV angular distributions have been measured for the ^{6}Li groups to the ground state of ^{18}O and to excited states at 1.98, 3.57, 5.10, 6.30, 7.8, 9.4 [± 0.04] MeV (84OE02) [see also for $S_{\rm rel.}$]. For the earlier work see (83AJ01).

^{18}F

GENERAL: See Table 18.23.

$$\mu_{1.12} = +2.86 \pm 0.03 \text{ n.m. [see (83AJ01)]}$$
$$Q_{1.12} = 0.13 \pm 0.03 \text{ b [see (83AJ01)].}$$

Table 18.23
^{18}F – general

Reference	Description
	Model Calculations
87LE1L	Low-lying non-normal parity states of ^{18}O & ^{18}F calculated in shell model + tensor force
87SH1O	Validity of M-3Y force equivalent G-matrix element for sd-shell nucl. struc. calcs.
88BR11	Semi-empirical effective interactions for the 1s-0d shell
89HJ03	Effective interactions through 3rd order for $A = 18$ nuclei with the Paris potential
89TR18	2-nucleon and 4-nucleon clusters in light & heavy nuclei
89ZH05	Evidence for unnatural parity-pairing correlations in some light nuclei
90HJ03	Choice of single-particle potential & the convergence of the effective interaction
90SK04	Study of $A = 18$ nuclei and the effective interaction in the sd shell
90SK1C	Effective interaction derived from the BAGEL approach
92HJ01	Folded-diagram effective interactions with the Bonn meson-exchange potential model
92JI04	Bonn potential used to evaluate energy spectra of some light sd-shell nuclei
92WA22	Effective interactions for the 0p1s0d nuclear shell-model space
	Special States
Review:	
89RA17	Compilation of exp. data on nuclear moments for ground & excited states of nucl.
Other Articles:	
87LE1L	Non-normal parity states of ^{18}O & ^{18}F calculated in shell model + tensor force
87MU16	Relativistic effects in the low-energy spectra of 1s0d-shell nuclei
87SH1O	Validity of M-3Y force equivalent G-matrix element for sd-shell nucl. struc. calcs.
88ET01	Analysis of magnetic dipole transitions between sd-shell states

Table 18.23 (continued)
^{18}F – General

Reference	Description
	Special States (continued)
89HJ03	Effective interactions through 3rd order for $A = 18$ nuclei with the Paris potential
89ZH05	Evidence for unnatural parity-pairing correlations in some light nuclei
90HJ01	3rd order number-conserving sets & effective interactions calc. with Bonn-Jülich potential
90HJ03	Choice of single-particle potential & the convergence of the effective interaction
90SK04	Study of $A = 18$ nuclei and the effective interaction in the sd shell
	Electromagnetic
Reviews:	
88HE1E	Report on charge symmetry, charge independence, parity and time reversal invariance
89MC1C	Nuclear tests of fundamental interactions
89RA17	Compilation of exp. data on nuclear moments for ground & excited states of nucl.
Other articles:	
88ET01	Analysis of magnetic dipole transitions between sd-shell states
88KA1U	Evaluation of the weak pion-nucleon vertex; predicts γ-asymmetry in ^{18}F
93EN03	Strengths of γ-ray transitions in $A = 5$–44 nuclei
	Astrophysical
Reviews:	
87RA1D	Nuclear processes & accelerated particles in solar flares
89WH1B	Abundance ratios as a function of metallicity
90AR10	Nuclear reactions in astrophysics
Other articles:	
87GO1G	Measurement of ^{21}Ne(p, α)^{18}F & its astrophysical implications (A)
88CA1N	Analytic expressions for thermonuclear reaction rates involving $Z \leq 14$ nuclei
89JI1A	Nucleosynthesis inside thick accretion disks around massive black holes
90TH1C	Explosive nucleosynthesis in SN 1987A: composition, radioactivities, neutron star mass
	Applications
Review:	
89WO1B	Biomedical applications of particle accelerators (A)
Other articles:	
88HI1F	Design & uses of positron emission tomography target systems (A)
88VO1D	Radionuclide production for positron emission tomography: accelerator choices (A)
88VO1E	Water targetry for ^{18}F prod. (calc. & exp. verification of beam heating & heat removal) (A)
89AR1J	Production and acceleration of radioactive ion beams at Louvain-la-Neuve
	Complex Reactions
87BU07	Projectile-like fragments from ^{20}Ne + ^{197}Au: counting simultaneously emitted neutrons
87FE04	Single-nucleon transfer reactions induced by 376-MeV ^{17}O on ^{208}Pb (DWBA analysis)

Table 18.23 (continued)
^{18}F – General

Reference	Description
	Complex Reactions (continued)
87HI05	Energy & linear-momentum dissipation in the fusion reaction ^{165}Ho + ^{20}Ne at 30 MeV/A
89SA10	Total cross sections of reactions induced by neutron-rich light nuclei
90GL01	Structure phenomena in the orbiting ^{12}C + ^{24}Mg system
	Hypernuclei
88MA1Q	Identification of one glue-like mechanism of the Λ-hyperon in hypernuclei
89BA2N	Evaluation of hypernucleus production cross-sections in relativistic heavy-ion collisions
89TA1T	Schmidt diagrams & configuration mixing effects on hypernuclear magnetic moments
	Symmetries and Fundamental Interactions
86AD1A	Parity and time-reversal violation in nuclei and atoms
86HA1I	Fundamental interaction studies in nuclei
88HE1C	Studies of symmetries and symmetry breaking using nuclei
88HE1E	Status report on charge symmetry & charge independence
89MC1C	Nuclear tests of fundamental interactions
	Other Topics
Review	
89AJ1A	Summary of recent work involving light nuclei (Sec. 4.2 covers $A = 18$)
Other articles:	
87MU16	Relativistic effects in the low-energy spectra of 1s0d-shell nuclei
88KA1U	Evaluation of the weak pion-nucleon vertex; predicts γ-asymmetry in ^{18}F
88TR02	Interacting boson scheme for light nuclei
89GE10	Threshold pion-nucleus amplitudes as predicted by current algebra
89ZH05	Evidence for unnatural parity-pairing correlations in some light nuclei
90HJ01	3rd order number-conserving sets & effective interactions calc. with Bonn-Jülich potential
90KA1F	Theoretical aspects of nuclear parity violation
90SK04	Study of $A = 18$ nuclei and the effective interaction in the sd shell
90SK1C	Effective interaction derived from the BAGEL approach
	Ground State Properties
Review:	
89RA17	Compilation of exp. data on nuclear moments for ground & excited states of nucl.
Other articles:	
89SA10	Total cross sections of reactions induced by neutron-rich light nuclei
89TR18	2-nucleon and 4-nucleon clusters in light & heavy nuclei
91UE01	Unitary pole approx. for Coulomb+Yamaguchi potential used for 3-body bound-state calc.

(A) denotes that only an abstract is available for this reference.

Table 18.24
Energy levels of ^{18}F [a])

E_x (MeV ± keV)	$J^\pi; T$	K^π	τ or $\Gamma_{c.m.}$	Decay	Reactions
0	$1^+; 0$	0^+	$\tau_{1/2} = 109.77 \pm 0.05$ min	β^+	1, 4, 5, 6, 9, 10, 12, 13, 15, 21, 23, 24, 25, 29, 31, 34, 35, 36, 37, 38, 40, 41, 42, 43, 44
0.93720 ± 0.06	$3^+; 0$	0^+	$\tau_m = 67.6 \pm 2.5$ psec ($g = +0.56 \pm 0.05$)	γ	2, 6, 9, 10, 13, 21, 23, 25, 30, 31, 35, 36, 38, 40, 41, 42, 44
1.04155 ± 0.08	$0^+; 1$		$\tau_m = 2.55 \pm 0.45$ fsec	γ	6, 9, 21, 25, 30, 31, 34, 35, 37, 38, 40, 42, 43
1.08054 ± 0.12	$0^-; 0$	0^-	$\tau_m = 27.5 \pm 1.9$ fsec	γ	6, 9, 10, 21, 25, 35, 37, 38, 40, 41, 42, 44
1.12136 ± 0.15	$5^+; 0$	0^+	$\tau_m = 234 \pm 10$ nsec ($\mu = +2.86 \pm 0.03$ n.m.) ($Q = 0.13 \pm 0.036$ b)	γ	5, 6, 9, 10, 13, 14, 21, 22, 25, 30, 31, 32, 35, 37, 40, 42, 44
1.70081 ± 0.18	$1^+; 0$	1^+	$\tau_m = 955 \pm 27$ fsec	γ	6, 10, 21, 25, 34, 35, 40, 42, 43, 44
2.10061 ± 0.10	$2^-; 0$	0^-	$\tau_m = 5.1 \pm 0.5$ psec	γ	6, 10, 13, 21, 23, 25, 35, 40, 42, 44
2.52335 ± 0.18	$2^+; 0$	1^+	$\tau_m = 590 \pm 24$ fsec	γ	6, 10, 21, 25, 30, 31, 40, 42
3.06184 ± 0.18	$2^+; 1$		$\tau_m < 1.2$ fsec	γ	6, 21, 25, 30, 31, 35, 38, 40, 42, 43
3.13387 ± 0.15	$1^-; 0$	1^-	$\tau_m = 0.39 \pm 0.02$ psec	γ	6, 10, 21, 25, 35, 38, 40, 42
3.3582 ± 1.0	$3^+; 0$	1^+	$\tau_m = 0.44 \pm 0.03$ psec	γ	6, 10, 21, 35, 40, 42, 44
3.72419 ± 0.22	$1^+; 0$		$\tau_m = 2.7^{+4.1}_{-2.7}$ fsec	γ	6, 10, 21, 23, 25, 31, 34, 35, 40, 42, 44
3.79149 ± 0.22	$3^-; 0$	1^-	$\tau_m = 1.91 \pm 0.13$ psec	γ	5, 10, 21, 23, 25, 35, 40, 42, 44
3.83917 ± 0.22	$2^+; 0$		$\Gamma = 19.0 \pm 2.7$ keV	γ	6, 10, 21, 23, 25, 30, 35, 40, 42, 44
4.11590 ± 0.25	$3^+; 0$		$\tau_m = 91 \pm 22$ fsec	γ	6, 10, 21, 23, 25, 30, 31, 35, 40, 42, 44
4.2258 ± 0.7	$2^-; 0$	(1^-)	$\tau_m = 110 \pm 15$ fsec	γ	6, 10, 21, 23, 35, 40, 42, 44
4.36015 ± 0.26	$1^+; 0$		$\tau_m = 27 \pm 10$ fsec	γ	10, 21, 25, 34, 35, 40, 42, 44
4.3981 ± 0.7	$4^-; 0$	0^-	$\tau_m = 58 \pm 12$ fsec	γ	6, 10, 13, 14, 21, 35, 40, 42, 44
4.652 ± 2	$4^+; 1$		$\tau_m < 10$ fsec	γ	6, 21, 24, 30, 31, 35, 40, 42

Table 18.24 (continued)
Energy levels of ^{18}F [a])

E_x (MeV ± keV)	$J^\pi; T$	K^π	τ or $\Gamma_{c.m.}$	Decay	Reactions
4.753 ± 3	$0^+; 1$			γ	21, 35, 38, 40, 42, 44
4.8483 ± 0.5	$5^-; 0$	1^-	$\tau_m = 5.2 \pm 0.9$ psec	γ	5, 23
4.860 ± 2	$1^-; 0$		$\tau_m = 66 \pm 18$ fsec	γ, α	6, 21, 40, 42, 44
4.9636 ± 0.8	$2^+; 1$		$\tau_m < 4$ fsec	γ	6, 21, 30, 40, 42
5.2976 ± 1.5	$4^+; 0$	1^+	$\tau_m = 30 \pm 5$ fsec	γ, α	6, 9, 10, 11, 21, 40, 42
5.502 ± 2	$3^{(-)}; 0$		$\tau_m = 63 \pm 25$ fsec	γ, α	6, 10, 21, 40, 42
5.60338 ± 0.27	1^+		$\Gamma = 43.3 \pm 1.6$ eV	γ, α	6, 8, 25, 40, 42, 44
5.60486 ± 0.28	$1^-; 0+1$		$\Gamma < 1.2$ keV	γ, α	6, 8, 10, 21, 25, 40, 42, 44
5.67257 ± 0.32 [d])	$1^-; 0+1$		$\Gamma < 0.8$ keV	γ, α	6, 8, 10, 21, 25, 40, 42, 44
5.786 ± 2.4	$2^-; 0$		$\tau_m = 15 \pm 10$ fsec	γ, α	6, 21, 40, 42, 44
6.0964 ± 1.1	$4^-; 0$	1^-	$\Gamma = 0.24 \pm 0.03$ keV	γ, p, α	6, 10, 21, 25, 29, 40, 42, 44
6.108 ± 3	$(1^+); 0$		$\Gamma = 0.034 \pm 0.003$ keV	γ, p, α	6, 8, 21, 23, 29, 42, 44
6.13647 ± 0.33	$0^+; 1$		$\Gamma \leq 1$ keV	γ, p	21, 25, 27, 42, 44
6.1632 ± 0.9	$3^+; 1$		$\Gamma = 14 \pm 0.5$ keV	γ, p, α	21, 25, 27, 42, 44
6.2404 ± 0.8	$3^-; 0+1$		$\Gamma = 0.19 \pm 0.03$ keV	γ, p, α	6, 21, 25, 27, 29, 42
6.242 ± 3	$3^-; 0+1$		$\Gamma = 0.18 \pm 0.04$ keV	γ, p, α	6, 8, 21, 25, 29, 42
6.262 ± 2.5	$1^+; 0$		$\Gamma = 0.60 \pm 0.12$ keV	γ, p, α	6, 8, 10, 21, 29, 34, 42
6.2832 ± 0.9	$2^+; 1$		$\Gamma = 10.0 \pm 0.5$ keV	γ, p, α	21, 25, 27, 29
6.3105 ± 0.8	$3^+; 0$		$\Gamma = 0.95 \pm 0.14$ keV	γ, p, α	6, 21, 25, 27, 29, 44
6.3855 ± 1.7	$2^+; 0+1$		$\Gamma = 0.49 \pm 0.09$ keV	γ, p, α	6, 21, 25, 29, 42
6.4849 ± 1.5	$3^+; 0$		$\Gamma = 0.40 \pm 0.10$ keV	γ, p, α	6, 21, 25, 29, 42, 44
6.5670 ± 1.5	$5^+; 0$	1^+	$\Gamma = 0.56 \pm 0.13$ keV	γ, p, α	6, 8, 9, 10, 11, 21, 29, 42
6.633 ± 10	1		$\Gamma = 80 \pm 2$ keV	p, α	29, 42
6.6437 ± 0.8	$2^-; 1$		$\Gamma = 0.60 \pm 0.07$ keV	γ, p, α	6, 7, 21, 25, 29
6.647 ± 4	1^-		$\Gamma = 91 \pm 4$ keV	p, α	8, 10, 29
6.777 ± 1.4	$4^+; 0$		$\Gamma = 9.2 \pm 1.0$ keV	γ, p, α	21, 25, 27, 29, 42
6.8031 ± 1.5	$1^+, 2, 3^+; 0$		$\Gamma \leq 2$ keV	γ, p	10, 21, 25, 27, 42
6.809 ± 5	2^-		$\Gamma = 88 \pm 2$ keV	p, α	7, 8, 29
6.811	(2^+)		$\Gamma = 3.0 \pm 0.5$ keV	p, α	29
6.857 ± 10	(3^-)		$\Gamma = 5.0 \pm 1.0$ keV	p, α	29, 42
6.8774 ± 1.7	$3, 4^-; 0$		$\Gamma \leq 2$ keV	γ, p, α	21, 25, 29
7.201 ± 2	$(4^+); 0$		$\Gamma = 6.5$ keV	p, α	8, 20, 42
7.247 ± 2	$(1^+); 0$		$\Gamma = 46.5$ keV	p, α	8, 29

Table 18.24 (continued)
Energy levels of ^{18}F [a])

E_x (MeV ± keV)	$J^\pi; T$	K^π	τ or $\Gamma_{c.m.}$	Decay	Reactions
7.291 ± 2	3^-		$\Gamma = 38$ keV	p, α	7, 8, 27, 29
7.315 ± 4	$(3^-; 0)$		$\Gamma = 52$ keV	p, α	29, 42
7.336 ± 2	$1^-; 1$		$\Gamma = 16 \pm 2$ keV	γ, p	25, 27
7.406 ± 2	1^+		$\Gamma = 14.6 \pm 1.4$ keV	p	27
7.447 ± 10			$\Gamma = 140$ keV	p, α	29, 31
7.454 ± 2	1^-		$\Gamma = 6$ keV	p	27
7.478 ± 2	(2)		$\Gamma = 12 \pm 3$ keV	γ, p, α	25, 27, 29
(7.485 ± 2)	(1^-)		$\Gamma = 32$ keV	p	27
7.506 ± 2	4^-		$\Gamma = 12 \pm 2$ keV	p, α	27, 29
7.513 ± 2			$\Gamma < 4$ keV	γ, p	25
7.528 ± 2	$2^-; 1$		$\Gamma = 16.5 \pm 3.0$ keV	γ, p, α	25, 27, 29
7.532 ± 5			$\Gamma = 75$ keV	p, α	27, 29
7.555 ± 2	(1^-)		$\Gamma = 30$ keV	p	27
7.584 ± 2			$\Gamma = 9 \pm 2$ keV	γ, p, α	25, 27, 29
7.685 ± 2	$3^+, 4^+$		$\Gamma = 36 \pm 4$ keV	p, α	27, 29
7.729 ± 4	≥ 1		$\Gamma = 66 \pm 5$ keV	p, α	27, 29
7.763 ± 4			$\Gamma = 70$ keV	p	27
7.878 ± 3	≥ 2		$\Gamma = 20$ keV	p, α	27, 29
7.899 ± 2	(2^-)		$\Gamma = 38$ keV	p, α	7, 8, 29
7.941 ± 12	(1^+)		$\Gamma = 112$ keV	p, α	7, 8, 29
8.064 ± 6	≥ 4		$\Gamma = 60$ keV	p, α	27, 29
8.115 ± 8			$\Gamma = 96$ keV	p	27
8.209 ± 2	2^-		$\Gamma = 52$ keV	p, α	27, 29
8.238 ± 2	4^+		$\Gamma = 20$ keV	p	27
9.02	$(5^-; 1)$				31
9.207 ± 15 [b])	$3, 4^-; 0$			p, d, α	16, 17, 18
9.50	$2, 3^+; 0$			n, d, α	16, 18
9.58 ± 20 [c])	6^+	1^+		d, α	9, 10, 11, 22, 31
10.58 ± 50					11
11.22 ± 30	7^+	1^+		d, α	9, 10, 11
12.75	$(6^-; 1)$				31
13.83	$4^-, 5^+$		$\Gamma = 60$ keV	d, α	18
14.02	$4^-, 5^+$		$\Gamma = 60$ keV	d, α	18
14.10	$4^-, 5^+$		$\Gamma = 60$ keV	d, α	18
14.18 ± 40	(8^+)	(1^+)		d, α	9, 10, 11

Table 18.24 (continued)
Energy levels of ^{18}F [a])

E_x (MeV ± keV)	J^π; T	K^π	τ or $\Gamma_{c.m.}$	Decay	Reactions
14.65	(7^+)				31
15.09	4^-, 5^+			d, α	18
15.34	5^+, 6^-			d, α	18
15.79 ± 100	$(6^-; 1)$				11, 31
16.07	4^-, 5^+		$\Gamma = 220$ keV	d, α	18
16.72	4^-, 5^+		$\Gamma = 60$ keV	d, α	18
17.43	4^-, 5^+, 6^-		$\Gamma = 70$ keV	d, α	18
18.62 ± 120					11
(19.00 ± 150)			$\Gamma = (500 \pm 150)$ keV	γ, ^{3}He	12
20.1 ± 200	$(2^-; 1)$		$\Gamma = 1600 \pm 100$ keV	γ, ^{3}He	12
22.7 ± 200	$(2^-; 1)$		$\Gamma = 1200 \pm 100$ keV	γ, ^{3}He	12
(24.1 ± 200)			$\Gamma = (1400 \pm 300)$ keV	γ, ^{3}He	12

[a]) See also Table 18.25 for radiative transitions and 18.26 for τ_m.
[b]) Uncertainty estimated by evaluators.
[c]) For other states with $E_x < 9.6$ MeV see footnote (e) in Table 18.17 of (78AJ03) and Table 18.27 here. For other states with $10.0 < E_x < 19.6$ MeV see Table 18.27 here, and Tables 18.14 and 18.16 in (78AJ03). These two tables in (78AJ03) display the states deduced from the yields of the isospin-forbidden α_1 groups in ^{14}N + α and ^{16}O + d, respectively. (76CH24) reports 151 isospin-mixed natural-parity states with $10.4 < E_x < 17.5$ MeV [^{14}N(α, α_1)] and (73JO13) reports 138 such states with $9.2 < E_x < 19.4$ MeV [^{16}O(d, α_1)] of which 16 have $E_x > 17.5$ MeV. In the region $10.4 < E_x < 20.8$ MeV some 167 states with mixed isospin and natural parity have been reported. See also reaction 29.
[d]) (89BO01).

Table 18.25
Radiative decays in ^{18}F [a])

E_i (MeV)	J^π_i	E_f (MeV)	Branch (%)	Widths and Mixing Ratios
0.94	$3^+; 0$	0	100	
1.04	$0^+; 1$	0	100	
1.08	$0^-; 0$	0	100	
1.12	$5^+; 0$	0.94	100	
1.70	$1^+; 0$	0	29.8 ± 1.3	
		1.04	70.2 ± 1.3	
2.10	$2^-; 0$	0	38 ± 1	$\Gamma_\gamma = (4.6 \pm 2.2) \times 10^{-5}$ eV
		0.94	31 ± 1	$\Gamma_\gamma = (4.0 \pm 1.9) \times 10^{-5}$ eV
		1.08	31 ± 1	

Table 18.25 (continued)
Radiative decays in ^{18}F [a])

E_i (MeV)	J^{π}_i	E_f (MeV)	Branch (%)	Widths and Mixing Ratios
2.52	$2^+; 0$	0	74.9 ± 1.8	$\delta = 3.0 \pm 1.0$
		0.94	21.5 ± 1.2	$\delta = -(1.5 \pm 0.6)$
		1.70	3.9 ± 0.6	$\delta = 0.94 \pm 0.4$
3.06	$2^+; 1$	0	23.2 ± 0.8	
		0.94	76.7 ± 0.8	
		1.04	0.11 ± 0.03	
3.13	$1^-; 0$	0	39 ± 2	$\delta = +(0.07 \pm 0.05)$ $\Gamma_\gamma = (5.7 \pm 2) \times 10^{-4}$ eV
		1.04	34 ± 2	$\Gamma_\gamma = (7.3 \pm 2.7) \times 10^{-4}$ eV
		1.08	25 ± 2	$\Gamma_\gamma = (4.8 \pm 1.8) \times 10^{-4}$ eV
		1.70	2.0 ± 0.5	$\delta = +(0.22 \pm 0.15)$
3.36	$3^+; 0$	0	45 ± 5	
		0.94	9 ± 3	
		1.70	40 ± 4	
		2.10	< 3	
		2.52	6 ± 3	$\delta = -0.4^{+0.3}_{-0.5}$
3.72	$1^+; 0$	0	5 ± 2	
		1.04	91 ± 2	$\Gamma_\gamma = (1.3 \pm 0.2) \times 10^{-3}$ eV [c])
		3.06	4 ± 2	
3.79	$3^-; 0$	2.10	68 ± 4	$\delta = -(0.22 \pm 0.06)$
		2.52	2.2 ± 1.1	
		3.06	30 ± 3	$\delta = -(0.09 \pm 0.09)$
3.84	$2^+; 0$	0	38 ± 2	$\delta = -(1.8 \pm 0.5)$
		0.94	8.9 ± 1.4	$\delta = -(0.3 \pm 0.3)$
		1.70	3.0 ± 1.0	
		3.06	50 ± 3	$\delta = -(0.1 \pm 0.3)$
4.12	$3^+; 0$	0	5 ± 3	
		3.06	95 ± 3	$\delta = +0.06 \pm 0.07$
4.23	$2^-; 0$	0	23 ± 2	$\delta = 0.15 \pm 0.15$
		0.94	49 ± 3	$\delta = 0.0 \pm 0.2$
		1.08	3.2 ± 1.0	
		1.70	9.3 ± 1.2	
		2.10	15 ± 5	
		3.13	0.9 ± 0.6	
4.36	1^+	3.06	100	
4.40	$4^-; 0$	0.94	13 ± 4	$\delta = -(0.2 \pm 0.3)$
		1.12	60 ± 6	$\delta = -(0.2 \pm 0.2)$
		2.10	27 ± 3	
4.65	$4^+; 1$	0.94	17 ± 3	
		1.12	83 ± 3	$\delta = 0.15 \pm 0.15$

Table 18.25 (continued)
Radiative decays in ^{18}F [a])

$E_{\rm i}$ (MeV)	$J^{\pi}_{\rm i}$	$E_{\rm f}$ (MeV)	Branch (%)	Widths and Mixing Ratios
4.75	0^+; 1	0	92 ± 4	
		1.70	8 ± 4	
4.85 [b])	5^-; 0	1.12	65 ± 4	
		3.79	35 ± 4	
4.86	1^-; 0	1.04	65 ± 11	
		1.08	8 ± 6	
		3.06	23 ± 7	$\delta = -(0.4 \pm 0.4)$
		3.13	4 ± 3	
4.96	2^+; 1	0	100	$\delta = 1.2 \pm 0.7$
5.30	4^+; 0	0.94	9 ± 2	$\delta = -(0.3 \pm 0.1)$
		1.12	7 ± 2	$\delta = -(1.1 \pm 0.5)$
		2.52	78 ± 3	$\Gamma_\gamma = 1.2 \pm 0.4 \times 10^{-2}$ eV [c])
		3.36	5 ± 1	$\delta = 2.5 \pm 0.8$
		4.65	1.3 ± 0.3	
5.50	$3^{(-)}$; 0	3.06	100	$\Gamma_\gamma = 2.1 \pm 0.7 \times 10^{-3}$ eV [c])
5.603	1^+	0	16.7 ± 2.3	$\Gamma_\gamma = 0.485 \pm 0.046$ eV [e])
		1.04	3.8 ± 1.2	
		3.06	79.5 ± 5.9	
5.605	1^-; $0+1$	0	6.7 ± 1.2	
		1.04	4.2 ± 0.8	
		1.08	54.3 ± 3.1	$\Gamma_\gamma = 0.87 \pm 0.07$ eV [c])
		3.06	2.6 ± 1.4	
		3.13	32.2 ± 2.5	$\delta = -0.05 \pm 0.02$
5.67	1^-; $0+1$	0	6.2 ± 0.4	$\delta = -0.01 \pm 0.04$
		1.04	8.1 ± 0.7	
		1.08	52 ± 3	$\Gamma_\gamma = 0.46 \pm 0.06$ eV [c])
		1.70	0.8 ± 0.3	
		2.10	0.4 ± 0.2	
		3.06	4.0 ± 0.4	$\delta = 0.04 \pm 0.06$
		3.13	28.5 ± 2.0	$\delta = +0.10 \pm 0.03$
5.79	2^-; 0	0.94	40 ± 8	
		1.08	60 ± 8	
6.10	4^-; 0	0.94	4.9 ± 0.9	$\Gamma_\gamma = 5.1 \pm 1.0 \times 10^{-2}$ eV [c])
		1.12	55 ± 3	
		2.10	27 ± 2	
		3.79	1.4 ± 0.3	
		4.12	1.8 ± 0.3	
		4.40	0.7 ± 0.3	
		4.65	8.7 ± 0.7	

Table 18.25 (continued)
Radiative decays in ^{18}F [a])

E_i (MeV)	J_i^π	E_f (MeV)	Branch (%)	Widths and Mixing Ratios
6.10	(1^+); 0	0	24 ± 3	
		0.94	11 ± 3	
		2.10	20 ± 6	
		3.06	45 ± 5	
6.14	0^+; 1	0	50 ± 3	$\Gamma_\gamma > 1.6$ eV
		1.70	12 ± 2	
		3.72	36 ± 3	
		4.36	2.1 ± 0.4	
		5.603	0.19 ± 0.02	
6.16	3^+; 1	0	0.2 ± 0.2	$\Gamma_\gamma = 0.96 \pm 0.26$ eV [c])
		0.94	51 ± 3	
		1.12	1.0 ± 0.1	
		2.52	5.5 ± 0.4	
		3.06	1.3 ± 0.3	
		3.79	11.6 ± 1.3	
		3.84	25.0 ± 1.6	
		4.12	1.5 ± 0.3	
		4.23	0.9 ± 0.3	
		4.40	2.0 ± 0.2	
6.240	3^-; $0+1$	0.94	4.6 ± 0.3	
		2.10	71.5 ± 3.0	$\Gamma_\gamma = 0.80 \pm 0.11$ eV [c])
		3.36	1.1 ± 0.4	
		3.79	10.6 ± 0.5	
		3.84	1.0 ± 0.2	
		4.12	0.5 ± 0.2	
		4.23	7.8 ± 0.4	
		4.40	2.9 ± 0.3	
6.242	3^-; $0+1$	0.94	4.1 ± 0.3	
		2.10	71.2 ± 3.0	$\Gamma_\gamma = 0.73 \pm 0.11$ eV [c])
		3.36	0.8 ± 0.3	
		3.79	11.6 ± 0.6	
		3.84	0.9 ± 0.2	
		4.12	1.1 ± 0.4	
		4.23	8.2 ± 0.4	
		4.40	2.1 ± 0.3	
6.26	1^+; 0	0	(100)	
6.28	2^+; 1	0	0.3 ± 0.1	$\Gamma_\gamma = 1.8 \pm 0.5$ eV [c])
		0.94	67 ± 3	
		1.04	1.3 ± 0.1	

Table 18.25 (continued)
Radiative decays in ^{18}F [a])

E_i (MeV)	J^{π}_i	E_f (MeV)	Branch (%)	Widths and Mixing Ratios
		1.70	5.7 ± 0.6	
		2.10	1.2 ± 0.3	
		2.52	0.3 ± 0.2	
		3.13	0.7 ± 0.3	
		3.36	2.3 ± 0.3	
		3.72	1.4 ± 0.5	
		3.84	15.8 ± 1.4	
		4.12	3.9 ± 0.2	
		4.36	0.5 ± 0.4	
6.31	3^+; 0	0	4.0 ± 0.7	$\Gamma_\gamma = 0.17 \pm 0.04$ eV [c])
		0.94	10.6 ± 1.0	
		1.70	3.0 ± 0.8	
		2.52	4.0 ± 0.5	
		3.06	57 ± 3	$\delta = -(0.03 \pm 0.10)$
		3.72	1.4 ± 0.7	
		3.84	4.6 ± 1.0	
		4.12	2.4 ± 1.7	
		4.96	13.0 ± 1.5	$\delta = -(0.01 \pm 0.14)$
6.39	2^+; $0 + 1$	0	1.5 ± 0.5	$\Gamma_\gamma = 0.44 \pm 0.18$ eV [c])
		0.94	75 ± 3	$\delta = -(0.25 \pm 0.10)$
		1.70	6.8 ± 1.7	
		3.84	14.1 ± 1.6	$\delta = 0.1 \pm 0.2$
		4.12	2.3 ± 0.5	
6.48	3^+; 0	0	13 ± 2	$\Gamma_\gamma = 74 \pm 21$ meV [c])
		0.94	33 ± 2	
		1.12	10 ± 2	
		1.70	4 ± 2	
		2.52	4 ± 2	
		3.06	21 ± 3	
		3.79	4 ± 2	
		3.84	9 ± 2	
		4.96	2 ± 2	
6.57	5^+; 0	0.94	15.2 ± 1.6	
		3.36	83 ± 3	$\Gamma_\gamma = 2.6 \pm 0.5 \times 10^{-2}$ eV [c,d])
		5.30	2.3 ± 0.6	
6.64	2^-; 1	0.94	8.9 ± 0.6	$\Gamma_\gamma = 1.4 \pm 0.4$ eV [c])
		2.10	58 ± 3	
		3.13	22.0 ± 1.3	
		3.72	0.9 ± 0.2	

Table 18.25 (continued)
Radiative decays in ^{18}F [a])

E_i (MeV)	J^π_i	E_f (MeV)	Branch (%)	Widths and Mixing Ratios
		3.79	2.4 ± 0.2	
		4.12	1.0 ± 0.3	
		4.86	2.6 ± 0.2	
		5.50	4.0 ± 0.3	
6.78	4^+; 0	0.94	12.6 ± 0.9	$\Gamma_\gamma = 0.31 \pm 0.08$ eV [c]) $\delta = -(0.35 \pm 0.18)$
		1.12	25.2 ± 1.3	$\delta = -(1.4 \pm 1.1)$
		4.65	62 ± 2	$\delta = 0.13 \pm 0.13$
6.80	1^+, 2^+, 3^+; (0)	0	20 ± 2	
		0.94	20 ± 2	
		3.06	50 ± 3	
		3.84	3.0 ± 1.6	
		4.96	7.0 ± 1.7	
6.88	3, 4^-; 0	2.10	9 ± 2	
		4.65	91 ± 2	
7.34	1^-; 1	0	4 ± 0.5	
		1.08	54 ± 2	
		2.10	18 ± 1	
		3.06	1 ± 0.5	
		3.13	8 ± 0.5	
		4.23	15 ± 0.6	
7.48	(2)	0.94	100	
7.52		0.94	5 ± 4	
		2.10	7 ± 5	
		3.79	33 ± 5	
		4.40	55 ± 7	
7.53	2^-	0	10 ± 3	
		0.94	14 ± 6	
		2.10	50 ± 9	
		3.79	26 ± 7	
7.59		0	18 ± 7	
		0.94	14 ± 12	
		1.12	9 ± 7	
		4.65	59 ± 16	

[a]) For earlier references see Tables 18.11 in (78AJ03) and 18.12 in (83AJ01). See these tables also for upper limits for transitions to other states.
[b]) (82FR15): see reactions 6 and 23.
[c]) Γ_γ = total radiative width for this state.
[d]) $\Gamma_\alpha = \Gamma \sim 560$ eV, $\Gamma_p < 4.5$ eV.
[e]) See Table 18.27

Table 18.26
Lifetime measurements of some ^{18}F states

^{18}F* (MeV)	$J^\pi; T$	τ_m	References
0.94	$3^+; 0$	67.6 ± 2.5 ps	mean [a])
1.04	$0^+; 1$	2.7 ± 0.4 fs	[b])
		2.2 ± 0.6 fs	(83CA21)
		2.55 ± 0.45 fs	(83CA21) [c])
1.08	$0^-; 0$	27.5 ± 1.9 ps	mean [a])
1.12	$5^+; 0$	234 ± 10 ns	mean [b])
1.70	$1^+; 0$	0.971 ± 0.30 ps	(82BA40)
		0.897 ± 0.057 ps	(83MO16) [d])
		0.955 ± 0.027 ps	mean
2.10	$2^-; 0$	5.12 ± 0.56 ps	(82BA40)
		4.93 ± 0.78 ps	(83MO16)
		5.06 ± 0.46 ps	mean
2.52	$2^+; 0$	0.605 ± 0.029 ps	(82BA40)
		0.554 ± 0.045 ps	(83MO16)
		0.590 ± 0.024 ps	mean
3.06	$2^+; 1$	< 1.2 fs	(82BA40) [a,e])
3.13	$1^-; 0$	0.403 ± 0.018 ps	(82BA40)
		0.343 ± 0.022 ps	(83MO16)
		0.39 ± 0.02 ps[A]	
3.36	$3^+; 0$	0.435 ± 0.041 ps	(82BA40)
		0.451 ± 0.034 ps	(83MO16)
		0.44 ± 0.03 ps[A]	
3.72	$1^+; 0$	4 ± 2 fs	(73RO04)
		$2.7^{+4.1}_{-2.7}$ fs[A]	(82BA40) [c])
3.79	$3^-; 0$	1.91 ± 0.17 ps	(82BA40)
		1.90 ± 0.20 ps	(83MO16)
		1.91 ± 0.13 ps	mean
3.84	$2^+; 0$	17.4 ± 3.6 fs	(82BA40)
		21 ± 4 fs	(83MO16)
		19.0 ± 2.7 fs	mean
4.12	$3^+; 0$	91 ± 22 fs	(73RO06)
4.23	$2^-; 0$	110 ± 15 fs	(73RO06)
4.36	$1^+; 0$	27 ± 10 fs	(73RO06)
4.40	$4^-; 0$	58 ± 12 fs	(73RO06)
4.65	$4^+; 1$	< 10 fs	(73RO06)
4.85	$5^-; 0$	5.2 ± 0.9 ps	(73RO06)
4.86	$1^-; 0$	66 ± 18 fs	(73RO06)
4.96	$2^+; 1$	< 4 fs	(73RO06)
5.30	$4^+; 0$	30 ± 5 fs	(73RO06)

Table 18.26 (continued)
Lifetime measurements of some ^{18}F states

^{18}F* (MeV)	$J^\pi; T$	τ_m	References
5.50	$3^{(-)}; 0$	63 ± 25 fs	(73RO06)
5.79	$2^-; 0$	15 ± 10 fs	(73RO06)

A = adopted
[a]) See Table 18.12 in (78AJ03).
[b]) See Table 18.13 in (83AJ01).
[c]) See also (85KE1C).
[d]) See also (82MO09).
[e]) See also (83MO16).

1. ^{18}F(β^+)^{18}O $\qquad Q_m = 1.655$

The positron decay is entirely to the ground state of ^{18}O [$J^\pi = 0^+$, $T = 1$]; the half-life is 109.77 ± 0.05 min [see Table 18.11 in (72AJ02)]; $\log ft = 3.554$. The fact that the β^+ transition to ^{18}O$_{g.s.}$ is allowed fixes $J^\pi = 1^+$ for ^{18}F$_{g.s.}$.

The ratio $\epsilon_K/\beta^+ = 0.030 \pm 0.002$: see (78AJ03, 87AJ02). See also (89SA1P, 89KA1S).

The influence of meson exchange currents of the second kind is discussed in (88SA12) and in (89SA1H) which also considers the effects of neutrino mass. Charged-current (ν_e, e$^-$) reactions on ^{18}O and the predicted effects on a proposed neutrino elastic scattering measurement of the Weinberg angle is discussed in (88HA22).

2. (a) ^{10}B(^{9}Be, n)^{18}F $\qquad Q_m = 14.455$
(b) ^{11}B(^{9}Be, 2n)^{18}F $\qquad Q_m = 3.001$

See (86CU02) for production cross sections of 0.94 MeV γ-rays.

3. (a) ^{12}C(^{6}Li, d)^{16}O $\qquad Q_m = 5.687 \qquad E_b = 13.213$
(b) ^{12}C(^{6}Li, α)^{14}N $\qquad Q_m = 8.798$
(c) ^{12}C(^{6}Li, ^{6}Li$'$)^{12}C

Cross sections for these and other charged particle channels have been measured for $E(^6\text{Li}) = 1.9$ to 36 MeV [see (78AJ03, 83AJ01)]. More recently, measurements of cross sections at $E(^6\text{Li}) = 210$ MeV are reported in (88NA02). Vector analyzing power measurements have been made at $E(^6\text{Li}) = 150$ MeV (87TA21, 88TA08) and at $E(^6\text{Li}) = 30$ MeV (94RE01) for elastic scattering and at $E(^6\text{Li}) = 30$ MeV (88VAZY, 89VA04) for inelastic scattering to ^{12}C*(4.43). Neutron yields from ^{6}Li + ^{12}C at $E(^6\text{Li}) = 40$ MeV have been measured by (87SC11).

The cross section for the isospin-forbidden α_1 group [to ^{14}N*(2.31), 0^+, $T = 1$] is 1 to 2% of the cross section of the allowed α_0 and α_2 groups for $E(^6\text{Li}) = 3.2$ to 6 MeV while for 9 to 14 MeV it varies from 0.4 to 1.8%. At 20 MeV, the α_1 yield is 0.02% of the allowed yield. Structures are reported at $E(^6\text{Li}) = 11.0$ and 13.0 MeV in the α_0 yield, at 11.5 and 13.0 MeV in the α_1 yield and at ≈ 11.7 and 12.8 MeV in the α_2 yield. A resonance is also reported in the α_1 yield at $E(^6\text{Li}) = 4.2$ MeV: $E_\text{x} = 15.99 \pm 0.02$ MeV, $\Gamma_\text{c.m.} = 290 \pm 30$ keV, $J^\pi = 2^+$ (one-level BW fit). It is suggested that this resonance is due to 2^+ states with $T = 0$ and $T = 1$ which are unresolved. Cross sections for populating ^{16}O*(8.87, 10.36, 11.08, 11.10) are reported by (81GL02).

The excitation functions for the ^{6}Li ions to ^{12}C*(0, 4.43) show a single isolated structure at $E(^6\text{Li}) = 22.8$ MeV, in the range 20–36 MeV, with $\Gamma \approx 0.8$ MeV. It is unlikely to be due to an isolated state in ^{18}F. Analyzing power measurements are reported for many deuteron and α groups and for elastically scattered ^{6}Li ions at $E(^6\text{Li}) = 20$ MeV. VAP measurements for elastic scattering are also reported at $E_\text{d} = 9.0$ and 19.2 MeV (83RU09) and at 150 MeV (86KA1C, 86TA1B).

For fusion studies see (82DE30, 87PA12). For references to earlier work and for additional comments see (78AJ03, 83AJ01, 87AJ02), ^{12}C in (85AJ01), ^{14}N in (86AJ01), and ^{16}O in (86AJ04, 93TI07).

4. ^{12}C(^{9}Be, t)^{18}F $\qquad Q_\text{m} = -4.475$

Angular distributions are reported at $E(^9\text{Be}) = 12$ to 27 MeV to $^{18}\text{F}_\text{g.s.}$ and to the unresolved states at 1 MeV: see (83AJ01). For excitation functions see (82HU06, 83JA09).

5. ^{12}C(^{11}B, αn)^{18}F $\qquad Q_\text{m} = -2.701$

For ^{18}F*(4.85) [5^-; $T = 0$] $\tau_\text{m} = 5.2 \pm 0.9$ psec. The E1 strength is $(3.4 \pm 0.6) \times 10^{-6}$ W.u. for the transition to ^{18}F*(1.12) [5^+; $T = 0$] and the E2 strength is 14.8 ± 2.6 W.u. for that to ^{18}F*(3.79) [3^-; 0]. The latter strength, which is that of a highly collective transition, corresponds to a quadrupole moment $Q_0 = 395 \pm 35$ mb and suggests that ^{18}F*(4.85) is the 5^- state of a (strongly decoupled) $K^\pi = 1^-$ band (82KO24). See also Tables 18.25 and 18.26.

6. ^{14}N(α, γ)^{18}F $\qquad Q_\text{m} = 4.415$

The non-resonant S-factor for this reaction is $S \approx 0.7$ MeV·b: see (78AJ03). A number of resonances have been observed for $E_\alpha < 3$ MeV: see Table 18.27. Studies of these, principally by the Toronto and Queen's groups [see references in (78AJ03, 83AJ01)] in conjunction with work on ^{14}N(α, α), ^{16}O(^{3}He, p), ^{17}O(p, γ) and ^{17}O(p, α) [see tables 18.29, 18.30, 18.31] have led to the determination of branching ratios, mixing ratios and widths

Table 18.27
Resonances in $^{14}N + \alpha$ below $E_\alpha = 5$ MeV [a]

E_α (MeV ± keV)	Particles out	$\Gamma_{c.m.}$ (keV)	$(2J+1)\Gamma_\gamma\Gamma_\alpha/\Gamma$ (eV)	$J^\pi; T$	E_x (MeV)
			$< 2 \times 10^{-5}$		4.657
0.559	γ		$(2.8 \pm 0.5) \times 10^{-4}$	1; 0	4.850
0.698			$< 0.5 \times 10^{-4}$	2^+; 1	4.958
1.136 ± 3	γ		0.084 ± 0.004	4^+; 0	5.299
1.398 ± 3	γ		0.022 ± 0.003	$3^{(-)}$; 0	5.502
1.527	γ, α_0		1.44 ± 0.14	1^+	5.603 [e]
1.529 ± 2	γ, α_0	< 1.2	2.60 ± 0.21	1^-; $0+1$	5.604 [f]
1.618 ± 2	γ, α_0	< 0.8	1.4 ± 0.2 [b]	1^-; $0+1$	5.673 [g]
1.765 ± 4	γ		0.047 ± 0.018	2^-; 0	5.788
2.160 ± 4	γ		0.20 ± 0.04	4^-; 0	6.095
2.166 ± 7	γ, α_0		0.08 ± 0.03	1, 2, $3^{(-)}$; 0	6.100
			[c]		
2.348 ± 3	γ, α_0	< 0.8		3^-; $0+1$	6.241 [h]
2.372 ± 3	γ, α_0	< 3		1^+; (0)	6.260 [i]
			[d]		
2.438 ± 4	γ		0.52 ± 0.12	3^+; 0	6.311
2.532 ± 4	γ		1.6 ± 0.4	2^+; $0+1$	6.384
	γ		0.16 ± 0.06	3^+; (0)	6.480
2.767 ± 4	γ, α_0	(< 0.8)	0.29 ± 0.06	5^+; 0	6.567
2.870 ± 4	γ, p_0	< 1.6	2.7 ± 0.5	2^-; 1	6.647
2.870 ± 6	α_0	93 ± 5	$\Gamma_\alpha/\Gamma = 0.85$	1^-	6.647
			0.12 ± 0.07	4^+; 0	6.78
			< 0.2	1^+, 2^+, 3^+; (0)	6.803
3.080 ± 6	p_0, α_0	101 ± 5		2^-	6.810
3.576 ± 4	α_0	< 4		(4^+)	7.196
3.67	α_0	45 ± 10		(1^+)	7.27
3.72	p_0, α_0	53 ± 6		(3^-)	7.31
4.00	p_0, α_0	35		(3^-)	7.53
4.05	p_0, α_0	60			7.57
4.11	p_0, α_0	40			7.61
4.28	p_0, α_0	120			7.74
4.50	p_0, α_0	30		(2^-)	7.92
4.55	p_0, α_0	70		(1^+)	7.95

[a] References are displayed in Tables 18.13 of (72AJ02, 78AJ03). Higher resonances observed in $^{14}N(\alpha, \alpha_1)$ are listed in Table 18.14 of (78AJ03).
[b] $\omega\gamma = 0.45 \pm 0.02$ (82BE29).
[c] ≤ 0.07 for $^{18}F^*$ (6.11, 6.16 MeV) (73RO03).
[d] ≤ 0.03 for $^{18}F^*$ (6.28 MeV) (73RO03).

e) $\Gamma_\alpha = 42.8 \pm 1.6$ eV, $\Gamma_\gamma = 0.485 \pm 0.046$ eV, $l_\alpha = 0$ (80MA26). See also Table 18.30.
f) $\Gamma_\alpha = 32.0 \pm 2.1$ eV, $\Gamma_\gamma = 0.891 \pm 0.074$ eV, $l_\alpha = 1$. ΔE_x for ^{18}F* (5.603, 5.605 MeV) is 1.84 ± 0.04 keV (80MA26). See also Table 18.30.
g) $\Gamma_\alpha = 130 \pm 5$ eV, $\Gamma_\gamma = 1.4 \pm 0.3$ eV, $l_\alpha = 1$ (80MA26). More recently, an accurate energy measurement for this level by (89BO01) gave $E_x = 5672.57 \pm 0.32$ keV.
h) This resonance corresponds to two states at $E_x = 6240$ and 6242 keV. The lower member of the doublet (both of which have $J^\pi = 3^-$ and mixed isospin) has $\Gamma_\alpha = 133 \pm 4$ eV, $\Gamma_\gamma = 0.80 \pm 0.11$ eV; the higher has $\Gamma_\alpha = 137 \pm 0.4$ eV, $\Gamma_\gamma = 0.73 \pm 0.11$ eV (79KI12).
i) $\Gamma_\alpha = 580 \pm 12$ eV, $\Gamma_p = 25^{+35}_{-25}$ eV (79KI12).

(table 18.25), lifetimes (table 18.26) and the E_x, J^π and K^π assignments for ^{18}F states with $E_x < 6.9$ MeV. The reader is referred to the series of papers by the Toronto group for the most complete and definitive arguments on the parameters of the low-lying states of ^{18}F.

A recent measurement reported in (89BO01) determines a value $E_x = 5672.57 \pm 0.32$ keV for the first ^{18}F level above the proton threshold. This level is important for calculating the rate of ^{17}O destruction during hydrogen burning in stars.

No evidence is seen for the excitation of the (forbidden) state at $E_x = 4.753$ MeV [$J^\pi = 0^+$, $T = 1$] (81LE1A, 83LE08). See also (87AJ02), and see the tables of reaction rates (88CA1N) and the reviews of (89KA24, 89WH1B, 89TH1C).

7. ^{14}N(α, p)^{17}O $\quad Q_m = -1.192 \quad E_b = 4.415$

Observed resonances are displayed in table 18.27. See also ^{17}O in (86AJ04, 93TI07).

8. (a) ^{14}N(α, α')^{14}N $\quad E_b = 4.415$
(b) ^{14}N(α, 2α)^{10}B $\quad Q_m = -11.613$
(c) ^{14}N(α, ^{6}Li)^{12}C $\quad Q_m = -8.798$

Observed anomalies in the elastic scattering [reaction (a)] are exhibited in Table 18.27. Resonances in the α_1 isospin-forbidden yield are displayed in Table 18.14 of (78AJ03). In the α_1 study, carried out for $E_\alpha = 7.6$–16.9 MeV, a partial-wave analysis involving a method of removing ambiguities and parametrizing S-matrix elements gives the level parameters of 151 isospin mixed, natural-parity states in ^{18}F with $10.4 < E_x < 17.5$ MeV. Many of these states have also been reported in the ^{16}O(d, α_1) reaction [Table 18.16 of (78AJ03)]. The agreement is best for low-lying 2^+ or 4^+ states, and is quite good for 3^- and 5^- states, while for high-J states the greater centrifugal barrier for ^{16}O + d at the same E_x leads to a relative suppression of high-J states in the ^{16}O + d work. A study of the energy dependence of averaged intensities of the partial waves shows some indication that the lower partial waves conserve isospin as E_x increases.

The total cross sections for formation of ^{10}B and ^{6}Li have been studied for $E_\alpha = 21$ to 42 MeV [see (78AJ03)], as has the cross section for production of 1.64 and 2.31 MeV γ-rays from threshold to $E_\alpha = 26$ MeV (85DY05). See also (87AJ02), and see (87BU1E, 89BE1R, 90WE1A, 91LE33).

9. (a) ^{14}N(^{6}Li, d)^{18}F $Q_m = 2.940$
   (b) ^{14}N(^{6}Li, dα)^{14}N $Q_m = -1.475$

Angular distributions have been measured for the deuteron groups to ^{18}F*(5.34 [4^+], 6.56 [5^+], 9.58, 11.2, 14.1) at E(^{6}Li) = 36 MeV. Angular correlations lead to $J^\pi = 6^+$ and 8^+ for ^{18}F*(9.58, 14.1) and the data are consistent with $J^\pi = 7^+$ for ^{18}F*(11.2) (83ET02). For the earlier work see (78AJ03).

10. ^{14}N(^{7}Li, t)^{18}F $Q_m = 1.948$

At E(^{7}Li) = 36 MeV the $K^\pi = 1^+$ band appears to be selectively populated. States at $E_x = 9.58 \pm 0.02$, 11.22 ± 0.03 and 14.18 ± 0.04 MeV are strongly populated. It is suggested that the first two are the 6^+ and 7^+ members of that band: see reaction 8. [Angular distributions are reported for ^{18}F*(1.70, 2.10, 2.52, 3.36, 4.40, 5.30, 6.57, 9.58, 11.22, 14.18).] See (78AJ03, 87AJ02) for the earlier work.

11. (a) ^{14}N(^{11}B, ^{7}Li)^{18}F $Q_m = -4.250$
    (b) ^{14}N(^{13}C, ^{9}Be)^{18}F $Q_m = -6.233$

These reactions have been studied at E(^{11}B) = 115 MeV and E(^{13}C) = 105 MeV. Differential cross sections at three angles are reported for the transitions to ^{18}F*(9.58, 10.57 ± 0.07, 11.2) in reaction (a) and to ^{18}F*(5.30, 6.57, 9.58, 10.60 ± 0.08, 11.2) in reaction (b). In addition to these states ^{18}F*(14.18) is strongly excited in both reactions, and transitions to ^{18}F*(15.79 ± 0.10, 18.62 ± 0.12) are also reported: see (83AJ01).

12. (a) ^{15}N(^{3}He, γ)^{18}F $Q_m = 14.156$
    (b) ^{15}N(^{3}He, α)^{14}N $Q_m = 9.745$ $E_b = 14.160$

Excitation functions have been measured for E(^{3}He) = 2.5 to 16 MeV for the γ_0 and $\gamma_{1\to4}$ yields. Resonances are observed corresponding to $E_x = (19.00 \pm 0.15)$ [$\gamma_{1\to4}$], (20.1 ± 0.2) [γ_0, $\gamma_{1\to4}$], (22.7 ± 0.2) [γ_0, $\gamma_{1\to4}$] and (24.1 ± 0.2) MeV [$\gamma_{1\to4}$], with $\Gamma_{c.m.} =$

(0.5 ± 0.15), (1.6 ± 0.1), (1.2 ± 0.1) and (1.4 ± 0.3) MeV, respectively. The γ_0 yield is dominated by ^{18}F*(20.10) [(83WA05): see for $(2J+1)\Gamma_{3\text{He}}\Gamma_\gamma$ values]. It is suggested that structures decaying by γ_0 have $J^\pi = 2^-$ (and possibly $T = 1$) (83WA05). For analyzing power measurements at $E(^3\text{He}) = 33$ MeV see (86DR03).

13. ^{15}N(^{6}Li, t)^{18}F $\qquad Q_\text{m} = -1.635$

At $E(^6\text{Li}) = 30$ MeV preferential excitation of odd-parity states of ^{18}F below $E_\text{x} =$ 5 MeV is reported. Angular distributions of the tritons to ^{18}F*(0, 0.94, 2.10, 4.40) [$J^\pi = 1^+$, 3^+, 2^-, 4^-] are all strongly forward peaked: see (78AJ03).

14. (a) ^{15}N(^{11}B, ^{8}Li)^{18}F $\qquad Q_\text{m} = -13.048$
(b) ^{15}N(^{12}C, ^{9}Be)^{18}F $\qquad Q_\text{m} = -12.119$

These reactions have been studied with $E(^{11}\text{B}) = E(^{12}\text{C}) = 115$ MeV. Reaction (a) is dominated by the transitions to ^{18}F*(1.12) [presumably $J^\pi = 5^+$ state, although the group is unresolved] and to ^{18}F*(7.15, 9.45) [$J^\pi = (7^-)$ and (6^-)]. No single state is strongly preferentially populated in reaction (b). Differential cross sections for ^{18}F*(4.40, 6.10, 7.15, 9.45) [$J^\pi = 4^-$, (5^-), (7^-), (6^-)], are fitted by FRDWBA: see (83AJ01).

15. ^{16}O(d, γ)^{18}F $\qquad Q_\text{m} = 7.526$

The capture cross section rises from 0.1 μb at $E_\text{d} = 0.4$ MeV to 25 μb at 3.5 MeV: Γ_γ over this range is ≈ 2 eV: see (72AJ02).

16. (a) ^{16}O(d, n)^{17}F $\qquad Q_\text{m} = -1.624 \qquad E_\text{b} = 7.526$
(b) ^{16}O(d, p)^{17}O $\qquad Q_\text{m} = 1.919$

Excitation functions and polarization studies have been carried out to $E_\text{d} = 17$ MeV [see (78AJ03, 83AJ01)] and at $E_\text{d} \approx 5.6$ to 8.3 MeV (85GR1B; p_0, p_3, p_4). Structures attributed to states in ^{18}F are displayed in Table 18.28. See also ^{17}O and ^{17}F in (86AJ04, 93TI07), (87AJ02), and see (92LA08) for applications.

17. ^{16}O(d, d$'$)^{16}O $\qquad E_\text{b} = 7.526$

Table 18.28
Maxima in the yields of $^{16}O + d$ [a])

E_d (MeV ± keV)	Particles out	$\Gamma_{c.m.}$ (keV)	$J^\pi; T$	E_x (MeV)
0.895	p_1, α_0	210 ± 25		(8.320)
1.048	p_1, d_0, α_0	88 ± 10	1^+	8.456
1.199	α_0	230 ± 30		(8.590)
1.298	p_1, d_0, α_0	13 ± 3		(8.678)
1.325	d_0, α_0			(8.702)
1.482	α_0	40 ± 5		(8.842)
1.563	d_0, α_0	121 ± 15		(8.914)
1.616	α_0	19 ± 15		(8.961)
1.765	d_0, α_0	141 ± 10		(9.093)
1.885	p_0, p_1, d_0, α_0	108 ± 12	$3, 4^-; 0$	9.200
2.22	n_0, α_0		$2, 3^+; 0$	9.50
2.28	α_0		$2, 3^+; 0$	(9.55)
2.34	n_0, p_1			(9.60)
2.55	p_1			(9.79)
2.92	n_0, p_0, p_1			10.12
3.05	α_0		$3, 4^-; 0$	10.24
3.13	n, p_1, α_0, α_1		$\geq 2; 0$	10.31
3.37	n_0, p_0, p_1, α_1			10.52
3.47	α_0		$4, 5^+; 0$	10.61
3.68	n_0, p_0, p_1, α_1		2^+	10.79
3.80	p_0, α_0		$\geq 2^+; 0$	10.90
3.94	n, p_1, α_1			11.03
3.95	p_1, α_0	$\simeq 35$	$3, 4^-; 0$	11.03
4.07	n, p_1			11.14
4.38	p_1, α_0		$4, 5^+; 0$	11.42
4.57	α_0		$5, 6^-; 0$	11.58
4.80	d_0, α_0		$\geq 3; 0$	11.79
4.93	α_0		$5, 6^-; 0$	11.90
5.05 ± 15	α_4	40		12.01
5.11	α_0, α_2, α_4	60	$4, 5^+; 0$	12.06
5.17	α_0	55	$T = 0$	12.12
5.32	α_0	70		12.25
5.34	α_0, α_2	170		12.27
5.40	α_0, α_4	130		12.32
5.47	α_4	80		12.38
5.49	α_2, α_3, α_4	120		12.40
5.59	α_0, α_2	120		12.49
5.65	α_0, α_2	140		12.54
5.77	α_0	180	2^+	12.65

Table 18.28 (continued)
Maxima in the yields of $^{16}O + d$ [a])

E_d (MeV ± keV)	Particles out	$\Gamma_{c.m.}$ (keV)	$J^\pi; T$	E_x (MeV)
5.80	α_0, α_2, α_4	160		12.68
5.81	α_3, α_4	80	5^-	12.69
5.91	α_2	160		12.77
6.00	α_0	120		12.85
6.11	α_0, α_4	120		12.95
6.19	α_2, α_3	200	$\geq 4; 0$	13.02
6.25	α_0, α_4	150	$T = 0$	13.08
6.30	α_0, α_2	160		13.12
6.34	α_0, α_3	160	$5, 6^-; 0$	13.16
6.38	α_0, α_3	145	$T = 0$	13.19
6.43	α_0, α_2	120		13.24
6.46	α_0, α_4	100		13.26
6.54	α_0, α_2	135		13.33
6.61	α_2, α_3, α_4	120		13.40
6.64	α_0, α_2	200		13.42
6.66	α_0	100		13.44
6.72	α_2	100		13.49
6.73	α_2	100		13.50
6.80	α_2, α_3	140		13.56
6.84	α_0, α_2, α_4	150		13.60
6.94	α_0, α_3	90		13.69
7.10	α_3, α_4	60	$4^-, 5^+$	13.83
7.27	α_3	150		13.98
7.31	α_2	60	$4^-, 5^+$	14.02
7.34	α_0, α_3, α_4	200		14.04
7.38	α_0, α_3	210		14.08
7.41	α_3	60	$4^-, 5^+$	14.10
7.49	α_0	220		14.18
7.58	α_0	200	$\geq 4; 0$	14.26
7.62	α_4	85		14.29
7.66	α_0, α_2, α_4	130	$T = 0$	14.33
7.67	α_0, α_2, α_3, α_4	250	$T = 0$	14.34
7.74	α_3	200	$3^+, 4^-$	14.40
7.80	α_0, α_4	70		14.45
7.82	α_0, α_2	225		14.47
7.99	α_4	200		14.62
8.02	α_0	150		14.65
8.03	α_3	310		14.66
8.07	α_0	120		14.69

Table 18.28 (continued)
Maxima in the yields of ^{16}O + d [a])

E_d (MeV ± keV)	Particles out	$\Gamma_{c.m.}$ (keV)	$J^\pi; T$	E_x (MeV)
8.08	α_3, α_4	310		14.70
8.21	α_2	250		14.82
8.25	α_4	380		14.85
8.30	α_0, α_2, α_3	210		14.90
8.34	α_4	115		14.93
8.37	α_0	130		14.96
8.37	α_0, α_3	250		14.96
8.40	α_0	310		14.99
8.43	α_4	120		15.01
8.52	α_3, α_4	160	4^-, 5^+	15.09
8.52	α_2	150		15.09
8.56	α_2	220		15.13
8.58	α_4	180		15.15
8.61	α_0, α_3	200		15.17
8.65	α_0, α_2	135		15.21
8.72	α_2, α_4	120		15.27
8.76	α_2	160		15.30
8.79	α_0	200		15.33
8.80	α_0, α_3, α_4	200	5^+, 6^-	15.34
8.89	α_3	110		15.42
8.93	α_3, α_4	190		15.46
8.97	α_2, α_4	210		15.49
9.00	α_0, α_2	190		15.52
9.62	α_3	220	4^-, 5^+	16.07
10.35	α_3	60	4^-, 5^+	16.72
11.15	α_3	70	4^-, 5^+, 6^-	17.43

[a]) For references see Table 18.15 in (78AJ03). This table does not include the structures in α_1 leading to isospin-mixed states in ^{18}F: for the latter see Table 18.16 in (78AJ03).

The yields and polarization observables of elastically scattered deuterons have been reported for $E_d = 0.65$ to 56 MeV: see (78AJ03, 83AJ01). More recent measurements are those by (85GR1B) [excitation functions for $E_d \approx 5.6$ to 8.3 MeV] and the polarization studies at $E_d = 20.5$ MeV (84FR14; TAP), 56 MeV (86MA32, VAP, TAP) and 200, 400 and 700 MeV (87NG01; VAP, TAP). An analysis for $E_d = 400$ MeV in terms of the folding model is discussed in (87GR16). Virtual breakup effects in (d, d) elastic scattering have been studied (88IS02). For references to earlier work see (87AJ02), and see the ^{16}O sections of (86AJ04, 93TI07).

18. ^{16}O(d, α)^{14}N $\qquad Q_m = 3.111 \qquad E_b = 7.526$

The yields of various groups of α-particles have been measured for $E_d \leq 20$ MeV: see (78AJ03, 83AJ01). The yield curves have been fitted in terms of a large number of states in ^{18}F: see Table 18.28 here, and 18.16 in (78AJ03).

A detailed study by (73JO13) of the isospin-forbidden α_1 yield, analyzed by S-matrix theory, identifies a large number of isospin-mixed states in ^{18}F, possibly as many as 138 with $9.2 < E_x < 19.4$ MeV. The reaction mechanism appears to be almost entirely compound nuclear. The isospin impurity, averaged over 1 MeV intervals, is 3–10% for the above E_x range. The average coherence width increases from ≈ 100 keV at $E_x = 14$ MeV to ≈ 500 keV at $E_x = 20$ MeV. The level densities appear to be consistent with predictions of the Fermi-gas model (73JO13). See also (85JO1A). [For mixed isospin states observed in ^{14}N(α, α_1) see Table 18.14 in (78AJ03).] Polarized beam measurements are reported for $E_d = 6.8$ to 16 MeV: see (78AJ03, 83AJ01).

19. ^{16}O(d, ^{6}Li)^{12}C $\qquad Q_m = -5.687 \qquad E_b = 7.526$

Vector and tensor polarized beam measurements are reported for the transitions to ^{12}C*(0, 4.4) at $E_d = 18$ and 22 MeV (87TA07; VAP, TAP) and 51.7 MeV (86YA12; VAP; also to ^{12}C*(14.1)).

20. ^{16}O(t, n)^{18}F $\qquad Q_m = 1.269$

Recent measurement of neutron yields for $E_x = 20$ MeV are discussed in (93DR03, 93DR04). Applications are discussed in (87BO16, 90BA1S). For earlier work see (83AJ01, 87AJ02).

21. ^{16}O(^{3}He, p)^{18}F $\qquad Q_m = 2.032$

Table 18.29
States in ^{18}F from ^{16}O(^{3}He, pγ)^{18}F [a]

E_x (keV) [b]	l [a]	J^π; T [c]	K^π [c]
0	0	1^+; 0	0^+
937.1 ± 0.4	2	3^+; 0	0^+
1040.9 ± 0.5	0	0^+; 1	
1080.1 ± 0.5		0^-; 0	0^-
1119.0 ± 0.6	4	5^+; 0	0^+
1701.4 ± 0.7	0	1^+; 0	1^+
2099.9 ± 0.6		2^-; 0	0^-
2523.4 ± 0.7	2	2^+; 0	1^+
3061.2 ± 0.5	2	2^+; 1	
3132.8 ± 0.6		1^-; 0	1^-
3358.2 ± 1.0		3^+; 0	1^+
3725.4 ± 0.8		1^+; 0	
3790 ± 0.9		3^-; 0	1^-
3838.4 ± 0.7	2	2^+; 0	
4114.5 ± 0.9		3^+; 0	
4225.8 ± 0.7		$2^{(-)}$; 0	(1^-)
4361.0 ± 0.7		$1^{(+)}$	
4398.1 ± 0.7		3^-, 4^-; 0 [d]	(0^-)
4652 ± 2	4	4^+; 1	
4753 ± 3		$(0^+$; 1)	
4860 ± 2		$1^{(-)}$; 0	
4963.6 ± 0.8		2^+; 1	
5297.6 ± 1.5		4^+	1^+
5502 ± 2		$3^{(-)}$; 0	
5603 ± 2		1^-; $0+1$	
5669 ± 2		1^-; $0+1$	
5785 ± 3		2^-; 0	
6097.4 ± 1.4		4^-; 0	1^-
6108 ± 3		1, 2, $3^{(-)}$; 0	
6138.3 ± 1.0		0^+; 1	
6164.0 ± 1.0		3^+; 1	
6241.2 ± 1.0		3^-; 1	
6263 ± 3		1^+	
6284.0 ± 1.0		2^+; $0+1$	
6310.5 ± 0.8		3^+; 0	
6383 ± 3		2^+; $0+1$	
6480 ± 2		3^+; (0)	
6567.0 ± 1.5		5^+	1^+
6643.0 ± 1.5		2^-; 1	
6777 ± 2 [c]		4^+	

Table 18.29 (continued)
States in ^{18}F from ^{16}O(^{3}He, pγ)^{18}F [a]

E_x (keV) [b]	l [a]	J^π; T [c]	K^π [c]
6803.0 ± 1.5		1^+, 2, 3^+; (0)	
6878 ± 2 [c]		$3^{(-)}$, 4^-; (0)	

[a] For earlier results derived from measurements of proton spectra and of γ-rays, see Table 18.18 in (72AJ02). See also Tables 18.25 and 18.26 here.
[b] (73RO03): γ-ray measurements.
[c] See Table 18.17 in (78AJ03).
[d] See p. 179 of (79KI12).

Excitation energies derived from measurements of γ-rays are displayed in Table 18.29 together with l-assignments obtained from distorted-wave analyses, and J^π, T and K^π assignments from branching ratios, radiative widths, linear polarization, γ-ray angular distributions and τ_m measurements [see also Tables 18.25 and 18.26]. Studies of this reaction, together with the work on ^{14}N(α, γ) and ^{17}O(p, γ), have defined the low-lying states of ^{18}F.

The g-factor of ^{18}F*(0.94) [$J^\pi = 3^+$] is ($+0.56 \pm 0.05$): see (83AJ01). The circular polarization of the 1.08 MeV $\rightarrow$ g.s. γ-ray, $P_\gamma = (-10 \pm 18) \times 10^{-4}$ (82AH07), $(2.7 \pm 5.7) \times 10^{-4}$ (85BI03, 88BI07), $(1.6 \pm 5.6) \times 10^{-4}$ (85EV03), $(1.7 \pm 5.8) \times 10^{-4}$ (87PA07). The weak pion-nucleon coupling constant deduced from the weighted average of all recent P_γ measurements [$(1.2 \pm 3.9) \times 10^{-4}$] is $(0.3^{+1.0}_{-0.3}) \times 10^{-7}$. Together with PNC matrix elements in other experiments this suggests that the isovector weak NN interaction may be strongly suppressed compared with the isoscalar weak NN interaction (85EV03, 87PA07). For a measurement of the ICC of the 0.94, 1.02, 1.04, and 1.08 MeV γ-rays see (86KR04). See also (78AJ03, 83AJ01, 87AJ02) and ^{19}Ne.

A discussion of nuclear tests of fundamental interactions is presented in (89MC1C). For recent work on the use of this reaction for oxygen analysis, see (91BA62, 92CO08). For applications related to ^{18}F production see (91GU05, 91SU17).

22. ^{16}O(α, d)^{18}F $\qquad Q_m = -16.321$

Angular distributions of the deuteron groups to ^{18}F*(1.12) [$J^\pi = 5^+$] have been studied at $E_\alpha = 28.0$ to 33.6 MeV: see (83AJ01). At $E_\alpha = 65.3$ MeV a number of angular distributions are reported to ^{18}F states with $E_x \leq 11.4$ MeV: ^{18}F* (9.49, 10.54) are suggested to have $J^\pi = 6^-$ and 7^+ respectively (86KA36). See, however, reactions 9 and 10. The use of this reaction in ^{18}F production is discussed in (91GU05).

23. ^{16}O(^{6}Li, α)^{18}F $\qquad Q_m = 6.051$

Angular distributions have been measured at $E(^6\text{Li}) = 5.5$ to 34 MeV [see (83AJ01)] and at $E(^6\text{Li}) = 48$ MeV (84CO05; α_0, α_1, α_4). (82FR15) report the excitation of a state

Table 18.30
Excited states of ^{18}F from ^{17}O(p, γ)^{18}F [a]

E_x (keV)	E_x (keV)
937.18 ± 0.06	3724.19 ± 0.22
1041.55 ± 0.08	3791.49 ± 0.22
1080.54 ± 0.12	3839.17 ± 0.22
1121.36 ± 0.15	4115.90 ± 0.25
1700.81 ± 0.18	4360.15 ± 0.26
2100.61 ± 0.10	5603.38 ± 0.27
2523.35 ± 0.18	5604.86 ± 0.28
3061.84 ± 0.18	5668 ± 2
3133.87 ± 0.15	6136.47 ± 0.33

[a]) See also Table 18.31 here, and Table 18.17 in (83AJ01).

at $E_x = 4848 \pm 0.5$ keV which decays $(35 \pm 4)\%$ to ^{18}F*(3.79) [$E_\gamma = 1056.8 \pm 0.4$ keV] and $(65 \pm 4)\%$ to ^{18}F*(1.12). Alpha-gamma angular correlations are consistent with $J^\pi = 5^-$, and $T = 0$ (82FR15). See also (86GL02) and (86IC01).

24. (a) ^{16}O(^{11}B, ^{9}Be)^{18}F $\qquad Q_m = -8.290$
(b) ^{16}O(^{13}C, ^{11}B)^{18}F $\qquad Q_m = -11.153$
(c) ^{16}O(^{14}N, ^{12}C)^{18}F $\qquad Q_m = -2.747$

See (83AJ01).

25. ^{17}O(p, γ)^{18}F $\qquad Q_m = 5.607$

Gamma-ray measurements lead to the very accurate E_x determinations for ^{18}F states below 6.2 MeV: see Table 18.30. Observed resonances are displayed in Table 18.31; branching ratios, radiative widths and multipole mixing ratios are shown in Table 18.25; and τ_m in Table 18.26.

The direct capture cross section has been studied for $E_p = 0.3$ to 1.9 MeV: ^{18}F*(5.603, 5.605, 5.668, 5.786 MeV) have $J^\pi = 1^+, 1^-, 1^-$ and 2^-. The 1^- states have mixed isospin. For astrophysical work, see the thermonuclear reaction rate tables in (85CA41) and the analytical expression presented in (88CA1N). See also (78AJ03, 83AJ01, 87AJ02).

26. ^{17}O(p, n)^{17}F $\qquad Q_m = -3.543 \qquad E_b = 5.607$

Table 18.31
Resonances in $^{17}O + p$ [a])

E_p (keV)	Particles out	$\Gamma_{c.m.}$ (keV)	$(2J+1)\Gamma_\gamma\Gamma_p/\Gamma$ (eV)	$J^\pi; T$	E_x (MeV ± keV)
517.0 ± 1.0	γ, α_0	0.24 ± 0.03	0.26 ± 0.05	$4^-; 0$	6.095
525	α_0	0.034 ± 0.003		(1^+)	6.102
561.2 ± 1.0	γ	≤ 1	2.2 ± 0.6	$0^+; 1$	6.136
587.1 ± 1.0	γ, p_0, α_0	14 ± 0.5	6.7 ± 1.8	$3^+; 1$	6.161
670.5 ± 1.0	γ, p_0, α_0	0.19 ± 0.03	(c)	$3^-; 0+1$	6.239
673.0	γ, α_0	0.18 ± 0.04	(c)	$3^-; 0+1$	6.242
690 ± 4	α_0	0.60 ± 0.12	≤ 0.02	$1^+; 0$	6.258
714.2 ± 1.0	γ, p_0, α_0	10.0 ± 0.5	9.1 ± 2.3	$2^+; 1$	6.281
741 ± 2	γ, p_0, α_0	0.95 ± 0.14	0.64 ± 0.17	$3^+; 0$	6.306
826 ± 2	γ, α_0	0.40 ± 0.09	0.60 ± 0.18	$2^+; 0+1$	6.386
926 ± 2	γ, α_0	0.40 ± 0.10	0.36 ± 0.15	$3^+; 0$	6.481
1015	α_0	0.56 ± 0.13	≤ 0.0023	$5^+; 0$	6.565
1090	α_0	80 ± 2		1	6.635
1098.4 ± 0.4	γ, α	0.60 ± 0.07	4.3 ± 1.2	$2^-; 1$	6.6439
1101 ± 4	α_0	89 ± 5			6.646
1240 ± 2 [b])	γ, p_0, α_0	9.2 ± 1.0	2.8 ± 0.7	$4^+; 0$	6.777
1270	γ, p_0	≤ 2	0.54 ± 0.20	$1^+, 2, 3^+; 0$	6.8031 ± 1.5
1274 ± 5	α_0	88 ± 2		2^-	6.809
1276	α_0	3.0 ± 0.5		(2^+)	6.811
1338	α_0	5.0 ± 1.0		(3^-)	6.870
1345 ± 3	γ, α_0	≤ 2	1.0 ± 0.4	$3, 4^-; 0$	6.876
1687.5 ± 1	α_0	6.5	3.9	$(4^+); 0$	7.199
1738 ± 2	α_0	46.5	8.8	$(1^+); 0$	7.247
1784 ± 2	p_0, α_0	38	47	3^-	7.291
1810 ± 4	α_0	52	8.5	$(3^-; 0)$	7.315
1832.5 ± 1	γ, p_0, p_1	16 ± 2	[d])	$1^-; 1$	7.336
1906 ± 2	p_0, p_1	14.6 ± 1.4		1^+	7.406
1950 ± 10	α_0	140	5.6		7.447
1957 ± 2	p_0	6		1^-	7.454
1983 ± 2	γ, p_1, α_0	12 ± 3	1.5	(2)	7.478
(1990 ± 2)	p_0	32		(1^-)	(7.485)
2012 ± 2	p_0, α_0	12 ± 2	7.2	4^-	7.506
2020 ± 2	γ	≤ 4			7.513
2036 ± 2	γ, p_0, p_1, α_0	16.5 ± 3.0	5.5 [e])	$2^-; 1$	7.528
2040 ± 5	p_1, α_0	75			7.532
2064 ± 2	p_0	30		(1^-)	7.555
2095 ± 2	γ, p_0, p_1, α_0	9 ± 2	3.7 [f])	[g])	7.584
2202 ± 2	p_0, p_1, α_0	36 ± 4	25.1	$3^+, 4^+$ [g])	7.685

Table 18.31 (continued)
Resonances in ^{17}O + p [a])

E_p (keV)	Particles out	$\Gamma_{c.m.}$ (keV)	$(2J+1)\Gamma_\gamma\Gamma_p/\Gamma$ (eV)	$J^\pi; T$	E_x (MeV ± keV)
2248 ± 4	p_1, α_0	66 ± 5	28.2	≥ 1	7.729
2284 ± 4	p_1	70			7.763
2406 ± 3	p_1, α_0	20	24.4	≥ 2	7.878
2429 ± 2	α_0	38	42	(2^-)	7.899
2473 ± 12	α_0	112	80	(1^+)	7.941
2603 ± 6	p_1, α_0	60	11	≥ 4	8.064
2657 ± 8	p_1	96			8.115
2757 ± 2	p_0, α_0	52	63	2^-	8.209
2788 ± 2	p_0	20		4^+	8.238
2828	α_0	$\simeq 50$			8.370
3915 ± 20	n	95			9.302
(4163 ± 20)	n	19			(9.536)
4235 ± 10	n	33			9.604
4330 ± 10	n	33			9.694
4490 ± 20	n	$\simeq 100$			9.845
(4790 ± 10)	n	28			(10.128)
4900 ± 20	n	$\simeq 140$			10.232

[a]) For references see Tables 18.18 in (78AJ03, 83AJ01).
[b]) See footnote (d) in Table 18.18 (78AJ03).
[c]) This corresponds to a doublet of 3^-, mixed isospin states, separated by 2.09±0.04 keV. $\omega\gamma_{p,\gamma} = 2.04 \pm 0.45$ eV for the lower resonance and 1.16 ± 0.26 eV for the higher one.
[d]) $\Gamma_\gamma = 3.5 \pm 1.0$ eV.
[e]) $\Gamma_\gamma = 0.44 \pm 0.10$ eV.
[f]) $\Gamma_\gamma = 0.11 \pm 0.03$ eV.
[g]) Assumed to be unresolved.

Observed resonances are displayed in Table 18.31. Analyzing power measurements are reported at $E_p = 135$ MeV (83PUZZ; n_0).

For astrophysics-related work see the thermonuclear reaction rate tables of (85CA41) and the analytical expressions of (88CA1N).

27. ^{17}O(p, p′)^{17}O $\qquad E_b = 5.607$

The elastic scattering has been studied for $E_p = 0.5$ to 13 MeV [see (78AJ03, 83AJ01)]: observed anomalies are displayed in Table 18.31. Analyzing powers have been measured at $E_p = 89.7$ MeV (85VO12).

28. ^{17}O(p, t)^{15}O $Q_m = -11.325$ $E_b = 5.607$

Analyzing powers have been reported at E_p = 89.7 MeV for the triton groups to a number of ^{15}O states (85VO12).

29. ^{17}O(p, α)^{14}N $Q_m = 1.192$ $E_b = 5.607$

The yield of α_0 shows a number of resonances for E_p = 0.49 to 3.0 MeV: see Table 18.31. The R-matrix fit of (79KI13), obtained using data from E_p = 400 to 1400 keV, confirms the earlier result [see, e.g., reaction 31 in (78AJ03)] that a significant quantity of ^{17}O is burned up in the (p, γ) rather than in the (p, α) reaction for a wide range of stellar temperatures (79KI13). See also (87AJ02, 87AS05).

Measurements (89BO01; see ^{14}N(α, γ)^{18}F reaction) of the first level ($J^\pi = 1^-$) of ^{18}F above the proton threshold determined $E_x = 5672.57 \pm 0.32$ keV. This result and a new value for the proton width of this level deduced from ^{17}O(^{3}He, d)^{18}F measurements (89LA19) lead to substantial changes in the stellar reaction rate for ^{17}O(p, α)^{14}N. [See discussion in (89LA19).] A direct search for the E_x = 70 keV resonance ($E_p = 5672.57 \pm 0.32$ keV) was carried out and an upper limit for the resonance strength ($\omega\gamma \leq 8\times10^{-10}$ eV) was reported in (92BE21).

30. ^{17}O(^{3}He, d)^{18}F $Q_m = 0.113$

At $E(^3$He) = 15 MeV DWBA analysis of angular distributions of deuteron groups corresponding to states of ^{18}F with $E_x < 5$ MeV have led to J^π values and spectroscopic information: see (72AJ02). Proton widths of states near the proton threshold were measured by (89LA19). See also (87ER05).

31. ^{17}O(α, t)^{18}F $Q_m = -14.207$

Measurements and DWBA analysis of differential cross sections at E_α = 65 MeV are reported in (92YA08). Measured level energies and spectroscopic information are included in Table 18.32.

32. ^{17}O(^{12}C, ^{11}B)^{18}F $Q_m = -10.350$

See (83AJ01).

33. ^{18}O(π^+, π^0)^{18}F $Q_m = 2.939$

Table 18.32
Some states in ^{18}F from ^{17}O(α, t) [a]

E_x (MeV) [b]	J^π [b]	σ_{int} (mb) [c]
0.0	1^+	0.26
0.93	3^+	0.41
1.04	$0^+, T = 1$	
1.12	5^+	1.92
2.52	2^+	0.02
3.06	$2^+, T = 1$	0.32
3.72	1^+	0.15
4.11	3^+	0.43
4.65	$4^+, T = 1$	0.61
7.44	(5^-) [d]	0.09
9.02	$(5^-, T = 1)$ [d]	0.09
9.58	(6^-) [d]	0.19
12.75	$(6^-, T = 1)$	0.03
14.65	(7^+) [d]	0.07
15.8	$(6^-, T = 1)$ [d]	0.03

[a]) (92YA08); $E_\alpha = 65$ MeV.
[b]) E_x and J^π values from (87AJ02).
[c]) Integrated cross section. See Tables III and IV in (92YA08) for spectroscopic factors.
[d]) J^π value assumed in analysis by (92YA08).

See (83AS01, 84AS05, 89LE1L).

34. ^{18}O(p, n)^{18}F $\qquad Q_m = -2.437$

(83AN05) have studied the distribution of Gamow-Teller (GT) strength. At E_p = 135 MeV angular distributions have been studied to the 0^+ state at 1.04 MeV and to the 1^+ states ^{18}F*(0, 1.70, 3.72, 4.36, 6.26 MeV) as well as to possible 1^+; $T = 1$ groups at $E_x = 9.9$, 10.9 and 11.9 MeV. 82% of the observed strength lies in the ground state group and 5.5% in the $T = 1$ states. The observed GT strength is $\approx \frac{2}{3}$ of that expected from the simple sum rule (83AN05). Multipole decomposition of data from measurements at $E_p = 494$ MeV is reported in (94ME07). See also (78AJ03, 87AJ02).

More recently the (p, n) reaction as a probe of beta decay strength is discussed in (87GO1V, 87TA13, 88MA53). See also (89RA1G). Studies of stretched state excitations are described in (86AN1E) and measurement of spin observables at E_p = 135 MeV are discussed in (89WAZZ, 90WAZT). Total cross sections for ^{18}F production from ^{18}O(p, n) were measured by (90WA10). See (88HI1F, 91GU05) for related applications.

Table 18.33
Branching in ^{18}Ne(β^+)^{18}F [a])

Decay to ^{18}F* (MeV)	$J^{\pi}; T$	E_{γ_0} (keV)	Branch [b]) (%)	$\log f_0 t$ [c])
0	$1^+; 0$		92.11 ± 0.21	3.096 ± 0.004
1.04 [d])	$0^+; 1$	1041.5 ± 0.3	7.70 ± 0.21	3.473 ± 0.013
1.08 [d])	$0^-; 0$	1080.76 ± 0.13 [b])	$(2.07 \pm 0.28) \times 10^{-3}$	7.012 ± 0.059
1.70	$1^+; 0$	1699.9 ± 0.3 [e])	0.188 ± 0.006	4.477 ± 0.015

[a]) For the earlier work see Tables 18.19 in (83AJ01) and 18.20 in (78AJ03).
[b]) (83AD03). See also (82HE04).
[c]) Based on $\tau_{1/2} = 1672 \pm 8$ ms: see (83AD03).
[d]) The splitting of the 0^+ and 0^- states is 39.20 ± 0.11 keV (83AD03).
[e]) And 659.2 ± 0.3 keV for the γ-ray to ^{18}F*(1.04) (82HE04).

35. ^{18}O(^{3}He, t)^{18}F $\qquad Q_{\rm m} = -1.674$

At $E(^3{\rm He}) = 16$ MeV, the triton spectrum is dominated by strong groups to ^{18}F*(0, 0.94) and to the 0^+ and 2^+, $T = 1$ states of ^{18}F*(1.04, 3.06). Angular distributions have been studied to these and many other states at this energy and at $E(^3{\rm He}) = 17.3$ MeV. $A_{\rm y}$ measurements for t_0 have been reported at $E(^3{\rm He}) = 33$ MeV. See (83AJ01) for references.

36. ^{18}O(^{6}Li, ^{6}He)^{18}F $\qquad Q_{\rm m} = -5.163$

The reaction was studied at $E(^6{\rm Li}) = 156$ MeV by (90MO13). Evaluated cross sections for Gamow-Teller transitions at 0° and strengths for analogous beta decays were compared.

37. ^{18}Ne(β^+)^{18}F $\qquad Q_{\rm m} = 4.446$

The half-life of ^{18}Ne is 1672 ± 8 msec [see ^{18}Ne]. The decay is to ^{18}F*(0, 1.04, 1.08, 1.70 MeV): see Table 18.33 and reaction 1 under ^{18}Ne.

38. ^{19}F(γ, n)^{18}F $\qquad Q_{\rm m} = -10.431$

Cross sections have been reported up to 30 MeV for the transitions to ^{18}F*(0.94, 1.04, 1.08, 3.06, 3.13, 4.75 MeV): see (83AJ01).

Cross sections for the (γ, n_0) photoneutron reaction were measured between 48° and 139° for $E_\gamma = 15$–25 MeV by (89KU10). The E1 absorption strength was deduced.

Table 18.34
γ-ray intensities in ^{18}Ne(β^+)^{18}F [a]

E_γ (keV)	E_i (keV)	E_f (keV)	I_γ [b]
659.0 ± 0.2	1701	1042	0.135 ± 0.005
1041.55 ± 0.08	1042	0	7.83 ± 0.21
1080.76 ± 0.13	1081	0	0.00226 ± 0.00021
1700.81 ± 0.18	1701	0	0.0538 ± 0.0018

[a]) (83AD03).
[b]) γ-ray intensities are per 100 parent decays.

39. ^{19}F(n, 2n)^{18}F $Q_m = -10.431$

Cross sections have been measured at E_n = 18, 21, 23, 25, and 27 MeV (91HA17).

40. ^{19}F(p, d)^{18}F $Q_m = -8.207$

Angular distributions have been reported to many states of ^{18}F with $E_x \leq 6$ MeV: see Table 18.20 in (83AJ01). See also (87AJ02). Spectroscopic factors derived from measurements at E_p = 18.6 MeV are discussed in (87VA28). See also (89VAZM).

41. ^{19}F(d, t)^{18}F $Q_m = -4.174$

See (72AJ02, 78AJ03), and see (89VAZM) for cross section measurements and deduced level energies and spectroscopic factors. A recent measurement of total cross sections at E_d = 5–12 MeV (93AB18) detected eight resonances with widths $\Gamma \approx$ 200–400 keV.

42. ^{19}F(^{3}He, α)^{18}F $Q_m = 10.146$

See (78AJ03, 87VA1I, 88GO1E), and see (89VAZM) for cross section measurements and deduced level energies and spectroscopic factors.

43. ^{20}Ne(p, ^{3}He)^{18}F $Q_m = -15.557$

See (78AJ03).

44. ^{20}Ne(d, α)^{18}F $\qquad Q_m = 2.796$

At E_d = 11 MeV α-groups are observed to many states of ^{18}F with E_x < 7 MeV. Weak or absent (each $\leq 0.3\%$ of the total yield at 30°) are the groups corresponding to ^{18}F*(1.04, 3.06, 4.66, 4.74, 4.96 MeV): $T = 1$. Measurements of the TAP for E_d = 10.25 to 12.0 MeV leads to assignments of 2^-, 1^+, 0^+, 1^-, 1^+, 3^+, 3^+ to ^{18}F*(4.23, 4.36, 4.75, 4.86, 5.603, 6.16, 6.48 MeV). See (72AJ02, 78AJ03, 83AJ01) for references and for other results and (87HI1B) for applications. Use of this reaction for ^{18}F production is discussed in (91GU05).

45. ^{21}Ne(p, α)^{18}F $\qquad Q_m = -1.741$

See (87GO1G).

46. ^{23}Na(p, X)^{18}F

The ^{18}F yield from protons on ^{23}Na at E_p = 20–67.5 MeV was measured (92LA25) and cross sections were deduced.

47. ^{23}Na(d, ^{7}Li)^{18}F $\qquad Q_m = -12.175$

See (84NE1A).

48. ^{27}Al(^{16}O, ^{25}Mg)^{18}F $\qquad Q_m = -9.616$

Cross sections have been measured for $E(^{16}O)$ = 13.6 GeV/nucleon by (93CU05).

^{18}Ne

GENERAL: See Table 18.35.
For B(E2) of ^{18}Ne* (1.89) and other parameters see (87RA01) and Table 2 (of the published version, *Nucl. Phys. A*595 (1995) 1).

1. ^{18}Ne(β^+)^{18}F $\qquad Q_m = 4.446$

Table 18.35
^{18}Ne – General

Reference	Description
Reviews:	
87LE1B	Strong interaction studies via meson-nucleus reactions
87RA1D	Nuclear processes and accelerated particles in solar flares
93EN03	Strengths of γ-ray transitions in $A = 5$–44 nuclei
Other articles:	
87BE1I	Search for a nucleon-participant multiplicity effect on anomalous fragment production
87BU12	An ISOL/post-accelerator facility for nuclear astrophysics at TRIUMF
87CO31	Simple parametrization for low energy octupole modes of s-d shell nuclei
87KA39	Delta-hole approach to pion double charge exchange (DCX) reactions
87PA1H	Anomalous behavior of low energy analog double charge exchange
88MA1Q	Identification of one glue-like mechanism of the Λ-hyperon in hypernuclei
88YU04	Contribution of the 2nd kind of meson exchange current to ^{18}O(π^+, π^-)^{18}Ne(g.s.)
89BA2N	Strangeness production in relativistic heavy-ion collisions
89CH1P	1s-0d effective interactions of isospin triplet & ^{18}Ne-^{18}O Coulomb displacement energies
89RA16	Predxns. from systematics & tabulation of B(E2; $0^+_1 \rightarrow 2^+_1$) values for even-even nucl.
89TR18	2-nucleon and 4-nucleon clusters in light & heavy nuclei
90BR13	Empir. p-n interactions: global trends, configuration sensitivity & $N = Z$ enhancements
90BR26	Shell-model calcs. of isospin-forbidden β-delayed proton emission of isobaric analog state
90LO11	Self-consistent calculations of light nuclei
90MAZW	Hybrid quark hadron model of DCX in the delta resonance region (A)
90PO04	New method of determining masses & quantum characteristics of light nuclei
92AV03	The proton-neutron interaction & mass calcs. for nuclei with $Z > N$
94CI02	Specific heat and shape transitions in light sd nuclei

(A) denotes that only an abstract was available for this reference.

The half-life of ^{18}Ne is 1672 ± 8 msec: see (78AJ03) and (83AD03). The decay is primarily to ^{18}F* (0, 1.04, 1.70 MeV). In addition there is an extremely weak branch [$(2.07 \pm 0.28) \times 10^{-3}$%] to ^{18}F* (1.08 MeV) [$J^\pi = 0^-$; $T = 0$] (83AD03): see Table 18.33 for the parameters of the decay. The parity mixing in the ^{18}F* (1.04, 1.08) 0^+–0^- doublet has been studied by (83AD03). It has been proposed as a probe of T-odd nuclear forces (92HE12). See also (82HE04). For the earlier work see (83AJ01, 87AJ02).

2. ^{12}C(^{12}C, ^{6}He)^{18}Ne $\qquad Q_m = -22.913$

This reaction was studied at ^{6}He angles from 0° to 10° with a magnetic spectrometer (92HAZZ). New levels at $E_x > 6$ MeV, including ^{18}Ne(6.15, 7.35 MeV), were found. Astrophysical implications were discussed.

3. ^{14}O(α, γ)^{18}Ne $\qquad Q_m = 5.112$

Table 18.36
Energy levels of ^{18}Ne [a]

E_x (MeV ± keV)	$J^\pi; T$	τ or $\Gamma_{c.m.}$	Decay	Reactions
0	$0^+; 1$	$\tau_{1/2} = 1672 \pm 8$ ms	β^+	1, 5, 9, 10
1.8873 ± 0.2	2^+	$\tau_m = 0.67 \pm 0.06$ ps	γ	5, 9, 10
3.3762 ± 0.4	4^+	$\tau_m = 4.4 \pm 0.6$ ps	γ	5, 7, 8, 10
3.5763 ± 2.0	0^+	$\tau_m = 4 \pm 2$ ps	γ	5, 10
3.6164 ± 0.6	2^+	$\tau_m = 63^{+30}_{-20}$ fs	γ	5, 10
4.519 ± 8	1^-	$\Gamma \leq 20$ keV	(p)	5, 10
4.561 ± 9	3^+			5
4.590 ± 8	0^+	$\Gamma \leq 20$ keV	(p)	5, 10
5.090 ± 8	$(2^+, 3^-)$	$\Gamma = 40 \pm 20$ keV	(p)	5, 10
5.146 ± 7	$(2^+, 3^-)$	$\Gamma = 25 \pm 15$ keV		5, 10
5.453 ± 10		$\Gamma \leq 50$ keV		10
6.15 [b,c]	(1^-)			2, 3
6.297 ± 10	(4^+)	$\Gamma \leq 60$ keV		5, 10
6.353 ± 10		$\Gamma \leq 60$ keV		10
7.059 ± 10	$(1^-, 2^+)$	$\Gamma = 180 \pm 50$ keV		5
7.35 [c]				2
7.713 ± 10		$\Gamma \leq 50$ keV		5, 10
7.910 ± 10	$(1^-, 2^+)$	$\Gamma \leq 50$ keV		5
7.950 ± 10		$\Gamma \leq 60$ keV		10
8.086 ± 10		$\Gamma \leq 50$ keV		5
8.500 ± 30		$\Gamma \leq 120$ keV		5
9.201 ± 9		$\Gamma \leq 50$ keV		10

[a]) See also Table 18.37.
[b]) (90GAZW).
[c]) (92HAZZ). This work reports the observation of several new levels in the region $E_x > 6$ MeV.

The thermonuclear reaction rates for this reaction have been estimated (87WI11) using information from the isobaric analog ^{18}O. A new ^{18}Ne level at $E_x = 6.15$ MeV (see ^{16}O(^{3}He, n)) has been observed (90GAZW) which may play a role in $^{14}\mathrm{O} + \alpha$ burning. See also (88CA1N).

4. ^{14}O(α, p)^{17}F $\qquad Q_m = 1.190$

This reaction is considered important in the generation of $Z \geq 10$ nuclei from products in the hot CNO cycle. Microscopic multichannel calculations for this reaction are discussed in (88FU02, 89FU01).

Table 18.37
Branching ratios and lifetimes of ^{18}Ne states [a]

E_i (MeV)	J_i^π	E_f (MeV)	Branch (%)	τ_m (ps)
1.89	2^+	0	100	0.67 ± 0.06
3.38	4^+	1.89	100 [b]	4.4 ± 0.6
3.58	0^+	1.89	100 [c]	4 ± 2
3.62	2^+	0	9 ± 2	
		1.89	91 ± 2 [d]	$0.063^{+0.030}_{-0.020}$

[a]) For references see Table 18.24 in (78AJ03).
[b]) Ground state decay is $< 1\%$.
[c]) Ground state decay is $< 5\%$.
[d]) The mixing ratio, δ, is consistent with 0.

5. ^{16}O(^{3}He, n)^{18}Ne $\quad$ $Q_m = -3.196$

See Table 18.38. See also (83AJ01).

Recent work reported in (91GA03) found that the 3^+ level in ^{18}Ne predicted by (88WI08) occurs at $E_x = 4.561 \pm 0.009$ MeV. Astrophysical consequences are discussed. New levels in ^{18}Ne at $E_x \geq 6$ MeV observed in ^{16}O(^{3}He, n) were reported in (90GAZW). [See discussion under ^{14}O(α, γ)^{18}Ne.] See also (89GAZW, 90GAZR). For applied work related to this reaction see (91GU05, 92DI04)

6. ^{16}O(α, nn)^{18}Ne $\quad$ $Q_m = -23.773$

See (91GU05) for measurements at $E_\alpha = 40$ MeV.

7. ^{16}O(^{10}B, ^{8}Li)^{18}Ne $\quad$ $Q_m = -18.951$

At $E(^{10}\text{B}) = 100$ MeV, the angular distribution to ^{18}Ne*(3.38) [$(d_{5/2})^2_{4^+}$ state], which is preferentially populated, has been studied. ^{18}Ne*(1.89) is also observed (see (83AJ01). See also (83OS07).

8. ^{16}O(^{12}C, ^{10}Be)^{18}Ne $\quad$ $Q_m = -22.663$

Measurements at $E(^{12}\text{C}) = 480$ MeV are reported in (88KR11, 88ME10). The 4^+ level at $E_x = 3.38$ MeV is observed.

Table 18.38
States in ^{18}Ne from ^{16}O(^{3}He, n) and ^{20}Ne(p, t) ^{a})

E_x (MeV ± keV)		$\Gamma_{c.m.}$ ^{b})	J^{π} ^{a,b})
A	B	(keV)	
0			0^+
1.8873 ± 0.2	1.886 ± 10		2^+
3.3762 ± 0.4	3.375 ± 10		4^+
3.5763 ± 2.0	3.580 ± 10		0^+
3.6164 ± 0.6	3.612 ± 10		2^+
4.513 ± 13	4.522 ± 10	≤ 20	1^-
4.561 ± 9 ^{c})		25 ^{c})	3^+ ^{c})
4.587 ± 13	4.592 ± 10	≤ 20	0^+
5.075 ± 13	5.099 ± 10	40 ± 20	$(2^+, 3^-)$
5.141 ± 10	5.151 ± 10	25 ± 15	$(2^+, 3^-)$
	5.453 ± 10	≤ 50	
6.291 ± 30 ^{d})	6.297 ± 10	≤ 60	(4^+)
	6.353 ± 10	≤ 60	
7.062 ± 12 ^{a})		180 ± 50	$(1^-, 2^+)$
7.712 ± 20	7.713 ± 10	≤ 50	
7.915 ± 12 ^{a})		≤ 50	$(1^-, 2^+)$
	7.949 ± 10	≤ 60	
8.100 ± 14 ^{a})		≤ 50	
8.50 ± 30		≤ 120	
	9.198 ± 10	≤ 50	

A: ^{16}O(^{3}He, n)^{18}Ne: for references see Table 18.23 (78AJ03) and (81NE09).
B: ^{20}Ne(p, t)^{18}Ne: (81NE09).
^{a}) See also Table 18.23 in (78AJ03).
^{b}) (81NE09).
^{c}) (91GA03). The width $\Gamma = 25$ keV is estimated from a Woods Saxon calculation.
^{d}) $\Gamma = 180 \pm 60$ keV.

9. ^{18}O(π^+, π^-)^{18}Ne $\qquad Q_m = -6.101$

Angular distributions have been studied at $E(\pi^+) = 164$ and 292 MeV [see (83AJ01)] and at 48.3 MeV (85AL15; to ^{18}Ne$_{g.s.}$) and 100 to 292 MeV (85SE08; to ^{18}Ne$_{g.s.}$). The excitation functions for production of ^{18}Ne* (0, 1.89) have been measured for $E(\pi^+) = 80$ to 292 MeV: see (83AJ01, 85SE08). See also (87AJ02).

The behavior of double charge exchange (DCX) cross sections at low energies (50 ± 30 MeV) was reviewed in (87PA1H, 88SE1A, 89BA1R). See also the review of (89ST1H). Measurements at energies of 300–500 MeV above the $\Delta(1232)$ resonance were reported in (89WI02). More recently a search for an η bound state in this reaction is described in (92JOZZ, 93JO03).

The contribution of the two-nucleon pion absorption emission mechanism is discussed in (90CH14). See also (89CH1O, 90CH1U) and see (89YU1A). A quark-antiquark annihilation mechanism is proposed in (89CH21). A two-amplitude model for the DCX energy dependence is described in (89FO02). In other recent work, the contribution of sequential charge exchange and delta-nucleon charge exchange is examined in (93GI03). Absorption contributions near $T_\pi = 50$ MeV are evaluated by (92OS05). High energy DCX and isovector renormalization is calculated and compared with data in (93OS01). See also (92MA46) for a discussion of dibaryon effects.

10. ^{20}Ne(p, t)^{18}Ne $Q_m = -20.022$

Observed triton groups are displayed in Table 18.38 as are J^π derived from a DWBA analysis of angular distributions: The 0_3^+ state, identified at $E_x = 4.59$ MeV, appears to have a largely $s_{1/2}^2$ configuration based on its large downward shift with respect to the analog state in ^{18}O (81NE09).

11. ^{20}Ne(^{3}He, nα)^{18}Ne $Q_m = -7.926$

See (91GU05).

^{18}Na
(not observed)

^{18}Na has not been observed; its atomic mass excess has been estimated to be 25.32 MeV (93AU05); it is then unbound with respect to proton emission by 1.6 MeV: see (78AJ03). See also (86AN07) and (83ANZQ).

^{18}Mg, etc.
(not observed)

See (86AN07) and (83ANZQ). See also the results of calculations of β^+/electron capture half lives for neutron deficient nuclei in (93HI08).

Table 18.39
Isospin triplet components ($T = 1$) in $A = 18$ nuclei [a]

^{18}O		^{18}F			^{18}Ne		
E_x (MeV)	J^π	E_x (MeV)	J^π; T	ΔE_x (MeV) [b]	E_x (MeV)	J^π	ΔE_x (MeV) [c]
0	0^+	1.04	0^+; 1	—	0	0^+	—
1.98	2^+	3.06	2^+; 1	+0.04	1.88	2^+	-0.09
3.55	4^+	4.65	4^+; 1	+0.06	3.38	4^+	-0.18
3.63	0^+	4.75	0^+; 1	+0.08	3.57	0^+	-0.06
3.92	2^+	4.96	2^+; 1	+0.002	3.62	2^+	-0.30
4.46	1^-	{ 5.60	1^-; $0+1$	+0.11	4.52	1^-	+0.06
		{ 5.67	1^-; $0+1$	+0.18			
5.10	3^-	{ 6.240	3^-; $0+1$	+0.10	5.09	$(2^+, 3^-)$	-0.01
		{ 6.242	3^-; $0+1$	+0.10	5.15	$(2^+, 3^-)$	+0.05
5.25	2^+	{ 6.28	2^+; 1	-0.01			
		{ 6.39	2^+; 1	+0.09			
5.34	0^+	6.14	0^+; 1	-0.24	4.59	0^+	-0.75
5.38	3^+	6.16	3^+; 1	-0.26			
5.53	2^-	6.64	2^-; 1	+0.07			
6.19	1^-	7.34	1^-; 1	+0.10			

[a]) As taken from Tables 18.9, 18.24 and 18.36.
[b]) Defined as $E_x(^{18}F) - E_x(^{18}O) - 1.04$ MeV.
[c]) Defined as $E_x(^{18}Ne) - E_x(^{18}O)$.

Table 18.40
($T = 2$) states in ^{18}N and ^{18}O [a])

^{18}N		^{18}O	
E_x (MeV)	J^π	E_x (MeV)	$J^\pi; T$
0	1^- [b])		
0.11	(2^-) [b,c])	16.4	$2^-; 2$
0.59	(2^-) [b])		
0.75	(3^-) [b,c])	17.03	$(3^-); 2$
		17.4	$1^-; (2)$
		18.7	$(4^-); 2$
		18.9	$1^+; 2$
		19.24	$(> 2); 2$
		19.4	$1^-; (2)$
		20.36	$(4^-); 2$
		21.42	$(4^-); (2)$
		22.40	$4^-; 2$
		27	$1^-; (2)$

[a]) As taken from Tables 18.4 and 18.9.
[b]) Coulomb-shift computations (R. Sherr, private communication) for these four levels suggest that the analogs of the ^{18}N 1^- and (2^-) levels at $E_x = 0$ and 0.59 MeV are the ^{18}O $1^{(-)}$ and $(3, 2)^-$ levels at $E_x = 16.21$ and 16.95 MeV respectively.
[c]) It is noted (A.H. Wapstra, private communication) that the combined evidence on these two levels and their analogs in ^{18}O is an argument for assignments of 2^- and (3^-) in both nuclei, and in ^{18}O they should lie above an unobserved $1^-; 2$ state near 16.3 MeV.

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(Closed October 31, 1994)

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