A = 16 Theoretical

Because of the very large body of theoretical work that has been carried out for the $A = 16$ nuclei, and the importance of the spherical shell model in this work, a general discussion of the shell model description of $A = 16$ nuclei is provided here.[1]

The spherical shell-model provides a complete basis for the description of nuclear states. It is convenient to use harmonic oscillator single-particle wave functions since the coordinate transformations necessary to separate spurious center of mass states, to relate shell-model to cluster-model wave functions, and so on, can be made exactly. Configurations are classified by the number of oscillator quanta that they carry beyond the minimum allowed by the Pauli principle as $0\hbar\omega$, $1\hbar\omega$, $2\hbar\omega$, ... excitations. Non-spurious states of $A = 16$ in general involve admixtures of $npnh$ configurations but the lowest excitations of each isospin can, with the exception of the $K^\pi = 0^-$ band with the ^{16}O 9.58 MeV 1^- state as band head, be thought of as dominantly $p^{-n}(sd)^n$ excitations. In fact, the lowest eigenstates of an $n\hbar\omega$ calculation can usually be written economically in terms of product states of low-lying p^{-n} and $(sd)^n$ eigenstates. In the simplest version of this weak-coupling model, one identifies the p^{-n} and $(sd)^n$ eigenstates with the physical states of the relevant nuclei and takes the diagonal expectation value of $H_p + H_{sd}$ from the known masses. The contribution from the cross-shell, or particle-hole, interaction can often be quite reliably estimated by using ph matrix elements extracted from the nominal $1p1h$ states of ^{16}O or ^{16}N.

The $2p2h$ states with $T = 0$ and 1 cannot, in general, be described in terms of the simple weak-coupling model, although there are examples to which such a description can be applied. Shell-model calculations which use empirical interactions fitted to data on $1\hbar\omega$ excitations in the mass region do, however, produce $2p2h$ $T = 1$ states in one-to-one correspondence with the lowest positive-parity states of ^{16}N (see Table 16.5). They also produce $T = 0$ $2p2h$ states starting at around 12 MeV in ^{16}O. In this case, the $2p2h$ states are interleaved with $4p4h$ states which begin at lower energies. The lowest $2p2h$ $T = 0$ states can be related in energy to the 14.82 MeV 6^+ state which is strongly populated by the addition of a stretched $d^2_{5/2}$ pair in the ^{14}N(α, d)^{16}O reaction. The lowest six $2p2h$ $T = 2$ states can be very well described in this way.

Weak-coupling ideas can be extended to the lowest $3p3h$ and $4p4h$ states. Since the 3 and 4 particle (or hole) configurations are strongly configuration mixed in the jj-coupling scheme, the ph interaction is usually represented in the simple monopole form $E_{ph} = a + bt_p.t_h$ plus a small attractive Coulomb contribution. The ph interaction then gives a repulsive contribution of $9a$ and $16a$ to $3p3h$ and $4p4h$ configurations and separates the $T = 0$ and $T = 1$ $3p3h$ states by b MeV. The empirical values of a and b are $a \sim 0.4$ MeV and $b \sim 5$ MeV, which put the $4p4h$ 0^+ state and the $3p3h$ 1^- states close to experimental candidates at 6.05, 12.44 and 17.28 MeV respectively, each of which is the lowest member of a band.

The weak-coupling states can be used as a basis for shell-model calculations, but the elimination of spurious center-of-mass motion is approximate even within an

[1] We are very grateful to Dr. John Millener for providing these comments on the shell model for the $A = 16$ system.

oscillator framework; orbits outside the $p(sd)$ space are needed and can be important components of states of physical interest. If complete $n\hbar\omega$ spaces are used, the choice of basis can be one of computational convenience. A more physical LS-coupled basis is obtained by classifying the states according to the Wigner supermultiplet scheme ($SU4 \supset SU2 \times SU2$ symmetry $[\tilde{f}]$ in spin-isospin space) and the SU3 symmetry $(\lambda\,\mu)$ of the harmonic oscillator. States with the highest spatial symmetry $[f]$ maximize the number of spatially symmetric interacting pairs to take advantage of the fact that the NN interaction is most strongly attractive in the relative $0s$ state and weak or repulsive in relative p states. These symmetries are broken mainly by the one-body spin-orbit interaction. In np and nh calculations, the lowest states are dominated by the $[f]\,(\lambda\,\mu)$ configurations $[n]\,(2n\,0)$ and $[4^2 4-n]\,(0\,n)$ respectively (these symmetries are very good if the one-body spin-orbit interaction is turned off). In $npnh$ calculations, the lowest states are dominated by the highest spatial symmetry allowed for given isospin T and $(2n\,n)$ SU3 symmetry. These states are identical to harmonic oscillator cluster-model states with $2n$ quanta on the relative motion coordinate between the nh core and the np cluster. States with a large parentage to the ground state of the core should be seen strongly in the appropriate transfer reaction.

In the above, a basic $n\hbar\omega$ (mainly $npnh$) shell-model structure has been matched, through characteristic level properties and band structures, with experimental candidates. The mixing between shell-model configurations of different $n\hbar\omega$ is of several distinct types.

First, there is direct mixing between low-lying states with different $npnh$ structure; the $p^2 \rightarrow (sd)^2$ mixing matrix elements (SU3 tensor character mainly $(4\,2)$) are not large (up to a few MeV) although the mixing can be large in cases of near degeneracy.

A second type of mixing is more easily understood by reference to cluster models in which an oscillator basis is used to expand the relative motion wave function. To get a realistic representation of the relative motion wave function for a loosely-bound state or an unbound resonance requires many oscillators up to high $n\hbar\omega$ excitation. A related problem, which also involves the radial structure of the nucleus, occurs for the expansion of deformed states (of which cluster states are an example) in a spherical oscillator (shell-model) basis; e.g., deformed Hartree-Fock orbits may require an expansion in terms of many oscillator shells. It is difficult to accomodate this type of radial mixing in conventional shell-model calculations, but symplectic Sp(6,R) shell-models, in which the $SU3$ algebra is extended to include $1p1h$ $2\hbar\omega$ monopole and quadrupole excitations, do include such mixing up to high $n\hbar\omega$.

A third type of mixing involves the coupling of $npnh$ excitations to high-lying $(n+2)\hbar\omega$ configurations via the strong $(\lambda\,\mu) = (2\,0)$ component of the $p^2 \rightarrow (sd)^2$ interaction. In the full $(0+2+4)\hbar\omega$ calculations, the large (30-45%) $2p2h$ admixtures in the ground state are mainly of the $(2\,0)$ type, which are intimately related to the ground-state correlations of RPA theory, and lead to enhancement (quenching) of excitations at low momentum transfer $\Delta T = 0$, $\Delta S = 0$ and to quenching otherwise.

For most detailed structure questions, a shell-model calculation is required to include the relevant degrees of freedom. For example, (90HA35) address two important problems with complete $(0+2+4)\hbar\omega$ and $(1+3)\hbar\omega$ model spaces. One is the rank-zero ^{16}N$(0^-) \rightarrow {}^{16}O(gs)$ β decay and the inverse μ capture which receive large two-body meson-exchange current contributions. The other is the distribution of M1 and Gamow-Teller strength based on the ^{16}O ground state; this is a complicated problem which involves $2p2h\ldots$ admixtures in the ground state which break SU4 symmetry.

Many interesting structure problems remain. A detailed understanding of the shapes and magnitudes of inelastic form factors is lacking, particularly the shapes at momentum transfers beyond 2 fm^{-1}. Even in the relatively simple case of M4 excitations, much studied via (e, e′), (p, p′) and (π, π') reactions, a rather low value of the oscillator parameter b is required to describe the form factor. Also, the configuration mixing which splits the 4^-; $T = 0$ strength into two major components and causes isospin mixing has not been satisfactorily described by a shell-model calculation. Similar interesting problems occur for isospin-mixed negative-parity states near 13 MeV excitation energy. It is worth noting that, to avoid some serious consistency problems, the large shell-model calculations have omitted orbits outside the $p(sd)$ space except to the degree needed to cleanly separate spurious center-of-mass states. A consistent treatment of $1p1h$ and $2p2h$ correlations in multi-$\hbar\omega$ shell-model spaces remains a challenging question.

^{16}He

(Not illustrated)

This nucleus has not been observed. See (82AV1A, 83ANZQ, 86AJ04).

^{16}Li

(Not illustrated)

This nucleus has not been observed. Shell model studies (88PO1E) are used to predict J^π and the magnetic dipole moment.

^{16}Be

(Not illustrated)

This nucleus has not been observed. Its atomic mass is calculated to be 59.22 MeV. It is then unstable with respect to breakup into ^{14}Be$\,+\,$2n by 2.98 MeV. See (74TH01, 86AJ04, 87SA15). The first three excited states with $J^\pi = 2^+, 4^+, 4^+$ are calculated to be at 1.90, 5.08, and 6.51 MeV using a $(0 + 1)\hbar\omega$ space shell model (85PO10).

^{16}B

(Not illustrated)

This nucleus has not been observed in the 4.8 GeV proton bombardment of a uranium target. It is particle unstable. Its mass excess is predicted to be 37.97 MeV; it would then be unstable with respect to decay into ^{15}B + n by 0.93 MeV. See (85WA02, 86AJ04). The ground state is predicted to have $J^\pi = 0^-$ and the first three excited states are predicted to lie at 0.95, 1.10, and 1.55 MeV [$J^\pi = 2^-$, 3^-, 4^-] in a $(0+1)\hbar\omega$ space shell model calculation. See (83ANZQ, 85PO10, 86AJ04). Predicted masses and excitation energies for higher isospin multiplets for $9 \leq A \leq 60$ are included in the compilation (86AN07). An experiment (85LA1A) involving in-flight identification of fragments from 44 MeV/u ^{40}Ar found no trace of ^{18}B or ^{16}B and provides strong evidence that ^{16}B is particle-unstable.

^{16}C

(Figs. 1 and 5)

GENERAL:

See Table 16.1.

1. ^{16}C(β^-)^{16}N $\qquad Q_\mathrm{m} = 8.012$

The half life of ^{16}C is 0.747 ± 0.008 s. It decays to ^{16}N*(0.12, 3.35, 4.32) [$J^\pi = 0^-$, 1^+, 1^+]: see Table 16.3 and 93CH1A. See also (86AJ04) and see (86KI05, 88WA1E, 92WA1L) for theoretical discussions of extended shell-model calculations of $0^+ \to 0^-$ transitions and determination of the mesonic enhancements ε_mec of the time-like component of the axial current. See also (92TO04) and see ^{16}N, Reaction 1.

2. ^{14}C(t, p)^{16}C $\qquad Q_\mathrm{m} = -3.013$

States of ^{16}C observed in this reaction are displayed in Table 16.2. See also Table 16.3 of (82AJ01), and see (77BA59).

3. ^{16}O(K$^-$, π^+)$^{16}_{\Sigma}$C

(85BE31) used negative kaons of 450 MeV/c to produce Σ hypernuclear states, which they interpreted as Σ^- particles in the $p_{3/2}$ and $p_{1/2}$ orbits of the $^{16}_{\Sigma}$C hypernucleus. Their energy splitting was used to constrain the Σ^- spin-orbit coupling.

(86HA26) performed a systematic shell-model analysis of Σ-hypernuclear states, in which they deduced a ΣN-spin-orbit interaction about twice as strong as the one for the nucleon. (86MA1J) reached a similar conclusion after extracting the one-particle spin-orbit splitting $\varepsilon_\Sigma = \varepsilon^\Sigma \mathrm{p}_{1/2} - \varepsilon^\Sigma \mathrm{p}_{3/2}$. (87WU05) used the continuum shell-model to study competition between resonant and quasi-free Σ-hypernuclear production. The observed structures in the excitation spectra are essentially accounted for by the quasi-free mechanism alone. (89DO1I) perform a series of shell model calculations of energy spectra of p-shell Σ hypernuclei, starting with several different parametrizations of the ΣN effective interaction. Production cross sections are estimated using DWBA. They suggest experiments to resolve open questions regarding the ΣN and Σ-nucleus interactions. (89HA32) uses the recoil continuum shell model to calculate in-flight Σ hypernuclei production of this reaction (and others). They needed to modify the ΣN central interaction to fit data.

Coupled channels (CC) calculations for Σ-hypernuclear spectra give an energy integrated cross section which is about 1.7 times the experimental value (87HA40). (88HA1I) report CC calculations emphasizing the proper treatment of the Σ continuum states. They find that a weak Σ central potential and a comparable $\Sigma\Lambda$ conversion potential are required to describe experimental results.

^{16}N

(Figs. 2 and 5)

GENERAL:

See Table 16.4.

For a comparison of analog states in ^{16}N and ^{16}O, see (83KE06, 83SN03).

1. $^{16}\mathrm{N}(\beta^-)^{16}\mathrm{O}$ $\qquad Q_\mathrm{m} = 10.419$

The half-life of ^{16}N is 7.13 ± 0.02 s: see Table 16.3 in (71AJ02). From the unique first-forbidden character of the β decay [see Table 16.25 and (84WA07)], ^{16}N must have $J^\pi = 2^-$: see ^{16}O, reaction 39. See also (85HE08, 88BA15).

The β-decay of ^{16}N*(0.12) [$J^\pi = 0^-$] has been measured (83GA18, 85HA22); adopted value: $\lambda_\beta = 0.489 \pm 0.020$ s^{-1} (85HE08). The relationship of this rate to that for $^{16}\mathrm{O}(\mu^-, \nu)^{16}\mathrm{N}(0^-)$ [see reaction 18] and the fact that the large values of these rates support the prediction (78KU1A, 78GU05, 78GU07) of a large ($\sim 60\%$) enhancement over the impulse approximation (e.g., $\varepsilon_\mathrm{mec} = 1.60$) has been the subject of a great deal of theoretical study, see, e.g. (81TO16, 86KI05, 86TO1A, 88WA1E, 90HA35). The work of (90HA35, 92WA1L) is a culmination of present knowledge on the determination and interpretation of ε_mec. See also (92TO04). A branching ratio $R(0^- \to 1^-)/(0^- \to 0^+) = 0.09 \pm 0.02$ has been reported (88CH30), implying $\log ft = 4.25 \pm 0.10$ for the $0^- \to 1^-$ transition to the ^{16}O 7.12-MeV level.

2. ^{7}Li(^{11}B, pn)^{16}N $\qquad Q_m = 2.533$

Gamma rays with $E_\gamma = 120.42\pm0.12$, 298.22 ± 0.08 and 276.85 ± 0.10 keV from the ground-state decays of ^{16}N*(0.12, 0.30) and the decay of the state at 397.27 ± 0.10 keV to the first excited state have been studied. τ_m for ^{16}N*(0.30, 0.40) are, respectively, 133 ± 4 and 6.60 ± 0.48 psec. See (86AJ04). Cross section measurements for ^{7}Li + ^{11}B at E(c.m.) = 1.45–6.10 MeV have been reported (90DA03).

3. (a) ^{9}Be(^{7}Li, n)^{15}N $\qquad Q_m = 18.082 \qquad E_b = 20.572$
(b) ^{9}Be(^{7}Li, 2n)^{14}N $\qquad Q_m = 7.249$
(c) ^{9}Be(^{7}Li, t)^{13}C $\qquad Q_m = 8.179$
(d) ^{9}Be(^{7}Li, α)^{12}B $\qquad Q_m = 10.461$
(e) ^{9}Be(^{7}Li, ^{8}Li)^{8}Be $\qquad Q_m = 0.368$

At incident ^{7}Li energies of 40 MeV, neutron yields at 0° for reactions (a) and (b) are 50 to 70 times smaller than for 40 MeV deuteron-induced reactions on ^{9}Be (87SC11). For reactions (c, d, e) see (82AJ01).

4. ^{9}Be(^{9}Be, np)^{16}N $\qquad Q_m = 1.652$

Cross sections were measured for characteristic ^{16}N gamma rays for incident ^{9}Be energies $E_{\text{c.m.}}$ = 1.4–3.4 MeV. The n, p and all other two-particle emission channels are enhanced by a factor of 2–3 relative to predictions of DWBA calculations (88LA25).

5. ^{10}B(^{7}Li, p)^{16}N $\qquad Q_m = 13.986$

See Table 16.6 and (82AJ01).

6. ^{12}C(^{16}O,^{16}N)^{12}N $\qquad Q_m = -27.757$

^{16}N spectra were measured for incident ^{16}O energies of 900 MeV/nucleon. Transitions to the low-lying GDR, the quasi-elastic, and the Δ-regions were observed (87EL14).

7. ^{13}C(α, p)^{16}N $\quad Q_{\rm m} = -7.422$

Differential cross sections measured (86AN30) at $E_\alpha = 118$ MeV were analyzed using DWBA calculations with microscopic form factors to obtain J^π and to locate multiparticle-multihole strength in ^{16}N: see Table 16.7. Measurements at $E_\alpha =$ 34.9 MeV are summarized in Table 16.5 of (86AJ04). See also (88BRZY, 88MIZY).

8. (a) ^{14}C(d,γ)^{16}N $\quad Q_{\rm m} = 10.474 \quad E_{\rm b} = 10.474$
(b) ^{14}C(d,n)^{15}N $\quad Q_{\rm m} = 7.984$
(c) ^{14}C(d,p)^{15}C $\quad Q_{\rm m} = -1.006$
(d) ^{14}C(d,d)^{14}C

For reaction (a) see (71AJ02). Resonances observed in reactions (b, c, d) are displayed in Table 16.5 of (82AJ01). Total cross sections for reaction (b) have been measured for $0.2 \le E_{\rm c.m.} \le 2.1$ MeV (92BR05).

9. ^{14}C(^{3}He,p)^{16}N $\quad Q_{\rm m} = 4.980$

Proton groups have been observed to ^{16}N states with $E_{\rm x} < 12$ MeV and angular distributions [with $E(^3{\rm He}) \le 15$ MeV] lead to the J^π assignments shown in Table 16.8.

10. ^{14}C(α,d)^{16}N $\quad Q_{\rm m} = -13.374$

At $E_\alpha = 46$ MeV the angular distributions of the groups to ^{16}N*(0.30, 3.96, 5.73, 7.60) have been determined: the most strongly populated state is the (5^+) state ^{16}N*(5.73). See (71AJ02).

11. ^{14}N(t,p)^{16}N $\quad Q_{\rm m} = 4.842$

Observed proton groups are displayed in Table 16.9. See also (86AJ04).

12. ^{15}N(n,γ)^{16}N $\quad Q_{\rm m} = 2.490$

The thermal cross section is 24 ± 8 μb: see (81MUZQ).

13. ^{15}N(n,n)^{15}N $E_b = 2.490$

The scattering amplitude (bound) $a = 6.44 \pm 0.03$ fm, $\sigma_{\rm free} = 4.59 \pm 0.05$ b, $\sigma_{\rm inc}^{\rm spin}$(bound nucleus) < 1 mb (79KO26). The total cross section has been measured for $E_n = 0.4$ to 32 MeV: see (77AJ02, 81MUZQ). Observed resonances are displayed in Table 16.10. See also (86AJ04, 88MCZT, 89FU1J).

14. ^{15}N(n,p)^{15}C $Q_m = -8.990$

The activation cross section was measured for neutron energies between 14.6 and 15.0 MeV (86RO1C).

15. ^{15}N(p,π^+)^{16}N $Q_m = -137.860$

This reaction was studied with 200 MeV protons for $E_x \leq 30$ MeV (87AZZZ). A strong transition to a state with $J^\pi = 5^+$ was observed at $E_x = 5.7$ MeV. Strong states were also observed at $E_x = 14.2$ and 16.1 MeV with cross sections falling sharply with angle.

16. ^{15}N(d,p)^{16}N $Q_m = 0.266$

Levels derived from observed proton groups and γ-rays are shown in Table 16.11. Gamma transitions are shown in the inset of fig. 2. The very strong evidence for $J^\pi = 2^-$, 0^-, 3^- and 1^-, respectively for ^{16}N*(0, 0.12, 0.30, 0.40) is reviewed in (71AJ02). These states provide a probe of the residual interaction relating the 1p and 2s 1d shells. See (84BI03) for a comparison of experiment and theory for M1 observables. See also (86AJ04, 86ME1A, 88VI1A).

17. ^{16}C(β^-)^{16}N $Q_m = 8.012$

See ^{16}C.

18. ^{16}O(μ^-, ν)^{16}N $\qquad Q_m = 95.239$

Partial μ^--capture rates have been observed to ^{16}N*(0.12, 0.40) [$J^\pi = 0^-, 1^-$] (79GU06). The rate for capture by the $J^\pi = 0^-$ state ["best" value: $\lambda_\mu = 1560 \pm 94\ \mathrm{s}^{-1}$ (85HE08)] and the "reverse" reaction ^{16}N*(0^-) $\overset{\beta}{\to}$ ^{16}O(0^+) [see reaction 1] were the first reactions which verify the prediction (78KU1A, 78GU05, 78GU07) of a large meson-exchange contribution to the weak, rank-zero axial charge. See ^{16}N, reaction 1 and (81TO16, 86NO04, 90HA35, 92WA1L). See also the measurement reported in (90BL1H) and the calculation of (90CH13).

19. ^{16}O(γ, π^+)^{16}N $\qquad Q_m = -149.986$

Pion spectra have been obtained with virtual photons in the energy range E_γ = 200–350 MeV (87JE02). Cross sections corresponding to the population of the four lowest states of ^{16}N (unresolved) were measured. Angular distributions were measured (87YA02, 87YA1D) at a photon energy of 320 MeV and the results compared to DWIA calculations. Measurements at E_e = 200 MeV and E_{π^+} = 30 MeV are cited in (86AJ04).

20. ^{16}O(n,p)^{16}N $\qquad Q_m = -9.637$

At E_n = 59.6 MeV differential cross sections for the protons to the first four states of ^{16}N (unresolved) and to ^{16}N*(6.2, 7.8) have been analyzed by DWBA. Comparisons are made with results from the ^{16}O(γ,n) and ^{16}N(p,γ_0) reactions in the GDR region of ^{16}O (82NE04, 84BR03). See also (83SC1A, 89BOYU, 88NO1B). Other (n, p)-like charge exchange reactions are reviewed in (89GA26), and data on (^{16}O, ^{16}N) is presented in (88HE1I).

21. ^{16}O(t,^{3}He)^{16}N $\qquad Q_m = -10.400$

At E_t = 23.5 MeV ^{16}N*(0, 0.30) [$J^\pi = 2^-, 3^-$] are strongly populated relative to ^{16}N*(0.12, 0.40) [$J^\pi = 0^-, 1^-$]: see (82AJ01). See also (88CL04).

22. ^{16}O(^{7}Li,^{7}Be)^{16}N $\qquad Q_m = -11.280$

Measurements at E(^{7}Li) = 50 MeV to ^{16}N*(0, 0.12, 0.30, 0.40, 3.35, 3.52, 3.96, 5.52, 5.73, 6.17) are reviewed in (86AJ04). A microscopic DWBA Coupled-Channels analysis of data at E(^{7}Li) = 50 MeV is reported in (86CL03). See also the review of charge-exchange reactions with ^{7}Li ions in (89GA26).

23. ^{17}O(γ, p)^{16}N $\qquad Q_m = -13.780$

Bremsstrahlung-weighted integrated cross sections have been measured (89OR07). About 90% of the photoproton emission populates the ground state (2^-) and the 0.298 MeV (3^-) levels. The 0.120 MeV (0^-) and 0.397 MeV (1^-) levels are also populated. See also (86OR1A). Measurements with quasimonoenergetic photons at $E_\gamma = 13.50$–43.15 MeV were carried out by (92ZU01) to study the GDR in ^{17}O.

24. ^{17}O(d,^{3}He)^{16}N $\qquad Q_m = -8.286$

See Table 16.10 in (82AJ01).

25. ^{18}O(π^+, 2p)^{16}N $\qquad Q_m = 118.526$

Coincidence measurements for $E_\pi = 116$ MeV, $\theta_{p_1} = 50°$, θ_{p_2} variable have been reported by (86SCZX, 86SC28). Transitions to the unresolved cluster of 4 states below 0.4 MeV excitation were observed to account for 6.1 ± 0.6% of the estimated two-nucleon absorption cross section below 20 MeV excitation. The results were compared with a model of pion absorption on quasi-deuteron pairs.

26. ^{18}O(p,^{3}He)^{16}N $\qquad Q_m = -14.106$

At $E_p = 43$ MeV, the angular distribution of the ^{3}He nuclei corresponding to a state at $E_x = 9.9$ MeV fixes $L = 0$ and therefore $J^\pi = 0^+$ for ^{16}N*(9.9): it is presumably the $T = 2$ analog of the ground state of ^{16}C. See (82AJ01, 86AJ04). See also (85BLZZ).

27. ^{18}O(d, α)^{16}N $\qquad Q_m = 4.248$

Alpha particle groups observed in this reaction are displayed in Table 16.11. For polarization studies see (82AJ01) and ^{20}F in (83AJ01, 88AJ01). τ_m for ^{16}N*(0.40) = 6.5 ± 0.5 ps and $|g| = 1.83 \pm 0.13$: see (82AJ01).

28. ^{19}F(n, α)^{16}N $\qquad Q_m = -1.522$

See (82AJ01) and ^{20}F in (83AJ01).

^{16}O

(Figs. 3 and 5)

GENERAL:

See Table 16.12.

$\langle r^2\rangle^{1/2} = 2.710 \pm 0.015$ fm (78KI01)
Abundance = $(99.762 \pm 0.015)\%$ (84DE1A)
g = $\pm(0.556 \pm 0.004)$ for ^{16}O*(6.13) (84AS03)

1. ^{9}Be(^{9}Be, 2n)^{16}O $\qquad Q_{\rm m} = 11.289$

Total reaction cross sections and characteristic γ-ray cross sections for ^{9}Be + ^{9}Be were measured for $E_{\rm c.m.} = 1.4$–3.4 MeV (88LA25). Gamma rays were observed from levels at 6.13 (3^-), 6.917 (2^+), and 7.1117 (1^-) MeV populated by the ^{9}Be(^{9}Be, 2n)^{16}O reaction. Cross sections calculated with optical models agreed with elastic scattering data, but the total reaction cross section was underpredicted by a factor of 2 to 3.

2. ^{9}Be(^{11}B, ^{16}O)^{4}H $\qquad Q_{\rm m} = 1.088$

Energy spectra of the ^{16}O nuclei were measured (86BE1A) for incident ^{11}B energies of 88 MeV to obtain information on the ^{4}H system.

3. ^{9}Be(^{14}C, ^{7}He)^{16}O $\qquad Q_{\rm m} = -7.006$

This reaction was studied by (88BEYJ).

4. (a) ^{10}B(^{6}Li, γ)^{16}O $Q_{\rm m} = 30.872$
   (b) ^{10}B(^{6}Li p)^{15}N $Q_{\rm m} = 18.745$ $E_{\rm b} = 30.872$
   (c) ^{10}B(^{6}Li, d)^{14}N $Q_{\rm m} = 10.136$
   (d) ^{10}B(^{6}Li, t)^{13}N $Q_{\rm m} = 5.840$
   (e) ^{10}B(^{6}Li, ^{3}He)^{13}C $Q_{\rm m} = 8.079$
   (f) ^{10}B(^{6}Li, α)^{12}C $Q_{\rm m} = 23.711$
   (g) ^{10}B(^{6}Li, ^{6}Li)^{10}B

At $E(^{6}\text{Li}) = 4.9$ MeV, the cross sections for reactions (b) to (f) leading to low-lying states in the residual nuclei are proportional to $2J_{\rm f} + 1$: this is interpreted as indicating that the reactions proceed via a statistical compound nucleus mechanism. For highly excited states, the cross section is higher than would be predicted by a $2J_{\rm f} + 1$ dependence: see (82AJ01, 86AJ04).

5. ^{10}B(^{10}B, α)^{16}O $Q_{\rm m} = 26.413$

States of ^{16}O observed at $E(^{10}\text{B}) = 20$ MeV are displayed in Table 16.10 of (77AJ02). At the higher excitation energies, states are reported at $E_{\rm x} = 17.200 \pm 0.020$, 17.825 ± 0.025, 18.531 ± 0.025, 18.69 ± 0.03, 18.90 ± 0.035, 19.55 ± 0.035, 19.91 ± 0.02, 20.538 ± 0.015, 21.175 ± 0.015, 21.84 ± 0.025, 22.65 ± 0.03 and 23.51 ± 0.03 MeV. The reaction excites known $T = 0$ states: $\sigma_{\rm t}$ follows $2J_{\rm f} + 1$ for 11 of 12 groups leading to states of known J. The angular distributions show little structure: see (77AJ02).

6. ^{11}B(^{7}Li, nn)^{16}O $Q_{\rm m} = 12.170$

Cross section measurements at $E_{\rm c.m.} = 1.46$–6.10 MeV were reported in (90DA03).

7. ^{12}C(α, γ)^{16}O $Q_{\rm m} = 7.161$

The yield of capture γ-rays has been studied for E_α up to 42 MeV [see Table 16.11 in (77AJ02) and (82AJ01)]. See also (86AJ04). Observed resonances are displayed in Table 16.15 here.

This reaction plays an important role in astrophysical processes. The cross sections at astrophysical energies have been obtained by fitting measured cross sections and extrapolating them to low energies utilizing standard R-matrix, Hybrid R-matrix and K-matrix procedures. A list of recent values of the E2 and E1 astrophysical factors for $E_0 = 300$ keV obtained from fits to the data is given in Table 16.16.

The influence of vacuum polarization effects on subbarrier fusion is evaluated in (88AS03), and the relevance of Coulomb dissociation of ^{16}O into ^{12}C + α is studied in (86BA50, 89BA2S, 92SH11). Calculations to test the sensitivity of stellar nucleosynthesis to the level in ^{12}C at 7.74 MeV are described in (89LI29). For other astrophysical studies see (82AJ01, 86AJ04) and (85TA1A, 86FI1B, 86MA1E, 86WO1A, 87AR1C, 87BO1B, 87DE32, 87RO1D, 88CA1N, 88PA1H, 88TRZZ, 90BL1K, 90BR1Q, 90JI02).

At higher energies the E2 cross section shows resonances at $E_x = 13.2$, 15.9, 16.5, 18.3, 20.0, and 26.5 MeV (see Table 16.16). Some E2 strength is also observed for $E_x = 14$ to 15.5 and 20.5 to 23 MeV. In the range $E_\alpha = 7$ to 27.5 MeV the $T = 0$ E2 strength is $\sim 17\%$ of the sum-rule value. It appears from this and other experiments that the E2 centroid is at $E_x \sim 15$ MeV, with a 15 MeV spread. Structures are observed in the yield of γ-rays from the decay to ^{16}O*(14.8 ± 0.1) for $E_x = 34$–39 MeV. It is suggested that these correspond to a giant quadrupole excitation with $J^\pi = 8^+$ built on the 6^+_1 state at $E_x = 14.815$ MeV: see (82AJ01, 86AJ04).

8. (a)^{12}C(α, n)^{15}O	$Q_m = -8.502$	$E_b = 7.161$
(b)^{12}C(α, p)^{15}N	$Q_m = -4.966$	
(c)^{12}C(α, d)^{14}N	$Q_m = -13.575$	

For reaction (a) cross section measurements from threshold to $E_\alpha = 24.7$ MeV [see (86AJ04)], and at $E_\alpha = 10.5$ to 20 MeV (see Table 16.16 here). For excitation functions from $E_\alpha = 21.8$ to 27.2 MeV, see (86AJ04). Thick-target neutron yields have been measured for $E_\alpha = 1.0$ to 9.8 MeV (89HE04) and for 4–7 MeV (82WE16). For reaction (b) cross section measurements from threshold to 33 MeV, see (86AJ04). The excitation curve for p_3 (to ^{15}N*(6.32), measured for $E_\alpha = 24$ to 33 MeV, shows a large peak at $E_x \approx 29$ MeV, $\Gamma \approx 4$ MeV. It is suggested that it is related to the GQR in ^{16}O: see (82AJ01). For reaction (c) deuteron spectra have been measured for $E_\alpha = 200$, 400, 600, 800 MeV/nucleon (91MO1B). For the observed resonances see Table 16.16 here.

9. ^{12}C(α, α)^{12}C $\qquad E_b = 7.161$

The yield of α-particles leading to ^{12}C*(0, 4.4, 7.7) and 4.4, 12.7 and 15.1 MeV γ-rays has been studied at many energies in the range $E_\alpha = 2.5$ to 42 MeV [see 86AJ04], and at $E_\alpha = 0.4$–1.8 MeV (90TO09). Observed resonances are displayed in Table 16.16. Attempts have been made to observe narrow states near ^{16}O*(8.87, 9.85). No evidence has been found for a narrow (100 eV) 0^+ state in the vicinity of the 2^- state at 8.87 MeV [see (82AJ01)] nor for a 3^- state near the 2^+ state at 9.84 MeV (86AJ04).

For total cross section measurements see (86AJ04) and for $E_\alpha = 100$ MeV (86DU15). For integral cross sections for inelastic scattering at 50.5 MeV, see (87BU1E). For elastic scattering differential cross sections at $E_\alpha = 96.6$ MeV see (90KO2C), at 90 MeV

(90GL02), at 90 and 98 MeV (91GO1J). For diffraction scattering at momentum 17.9 GeV/c, see (91AB1F). For inelastic scattering and polarization of ^{12}C (9.64 MeV, 3^-) see (89KO55, 91KO1F), who report that the reaction at $E_\alpha = 27.2$ MeV proceeds mostly via an 8^+ state in the compound system. For pion production at momenta 4.5 GeV/c per nucleon see (90AB1D), at 4.2 GeV/c per nucleon (87AG1A), at energies of 3.6 GeV per nucleon (87AN1B), and at 200 to 800 MeV per nucleon (87LH01), at $E_\alpha = 0.8$, 1.6 GeV (91LE06). Differential cross sections at $E_\alpha = 1$–6.6 MeV measured to obtain information on ^{12}C(α, γ) stellar reaction rates are reported by (87PL03).

Calculations of total cross sections for $E_\alpha = 96.6$–172.5 MeV are presented in (89KU1U) and distributions of α-particle strengths in (88LE05). Energy dependence at high energies ($\sim$ 1 GeV/nucleon) is studied in (88MO18). The iterative-perturbative method for S-matrix to potential inversion was applied to $\alpha + {}^{12}$C phase shifts at $E_{\rm lab} = 1.0$–6.6 MeV in (90CO29). See also (91LI25). Nucleus-nucleus scattering and interaction radii were studied in (86SA30). Core-plus alpha particle states in ^{16}O populated in $\alpha + {}^{12}$C scattering are studied in terms of vibron models in (88CS01). See also (91AB10, 91DE15, 91ES1B, 91RU1B, 92SA1F). The effects of electron screening on low energy fusion reactions of astrophysical interest are explored in (87AS05, 90TO09). The nature of the $\alpha + {}^{12}$C potential at low energy is explored in (90AL05). For other theoretical work see (86MI24, 86SU06, 87BA1P, 89BA2N, 90DA1Q).

10. (a) ^{12}C(α, ^{8}Be)^{8}Be $\qquad Q_{\rm m} = -7.458 \qquad E_{\rm b} = 7.16195$

(b) ^{12}C(α, 2α)^{8}Be $\qquad Q_{\rm m} = -7.365$

The yield of ^{8}Be from reaction (a) shows a number of resonances: see Table 16.16. There is no evidence below $E_{\rm x} \sim 24$ MeV for $J^\pi = 8^+$ states although the existence of such states below this energy cannot be ruled out since it is possible that the L of the entrance channel inhibits the formation of such states. Above 26 MeV $L = 8$ becomes dominant: see (82AJ01, 86AJ04). See also the angular distribution measurements of (91GL03) at $E_\alpha = 90$ MeV. For differential cross sections for reaction (b) at $E_\alpha = 27.2$ MeV see (87KO1E). See also (77AJ02).

11. ^{12}C(^{6}Li, d)^{16}O $\qquad Q_{\rm m} = 5.686$

This reaction has been studied at many energies: see (77AJ02) and Table 16.17 here. At higher energies the spectra are dominated by states with $J \geq 4$ and natural parity (86AJ04). A kinematic coincidence technique was applied in (86CA19) to study the unresolved doublet at $E_{\rm x} = 11.09$ MeV enabling clear observation of the γ-decaying 3^+ member at 11.080 MeV although it contributes only $\sim$ 15% of the singles yield of the doublet which is dominated by the 4^+ member at 11.096 MeV. Angular correlation measurements (80CU08) suggested that the 11.096 4^+ state is populated via a two-step process, and this interpretation was confirmed in calculations by (88SE1E). See also (86AJ04). An interference effect was observed in the angular correlation function for the 7^- level at $E_x = 20.9$ MeV in measurements by (87AR28). See also (86AR1A, 88ARZU, 87BE1C, 87GO1C).

Inclusive deuteron spectra from the break-up of ^{6}Li ions at 156 MeV are described in (89JE07). See also (86AJ04).

A numerical method for evaluation of (^{6}Li, d) stripping into the 5^- (15.6 MeV) and 6^+ (16.3 MeV) states is presented in (89SE06). See also (91SE12). An extensive discussion of alpha clustering in nuclei is presented in (90HO1Q). Cluster stripping and heavy-group substitution in the reaction is discussed in (88BE49), and the effect of including Coulomb forces in the Faddeev formalism is studied in (88OS05).

12. ^{12}C(^{7}Li, t)^{16}O $\qquad Q_m = 4.694$

This reaction has been studied extensively: see (77AJ02, 82AJ01) and Table 16.17 here. Measurements of α-t angular correlations for the process ^{12}C(^{7}Li, t)^{16}O(α)^{12}C are reported in (88AR22) for the 7^- (20.9 MeV), 6^+ (16.3 MeV), and 5^- (14.6 MeV) levels in ^{16}O. Analyses of the (^{7}Li, t) reaction for cluster states in ^{16}O are reported in (86CO15, 88BE49). See also (87BE1C, 88BE1D, 88BE1J, 89AL1D, 90HO1Q) and the sections on ^{19}F in (83AJ01, 88AJ01).

13. ^{12}C(^{10}B, ^{6}Li)^{16}O $\qquad Q_m = 2.702$

Angular distributions at $E(^{10}\text{B}) = 18$ and 45 MeV have been studied involving ^{16}O*(0, 6.1, 7.1, 8.9, 9.9, 10.4). At $E(^{10}\text{B}) = 68$ MeV angular distributions to ^{16}O*(0, 6.1, 6.9, 10.4, 11.1, 14.7, 16.2, 20.9) are forward peaked and fairly structureless. ^{16}O*(0, 6.9, 11.1) are weakly excited: see (82AJ01, 86AJ04, 90HO1Q).

14. ^{12}C(^{12}C, ^{8}Be)^{16}O $\qquad Q_m = -0.204$

Angular distributions have been reported at $E(^{12}\text{C})$ to 63 MeV [see (77AJ02)] and at 4.9 to 10.5 MeV, and 11.2 to 12.6 MeV [see (86AJ04)]. Angular correlations at $E(^{12}\text{C}) = 78$ MeV confirm $J^\pi = 4^+, 5^-, 6^+$ and 7^- for ^{16}O*(10.36, 14.59, 16.3, 20.9). $\Gamma_{\gamma_0}/\Gamma = 0.90 \pm 0.10$, 0.75 ± 0.15 and 0.90 ± 0.10, respectively, for the first three of these states. In addition a state is reported at $E_x = 22.5 \pm 0.5$ MeV which may be the 8^+ member of the $K^\pi = 0^+$, 4p-4h rotational band (79SA29). For further work at $E(^{12}\text{C}) = 90$, 110 and 140 MeV see (86SH10). At $E(^{12}\text{C}) = 120$ MeV α_0 decays of ^{16}O*(16.3, 20.9) [$J^\pi = 6^+, 7^-$] and α_1 decays of ^{16}O*(19.1, 22.1, 23.5) are observed as is a broad structure in both channels corresponding to ^{16}O*(30.0) with $J^\pi = 9^- + 8^+$. A gross structure ^{12}C–^{12}C resonance at $E_{\text{c.m.}} = 25$ MeV in the reaction leading to the ^{16}O 11.09 MeV 4^+ state is reported in (87RA22). For other work on alpha cluster resonances see (86ALZN, 86RAZI, 87RA02, 90HO1Q). Measurements of differential cross sections at sub-barrier energies $2.43 \leq E_{\rm c.m.} \leq 5.24$ MeV are reported in (89CU03) and a statistical model calculation is discussed in (90KH05). See also (91CE09). For the decay of ^{20}Ne states see (83AJ01, 86AJ04, 88AJ01), and for excitation functions see (86AJ04).

15. (a) ^{12}C(^{14}N, ^{10}B)^{16}O $\quad Q_{\rm m} = -4.450$
    (b) ^{12}C(^{17}O, ^{13}C)^{16}O $\quad Q_{\rm m} = 0.803$

Angular distributions are reported at $E(^{14}{\rm N}) = 53$ MeV involving ^{16}O*(0, 6.05, 6.13, 6.92) and various states of ^{10}B, and at 78.8 MeV involving $^{16}{\rm O}_{\rm g.s.}$: see (82AJ01). Angular distributions have been measured for the g.s. in reaction (b) for $E(^{17}{\rm O}) =$ 40 to 70 MeV (86AJ04). See also (86AR04, 89WUZZ, 90HO1Q), the two-center shell model basis calculations of (91TH04) and the review of Landau-Zener effect investigations in (90TH1D).

16. ^{12}C(^{20}Ne, ^{16}O)^{16}O $\quad Q_{\rm m} = 2.427$

Angular distributions have been measured to $E(^{20}{\rm Ne}) = 147$ MeV: see (77AJ02). For yield measurements see (86AJ04). Studies of projectile-breakup and transfer re-emission in the ^{12}C+^{20}Ne system at an incident ^{20}Ne energy of 157 MeV are described in (87SI06). See also (90HO1Q).

17. (a)^{13}C(^{3}He, γ)^{16}O $\quad Q_{\rm m} = 22.793$
    (b)^{13}C(^{3}He, n)^{15}O $\quad Q_{\rm m} = 7.130$ $\quad E_{\rm b} = 22.793$
    (c)^{13}C(^{3}He, p)^{15}N $\quad Q_{\rm m} = 10.666$
    (d)^{13}C(^{3}He, d)^{14}N $\quad Q_{\rm m} = 2.507$
    (e)^{13}C(^{3}He, ^{3}He)^{13}C
    (f)^{13}C(^{3}He, α)^{12}C $\quad Q_{\rm m} = 15.632$
    (g)^{13}C(^{3}He, ^{8}Be)^{8}Be $\quad Q_{\rm m} = 8.174$

The yield of capture γ-rays (reaction a) has been studied for $E(^3{\rm He})$ up to 16 MeV [see (77AJ02)], as have angular distributions. Observed resonances are displayed in Table 16.18. It is suggested that the structures at $E_{\rm x} \approx 26$–29 MeV are related to the giant resonances built on the first few excited states of ^{16}O (79VE02). See also (86AJ04).

The excitation functions (reaction b) up to $E(^3{\rm He}) = 11$ MeV are marked at low energies by complex structures and possibly by two resonances at $E(^3{\rm He}) = 1.55$ and 2.0 MeV: see Table 16.18. See also (77AJ02) for polarization measurements.

Excitation functions (reaction c) for $E(^3\text{He}) = 3.6$ to 6.6 MeV have been measured for p_0, p_{1+2}, p_3: a resonance is reported at $E(^3\text{He}) = 4.6$ MeV. A resonance at 6 MeV has also been observed: see Table 16.18. A comparison of polarization measured in this reaction and of analyzing powers measured in ^{15}N(p, ^{3}He) has been made [see (86AJ04)]. Analyzing powers have been measured at $E(^3\text{He}) = 33$ MeV for the elastic scattering (reaction d) and the deuteron groups to ^{14}N*(0, 2.31, 3.95, 9.51) (86DR03).

Yields of α_0, α_1, α_2, and γ-rays from the decay of ^{12}C*(12.71, 15.11) (reaction f) have been studied up to $E(^3\text{He}) = 12$ MeV. Observed resonances are displayed in Table 16.18. Those seen in the yield of $\gamma_{15.1}$ are assumed to correspond to ^{16}O states which have primarily a $T = 1$ character. Analyzing power measurements are reported at $E(^3\text{He}) = 33$ MeV to ^{12}C*(4.4). Excitation functions for α_0 and α_1 are also reported for $E(^3\text{He}) = 16$ to 23 MeV (86AJ04). DWBA analyses for data at $E(^3\text{He}) = 50$, 60 MeV are described in (90ADZU). See also (86ZE1B). The excitation function for ^{8}Be(g.s.) (reaction g) has been studied for $E(^3\text{He}) = 2$ to 6 MeV. It shows a strong resonance at $E(^3\text{He}) = 5.6$ MeV corresponding to a state in ^{16}O at $E_x = 27.3$ MeV. J^π appears to be 2^+ from angular distribution measurements. A search for anomalous deuterons at 10.8 GeV has been reported (86AJ04).

18. ^{13}C(α, n)^{16}O $\qquad Q_m = 2.215$

Angular distributions for the n_0 group have been measured for $E_\alpha = 12.8$ to 22.5 MeV: see (71AJ02). Polarization measurements for n_0 at $\theta = 0$–$70°$ at $E_\alpha = 2.406$ and 3.308 MeV are reported in (90WE10). The energy of the γ-ray from the decay of ^{16}O*(6.13) is 6129.266 ± 0.054 keV (86AJ04) [based on the ^{198}Au standard $E_\gamma = 411804.4 \pm 1.1$ eV]. See also (82AJ01). In (88CA1N), analytical expressions for reaction rates for ^{13}C(α, n)^{16}O and other astrophysically important low-mass reactions are given. See also the related work of (86SM1A, 87HA1E, 89KA24, 90HO1I).

19. ^{13}C(^{6}Li, t)^{16}O $\qquad Q_m = 6.997$

See Table 16.19. See also (82AJ01) and ^{19}F in (83AJ01).

20. ^{13}C(^{9}Be, ^{6}He)^{16}O $\qquad Q_m = 1.617$

See (86AJ04).

21. ^{13}C(^{12}C, ^{9}Be)^{16}O $Q_{\rm m} = -3.485$

At $E(^{13}{\rm C}) = 105$ MeV, ^{16}O*(6.05, 6.13, 10.35, 16.3, 20.7) are strongly populated: see (86AJ04, 82AJ01, 77AJ02). Excitation functions ($E_{\rm c.m.} = 13.4$–16.8 MeV) and angular distributions ($E_{\rm c.m.} = 13.4$, 16.38 MeV) have been measured (88JA1B).

22. ^{13}C(^{17}O, ^{14}C)^{16}O $Q_{\rm m} = 4.033$

See (82AJ01).

23. ^{14}C(^{3}He, n)^{16}O $Q_{\rm m} = 14.617$

At $E(^{3}{\rm He}) = 11$ to 16 MeV, neutron groups are observed to $T = 2$ states at $E_{\rm x} = 22.717\pm0.008$ and 24.522 ± 0.011 MeV ($\Gamma < 30$ keV and < 50 keV, respectively). These two states are presumably the first two $T = 2$ states in ^{16}O, the analog states to ^{16}C*(0, 1.75). J^{π} for ^{16}O*(24.52) is found to be 2^{+} from angular distribution measurements (70AD1A). At $E(^{3}{\rm He}) = 25.4$ MeV forward angle differential cross sections have been determined to the 0^{+} states of ^{16}O*(0, 6.05, 12.05) (86AJ04).

24. ^{14}N(d, γ)^{16}O $Q_{\rm m} = 20.736$

The γ_0 yield has been studied for $E_{\rm d} = 0.5$ to 5.5 MeV. Observed resonances are displayed in Table 16.20. Radiative capture in the region of the GDR [$E_{\rm d} = 1.5$ to 4.8 MeV] has been measured with polarized deuterons. See (86AJ04).

25. ^{14}N(d, n)^{15}O $Q_{\rm m} = 5.073$ $E_{\rm b} = 20.736$

For $E_{\rm d} = 0.66$ to 5.62 MeV, there is a great deal of resonance structure in the excitation curves with the anomalies appearing at different energies at different angles: the more prominent structures in the yield curves are displayed in Table 16.20. For polarization measurements see (77AJ02) and (81LI23) in ^{15}O(86AJ01).

26. ^{14}N(d, p)^{15}N $Q_{\rm m} = 8.609$ $E_{\rm b} = 20.736$

The yield of various proton groups for $E_{\rm d} < 5.0$ MeV shows some fluctuations and two resonances: see Table 16.20 and (82AJ01). For polarization measurements see (86AJ04, 82AJ01). Analyzing power measurements at $E_{\rm d} = 70$ MeV are reported in (86MO27).

27. ^{14}N(d, d)^{14}N $E_b = 20.736$

The yield of elastically scattered deuterons has been studied for $E_d = 0.65$ to 5.5 MeV and for 14.0 to 15.5 MeV: see (71AJ02, 77AJ02). There is indication of broad structure at $E_d = 5.9$ MeV and of sharp structure at $E_d = 7.7$ MeV in the total cross section of the d_1 group to the $T = 1$ (isospin-forbidden), $J^\pi = 0^+$ state at $E_d = 2.31$ MeV in ^{14}N. The yield of deuterons (d_2) to ^{14}N*(3.95) [$J^\pi = 1^+$, $T = 0$] shows gross structures at $E_d = 7.4$ and 10.2 MeV (70DU04): see Table 16.20 The yield of d_1 has also been studied for $E_d = 10.0$ to 17.9 MeV: see (82AJ01). For polarization measurements see (86AJ04, 82AJ01).

28. (a) ^{14}N(d, t)^{13}N $Q_m = -4.296$ $E_b = 20.736$

(b) ^{14}N(d, ^{3}He)^{13}C $Q_m = -2.057$

See (82AJ01).

29. ^{14}N(d, α)^{12}C $Q_m = 13.575$ $E_b = 20.736$

There is a great deal of structure in the yields of various α-particle groups for $E_d = 0.5$ to 12 MeV. Broad oscillations ($\Gamma \sim 0.5$ MeV) are reported in the α_0 and α_1 yields for $E_d = 2.0$ to 5.0 MeV. In addition, ^{16}O*(23.54) is reflected in the α_3 yield (see Table 16.20). The yield of 15.11 MeV γ-rays, [from the decay of ^{12}C*(15.11), $J^\pi = 1^+$, $T = 1$] which is isospin-forbidden, has been studied for $E_d = 2.8$ to 12 MeV. Pronounced resonances are observed at $E_d = 4.2$, 4.58 and 5.95 MeV and broader peaks occur at $E_d = 7.1$ and, possibly, at 8.5 MeV: see (82AJ01). For polarization measurements see (82AJ01, 86AJ04).

30. (a) ^{14}N(^{3}He, p)^{16}O $Q_m = 15.242$

(b) ^{14}N(^{3}He, pα)^{12}C $Q_m = 8.081$

Observed proton groups are displayed in Table 16.21. Angular distributions have been measured at $E(^3\text{He}) = 2.5$ to 24.7 MeV: see (82AJ01). Branching ratios and τ_m measurements are shown in Tables 16.13 and 16.14.

31. ^{14}N(α, d)^{16}O $\qquad Q_{\mathrm{m}} = -3.112$

Angular distributions to states of ^{16}O have been reported at many energies to $E_\alpha = 48$ MeV: see (71AJ02, 77AJ02). Among the states which have been reported [see Table 16.7 in (77AJ02)] are ^{16}O*(11.094 ± 3, 13.98 ± 50, 14.32 ± 20, 14.400 ± 3, 14.815 ± 2, 15.17 ± 50, 15.44 ± 50, 15.78 ± 50, 16.214 ± 15, 17.18 ± 50) [MeV $\pm$ keV]: the results are consistent with $J^\pi = 5^+, 6^+, 4^+$ for ^{16}O*(14.40, 14.82, 16.29) [2p-2h] and with 6^+ for ^{16}O*(16.30) [4p-4h]. [See references in (77AJ02).] Work reported in (79CL10) and reviewed in (82AJ01) determined $\Gamma_{\mathrm{c.m.}} = 34 \pm 12$, 27 ± 5 and 70 ± 8 keV, respectively for ^{16}O*(14.31 ± 10, 14.40 ± 10, 14.81).

32. ^{14}N(^{6}Li, α)^{16}O $\qquad Q_{\mathrm{m}} = 19.261$

See (77AJ02).

33. (a) ^{14}N(^{11}B, ^{9}Be)^{16}O $\qquad Q_{\mathrm{m}} = 4.921$
(b) ^{14}N(^{12}C, ^{10}B)^{16}O $\qquad Q_{\mathrm{m}} = -4.450$
(c) ^{14}N(^{13}C, ^{11}B)^{16}O $\qquad Q_{\mathrm{m}} = 2.057$
(d) ^{14}N(^{14}N, ^{12}C)^{16}O $\qquad Q_{\mathrm{m}} = 10.463$

For reactions (a) and (c) see (82AJ01). For reactions (b), (c), and (d) see (86AJ04).

34. ^{15}N(p, γ)^{16}O $\qquad Q_{\mathrm{m}} = 12.127$

The yield of γ-rays has been measured for $E_{\mathrm{p}} = 0.15$ to 27.4 MeV [see (86AJ04)] and for $E_{\mathrm{p}} = 6.25$–13.75 MeV (88WI16), 20–100 MeV (88HA04), 20–90 MeV (89KA02), and 10–17 MeV (87BA71): observed resonances are displayed in Table 16.22. The γ_0 cross section shows a great deal of structure up to $E_{\mathrm{p}} = 17$ MeV. Above that energy the γ_0 yield decreases monotonically. Besides the GDR which peaks at ^{16}O*(22.15) there is evidence for the emergence of a giant structure (E2) with $E_{\mathrm{x}} = 24$–29 MeV in the $\gamma_{1+2+3+4}$ yield (78OC01). Measurements for (p, γ_0) cross sections and analyzing powers for $E_{\mathrm{p}} = 6.25$–13.75 MeV indicated a clear enhancement of the E2 cross section above $E_{\mathrm{x}} = 22$ MeV. Differential cross sections for γ_0 and several other (unresolved) γ-rays at $E_{\mathrm{p}} \approx 28$ to 48 MeV generally show a broad bump at $E_{\mathrm{x}} \approx 34 \pm 2$ MeV. The angular distributions show a dominant E1 character (86AJ04). See also (88HA04, 88KI1C, 89BOYU) and the review of (88HA12). For comparisons with measurements of the inverse reaction see (91FI08).

Measurements of (p, γ_1) yields (87BA71) indicated a pronounced concentration of dipole strength which was interpreted as an E1 giant resonance built on the ^{16}O first excited state. Other measurements of proton capture to excited states for $E_p = 20$–90 MeV are reported in (89KA02).

Cross sections and analyzing powers for capture into the 3^- state at $E_x = 6.13$ MeV were studied by (88RA15). Studies of quadrupole and octupole radiation from ^{16}O at $E_x = 39$ MeV determine $\sigma_{E2}/\sigma_{E1} = 0.124 \pm 0.015$, and $\sigma_{E3}/\sigma_{E1} = 0.0051 \pm 0.0026$ (89KO29).

A study of the M1 decays of ^{16}O*(16.21, 17.14) [both $J^\pi; T = 1^+; 1$] to ^{16}O*(6.05) finds B(M1, $1^+ \rightarrow 0_2^+$)/B(M1, $1^+ \rightarrow 0_1^+$) = 0.48 ± 0.03 and 0.55 ± 0.04, respectively. ^{16}O*(18.03) is a 3^-; 1 state with a strength $\Gamma_p \Gamma_{\gamma 2}/\Gamma = 1.96 \pm 0.27$ eV and ^{16}O*(18.98) is the 4^-; 1 stretched particle-hole state with a strength of (0.85 ± 0.10) eV (83SN03). See also (83SN03) for the identification of analog states in ^{16}N and in ^{16}O, and for a discussion of Gamow-Teller matrix elements in $A = 14$–18 nuclei. See also the review of (87BE1G). A study of the strong M2 transitions $E_x = 12.53 \rightarrow 0$ MeV and $E_x = 12.97 \rightarrow 0$ MeV is reported in (86ZI08).

For astrophysical considerations see (86AJ04) and (85CA41, 88CA1N, 89BA2P). See also Table 16.14 here. An application of this reaction for thin film analysis is described in (92EN02).

Calculations of the decay of the GDR and GQR by (90BU27) have included 1p-1h and 2p-2h configurations, but the fine structure of the GDR remains unexplained. RPA calculations overestimate p_0 decay but the use of a non-local mean field partially corrects this. The ISGQR is misplaced by RPA calculations, but is lowered by coupling to α-^{12}C channels. Data from (e, e$'\alpha$) experiments are needed. RPA spectra have been examined (88BL10) using a relativistic Hartree-Fock model for the ground state. Hartree-Fock based calculations appear to be insensitive to short-range repulsion. 1^- and $T = 1$ strength distributions for ^{16}O have been calculated using Hartree and Hartree-Fock methods. Shell-model plus R-matrix and continuum shell-model results for 1p shell nuclei have been considered (87KI1C), but underestimate ground-state (γ, N_0) decay branches. Ground state shell-model plus R-matrix calculations describe the GDR region reasonably well.

35. ^{15}N(p, n)^{15}O $\qquad Q_m = -3.536 \qquad E_b = 12.127$

Excitation functions and cross sections have been measured for $E_p = 3.8$ to 19.0 MeV: see (82AJ01). For a listing of observed resonances see Table 16.23. (83BY03) have measured the polarization and analyzing power for the n_0 group for $E_p = 4.5$ to 11.3 MeV and have deduced integrated cross sections. Differential cross sections and analyzing powers at $E_p = 200$ and 494 MeV have been measured (88CIZZ). See also (86AJ04).

The theoretical work of (87BE1D) has shown the sensitivity of the (p, n) reaction to spin dynamics and pionic fields for $E_p = 150$–500 MeV and isovector density below 50 MeV. The importance of configuration mixing in Gamow-Teller quenching is also considered. The authors of (89RA15) discuss the failure of the DWIA to explain the analyzing power for (p, n) at 500 MeV, focusing on transverse and longitudinal spin-flip cross sections and projectile non-spin-flip cross sections as the sensitive terms primarily responsible for the inadequacies of this method.

36. (a) ^{15}N(p, p)^{15}N $E_b = 12.127$
(b) ^{15}N(p, α)^{12}C $Q_m = 4.966$
(c) ^{15}N(p, ^{3}He)^{13}C $Q_m = -10.666$

Elastic scattering studies have been reported for $E_p = 0.6$ to 15 MeV and angular distributions and excitation functions have been measured for $E_p = 2.5$ to 9.5 MeV for the ($p_{1+2}\gamma$) and ($p_3\gamma$) transitions [see (86AJ04)]. Measurements of the depolarization parameter $K_y^{y'}$ at $E_p = 65$ MeV are reported in (90NA15). Excitation functions for α_0 and α_1 particles [corresponding to ^{12}C*(0, 4.43)] and of 4.43 MeV γ-rays have been measured for $E_p = 93$ keV to 45 MeV [see (82AJ01)] and at $E_p = 77.6$ keV to 9.5 MeV (86AJ04). The yield of 15.1 MeV γ-rays has been measured for $E_p = 12.5$ to 17.7 MeV (78OC01). Measurements of the 430 keV resonance in ^{15}N(p, $\alpha\gamma$)^{12}C were carried out by (87OS01, 87EV01). Observed anomalies and resonances are displayed in Table 16.22. The resonance at $E(^{15}\text{N}) = 6.4$ MeV observed in the reaction ^{1}H(^{15}N, $\alpha\gamma$)^{12}C has been used extensively to determine the hydrogen concentration in thin films. See (87EV01, 87OS01, 90FU06, 90HJ02, 92FA04).

A phase shift analysis of angular distributions of cross section and analyzing power for elastic scattering has yielded information on many ^{16}O states in the range $E_x =$ 14.8 to 18.6 MeV. In particular a broad $J^\pi = 2^-$, $T = 1$ state at 17.8 MeV appears to be the analog of the 1p-1h ($d_{3/2}$, $p_{1/2}^{-1}$) ^{16}N state at $E_x \approx 5.0$ MeV (86AJ04). The isospin mixing of the 2^- states ^{16}O*(12.53, 12.97) has been studied by (83LE25): the charge-dependent matrix element responsible for the mixing is deduced to be 181 ± 10 keV. The α_0 yield and angular distribution study by (82RE06) leads to a zero-energy intercept of the astrophysical S(E) factor, S(0) = 65 ± 4 MeV·b. See (86AJ04, 82AJ01) for the earlier work. See also (87RO1D), and see the tables of thermonuclear reaction rates in (85CA1A).

Among recent theoretical developments related to these reactions, electron screening effects for ^{15}N(p, α)^{12}C at very low energies ($<$ 50 keV) have been evaluated (87AS05). Expressions for longitudinal and irregular transverse PNC analyzing powers in cases of parity-mixed resonances such as ^{15}N($\vec{p}$, p)^{15}N and ^{15}N($\vec{p}$, α)^{12}C are derived in (89CA1L). Recent theoretical studies of the parity- and isospin-forbidden α-decay of the 12.97 MeV state to the ^{12}C ground state are reported in (91KN03, 91DU04). See also the theoretical study of single particle resonances in (91TE03).

An investigation into the separation of the strength of the giant resonance for underlying levels neglecting statistical assumptions (86KL06) has shown deviations from statistical behavior at the tops of resonances, leading to missing spectroscopic strength. A calibration method for heavy-ion accelerators has been described by (87EV01), who have also determined the energy of the $E_p = 430$ keV resonance in the ^{15}N(p, $\alpha\gamma$)^{12}C reaction. Quantum fluctuations are shown to cause structures having collective properties (86RO26). These new collective states are dissipative.

^{15}N(p, p)^{15}N is considered for $25 < E_p < 40$ MeV. (88RO09) consider the transition from resonance to direct reactions as well as the significance of quantum fluctuations.

37. ^{15}N(d, n)^{16}O $\qquad Q_m = 9.9030$

Observed neutron groups, l-values and spectroscopic factors are displayed in Table 16.24. See also (86AJ04).

38. ^{15}N(^{3}He, d)^{16}O $\qquad Q_m = 6.633$

See Table 16.24.

39. ^{16}N(β^-)^{16}O $\qquad Q_m = 10.419$

The ground state of ^{16}N decays to seven states of ^{16}O: reported branching ratios are listed in Table 16.25. The ground state transition has the unique first-forbidden shape corresponding to $\Delta J = 2$, fixing J^π of ^{16}N as 2^-: see (59AJ76). The unique first-forbidden decay rates to the 0^+ ground state and 6.06-MeV level are well reproduced by a large-basis $(0+2+4)\hbar\omega$ shell-model calculation (92WA25). The decays to odd-parity states (see Table 16.25) are well reproduced by recent calculations of Gamow-Teller matrix elements (93CH1A). For the β-decay of ^{16}N*(0.12), see Reaction 1 in ^{16}N.

The β-delayed α-decays of ^{16}O*(8.87, 9.59, 9.84) have been observed: see (71AJ02). The parity-forbidden α-decay from the 2^- state ^{16}O*(8.87) has been reported: $\Gamma_\alpha = (1.03 \pm 0.28) \times 10^{-10}$ eV [$E_\alpha = 1282 \pm 5$ keV]: see (77AJ02).

Transition energies derived from γ-ray measurements are: $E_x = 6130.40 \pm 0.04$ keV [$E_\gamma = 6129.142 \pm 0.032$ keV (82SH23)], $E_x = 6130.379 \pm 0.04$ [$E_\gamma = 6129.119 \pm 0.04$ keV (86KE15)] and $E_x = 7116.85 \pm 0.14$ keV [$E_\gamma = 7115.15 \pm 0.14$ keV]. See (77AJ02). See also p. 16 in (82OL01).

See (90JI02) for an R-matrix analysis for the 9.59-MeV level and discussion of its astrophysical significance and see astrophysical related work of (91BA1K, 91HU10).

40. (a) ^{16}O(γ, n)^{15}O $\qquad Q_{\rm m} = -15.663$

(b) ^{16}O(γ, 2n)^{14}O $\qquad Q_{\rm m} = -28.885$

(c) ^{16}O(γ, pn)^{14}N $\qquad Q_{\rm m} = -22.960$

(d) ^{16}O(γ, 2p)^{14}C $\qquad Q_{\rm m} = -22.335$

(e) ^{16}O(γ, 2d)^{12}C $\qquad Q_{\rm m} = -31.009$

The absorption cross section and the (γ, n) cross section are marked by a number of resonances. On the basis of monoenergetic photon data, excited states of ^{16}O are observed at $E_{\rm x}$ = 17.3 [u], 19.3 [u] and 21.0 MeV [u=unresolved], followed by the giant resonance with its principal structures at 22.1 and 24.1 MeV, and with additional structures at 23 and 25 MeV: see (86AJ04, 88DI02). The integrated nuclear absorption cross section for E_γ = 10 to 30 MeV is 182 ± 16 MeV·mb (86AJ04). See also Reaction 42. The (γ, n) cross section has been measured for E_γ = 17 to 33 MeV: in that energy interval the (γ, 2n) cross section is negligible. The cross section for formation of the GDR at 22.1 MeV is 10.0 ± 0.4 mb and the integrated cross section to 30 MeV is 54.8 ± 5 MeV·mb. There is apparently significant single particle-hole excitation of ^{16}O near 28 MeV and significant collectivity of the GDR. A sharp rise is observed in the average $E_{\rm n}$ above 26 MeV. The cross section for (γ, n$_0$) decreases monotonically for $E_{\rm x}$ = 25.5 to 43.8 MeV. In the range 30–35 MeV the E2 cross section exhausts about 4% of the isovector E2 EWSR. Over the range 25.5 to 43.8 MeV it exhausts ∼ 68% of the isovector E2 EWSR [see (86AJ04) and references cited there]. M1, E1, and E2 strengths were studied by recent polarization and cross section measurements for E_γ = 17 to 25 MeV (91FI08). An atlas of photoneutron cross sections obtained with monoenergetic photons is presented in (88DI02).

The absorption cross section has been measured with bremsstrahlung photons of energies from $E_{\rm bs}$ = 10 MeV to above the meson threshold: see (82AJ01). The (γ, n), (γ, 2n) and (γ, Tn) cross sections have been studied with monoenergetic photons for E_γ = 24 to 133 MeV. Above 60 MeV, the main reaction mechanisms appear to be absorption of the photons by a correlated n-p pair in the nucleus: the integrated cross section from threshold to 140 MeV is 161 ± 16 MeV·mb (86AJ04). Differential cross sections for (γ, n$_0$) have been measured at E_γ = 150, 200, and 250 MeV at $\theta_{\rm lab}$ = 49°, 59°, and 88° (88BE20, 89BE14). See also ^{15}O in (91AJ01). For reaction (b) and pion production see (86AJ04). For reaction (c) measurements have been carried out with bremsstrahlung photons with $E_\gamma \leq 150$ MeV (89VO19), and with tagged photons in the Δ(1232) resonance region (87KA13). See also (91VA1F). Measurements of reactions (d) and (e) were made with tagged photons of energies 80–131 MeV (91MA39). Measurements of the total cross section at E_γ = 90–400 MeV are described in (88AH04). Calculations which indicate that molecular effects are important in screening corrections to the cross section in the Δ resonance region are discussed. The hadron production cross section has been studied over the range 0.25 to 2.7 GeV see (86AJ04).

Sum rules and transition densities for isoscalar dipole resonances are discussed in (90AM06). For a calculation of monopole giant resonances see (90AS06). Calculations relating to polarization effects are discussed in (90LO20, 90BO31). The contribution of six-quark configurations to the E1 sum rule has been considered (89AR02), and upper bounds for the production probabilities of 6q-clusters have been derived. The continuum self-consistent RPA-SK3 theory predicts charge transition densities in ^{16}O for excitation of GDR (88CA07). Neutron and proton decay is also indicated. See also (91LI28, 91LI29). A contiuum shell model description of (γ, n) and (γ, p) data at medium energies is reported in (90BRZY). Radial dependence of charge densities depends on whether r-values correspond to the interior of the nucleus or to the surface (88CA07). In (85GO1A) (γ, n) and (γ, p) experimental results are compared with those of large-basis shell model calculations. Good results were obtained, but a new source of spreading is warranted. Ratios of (γ, n)-to-(γ, p) cross sections have been computed using R-matrix theory including configuration splitting, isospin splitting, and kinematics effects (86IS09). Computations of the partial photonuclear cross sections have been performed (87KI1C) using the continuum shell model. GDR and other giant multipole resonances are also considered. The authors of (88RO1R) use the continuum shell model as a basis for their study of "self-organization". The role of the velocity-dependent part of the NN interaction is also examined. A method for solving the RPA equations, and an examination of the long-wavelength approximation is discussed in (88RY03). Levinger's modified quasi-deuteron model is applied for $7 \leq A \leq 238$ and $E_\gamma = 35$–140 MeV (89TE06). The quantities $L = 6.1 \pm 2.2$ and $D = 0.72\ A$ are also deduced. The role of distortion in (γ, np) reactions is explored in (91BO29).

41. (a) ^{16}O(γ, p)^{15}N	$Q_m = -12.127$
(b) ^{16}O(γ, d)^{14}N	$Q_m = -20.736$
(c) ^{16}O(γ, α)^{12}C	$Q_m = -7.161$
(d) ^{16}O(γ, π^0)^{16}O	$Q_m = -134.974$
(e) ^{16}O(γ, π^+)^{16}N	$Q_m = -149.986$
(f) ^{16}O(γ, π^-)^{16}F	$Q_m = -154.984$
(g) ^{16}O(γ, π^-p)^{15}O	$Q_m = -154.449$

The (γ, p$_0$) cross section derived from the inverse capture reaction (reaction 34) confirms the giant resonance structure indicated above in reaction 40, as do the direct (γ, p$_0$) measurements. For the earlier work see (82AJ01). For results of measurements with linear polarized photons at $E_{bs} = 22$ and 30 MeV and for differential cross sections at $E_\gamma = 101.5$–382 MeV and proton spectra at $E_\gamma \approx 360$ MeV, see (86AJ04). See also the reviews (87BE1G, 88KO1S), and see (87MA1K). Angular distributions for (γ, p) reactions populating low-lying states of ^{15}N were measured (88AD07) with bremsstrahlung photons with $E_\gamma = 196$–361 MeV. Differential cross sections measurements with $E_\gamma \approx 300$ MeV tagged photons (90VA07) were used to study the interaction mechanism. Proton spectra measured at 90° (90VA07) showed evidence for an absorption process in which the photon interacts with a $T = 1$ np pair. See also the comment (92SI01) and reply on the interpretation of these data. A related calculation concerning quasideuteron behavior of np pairs is described in (92RY02). See also (87OL1A).

For reaction (b) see (82AJ01). A study of the ^{16}O(γ, α_0) reaction (c) at $\theta = 45°$ and 90° shows a 2^+ resonance at $E_x = 18.2$ MeV with an E2 strength which is spread out over a wide energy interval. A strong resonance corresponding to an isospin-forbidden 1^- state at $E_x \approx 21.1$ MeV is also observed (86AJ04). The systematics of cross sections for reaction (d) are discussed in (91BO26). For pion production reactions (e), pion angular distributions were measured for a mixed flux of real and virtual photons at $E_\gamma = 320$ MeV (87YA02). Double differential cross sections with tagged photons with $E_\gamma = 220$–450 MeV are reported in (91AR06). See also ^{16}N and (86AJ04). Exclusive cross sections for reaction (g) in the Δ resonance region are reported by (92PH01)

Recent theoretical work includes calculations of sum rules and transition densities (90AM06), monopole giant resonances (90AS06), and polarization effects (90LO20, 90BO31). A scheme using fractional-parentage coefficients to separate the wavefunction into three fragments in arbitrary internal states has been proposed, and examples include ^{7}Li(γ, t)^{4}He, ^{16}O(γ, dd)^{12}C and ^{12}C(γ, pd)^{9}Be (88BU1N). A formula for cross sections for $A(\gamma, \mathrm{d}\gamma')A-2$ reactions with $E_\gamma = 2.23$ MeV has been derived (88DU04). In a study of Dirac negative energy bound states, a relativistic shell model predicts $\gamma + {}^{16}\mathrm{O} \rightarrow {}^{15}_{\bar{\mathrm{p}}}\mathrm{N} + \mathrm{p}$ has a threshold at 1.2 GeV and rises to about 5 μb by 1.6 GeV (88YA08). (88LO07) calculate ^{16}O(γ, p)^{15}N using Dirac phenomenology. Dirac spinors are used to describe the proton dynamics in a DWBA calculation, and results are compared to data. ^{16}O(γ, p)^{15}N for $E_\gamma = 50$–400 MeV has been calculated (86LU1A) using a coupled-channels continuum shell-model technique. A single particle direct knock-out model is used by (87RY03) to calculate (γ, π) cross sections for $E_\gamma = 40$–400 MeV. See also (90BRZY, 91IS1D). ^{16}O(γ, p) at intermediate energies has been calculated using both a single particle and a pion-exchange-current mechanism in a relativistic form of the nucleon current operator and four-component nucleon wave functions (88MC03). See also the study of the effects of current conservation in these reactions (91MA39) and of scaling (91OW01). An expression for the (γ, N) cross section with incident circularly polarized photons and outgoing nucleon polarization being detected is given in (86PO14). A direct-semidirect model calculation for ^{16}O(γ, N$_0$) at 60 MeV is given as an example. A model, based on basic interactions between photons, pions, nucleons and isobars, providing an adequate description of the γN $\rightarrow$ πN reaction is described in (92CA04)

42. ^{16}O(γ, γ)^{16}O

Resonances have been reported (70AH02) at $E_\gamma = 22.5 \pm 0.3$, 25.2 ± 0.3, 31.8 ± 0.6 and 50 ± 3 MeV: the dipole sum up to 80 MeV exceeds the classical value by a factor 1.4. Elastic photon scattering cross sections for $E_\gamma = 25$ to 39 MeV have been measured. The E2 strength is $1.25^{+1.3}_{-0.9}$ times the total EWSR strength over that interval. The widths of ^{16}O*(6.92, 7.12) are, respectively, 94 ± 4 and 54 ± 4 meV

(85MO10, 86AJ04). Differential cross sections at angles of 135° and 45° for elastic scattering of tagged photons between 21.7 and 27.5 MeV in the giant dipole resonance region have been measured by (87LE12). Differential cross sections for tagged photons with $E_\gamma = 27$–68 MeV have been reported by (90MEZV). Polarizabilities of nucleons imbedded in ^{16}O were measured via Compton scattering of 61 and 77 MeV photons by (92LU01). See also Table 16.14.

A non-perturbative study of damping of dipole and quadrupole motion in ^{16}O is discussed in (92DE06). (87VE03) have used an extended isobar doorway model including open-shell configurations in both ground and excited states to calculate elastic and inelastic photon scattering in the Δ-region, and for linearly polarized photons.

43. (a) ^{16}O(e, e)^{16}O

(b) ^{16}O(e, e′p)^{15}N $\qquad Q_m = -12.127$

(c) ^{16}O(e, e′α)^{12}C $\qquad Q_m = -7.161$

The ^{16}O charge radius $= 2.710 \pm 0.015$ fm (78KI01). Form factors for transitions to the ground and to excited states of ^{16}O have been reported in many earlier studies [see (82AJ01, 86AJ04)], and by (87HY01); see Table 16.26. Table 16.26 lists the excited states observed from (e, e′). The form factor for ^{16}O*(9.84) indicates a transition density peaked in the interior (86BU02). The energy-weighted M2 strength is nearly exhausted by the M2 states which have been observed. The isospin-forbidden (E1) excitation of ^{16}O*(7.12) is reported: the isovector contribution interferes destructively with the isoscalar part and has a strength $\sim 1\%$ of the $T = 0$ amplitude. The 0^+ states of ^{16}O*(6.05, 12.05, 14.00) saturate $\sim 19\%$ of an isoscalar monopole sum rule. In a recent measurement, the magnetic monopole $0^+ \to 0^-$ transition to ^{16}O*(10.957) was observed (91VO02). The E2 strength is distributed over a wide energy region: see Table 16.26, and (82AJ01, 86AJ04) for references. See also the compilation of nuclear charge density distribution parameters (87DE1B), and the reviews of (89DR1C, 87HO1F).

A study of reaction (b) at 500 MeV shows separation energies of 12.2 and 18.5 MeV, corresponding to ^{15}N*(0, 6.32). The momentum distribution of the recoiling nucleus has been measured. High precision data with ~ 100 keV resolution in the missing mass are reviewed in (90DE16). The excitation of ^{16}O*(11.52, 12.05, 22.3) and some other states is reported at $E_e = 112$–130 MeV in (e, e′). The (e, e′p) and (e, eα) processes lead to the excitation of ^{15}N*(0, 6.32) and of ^{12}C*(0, 4.44). (See 82AJ01, 86AJ04 for the references). In a recent measurement the nuclear response function R_{LT} for ^{15}N*(0, 6.32) was determined in (e, e′p) by (91CH39). See also (90MO1K). Coincidence experiments at $E_e = 130$ MeV are reported by (87DM1A). See also (87RI1A). Non-spherical components in the ^{16}O ground state are indicated by the (e, e′p) data of (88LEZW). The inelastic cross section for 537 and 730 MeV electrons has been measured by (87OC01), and the electromagnetic excitation of the Δ resonance was studied.

Angular correlation measurements for reaction (c) to determine isoscalar E2 strengths in ^{16}O are reported in (92FR05).

Inelastic electron-nucleus interactions for ^{16}O at 5 GeV are reported in (90DE1M).

In theoretical work on reactions (a) and (b), models for relativistic Coulomb sum rules are developed in (89DO05). See also (91LE14). A shell-model study of giant resonances and spectroscopic factors in ^{16}O is described in (88HO10). See also (90BO31). (88AM1A) studied an isoscalar dipole excitation in ^{16}O (7.12 MeV state). Core polarization was used in their limited shell model treatment. Exchange amplitudes proved crucial in fitting (p, p′) data. A relativistic Dirac-Hartree-Fock approach is shown to give a reasonably good account of binding energies, single-particle energies and charge, as well as proton and neutron densities of ^{16}O and other closed shell nuclei (88BL1I). The application of Monte Carlo methods in light nuclei including ^{16}O is reviewed in (91CA1C). Non-locality of the nucleon-nucleus optical potential has been used (87BO54) to evaluate the missing single particle strength observed in (e, e′p) data. (88BO40) have studied the charge form factor by taking the one- and two-body isoscalar charge operands into account in the topological soliton model. Nuclear responses were calculated (87CA16) using self-consistent HF and RPA theory with a SK3 interaction. Decay properties in (e, e′p) and (e, e′n) for semidirect and knockout processes are also discussed. A self-consistent RPA with the SK3 interaction has been used by (88CA10) to calculate ($\vec{e}$, e′x) reactions. Polarization structure functions are also discussed. (89CA13) use self-consistent RPA with SK3 interactions to calculate monopole excitations in (e, e′) and ($\vec{e}$, e′x) reactions. Evidence has been presented by (89FR02) for a violation of Siegert's theorem, based on cross section measurements of the electro-excitation of the first 1^- level in ^{16}O. Previous Hartree-Fock calculations were used by (90CA34) to study Siegert's Theorem in E1 decay in ^{16}O. Their results show that the previously claimed violation cannot be definitely asserted. A pole graph method is used by (87CH10) to calculate production of hypernuclei in the continuum. Radial wave functions obtained from realistic nuclear potentials have been used to calculate electron scattering form factors for stretched configurations, which are compared to data (88CL03). (87CO24) exhibit and discuss DWBA structure functions for ($\vec{e}$, e′x) cross sections. A numerical study of the decay of giant resonances of ^{16}O was also conducted. The ratio of transverse-to-longitudinal electromagnetic response in (e, e′p) reactions has been examined in terms of relativistic dynamics and medium modifications (87CO26). Electron scattering form factors have been calculated (90DA14) using relativistic self-consistent RPA descriptions of discrete excitations. (86GU05) derived an expression for the transition charge density in the Helm model, and (88GU03) calculated charge density distributions using harmonic oscillator wave functions. Experimental values have been compared with calculated transition charge densities from various models in (88GU14). (88KU18) calculated binding energy, excitation spectra to $\sim$ 12 MeV, and e-scattering form factors using the mean-field approximation and the BZM boson image of the shell model Hamiltonian. Results appear superior to the standard shell model. The two-body pion exchange current contributions to the form factor of inelastic electron scattering has been calculated by (86LA15) using the effective pion propagator approximation. Effects due to meson exchange currents and unbound wavefunctions for the valence nucleon were included in calculations of electron scattering form factors (87LI30). Special attention was paid to $1\hbar\omega$ stretched states. A sum rule formalism was used by (89LI1G) to investigate giant resonances. Surface effects, non-Hermitian operators, and magnetic excitations were considered.

Normalized correlated wavefunctions were used by (88MA29) to simplify a previously derived expression for the charge form factor in the non-unitary model operator approach, and compared to data. (89MA06, 90MA63) derived an approximate formula for the two-body term in the cluster expansion of the charge form factor, and discussed the correlation parameter. (89MC05) used the Gelerkin approach to calculate a finite nucleus Dirac mean field spectrum, and then applied it to Dirac RPA response and the present results for 1^- and 3^- longitudinal form factors. A comprehensive study of a full set of 18 response functions relevant to the ($\vec{e}$, e′p) reaction is presented by (89PI07). (88PR05) have studied the linear response of ^{16}O to external electroweak current in a relativistic model. Hartree-Fock-RPA quasi-elastic cross sections for ^{16}O(e, e′p) are calculated by (89RY01), who also discuss final state interactions. Electromagnetic quasi-free proton knockout in a one-photon exchange approximation is studied in (91BO10, 91PA06). (89RY06) performed self-consistent HF-RPA model calculations for (e, e′p) and (e, e′n) using Skyrme interactions in parallel and perpendicular kinematics. A consistent extension of the QHD1 mean-field RPA theory including correlations induced by isoscalar σ and ω mesons of QHD1 is used by (89SH27) to calculate (e, τ') form factors and transition charge and current densities. See also (91ZH17). (86TK01) calculated M1 resonances taking 1p-1h $\times$ phonon excitations into account. Comparisons were made with data. (87YO04) studied $1\hbar\omega$ stretched excitations in configuration mixing calculations based on first-order perturbation theory.

44. ^{16}O($\pi^\pm$, $\pi^\pm$)^{16}O

Angular distributions of elastically scattered pions have been studied at $E_{\pi^-} = 20$ to 240 MeV and at 1 GeV/c as well as at $E_{\pi^\pm} = 20$ to 315 MeV [see (82AJ01, 86AJ04)] and recently at $E_{\pi^\pm} = 100$–250 MeV at 175° (lab) (87DH01), and at $E_{\pi^-} =$ 30, 50 MeV (90SE04). At $E_{\pi^\pm} = 164$ MeV, ^{16}O*(0, 6.1, 6.9, 7.1, 11.5, 17.8, 19.0, 19.8) are relatively strongly populated. The π^+ and π^- cross sections to ^{16}O*(17.8, 19.8) [$J^\pi = 4^-$; $T = 0$] are substantially different while those to ^{16}O*(19.0)[4^-; 1] are equal. Isospin mixing is suggested with off-diagonal charge-dependent mixing matrix elements of -147 ± 25 and -99 ± 17 keV (80HO13). [See also reaction 67, ^{17}O(d, t)]. The inelastic pion scattering is dominated by a single quasi-free pion-nucleon interaction mechanism at $E_{\pi^+} = 240$ MeV (83IN02): this is not the case at energies below the Δ-resonance (114 and 163 MeV). For recent inelastic measurements see (87BL1A).

For a study of (π^+, 2p) and ($\pi^\pm$, pn) at $T_{\pi^+} = 165$ MeV see (86AL22), at $T_{\pi^+} =$ 115 MeV see (92MA09). See also (86KY1A, 86KY1B). Pion absorption at $T_{\pi^+} =$ 65 MeV followed by multinucleon emission is reported by (92BA31). For (π^+, π^0p) at

$T_{\pi^+} = 165$ and 245 MeV see (91HO03, 88HO1L, 86GI15). For (π^+, π^-) and (π^-, π^+) at $T_{\pi^+} = 180$, 240 MeV see (89GR06). For (π^+, $\pi^+\pi^-$) at $T_{\pi^+} = 280$ MeV see (89GR05). See also (87ME12, 89ME10, 90KO36).

A calculation of differential elastic cross sections in a local approximation to the delta-hole model is described in (91GA07).

Optical-model calculations for pion scattering on ^{16}O are discussed in (90CA09, 90LI10).

45. ^{16}O(n, n$'$)^{16}O

Angular distributions have been measured at E_n to 24 MeV [see (82AJ01, 86AJ04)] and recently at $E_n = 18$ to 26 MeV (87IS04, 88MEZX); n's were observed leading to ^{16}O*(6.05, 6.13, 6.92, 7.12, 9.85, 10.35, 11.0, 11.52). For small-angle measurements at $E_n = 14.8$ MeV, see (92QI02). Differential cross sections for (n, n) and (n, n$'$) at $E_n = 21.6$ MeV are reported by (90OL01). Polarization of gamma rays from (n, n$'$) with polarized neutrons to ^{16}O*(6.05, 6.13) was studied by (88LI34) [see also (87PO11)]. See also the evaluation of $E_n = 10^{-5}$ eV–20 MeV neutron data for ^{16}O in (90SH1D).

The folding model has been used to calculate the nucleon–^{16}O interaction potential, and the effect of different nucleon-nucleon forces has been discussed (89HA24). See also the analysis with nonlocal potentials based on RGM formulations by (92KA21) and the optical model study of (92BO04). See also (91KA19, 91KA22, 91SH08).

46. (a) ^{16}O(p, p$'$)^{16}O

(b) ^{16}O(p, 2p)^{15}N $\quad Q_m = -12.127$

(c) ^{16}O(p, pd)^{14}N $\quad Q_m = -20.736$

(d) ^{16}O(p, pt)^{13}N $\quad Q_m = -25.032$

(e) ^{16}O(p, pα)^{12}C $\quad Q_m = -7.161$

(f) ^{16}O($\bar{p}$, $\bar{p}$)^{16}O

Angular distributions of elastically and inelastically scattered protons have been measured at many energies up to $E_p = 1000$ MeV [see (82AJ01, 86AJ04)] and recently at $E_p = 7.58$ MeV (87KR19; p to ^{16}O*(6.05)), 8.9–50 MeV (88LE08; p to ^{16}O*(6.129)), 35 MeV (90OH04; p to ^{16}O*($E_x \leq 12.97$)), 40–85 MeV (87LA11; p to ^{16}O*(6.1299, 8.8719)), 22, 35, 42 MeV (88SA1B; p to ^{16}O*(6.129)), 135 MeV (86GA31; p to ^{16}O*(6.044, 7.117, 12.043)), (89KE03; p to ^{16}O*(6.049, 6.130, 6.917, 7.117, 9.847, 10.353, 11.09)), 180 MeV (90KE03; p to ^{16}O*($E_x \leq 12.1$)), 200 MeV (86KIZW; p to ^{16}O*(10.957)), (89SAZZ; p to ^{16}O*(10.957, 12.797)), 201 MeV. (87DJ01; p to many states [see Table 16.27]), 320–800 MeV (88BL07), 318 and 500 MeV (88FEZX, 89FEZV, 91FL01, 91KE02), 100 and 200 MeV (88SEZU, 90GL09), 200, 318 MeV (90FEZY), 400 MeV (91KI08) and 1000 MeV (88BE2B). Parameters of the observed groups are displayed in Table 16.27. See also (90OP01) and the analysis of (90ER09).

For reaction (b) see (91CO13; 151 MeV), (86MC10; 505 MeV) and the review of (87VD1A). For reaction (c) see (86BO1A; 50 MeV), (86SA24; 76.1, 101.3 MeV). For reaction (p, pα) see (86VD04; 50 MeV). See also the study with antiproton beams of (86KO22).

(87CO25) have performed calculations using the Dirac equation for p and n distortions for the ^{16}O($\vec{\rm p}$, nπ^+)^{16}O reaction. A coupled-channels calculation using Dirac phenomenology for inelastic scattering of 800 MeV protons from ^{16}O is presented in (88DE1L). (88DE31) have studied the importance of a deformed spin-orbit potential in the calculations of (88DE1L). Approximate treatment of the nucleon-nucleus interaction in the resonating group method is discussed in (91KA19). First order Kerman-McManus-Thaler optical potentials have been constructed from realistic meson-exchange models of NN interaction including off-shell effects, and are found to be important for spin observables at 200–500 MeV (89EL02). Optical phase shifts have been calculated to fifth order by (88FR06), taking into account cm correlations. The significance of higher-order corrections is assessed. (89GU06) consider breakup reactions in high temperature plasmas, including production of 6.129 MeV γ's from ^{16}O: mainly from p + ^{16}O → p′ + ^{16}O* γ + ^{16}O → γ' + ^{16}O*, and p + ^{20}Ne → X + ^{16}O*. (88HA08) found Dirac optical potentials constrained by relativistic Hartree theory to give good agreement with elastic scattering data. See also (90TJ01, 91SH08). Spin observables have been calculated by (88HO1K) for proton quasi-elastic scattering in the relativistic plane wave-impulse approximation, and compared to (p, p′) data at 490 MeV. Isoscalar spin response functions are studied in (90SH10). (87KE1A) constructed a parametrization of medium modifications of the 2N effective interaction to reproduce nuclear matter theory, and adjusted it to reproduce proton inelastic scattering data. They obtained good fits to cross section and analyzing power for nine states simultaneously. (89KE05) performed similar calculations, and fitted 135 MeV proton cross section and analyzing power data with the effective interactions. (86KU15) performed a DWIA calculation of $\sigma(\theta)$ and $A_y(\theta)$ for ^{16}O($\vec{\rm p}$, 2p) at 200 MeV including spin-orbit and off-shell effects. (87LU02) performed a semi-relativistic multiple scattering model calculation of intermediate energy proton elastic scattering, and investigated target nucleon correlation contributions. Multiple diffraction scattering theory was used to calculate cross sections and polarization observables in (88BE57, 91BE1E, 91BE1Q, 92BE03). See also (91CH28, 91CR04, 92CR05). A Skyrme force approach was explored in (88CH08). A scalar-vector form of a second-order relativistic impulse approximation optical model including dispersion effects was used by (88LU03) to calculate elastic proton scattering at 500 and 800 MeV. Evidence for a small imaginary potential or actual flux emission was presented (88MA05) for nucleon scattering from ^{16}O at 30 MeV. As an alternate explanation of the (88MA05) findings, (88MA31) discuss the "ψ-potentials", related to projectile current. (88MA1X) contains a review of relativistic theory of nuclear matter and finite nuclei. A relativistic microscopic optical potential derived from the relativistic Brueckner-Bethe-Goldstone equation is discussed in (92CH1E). Polarization transfer measurements in (p, p′) reactions have been examined by (86OR03) with regard to correlations of tensor character.

(86OS08) used the T-matrix approximation with distorted waves to analyze knock-off nucleon (p, pN) and cluster (p, pX) proton induced reactions from 30 to 100 MeV. The scattering of 500 MeV protons has been calculated by (87OT02) using the Dirac equation with and without recoil corrections. Both cross section and spin observables are examined and compared to data. See also (91KA22). (88OT04) present systematics of Dirac impulse approximation for cross sections and spin observables in elastic p scattering at 200, 500, and 800 MeV. Results are compared to data. A mixed-density expansion of the off-diagonal density matrix is used by (88PE09) to study the non-local knockout exchange amplitude for nucleon-nucleus scattering. (87PI02) studied $0^+ \rightarrow 0^-$ transitions by medium energy protons using the relativistic impulse approximation. (89PI01) considered corrections arising from the energy dependence of the NN interaction, especially for $0^+(\vec{p},\ \vec{p}')0^-$ reactions. Relativistic and non-relativistic dynamical scattering models have been used by (88RA02) to predict elastic scattering observables in the forward angle for $p + {}^{16}O$ at 500 and 800 MeV. See also (90CO19, 90RA12). (89RA02) have obtained the leading three-body anti-symmetrization correction to nucleon-nucleus elastic scattering calculations using multiple scattering theory. Small effects are found at intermediate energies. Folding model potentials are used by (86YA16) to perform a systematic analysis of proton elastic scattering from 65–200 MeV. See also (90AR11, 90CR02, 90EL01, 91AR11, 91AR1K). Effects of short-range correlations on the self energy in the optical model of ^{16}O are studied in (92BO1C). See also (92LI1D).

47. (a) $^{16}O(d,\ d')^{16}O$
    (b) $^{16}O(d,\ n)^{17}F$ $\qquad Q_m = -1.623$

Angular distribution studies have been carried out for E_d up to 700 MeV [see (86AJ04)] and recently angular distributions and analyzing powers with polarized deuterons were measured at 19–24 MeV (91ER03) and at 200, 400, 700 MeV (87NG01). Observed deuteron groups are displayed in Table 16.27. See also ^{18}F in (87AJ02), and see the analysis of (90ER09).

Reaction (b) has been used for analysis of oxygen in fluoride glasses (90BA1M).

Coupled-channels variational formalism is discussed and applied to $^{16}O(d,\ d)^{16}O$ (86KA1A). Coupling to the proton channel is significant at 11 MeV, but can be ignored at ≥ 40 MeV. Coupling to d-breakup channels decreases as E increases, but is still significant at 60 MeV. (88IS02) use folding interactions to investigate polarized d-scattering at $E_d = 56$ MeV. Breakup channels are important, as is the D-state admixture in the deuteron ground state — especially for tensor analyzing powers. (88IS02) employed the continuum-discretized coupled-channels (CDCC) method, and obtained good agreement with data. (87GR16) studied d-scattering at 400 MeV using the folding model, but failed to describe A_{yy} at relatively low momentum transfers. They attribute this failure to inadequacies in off-shell properties of NN potentials. (86MA32) analyzed elastic data at 56 MeV using an optical model potential containing a complex tensor term. The OM potential was compared with folding-model results. (87MA1D) evaluate the Pauli-blocking correction of the three-body Schrödinger equation for d-nucleus reactions.

48. ^{16}O(t, t)^{16}O

Angular distributions are reported for E_t to 20.01 MeV: see (77AJ02) and recently at 36 MeV (86PE13, 87EN06). See also ^{19}F in (87AJ02), and see the analysis of (90ER09).

(89WA26) studied the spin-orbit potential for triton scattering to explain previous discrepancies with folding model predictions.

49. (a) ^{16}O(^{3}He, ^{3}He)^{16}O
(b) ^{16}O(^{3}He, α) $\qquad Q_m = 4.915$

Angular distributions have been measured to $E(^3\text{He}) = 132$ MeV [see (82AJ01, 86AJ04)] and at $E(^3\text{He}) = 60$ MeV (90ADZU). The matter radius $\langle r^2 \rangle^{1/2} = 2.46 \pm 0.12$ fm (82VE13). Inelastic groups are shown in Table 16.27. See also the analysis of (90ER09). Differential cross sections for reaction (b) have been measured at $E(^3\text{He}) =$ 60 MeV (90ADZT). The reaction has also been used in thin film analysis (90AB1G).

(86WAZM) studied the spin-orbit potential for ^{3}He scattering to explain previous discrepancies with folding model predictions. The M3Y double folding model is used (87CO07) to fit data at 33 MeV. No change in the spin-orbit strength is necessary. The three-parameter strong absorption model of Trahn and Venter is applied to data at 25 and 41 MeV. (87RA36) obtain radii, diffusivities and quadrupole deformation parameters. (87TR01) perform a simple optical model analysis of elastic ^{3}He scattering from 10 to 220 MeV.

50. (a) ^{16}O(α, α')^{16}O
(b) ^{16}O(α, αp)^{15}N $\qquad Q_m = -12.127$
(c) ^{16}O(α, 2α)^{12}C $\qquad Q_m = -7.161$

Angular distributions and/or differential cross sections of α-particles have been measured up to $E_\alpha = 146$ MeV [see (82AJ01, 86AJ04)] and recently at $E_\alpha = 48.7$, 54.1 MeV (87AB03; α_0): see ^{20}Ne in (83AJ01, 87AJ02). See also the work on (α, α_0) resonances at $E_\alpha = 2.0 - 3.6$ MeV (85JA17, 88BL1H). A search at $E_\alpha = 10.2$–18 MeV for continuum levels in ^{20}Ne with a large [$^{16}\text{O}^*(0_2^+)+\alpha$] parentage is described in (92LA01). Reaction (a) has also been observed in astrophysical measurements (89LA1G). Observed excited states are displayed in Table 16.27. See also the analysis of (90ER09), and see (90DA1Q, 90IR01).

Reaction (b) has been studied at $E_\alpha = 13.92$ MeV in a quasifree geometry (87SA01). Angular correlations (reaction (c)) have been studied to $^{12}C_{g.s.}$ at $E_\alpha =$ 23.0 to 27.5 MeV to try to determine if a 3^- state exists near the 2^+ state ^{16}O*(9.84): the evidence is strong that this is not the case (86AJ04). The isoscalar (E2, $T = 0$) giant resonance decays predominantly via the α_1 channel which contains $\sim 40\%$ of the E2 EWSR, rather than via the α_0 and p_0 channels. For the (α, αd), (α, αt) and (α, α^3He) reactions see references in (86AJ04).

In a theoretical study of nucleus-nucleus potentials, (87BA35) determine shallow potentials that are phase equivalent to deep ones. This method eliminates non-physical bound states encountered in some microscopically founded potentials. (87BU06) calculate the probability of direct alpha-decay of the giant quadrupole resonance in ^{16}O. They find direct and statistical mechanisms to be commensurate, and obtain good agreement with the data. The construction of a cranked cluster wave function for molecular-like states is discussed by (86HO33). (86MA35) study the radial shape and the energy dependence of the dispersive contribution to the real potential and apply it to alpha-particle scattering from ^{16}O. (89MI06) show that alpha-particle scattering from ^{16}O near the Coulomb barrier can be described if the interaction is angular momentum dependent and has a less diffuse surface than that used to describe scattering at higher energies. The separable potential expansion method based on Coulomb-Sturmian functions is presented (88PA21) and the $l = 3$ phase shift is calculated for $\alpha + {}^{16}$O at $E = 12$ MeV. (87SA55) show the one-channel orthogonality condition model provides results which agree with experiment for $E_\alpha \leq 7.5$ MeV. (87WA1B) compare a microscopic potential obtained from RGM calculations with the optical model potential. They conclude that internucleus antisymmetrization is responsible for a large part of the energy dependence of the real part of OM potential. (89YA15, 91YA08) use the many body theory which takes the Pauli principle into account to calculate the α–^{16}O complex potential from a realistic effective two-nucleon interaction. The role of the Pauli principle is also examined in (91OM03). Internucleus potentials in $\alpha + {}^{16}$O systems are calculated with Skyrme-type forces in (90WA01). Nuclear molecular resonances are discussed in the analyses of (90AB10, 92SA1F). See also (90KR16). A peripheral 3-body coupling model is applied to reaction (c) in (92JA04).

51. (a) ^{16}O(^{6}Li, ^{6}Li)^{16}O
    (b) ^{16}O(^{7}Li, ^{7}Li)^{16}O

Elastic angular distributions for reaction (a) have been measured at $E(^6\text{Li}) =$ 4.5 to 75.4 MeV and $E(^{16}\text{O}) = 36$ to 94.2 MeV [see (86AJ04) and Tables 16.25 in (77AJ02) and 16.23 in (82AJ01)] and recently at $E(^6\text{Li}) = 50$ MeV (88TRZY). See also (87GO1C). Vector analyzing power has been measured with polarized ^{6}Li beams at $E(^6\text{Li}) = 25.7$ MeV (87VAZY, 89VA04). See also ^{6}Li in (88AJ01). For studies of d–α angular correlations see ^{20}Ne in (83AJ01, 87AJ02). For a fusion cross section study see (86MA19). Inelastic scattering to states in ^{16}O are reported at $E(^6\text{Li}) = 50$ MeV by (90TR1A).

Elastic distributions for reaction (b) have been studied at $E(^7\text{Li}) = 9.0$ to 68 MeV [see (86AJ04) and Tables 16.25 in (77AJ02) and 16.23 in (82AJ01)] as well as at $E(^7\text{Li}) = 10.3$–22.40 MeV (88MA07). For fusion cross section studies see (88SC14) and references in (86AJ04). See also (88KE07).

A generalized optical model within the method of orthogonal conditions (MOC) has been formulated by (88GR32). Taking account of antisymmetrization improves the description of angular distribution data. See also (90SA1O).

52. $^{16}\text{O}(^9\text{Be}, ^9\text{Be})^{16}\text{O}$

Elastic angular distributions have been reported at $E(^9\text{Be}) = 20$ to 43 MeV and $E(^{16}\text{O}) = 15$ to 29.5 MeV [see (86AJ04) and Table 16.23 in (82AJ01)] and recently at $E_{\text{c.m.}} = 7.2$, 8.4, 9.0, 9.6, 10.2 MeV (89WE1I). Projectile decomposition measurements were reported at $E(^{16}\text{O}) = 32$ MeV/nucleon. For fusion cross sections see (82AJ01, 86AJ04, 88HAZS). See also (85BE1A).

53. (a) $^{16}\text{O}(^{10}\text{B}, ^{10}\text{B})^{16}\text{O}$
(b) $^{16}\text{O}(^{11}\text{B}, ^{11}\text{B})^{16}\text{O}$

Angular distributions have been reported at $E(^{10}\text{B}) = 33.7$ to 100 MeV and at $E(^{11}\text{B}) = 41.6$, 49.5 and 115 MeV [see (86AJ04) and Table 16.23 in (82AJ01)] and recently at $E_{\text{c.m.}} = 14.17$, 16.15, and 18.65 MeV (89KO10). See also (89KO2A). For fusion cross section measurements (reaction (a)) see (82AJ01, 86AJ04).

54. (a) $^{16}\text{O}(^{12}\text{C}, ^{12}\text{C})^{16}\text{O}$
(b) $^{16}\text{O}(^{12}\text{C}, \alpha^{12}\text{C})^{12}\text{C}$ $\qquad Q_{\text{m}} = -7.161$

Angular distributions have been reported at many energies to $E(^{16}\text{O}) = 1503$ MeV [see (82AJ01, 86AJ04)] and recently at $E(^{16}\text{O}) = 49.14$, 48.14, 48.06 MeV (86BA80). A peak in the excitation function at $E_{\text{c.m.}} = 33.5$ MeV was observed by (90KO1X). See also the review of (86BA1D) and analyses of (88BR04, 88RO01, 89VI09). Many of the studies of this reaction have involved yield and cross section measurements, as they apply to compound structures in ^{28}Si, fusion cross sections and evaporation residues. See (90SM1A). Some involve multinucleon transfer. Others involve fragmentation of the incident particle. See (82AJ01, 86AJ04) and (86GA13, 86IK03, 86SU1G, 87SU03, 88KO17, 88SZ02, 90BO1X). See also (86CH41, 86DE40, 86SN1B, 86WU03, 87HO1C, 87NA1C, 87YO1A, 88BR1N, 88CAZV, 88KR11, 88ME1H, 89BEZC, 89KRZX, 89SU1I, 89WE1E, 90BA1Z).

At $E(^{16}\text{O}) = 100$ MeV members of the $K^\pi = 0^+$ [^{16}O*(6.05, 6.92, 10.35, 16.3)] and $K^\pi = 0^-$ bands [^{16}O*(9.63, 11.60, 14.67)] are reported to be preferentially populated.

In reaction (b), as well as in the scattering of 140 MeV ^{16}O on ^{13}C and ^{28}Si, ^{16}O* states (9.83, 10.33, 11.04, 11.47, 11.98, 12.38, 13.81, 14.75, 15.33, 17.76), with $J^\pi = 2^+$, 4^+, 4^+, 2^+, 0^+, 1^-, 2^+, 4^+, 6^+, 3^-, respectively, for the first ten states, are populated: the state at 11.5 MeV is preferentially populated [see references in (82AJ01, 86AJ04)]. For pion emission see (86AJ04, 88SA31, 89LE12). (87BA50) have investigated the two-proton correlation function using the BUU (semiclassical transport equations) model with conserved total momentum. Experimental features of the correlation function are reproduced. (88BA43) study the energy dependence of the real part of the nucleus-nucleus potential using a modified Seyler-Blanchard two-body effective interaction containing density and momentum dependence. (87BRZW) perform an optical model analysis of ^{12}C–^{12}C and ^{16}O–^{12}C elastic scattering from 10–94 MeV; real part: double folding of a density dependent M3Y interaction — imaginary part: phenomenological.

(88BR20) examine dips in the far-side cross sections which reduce or eliminate potential ambiguities from analyses as in (87BRZW). (88BR29) analyzed elastic data at 9 to 120 MeV per nucleon using a folded potential based on the density and energy-dependent DDM3Y interaction. (87DA02) present a solution to the inversion problem (i.e., obtaining potentials from data) and apply it to ^{16}O + ^{12}C at 1503 MeV with good results. A microscopic calculation of pion-production in heavy-ion collisions is applied (86DE15) to coherent pion-production in ^{16}O + ^{12}C collisions. Effects of Pauli blocking and a surface contribution to the optical potential are investigated by (89EL01). Data require that a collective surface contribution be added to the volume part.

(88FR14) resolve optical potential model ambiguities by using dips in far side cross section data along with other special features of the angular distributions of elastic scattering data. (86HA13) performed a barrier penetration calculation of heavy-ion fusion cross sections, valid both above and below the Coulomb barrier. (86KA1B) survey projectile breakup processes using the method of coupled discretized continuum channels. An optical model potential containing a parity dependence which accounts for elastic α-particle transfer can explain the oscillations seen in the total fusion excitation function of ^{16}O on ^{12}C (88KA13). (88KO27) perform an optical model analysis of ^{16}O scattering data at $E/A = 94$ MeV. They explored potential shapes more general than folded or Woods-Saxon; no improvement in agreement with data. (89LE23) analyzed reaction data using an eikonal approach. They input only the densities and transition densities of the nuclei and elementary nucleon-nucleon scattering amplitudes. Good agreement with data was obtained. The ^{12}C + ^{16}O internucleus potential is calculated with the use of Skyrme type forces by (90WA01).

(89MI1K) calculate zero-degree and transverse energy for relativistic collisions. Results fit data very well. Low energy optical potentials are derived (87PA24) from effective interactions using double-folding. Only the effective interaction of Satchler and Love give good results over a wide energy range. (88RA1G) explores the relationship between clustering and shell effects, and find that this relationship is a close one. (86SA1D) perform a microscopic coupled-channels calculation. Breakup and virtual breakup effects are found to be important. (87SC34) present an expression for the real part of the nucleus-nucleus potential (energy dependent) which arises in the framework of the elastic model for heavy-ion fusion. This model is applied to sub-barrier fusion. (88WU1A) propose a non-compact group model to describe quasi-molecular nuclei.

55. (a) ^{16}O(^{13}C, ^{13}C)^{16}O
(b) ^{16}O(^{14}C, ^{14}C)^{16}O

For elastic scattering studies see Table 16.23 in (82AJ01), and see the more recent work at $E_{\rm c.m.} = 48.06$, 48.48, 49.14 MeV (86BA80), and $E_{\rm c.m.} = 19$–30 MeV (89FR04). For fusion cross sections see (86AJ04) and recent work at $E_{\rm c.m.} = 7.8$–14.6 MeV (86PA10). See also the review of (86ST1A). For the excitation of a number of states in ^{16}O in reaction (a) see (86AJ04). Cross sections for different exit channels of ^{16}O + ^{13}C at $E_{\rm c.m.} = 4.8$–9.8 MeV were measured by (91DA05). Emission ratios for pn to d and αpn to αd were studied in (86GA13). Competition between p2n, dn, and t emission was studied at $E_{\rm c.m.} = 10$–16 MeV (90XE01). For reaction (b) a search for resonances in elastic scattering at $E_{\rm lab} = 38$–54 MeV is reported in (90AB07).

(87DA34) performed a six-parameter optical model analysis of ^{13}C(^{16}O, ^{16}O)^{13}C. A two-center shell model is applied (87NU02) to the ^{13}C + ^{16}O system. Parity dependence of collisions between p- and sd-shell nuclei is studied (86BA69) microscopically in the two-center harmonic oscillator model.

56. (a) ^{16}O(^{14}N, ^{14}N)^{16}O
(b) ^{16}O(^{15}N, ^{15}N)^{16}O

For elastic scattering studies see (86AJ04) and Table 16.23 in (82AJ01) and (77AJ02). Recent measurements on reaction (b) at $E_{\rm lab} = 30$–70 MeV were reported in (86HA1F). For yield and total fusion cross-section measurements see (82AJ01, 86AJ04). See also (86BA69).

57. ^{16}O(^{16}O, ^{16}O)^{16}O

The angular distributions for elastic scattering have been measured with $E(^{16}{\rm O})$ up to 140.4 MeV [see (82AJ01, 86AJ04)] and recently at $E_{\rm c.m.} = 17$ MeV (87TI01), $E(^{16}{\rm O}) = 350$ MeV (89ST08) and $E(^{16}{\rm O}) = 38$ MeV/nucleon (86BR25). Inelastic scattering studies involving ^{16}O*(6.05) [$J^\pi = 0^+$] (89ZUZZ) are reported at $E(^{16}{\rm O}) =$ 51.0 to 76.0 MeV, and similar studies involving ^{16}O*(6.13) [$J^\pi = 3^-$] (88PAZZ) are reported at $E_{\rm c.m.} = 26.5$–43.0 MeV. Coupled channels effects are important at energies a few times the Coulomb barrier (77AJ02, 86AJ04). Intermediate and compound structure studies are described in (86GA10, 86GA24).

For yield and fusion cross sections see (82AJ01, 86AJ04) and more recent work (86IK03, 86TH1A, 87GO30, 87KU02, 88AU03). At $E(^{16}O) = 72$ MeV, (88AU1A) see no evidence for a low-ℓ fusion window. At $E(^{16}O) = 70 - 130$ MeV measurements of evaporation residues by (86IK03) find no evidence for a low-ℓ cutoff. For a study of α-transfer at near-barrier energies see (86CA24). Light-particle emission at $E(^{16}O) =$ 25 MeV/nucleon was studied by (86CH27). Related work includes an investigation of the role of isospin in the statistical decay of the GDR by (86HA30) and the review of hot nuclear matter (89SU1I). See also (89FE1F, 89SC1I).

(88AS03) evaluate the influence of the Uehling potential on subbarrier fusion. (87GO19) report a calculation of the fusion cross section using a classical microscopic equations of motion approach. (87LO01) study the effect of elastic transfer process on sub-barrier fusion reactions between similar nuclei. (87OH08) show that internal and barrier waves based on a semiclassical picture can account for the oscillations seen in fusion excitation functions. (87RA28) use statistical theory to study the behavior of high spin states formed in fusion reactions. (87SP11) calculate the fusion excitation function using the one-body wall friction.

(87TO10) investigate the influence of nucleon-nucleon collisions in the low angular momentum limit for fusion predicted by TDHF. A relativistic mean-field model consisting of nucleons coupled to scalar and vector mesons is used to solve the time-dependent mean-field equations. A relativistic Vlasov equation derived from mean field theory is applied in (90JI1C). An extended TDHF theory has been used (89GO1F) to study mass fluctuations in deep-inelastic collisions. Results show differences from conventional TDHF calculations (87BA10). (88RE1A) performed TDHF calculations of $^{16}O + ^{16}O$ using various Skyrme forces. (86TO14) calculate subthreshold pion-production using the TDHF formalism, and compare their findings with data. (86UM02) study fusion of $^{16}O + ^{16}O$ using TDHF and Skyrme forces. See also the study of (90SL01).

(86CH44) perform an optical model analysis of elastic scattering data using a calculated real part of the potential. The potentials are constructed in the energy density formalism with nuclear density distributions obtained in the framework of the method of hyperspherical functions. (89DA1C) develop a simple theory of a heavy-ion optical model potential. Colliding ions are described as two slabs of nuclear matter, with energy densities from properties of nuclear matter. (86FA1A) extend and refine the calculation of the real and imaginary parts of the optical model potential in the 20–100 MeV/nucleon range. Techniques for choosing a unique potential are discussed in (90KO18). See also (90RE1E). (88NA10) calculate microscopic nucleus-nucleus potentials using the energy-density formalism. See also (91MA29). (87PA24) derive real parts of the low-energy optical potential using the double-folding model. Pauli exchange effects within this model are studied in (91KH08). A semiclassical method for calculating elastic scattering cross sections was used in (91SA20).

(89HU1C) combine the concepts from a partition temperature model and the wounded nucleon model to describe high-energy nucleus-nucleus collisions. (88IT03) have applied coupled equations which treat the relative motion and internal excitation simultaneously to the case of $^{16}O + ^{16}O$ at intermediate energies. (87KA04) study subthreshold pion production mechanisms for $^{16}O+^{16}O$ at 40 and 80 MeV/nucleon. A quantum transport equation with two-body collisions included via a relaxation-time method is applied to ^{16}O–^{16}O collisions between 40 and 200 MeV/nucleon (88KO02). (88KO09) compare predictions of momentum dependence of nucleus-nucleus interactions deduced from various models. (89KO23) describe resonant phenomena in ^{16}O + ^{16}O in terms of an ion-ion potential. (88MA1O) solve the inverse scattering problem for fixed angular momentum using E-dependent phases and a Povzner-Levian representation of the wave function. Adiabatic bound and Gamow states have been calculated (86MI22) in a realistic two-center potential. Specific results for a neutron in a ^{16}O + ^{16}O potential are presented. (85SH1A) develop a microscopic approach to describe elastic and inelastic cross sections. They employ the quasiparticle phonon model for heavy ions and resolve the "fusion-window-anomaly". The resonating group method is used by (88WA31) to investigate constituent components of the ^{16}O–^{16}O exchange potential. A two-center shell model description is discussed in (90KH04).

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

Angular distributions of elastically scattered ions have been studied at $E(^{16}\mathrm{O})$ = 24, 28 and 32 MeV and $E(^{17}\mathrm{O})$ = 53.0 to 66 MeV, $E(^{17}\mathrm{O})$ = 22 MeV (reaction (a)) and at $E(^{16}\mathrm{O})$ = 24 to 54.8 MeV and $E(^{18}\mathrm{O})$ = 35 to 89.3 MeV (reaction (b)) [see (82AJ01, 86AJ04)]. Yields and fusion cross sections are reported in (82AJ01, 86AJ04). See also the studies on light-particle emission ratios in these reactions (86GA13, 90XE1A).

(87IMZZ) have studied the effects of rotational couplings by using the rotating molecular orbitals model. (87IM1C) develop and use a formalism for dynamical treatment of the molecular orbitals of valence nucleons in nucleus-nucleus collisions. (88IM02) consider the role of rotational coupling interactions in the transition between nucleon molecular orbitals. (87MA22) use the semiclassical approach including both one- and two-step contributions to calculate the two-particle elastic transfer reaction, while (88KA39) calculate differential cross sections for transfer of two neutrons taking Coulomb effects into account in a four-body model. (86MI22) use a realistic two-center potential to show that a substantial fraction of the particle emission comes from sequential decay of the excited fragments after separation, and (86VI08) consider two-particle exchange reactions using a parity-dependent optical potential.

59. (a) ^{16}O(^{19}F, ^{19}F)^{16}O
    (b) ^{16}O(^{20}Ne, ^{20}Ne)^{16}O

Elastic scattering angular distributions have been studied at $E(^{16}\mathrm{O})$ = 21.4 and 25.8 MeV and at $E(^{19}\mathrm{F})$ = 33 and 36 MeV: see (77AJ02). Angular distributions in reaction (b) have been measured at $E(^{16}\mathrm{O})$ = 40.7 to 94.8 MeV, 25.6 to 44.5 MeV, 44.1 to 63.9 MeV [see (86AJ04)], 60–80 MeV (86FUZV), and at $E(^{20}\text{Ne}) = 50$ MeV (86AJ04). Recent excitation functions were measured for reaction (b) at $E_{\text{c.m.}} = 21.5$–31.2 MeV (88HE06). See also (89SA14). For yield and fusion cross section measurements see (86AJ04). Projectile breakup studies are reported at 3.6 GeV/nucleon. See also (87AN1C). Hyperon production is investigated in (86FUZV, 88BO1D). See also (86HE1A, 88BE2A).

(86FU1C) discuss ways of accounting for the phase anomaly between elastic and inelastic scattering of $^{19}\text{F} + ^{16}\text{O}$. (89GA05) derive a parity-dependent potential for $^{16}\text{O} + ^{20}\text{Ne}$.

60. (a) $^{16}\text{O}(^{23}\text{Na}, ^{23}\text{Na})^{16}\text{O}$
 (b) $^{16}\text{O}(^{24}\text{Mg}, ^{24}\text{Mg})^{16}\text{O}$
 (c) $^{16}\text{O}(^{25}\text{Mg}, ^{25}\text{Mg})^{16}\text{O}$
 (d) $^{16}\text{O}(^{26}\text{Mg}, ^{26}\text{Mg})^{16}\text{O}$

Elastic angular distributions are reported at $E(^{16}\text{O}) = 35$ to 60.7 MeV (reaction (b)) and 27.4 to 50 MeV (reaction (d)) [see (82AJ01)] and $E(^{16}\text{O}) = 150$ MeV (86AJ04; reaction (b); elastic). More recent work on reaction (b) includes elastic scattering excitation function measurements at $E_{\text{c.m.}} = 31.6$–45.2 MeV (86DR11, 86DR1B) and inelastic measurements at $E_{\text{c.m.}} = 33.6$–49.2 MeV (86NU01, 86NU1A) and at $E_{\text{c.m.}} = 64$–88 MeV (86PE1G). Orbiting cross sections for reaction (b) are reported in (89BLZZ). For yield, evaporation residue and fusion measurements, see references in (82AJ01, 86AJ04).

(88AL06) show that algebraic scattering theory provides a simple yet detailed description of the complex coupled channels problem ($^{16}\text{O}+^{24}\text{Mg}$). (89FI03) calculate the effect of the dynamic α-transfer potential on several channels of the $^{24}\text{Mg} + ^{16}\text{O}$ systems. (87NA13) obtain an energy and angular momentum-dependent polarization potential from a compound nucleus level density dependent imaginary potential. They find that the elastic and fusion cross sections of $^{16}\text{O} + ^{24}\text{Mg}$ are hardly affected by this potential.

61. $^{16}\text{O}(^{27}\text{Al}, ^{27}\text{Al})^{16}\text{O}$

An elastic angular distribution has been measured at $E(^{16}\text{O}) = 46.5$ MeV: see (82AJ01). For yield, fusion and evaporation residue studies see (82AJ01, 86AJ04) and (87IK01, 88KO01, 89CA14, 89DE02, 90KR1D). See also (86BR26, 87DEZV). For fragmentation studies see (86AJ04) and (86SH1F, 87SH1C, 87SH23, 88AI1C, 88BR1N, 88SH1H, 89CA1F, 89YI1A, 90PAZW). For work on deeply inelastic collisions see (86AJ04) and (87SH21). For pion production see (86AJ04) and (87HU1C, 88BA21, 88JU02, 89FO07). For total reaction cross sections see (87KO12). Angular correlations have been studied at $E(^{16}\text{O}) = 65$–65.6 MeV (86AJ04) and at

$E(^{16}O) = 82.7$ MeV (88SH1H), at 215 MeV (90KR14), at $E_{c.m.} = 80 - 250$ MeV (88DE1A, 89DE02), and at $E(^{16}O) = 4$–5 MeV/nucleon (87CA1E). The sequential decay of $^{16}O^*(10, 11.6, 13.2, 15.2, 16.2, 21)$ is reported via α_0 [see (86AJ04)].

(87BA01) evaluate the energy dependence of the real part of the nucleus-nucleus potential using two-body effective interactions, calculate $^{16}O + ^{27}Al$, and compare to data. (89CA11) introduce "pre-equilibrium" temperature to describe the thermodynamics of nuclear systems prior to equilibrium. (88DA11) modify the coalescence model for complex-particle emission by correcting for the Coulomb barrier and the ejectile's binding energy.

62. (a) $^{16}O(^{28}Si, ^{28}Si)^{16}O$
 (b) $^{16}O(^{29}Si, ^{29}Si)^{16}O$
 (c) $^{16}O(^{30}Si, ^{30}Si)^{16}O$
 (d) $^{16}O(^{31}P, ^{31}P)^{16}O$

Angular distributions for reaction (a) have been reported at $E(^{16}O) = 29.3$ to 215.2 MeV [see (82AJ01, 86AJ04)], and recently at $E(^{16}O) = 94$ MeV/nucleon (87RO04). Elastic angular distributions for reactions (b) and (c) are reported at $E(^{16}O) = 60$ MeV (86AJ04). For yield, fusion cross section and evaporation residue measurements see (82AJ01, 86AJ04). See also (86BL08). For a crystal-blocking measurement of time delays in reaction (a) see (89MA23). For pion production see (86AJ04).

(88AL08) obtain expressions for the elastic S-matrix which include effects of the coupling to α-transfer channels to all orders. They study $^{16}O+^{28}Si$ at 180°. (88AS03) evaluate the influences of the Uehling potential on sub-barrier fusion and obtain noticeable modifications of the barrier penetrability. (86BR11) study the E-dependence of an optical potential which fits all $^{16}O + ^{28}Si$ elastic data for $E = 54.7$–215.2 MeV. (86HO18) employ a fixed energy potential inversion method to generate an optical model potential which fits $^{16}O + ^{28}Si$ elastic scattering data at 34.8 MeV. (86BR19) create a deformed optical potential consistent with calculations based on nuclear structure information which fits $^{16}O + ^{28}Si$ scattering and fusion data. (86BR23) use an optical model with repulsive core and coupled channels method to describe $^{16}O + ^{28}Si$ scattering data at large angles for $E = 29$–35 MeV. (88CH28) use a Monte Carlo simulation to calculate the nucleon transfer part of the imaginary optical-model potential. (87HU11) find good agreement with back angle elastic data in $^{16}O+^{28}Si$ by including a derived α-transfer polarization potential. (90DE35) employ a multistep α-transfer treatment to study back angle scattering of $^{16}O + ^{28}Si$. (85KH10) use a conventional optical model potential for $E_{lab} = 33.16$–55 MeV. They parameterize the S-matrix in terms of Regge poles and look at semiclassical features. (85KR1A) show that existing data do not allow one to draw conclusions about the relevance of Regge poles in $^{16}O+^{28}Si$. (89MA08) use elastic phase shifts obtained by the algebraic approach to scattering theory in a fixed energy inversion procedure. Results point to an underlying nonlocal interaction. (87NA13) show that the elastic and fusion cross sections are hardly affected by a strongly attractive real-polarization-potential. (87VA03) have applied a fast algorithm-based method for performing unconstrained phase-shift analyses to ^{16}O+^{28}Si at 21.1 MeV ($E_{\rm c.m.}$). (87XI01) formulate a molecular orbit theory for the 3α-transfer process and apply it to ^{16}O + ^{28}Si for E = 18.67–34.80 MeV, and compare it to data.

63. (a) ^{16}O(^{40}Ca, ^{40}Ca)^{16}O
(b) ^{16}O(^{42}Ca, ^{42}Ca)^{16}O
(c) ^{16}O(^{44}Ca, ^{44}Ca)^{16}O
(d) ^{16}O(^{48}Ca, ^{48}Ca)^{16}O
(e) ^{16}O(^{48}Ti, ^{48}Ti)^{16}O

Elastic angular distributions are reported on ^{40}Ca at $E(^{16}$O) = 50 to 214.1 MeV [see (82AJ01, 86AJ04) and recently at $E(^{16}$O) = 94 MeV/nucleon (88RO01). Elastic angular distributions were reported at $E(^{16}$O) = 60 MeV (^{42,44}Ca; also inelastic distributions) and 150 MeV [see (86AJ04)]. Similar measurements have been reported for ^{48}Ca at $E(^{16}$O) = 60 MeV [see (82AJ01)] and at 56 MeV (86AJ04; also ^{48}Ca*) and 158.2 MeV (86AJ04; also ^{48}Ca*). Yield, fusion cross section and evaporation residue measurements are reported in (82AJ01, 86AJ04) and by (86SA25, 87BEZY, 87BR20, 87HI10, 88KO1U, 89BE17). See also (86GU1C). For a measurement of the total non-fusion reaction cross section at $E(^{16}$O) = 158.2 MeV (reaction (d)) see (86AJ04). For a study of deep inelastic collisions at 142 MeV (reaction (d)) and for reaction (e) see (86AJ04).

A microscopic study of the ^{16}O+^{40}Ca potential is discussed in (86WA1C). (86AN18) calculate angular distributions for elastic scattering using a simple prescription for the part of the imaginary potential arising from inelastic processes and a folding expression for the real part of the potential, and fit it to the data. (86CH20) perform a microscopic optical model analysis using folding and realistic NN interactions (direct and exchange terms). They compare their results to data. (86CH38) calculate the real part of the optical model potential in a folding approximation using the density dependent M3Y interaction in factorized form. They also compare their results to data. (89DA1C) describe colliding nuclei as two slabs of nuclear matter. Energy density is derived from properties of nuclear matter. (89ES07) obtain good agreement with elastic and inelastic data using a coupled-channels treatment. (87GR04) study peripheral reactions. Neutrons and protons behave separately in an effective mean field. They find a transition between incomplete deep inelastic processes and fragmentation reactions near 35 MeV/nucleon. (86HA13) calculate barrier penetrations with Coulomb included. They obtain good agreement with data in the above and sub-barrier fusion regions. (89HO10) calculated heavy-ion fusion reactions with a macroscopic model proposed by Bertsch. They give a good account of the fusion cross section up to very high energies. (87DA23) develop a semi-microscopic model of elastic and inelastic scattering with a full finite range NN interaction. They also study the role of NN exchange correlations. The real and imaginary potentials have been derived (87VI04) in a model which includes a large set of non-elastic channels. (88PA20) calculate the particle transfer flux between two scattering nuclei from the time-dependent single-particle wave functions in the field of two moving potential pockets. They deduce the absorptive potentials which compare well with phenomenological ones. (89SU05) study the excitation of the GDR within the framework of the Landau-Vlasov equation. They analyze the GDR excited in peripheral ^{16}O + ^{40}Ca reactions at $E = 5$ MeV/nucleon.

64. ^{17}Ne(β^+)^{17}F* → ^{16}O + p $Q_m = 13.928$

The beta-delayed proton emission in the ^{17}Ne decay has been studied by (88BO39). See Tables 17.16 and 17.27. The half life is measured to be $T_{1/2} = 109.3 \pm 0.6$ ms.

65. ^{17}O(γ, n)^{16}O $Q_m = -4.143$

See (86AJ04, 89OR07, 90MC06) and ^{17}O.

66. ^{17}O(p, d)^{16}O $Q_m = -1.919$

Angular distributions for the ground-state deuteron group have been studied at $E_p = 8.62$ to 11.44 MeV. At $E_p = 31$ MeV, angular distributions are reported for the deuterons corresponding to ^{16}O*(0, 6.05+6.13, 7.12, 8.87, 10.36, 12.97, 13.26). States at $E_x = 15.22$ and 15.42 MeV were also observed. Spectroscopic factors were obtained from a DWBA analysis: see (77AJ02, 86AJ04). See also (89DE1P, 89OB1B).

67. ^{17}O(d, t)^{16}O $Q_m = -2.114$

Differential cross sections and analyzing powers for the reaction were measured at $E_d = 89$ MeV by (90SA27) and summarized in Table 16.28. Earlier information obtained at $E_d = 52$ MeV is displayed in Table 16.20 of (86AJ04). As discussed there, comparison of the (d, t) and (d, ^{3}He) reactions leads to assignments of analog states in ^{16}N and in ^{16}O [see Table 16.10 in (82AJ01)]. A study of this reaction, the (d, ^{3}He) reaction, and reaction 67 [^{17}O(^{3}He, α)^{16}O] below, suggests that there is more than 17% isospin mixing of the 2^- states in ^{16}O*(12.97, 12.53): the corresponding mixing matrix element is $\geq 155 \pm 30$ keV. An isospin mixing matrix element of 110 ± 10 keV for the 4^- states of ^{16}O*(17.79, 18.98, 19.80) is compatible with the results from this reaction and with pion scattering (86AJ04). See also reaction 44 [^{16}O($\pi^\pm$, $\pi^\pm$)^{16}O].

68. ^{17}O(^{3}He, α)^{16}O $\qquad Q_m = 16.435$

Angular distributions have been reported at $E(^3\text{He}) = 11$ MeV [see (77AJ02)], at $E(^3\text{He}) = 14$ MeV (α_0) and at $E(^3\text{He}) = 33$ MeV (to many states of ^{16}O) [see (86AJ04)]. Table 16.28 displays some of the information derived from this reaction. For polarization measurements see (86AJ04) and ^{20}Ne in (83AJ01, 87AJ02). See also (82AJ01).

69. ^{18}O(π^+, d)^{16}O $\qquad Q_m = 130.387$

See (86AJ04).

70. ^{18}O(p, t)^{16}O $\qquad Q_m = -3.706$

Angular distributions of tritons have been measured for $E_p = 43.7$ MeV [see (82AJ01)] and at $E_p = 90$ MeV (86VO10) (to ^{16}O*(6.1, 6.92, 7.12, 9.84, 13.26, 16.35)): see also (85BL1A). It is noted in (86VO10) that the 16.35 MeV state may be the (0^+, 1^-, 2^+) multiplet at $E_x = 16.35$ and 16.144 MeV (82AJ01). The population of ^{16}O*(22.7, 24.5) is consistent with $L = 0$ and 2, respectively, and with assignments of $T = 2$, $J^\pi = 0^+$ and 2^+. The decay of ^{16}O*(22.7), J^π; $T = 0^+$; 2, is via α_0, α_1 and α_2 [^{12}C*(0, 4.4, 7.7)] with (1.6 ± 0.7), (1.9 ± 0.7) and (14 ± 2)% branches and Γ_i(eV) $= 190 \pm 100$, 230 ± 110 and 1680 ± 550 eV, respectively; via p_0, p_{1+2}, p_3 with (7 ± 2), (11 ± 2) and (5 ± 2)% branches and Γ_i(eV) $= 840 \pm 343$, 1320 ± 454 and 600 ± 300 eV; and via n_{1+2} with a (23 ± 15)% branch [$\Gamma_n = 2760 \pm 1970$ eV] (the n_0 branch is < 15%) [Γ_i are based on a total width of 12 ± 3.5 keV]. See (86AJ04). See also (82AJ01) and ^{19}F in (87AJ02).

71. ^{18}O(α, ^{6}He)^{16}O $\qquad Q_m = -11.213$

Angular distributions have been measured at $E_\alpha = 58$ MeV to ^{16}O*(0, 6.1, 6.92, 7.12). Groups at $E_x = 10.4$, 13.3 ± 0.1 and 16.3 ± 0.1 MeV were also observed: see (77AJ02, 86AJ04).

72. ^{18}O(^{18}O, ^{20}O)^{16}O $\qquad Q_m = -0.623$

Angular distributions involving $^{16}\text{O}_{\text{g.s.}}$ and ^{20}O states are reported at $E(^{18}\text{O}) = 24$ to 36 MeV and at 52 MeV: see (82AJ01, 86AJ04).

73. ^{19}F(p, α)^{16}O $\qquad Q_m = 8.115$

Angular distributions have been measured at many energies up to $E_p = 44.5$ MeV [see (82AJ01)] and $E_p = 1.55$ to 2.03 MeV (α_0, α_1), 1.66 to 1.86 MeV (α_0), 10.0 to 11.4 MeV (^{16}O*(0, 6.05, 6.13, 6.92, 7.13, 8.87, 9.84, 10.36, 10.96, 11.08 + 11.10)) [see (86AJ04)]. See also Table 16.31 in (71AJ02). For a DWBA analysis of data for incident energies below the Coulomb barrier see (91HE16). A recent measurement of the absolute differential cross section at $E_p = 2$–3.4 MeV is reported in (86OU01). Measurements at $E_p = 1.55$–1.64 MeV by (90AZZY) were used to study resonances corresponding to states in ^{20}Ne. Absolute yields, angular distributions and resonance widths of the 6.13, 6.92, and 7.12 MeV photons from the 340.5 keV resonance are reported in (91CR06). See also (91MC08) for a study of resonance-yield deconvolution techniques.

The internal conversion to pair production ratio of the E0 transition ^{16}O*(6.05 $\rightarrow$ g.s.) $[0^+ \rightarrow 0^+]$ is $(4.00 \pm 0.46) \times 10^{-5}$. The ratio of double γ-emission to pair production $\Gamma_{E1E1}/\Gamma_{E0(\pi)} = (2.5 \pm 1.1) \times 10^{-4}$. τ_m for ^{16}O*(6.05, 6.13) are 96 ± 7 psec and 26.6 ± 0.7 ps, respectively. See (82AJ01) for references. $|g|$ for ^{16}O*(6.13) = 0.556 ± 0.004 (84AS03, 86AJ04). For γ-ray branching ratios and mixing ratios see Table 16.14 and (86AJ04).

See also ^{20}Ne in (83AJ01, 87AJ02), and see (86KH1A, 87KH1A, 88GN1A, 88UM1A; applied) and (88CA1N; astrophysics).

74. ^{19}F(t, ^{6}He)^{16}O $\qquad Q_m = 0.608$

Differential cross section measurements at $E_t = 38$ MeV are reported in (92CL04).

75. ^{19}F(^{3}He, ^{6}Li)^{16}O $\qquad Q_m = 4.096$

See (77AJ02).

76. ^{19}F(α, ^{7}Li)^{16}O $\qquad Q_m = -9.233$

See (88SH1E).

77. (a) ^{20}Ne(γ, α)^{16}O $\qquad Q_m = -4.734$
(b) ^{20}Ne(p, pα)^{16}O $\qquad Q_m = -4.734$

See (82AJ01, 86AJ04) and ^{20}Ne in (83AJ01, 87AJ02). See also (89TH1C).

78. ^{20}Ne(α, 2α)^{16}O $\qquad Q_m = -4.734$

See (88SH05) for a DWBA analysis of differential cross section data at E_α = 140 MeV.

79. ^{20}Ne(d, ^{6}Li)^{16}O $\qquad Q_m = 3.259$

Angular distributions have been studied at E_d to 80 MeV: see (82AJ01). At E_d = 55 MeV ^{16}O*(0, 6.05, 6.13, 6.92, 9.8, 11.10) are strongly populated (86AJ04.).

80. ^{23}Na(d, ^{9}Be)^{16}O $\qquad Q_m = -3.006$

The angular distribution to $^{16}O_{g.s.}$ has been measured at E_d = 13.6 MeV (86AJ04).

81. ^{24}Mg(α, ^{12}C)^{16}O $\qquad Q_m = -6.772$

Angular distributions have been reported at E_α = 22.8 to 25.4 MeV and at 90.3 MeV, the latter to ^{16}O*(0, 6.1, 7.0, 8.8, 9.8, 10.3) [see (82AJ01)] and at E_α = 25.1 to 27.8 MeV (86AJ04). Excitation functions measured for E_α = 26 − 37 MeV at θ_{lab} = 30°, 40°, 60° have been reported (86ESZV, 89ES06). See also (87SH1B, 88SH1F).

82. ^{24}Mg(^{12}C, ^{20}Ne)^{16}O $\qquad Q_m = -2.149$

The ground state angular distribution has been studied at $E(^{12}C)$ = 40 MeV [see (86AJ04)]. ^{16}O+^{8}Be breakup of ^{24}Mg following inelastic scattering of ^{24}Mg projectiles on ^{12}C has been reported (89FU10).

83. ^{28}Si(^{12}C, ^{24}Mg)^{16}O $\qquad Q_m = -2.822$

Forward-angle yields of ^{16}O measured at $E(^{28}Si)$ = 100–170 MeV have been reported (86SH25).

84. ^{28}Si(^{14}N, ^{16}O)^{26}Al $\qquad Q_m = -1.682$

Forward-angle yields of ^{16}O measured at $E(^{28}\text{Si})$ = 100–170 MeV have been reported (86SH25).

^{16}F

(Figures 4 and 5)

GENERAL:See Table 16.29.

1. (a) ^{14}N(^{3}He, n)^{16}F $\qquad Q_m = -0.957$
   (b) ^{14}N(^{3}He, np)^{15}O $\qquad Q_m = -0.421$

Observed neutron groups from reaction (a) and results from reaction (b) are displayed in Table 16.31. A recent measurement of n-p angular correlations from ^{14}N(^{3}He, n)^{16}F(p)^{15}O is reported in (86RYZZ).

2. ^{15}N(p, π^-)^{16}F $\qquad Q_m = -142.858$

Measurements of pion spectra with polarized protons at E_p = 200 MeV are reported in (87AZZY). Levels in ^{16}F at 0.39 (2^-), 0.72 (3^-), 5.40, 6.37 (4^-), 7.85, and 11.52 MeV are observed.

3. ^{16}O(γ, π^-)^{16}F $\qquad Q_m = -154.985$

Angular distributions and photoproduction cross sections vs. energy have been measured for E_p = 200–350 MeV (87JE02). See also (86AJ04).

4. ^{16}O(p, n)^{16}F $\qquad Q_m = -16.199$

Observed neutron groups are displayed in Table 16.31. Angular distributions of cross sections and/or polarization observables have been studied at E_p = 35–135.2 MeV (86AJ04) and recently at E_p = 35 and 40 MeV (87OH04) and at E_p = 135 MeV (89WAZZ). See also (83WA29). For a comparison of (p, n) cross sections with B(M1) see (86AJ04). A study of Gamow-Teller strengths is described in (88MA53). An investigation of $0^+ \rightarrow 0^-$ transitions is discussed in (86GA31). See also (89GA26) and the reviews of (86AN1E, 86BA78).

5. ^{16}O(^{3}He, t)^{16}F $\qquad Q_m = -15.436$

Observed triton groups are shown in Table 16.31. Angular distributions at $E(^3\mathrm{He}) =$ 81 MeV, analyzed by DWBA, and angular correlation measurements [mainly involving protons to ^{15}O*(0, 6.18)], together with information from reactions 1 and 4, lead to the J^π values shown in the table. The analog of the giant dipole resonance [$E_x \sim 9.5$ MeV] is strongly excited. The magnetic quadrupole strength has two strong components in ^{16}F*(0.42, 7.5). The 4^- state at 6.4 MeV and the GDR have also been observed at $E(^3\mathrm{He}) = 170$ MeV [see (86AJ04, 82AJ01). A recent measurement of differential cross sections at $E(^3\mathrm{He}) =$ 66–90 MeV and DWBA analysis is reported in (89VA09). See also (85VA1A, 90VA08).

6. (a) ^{16}O(^{6}Li, ^{6}He)^{16}F $\qquad Q_m = -18.924$

(b) ^{16}O(^{7}Li, ^{7}He)^{16}F $\qquad Q_m = -26.62$

Measurements have been reported at $E(^6\mathrm{Li}) = 93$ MeV, $E(^7\mathrm{Li}) = 78$ MeV [see (86AJ04)]. See also (89GA26).

7. ^{19}F(^{3}He, ^{6}He)^{16}F $\qquad Q_m = -14.828$

See Table 16.31 and (82AJ01, 86AJ04).

^{16}Ne

(Fig. 5)

GENERAL:

See Table 16.29.

Mass of ^{16}Ne: The Q-values of the ^{20}Ne(α, ^{8}He) and ^{16}O(π^+, π^-) reactions lead to atomic mass excesses of 23.93 ± 0.08 MeV (78KE06), 23.978 ± 0.024 MeV (83WO01) and 24.048 ± 0.045 MeV (80BU15) [recalculated using the (85WA02) masses for ^{8}He, ^{16}O and ^{20}Ne]. The weighted mean is 23.989 ± 0.020 MeV, which is also the (85WA02) value. ^{16}Ne is then bound with respect to decay into ^{15}F+p by 0.07 MeV and unbound with respect to ^{14}O + 2p by 1.40 MeV (86AJ04).

1. ^{16}O(π^+, π^-)^{16}Ne $\qquad Q_m = -24.77$

For ground state cross sections and analyses for $E_{\pi^+} = 80$ to 292 MeV see (82AJ01, 86AJ04). A recent measurement at $\theta_{\mathrm{lab}} = 5°$ for $E_{\pi^+} =$ 140–292 MeV has been reported (90SE11).

2. ^{20}Ne(α, ^{8}He)^{16}Ne $\qquad Q_{\rm m} = -60.21$

At $E_\alpha \approx 117.5$ MeV, ^{16}Ne*(0, 1.69 ± 0.07) are populated, the former with a differential cross section of 5 ± 3 nb/sr at 8°(lab). The $\Gamma_{\rm c.m.}$ for the ground state group is 200 ± 100 keV; applying penetrability corrections leads to a total decay width of 5–100 keV. The di-proton branching ratio is 10–90%, with the most probable value being 20%. The cubic term, d, in the IMME (Isobaric Multiplet Mass Equation) is 8 ± 5 keV, 15 ± 6 keV based, respectively, on the masses of ^{16}Ne*(0, 1.69). The first $T = 2$ states in ^{16}F[0^+, 2^+] are predicted to lie at $E_{\rm x} = 10.08 \pm 0.02$ and 11.87 ± 0.03 MeV (78KE06). At $E_\alpha = 129$ MeV (83WO01) find $\Gamma_{\rm c.m.}$ for ^{16}Ne$_{\rm g.s.}$ $= 110 \pm 40$ keV and the d and e coefficients in the IMME are both 4 ± 3 keV.

^{16}Na, ^{16}Mg, ^{16}Al, ^{16}Si
(Not observed)

See (86AN07).

Table 16.1
^{16}C – General

Reference	Description
	Complex Reactions
86BI1A	Heavy ion secondary beams - Results from GANIL
87GU04	Exotic emission of ^{14}C and other heavy clusters in the fragmentation of Ra & U
87RI03	Isotopic distributions of fragments in intermediate energy heavy ion reactions
87SA25	The LISE spectrometer at GANIL (secondary radioactive beam production)
87SN1A	Partitioning of a 2-component particle system & isotope distribution in fragmentation
87VI02	Anisotropies in transfer-induced fission of ^{16}O + ^{232}Th
88RU01	Dynamic treatment of ternary fission - calculates light charged particle formation
89SA10	Total cross sections of reactions induced by neutron-rich light nuclei (exp. results)
	Hypernuclei
87FA1A	Review of International Conference on a European Hadron Facility
88MA09	Hypernucleus production by K^- capture at rest on ^{16}O targets
89BA2N	Strangeness production by heavy ions
	Other Topics
86AN07	Predicted masses and excitation energies in higher isospin multiplets for $9 \leq A \leq 60$
87BL18	Calc. ground state energy of light nucl. (and excited states for N = Z) using HF method
89PO1K	Exotic light nuclei and nuclei in the lead region
89RA16	Predictions of B(E2; 0_1^+–2_1^+) values for even-even nuclei
	Ground State Properties
87BL18	Calculated ground state energies using Gogny's effective interaction and HF method
87SA15	Hartree-Fock calculations of light neutron-rich nuclei using Skyrme interactions
88PO1E	Shell model study of light exotic nuclei - compares calc. ground state prop. to data
89RA16	Predictions of B(E2; 0_1^+–2_1^+) values for even-even nuclei
89SA10	Total cross sections of reactions induced by neutron-rich light nuclei

Table 16.2
Energy Levels of ^{16}C

E_x (MeV ± keV)	$J^\pi; T$	$\tau_{1/2}$ (s) or Γ (keV)	Decay	Reactions
0	$0^+; 2$	$\tau_{1/2} = 0.747 \pm 0.008$	β^-	1, 2
1.766 ± 10	2^+		γ	2
3.027 ± 12	(0^+)		(γ)	2
3.986 ± 7	2		γ	2
4.088 ± 7	$3^{(+)}$		γ	2
4.142 ± 7	4^+		γ	2
6.109 ± 15	$(2^+, 3^-, 4^+)$	$\Gamma \leq 25$		2

Table 16.3
The β^- decay of ^{16}C

Decay to ^{16}N* (MeV)	J^π	Branch (%)	log $f_0 t$
0.120	0^-	$0.68^{+0.09}_{-0.11}$ [a])	$6.70^{+0.07}_{-0.05}$
0.298	3^-	< 0.5 [b])	> 6.83
0.397	1^-	< 0.1 [a])	> 7.46
3.35	1^+	84.4 ± 1.7 [b])	3.551 ± 0.012
4.32	1^+	15.6 ± 1.7 [b])	3.83 ± 0.05

[a]) (83GA03). See also (84GA1A).
[b]) (76AL02).

Table 16.4
^{16}N – General

Reference	Description
	Model Calculations
84VA06	Shell-model treatment of $(0+1)\hbar\omega$ states in $A = 4$–16 nuclei
87VA26	An effective interaction derived from spectra and static moments for $A = 4$–16
88VA03	Static moments from a phenomenological interaction
88MI1J	Shell model transition densities for electron and pion scattering
92WA22	Effective interactions for the 0p1s0d nuclear shell-model space
	Complex Reactions
86BI1A	Heavy ion secondary beams of radioactive nuclei
86GA1I	Spin response function obtained in heavy ion charge-exchange reactions
86HA1B	Microscopic model of nucleus-nucleus collisions
86PO06	Calc. half-lives & kinetic energies for spontaneous emission of heavy ions from nuclei
87AN1A	Achromatic spectrometer LISE at GANIL: produc. and ident. of nuclei far from $Z = N$
87BA1T	Spin-isospin excitations in nuclei with relativistic heavy ions
87BA38	Systematics of the ^{14}N + ^{159}Tb reaction between 6 and 33 MeV/u
87BU07	Projectile-like frags. from ^{20}Ne + ^{197}Au – counting simultaneously emitted neutrons
87EL14	Isovector excitations in nuclei with composite projectiles: (^{3}He, t), (d, ^{2}He) & heavy ions
87RI03	Isotopic distributions of fragments from ^{40}Ar + ^{68}Zn at E=27.6 MeV/u
87VI02	Anisotropies in transfer-induced fission of ^{16}O + ^{232}Th
88SA19	Sytematics of isotope production rates: unification of different methods of analysis
89BA2N	Strangeness production by heavy ions
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
	Hypernuclei
88RO11	Distorted wave impulse approximation study of hypernuclear photoproduction
89BA2N	Strangeness production by heavy ions
89BE02	Kaon photoproduction from nuclei in a relativistic nuclear model
89BE11	Electromagnetic production of Σ hypernuclei
89TA04	Absorptive effects in K + Λ photoproduction on nucleons and nuclei
89TA17	Compound-hypernucl. interpretation on $^{4}_{\Lambda}$H formation in stopped-K^{-} absorption
89TA1T	Schmidt diagrams and configuration mixing effects on hypernuclear magnetic moments
	Reactions involving pions, muons and neutrinos
85GR1A	Induced weak currents in nuclei
89CH31	Photoproduction of pions off nucleons and nuclei
	Ground-state Properties
86AN07	Predicted masses & excitation energies in higher isospin multiplets for $9 \leq A \leq 60$
89RA17	Table of nuclear moments (^{1}H–^{254}Es)

Table 16.5
Energy Levels of ^{16}N

E_x(MeV ± keV)	$J^\pi; T$	τ or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
0	$2^-; 1$	$\tau_{1/2} = 7.13 \pm 0.02$ s	β^-	1, 2, 4, 5, 7, 9, 11, 12, 16, 19–25, 27, 28
0.12042 ± 0.12	0^-	$\tau_m = 7.58 \pm 0.09$ μs	γ, β^-	1, 2, 4, 5, 7, 9, 11, 16–25, 27, 28
0.29822 ± 0.08	3^-	131.7 ± 1.9 ps	γ	2, 4, 5, 7, 9–11, 16, 19–25, 27, 28
0.39727 ± 0.10	1^-	$\{ \lvert g\rvert = 0.532 \pm 0.020$; $\tau_m = 5.63 \pm 0.05$ ps	γ	2, 4, 5, 7, 9, 11, 16, 18–22, 27, 28
3.3528 ± 2.6	(1^+) [c]	$\{ g = -1.83 \pm 0.13$; $\Gamma = 15 \pm 5$	n	5, 7, 9, 11, 13–17, 22, 25, 27
3.5227 ± 2.6	2^+	3	n	5, 7, 9, 11, 13, 16, 22, 25, 27
3.9627 ± 2.6	3^+	≤ 2	n	5, 7, 9–11, 13, 16, 22, 25, 27
4.3204 ± 2.7	1^+	20 ± 5	n	5, 9, 11, 13–17
4.3914 ± 2.7	1^-	82 ± 20	n	5, 7, 9, 11, 13, 16
4.76 ± 50	1^-	250 ± 50	n	11, 13, 16
4.7828 ± 2.7	2^+	59 ± 8	n	5, 7, 9, 11, 13, 16
5.0537 ± 2.7	2^-	19 ± 6	n	5, 9, 11, 13, 16
5.129 ± 7	≥ 2 [a]	$\leq 7 \pm 4$	n	5, 7, 9, 11, 13, 16, 25
5.150 ± 7	$(3)^-; 1$ [a,d]	$\leq 7 \pm 4$	n	5, 7, 9, 11, 13, 16, 25
5.2301 ± 2.6	3^+	≤ 4	n	5, 9, 11, 13, 16, 27
5.25 ± 70	2^-	320 ± 80	n	11, 16
5.318 ± 3	$(0^-, 1^+)$	(260)	n	5, 13
5.5216 ± 2.5	3^+	$\leq 7 \pm 4$	n	5, 7, 9, 11, 13, 16, 22, 24, 27
5.7317 ± 2.5	(5^+) [e]	$\leq 7 \pm 4$	n	5, 7, 9–11, 13, 15, 16, 22, 24, 27
6.003 ± 3	1^-	270 ± 30	n	5, 11, 13, 27
6.1707 ± 2.4	$4^-; 1$	$\leq 7 \pm 4$	n	5, 7, 9, 11, 16, 20, 22, 24, 27
6.3739 ± 2.8	$(3^-; 1)$	30 ± 6	n	5, 7, 11, 13, 16, 22, 27
6.426 ± 7		300 ± 30		11, 16
6.5054 ± 2.8	1^+	34 ± 6	(n)	5, 11, 13, 16, 24, 27
6.6085 ± 2.8	(4)	$\leq 7 \pm 4$		5, 7, 11, 16, 27
6.845 ± 4		$\leq 7 \pm 4$		7, 9, 11, 16, 27
(6.84)	≥ 2	> 140	n	13
7.02 ± 20	1^+	22 ± 5	n	11, 13, 16, 27
7.134 ± 7		$\leq 7 \pm 4$		9, 11, 16, 27
7.250 ± 7	≥ 2	17 ± 5	n	7, 11, 13, 16, 27
7.572 ± 4	≥ 3 [b]	$\leq 7 \pm 4$	n	7, 9–11, 13, 16, 27
7.637 ± 4	$(3, 4, 5)^+$ [b]	$\leq 7 \pm 4$		7, 9–11, 16, 27
7.674 ± 4	(b)	$\leq 7 \pm 4$	n	7, 9, 11, 13, 16, 24, 27
7.877 ± 9	≥ 4	100 ± 15	n	7, 11, 13, 16, 20, 27
8.048 ± 9		85 ± 15	n	11, 13, 27

Table 16.5 – continued
Energy Levels of ^{16}N

E_x(MeV ± keV)	J^π; T	τ or $\Gamma_{c.m.}$ (keV)	Decay	Reactions
8.199 ± 5	$(3,2)^+$	28 ± 8		9, 11, 27
8.282 ± 8		24 ± 8		11, 27
8.365 ± 8	≥ 1	18 ± 8	n	7, 11, 13, 27
8.49 ± 30	≥ 1	≤ 50	n	13, 27
8.72	≥ 1	40	n	13
8.819 ± 15		≤ 50	n	7, 13, 27
9.035 ± 15		≤ 50		27
9.16 ± 30	≥ 2	100	n	13, 27
9.34 ± 30		≤ 50	n	13, 27
9.459 ± 15	≥ 2	100	n	7, 13, 24, 27
9.760 ± 10	$T = 1$	15 ± 8		7, 9, 27
9.813 ± 10	$T = 1$			9
9.928 ± 7	$0^+;\ T = 2$	< 12		9, 26
10.055 ± 15	≥ 3	30	n	7, 13, 27
10.37 ± 40	≥ 2	165	n	7, 13
10.71	≥ 2	120	n	13
11.16 ± 40				7
11.49	≥ 3		n	13
11.61	≥ 3	220	n, d	8,13
11.701 ± 7	$2^+; 2$	< 12		9
11.75 ± 40		< 50		7
(11.92)		390	n,d	8
(12.09)			n	13
12.39 ± 60		290	n, p, d	7, 8
12.57 ± 60		180	n, p, d	7, 8
12.88		155	n, p, d	8, 13
(12.97)		175	n, d	8
13.11 ± 60			n, (d)	7, 8, 13
13.83			n	13
14.1	$(7^+; 2)$ [f]			
14.36 ± 50	$(3)^+$	180	d	7, 8

[a]) See also Table 16.6.
[b]) See also Table 16.7.
[c]) May be a doublet. See (85BLZZ) and see Table 16.15.
[d]) Probably the analog of ^{16}O*(18.029), D.J. Millener, private communication.
[e]) May be a 2^-, 5^+ doublet – the analogs of ^{16}O states at $E_x = 18.454$ and 18.640 MeV, $J^\pi = (2^-)$ and 5^+, respectively (D.J. Millener, private communication).
[f]) (87AZZZ) and D.J. Millener, private communication.

Table 16.6
States of ^{16}N from ^{10}B(^{7}Li, p) [a]

E_x [b] (MeV)	J [c]	E_x [b] (MeV)	J [c]
0		5.142	[e]
0.124		5.230	[f]
0.296		5.318	0, 1
0.400		5.525	4, 3 [g]
3.352	[c]	5.734	[h]
3.524	[c]	6.002	1 [f]
3.964	[c]	6.172	[i]
4.321	[c]	6.374	[c]
4.392	[c]	6.504	[c]
4.785	[c]	6.608	4 [j]
5.054	1, 2 [d]		

[a] For references see (86AJ04).
[b] ±3 keV
[c] Based on the assumption that the angle-integrated cross section is proportional to $2J + 1$. These states have J consistent with known values.
[d] If a doublet, $J = 1$ and 0.
[e] Doublet. (86AJ04).
[f] Narrow state.
[g] If a doublet, and if one state is 3^+, the second member would have $J = 0$.
[h] If a doublet of which one member is 5^+, the other would have $J = 2$ (1, 3).
[i] May be a doublet. (86AJ04).
[j] $J = 4$, if a single state.

Table 16.7
States of ^{16}N from ^{13}C(α, p) [a]

E_x (MeV)	Γ (keV)	J^π	E_x (MeV)	Γ (keV)	J^π
0.00		2^-	8.83	45 ± 30	
0.12		0^-	9.08 [b]	195 ± 30	
0.30		3^-	9.35 [b]	90 ± 30	
0.40		1^-	9.49 [c]	70 ± 30	
3.36			9.70 [d]	≤ 30	
3.52			9.81 [d]	90 ± 30	
3.96	≤ 20		10.07	35 ± 20	
4.40	110 ± 30		10.40		
4.77 [b]	170 ± 30		10.80		
5.05 [b]			11.21 [d]	≤ 30	(6^-)
5.14 [b,d]			11.66	170 ± 40	
5.23 [b]			11.81 [d]	≤ 20	(7^-)
5.73 [d]	< 20	doublet 4^-, 5^+	12.27 [b]	~ 100	
6.17	< 20	4^-	12.46 [b,d]	90 ± 30	
6.44	260 ± 50		12.61	100 ± 30	
6.60 [c]	< 20		12.95	170 ± 30	
6.82 [b]	< 20		13.35	60 ± 30	
7.57 [b]	< 20		13.65 [c]	45 ± 30	
7.64 [b]	< 20		14.41 [a]	~ 100	
7.68 [b]	< 20	unresolved 4^-, 5^-			
		4^-, 5^-			

[a] (86AN30) $E_d = 118$ MeV; DWBA analysis.
[b] Data available at less than four angles.
[c] Angular distributions over limited angular range.
[d] State is observed strongly in ^{13}C(^{6}Li, ^{3}He)^{16}N (77MA1B).

Table 16.8
States of ^{16}N from ^{14}C(^{3}He, p) [a]

E_x (MeV ± keV)	Γ (keV)	$J^\pi;\ T$	E_x (MeV ± keV)	Γ (keV)	$J^\pi;\ T$
0.121 ± 6		0^-	5.724 ± 5		5^+
0.298 ± 6		3^-	6.168 ± 5		
0.396 ± 7			6.843 ± 5		
3.348 ± 7		1^+	7.113 ± 5		
3.517 ± 7		2^+, $(3)^+$	7.570 ± 5		
3.958 ± 7		$(2)^+$, 3^+	7.636 ± 5		
4.313 ± 9		1^+	7.673 ± 5		
4.386 ± 9			8.205 ± 5		
4.768 ± 11			9.760 ± 10	15 ± 8	$T = 1$
5.052 ± 9			9.813 ± 10		$T = 1$
5.137 ± 9			9.928 ± 7	< 12	0^+; 2
5.234 ± 9		$(1, 2, 3)^+$	11.701 ± 7	< 12	1^-, 2^+; 2
5.512 ± 5		$(1, 2, 3)^+$			

[a]) For references see Table 16.5 in (77AJ02).

Table 16.9
States in ^{16}N from ^{14}N(t, p) [a]

E_x (MeV ± keV)	Γ(keV)	L	J^π
0		3	2^- [f]
0.120 ± 10		1	0^- [f]
0.300 ± 10		3	3^- [f]
0.399 ± 10 [b]		1	1^- [f]
3.359 ± 10	15 ± 5	0	1^+ [f]
3.519 ± 10	$\leq 7 \pm 4$	[d]	
3.957 ± 10	$\leq 7 \pm 4$	2	3^+ [f]
4.318 ± 10	20 ± 5	0	1^+ [f]
4.391 ± 10	82 ± 20	1	1^- [f]
4.725 ± 10 [c]	290 ± 30	1	1^-
4.774 ± 10	59 ± 8	2	2^- [f]
5.053 ± 10	19 ± 6	$(1 + 3)$	2^-
5.130 ± 10	$\leq 7 \pm 4$	[d]	
5.150 ± 10	$\leq 7 \pm 4$		
5.226 ± 10	$\leq 7 \pm 4$	2	$(1, 2, 3)^+$
5.305 ± 10 [c]	260 ± 30	[d]	
5.520 ± 10	$\leq 7 \pm 4$	$(0, 1) + 2 + 4$ [e]	
5.730 ± 10	$\leq 7 \pm 4$	$(1, 3) + 4$ [e]	
6.009 ± 10	270 ± 30	1	1^-
6.167 ± 10	$\leq 7 \pm 4$	(3)	(4^-)
6.371 ± 10	30 ± 6	(3)	(3^-)
6.422 ± 10	300 ± 30	$0 + (2, 4)$ [e]	
6.512 ± 10	34 ± 6	$0 + (2, 3)$	1^+
6.613 ± 10	$\leq 7 \pm 4$	$(2 + 4)$ or 3	
6.854 ± 10	$\leq 7 \pm 4$	3 or $(2 + 4)$	
7.006 ± 10	22 ± 5	$0(+2)$	1^+
7.133 ± 10	$\leq 7 \pm 4$	(3, 2)	
7.250 ± 10	17 ± 5	$(2 + 4)$ or 3	
7.573 ± 10	$\leq 7 \pm 4$	3 or $(2 + 4)$	3, 4^-
7.640 ± 10	$\leq 7 \pm 4$	4	$(3, 4, 5)^+$
7.675 ± 10	$\leq 7 \pm 4$	$(1 + 4)$	
7.876 ± 10	100 ± 15	$1 + 4$ [e]	
8.043 ± 10	85 ± 15	$(2 + 4)$ or 3	
8.183 ± 10	28 ± 8	$2(+4)$	$(3, 2)^+$
8.280 ± 10	24 ± 8	(1)	$((0, 1, 2)^-)$
8.361 ± 10	18 ± 8	$(1 + 4)$ [e]	

[a]) For references see Table 16.7 in (82AJ01).
[b]) $\tau_m = 5.1 \pm 0.3$ ps.
[c]) The errors listed here for E_x for these two broad peaks are probably underestimates (86AJ04).
[d]) Results are ambiguous.
[e]) May be a doublet.
[f]) Identified with shell-model counterparts.

Table 16.10
Resonances in ^{15}N(n, n)^{15}N [a,b]

E_n (MeV ± keV)	Γ_{lab} (keV)	E_x (MeV)	J^π
0.921	14	3.354	1^+ [c]
1.095	3	3.517	1
1.563	≤ 2	3.955	1
1.944	29	4.312	1^+ [d]
2.038	56	4.400	1^- [d]
2.30 ± 70 [e]	410 ± 100 [e]	4.65	1^- [d]
2.399	107	4.738	2^+ [d]
2.732	35	5.050	1^-
2.830	12	5.142	$3^{(-)}$
2.84 ± 70 [f]	70 ± 100 [f]	5.15	2^- [d]
2.915	4	5.222	≥ 2
2.93	260	5.24	1^+
3.225		5.512	
3.454	24	5.727	1^+
3.69	297	5.95	1^-
3.987	88	6.226	(1^+)
4.126	78	6.356	(3^-)
4.252	113	6.474	(2^+)
4.64	> 150	6.84	≥ 2
4.80	37	6.99	≥ 1
5.055	25	7.227	≥ 2
5.43	30	7.58	≥ 3
5.56		7.70	
5.73	165	7.86	≥ 4
5.90		8.02	
6.28		8.37	≥ 1
6.42		8.51	≥ 1
6.65	45	8.72	≥ 1
6.76		8.82	
7.10	110	9.14	≥ 2
7.31		9.34	
7.44	105	9.46	≥ 2
7.71	150	9.71	≥ 2
8.07	30	10.05	≥ 3
8.30	175	10.27	≥ 2
8.77	130	10.71	≥ 2
9.61		11.49	≥ 3

Table 16.10 – continued
Resonances in $^{15}N(n, n)^{15}N$ [a,b]

E_n (MeV ± keV)	Γ_{lab} (keV)	E_x (MeV)	J^π
9.77		11.64	≥ 3
10.25		12.09	
10.64		12.46	
11.09		12.88	
11.41		13.12	
12.10		13.83	

[a]) For references see Table 16.7 in (77AJ02).
[b]) Below $E_n = 4.5$ MeV, the multilevel R-matrix formalism was used to determine E_λ, Γ_λ and whenever possible J^π by a χ^2 fitting and minimization technique. Above this energy the $2J+1$ dependence was used; the parity cannot be determined because no marked interference effects are observed between resonance and potential scattering. Above 5.65 MeV all J-values are lower limits because the inelastic channel is open. [A channel radius $a = 4.69$ fm was used.]
[c]) Parity determined from angular distribution.
[d]) J^π also obtained by phase-shift analysis.
[e]) The phase-shift analysis indicates that the resonance is at $E_n = 2.42 \pm 0.08$ MeV with $\Gamma = 250 \pm 50$ keV. This is one of two $(d_{3/2}p_{1/2}^{-1})$ single-particle resonances.
[f]) The phase-shift analysis finds $E_\lambda = 2.94 \pm 0.1$ MeV, $\Gamma = 320 \pm 80$ keV. This is the other $(d_{3/2}p_{1/2}^{-1})$ single-particle resonance.

Table 16.11
Levels of ^{16}N from ^{15}N(d, p) and ^{18}O(d, α) [a]

E_x [b] (MeV ± keV)	l_n [b]	E_x [c] (MeV ± keV)	J^π [a]
0		0	2^-
0.1201 ± 0.5 [d]		0.119 ± 15	0^-
0.2962 ± 1.0 [e]		0.301 ± 15	3^-
0.3973 ± 1.0 [e]		0.400 ± 15	1^-
3.365 ± 10		3.358 ± 15	1^-
3.523 ± 10	2 or $1+3$	3.524 ± 15	2^+
3.964 ± 10	3	3.964 ± 15	3^+ [h]
4.325 ± 10	1	4.324 ± 15	1^+
4.40	0	4.383 ± 15	$(0,1)^-$
4.715 ± 10	1		$(1,2,3)^+$
4.780 ± 10		4.787 ± 15	
(4.90 ± 10)			
5.032 ± 10	2	5.065 ± 15	2^-
5.128 ± 10	≥ 2		≥ 2
		5.139 ± 15	
5.150 ± 10	2		$(2,3)^-$
5.231 ± 10	3	5.240 ± 15	3^+
5.310 ± 10			
5.523 ± 10	3	5.528 ± 15	3^+
5.739 ± 10	2	5.740 ± 15	$(1,2)$ [i]
		6.01 ± 15	
6.170 ± 10	≥ 3	6.168 ± 15	4^- [h]
(6.28 ± 10)	1		$(0,1,2)^+$
6.376 ± 10	2	6.37 ± 15	$(1,2,3)^-$
6.431 ± 10			
6.514 ± 10	1	6.512 ± 15	$(0,1,2)^+$
6.609 ± 10		6.620 ± 15	
(6.79 ± 10)			
6.847 ± 10		6.852 ± 15	
7.034 ± 10		7.01 ± 15	
7.135 ± 10		7.141 ± 15	
7.250 ± 10		7.247 ± 15	
7.577 ± 10		7.596 ± 15	
7.638 ± 10		7.64 ± 15	
7.676 ± 10		7.683 ± 15	
7.840 ± 10		7.88 ± 15	

Table 16.11

Levels of ^{16}N from ^{15}N(d, p) and ^{18}O(d, α) [a]

E_x [b] (MeV $\pm$ keV)	l_n [b]	E_x [c] (MeV $\pm$ keV)	J^π [a]
		8.06 ± 15	
		8.18 ± 15	
		8.286 ± 15	
		8.374 ± 15	
		8.49 ± 30 [f]	
		8.819 ± 15 [g]	
		9.035 ± 15	
		(9.16 ± 30)	
		(9.34 ± 30)	
		9.459 ± 15	
		(9.66 ± 40)	
		9.794 ± 15 [g]	
		9.90 ± 30	
		10.055 ± 15 [g]	
		(10.17 ± 30)	
		(10.26 ± 30)	

[a]) For the earlier references and additional information see Table 16.9 in (82AJ01).

[b]) ^{15}N(d, p)^{16}N.

[c]) ^{18}O(d, α)^{16}N.

[d]) $\tau_m = 7.58 \pm 0.09$ μs.

[e]) $\tau_m = 131.7 \pm 1.9$ and 5.63 ± 0.05 ps, respectively, for ^{16}N*(0.30, 0.40); $|g| = 0.532 \pm 0.020$ for ^{16}N*(0.30) (84BI03).

[f]) Γ for this level and the ones listed below $\leq$ 40–50 keV.

[g]) These levels appear to be correlated with thresholds for neutron emission to excited states of ^{15}N.

[h]) (82MA25): $E_d = 52$ MeV.

[i]) A closely spaced doublet appears to be present. At least one of the states has unnatural parity.

Table 16.12
^{16}O – General

Reference	Description
	Shell Model
Review:	
87KI1C	Microscopic studies of electric dipole resonances in 1p shell nuclei
Other Articles:	
86DE1E	Gamow-Teller strength from spin-isospin saturated nuclei (A)
86FU1B	Relativistic shell model calculations
86HA26	Shell model analysis of Σ-hypernuclear spectra for $A = 12$ & 16
86KL06	Interplay between giant res. & background - investigated with continuum shell model
86LE1A	Extended basis shell-model calculations for three-nucleon transfer (A)
86YE1A	Hartree-Fock calculations with extended Skyrme forces for ^{16}O and ^{40}Ca
87AV08	Neutron and proton hole states in double magic nuclei
87MA30	Contrib. of particle-particle, hole-hole & particle-hole ring diagrams to binding energies
87SU12	Nuclear ground-state properties & nuclear forces in unitary-model-operator approach
87YA1B	Effective shell-model matrix elements calculated for the sd-shell
88BL02	Quantized TDHF for giant monopole vibrations in ^{16}O, ^{40}Ca & ^{110}Zr
88BL1I	Relativistic Hartree-Fock calculations for nuclear matter & closed-shell nuclei
88BO10	Temperature-dependent shell effects in ^{16}O & ^{40}Ca with realistic effective Hamiltonian
88BO40	Nuclear charge form factor in the topological soliton model
88FI01	Effective interactions from sd-shell-model calculations
88GU13	Correlated basis functions computation of spectra of light nuclei
88HO10	Shell-model calculation with Hartree-Fock condition
88MI1J	Shell model transition densities for electron & pion scattering
88WO04	Expansion of the shell-model space for light nuclei
89GU06	Hartree-Fock & shell-model charge densities of ^{16,18}O, ^{32,34}S; & ^{40,48}Ca
90HA35	Weak-interaction rates in ^{16}O; nonspurious $4\hbar\omega$ shell model calculation
90WO09	p-shell nuclei in a $(0+2)\hbar\omega$ model space, Part 1: Method
90WO10	90WO09 continued, Part 2: Results
91BO02	Meson exchange effects on magnetic dipole moments of p-shell nuclei
91GM02	Relativistic mean-field fit to microscopic results in nuclear matter
91GO12	Method of multiple interactions - realistic NN potential (A)
91KA09	Non-orthogonality problem in continuum RPA studied by orthogonality condition
91KN04	RPA calculations of nuclear response in the continuum using a finite-range interaction
91MA33	Super-RPA ground-state correlations
91MU04	Effects of correlations on calc. of binding energy & radii of nuclei
91YA08	$\alpha + {}^{16}$O studied with complex effective interact. & antisymmetrized many-body theory
91ZH16	Retardation effect in finite nuclei in relativistic mean field theory
92MI01	Comments on 90WO09 & 90WO10; inconsistency problems
92WA25	Large-basis shell-model treatment of A=16 nuclei

Table 16.12 (continued)
^{16}O – General

Reference	Description
	Collective, Deformed and Rotational Models
Review:	
87TA1C	Microscopic cluster theory in nuclear physics
Other articles:	
86GO16	Deformed excited 0^+ states of ^{16}O & ^{40}Ca studied with the Hartree-Fock method
86LE16	Relativistic Hartree calculations for axially deformed nuclei
87DE21	Microscopic description of the ^{16}O spectrum in a multiconfiguration cluster model
87PR03	Self-consistent Hartree descrip. of deformed nuclei in a relativistic quantum field theory
87RO06	Coupling of valence shell and particle-hole degrees of freedom in a partial RPA
88ZH07	Many-particle-many-hole deformed state energies from HF with Skyrme interactions
89BU15	Configurational quasidegeneracy and the liquid drop model
91AB1C	Perturbative calculation of periodic solutions
91BA1M	Symmetry & surface energy coefficients with an effective interaction (A)
91DE11	Generalization of Frenkel-Dirac variational principle for systs. outside thermal equilib.
91KA12	Single-particle states with an excited core in ^{13}N & ^{16}O
91KN04	RPA calculations of nuclear response in the continuum using a finite-range interaction
91KO18	Relativistic investigation of the spin-orbit field in superdeformed nuclei
91SH1F	Systematics of superdeformation for $8 > A > 248$
91ZH05	Relativistic model incorporating vacuum polarization
	Cluster and α-particle models
86CO15	DWBA analysis for (^{7}Li, t) reactions producing α-cluster states in ^{16}O & ^{20}Ne
86OR1C	Faddeev-Yakubovsky calc. of 4α particle system with realistic alpha-alpha interactions
86SU13	Unitary-model-operators & calculation of energies of ground & one-body states
86SU16	(86SU13 cont.) Three-body-cluster effects on properties of ^{16}O
87DE21	Microscopic description of the ^{16}O spectrum in a multiconfiguration cluster model
87OS03	Four-body problem for four bound α particles in ^{16}O
87SU12	Nucl. ground-state properties & nucl. forces in unitary-model-operator approach to ^{16}O
87ZE05	Microscopic evaluation of clustering in ^{4}He, ^{12}C and ^{16}O
88CS01	Core-plus-alpha-particle states of ^{20}Ne and ^{16}O in terms of vibron models
88KA1Z	Systematic construction method of multi-cluster Pauli-allowed states
88TA1P	Measurement of a fragmentation event of a relativistic O nucleus (A)
89FU1N	Three-α potential in 3α and 4α orthogonality condition models
89KU31	Effective numbers of d-, t-, ^{3}He- and α-clusters and their distributions (in Russian)
89SU01	Isoscalar E0 & E2 strength of ^{16}O in an $\alpha + {}^{12}$C cluster & symplectic mixed basis
91BAZW	4-α breakup of ^{16}O; comparisons with prompt & sequential mechanisms (A)
91CS01	Cluster spectroscopic factor in the vibron model
91KA12	Single-particle states with an excited core in the nuclei ^{13}N and ^{16}O
91OR02	4α model calculation for the ^{16}O nucleus by the four-body integral equation

Table 16.12 (continued)
^{16}O – General

Reference	Description
	Special States
Reviews:	
85AD1A	Parity violation in the nucleon-nucleon interaction
86HA1E	Breaking of isospin symmetry in compound-nucleus reactions
86VO07	0^+ states and E0 transitions in even-even nuclides
87CA1E	New spin excitation modes in nuclei
89SP01	Reduced electric-octupole transition probabilities for even-even nuclides
Other Articles:	
86AN07	Predicted masses and excitation energies in higher isospin multiplets for $9 \leq A \leq 60$
86AN08	Nucleon momentum & density distributions in the generator co-ordinate method
86AY01	Effect of higher states on the ground & low-lying excited 0^+ states of ^{16}O & ^{40}Ca
86BE1F	Inelastic scattering to unnatural parity states in light nuclei using elementary probes
86CO1C	Deformed excited 0^+ states of ^{16}O & ^{40}Ca studied with the Hartree-Fock method
86EK1A	Highly excited & high-spin states in ^{16}O populated by (^{12}C, ^{8}Be$_{\rm g.s.}$) reaction
86KL06	Interplay between giant res. & background — investigated with continuum shell model
86OR1C	Faddeev-Yakubovshy calculation of 4α particle system with realistic α-α interactions
86RO26	Self-organization in nuclei
86TOZQ	Axial charge transitions in relativistic nucl. models & nonrelativ. meson exch. currents
87AV08	Neutron & proton hole states in doubly magic nuclei
87BL18	Excited states of light $N = Z$ nuclei with a specific spin-isospin order
87CO31	Simple parametrization for low energy octupole modes of s-d shell nuclei
87DE21	Microscopic description of the ^{16}O spectrum in a multiconfiguration cluster model
87KI1C	Microscopic studies of electric dipole resonances in 1p shell nuclei
87PR03	Self-consistent Hartree descrip. of deformed nuclei in a relativistic quantum field theory
87SK02	TDH solution of the Suzuki model of nuclear monopole oscillation
88AM03	Study of the isoscalar dipole excitation (7.12 MeV) in ^{16}O
88BL10	RPA for light nuclei based on fully relativistic Hartree-Fock calculations
88BL1I	Relativistic Hartree-Fock calculations for nuclear matter & closed shell nuclei
88DE22	Search for elusive neutral particles in the $0^+ \rightarrow 0^+$ transition at 6.05 MeV in ^{16}O
88GU13	Correlated basis functions calculation of spectra of light nuclei
88KU18	Nuclear structure of ^{16}O in a mean-field boson approach
88MI1J	Shell model transition densities for electron & pion scattering
88MU20	Reduction of stretched-magnetic-transition strengths by core polarization
88PR05	Nuclear linear response to electroweak interactions in a relativistic theory for ^{16}O
88RO09	Order out of chaos in atomic nuclei; microscopic calcs. of nucleon-induced rxns.
89BI1A	Search for the emission of a neutral particle in the decay of the first excited state in ^{16}O
89DE22	Addendum to 88DE22
89FO1D	Cold fusion results still unexplained
89SU01	Isoscalar E0 & E2 strength of ^{16}O in an $\alpha + ^{12}$C cluster & symplectic mixed basis
91AB1C	Perturbative calculation of periodic solutions of the time-dependent mean-field eqs.
91DE11	Generalization of Frenkel-Dirac variational principle for systs. outside thermal equilib.
91KA09	Non-orthogonality problem in continuum RPA studied by orthogonality condition

Table 16.12 (continued)
^{16}O – General

Reference	Description
	Electromagnetic Transitions
84VA06	Shell model treatment of $(0+1)\hbar\omega$ states in $A = 4$–16 nuclei
86HI07	Neutron-proton correlation in energy systematics of E1 & M2 states
86TK01	Microscopic calculation of properties of the low-lying M1 resonances in ^{16}O
86VO07	0^+ states and E0 transitions in even-even nuclides (reviews various models)
87CA1E	New spin excitation modes in nuclei
87DE21	Microscopic description of the ^{16}O spectrum in a multiconfiguration cluster model
87RA01	Transition probability from ground to first-excited 2^+ state of even-even nuclides
87TO1B	Quenching of spin matrix elements in nuclei
88AD08	Sum rules in extended RPA theories
88MU20	Reduction of stretched-magnetic-transition strengths by core polarization
89HAZY	Two-photon decay of the 0^+(6.05 MeV) state in ^{16}O (A)
89KA28	Microscopic model incorporating 2p-2h configs. in magic nucl.; calc. of M1 excitations
89LI1G	Sum rules & giant resonances in nuclei
89RA16	Predictions of B(E2; $0_1^+ - 2_1^+$) values for even-even nuclei
89SU01	Isoscalar E0 and E2 strength of ^{16}O in an $\alpha + {}^{12}$C cluster and symplectic mixed basis
91LE14	Theoretical evaluation of the Coulomb sum rule in nuclei
91LI29	Sum rules for nuclear excitations with the Skyrme-Landau interaction
	Giant Resonances
86HI07	Neutron-proton correlation in energy systematics of E1 & M2 states
86KL06	Interplay between giant res. & background - investigated with continuum shell model
87BU06	Alpha decay of giant electric quadrupole resonances
87KI1C	Microscopic studies of electric dipole resonances in 1p shell nuclei
87QU02	Giant dipole transitions in the nuclear WSp(6, R) Model
87TH03	Exotic isoscalar dipole resonances in the Walecka model
88BE24	Simple microscopic approach to the nuclear giant monopole & quadrupole resonances
88BL02	Quantized TDHF for giant monopole vibrations
88CA07	Charge transition densities for excitation & nucleon decay of the ^{16}O GDR
88CO1G	Charge response in ^{12}C & ^{40}Ca; also includes RPA calc. for ^{16}O
88DI07	Scaling- & antiscal.-type oscillations in isoscalar & isovector nucl. monopole vibrations
88DR02	Quantized TDHF for isoscalar giant quadrupole resonances in spherical nuclei
88HO10	Shell-model + Hartree-Fock condition calc. of giant resnc. excitation energies in ^{16}O
88LI13	Surface & temperature effects in isovector giant resonances
88PA05	Time-depend. Hartree-Fock calc. of escape width of giant monopole resonance in ^{16}O
89LH02	Isoscalar giant resonances in a relativistic model of doubly-closed-shell nuclei
89LI1G	Sum rules & giant resonances in nuclei
91BO39	Compressibility of nuclei in relativistic mean field theory
91LI28	Self-consistent RPA calc. of giant multipole resncs. using Skyrme-Landau interaction

Table 16.12 (continued)
^{16}O – General

Reference	Description

Astrophysics

Reference	Description
Reviews:	
86WO1A	The physics of supernova explosions
90RO1C	Radiative capture reactions in nuclear astrophysics
Other Articles:	
86BA50	Coulomb dissociation as a source of information on radiative capture processes
86LA1C	The chemical composition of 30 cool Carbon stars in the galactic disk
86MA1E	Effects of the new ^{12}C(α, γ)^{16}O rate on chemical evolution of the solar neighborhood
86SM1A	Chemical composition of red giants: He burning and the s-process in the MS & S stars
86TR1C	Frequency of occurrence of O-Ne-Mg white dwarfs in classical nova systems
87AD1A	Direct meas. of the charge state of the anomalous O component of cosmic rays (A)
87AL1B	Carbon, nitrogen and oxygen abundances in Procyon, Sun and Arcturus
87BE1H	^{12}C/^{13}C & ^{16}O/^{18}O ratios in Venus' atmosphere from high-res. 10-μm spectroscopy
87CU1A	Interstellar medium composition der. from anomalous cosmic ray component meas. (A)
87DO1A	^{12}C/^{13}C & ^{16}O/^{17}O isotopic ratios in seven evolved stars (types MS, S & SC)
87DW1A	Cosmic-ray elemental abundances from 1 to 10 GeV/amu for boron through nickel
87FA1C	^{16}O excess in hibonites discredits late supernova injection origin of isotopic anomalies
87HA1C	^{12}C/^{13}C and ^{16}O/^{18}O ratios in the solar photosphere
87HA1D	Oxygen istopic abundances in 26 evolved carbon stars
87HA1E	Search for ^{14}C^{16}O in the atmospheres of evolved stars - none found
87LA1C	Line shapes and linear polarizations of certain γ-rays emitted from solar flares (A)
87MC1A	Oxygen isotopes in refractory stratospheric dust: proof of extraterrestrial origin
87ME1B	Solar coronal isotopic abundances derived from solar energetic particle meas. (A)
87PL03	Scattering of α particles from ^{12}C and the ^{12}C(α, γ)^{16}O stellar reaction rate
87PR1A	Neutron capture nucleosynthesis during core helium burning in massive stars
87RA1D	Nuclear processes and accelerated particles in solar flares
87SA1D	Linear polarization of ^{12}C* & ^{16}O* γ-rays as particle direction indicators in solar flares
88AN1D	Evolution of Fe, r, and s-elements in our galaxy
88CL1C	Isotopic anomalies: chemical memory of galactic evolution
88CU1A	Elemental composition of anomalous cosmic-ray component (A)
88DU1B	Spectrophotometry & chemical composition of the O-poor bipolar nebula NGC 6164-5
88DU1G	Abundances of carbon & nitrogen in I Zw 18 (an oxygen-poor galaxy)
88FO1E	Nuclear line spectroscopy of solar flares; deduced elemental abundances
88KA1G	Steady state models of white dwarfs accreting helium or carbon/oxygen-rich matter
88RE1E	Bimodal abundances in the energetic particles of solar and interplanetary origin
89AB1J	Oxygen abundances in unevolved metal-poor stars: interpretation & consequences
89BE2H	Effect of enhanced α-elements in helium-burning population II stars
89CH1X	Stability analysis of C-N-O nuclear reaction inside stars
89CU1E	Observed radial & latitudinal gradients of anomalous cosmic ray oxygen (A)
89FU02	Reaction cross section for "solar flare neutrinos" with ^{37}Cl and ^{16}O targets
89GU06	Hartree-Fock & shell-model charge densities of ^{16,18}O, ^{32,34}S and ^{40,48}Ca

Table 16.12 (continued)
^{16}O – General

Reference	Description
	Astrophysics — continued
89GU1I	Thermonuclear breakup reactions of light nuclei. I. Processes & effects
89GU1J	(cont. from 89GU1I) Part II. Gamma-ray line production & other applications
89GU1Q	Abundances of light nuclei at the cosmic-ray source from fragmentation cross sections
89JI1A	Nucleosynthesis inside thick accretion disks around massive black holes
89LI1I	Anthropic significance of the existence of an excited state of ^{12}C
89ME1C	Isotope abundances of solar coronal material derived from solar energetic particle meas.
89SP1G	Oxygen and Carbon abundances in a few F supergiants of the small Magellanic cloud
89TA26	Microscopic calc. of rates of electron capture which induce collapse of O+Ne+Mg cores
90AB1E	Early nucleosynthesis of O and Fe
91AL02	N-$\bar{\text{N}}$ oscillation times estimated from Paris N$\bar{\text{N}}$ potential
91AN1E	^{26}Al and ^{16}O in the early solar system: clues from meteoritic Al_2O_3
91BE05	Direct projectile break-up & its relation to the astrophysically relevant fusion reactions
91PA1C	Extremum prob. treatment of C, N & O abundances in late-type star atmospheres (A)
91RA1C	Carbon burning and galactic enrichment in massive stars
	Applications
86MU1A	Analysis of oxygen on & in beryllium using 2 MeV Helium ions (A)
86ZA1A	Passage of nitrogen and oxygen ions through carbon and celluloid films
87BO16	Analytical possibilities of $3 < E < 12$ MeV tritium beams & appl. to analysis of O in InP
87NA1D	Sputtering of carbon by oxygen and neon
87ZU1A	Oxygen isotope effect in high-temperature oxide superconductors
88AL1K	Analysis of “Desert Rose” (geological sample) using RBS and PIXE techniques
88BL1H	Surface analysis of high Z oxides using 3.05 MeV ^{4}He–^{16}O backscattering resonance
88GOZR	Non-Rutherford elastic backscattering for light element cross section enhancement (A)
88IL1A	Light element materials study by Rutherford backscattering spectroscopy (A)
88RO1L	Ion implantation in targets for nuclear physics studies (A)
	Complex Reactions
Reference	Description
Reviews:	
87MC1B	Introduction to quark-gluon plasma and high energy heavy ion collisions (A)
89GR1J	Cluster radioactivities
Other Articles:	
86AB06	Calculation of mass yields for proton-nucleus spallation reactions
86AL25	Incomplete & complete fusion in intermediate energy heavy ion reactions
86AV1A	Search for anomalons & fragments with fractional charge in ^{16}O fragmentation
86BA1E	Multistep fragmentation of heavy ions in peripheral collisions at relativistic energies
86BO1B	Observation of fission of relativistic ^{24}Mg & ^{28}Si into two fragments of $\sim$ equal charge

Table 16.12 (continued)
^{16}O – General

Reference	Description
	Complex Reactions — continued
86HA1B	Microscopic model of nucleus-nucleus collisions
86KI1C	Apparent anomalously short mean free paths observed in relativistic heavy-ion collis.
86MA13	Experimental search for nonfusion yield in the heavy residues emitted from ^{11}B + ^{12}C
86ME06	Quasi-elastic, deep-inelastic, quasi-compound nucleus mechanisms from ^{89}Y + ^{19}F
86NA1B	Correlation of linear momentum & angular momentum transfer in ^{154}Sm + ^{16}O
86PL02	Element distributions after binary fission of ^{44}Ti
86PO06	Calc. half-lives & kinetic energies for spontaneous emission of heavy ions from nuclei
86SA30	Nucleus-nucleus scattering and interaction radii of stable & unstable nuclei
86SC29	Partition of excitation energy in peripheral heavy-ion reactions
86SHZY	Equilibration in orbiting reactions; ^{12}C & ^{16}O yields from ^{14}N + ^{28}Si (A)
86SH1F	Measurements of projectile-like fragments produced by ^{27}Al + ^{16}O
86SH25	Equilibration in orbiting reactions; ^{12}C & ^{16}O yields from ^{14}N + ^{28}Si
86SO10	Particle-bound excited state yields produced in the reaction of 181 MeV ^{19}F + ^{159}Tb
86ST13	Microscop. calc. of ener. & transitional densities of giant monopole resonances in nucl.
86VA18	Excitation-energy sharing in ^{20}Ne induced reactions
86VA23	Peripheral reactions induced by ^{20}Ne at 11 and 15 MeV/nucleon
87AN1C	Fast frags. of target in interactions of relativistic nuclei with nuclei of nucl. emulsion
87BA02	Energy spectra of fragments calculated using statistical multifragmentation model
87BA1T	Spin-isospin excitations in nuclei with relativistic heavy ions
87BA31	Isotope distribution in nuclear multifragmentation
87BA38	Systematics of the ^{14}N + ^{159}Tb reaction between 6 and 33 MeV/u Part I. Inclusive data
87BE1F	Target fragmentation at ultrarelativistic energies using oxygen beams
87BO1K	Collectivity in composite fragment emission from relativistic heavy ion collisions
87BO23	Intermediate-mass fragments from nonbinary processes in ^{14}N + Ag at $E/A = 35$ MeV
87BU07	Projectile-like fragments from ^{20}Ne + ^{197}Au — counting simultaneously emitted neutrons
87DEZV	^{16}O breakup in the ^{27}Al + ^{16}O interaction at 96 MeV (A)
87FA09	Source properties of intermediate-mass frags. emitted in ^{14}N + ^{232}Th at $E/A = 35$ MeV
87FE1A	Study of deep inelastic collisions in ^{12}C + ^{27}Al at 61.8 MeV
87GE1A	Charges & angular distributions of fast fragments produced in 3.2-TeV ^{16}O + Pb
87GO1E	Photon and charged particle spectra in ^{16}O + W at 200 GeV/nucleon (A)
87JA1B	Model of transverse energy production in high energy nucleus-nucleus collisions
87KO15	Intermediate mass fragments in ^{6}Li + ^{46}Ti at $E/A = 26$ MeV
87LI04	Multistep effects in ^{17}O + ^{208}Pb near the Coulomb barrier
87LY04	Fragmentation & the emission of particle stable and unstable complex nuclei
87MA1B	Peripheral like interaction model of spectator residue with central fireball
87MI1B	Projectile fragmentation of ^{16}O at medium energies (A)
87MU03	Study of the emission of clusters by excited compound nuclei
87NA01	Linear momentum & angular momentum transfer in ^{154}Sm + ^{16}O
87PA01	Complete & incomplete fusion in ^{20}Ne + ^{93}Nb
87PA1D	Recoil accelerator mass spectrometry of nuclear reaction products
87RI03	Isotopic distributions of fragments from ^{40}Ar + ^{68}Zn at $E = 27.6$ MeV/u
87RO10	Projectile fragmentation in heavy-ion reactions at intermediate energies

Table 16.12 (continued)
^{16}O – General

Reference	Description
	Complex Reactions — continued
87SH23	Dissipative phenomena and α-particle emission in $^{16}O + ^{27}Al$ between 46 and 85 MeV
87SU07	Correlated fluctuations in the ^{89}Y(^{19}F, x)y excitation functions
87VI1B	Mechanisms of momentum & energy transfer in intermediate-energy collisions
88AN1C	Multiple angular scattering of ^{16,17}O, ^{40}Ar, ^{86}Kr and ^{100}Mo at 20–90 MeV/u
88AR1D	Interactions of 60 & 200 A GeV ^{16}O ions in nuclear emulsion
88AY03	Transport description for capture processes in nuclear collisions
88BO13	Deeply inelastic collisions as a source of intermediate mass fragments at $E/A = 27$ MeV
88BR1N	Fragmentation cross sections of ^{16}O at 60 & 200 GeV/nucleon
88CA1G	Experimental indications of selective excitations in dissipative heavy ion collisions
88FE1A	Meas. C, O, & Fe charge changing σ in He & H at high E; appl. to cosmic-ray propag.
88GA11	Neutron pickup & 4-body processes in reactions of $^{16}O + ^{197}Au$ at 26.5 & 32.5 MeV/u
88GA12	Stripping- & pickup-induced breakup in 11- & 17-MeV/u $^{20}Ne + ^{197}Au$ reactions
88GO11	Emissions of complex frags. & effective temps. for collisions of $^{58}Ni + ^{58}Ni$ at 11 MeV
88HA03	Spin dependence of neutron transfer in heavy ion reactions
88KH1B	Excit.-decay vs. fragment production for $^{12}C(^{16}O,^{15}N + p)$; $E = 1.05$ & 2.1 A GeV (A)
88MI1I	Multifragmentation as a possible signature of liquid-gas phase transitions
88MO05	Dynamical model for projectile break-up & incomplete fusion in $^{20}Ne + ^{197}Au$
88PO1A	Multifragmentation of the projectiles ^{16}O, ^{14}N, and ^{12}C at 32.5 MeV/A (A)
88SH03	$^{28}Si + ^{14}N$ orbiting interaction (experimental data) & importance of phase space
88SH1H	Coincidence meas. between α-particles & projectile-like frags. in 82.7 MeV $^{16}O + ^{27}Al$
88SI01	Fragmentation of ^{16}O projectiles at 100 MeV/nucleon
88TE03	Incomplete deep-inelastic scattering in $^{20}Ne + ^{197}Au$ collisions at 20 MeV/nucleon
88UT02	Quasi-free stripping mechanism of Serber model extended to complex projectiles
88WI1F	Electromagnetic spallation of 3.2 TeV ^{16}O nuclei (A)
89AD1B	Production of He projectile fragments in ^{16}O-emulsion interactions at $E/A = 2$–200 GeV
89BR14	Dynam. anal. of deep inelas. interac. in $^{19}F + ^{24}Mg$ above Coulomb barrier
89CA15	Fusion & binary reactions in the collision of ^{32}S on ^{26}Mg at $E_{\rm lab} = 163.5$ MeV
89FI05	Non-eq. vs. equilibrium complex. frag. emiss.; $^{14}N + Ag$ & $^{14}N + Au$ at $E/A = 20$–50 MeV
89GE1A	Complex fragments emitted in excited states
89GR13	Compound nucleus emission of intermediate mass fragments in $^{6}Li + Ag$ at 156 MeV
89MA45	Target excitation & angular momentum transfer in $^{28}Si + ^{181}Ta$ from multiplicity meas.
89PO06	Approach to criticality in the fragmentation of Xe by 1–19 GeV protons
89PO07	Excitation & multiple dissociation of ^{16}O, ^{14}N, and ^{12}C projectiles at 32.5 MeV/u
89RE08	Large transient magnetic fields for single electron O ions on a 10 fs time scale (O + Gd)
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
89YO09	Energy damping feature in light heavy-ion reactions (including 118 MeV $^{16}O + ^{48}Ti$)
89ZHZY	Mass measurement of $Z = 7$–19 neutron-rich nuclei using the TOFI spectrometer (A)
90BO01	Critical excitation energy in fusion-evaporation reactions
90SE1H	Total reaction cross section for the interaction of light nuclei in Glauber-Sitenko theory
90YE02	Intermediate mass fragment emission in the p + Ag reaction at 161 MeV

Table 16.12 (continued)
^{16}O – General

Reference	Description
	Muon and Neutrino capture and reactions
Reviews:	
85GR1A	Induced weak currents in nuclei
86TO1D	Meson-exchange currents in time-like axial-charge transitions
Other Articles:	
86DO06	Experimental results on radiative muon capture in complex nuclei
86GM02	Continuity-equation constraint for electron scattering & radiative muon capture
86LI13	Signature for the existence of η-mesic nucleus
86MA16	Emission of nucleons & nucleon pairs following muon capture in ^{12}C, ^{16}O & ^{27}Al
86NA14	Sum rule approach to total muon capture rates
86TO1A	Weak interaction probes of light nuclei
87GM01	Radiative capture of polarized muons on ^{16}O & ^{40}Ca
87OH1B	Energetic neutrons after muon capture modeled using realistic nuclear Fermi motion
88DO05	Radiative muon capture in ^{12}C, ^{16}O, ^{27}Al, ^{40}Ca, ^{nat}Fe, ^{165}Ho & ^{209}Bi
88FR19	Radiative muon absorption in ^{16}O
88HA22	Neutrino reactions on oxygen & a proposed measurement of the Weinberg angle
88PR05	Nuclear linear response to electroweak interactions in a relativistic theory for ^{16}O
89FU02	Reaction cross section for "solar flare neutrinos" with ^{37}Cl & ^{16}O targets
89KA35	Second class meson exchange currents & neutrino mass in μ^--capture by light nuclei
89NA01	Some relations for radiative-pion-capture & muon-capture rates
	Pion, Kaons & other Mesons
Reviews:	
86BA1C	Pion-nucleus double charge exchange: the modern era
86DO1B	Strange probes of the nucleus
86PE1E	Scattering of electrons, nucleons, and pions as probes of nuclear structure
87FA1A	Conclusions & outlook (from Proc. of the Int. Conf. on a European Hadron Facility)
87GI1C	Pion-nucleus interactions
88FA1B	Strange particles: a probe for new physics in particles and nuclei
88JO1E	Pions & the nuclear spin-isospin response
88KR1E	Meson exchange models of the nuclear response function
88KY1A	Studies of pion absorption at SIN; includes quasi-deuteron absorption in ^{16}O
88PE1F	The (π, η) and (π^+, K$^+$) reactions in nuclei
88RO1M	Nuclear scattering & reactions with low-energy pions
88WA1B	Production of hypernuclei in the (K, π) reaction
89CH32	Recent experiments in novel nuclear excitations at the BNL AGS
89JO1B	Phenomenological optical-model anal. of pion elastic & charge-exchange scat.
89KH1E	Problems of pion-nucleus interaction
89RI1E	Exchange currents
Other Articles:	
86BE22	Stability of the ground state of finite nuclei against neutral pion condensation
86BE42	(K$^+$, K$^+\pi$) in light nuclear-emulsion nuclei with small momentum transfer to nucleus
86BL04	Pion condensates in excited states of finite nuclei & nuclear matter

Table 16.12 (continued)
^{16}O – General

Reference	Description
	Pion, Kaons & other Mesons — continued
86CE04	Inclusive n, p & d energy spectra from stopped π-absorption in ^{6}Li, ^{9}Be, ^{16}O, ^{27}Al
86CH39	Compar. of $\pi\Delta$ interact. mechan. & dbl. chrg. exch. (exp. data on self-conjugate nucl.)
86CO1B	(e, e$'$K^{+}) & low-lying hypernuclear states using relativistic field theory (A)
86DI07	Analytic distorted wave approx. for electro- & photopion produc. on ^{12}C near threshold
86FI1A	Conversion width of the Σ- & Ξ-hyperons in nuclei & one-meson exchange
86FR20	Kemmer-Duffin-Petiau eq. for pionic atoms & anomalous strong interaction effects
86GI13	Nuclear-structure aspects of nonanalog pion double charge exchange
86HA26	Shell model analysis of Σ-hypernuclear spectra for $A = 12$ & 16
86HA39	Strangeness exchange reactions with the recoil corrected continuum shell model
86KI1D	Quasifree process in hypernuclear formation
86LE22	Test of effective cluster interactions by pion scattering
86LI1B	Evidence & search for the eta-mesic nucleus
86LI1C	Extraction of particle-hole strengths for $1\hbar\omega$ stretched states
86MEZX	Total reaction cross sections of 50 & 65 MeV pions on nuclei (A)
86OS03	Theoretical study of inclusive (π, 2π) reactions in nuclei
86SCZX	^{16,18}O(π^{+}, 2p)^{14,16}N reactions at $T = 116$ MeV with energy resolution < 2 MeV (A)
86SI11	Effects of nuclear correlations on low-energy pion charge-exchange scattering
86TO1A	Weak interaction probes of light nuclei
86WH03	Energy dependence of the low energy pion-nucleus optical potential
87AM1A	Spectroscopic aspects of the reaction ^{16}O(π^{+}, 2p)^{14}N at $T = 116$ MeV (A)
87BU20	p & d production in nucl. (in inclusive reactions) induced by 1.5 GeV/c π^{+} & π^{-} mesons
87CH10	Continuum effects & the interpretation of Σ hypernuclei
87CH1D	Search for the bound states of an η-meson in the nuclear potential (A)
87CO09	(e, e$'$K^{+}) & low hypnuc. excits. using relativ. transit. operat. & nuc. struc. model
87CO1G	Studies of the nuclear (e, e$'$K^{+}) reaction in a relativistic model (A)
87CO25	The ($\vec{p}$, nπ) ground state reaction in a relativistic framework
87GI01	The isoscalar pion-nucleus interaction from pionic atoms
87GM02	Momentum-space second-order optical potential for pion-nucleus elastic scattering
87GM04	Pion-nucleus scattering at low & resonance energies
87GO05	^{16}O(π^{+}, pp)^{14}N at 60 MeV — testing the quasi-deuteron mechanism
87HA40	Coupled channel calculation of Σ-hypernuclear spectra from ^{12}C, ^{16}O, & ^{6}Li
87JE02	Photoproduction of charge pions on ^{16}O to bound states of the nuclei ^{16}N and ^{16}F
87KA39	Delta-hole approach to pion double charge exchange
87KH1B	New approach to the description of pion-nucleus scattering at low energies
87KO1F	Σ-hypernuclear spectra from (K^{-}, π) inclusive reactions (A)
87KO30	Σ-hypernuclear spectra from (K^{-}, π) inclusive reactions
87LE1B	Strong interaction studies via meson-nucleus reactions
87MA1I	Inclusive pion double charge exchange in light nuclei (A)
87MA1M	E & θ dependence of non-analog pion double charge exchange reaction (A)
87NA04	Sum rule approach to radiative pion capture: full hamiltonian calc. for 1p shell nuclei
87PI1B	Studies of hypernuclei by associated production (A)
87TE01	Inclusive π^{+} & π^{-} prod. in nucleon-nucleus & α-nucleus collisions in the GeV region

Table 16.12 (continued)
^{16}O – General

Reference	Description
	Pion, Kaons & other Mesons — continued
88CH1H	Search for bound states of the η meson in light nuclei
88DH1A	Delta-hole model in the local density approximation (see (88ER04))
88DO05	Radiative muon capture in nuclei; also measured pion capture
88ER04	Delta-hole model in the local-density approximation
88FR02	Strong-interaction finite-range effects in light pionic atoms
88GR1E	Systematics of inclusive double charge exchange
88HA12	Charge exchange reactions used to study giant resonances: ($\pi^{\pm}$, γ), ($\pi^{\pm}$, π^0)
88HA1I	Phenomenological analysis of Σ-hypernuclear spectra from (K$^-$, π^+) reactions
88HA2A	s-wave repulsion of pion-nucl. interaction, data contradicts relativistic mean-field calc.
88HYZY	Coincidence measurements of the reaction ^{16}O(π^+, 2p)^{14}N at 165 MeV (A)
88HYZZ	Measurement of the reactions ^{16}O(π^+, p) & ^{16}O(π^+, 2p)^{14}N at 165 MeV (A)
88IT02	Pi-mesonic decay of hypernuclei & pion wave function
88JO1F	The (π, 2π) reaction; experimental data compared to calc. of (86OS03)
88KH01	Pion-nucleus dynamics at low energies
88KR09	RPA correlation effects in radiative pion capture
88KR1E	Meson exchange models of the nuclear response function
88LI1P	Large-angle elastic scattering of π^+ & π^- from ^{16}O at 114 MeV (A)
88MA09	Study of hypernucleus production by K$^-$ capture at rest
88MA27	Non-analog double charge exchange transition: ^{16}O(π^+, π^-)^{16}Ne(g.s.)
88MA37	Observation of pionic atom anomaly in low-energy pion scattering
88MAZM	Dominance of the two-nucleon mechanism in ^{16}O(π^+, 2p) at 115 MeV (A)
88MI1N	Λ-nucleus single-particle potential obtained from analysis of Λ-hypernuclei spectra data
88MO1B	The (π^+, K$^+$) reaction to probe Λ and Σ states in hypernuclei
88MO23	Hypernuclear production by the (π^+, K$^+$) reaction
88OS1C	Meson exchange currents in p decay in nuclei
88PE1H	Associated production of hypernuclei with (π^+, K$^+$) reaction
88PI1E	Search for bound states of the η-meson in light nuclei
88SA24	Computer simulation of inclusive pion nuclear reactions
88SC14	Exclusive quasi-deuteron absorption of pions in ^{16}O & ^{18}O at 116 MeV
88TA21	One-nucleon knockout by pions and deltas
88WI1B	Large angle pion-nucleus scattering from ^{12}C & ^{16}O (A)
88WI1I	Pion double charge exchange above the Δ(3, 3) resonance (A)
89BA06	Polarization of hypernuclei in the (π^+, K$^+$) reaction
89BA2N	Strangeness production by heavy ions
89BA63	Slow π^- meson capture by C, N, & O in nucl. emulsion with prod. of 3 charged particles
89BE02	Kaon photoproduction from nuclei in a relativistic nuclear model
89BE11	Electromagnetic production of Σ hypernuclei
89CA04	Quantized meson-exchange picture of the nuclear interactions
89CH04	J dependence in the reaction ^{16}O(π^+, 2p)^{14}N at 116 MeV
89CH31	Photoproduction of pions off nucleons & nuclei

Table 16.12 (continued)
^{16}O – General

Reference	Description
	Pion, Kaons & other Mesons — continued
89FE07	Skyrme-Hartree-Fock calculation of Λ-hypernuclear states from (π^+, K^+) reactions
89GA09	Pionic distortion factors for radiative pion capture studies
89HA07	Shell model calculation of Λ-hypernuclear spectra from (π^+, K^+) reactions (talk)
89HA29	Shell model calculation of Λ-hypernuclear spectra from (π^+, K^+) reactions
89HY1B	Inclusive & exclusive measurements of ^{16}O(π^+, p) & ^{16}O(π^+, 2p)^{14}N at 165 MeV (A)
89KA37	Finite-range effects in pionic atoms
89KH01	On the reactive content of the pion-nucleus optical potential at low-energies
89LI1H	Proton-induced production of η on nuclei
89MO17	(π, K^+) hypernucl. product. & struc.; DWIA calc. based on Kapur-Peierls framework
89NA01	Some relations for radiative-pion-capture & muon-capture rates
89PI11	Study of hypernuclei from $^{9}_{\Lambda}$Be to $^{89}_{\Lambda}$Y using the (π^+, K^+) reaction
89SI09	Mechanism of (K^+, K^+p) on light nuclei at kaon energies 130 & 283 MeV
89TA04	Absorptive effects in $K^+\Lambda$ photoproduction on nucleons & nuclei
89TA16	Formation of $^{4}_{\Lambda}$H hypernuclei from K^- absorption at rest on light nuclei
89TA17	Compound-hypernuc. interpretation on $^{4}_{\Lambda}$H formation prob. in stopped-K^- absorp.
89TA19	$^{4}_{\Lambda}$H formation from K^- absorption at rest on ^{4}He, ^{7}Li, ^{9}Be, ^{12}C, ^{16}O, & ^{40}Ca
89TO11	Structure & formation of deeply-bound pionic atoms
89VI1D	Inclusive pion-nucleus double charge exchange
89WI20	Pion double charge exchange in the D33 resonance region
90MO36	Meson exchange current corrections to magnetic moments in quantum hadro-dynamics
91CI08	Momentum-space method for pionic atoms
91LE13	Cross sections for production of eta nuclei by photons
91PI07	Study of hypernuclei by associated production through the (π^+, K^+) reaction
	Hypernuclei
Reviews:	
86CH1I	Summary — hypernuclear sessions of "Interactions Between Particle & Nuclear Physics"
86CO1B	(e, e′K^+) & low-lying hypernuclear states using relativistic field theory (A)
86GA1H	Hypernuclear interactions
88CH48	Studies of hypernuclei by associated production
88GA1A	Recent developments in hypernuclear spectroscopy
88GA1I	Issues in hypernuclear physics
88HA41	Nuclear physics with strange probes
88PO1H	Flavour and the structure of hadrons and nuclei
88WA1B	Production of hypernuclei in the (K, p) reaction
89CH32	Recent experiments in novel nuclear excitations at the BNL AGS
89DO1I	On the production & spectroscopy of hypernuclei
89RE1C	Relativistic mean-field description of nuclei and nuclear dynamics
89ZO1A	Hypernuclear physics
Other articles:	
86BA1H	Pionic decay of hypernuclei
86GA14	Calc. of (K^-, π) hypernuclear yields for stopped kaons in ^{12}C & 1p$_{\Lambda}$ states in $^{16}_{\Lambda}$O

Table 16.12 (continued)
^{16}O – General

Reference	Description
	Hypernuclei — continued
Other articles:	
86HA26	Shell model analysis of Σ-hypernuclear spectra for $A = 12$ & 16
86HA39	Strangeness exchange reactions with the recoil corrected continuum shell model
86MA1C	Decay properties of hypernuclear resonances
86MO1A	The ΛN interaction & structures of the $^{16-18}$O hypernuclei
87CO09	(e, e$'$K$^+$) & low hypnuc. excits. using relativ. transit. operator & nuc. struc. model
87MI1A	Semiphenomenological studies of the ground state binding energies of hypernuclei
87PI1C	Hypernuclei studied with the (π^+, K$^+$) reaction (A)
87RU1A	Single-particle spectra of Λ hypnucl. & enhanced interact. radii of multi-strange objects
87WU05	Resonant and quasi-free mechanisms of Σ-production on nuclei
87YA1C	Density-dependent effective ΛN & ΛNN interaction applied to light hypernuclei
88HA1I	Phenomenological analysis of Σ-hypernuclear spectra from (K$^-$, π^+) reactions
88MA09	Study of hypernucleus production by K$^-$ capture at rest
88MA1G	Non-mesonic hypernuclear weak decays — systematic testing in the shell model
88MI1N	Λ-nucleus single-particle potential from analysis of Λ-hypernuclei spectra data
88MO1B	(π^+, K$^+$) reaction used to probe Λ and Σ states in hypernuclei
88MO23	Hypernuclear production by the (π^+, K$^+$) reaction
88PE1H	Associated production of hypernuclei with (π^+, K$^+$) reaction
89BA06	Polarization of hypernuclei in the (π^+, K$^+$) reaction
89BA1E	Production of hypernuclei in relativistic ion beams
89BA2N	Strangeness production by heavy ions
89FE07	Skyrme-Hartree-Fock calculation of Λ-hypernuclear states from (π^+, K$^+$) reactions
89HA29	Shell model calculation of Λ-hypernuclear spectra from (π^+, K$^+$) reactions
89HA32	Σ-hypernuclear production in flight
89KO37	Relativistic motion of the Λ in hypernuclei using Woods-Saxon & Gaussian potentials
89LA1I	Indirect methods of study of decays of excited hypernuclei — hypernuclear spectroscopy
89MA30	On Λ-hyperon(s) in the nuclear medium; relativistic mean field theory analysis
89MO17	(π, K$^+$) hypernuc. product. & struc.; DWIA calc. based on Kapur-Peierls framework
89PI11	Study of hypernuclei from $^{9}_{\Lambda}$Be to $^{89}_{\Lambda}$Y using the (π^+, K$^+$) reaction
89TA16	Formation of $^{4}_{\Lambda}$H hypernuclei from K$^-$ absorption at rest on light nuclei
89TA17	Compound-hypernuc. interpretation on $^{4}_{\Lambda}$H formation probab. in stopped-K$^-$ absorption
89TA19	$^{4}_{\Lambda}$H formation from K$^-$ absorption at rest on ^{4}He, ^{7}Li, ^{9}Be, ^{12}C, ^{16}O, & ^{40}Ca
89TA1T	Schmidt diagrams & configuration mixing effects on hypernuclear magnetic moments
91BE01	Electromagnetic production of polarization in hypernuclei
91FE06	Effective ΛN-interaction & spectroscopy of low-lying states of 1p-shell hypernuclei
91PI07	Study of hypernuclei by associated production through the (π^+, K$^+$) reaction
	Antinucleon Interactions
Reviews:	
87GR1I	Low energy antiproton physics in the early LEAR era
87YA1E	Why study ($\bar{\text{p}}$, $\bar{\text{n}}$) on nuclei?

Reference	Description
	Antinucleon Interactions
Other Articles:	
86DU10	Microscopic calculation of antiproton atomic-like bound states in light nuclei
86FR10	Fourier-Bessel potential description of antiproton-nucleus elastic scattering data
86KO1E	Search for $\bar{p}$-atomic X-rays; observed spin-dependence of $\bar{p}$-nucleus interaction
86MA46	Relativistic impulse approx. analysis of elastic $\bar{p}$ scattering at intermediate energies
86RO23	Measurement of the $4f$ strong interaction level width in light antiprotonic atoms
86ZA06	Sensitivity of σ_R & forward scattering amp. to form of nucl. optical pot. for N & $\bar{N}$
87AD04	Microscopic analysis of antiproton-nucleus elastic scattering
87BA18	Optical model analysis of antiprotonic Oxygen atom data
87BA21	Neutron-antineutron oscillations in ^{16}O
87BE26	$\bar{p}$-neutron scattering amplitude from $\bar{p}$-nucleus elastic scattering data; Glauber model
87CU1B	Nucleus excitation and deexcitation following $\bar{p}$-annihilation at rest
87DA1D	Glauber-Sitenko description of low-energy antiproton-nucleus interactions
87GR20	Widths of $4f$ antiprotonic levels in the Oxygen region
87MA04	Spin effects in elastic $\bar{p}$-nucleus scattering; Glauber analysis
87SP05	Spin and isospin effects in a relativistic treatment of $\bar{p}$-atom shifts and widths
87ZA08	Strong absorption and noneikonal effects in antiproton-nucleus scattering
88JA09	Residual mass distribution following $\bar{p}$-nucleus annihilation
88LI1O	Optical potential analysis of antiproton-nucleus elastic scattering (A)
89CH13	Phenomenological model analysis of elastic & inelastic scat. of 180 MeV $\bar{p}$ from nuclei
89HE21	Microscopic calculation of antiproton elastic scattering on even-even nuclei
89TA24	Spin & $\bar{N}$ annihilation effects in elastic antiproton-nucleus scattering (Glauber theory)
90TA31	Elastic scattering & spin effects of antiprotons from nuclei
91AL02	N-$\bar{N}$ oscillation times estimated from Paris N$\bar{N}$ potential
91BA44	Finite-range effects in kaonic and antiprotonic atoms
91LA02	Geometries of the antiproton-nucleus optical potentials at 180 MeV
	Other Topics
Review:	
88HE1G	A summary of theoretical discussion regarding hadronic parity violation
Other Articles:	
86BE23	Realistic many-body wave functions & nucleon momentum distributions in finite nuclei
86DE11	Nuclear spin-isospin polarizability & the spatial non-locality of the mean field
86IN1A	The dynamical origin of nuclear mass number dependence in EMC-effect
86IS04	Anomalous absorption of proton partial waves by the optical potential
86PA23	Methods of in-beam internal-pair spectroscopy applied to nucl. structure investigations
86RO26	Self-organization in nuclei
87AB21	Evid. of subshell closures from binding-ener. systematics & ener. lvls. of dbl. even nucl.
87CH11	Lifetimes of monopole resonances in time-dependent Hartree-Fock theory
87FUZZ	Relativistic RPA calculations of finite nuclei including negative-energy states (A)
87KR1F	Local scale transform. meth. with >1 scalar func. for descr. of monopole excits. in nucl.
88KO23	Information on three-body interactions from inversion of the energy equations

Table 16.12 (continued)
^{16}O – General

Reference	Description
	Other Topics — continued
88TO09	Damping of quadrupole motion in time-dependent density-matrix theory
88TO1C	Quenching of Gamow-Teller strength
88ZH1G	Self-consistent calculation of relativistic microscopic optical potential (in Chinese) (A)
89CEZZ	Composite particle production in intermediate energy nuclear reactions (A)
89PO05	Isobaric multiplets reconstructed from equidistance rule for separation & decay energies
89SH13	Continuum RPA with exchange term & appls. to spin-isosp. & longitudinal resp. funcs.
90BL16	Microscopic approach to the calculation of the vertex constants of neutron cleavage
90HO24	Relativistic RPA for finite nuclei with Skyrme type interaction
90ZHZV	Effects of central, spin-orbit & tensor interactions in nuclei (A)
91UM01	Nuclear Hartree-Fock calculations with splines
	Ground State Properties
Review:	
88MA1X	Relativistic theory of nuclear matter and finite nuclei
Other Articles:	
85SH1A	Unified microscopic description of elastic & inel. cross sections of heavy-ion reactions.
86AN08	Nucleon momentum & density distributions in the generator co-ordinate method
86ANZM	A multi harmonic oscillator calculation of binding energies & charge radii
86AY01	Effect of higher states on the ground & low-lying excited 0^+ states of ^{4}He & ^{16}O
86DE33	Correlations in the Sp(1, R) model for the monopole oscillations
86FU1B	Relativistic shell model calculations
86GL1A	Effects of particle-hole excitations in light nuclei
86HE26	Nuclear single-particle energies as functions of the binding energies for $4 \leq A \leq 90$
86MAZE	Form & relative importance of first-order contributions to density distribution of ^{16}O
86PE22	Effects of the Dirac sea on finite nuclei
86QU1A	Relativistic self-consistent field calculations for closed-shell nuclei
86SU13	Unitary-model-operators & the ground-state & one-body energies of ^{16}O
86SU16	((86SU13) cont.) Three-body-cluster effects on properties of ^{16}O
86TO16	Hartree-Fock calculations of nuclear matter saturation density
86YE1A	Hartree-Fock calculations with extended Skyrme forces for ^{16}O and ^{40}Ca
87AB03	Measurement & folding-potential analysis of the elastic α-scattering on light nuclei
87BL18	Calc. ground & excited states of light $N = Z$ nuclei; also spin-isospin order for excited
87BL20	Relativistic Hartree-Fock calculations for ^{16}O and ^{40}Ca
87BO11	Relativistic description of nuclear systems in the Hartree-Fock approximation
87BO42	Monte Carlo test of the convergence of cluster expansions in Jastrow correlated nuclei
87CA27	Mean field approach to the momentum distribution
87ES06	Consistent description of effect of long-range residual interaction on the RMS radius
87HA37	Excitation of $\Delta(3, 3)$ resonance in compressed finite nuclei (early version of (87HA42))
87HA42	Exc. of $\Delta(3, 3)$ resonance in compressed finite nucl. from constrained mean-field method
87KR1B	Microscopic calc. of model for ^{16}O: 16 nucleons interacting via Malfliet-Tjon potential
87MA30	Contrib. of particle-particle, hole-hole & particle-hole ring diagrams to binding energies
87PR03	Self-consistent Hartree descrip. of deformed nuclei in a relativistic quantum field theory

Table 16.12 (continued)
^{16}O – General

Reference	Description
	Ground State Properties — continued
87SU08	Effects of self-consistent single-particle potential on nuclear effective interaction
87SU12	Nuclear ground-state properties & nuclear forces in unitary-model-operator approach
87TZ1A	Particle-particle ring diagrams in ^{16}O & Skyrme effective interactions (A)
87ZE1A	Microscopic estimation of clustering in ^{4}He, ^{12}C and ^{16}O
88AL1N	Scaling in electron scattering from a relativistic Fermi gas
88AN18	Generator coordinate calcs. of nucleon momentum & density dists. in ^{4}He, ^{16}O & ^{40}Ca
88BO04	Correlated basis functions theory of light nuclei: general description & ground states
88DE09	^{15}N ground state studied with elastic electron scattering; also calc. ^{16}O charge density
88GU03	Charge-density distribution of 1s-1p & 1d-2s shell nuclei & filling numbers of the states
88HO10	Shell-model with Hartree-Fock condition calc. of giant resnces. & spectroscopic factors
88KU18	Nuclear structure of ^{16}O in a mean-field boson approach
88LU1A	Relativistic Hartree calculations of ^{16}O & ^{40}Ca using effective interactions
88ME09	Three-dimensional, spherically symmetric, saturating model of an N-boson condensate
88MU04	Dirac-Brueckner-Hartree-Fock approach to finite nuclei
88RA1G	Clustering phenomena and shell effects in nuclear structure & reactions
88RU04	Optimal parametrization for the relativistic mean-field model of the nucleus
88SA03	Thermodynamic coefficients of hot nuclei
88SO03	Model ground state calculations with two-variable integro-differential equations for ^{16}O
88VA03	Static moments from a phenomenological interaction
88WO04	An expansion of the shell-model space for light nuclei
88YE1A	Calc. charge density distribs. & radii from Hartree-Fock method with Skyrme forces
89AN10	1- & 2-nucleon momentum distributions in nuclei in coherent density fluctuation model
89CA04	Quantized meson-exchange picture of nuclear interactions; application to ^{16}O & ^{40}Ca
89DO04	Kuchta mean-field boson approach used to describe structure of ^{16}O
89DO05	Relativistic Coulomb sum rules — expansions in moments of nucl. momentum density
89FI04	Systematic study of potential energy surfaces of light nuclei in relativistic Hartree calcs.
89LE24	Nuclei with diffuse surfaces for future Boltzmann-Uehling-Uhlenbeck calculations
89LI01	Self-consistent semiclassical calculation of rms radii of spherical nuclei
89MA41	Descr. of nucleon high-momentum components due to short-range correlations in nuclei
89MC05	Finite nucleus Dirac mean field theory & RPA using finite B splines for ^{16}O & ^{40}Ca
89PI1F	Ground state of closed-shell nuclei (A)
90MU15	Dirac-Brueckner-Hartree-Fock calculation of the ground state properties of ^{16}O
91BO02	Meson exchange effects on magnetic dipole moments of p-shell nuclei
91CR1A	Finite velocity meson exchange in nuclei
91GM02	Relativistic mean-field fit to microscopic results in nuclear matter
91KO23	Scalar coupling in relativistic mean field theory & properties of nuclei & nuclear matter
91MA33	Super-RPA ground-state correlations
91MU04	Effects of correlations on calc. of binding energy & radii of nuclei
91RA14	Thermal properties of finite nuclei based on a realistic interaction
91SC26	Meson exchange potentials & the problem of saturation in finite nuclei
91TO03	Properties of nuclei far from stability & spherical nuclei in relativistic Hartree theory

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

Table 16.13
Energy Levels of ^{16}O [a])

E_x (MeV ± keV)	J^π; T	K^π	$\Gamma_{c.m.}$ or τ_m (keV)	Decay	Reactions
0	0^+; 0		stable		5, 7, 11–19, 22–24, 30, 32–34, 37–68, 70–82
6.0494 ± 1.0	0^+; 0	0^+	$\tau_m = 96 \pm 7$ ps	π	5, 7, 11–13, 15, 17, 19, 21, 23, 30, 32–34, 38, 39, 43, 44, 47, 54, 55, 57, 66, 67, 70, 71, 73, 79, 81
6.129893 ± 0.04	3^-; 0		$\tau_m = 26.6 \pm 0.7$ ps; $g = +0.556 \pm 0.004$	γ	1, 5, 7, 11–13, 15, 17–19, 21, 30–34, 37–39, 43–46, 49–51, 53, 54, 66–68, 70, 71, 73, 79, 81
6.9171 ± 0.6	2^+; 0	0^+	$\tau_m = 6.78 \pm 0.19$ fs	γ	1, 5, 7, 11–13, 15, 17, 19, 30–34, 37, 38, 42–47, 49, 50, 53–55, 67, 68, 70, 71, 73, 78, 80
7.11685 ± 0.14	1^-; 0		$\tau_m = 12.0 \pm 0.7$ fs	γ	1, 5, 7, 11–13, 17, 30–34, 37–39, 42–44, 46, 47, 50, 66–68, 70, 71, 73, 81
8.8719 ± 0.5	2^-; 0		$\tau_m = 180 \pm 16$ fs	γ, α	5, 7, 11, 12, 16, 19, 30, 31, 33, 37–39, 43, 45–47, 49, 50, 67, 68, 73, 81
9.585 ± 11	1^-; 0	0^-	$\Gamma = 420 \pm 20$	γ, α	7, 9, 11, 12, 30, 38, 39, 45–47, 49, 50, 54, 55
9.8445 ± 0.5	2^+; 0	2^+ [b])	0.625 ± 0.100	γ, α	5, 7, 9, 11, 12, 19, 30, 31, 33, 37–39, 43, 46, 47, 49, 50, 54, 55, 66, 68, 70, 73, 78, 81
10.356 ± 3	4^+; 0	0^+	26 ± 3	γ, α	5, 7, 9, 11–14, 16, 19, 21, 30, 31, 33, 38, 43, 46, 47, 49, 50, 54, 55, 61, 66, 68, 71, 73, 81
10.957 ± 1	0^-; 0		$\tau_m = 8 \pm 5$ fs		5, 30, 37, 38, 46, 47, 68, 73
11.080 ± 3	3^+; 0	2^+ [b])	$\Gamma < 12$	γ	5, 30, 37, 38, 68, 73
11.0967 ± 1.6	4^+; 0		0.28 ± 0.05	γ, α	5, 7, 9, 11, 13, 14, 16, 19, 30, 31, 43, 46, 47, 49, 50, 54, 55, 73
(11.26) [c])	(0^+; 0)		(2500)	(α)	9, 38
11.520 ± 4	2^+; 0		71 ± 3	γ, α	5, 7, 9, 19, 30, 43, 44, 46, 47, 49, 50, 54, 55, 61
11.60 ± 20	3^-; 0	0^-	800 ± 100	α	9, 14, 54, 55
12.049 ± 2	0^+; 0		1.5 ± 0.5	γ, α	9, 19, 23, 30, 43, 46, 47, 49, 50, 54, 55
12.440 ± 2	1^-; 0		91 ± 6	γ, p, α	7–9, 30, 34, 36–38, 43, 47, 50, 54, 55
12.530 ± 1	2^-; 0		$(97 \pm 10) \times 10^{-3}$	γ, p, α	5, 19, 30, 34, 36–38, 43, 46, 47, 50, 67
12.796 ± 4	0^-; 1		40 ± 4	γ, p	30, 36–38, 46
12.9686 ± 0.4	2^-; 1		1.34 ± 0.04	γ, p, α	19, 30, 34, 36–38, 43, 66–68
13.020 ± 10	2^+; 0		150 ± 10	γ, p, α	7, 9, 43, 46, 47, 49, 50, 54, 55, 61
13.090 ± 8	1^-; 1		130 ± 5	γ, p, α	7–9, 11, 30, 37, 38, 43, 68
13.129 ± 10	3^-; 0		110 ± 30	γ, p, α	6–9, 30, 38

Table 16.13 (continued)
Energy Levels of ^{16}O [a])

E_x (MeV ± keV)	J^π; T	K^π	$\Gamma_{c.m.}$ or τ_m (keV)	Decay	Reactions
13.259 ± 2	3^-; 1		21 ± 1	γ, p, α	7–9, 30, 36–38, 43, 46, 66–68, 70, 72
13.664 ± 3	1^+; 0		64 ± 3	γ, p, α	30, 34, 36, 47
13.869 ± 2	4^+; 0		89 ± 2	p, α	5, 9, 30, 36, 43, 45, 49, 50, 54, 55
13.980 ± 2	2^-		20 ± 2	p, α	5, 30, 31, 36
14.032 ± 15	0^+		185 ± 35	γ, α	9, 43
14.1 ± 100	3^-		750 ± 200	α	9
14.302 ± 3	$4^{(-)}$		34 ± 12		19, 30, 31
14.399 ± 2	5^+		27 ± 5		5, 12, 19, 30, 31
14.620 ± 20	$4^{(+)}$		490 ± 15	α	9, 11
14.660 ± 20	5^-	0^-	670 ± 15	α	9, 11–14, 54, 55
14.8153 ± 1.6	6^+; 0		70 ± 8	α	5, 9, 11, 19, 30, 31, 49, 50, 54, 55
14.926 ± 2	2^+		54 ± 5	p, α	5, 30, 36, 43
15.097 ± 5	0^+		166 ± 30	p, α	8, 9, 30, 36
15.196 ± 3	2^-; 0		63 ± 4	p, α	30, 31, 36, 43, 46, 49, 66–68
15.26 ± 50	2^+; (0)		300 ± 100	p, α	36, 43, 46, 49
15.408 ± 2	3^-; 0		132 ± 7	p, α	8, 9, 30, 31, 36, 43, 46, 50, 54, 55, 61, 66–68
15.785 ± 5	3^+		40 ± 10		19, 30, 31
15.828 ± 30	3^-		700 ± 120	α	9, 43
16.20 ± 90	1^-; 0		580 ± 60	γ, p, α	7, 30, 36
16.209 ± 2	1^+; 1		19 ± 3	γ, n, p	30, 31, 34–36, 41, 43
16.275 ± 7	6^+	0^+ [b])	420 ± 20	α	5, 9, 11–14, 21, 31, 54, 55, 61
16.352 ± 8	(2^+) [d])		61 ± 8	p, α	8, 9, 30, 36, 46, 49, 50, 70
16.4423 ± 1.6	2^+; 1		25 ± 2	γ, n, p, α	7–9, 30, 36, 43
16.817 ± 2	$(3^+; 1)$ [b,e])		28 ± 3	γ, p, α	19, 30, 34, 36
16.844 ± 21	4^+		570 ± 60	α	9
16.93 ± 50	2^+		~ 280	α, ^{8}Be	9, 10
17.09 ± 40	1^-; 1		380 ± 40	γ, p	34, 36
17.129 ± 5	2^+		107 ± 14	n, p, α	8, 9
17.140 ± 10	1^+; 1		34 ± 3	γ, n, p, α	9, 34–36, 43
17.197 ± 17	2^+		160 ± 60	α, ^{8}Be	5, 9, 10, 31, 38, 46, 49, 50
17.282 ± 11	1^-; 1		78 ± 5	γ, n, p, α	8, 34–36, 41, 43
17.510 ± 26	1^-		180 ± 60	α	9
17.555 ± 21	(6^+)		180 ± 70	n, α	8, 9
17.609 ± 7	2^+; (1)		114 ± 14	p, α	8, 9, 36
17.72	$(0^+, 2^+)$		~ 75	p, α, ^{8}Be	9, 10
17.775 ± 11	4^-; 0		45 ± 7	p	19, 43, 44, 46, 49, 50, 67, 68

Table 16.13 (continued)
Energy Levels of ^{16}O [a])

E_x (MeV ± keV)	J^π; T	K^π	$\Gamma_{c.m.}$ or τ_m (keV)	Decay	Reactions
17.784 ± 15	4^+		400 ± 40	n, α, ^{8}Be	8–10, 43, 54, 55
17.877 ± 6	$(2)^-; 1$ [b])		24 ± 3	γ, p, (α)	34, 36, 41
18.016 ± 1	4^+; (0)		14 ± 2	n, p, α, ^{8}Be	8–10, 19
18.029 ± 5	$3^{(-)}$; 1		26 ± 4	γ, n, p, α	19, 34–36, 43, 67
18.089 ± 25	(0^+)		288 ± 44	(γ), n, p, α	7–9, 35, 46, 50
18.202 ± 8	2^+		220 ± 50	γ, p	36, 43, 46, 50
18.29			~ 380	γ, p, α	7–9
18.404 ± 12	5^-		550 ± 40	α	9
18.430 ± 15	2^+; 0		90 ± 40	p	36, 46, 49, 50
18.484 ± 6	$(1^-, 2^-)$		35 ± 6	p	36
18.6	$(1^-, 5^-)$		~ 150	α	9
18.6	(4^+)		~ 300	α, ^{8}Be	9, 10
18.640 ± 15	(5^+)		22 ± 7	(n, p)	5, 19, 43
18.773 ± 22	1^-		215 ± 45	p, α	8, 9
18.785 ± 6	4^+		260 ± 20	n, p, α, ^{8}Be	8–10
18.79 ± 10	1^+; 1		120 ± 20	γ, p	34, 36, 43
18.977 ± 6	4^-; 1		8.2 ± 3.8	γ, p, α	19, 34, 36, 43, 44, 46, 49, 67, 68
19.001 ± 24	2^-; 1		420 ± 50	γ, p	34, 36, 43
19.08 ± 30	2^+; (1)		~ 120	γ, (n), p, α	8, 9, 14, 34, 36
19.206 ± 12	3^-; 1		68 ± 10		43, 67, 68
19.253 ± 30	(5^-)		50 ± 45	n, α	8, 9
19.257 ± 9	2^+; (1)		155 ± 25	γ, p, α	8, 9, 34, 36
19.319 ± 14	(6^+)		65 ± 35	p, α, ^{8}Be	8–10
19.375 ± 2	4^+		23 ± 4	p, α	8, 9
19.47 ± 30	1^-; 1		200 ± 70	γ, p	34, 36, 43
19.539 ± 19	2^+; 0		255 ± 75	n, α	5, 8, 9, 46, 50
19.754 ± 16	2^+		290 ± 50	p, α	8, 9
19.808 ± 11	4^-; 0		32 ± 4		19, 44, 46, 67, 68
19.895 ± 7	3; 1		42 ± 9	γ, p, α	5, 34, 36
20.055 ± 13	2^+; 0		400 ± 32	γ, n, p, α	7–9, 49, 50
20.412 ± 17	$(2^-, 4^+)$; 1		190 ± 20	γ, n, p	34–36, 43, 67, 68
20.510 ± 0.025	$(4^-; 1)$		50 ± 30	γ	43
20.541 ± 2	$5^-; 1$		11 ± 2	p, α	5, 8, 9
20.560 ± 2	even π		< 5	p, α	8, 9
20.615 ± 3	even π		< 10	α	9
(20.8)			(~ 60)	n, p, α	8
20.857 ± 14	7^-	0^-	900 ± 60	α	9, 11–14
20.945 ± 20	1^-; 1		300 ± 10	γ, n, p	34–36, 43
21.05 ± 50	$(2^+; 0)$		298 ± 43		46, 50

Table 16.13 (continued)
Energy Levels of ^{16}O [a])

E_x (MeV ± keV)	J^π; T	K^π	$\Gamma_{c.m.}$ or τ_m (keV)	Decay	Reactions
21.052 ± 6	6^+		205 ± 15	α	9
21.175 ± 15					5
21.50	$(1 \to 4)$		120	p	36
21.623 ± 11	7^-		60 ± 30	n, p, α	8, 9
21.648 ± 3	6^+		115 ± 8	n, α	8, 9, 11
21.776 ± 9	3^-		43 ± 20	n, p, α	5, 8, 9
22.04	0^+		60	n, d, α	8, 25
22.150 ± 10	1^-; 1		680 ± 10	γ, n, p, d, α	14, 24, 26, 29, 34–36, 40–42
22.35	2^+		175	n, d, α	25, 29
22.5 ± 100	3^-		400 ± 50	p, d, α	26, 29, 50
22.65 ± 30			60	n, α, ^{8}Be	5, 8, 10
22.721 ± 3	0^+; 2		12.5 ± 2.5	n, p, d, α	8, 9, 23, 26, 29, 70
22.89 ± 10	1^-; 1		300 ± 10	γ, p, d	24, 26, 34, 36
23.0 ± 100	6^+		$\lesssim 500$	(d), α, ^{8}Be	10, 11, 29
23.1			~ 20	(n), d, α, ^{8}Be	9, 10, 25, 29
23.235 ± 62	$(1^-; 1)$		560 ± 150	n, p, d	25–27, 35, 46
23.51 ± 30	(5^-)		300	p, d, α	5, 9, 14, 26, 27, 29, 49, 50
23.879 ± 6	6^+		26 ± 4	p, α, ^{8}Be	8–11
24.07 ± 30	1^-; 1		550 ± 40	γ, p, ^{3}He	17, 34, 36, 46
24.36 ± 70	$(2^+, 3^-)$; 0		424 ± 45	n, p	35, 50
24.522 ± 11	2^+; 2		< 50		23, 70
24.76 ± 50	$(2,4)^+$; 1		340 ± 60	γ, n, p	34–36
25.12 ± 50	1^-; 1		3000 ± 300	γ, p, ^{3}He, α	17, 34, 36, 42, 49
25.50 ± 150	1^-; 1		1300 ± 300	γ	43, 46
25.6	(3^-); 1		450	^{3}He, α	9, 17
26.0 ± 100	1^-; (1)		500–1000	γ, ^{3}He, α	17
26.363 ± 62	$(2,4)^+$; 1		550 ± 70	γ, n, p, α	9, 34–36
27.35 ± 100	$(2,4)^+$; 1		830 ± 110	γ, p, ^{3}He, α, ^{8}Be	17, 34, 36
27.5	$(3^-; 0)$		~ 2500	γ, ^{3}He	17
28.2	7^-		1000	α	9, 11
28.6 ± 200				γ, ^{3}He	17
29.0	7^-		1000	p, α	9, 11
29.8 ± 100	$9^- + 8^+$		500–1000	^{3}He, α	14, 17
31.8 ± 600				γ, α	11, 42
34	$10^+(9^-)$		2300	α	9, 11
35				α	11

[a]) See also Tables 16.14 and 16.26.
[b]) D.J. Millener, private communication.
[c]) See (86AJ04).
[d]) See reaction 70 and (86VO10).
[e]) (83SN03). See also Table 16.22.

Table 16.14
Radiative decays in ^{16}O [a])

E_i (MeV)	$J^\pi_i; T$	E_f (MeV)	$J^\pi_f; T$	Branch (%)	Γ_{rad} (eV)
6.05	$0^+; 0$	0	$0^+; 0$	100	3.55 ± 0.21 [b])
6.13	$3^-; 0$	0	$0^+; 0$	100	$(2.60 \pm 0.13) \times 10^{-5}$
6.92	$2^+; 0$	0	$0^+; 0$	> 99	0.097 ± 0.003 [c])
		6.05	$0^+; 0$	$(2.7 \pm 0.3) \times 10^{-2}$	$(2.7 \pm 0.3) \times 10^{-5}$
		6.13	$3^-; 0$	$\leq 8 \times 10^{-3}$	
7.12	$1^-; 0$	0	$0^+; 0$	> 99	0.055 ± 0.003 [c])
		6.05	$0^+; 0$	$< 6 \times 10^{-4}$	
		6.13	$3^-; 0$	$(7.0 \pm 1.4) \times 10^{-2}$	
8.87	$2^-; 0$	0	$0^+; 0$	7.2 ± 0.8	$(2.6 \pm 0.4) \times 10^{-4}$
		6.05	$0^+; 0$	0.122 ± 0.033	$(3.1 \pm 1.0) \times 10^{-6}$
		6.13 [f])	$3^-; 0$	77.7 ± 1.6 [i])	$(2.8 \pm 0.3) \times 10^{-3}$ [d])
		6.92	$2^+; 0$	3.6 ± 0.5 [i])	$(1.5 \pm 0.3) \times 10^{-4}$
		7.12	$1^-; 0$	11.4 ± 0.5 [i])	$(4.2 \pm 0.8) \times 10^{-4}$ [e])
9.59	$1^-; 0$	0	$0^+; 0$	~ 100	$(2.5 \pm 0.4) \times 10^{-2}$
		6.92	$2^+; 0$		$(2.9 \pm 1.0) \times 10^{-3}$
9.84	$2^+; 0$	0	$0^+; 0$	61 ± 4	$(5.7 \pm 0.6) \times 10^{-3}$
		6.05	$0^+; 0$	18 ± 4	$(1.9 \pm 0.4) \times 10^{-5}$
		6.92	$2^+; 0$	21 ± 4	$(2.2 \pm 0.4) \times 10^{-5}$
10.36	$4^+; 0$	0	$0^+; 0$		$(5.6 \pm 2.0) \times 10^{-8}$
		6.13	$3^-; 0$		$< 1.0 \times 10^{-3}$
		6.92	$2^+; 0$	~ 100	$(6.2 \pm 0.6) \times 10^{-2}$
10.96	$0^-; 0$ [g])	7.12	$1^-; 0$	> 99	0.08 ± 0.05
11.10	$4^+; 0$	6.13	$3^-; 0$		$(3.1 \pm 1.3) \times 10^{-3}$
		6.92	$2^+; 0$		$(2.5 \pm 0.6) \times 10^{-3}$
11.52	$2^+; 0$	0	$0^+; 0$	91.7	0.61 ± 0.02
		6.05	$0^+; 0$	4.2 ± 0.7	$(3.0 \pm 0.5) \times 10^{-2}$
		6.92	$2^+; 0$	4.0 ± 1.0	$(2.9 \pm 0.7) \times 10^{-2}$
		7.12	$1^-; 0$	≤ 0.8	
12.05	$0^+; 0$	0	$0^+; 0$		4.03 ± 0.09 [b])
12.44	$1^-; 0$	0	$0^+; 0$	~ 100	12 ± 2
		6.05	$0^+; 0$	1.2 ± 0.4	0.12 ± 0.04
12.53	$2^-; 0$	0	$0^+; 0$		$(3.3 \pm 0.5) \times 10^{-2}$ [j])
		6.13	$3^-; 0$	60 ± 6	2.1 ± 0.2
		6.92	$2^+; 0$	< 10	< 0.34
		7.12	$1^-; 0$	15 ± 3	0.5 ± 0.1
		8.87	$2^-; 0$	25 ± 3	0.9 ± 0.1
12.80	$0^-; 1$	7.12	$1^-; 0$	~ 100	2.5 ± 0.2

Table 16.14 (continued)
Radiative decays in ^{16}O [a])

E_i (MeV)	$J^\pi_i; T$	E_f (MeV)	$J^\pi_f; T$	Branch (%)	Γ_{rad} (eV)
12.97	$2^-; 1$	0	$0^+; 0$		$(3.4 \pm 0.9) \times 10^{-2}$ [j])
		6.13	$3^-; 0$	63 ± 6	2.3 ± 0.2
		7.12	$1^-; 0$	12 ± 3	0.44 ± 0.10
		8.87	$2^-; 0$	25 ± 3	0.90 ± 0.10
13.09 [h])	$1^-; 1$	0	$0^+; 0$	~ 100	32 ± 5
		6.05	$0^+; 0$	0.58 ± 0.12	
		7.12	$1^-; 0$	3.1 ± 0.8	1.4 ± 0.4

[a]) See tables 16.12 in (71AJ02), 16.15 in (77AJ02) and 16.12 in (82AJ01) for the earlier work and for references. See also table 16.15 here.
[b]) Monopole matrix element in fm^2.
[c]) Weighted mean of earlier measurements and of a newer one reported in reaction 42 (85MO10).
[d]) $(3.0 \pm 0.4) \times 10^{-4}$ [M1], $(2.5 \pm 0.2) \times 10^{-3}$ [E2] (82VE04).
[e]) $(8 \pm 3) \times 10^{-5}$ [M1], $(3.4 \pm 0.5) \times 10^{-4}$ [E2] (82VE04).
[f]) $E_\gamma = 2471.5 \pm 0.5$ keV for $(8.87 \rightarrow 6.13)$ transition.
[g]) Pairs due to this transition are not observed.
[h]) For the radiative decay of higher states see tables 16.15, 16.22, and 16.26.
[i]) (82VE04). See also for δ.
[j]) (86ZI08).

Table 16.15
Resonances in $^{12}C + \alpha$ [a])

No.	E_α (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	Outgoing particles [b])	Γ_x	Γ_{α_0}/Γ	$^{16}O^*$ (MeV ± keV)	J^π; T
						8.87	
1	3.324	480 ± 20	γ_0	15.6 ± 1.2 meV [c])		9.580 ± 12	1^-
			γ_3	1.4 ± 1.4 meV [c])			
			γ_4	7.8 ± 1.6 meV [c])			
			α_0		~ 1		
2	3.5770 ± 0.5	0.625 ± 0.100	γ_0	5.7 ± 0.6 meV		9.8440 ± 0.5	2^+
			γ_3	2.2 ± 0.4 meV			
			α_3				
3	4.259	27 ± 3	γ_0	≤ 0.4 meV		10.356 ± 6	4^+
			γ_3	62 ± 6 meV			
			α_0		1		
4	5.245 ± 8	0.28 ± 0.05	γ_2	3.1 ± 1.3 meV		11.094	4^+
			γ_3	2.5 ± 0.6 meV			
			α_0				
5	5.47	2500	α_0			(11.26)	(0^+)
6	5.809 ± 18	73 ± 5	γ_0	0.65 ± 0.08 eV		11.52	2^+
			γ_3	29 ± 7 meV			
			α_0		1		
7	5.92 ± 20	800 ± 100	α_0		1	11.60	3^-
8	6.518 ± 10	1.5 ± 0.5	α_0			12.049	0^+
9	7.043 ± 4	99 ± 7	γ_0	9.5 ± 1.7 eV [d])		12.442 ± 4	1^-; 0
			γ_1	0.12 ± 0.06 eV [d])			
			p	1.1 keV			
			α_0	92 ± 8 keV	1.0		
			α_1	0.025 keV			
10	7.82 ± 10	150 ± 11	γ_0	[e])		13.02	2^+
			α_0	150 ± 11 keV	~ 1.0		
11	7.904 ± 11	130 ± 5	γ_0	44 ± 8 eV [f])		13.088 ± 11	1^-; 1
			γ_4	1.35 ± 0.4 eV			
			p	100 keV			
			α_0	45 ± 18 keV	0.3		
			α_1	1 keV			
12	7.960 ± 10	110 ± 30	γ_0	> 0.01 eV		13.129	3^-; 0
			p	1 keV			
			α_0	90 ± 14 keV	0.7		
			α_1	~ 20 keV			
13	8.130 ± 15	26 ± 7	γ			13.257	3^-; 1
			p	4.5 keV			
			α_0	9 ± 4 keV			
			α_1	7.5 keV			
			$\gamma_{4.4}$				

Table 16.15 (continued)
Resonances in $^{12}C + \alpha$ [a])

No.	E_α (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	Outgoing particles [b])	Γ_x	Γ_{α_0}/Γ	$^{16}O^*$ (MeV ± keV)	$J^\pi; T$
14	8.960 ± 10	75 ± 7	α_0	49 keV	0.65 ± 0.05	13.879 ± 8	4^+
			α_1	23 keV			
15	9.1	4800	α_0			(14.0)	(0^+)
16	9.164 ± 15	200 ± 15	α_0	~ 200 keV	> 0.9	14.032	0^+
17	9.3 ± 100	750 ± 200	α_0		0.2 ± 0.1	14.1	3^-
			α_1				
18	9.948	487 ± 12	α_0		0.8 [h])	14.620 ± 11 [g])	(4^+)
			α_1				
19	10.002	672 ± 11	α_0		0.94	14.660 ± 11 [g])	5^-
			α_1				
20	10.195 ± 7	70 ± 8	α_0	22 keV	0.45 ± 0.05	14.805	6^+
			α_1	48 keV			
21	10.544	166 ± 30	α_0, α_1, p_0		0.35	15.066 ± 11	0^+
22	10.999	133 ± 7	α_0, α_1, p_0		0.58	15.408 ± 2	3^-
23	11.560	703 ± 113	α_0, (α_1), $\gamma_{4.4}$		0.21	15.828 ± 30	3^-
24	11.6	~ 600	γ_0	$\Gamma_\alpha\Gamma_\gamma/\Gamma \sim 0.4$ eV		15.9	2^+
25	12.156	422 ± 14	α_0		0.93	16.275 ± 7	6^+
26	12.272	65 ± 45	α_0, (α_1, α_2), p_0		0.07	16.362 ± 20	$(0^+, 1^-)$
27	12.380	22 ± 3	γ_0, n, p_0, α_0, α_1, α_2,$\gamma_{4.4}$	$\Gamma_\alpha\Gamma_\gamma/\Gamma = 0.45$ eV	0.28	16.443 ± 2	2^+; (1)
28	12.5	730	p_0, α_0			(16.5)	
29	12.915	567 ± 60	α_0		0.28	16.844 ± 21	4^+
30	13.0	700	α_0			(16.9)	5^-
31	13.05	~ 280	α_2, ^{8}Be			16.94	2^+
32	13.296	107 ± 14	n, p_0, α_0, α_1, $\gamma_{4.4}$		0.37	17.129 ± 5	2^+
33	13.32	36 ± 5	α_0, α_1			17.15	
34	13.35	160 ± 60	α_2, ^{8}Be			17.17	2^+
35	13.50	< 100	n			17.28	
36	13.805	182 ± 56	α_0, (α_1), α_2		0.16	17.510 ± 26	1^-
37	13.865	178 ± 66	n, (α_0, α_1)		0.07	17.555 ± 21	(6^+)
38	13.948	175 ± 55	p_0, α_0		0.32	17.618 ± 20	$(0^+, 1^-)$
39	14.08	(~ 75)	(p_0), ^{8}Be			17.72	$(0^+, 2^+)$
40	14.170	396 ± 41	n, α_0, α_1, $\gamma_{4.4}$, ^{8}Be		0.34	17.784 ± 15	4^+
41	14.480	14 ± 2	(n), p_0, α_0, α_1, $\gamma_{4.4}$, ^{8}Be		0.36	18.016 ± 1	4^+; (0)
42	14.577	248 ± 90	(γ_0), n_0, p_0, α_0		0.31	18.089 ± 25	(0^+)
43	(14.62)	(~ 45)	α_0			(18.12)	$(\neq 4^+)$
44	14.85	~ 380	γ_0, p_0, $(\alpha_1, \gamma_{4.4})$	$\Gamma_\alpha\Gamma_\gamma/\Gamma = 0.95$ eV		18.29	
45	14.997	544 ± 39	α_0		0.40	18.404 ± 12	5^-
46	15.2	~ 150	α_0, α_1, α_2, $\gamma_{4.4}$			18.6	$(1^-, 5^-)$
47	15.2	~ 300	α_2, ^{8}Be			18.6	(4^+)
48	15.490	215 ± 45	p_0, α_0		0.26	18.773 ± 22	1^-
49	15.506	260 ± 16	n, p_0, α_0, (α_1), ^{8}Be		0.48	18.785 ± 6	4^+

Table 16.15 (continued)
Resonances in $^{12}C + \alpha$ [a])

No.	E_α (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	Outgoing particles [b])	Γ_x	Γ_{α_0}/Γ	$^{16}O^*$ (MeV ± keV)	$J^\pi; T$
50	15.8	~ 550	(α_0), α_1, $\gamma_{4.4}$			19.0	(5^-)
51	15.96	41	(n), α_0			(19.12)	$(2^+, 4^+)$
52	16.130	50 ± 45	(n), (α_0)		0.04	19.253 ± 30	(5^-)
53	16.137	155 ± 23	p_0, α_0, (α_1)		0.34	19.257 ± 9	2^+
54	16.219	63 ± 33	p_0, (α_0), α_1, α_2, ^{8}Be		0.07	19.319 ± 14	(6^+)
55	16.293	23 ± 4	p_0, α_0, α_1, α_2		0.23	19.375 ± 2	4^+
56	16.496	255 ± 75	(n), α_0, (α_1, α_2)		0.20	19.527 ± 26	2^+
57	16.799	286 ± 44	p_0, α_0, α_1		0.29	19.754 ± 16	2^+
58	(16.92)	(~ 175)	α_2			(19.85)	
59	(17.05)	(~ 30)	(α_0)			(19.94)	$(\neq 3^-)$
60	17.201	432 ± 40	γ_0, n, (p_0), α_0, (α_1)		0.43	20.055 ± 13	2^+
61	(17.27)	(~ 45)	(α_0)			(20.11)	$(\neq 3^-)$
62	17.5	~ 1500	p_0			(20.3)	
63	(17.66)	(~ 150)	n, (p_0), α_0, α_2			(20.40)	(4^+)
64	(17.8)	(~ 300)	(α_0), α_1			(20.5)	
65	17.849	11 ± 2	p_0, α_0, α_1, α_2		0.14 ± 0.02	20.541 ± 2	5^-
66	17.875	< 5	α_0			20.560 ± 2	even
67	17.948	< 10	α_0			20.615 ± 3	even
68	(18.2)	(~ 60)	n, (p_0)			(20.8)	
69	18.271	904 ± 55	α_0		0.60	20.857 ± 14	7^-
70	(18.3)		α_0			(20.9)	2^+
71	(18.48)	(~ 50)	n, p_0, (α_0)			(21.01)	
72	18.50 ± 25	240 ± 80	γ_0, (α_0, α_1)		0.20	21.03	(1^-)
73	18.5	900	α_0		[i])	(21.0)	5^-
74	18.531	205 ± 14	α_0		0.50	21.052 ± 6	6^+
75	18.593	306 ± 46	(α_0)		0.20	(21.098)	4^+
76	19.294	61 ± 32	n, p_0, α_0, α_2		< 0.05	21.623 ± 11	7^-
77	19.327 [j])	115 ± 8	n, α_0, α_1, α_2		0.41	21.648 ± 3	6^+
78	19.498 [j])	43 ± 20	n, p_0, α_0, α_1, α_2		0.07	21.776 ± 9	3^-
79	19.85	60	n			22.04	
80	19.89	340	n			22.07	
81	19.95	< 150	n, ^{8}Be			22.11	
82	20.49	375	n			22.52	
83	20.71	60	n, ^{8}Be			22.68	
84	20.760 ± 5	12.5 ± 2.5	n_0, p_0, α_0, α_2			22.721	$0^+; T = 2$
85	21.28	~ 20	α_1, α_2, ^{8}Be			23.11	
86	21.3	≤ 500	^{8}Be			23.1	6^+
87	21.67	< 40	n, α_0, α_2		$\simeq 0.31$	23.40	(5^-)
88	21.85	300	α_0, α_1			23.54	
89	22.0	1500	$\gamma_{12.71}$			23.6	
90	22.14	120	n			23.75	

Table 16.15 (continued)
Resonances in $^{12}C+\alpha$ [a])

No.	E_α (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	Outgoing particles [b])	Γ_x	Γ_{α_0}/Γ	$^{16}O^*$ (MeV ± keV)	$J^\pi; T$
91	22.306 ± 6	26 ± 4	p_0, α_0, α_1, α_2, ^8Be	[k])	0.06 ± 0.02	23.879	6^+
92	22.37	165	n			23.93	
93 [m])	22.75	≤ 500	^8Be			24.21	
94	23.2	750	$\gamma_{12.71}$, $\gamma_{15.11}$			24.5	$T=1$
95	24.1	450	$\gamma_{15.11}$			25.2	$T=1$
96	24.6	450	$\gamma_{15.11}$			25.6	$T=1$
97	25.5	450	$\gamma_{15.11}$			26.3	$T=1$
98	25.6	1200	α_0, $\gamma_{12.71}$	$\Gamma_\alpha\Gamma_\gamma/\Gamma = 1.2$ eV		26.3	2^+
99	28.1	1000	α_0		0.35	28.2	7^-
100	29.1	1000	α_0, α_1, p_3		0.35	29.0	7^-
101	35.8 [n])	2300	α_0, α_2		0.1 [l])	34.0	10^+; (9^-)

[a]) References are listed in tables 16.11 (71AJ02), 16.12 (77AJ02), 16.13 (82AJ01), and 16.12 (86AJ04).
[b]) p_0 corresponds to $^{15}N(0)$. α_0, α_1 corresponds to $^{12}C^*(0, 4.4)$ and $\gamma_{4.4}$ corresponds to the γ-ray from the decay of $^{12}C^*(4.4)$; γ_0, γ_1, γ_2, γ_3, γ_4 correspond to the transitions to $^{16}O^*(0, 6.05, 6.13, 6.92, 7.12)$.
[c]) These are observed widths from (87RE02). We are indebted to Dr. F.C. Barker who informed us of these and other recent observed width determinations. $\Gamma^0_{\gamma_3} = 2.4 \pm 1.4$ meV (87RE02), $\Gamma_{\gamma_3} = 2.4$ meV, $\Gamma_{\gamma_4} = 8.0$ meV (91BA1K), $\Gamma_{\gamma_0} = 16.4$ meV (R-matrix fit by (91HU10)).
[d]) Branching ratios to $^{16}O^*(0, 6.05) = 98.8\%$, 1.2%.
[e]) $\Gamma_{\gamma_0} = 0.7 \pm 0.2$ eV, based on $\Gamma_{\alpha_0}/\Gamma = 1.0$ and $\Gamma_{c.m.} = 190 \pm 40$ keV.
[f]) $\Gamma_{\alpha_0}\Gamma_{\gamma_0}/\Gamma^2 = (1.49 \pm 0.17) \times 10^{-4}$.
[g]) Uncertainties in E_x may be larger.
[h]) For this and the states below Γ_α/Γ is ± 0.10 for isolated narrow levels.
[i]) $\Gamma_{\alpha_2}/\Gamma = 0.16$ (82KA30).
[j]) A resonance is reported at $E_\alpha = 19.4$ MeV: 4^+ is dominant, $\Gamma_\alpha/\Gamma \ll 1$, $\Gamma \geq 0.48$ (82KA30).
[k]) $\Gamma_{^8Be}$, Γ_{α_0}, and $\Gamma_{\alpha_2} \sim 3.5$, 1.5 ± 0.5 and ~ 6 keV, respectively.
[l]) $\Gamma_{\alpha_2}/\Gamma = 0.2$ (83AR12).
[m]) Broad maxima are reported in the activation cross section at $E_\alpha = 22.8$, 24.3, 25.3 and 26.9 MeV (83KO1A; prelim.).
[n]) See (81SA07) for (α,$\gamma_{14.8}$) measurements which indicate an 8^+ GQR built on the 6^+_1 state $^{16}O^*(14.82)$.

Table 16.16
Astrophysical factors for ^{12}C(α γ) [a])

Reference	$S_{E1}(E_0)$ (MeV · b)	$S_{E2}(E_0)$ (MeV · b)
(87RE02)	$0.20^{+0.27}_{-0.11}$ [b]) $0.09^{+0.10}_{-0.06}$, $0.14^{+0.12}_{-0.08}$ [c])	$0.096^{+0.024}_{-0.030}$
(87PL03)	0.20 ± 0.08 [b]) 0.16 ± 0.10 [c])	0.089 ± 0.030
(87BA53)	$0.14^{+0.13}_{-0.05}$, $0.18^{+0.16}_{-0.10}$ [b])	$0.03^{+0.05}_{-0.03}$
(88KR06)	$0.01^{+0.13}_{-0.01}$ [b]) 0.08 [c])	
(89FI08)	$0.03^{+0.14}_{-0.03}$ [d])	$0.007^{+0.024}_{-0.005}$ [d])
(91BA1K)	$0.15^{+0.17}_{-0.07}$, $0.26^{+0.14}_{-0.16}$ [b])	$0.12^{+0.06}_{-0.07}$
(91HU10)	$0.043^{+0.020}_{-0.016}$ [d])	

[a]) We are indebted to Dr. F.C. Barker for providing this list of recent values.
[b]) 3-level R fitting.
[c]) Hybrid R fitting.
[d]) K fitting.

Table 16.17
States of ^{16}O from ^{12}C(^{6}Li, d) and ^{12}C(^{7}Li, t)

E_x [a]) (MeV ± keV)	$\Gamma_{c.m.}$ [b]) (keV)	$\theta^2_\alpha/\theta^2_\alpha(2^+)$ [c])	Γ_{α_0}/Γ	J^π; K^π
0		0.93, 0.18		0^+
6.05		0.38, 1.10		0^+; 0^+
6.13		0.23, 0.22		3^-
6.92		≡ 1.0		2^+; 0^+
7.12		0.53, 0.39		1^-
8.87	< 20			2^-
9.63 ± 30 [d])	400 ± 10	0.30, 0.60		1^-; 0^-
9.84	< 20	≤ 0.05, ≤ 0.01		2^+
10.346 ± 6 [e])	35 ± 5	0.25, 0.47	0.86 ± 0.09	4^+; 0^+
10.96				0^-

Table 16.17 (continued)
States of ^{16}O from ^{12}C(^{6}Li, d) and ^{12}C(^{7}Li, t)

E_x [a]) (MeV ± keV)	$\Gamma_{c.m.}$ [b]) (keV)	$\theta^2_\alpha/\theta^2_\alpha(2^+)$ [c])	Γ_{α_0}/Γ	J^π; K^π
11.10 [e])	< 30	≤ 0.06, ≤ 0.03	0.31 ± 0.03 ($J = 4^+$)	$3^+ + 4^+$
11.59 ± 20	700 ± 100	∼ 0.4		3^-; 0^-
13.09	∼ 230			1^-
14.363 ± 15	< 120			> 5, π = nat.
14.66 ± 20	500 ± 50		1.03 ± 0.1	5^-; 0^-
14.82	45 ± 10			(6^+)
16.30 ± 20	300 ± 50		1.07 ± 0.11	6^+; 0^+
17.65 ± 50	100 ± 50			
17.85 ± 50	∼ 200			
(18.6) [f])				(5^-)
19.30 ± 50	∼ 200			
20.8 ± 100 [e])	500 ± 100		1.16 ± 0.23	7^-; 0^-
21.6 ± 100	≤ 100		0.67 ± 0.14	6^+
23.0 ± 100	∼ 200			(6^+)
23.8 ± 100	1980 ± 250			(6^+)
26.9 ± 100	1700 ± 250			(7^-)
27.7 [f])				(7^-)
(29.3) [f])				(7^-)
32 [g])	broad			
34 [h])				$10^+(9^-)$
35 [g])	broad			

[a]) E_x quoted without errors are from Table 16.13. For the earlier references see Table 16.14 (82AJ01). Angular distributions are reported in both reactions for the first nine states.
[b]) Line widths, not corrected for α-penetrabilities.
[c]) Ratio of dimensionless reduced α-width calculated at a channel radius of 5.4 fm, relative to that for ^{16}O*(6.92). (N, L) here are taken to be (2, 0) and (4, 1) respectively, for ^{16}O*(0, 7.12). The first number listed is the value reported at $E(^6\text{Li}) = 42$ MeV, the second at $E(^6\text{Li}) = 90.2$ MeV.
[d]) On the basis of studies of the ^{12}C(^{6}Li, d), ^{12}C(^{7}Li, t), ^{12}C(^{10}B, ^{6}Li) and ^{19}F(p, α) reactions, the energy of ^{16}O*(9.6) is 9619 ± 15 keV with $\Gamma = 400 \pm 100$ keV (line width). $\Gamma_R = 430 \pm 10$ keV as inferred from the best fit B-W line shape. This value is corrected for penetrability (81OV02; Becchetti, private communication.).
[e]) Angular distributions are reported at $E(^6\text{Li}) = 35.5$–35.6 MeV to ^{16}O*(10.36) and to the unresolved 3^+ and 4^+ states at 11.1 MeV (86AJ04). More recent coincidence measurements (86CA19) have indicated that while the 4^+ state is dominantly populated and decays by α emission, the 3^+ state decays by γ emission. Angular correlation measurements (80CU08) and analysis (88SE1E) indicate that the 4^+ state is populated by a two-step process.
[f]) (82AR20); decay primarily by α_0.
[g]) (82AR20); decay primarily by α_1.
[h]) (82AR20, 83AR12); decays primarily by α_2.

Table 16.18
Resonances in $^{13}C + {^3He}$ [a]

$E(^3He)$ (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	Outgoing particles	$^{16}O^*$ (MeV)	$J^\pi; T$
1.55	~ 80	n_0, n_3	24.05	
1.55 ± 100	450	γ_0	24.1	
2.0	~ 250	n_0	24.4	
2.6 ± 100		$\alpha\gamma_{15.1}$	24.9	$(T = 1)$
2.87 ± 50	600	γ_0	25.12	1^-
~ 3.1		α_0, α_2	~ 25.3	
~ 3.5	~ 300	α_0	~ 25.6	(3^-)
~ 4	~ 300	α_0, α_1, α_2	~ 26	(3^-)
4.0 ± 100	[b]	γ_0, γ_{1+2}, $\alpha\gamma_{15.1}$	26.0	1^-; (1)
4.6 ± 100 [c]	720 ± 160 [c]	γ_2, p_0	26.5	2^+, 4^+
5.2 ± 100	[b]	$\alpha\gamma_{15.1}$	27.0	$(T = 1)$
5.6 ± 100	~ 600	γ_0, γ_{1+2}, $\alpha\gamma_{15.1}$, ^8Be	27.3	(1^-)
~ 5.8	~ 2500	γ_{3+4}	27.5	
6.0 ± 100	~ 500	p_0, p_{1+2}, ^3He, α_1, α_2	27.7	$(3^-; 0)$
~ 6		γ_0	28	
6.5 ± 100	[b]	$\alpha\gamma_{15.1}$	28.1	$(T = 1)$
6.8 ± 100		α_0, α_1, α_2	28.3	$(T = 0)$
7.1 ± 200		γ_{1+2}	28.6	
7.5 ± 100	[b]	$\alpha\gamma_{15.1}$	28.9	$(T = 1)$
8.6 ± 100	[b]	$\alpha\gamma_{15.1}$	29.8	$(T = 1)$
9.4 ± 100	[b]	$\alpha\gamma_{15.1}$	30.4	$(T = 1)$
10.1 ± 100	[b]	$\alpha\gamma_{15.1}$	31.0	$(T = 1)$

[a]) For references see Tables 16.15 in (71AJ02), 16.13 in (77AJ02), and 16.15 in (82AJ01).
[b]) Lab widths 0.5–1 MeV.
[c]) Based on $\Gamma_{c.m.} = 530 \pm 80$ keV [from $^{15}N(p, \gamma)$, see Table 16.22], $\Gamma_{p_0} = 150 \pm 45$ keV [$J^\pi = 2^+$], 110 ± 35 keV [4^+]; $\Gamma_{p_0}/\Gamma = 0.29 \pm 0.10$ [2^+], 0.21 ± 0.07[4^+]; $\Gamma_{\gamma_2} = 740 \pm 240$ eV [2^+], 410 ± 140 eV [4^+]. See (86AJ04, 77CH16, 78CH19).

Table 16.19
States of ^{16}O from ^{13}C(^{6}Li, t)^{16}O

E_x [a] (MeV ± keV)	$\Gamma_{c.m.}$ [c] (keV)	Comments [d]
0 [b]		
6.13 [b]		
7.0 [u,b]		
8.87 [b,c]		c.n.
9.84 [b,c]		c.n.
10.36 [b,c]		c.n.
11.10 [u,b,c]		4^+ probably dominates; m.s.
11.52 [c]		
12.05 [c]		consistent with $L = 1 \rightarrow 0^+$
12.53 [c]		consistent with $L = 2 \rightarrow 2^-$
12.97 [c]		consistent with $L = 2 \rightarrow 2^-$
13.10 [u,c]		$L = 2$, but which state is involved?
14.3 [c]		$L = 4 \rightarrow 4^{(-)}$
14.40 [c]		anomalous shape
14.82 [c]		$L = 5$; probably $J^\pi = 6^+$
15.79 [c]		consistent with $L = 3 \rightarrow 3^+$
16.812 ± 15 [c]	28 ± 7	consistent with $L = 3 \rightarrow 3^+$
17.764 ± 15 [c,e]	45 ± 7	$L = 4$ or $L = 5$
18.032 ± 15 [u,c,f]	40 ± 7	$L = 3$; both states are probably populated
18.640 ± 15 [c]	22 ± 7	$L = 4$ or 5; probably 5^+
18.976 ± 15 [c]	25 ± 7	probably 4^-
19.814 ± 15 [c]	23 ± 7	
20.5 [u]		very strongly excited

u = unresolved.
c.n. = formation appears to be by a compound nuclear process.
m.s. = multistep process.
[a]) E_x without uncertainties are from Table 16.13.
[b]) Angular distributions have been reported at $E(^6\text{Li}) = 25$ MeV to the first seven groups shown here and at 28 MeV: see (86AJ04) for references. See also (82AJ01).
[c]) Angular distribution at $E(^6\text{Li}) = 34$ MeV (see 83KE06, 86AJ04).
[d]) For abbreviations see above. When an L value is shown, stripping patterns are evident (83KE06).
[e]) There is some evidence for a state at $E_x = 17.90$ MeV (83KE06, 86AJ04).
[f]) There is some evidence for a state at $E_x = 18.46$ MeV with $\Gamma \sim 60$ keV (83KE06, 86AJ04).

Table 16.20
Structure in ^{14}N + d [a]

E_d (MeV)	Resonant channel	$\Gamma_{c.m.}$ (keV)	$J^\pi; T$	E_x (MeV)
1.4	n_0, α_0	300 [e]	0^+ [e]	22.0
1.7 ± 0.1	γ_0, p_0, p_1, α_0–α_3	400 [e]	1^- [e]	22.2
1.85	n_0, α_0	175	2^+ [e]	22.35
2.0 ± 0.1	p_0, p_1, α_0, α_3	350 [e]	3^- [e]	22.5
2.272 ± 0.005 [b]	p_0, p_{1+2}, (p_3), p_4, p_5, α_0, α_2			22.722
2.40 ± 0.05 [c]	γ_0 [d], p_0, p_1	500 [e]	$1^-; 1$	22.83
2.5	α_0			22.9
2.6	(n_0), α_0, α_1	200 [e]	4^+ [e]	23.0
2.8	(n_0), p_0, p_1, d_0	350 [e]	2^+ [e]	23.2
3.24	p_0, p_{1+2}, p_4, p_5, p_6, d_0, α_3			23.57
4.2	γ_0, (p_0), d_0, $\gamma_{15.1}$			24.4
4.58	(p_0), d_0, $\gamma_{15.1}$			24.74
4.9	n_0, p_0			25.0
5.95	d_1, $\gamma_{15.1}$			25.9
7.1	$\gamma_{15.1}$			26.9
7.4	d_2			27.2
7.7	d_1			27.5
(8.5)	($\gamma_{15.1}$)			(28.2)
10.2	d_2			29.7

[a]) For earlier references see Table 16.14 in (77AJ02) and 16.16 in (82AJ01, 86AJ04).
[b]) $(\Gamma_{d_0}\Gamma_i/\Gamma^2) \times 10^{-3}$ are greater than 1.6 ± 0.4, 0.27 ± 0.13, 0.41 ± 0.15 and 0.07 ± 0.05 for the α_2, p_0, p_{1+2}, and p_3 groups.
[c]) If this resonance is fitted with a single-level Breit-Wigner shape, penetrability effects could lower the resonance energy by as much as 50 keV, assuming $l = 1$.
[d]) The angular distribution of γ_0 is consistent with E1.
[e]) See references in (86AJ04).

Table 16.21

^{16}O states from ^{14}N(^{3}He, p)^{16}O [a])

E_x (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	L	J^{π}
0		$0+2$	
6.052 ± 5		(0) [b])	
6.131 ± 4		$1+3$	
6.916 ± 3		(0)	
7.115 ± 3		$1+3$	
8.870 ± 3	< 20	$3+1$	
9.614 ± 30	510 ± 60		
9.847 ± 3	< 20	$0(+2)$	
10.356 ± 3	25 ± 5	[b])	
10.957 ± 1	< 12	1	
11.080 ± 3 11.098 ± 2	< 12 < 12 }	$2+4$ [c])	
11.520 ± 4	64 ± 5	[b])	
12.049 ± 2	< 12	0	
12.438 ± 3	70 ± 10	1	
12.530 ± 2 [d])	< 12	$1+3$	
12.797 ± 4	40 ± 10	1	0^-; $T = 1$ [f])
12.970 ± 1	< 12	$1+3$	2^-; $T = 1$ [f])
13.105 ± 15	160 ± 30	$0+3$ [c])	
13.257 ± 2	20 ± 5	$(1+3)$	3^-; $T = 1$ [f])
13.663 ± 4	63 ± 7	0	
13.869 ± 2	85 ± 20	(4) [b])	
13.979 ± 2 [d])	14 ± 5	$1(+3)$	
14.302 ± 3	< 20	[b])	
14.399 ± 2 [d])	27 ± 5	(4)	
14.818 ± 3		2	$(0 \rightarrow 4)^+$
14.927 ± 2 [d])	60 ± 10	$0(+2)$	$(0, 1, 2)^+$ [g])
15.103 ± 5			
15.196 ± 3		$(0+2)$	
15.409 ± 6		[b])	
15.785 ± 5 [d])	40 ± 10	$2(+4)$	$(2, 3, 4)^+$ [g])
16.114 ± 4 [e])			
16.209 ± 2 [d])	40 ± 10	$0+2$	
16.350 ± 13			

Table 16.21 (continued)
^{16}O states from ^{14}N(^{3}He, p)^{16}O [a]

E_x (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	L	J^π
16.440 ± 13	~ 30	$0+2$	
16.817 ± 2	70 ± 10		
[h]			

[a]) For references see Table 16.17 in (82AJ01).
[b]) Mostly compound nucleus.
[c]) Unresolved.
[d]) Also reported in p$\gamma_{4.4}$ coincidences.
[e]) Very weak proton group. See (86AJ04).
[f]) (78FO27) have compared the cross section ratios of these three $T = 1$ states with their analogs in ^{16}N populated in the (t, p) reaction: only the 2^- states have the expected cross section ratio of 0.5 for (^{3}He, p)/(t, p). The populations of the 0^- and 3^- states in ^{16}O are lower by a factor of two.
[g]) (78FO19) suggest that these two states [^{16}O*(14.93, 15.79)] are 1^+ and 3^+ 2p-2h states with $T_p = T_h = 0$.
[h]) States at 17.82 and 18.04 (± 0.04) MeV are also reported in p$\gamma_{4.4}$ coincidences.

Table 16.22
Levels of ^{16}O from ^{15}N(p, γ),^{15}N(p, p) and ^{15}N(p, α)

No.	$E_{\rm p}$ (keV)	Γ_{γ_0} (eV)	Γ_{γ_1} (eV)	$\Gamma_{\rm p}$ (keV)	$\Gamma_{\rm p}\Gamma_\gamma/\Gamma$ (eV)	Γ_{α_0} (keV)	Γ_{α_1} (keV)	$\Gamma_{\rm lab}$ (keV)	$J^\pi; T$	$E_{\rm x}$ (MeV ± keV)
1	335 ± 4 [a]	12 ± 2	0.12 ± 0.04	0.9 ± 0.1		102 ± 4	0.025	110 ± 4	1^-; 0	12.442
2	429.57 ± 0.09 [b]	$(33 \pm 5) \times 10^{-3}$ [c]	2.1 ± 0.2	0.016 ± 0.003 [c]		nr	0.092 ± 0.010 [c]	0.103 ± 0.011	2^-; 0	12.530
3	710 ± 7			40		nr		40 ± 40	0^-; 1	12.793
4	897.37 ± 0.29	$(34 \pm 9) \times 10^{-3}$ [c]		1.04 ± 0.07 [c]		nr	0.30 ± 0.06 [c]	1.47 ± 0.04 [c]	2^-; 1	12.9686
5	1028 ± 10	32 ± 5		100		40	r	140 ± 10	1^-; 1	13.091
6	1050 ± 150					$\Gamma_{\rm p}\Gamma_{\alpha_0} =$ 500 keV^2			2^+	13.1
7	1210 ± 3			4.1		r	8.2 ± 1.1	22.5 ± 1	3^-; 1	13.262
8	1640 ± 3	< 1 [d]		10		nr	59 ± 6	68 ± 3	1^+; 0	13.664
9	1890 ± 20			0.5		r	(r)	90 ± 2		13.90
10	1979 ± 3			r		nr	r	23 ± 2	2^-	13.982
11	2982 ± 6 [e]			20 ± 3 [f]		1.5	30 [g]	55 ± 5 [e]	2^+	14.921 [l]
12	3170 [h]			12 [i]		152	163	330 ± 100	0^+	15.10 [l]
13	3264 ± 11 [e]			[j]		nr	7 [k]	67 ± 4 [e]	2^-	15.186 [l]
14	3340 [h,m]			15 [i]		12	182	315 ± 100	2^+; (0)	15.26 [l]
15	3499 ± 8 [e,m]			15 ± 5 [f]		103	1	131 ± 18 [e]	3^-	15.406 [l]
16	4350 ± 90 [f]			210 ± 38 [f]				620 ± 60 [f]	1^-; 0	16.20
17	4357 ± 5 [e]	3.7 ± 0.5 [n]	0.44 ± 0.06 [n]	7 ± 3 [f]	2.70 ± 0.25 [d]			20 ± 3 [e]	1^+; 1	16.210
18	4505 ± 12 [f]			53 ± 12 [f]				65 ± 8 [f]	0^+; 0	16.349
19	4612 ± 9 [d]			r	1.11 ± 0.24 [o]	r	r	26 ± 8 [d]	$1 - 4$; 1 [d]	16.449
20	5001 ± 5 [e,m]			7 ± 2 [f]	[p]	nr	r	28 ± 4 [e]	3^+; $0 + 1$ [d]	16.813
21	5300 ± 40 [f]	r		[q]				405 ± 43 [e]	1^-; 1	17.09
22	5329 ± 5 [e]	6.7 ± 1.0	1.00 ± 0.17 [n]	22 [d]	3.90 ± 0.50 [d]			33 ± 4 [e]	1^+;1	17.120
23	5487 ± 9 [e]	67		45	[r]			80 ± 8 [e]	1^-; 1	17.268
24	5848 ± 8 [f]			37 ± 8 [f]				117 ± 15 [f]	2^+; (1)	17.607
25	6100 ± 100 [f]			500 ± 100 [f]				875 ± 110 [f]	2^-	17.84

Table 16.22 (continued)
Levels of ^{16}O from ^{15}N(p, γ),^{15}N(p, p) and ^{15}N(p, α)

No.	E_p (keV)	Γ_{γ_0} (eV)	Γ_{γ_1} (eV)	Γ_p (keV)	$\Gamma_p\Gamma_\gamma/\Gamma$ (eV)	Γ_{α_0} (keV)	Γ_{α_1} (keV)	Γ_{lab} (keV)	J^π; T	E_x (MeV ± keV)
26	6137 ± 6 [e])			6 [d])	(r)		r	26 ± 3 [e])	1^-; 2^-; 1	17.877
27	6297 ± 6 [e])	nr	4.8 ± 1.9 [t])	13 ± 3 [f,u])			8.9 ± 3.2 [d])	28 ± 6	3^-; 1 [y])	18.027
28	6490 ± 15 [f])			33 ± 12 [f])				150 ± 26	2^+	18.208
29	6727 ± 15 [f])			11 ± 6				97 ± 41	2^+	18.430
30	6785 ± 6 [f])			17 ± 3				37 ± 6	1^-	18.484
31	7100 ± 100 [d])	≥ 3.6 [n])		[v])					1^+; 1	18.78
32	7313 ± 9 [d])		7.1 ± 3.1 [w])	[x])	[x])		0.57 ± 0.49 [d])	8.7 ± 4.1 [d])	4^-; 1 [y])	18.979
33	7330 ± 30	38		≤ 130	$\geq 1.8 \pm 0.3$			~ 260	1^+	18.99
34	7420	r		~ 30				~ 130	2^+; (1)	19.08
35	7600 ± 30 [z])	nr	1.5 [aa])					100	(2, 3; 1)	19.25
36	7840 ± 30 [z])			(r)				350	1^-; 1	19.47
37	8289 ± 7 [d])	nr	17 ± 6 [bb])	25 ± 10 [cc])	[dd])		r	45 ± 10	3; 1 [d])	19.893
38	8843 ± 17 [d])	nr	38 [ee])	[ee])	[ee])			200 ± 20	$1-4$; 1	20.412
39	8990			[ff])				160		20.55
40	9410 [h])	170		[ff])	21 ± 1			320 ± 10	1^-; 1	20.945 ± 20
41	10000 [h])			[hh])				130	$1 \rightarrow 4$	21.50
42	10180 [h])			[ii])		r		< 45	$T = 0$	21.66
43	10700 [h,gg])	r		[hh])	488 ± 20			730 ± 10	1^-; 1	22.150 ± 10
44	11490 [h])	120	27 [aa])	[hh])	69 ± 5			320 ± 10	1^-; 1	22.89 ± 10
45	12740 [h])	r			130 ± 13			590 ± 40	1^-; 1	24.07 ± 30
46	13490 ± 60		230 ± 90, or 130 ± 50 [jj])	85 [cc])				360 ± 60	$(2,4)^+$; 1	24.76
47	13870 [h])	r			651 ± 117		[kk])	3150 ± 320	1^-; 1	25.12 ± 60
48	15250 ± 80		740 ± 240, or 410 ± 140 [jj])	122 [cc])			[kk])	565 ± 85 [ll])	$(2,4)^+$; 1	26.41
49	16250 ± 100		1070 ± 380, or 590 ± 10 [jj])	206 [cc])			[kk])	880 ± 125	$(2,4)^+$; 1	27.35

nr = non-resonant
r = resonant
For earlier references see Tables 16.21 in (71AJ02), 16.19 in (77AJ02) and 16.18 in (82AJ01) and 16.18 in (86AJ04).

[a]) (82RE06).
[b]) (87OS01). See also the result $E_{\rm p} = 429.88 \pm 0.14$ from the ^{1}H(^{15}N, $\alpha\gamma$) reaction.
[c]) (86ZI08).
[d]) See (83SN03).
[e]) Weighted mean of values obtained by (83SN03, 84DA18) and in earlier work [see 82AJ01)].
[f]) (84DA18). See also for calculated $\Gamma_{\rm n}$.
[g]) $\Gamma_{\rm p}\Gamma_{\alpha_1}/\Gamma = 16.4$ keV (83SN03).
[h]) Nominal $E_{\rm p}$ calculated from $E_{\rm x}$.
[i]) Not observed in $\rm p_0$ channel.
[j]) 35 ± 3 keV ($s = 1$), 15 ± 2 keV ($s = 0$); $\Gamma_{\rm p}/\Gamma = 0.78$ (84DA18).
[k]) $\Gamma_{\rm p}\Gamma_{\alpha_1}/\Gamma = 10.9$ keV (83SN03).
[l]) See also footnote [c]) in table 16.18 (82AJ01).
[m]) Broad structures have also been observed at $E_{\rm p} \sim 3.5$ MeV in ($\alpha_1\gamma$) and at 5.7 MeV in ($\alpha_1\gamma$) and (γ_{1+2}) (83SN03).
[n]) Γ_γ uncertainties neglect the error in $\Gamma_{\rm p}/\Gamma$ (83SN03).
[o]) $\Gamma_{\rm p}\Gamma_{\gamma_2}/\Gamma$; also $\Gamma_{\gamma_2} \simeq 11$ eV (83SN03).
[p]) $\Gamma_{\rm p}\Gamma_{\gamma_2}/\Gamma = 0.48 \pm 0.09$ eV, $\Gamma_{\rm p}\Gamma_{\gamma_{3+4}}/\Gamma = 0.62 \pm 0.13$ eV, $\Gamma_{\rm p}\Gamma_{\alpha_1}/\Gamma = 6.8$ eV; $\Gamma_{\gamma_2} = 1.0$ eV, $\Gamma_{\gamma_3} = 1.2$ eV, $\Gamma_{\rm p}/\Gamma = 0.5$ [see, however, values shown for $\Gamma_{\rm p}$ and Γ] (83SN03).
[q]) $\Gamma_{\rm p} = 24 \pm 6$ ($l = 0$), 246 ± 24 keV ($l = 2$) (84DA18).
[r]) $\Gamma_{\gamma_3} = 8$ eV, $\Gamma_{\rm p}\Gamma_{\gamma_3}/\Gamma = 3.27 \pm 0.41$ eV (83SN03).
[s]) $\Gamma_{\gamma_4} = 2$ eV, $\Gamma_{\rm p}\Gamma_{\gamma_4}/\Gamma = 0.69 \pm 0.10$ eV, $\Gamma_{\rm p}\Gamma_{\alpha_1}/\Gamma = 1.48$ keV (83SN03).
[t]) Γ_{γ_2}; $\Gamma_{\gamma_3} = 0.76 \pm 0.39$ eV: see (83SN03).
[u]) $\Gamma_{\rm p_0} = 7.8 \pm 2.8$ keV, $\Gamma_{\rm p_{1+2}} = 2.7 \pm 1.2$ keV; $\Gamma_{\rm p}\Gamma_{\gamma_2}/\Gamma = 1.96 \pm 0.27$ eV, $\Gamma_{\rm p}\Gamma_{\gamma_{3+4}}/\Gamma = 0.31 \pm 0.11$ eV, $\Gamma_{\rm p}\Gamma_{\rm p_{1+2}}/\Gamma = 1.11 \pm 0.26$ keV, $\Gamma_{\rm p}\Gamma_{\alpha_1}/\Gamma = 4.25 \pm 1.00$ keV: see (83SN03).
[v]) $\Gamma_{\rm p}/\Gamma \leq 0.5$, $\Gamma_{\rm p}\Gamma_{\gamma_0}/\Gamma \geq 1.8 \pm 0.3$ eV (83SN03).
[w]) $\Gamma_{\rm p}\Gamma_{\gamma_2}$; $\Gamma_{\rm p}\Gamma_{\gamma_3} < 0.3$ eV: see (83SN03).
[x]) $\Gamma_{\rm p_0} = 0.98 \pm 0.19$ keV, $\Gamma_{\rm p_{1+2}} = 5.2 \pm 2.3$ keV; $\Gamma_{\rm p}\Gamma_{\gamma_2}/\Gamma = 0.85 \pm 0.01$ eV, $\Gamma_{\rm p}\Gamma_{\gamma_{3+4}}/\Gamma < 0.03$ eV, $\Gamma_{\rm p}\Gamma_{\rm p_{1+2}}/\Gamma = 0.62 \pm 0.09$, $\Gamma_{\rm p}\Gamma_{\alpha_0}/\Gamma < 0.09$ keV: see (83SN03).
[y]) See also Table IV in (83SN03).
[z]) See also (83SN03).
[aa]) $\gamma_1 + \gamma_2$.
[bb]) Γ_{γ_0} (77CH19). See also (83SN03).
[cc]) $\Gamma_{\rm p_0}$ based on $\Gamma_{\rm c.m.}$ and values of $\Gamma_{\rm p_0}/\Gamma$ assumed by (77CH19).
[dd]) $\Gamma_{\rm p}\Gamma_{\gamma_2}/\Gamma = 3.9 \pm 0.56$ eV, $\Gamma_{\rm p}\Gamma_{\rm p_{1+2}}/\Gamma = 4.48$ keV, $\Gamma_{\rm p}\Gamma_{\rm p_3}/\Gamma = 0.52$ keV, $\Gamma_{\rm p}\Gamma_{\alpha_1}/\Gamma = 1.07$ keV (83SN03).
[ee]) $\Gamma_{\gamma_2} = 38$ eV; $\Gamma_{\rm p}\Gamma_{\gamma_2}/\Gamma = 18.8 \pm 3.9$ eV, $\Gamma_{\rm p}\Gamma_{\rm p_{1+2}}/\Gamma = 15.8$ keV, $\Gamma_{\rm p}\Gamma_{\rm p_3}/\Gamma = 5.8$ keV, $\Gamma_{\rm p}\Gamma_{\rm n_0}/\Gamma = 22$ keV; the state is probably 4^+; $T = 1$: see (83SN03).
[ff]) Resonant in $\rm p_2$.
[gg]) $\sigma = 12.9$ mb at peak of GDR (78OC01).
[hh]) Resonant in $\rm p_1$.
[ii]) Resonant in $\rm p_0$, $\rm p_1$, $\rm p_6$.
[jj]) Γ_{γ_2} (eV).
[kk]) Apparent resonance in yield of ($\alpha\gamma_{15.1}$) (78OC01).
[ll]) Average of values obtained in this experiment and in ^{12}C(α, γ_2).

Table 16.23
Resonances in ^{15}N(p, n)^{15}O [a]

E_p (MeV ± keV)	$\Gamma_{c.m.}$ (keV)	$J^\pi; T$ [b]	E_x (MeV)
4.37 ± 15	19 ± 6	$1^{(+)}; 1$	16.22
4.45 ± 30	240 ± 30	$0^{(-)}$	16.30
5.35 ± 15	33 ± 5	$1^{(-)}; 1$	17.14
5.52 ± 15	90 ± 10	$1^-; 1$	17.30
5.88 ± 15	59 ± 10	$\geq 1; 1$	17.64
6.12 ± 15	101 ± 10	$\geq 1; 1$	17.86
6.23 ± 15 [c]	≤ 50	$T = 1$	17.96
6.33 ± 15	26 ± 5	$\geq 1; 1$	18.06
6.43 ± 30	$\simeq 300$		18.15
6.76 ± 25	$\simeq 160$		18.46
7.03 ± 30	260 ± 30		18.71
7.59 ± 25	90 ± 10	$2^-; 1$	19.24
7.86 ± 30	300 ± 80		19.49
8.30 ± 25	120 ± 40		19.90
8.88 ± 40 [d]	200 ± 50	2	20.45
9.08 ± 40	130 ± 50		20.63
9.42 ± 100	235 ± 45		20.95
10.73 ± 100	800 ± 95	1	22.18
11.01 ± 100	300 ± 100		22.44
11.92 ± 100	520 ± 200		23.29
13.03 ± 100	520 ± 100		24.33
13.63 ± 100	~ 280	2, 4	24.89
15.12 ± 100	610 ± 140	2, 4	26.29
18.4 ± 200	470 ± 150		29.4

[a]) For references see Table 16.19 in (82AJ01).
[b]) Assignments are from (p, n) and (p, γ) results. The T-assignments are made on the basis of energy and width comparisons with states of ^{16}N.
[c]) Probably a doublet.
[d]) Values of $(2J+1)\Gamma_{p_0}\Gamma_{n_0}/\Gamma^2$ are derived for this resonance and the ones below: see (78CH09).

Table 16.24
States in ^{16}O from ^{15}N(d, n) and ^{15}N(^{3}He, d)

^{16}O* (MeV ± keV)	$J^{\pi}; T$	l [a]	l [b]	S [c]
0	0^{+} ; 0	1	1	3.1
6.05	0^{+}; 0		1	[d]
6.13	3^{-}; 0	2	2	
6.92	2^{+}; 0	not direct	$1 + 3$	[d]
7.12	1^{-}; 0	0	$0 + 2$	
8.87	2^{-}; 0	2	2	0.72
9.59	1^{-}; 0		0	[d]
9.84	2^{+}; 0	1	not direct	[d]
10.36	4^{+}; 0		3	[d]
10.96	0^{-}; 0	0	0	0.76
11.08	3^{+}; 0	3	3	0.18
11.26	0^{+}; 0		broad	
12.44	1^{-}; 0	0	0	0.40
12.53	2^{-}; 0	2	2	0.72
12.80	0^{-}; 1	0	0	0.44
12.97	2^{-}; 1	2	2	0.40
13.09	1^{-}; 1	(0)		0.58
			$2(+ 0)$	
13.13 [e]	3^{-}; 0	(2)		0.32
13.26	3^{-}; 1	2	2	0.46
17.14			obs.	
17.20	2^{+}		obs.	

[a] ^{15}N(d, n); $E_{\rm d} = 4.8$ to 6 MeV; see (77AJ02) for references.
[b] ^{15}N(^{3}He, d); $E(^{3}$He$) = 11$, 16.0 and 24.0 MeV; see (77AJ02).
[c] "Best" values from (d, n) and (^{3}He, d) data. See Table 16.22 in (77AJ02) for a more complete display.
[d] Very small value of S: see (77AJ02).
[e] $\Gamma = 128$ keV.

Table 16.25
Beta decay of the ground state of ^{16}N

Final State			
^{16}O* (MeV)	J^π	Branch (%)	log ft
0	0^+	28.0 ± 0.5 [a])	9.077 ± 0.005 [d,e])
6.05	0^+	$(1.2 \pm 0.4) \times 10^{-2}$	9.96 ± 0.15 [d])
6.13	3^-	66.2 ± 0.6 [b])	4.48 ± 0.04
7.12	1^-	4.8 ± 0.4	5.11 ± 0.04
8.87	2^-	1.06 ± 0.07 [c])	4.41 ± 0.03 [c])
9.59	1^-	$(1.20 \pm 0.05) \times 10^{-3}$	6.12 ± 0.05 [f])
9.84	2^+	$(6.5 \pm 2.0) \times 10^{-7}$	9.07 ± 0.13 [d])

[a]) Adopted value average of (84WA07, 85HE08).
[b]) Recalculated so that the sum of the branches is 100%.
[c]) See (86AJ04).
[d]) log $f_1 t$.
[e]) E.K. Warburton, private communication. We are indebted to Dr. Warburton for his very useful comments.
[f]) See also (93CH1A).

Table 16.26
Excited states observed in $^{16}O(e, e')^{16}O$ [a])

E_x (MeV ± keV)	$J^\pi; T$	Mult.	$\Gamma_{c.m.}$ (keV)	Γ_{γ_0} (eV)
6.05	0^+	E0		3.55 ± 0.21 [c])
6.13	3^-	E3		$(2.60 \pm 0.13) \times 10^{-5}$
6.92	2^+	E2		0.105 ± 0.007
7.12	1^-	E1		$(4.6 \pm 2.3) \times 10^{-2}$
8.87 [b])	2^-	M2		
9.84	2^+	E2		$(8.8 \pm 1.7) \times 10^{-3}$
10.36	4^+	E4		$(5.6 \pm 2.0) \times 10^{-8}$
11.52	2^+	E2		0.61 ± 0.02
12.05	0^+	E0		4.03 ± 0.09 [c])
12.44 [b])	1^-	E1		
12.53 [b])	2^-	M2		0.021 ± 0.006
12.97 [b])	2^-	M2		0.071 ± 0.002
13.02	2^+	E2		0.89
13.10 ± 250	$1^-; 1$	E1		$\leq 49 \pm 13$
13.26 [b])	3^-	E3		
13.87 [b])	4^+	E4		
14.00 ± 50 [b])	0^+	E0	170 ± 50	3.3 ± 0.7 [c])
~ 14.7 [b])			~ 600	
14.93 [b])	2^+	E2		
15.15 ± 150	2^+	E2	500 ± 200	1.0 ± 0.5
15.20 [b])	2^-	M2		
15.41 [b])	3^-	E3		
~ 15.85			~ 600	
16.22 ± 10 [b,d])	$1^+; 1$	M1	18 ± 3	3.2 ± 0.3
16.45 ± 10 [b,d])	2^+	E2	32 ± 4	0.18 ± 0.01
16.82 ± 10 [b,d])	2^-	M2	30 ± 5	0.05 ± 0.01
17.14 ± 10 [b,d])	$1^+; 1$	M1	< 25	6.1 ± 0.5
17.30 ± 10 [b,d])	1^-	E1	70 ± 10	3.4 ± 2.3
17.774 ± 17 [b])	$4^-; 0$	M4		
17.78 ± 10 [d,e])	2^-	M2		0.07 ± 0.01
17.880 ± 15 [f])	$(4^+; 1)$	E4	20 ± 20	
18.021 ± 23 [b])	$3^-; 1$			
18.20 ± 10 [d])	2^+	E2	280 ± 20	1.68 ± 0.22
~ 18.3 [f])			~ 430	

Table 16.26 (continued)
Excited states observed in ^{16}O(e, e$'$)^{16}O [a]

E_x (MeV ± keV)	$J^\pi; T$	Mult.	$\Gamma_{c.m.}$ (keV)	Γ_{γ_0} (eV)
18.50 ± 10 [b,d]	2^-	M2	70 ± 5	0.38 ± 0.07
18.635 ± 20 [f]	(4^-; 1)		35 ± 30	
18.79 ± 10 [d]	1^+; 1	M1	120 ± 20	5.3 ± 0.3
18.968 ± 17 [b,g]	4^-; 1	M4		
19.02 ± 40 [d,h]	2^-; 1	M2	420 ± 50	2.52 ± 0.38
19.206 ± 12 [b]	3^-; 1	E3		
19.430 ± 20 [f]			150 ± 15	
20.185 ± 40 [f]			400 ± 100	
20.335 ± 25 [f]			∼ 200	
20.510 ± 25 [f]	(4^-; 1)		50 ± 30	
20.88 [b]			∼ 90	
20.95 ± 50	1^-; 1	E1	270 ± 70	180 ± 50
∼ 21.46 [b]			∼ 300	
22.60 ± 20 [b]			90 ± 40	
23.0				
23.7 ± 250	(2^-; 1)			
24.2				
25.5 ± 250	1^-; 1	E1		
26.7 ± 250	1^+	M1		
44.5	(1^-; 1)		2000–3000	5300
49	(1^-; 1)		2000–3000	19000

[a]) See also Table 16.26 in (71AJ02). For references see Table 16.24 in (77AJ02). See also the text.
[b]) (85HY1A: momentum transfer range 0.8 to 2.5 fm^{-1}). See (86AJ04).
[c]) Monopole matrix element in fm^2.
[d]) (83KU14).
[e]) An unresolved complex of M1 strength has a centroid at $E_x \sim 17.7$ MeV: the total Γ_{γ_0} is 7.4 ± 1.9 eV (83KU14).
[f]) (87HY01).
[g]) See also (86AJ04).
[h]) The total cross section ($E_x = 18.7$–19.4 MeV) is 12% M1 and 88% M2, leading to $B(\text{M1})\uparrow = 0.13 \pm 0.03\ \mu_N^2$ and $B(\text{M2})\uparrow = 341 \pm 51\ \mu_N^2 \cdot \text{fm}^2$: see (86AJ04).

Table 16.27

Excited states of ^{16}O from ^{16}O(p, p′),(d, d′), (^{3}He, ^{3}He′) and (α, α′) [a]

No.	E_x [b] (MeV ± keV)	L [b]	E_x [c] (MeV)	E_x [d] (MeV ± keV)	E_x [e] (MeV ± keV)	L [e]	Γ [b] (keV)	J^π; T [b]
1			6.05					
2	6.13 [f]	3	6.13	6.13 [i]	6.13	3		3^-; 0
3	6.92 [f]	2	6.92	6.92 [d]	6.92	2		2^+; 0 [f]
4	7.12 [f]	1	7.12		7.12	1		1^-; 0
5	8.87 [g]		8.87	8.87 ± 30 [d]	8.87	3 [a]		2^-; 0 [g]
6	9.84 [f]	2	9.85	9.84 ± 30	9.85	2		2^+; 0 [d,f]
7	10.35 ± 20 [f]	4	10.34	10.35 ± 30	10.35 ± 30	4		4^+; 0
8	10.95 ± 30 [h]	1	10.95					0^-; 0
9	11.10 ± 20 [f]	4	11.1 [i]	11.09 ± 30 [i]	11.10 ± 30	4		4^+; 0
10	11.52 ± 20 [f]	2	11.52	11.52 ± 30 [d]	11.52 ± 30	2	74 ± 4	2^+; 0
11	12.05 ± 20 [f]		12.05	12.04 ± 30	12.05 ± 30	(0)		0^+; 0^-
12			12.44		12.44	1		1^-; 0
13	12.53 ± 20 [g]	1	12.53		12.51 ± 30			2^-; 0 [g]
14	12.80 [h]							0^-; 1
15	12.97 [g]							2^-; 1
16	13.02 ± 20	2	13.1 [i]	13.11 ± 30	13.07 ± 20 [i]	2		2^+; 0
17	13.26 ± 30	3						3^-; 1
18			13.66					
19	13.95 ± 50	(0 + 4)		13.97 ± 30	13.95 ± 50 [i]	4		4^+; 0
20	14.0 [g,i]							(1^+; 1)
21				14.94 ± 30	14.87 ± 100	6		6^+
22	15.26 ± 50	(3)		15.4				
23	15.50 ± 30 [f]	3			15.50 ± 50	3	200 ± 60	3^-; 0
24	16.22 ± 10 [g]							1^+; 1
25	16.52 ± 50	2		16.46 ± 30	16.40 ± 100		< 100	2^+
26	16.93 ± 50	(3)						
27	17.14 ± 10 [g]							1^+; 1
28	17.25 ± 50 [f]			17.19 ± 30	17.25 ± 80	(2)	160 ± 60	1^+; 0 [f]
29	17.79 ± 40	(3)		17.8	17.83 ± 100		150 ± 60	4^-; 0
30	18.15 ± 50	(2)			18.0 ± 100	2	300 ± 50	(2^+); 0
31	18.40 ± 100	2		18.52 ± 30	18.5 ± 100	2	250 ± 50	2^+; 0
32	18.60 ± 100				18.70 ± 100	(3)	280 ± 80 [i]	
33	18.77 ± 10 [g]							1^+; 1

Table 16.27 (continued)
Excited states of ^{16}O from ^{16}O(p, p′),(d, d′), (^{3}He, ^{3}He′) and (α, α′) [a]

No.	E_x [b] (MeV ± keV)	L [b]	E_x [c] (MeV)	E_x [d] (MeV ± keV)	E_x [e] (MeV ± keV)	L [e]	Γ [b] (keV)	$J^\pi; T$ [b]
34	18.98 ± 40	(3)		19.09 ± 30			< 100	4^-; 1
35	19.35 ± 80	(1)						
36	19.56 ± 50 [f]				19.50 ± 100	(2,3)	300 ± 50	3^-; 0
37	19.80 ± 40	3					< 100	4^-; 0
38				20.2 ± 200 [i]	20.15 ± 100	2	350 ± 50	2^+; 0
39	20.40 [g,i]							2^-; 1
40	20.56 ± 80	(1, 2)					370 ± 100	
41	20.90 [g,i]							2^-; 1
42	21.05 ± 50	1			21.0 ± 100	2	320 ± 50	(2^+; 0)
43				21.6 ± 200			1000 ± 300	2^+
44	21.80 ± 80	1			21.85 ± 100	2	400 ± 50	(2^+; 0)
45	22.40 ± 80	(1, 2)					420 ± 100	1^-; 1
46					22.5 ± 100		400 ± 50	(2^+, 3^-); 0
47	23.20 ± 80	1					600 ± 200	1^-; 1
48				23.50 ± 150	23.25 ± 100	2	400 ± 50	2^+; 0
49					23.85 ± 100	(0)	400 ± 50	(2^+, 0^+); 0
50	24.00 ± 100	(1, 2)					1200 ± 300	1^-; 1
51					24.4 ± 100		400 ± 50	(2^+, 3^-); 0
52					25.15 ± 300		2800 ± 600	2^+
53	25.50 ± 150	(1)					1300 ± 300	1^-; 1

[a]) For references see Table 16.24 in (82AJ01).
[b]) (p, p′).
[c]) (d, d′). Energies are nominal (± 100 to ± 260 keV); angular distributions reported to all but last state.
[d]) (^{3}He, ^{3}He′).
[e]) (α, α′).
[f]) (84AM04): $E_p = 135$ MeV.
[g]) (87DJ01).
[h]) (84HO17); $E_p = 65$ MeV.
[i]) Unresolved states.

Table 16.28
States in ^{16}O from ^{17}O(d, t) and ^{17}O(^{3}He, α)

E_x [a]) (MeV ± keV)	J^π; T	l [a])	j [a])	C^2S [a])	$(d\sigma/d\Omega)_{max}$ [a]) (μb/sr)	l [c])	S [c])
0.000	0^+; 0	2	$\frac{5}{2}$	1.034 ± 0.084	1736 ± 21.9	2	0.88
6.045 ± 8	0^+; 0	2	$\frac{5}{2}$	0.016 ± 0.004	17.9 ± 2.2	2	0.009
6.131 ± 3	3^-; 0	1	$\frac{1}{2}$ $\frac{3}{2}$	0.578 ± 0.137 0.373 ± 0.081	527 ± 21.9	1 [d])	0.37
6.913 ± 4	2^+; 0	(2)	$(\frac{5}{2})$	(0.030 ± 0.004)	78.9 ± 11.9	$(2+0)$	0.022
7.115 ± 3	1^-; 0	1	$\frac{3}{2}$	0.055 ± 0.006	39.2 ± 3.2	$(3+1)$	0.007
8.870 ± 3	2^-; 0	1	$\frac{1}{2}$ $\frac{3}{2}$	0.335 ± 0.086 0.137 ± 0.048	289 ± 24.0	1 [d])	0.26
9.841 ± 6	2^+; 0	2	$\frac{5}{2}$	0.007 ± 0.003	12.9 ± 2.7	2	0.025
10.354 ± 3	4^+; 0	(2)	$(\frac{5}{2})$	(0.016 ± 0.004)	19.9 ± 3.5	2	0.025
10.955 ± 9	0^-; 0				6.7 ± 3.4	$(3+1)$	0.008
11.08 [b])	3^+; 0					2	0.044 or 0.086
11.095 ± 6	4^+; 0				26.1 ± 5.3		
11.525 ± 9	2^+; 0				20.0 ± 18.5		
12.528 ± 6	2^-; 0	1	$\frac{1}{2}$ $\frac{3}{2}$	0.234 ± 0.046 0.036 ± 0.015	53.5 ± 22.3		
12.782 ± 23	0^-; 1				29.8 ± 5.0		
12.971 ± 3	2^-; 1	1	$\frac{1}{2}$	0.396 ± 0.101	356 ± 22.2	1 [d])	0.38
13.09 [b])	1^-; 1					1	0.1
13.148 ± 14	3^-; 0	1	$\frac{1}{2}$ $\frac{3}{2}$	0.058 ± 0.019 0.019 ± 0.012	62.1 ± 17.0		
13.256 ± 3	3^-; 1 [b])	1	$\frac{1}{2}$	0.562 ± 0.106	335 ± 21.9	1 [d])	0.34
13.857 ± 30	4^+; 0	(2)	$(\frac{5}{2})$	(0.015 ± 0.003)	10.3 ± 4.6		
13.979 ± 17	2^-	1	$\frac{3}{2}$	0.016 ± 0.004	11.9 ± 4.7		
14.313 ± 18	$4^{(-)}$				24.1 ± 9.2		
14.409 ± 11	5^+				7.8 ± 6.2		
15.195 ± 32	2^-; 0	1	$\frac{3}{2}$	0.106 ± 0.030	38.4 ± 16.8	[d])	
15.414 ± 6	3^-; 0	1	$\frac{3}{2}$	0.242 ± 0.038	76.3 ± 16.7	[d])	
16.808 ± 11	3^+; 1	(2)	$(\frac{5}{2})$	(0.015 ± 0.005)	72 ± 4.3		
17.776 ± 11	4^-; 0	1	$\frac{3}{2}$	0.089 ± 0.045	48.3 ± 13.2	[d])	($\Gamma < 50$ keV) [b])
18.027 ± 7	$3^{(-)}$; 1	1	$\frac{3}{2}$	0.102 ± 0.023	76.1 ± 20.8		
18.483 ± 17	1^-; 1	1	$\frac{3}{2}$	0.129 ± 0.028	94.6 ± 26.0	[d])	
18.978 ± 7	4^-; 1	1	$\frac{3}{2}$	0.706 ± 0.065	502 ± 11.2	[d])	

Table 16.28 (continued)
States in ^{16}O from ^{17}O(d, t) and ^{17}O(^{3}He, α)

E_x [a]) (MeV ± keV)	$J^\pi;\ T$	l [a])	j [a])	C^2S [a])	$(d\sigma/d\Omega)_{max}$ [a]) (μb/sr)	l [c])	S [c])
19.210 ± 14	3^-; 1	1	$\frac{3}{2}$	0.338 ± 0.036	227 ± 9.9	[d])	$\Gamma = 68 \pm 10$ keV [b])
19.806 ± 11	4^-; 0	1	$\frac{3}{2}$	0.423 ± 0.116	281 ± 127	[d])	$\Gamma = 36 \pm 5$ keV [b])
20.481 ± 8	2^-; 1	1	$\frac{1}{2}$ $\frac{3}{2}$	0.015 ± 0.018 0.144 ± 0.029	65.3 ± 10.0	[d])	
20.922 ± 30	1^-; 1	1	$\frac{3}{2}$	0.032 ± 0.009	15.6 ± 5.6		
22.857 ± 60	1^-; 1	1	$\frac{3}{2}$	0.109 ± 0.023	50.0 ± 12.4		

[a]) ^{17}O(d, t); $E_d = 89$ MeV (90SA27).
[b]) See table 16.20 (86AJ04).
[c]) ^{17}O(^{3}He, α); $E(^3$He$) = 11$ MeV (71BO02).
[d]) ^{17}O(^{3}He, α); $E(^3$He$) = 33$ MeV (82KA12).

Table 16.29
^{16}F & ^{16}Ne – General

Reference	Description
Reviews:	
86AN07	Predicted masses & excitation energies in higher isospin multiplets for $9 \leq A \leq 60$
86BA1C	Pion-nucleus double charge exchange: review of LAMPF workshop
87GI1C	Pion-nucleus interactions
88CO15	Thomas-Ehrman shift; charge-symmetric mass relationship calcs. for proton-rich nuclei
Other Articles:	
86CH39	$\pi\Delta$ interaction mechanism comp. with double charge exchange exp. data on $N = Z$ nuclei
86GI13	Nuclear-structure aspects of nonanalog pion double charge exchange
87KA39	Delta-hole approach to pion double charge exchange
87LE1B	Strong interaction studies via meson-nucleus reactions
88GO21	Neutron-excessive nuclei & two-proton radioactivity
88MA27	Non-analog dbl. chrg. exchng. transition: ^{16}O(π^+, π^-)^{16}Ne(g.s.) & ^{12}C(π^+, π^-)^{12}O(g.s.)
89WI1E	Hot proton-proton chains in low-metallicity objects
90LO11	Self-consistent calculations of light nuclei: binding energies & radii
90PO04	Determining masses of light nuclides & quantum characteristics of corresponding nucl.

Table 16.30
Energy levels of ^{16}F [a]

E_x (MeV ± keV)	$J^\pi; T$	$\Gamma_{c.m.}$ (keV)	Decay	Reactions
0	$0^-; 1$	40 ± 20 [b]	p	1–7
0.193 ± 6	1^-	< 40 [b]	p	1, 4, 5, 7
0.424 ± 5	2^-	40 ± 30	p	1, 4, 5, 7
0.721 ± 4	3^-	< 15	p	1, 4, 5, 7
3.758 ± 6	1^+	< 40	p	1, 4, 5, 7
3.870 ± 6	2^+	< 20	p	1, 4, 5, 7
4.372 ± 6	3^+	50 ± 20	p	1, 4, 5, 7
4.654 ± 6	1^+	60 ± 20	p	1, 4, 5, 7
(4.71 ± 20)				7
4.977 ± 8	(2^+)	60 ± 40	p	1, 5, 7
5.272 ± 8	(1^-)		p	1, 4, 5
5.404 ± 10	4		p	1, 5, 7
5.449 ± 14			p	1
5.524 ± 9	$\pi = +$		p	1, 5, 7
(5.57 ± 20)			p	1
5.856 ± 10	2^-		p	1, 4, 5
(6.05 ± 20)				7
6.224 ± 14				1, 4
6.372 ± 9	4^-			1, 4, 5
6.559 ± 10 }	$(3^- + 1^-)$	≤ 45	p	4
6.679 ± 8 }				1, 5, 7
(6.93 ± 20)				7
7.110 ± 20				1
7.50 ± 30	2^-	950 ± 100	p	4, 5
7.90 ± 15		< 100		1, 4, 5
9.50 ± 30	$1^-(+2^-)$	1050 ± 100	p	4, 5
9.60 ± 20		250 ± 50		5
11.50 ± 50	$1^-(+2^-)$	1900 ± 500	p	4, 5

[a] See Table 16.24 in (86AJ04).
[b] (84ST10) report $\Gamma_{c.m.} \sim 25$ and ~ 100 keV for ^{16}F*(0, 0.19).

Table 16.31

^{16}F levels from ^{14}N(^{3}He, n), ^{16}O(p, n), ^{16}O(^{3}He, t) and ^{19}F(^{3}He, ^{6}He) [a]

^{16}F* [b] (MeV ± keV)	L [b]	^{16}F* [c] (MeV ± keV)	J^{π} [d]	^{16}F* [e] (MeV ± keV)	Δl [f]	^{16}F* [g] (MeV ± keV)	^{16}F* [h] (MeV ± keV)	$\Gamma_{c.m.}$ [i] (keV)	J^{π} [j]
0	1	0	(1^-)	0		0	0	40 ± 20	0^-
0.192 ± 15	1	0.190 ± 20	(0^-)	0.197 ± 12		0.19 ± 20	0.192 ± 10	< 40	1^-
0.425 ± 15	3	0.425 ± 10	(≥ 2)	0.424 ± 5	1	0.425 ± 20	0.424	40 ± 30	2^-
0.722 ± 10	(3)	0.725 ± 10	(≥ 2)	0.720 ± 6	3	0.72 ± 20	0.722 ± 10	< 15	3^-
3.751 ± 10	0	3.775 ± 10 [k]	(1)	3.76	0	3.75 ± 20	3.740 ± 15 [n]	< 40	1^+
3.861 ± 10	2	3.880 ± 10 [k]	≥ 1			3.86 ± 20	3.873 ± 15 [n]	< 20	2^+
4.370 ± 10		4.375 ± 10 [k]	(≥ 2)	4.37	2	4.37 ± 20	4.372 [n]	50 ± 20	3^+
4.646 ± 10	0	4.661 ± 10 [k]	≥ 1	4.65	0	4.66 ± 20	4.652 ± 10 [n]	60 ± 20	1^+
						4.71 ± 20 [m]			
4.973 ± 10	2	4.97 ± 20 [l]	≥ 2			4.97 ± 20	5.007 ± 20	60 ± 40	(2^+)
5.264 ± 20		5.27 ± 20 [l]		5.27	1		5.274 ± 10 [n]		(1^-)
5.390 ± 20	2	5.40 ± 20 [l]				5.39 ± 20	5.414 ± 15		4
5.448 ± 20		5.45 ± 20 [l]							
5.528 ± 20	2	5.52 ± 20 [l]				5.53 ± 20	5.521 ± 15		$\pi = ^+$
		(5.57 ± 20) [l]							
5.840 ± 40				5.86	3		5.858 ± 10 [n]		2^-
						6.05 ± 20 [m]			
6.230 ± 50				6.22	0		6.224 ± 15		
6.371 ± 20				6.37	3		6.372 ± 10		4^-
							6.559 ± 10 [n]		
6.678 ± 10		6.68 ± 20 [l]	≥ 1			6.68 ± 20		≤ 45	$(3^- + 1^-)$
						6.93 ± 20 [m]			

Table 16.31

^{16}F levels from ^{14}N(^{3}He, n), ^{16}O(p, n), ^{16}O(^{3}He, t) and ^{19}F(^{3}He, ^{6}He) [a]

^{16}F* [b] (MeV ± keV)	L [b]	^{16}F* [c] (MeV ± keV)	J^{π} [d]	^{16}F* [e] (MeV ± keV)	Δl [f]	^{16}F* [g] (MeV ± keV)	^{16}F* [h] (MeV ± keV)	$\Gamma_{c.m.}$ [i] (keV)	J^{π} [j]
7.110 ± 20									
				∼ 7.5	1		7.50 ± 30 [n,o]	950 ± 100	2^-
7.730 ± 40							7.90 ± 15	< 100	
				∼ 9.5	1		9.50 ± 30 [n,o]	1050 ± 100	$1^- + (2^-)$
							9.60 ± 20	250 ± 50	
				∼ 11.5	1		11.50 ± 50 [n,o]	1900 ± 500	$1^- + (2^-)$

[a] See also Tables 16.33 in (71AJ02) and 16.26 in (82AJ01) for earlier work and for references.
[b] ^{14}N(^{3}He, n)^{16}F.
[c] ^{14}N(^{3}He, np)^{15}O.
[d] From angular correlation studies.
[e] ^{16}O(p, n)^{16}F. E_x shown without uncertainties are from Table 16.30.
[f] (82FA06; E_p = 99.1 and 135.2 MeV).
[g] ^{16}O(^{3}He, t) and ^{19}F(^{3}He, ^{6}He)^{16}F.
[h] ^{16}O(^{3}He, t): (84ST10; $E(^{3}$He) = 81 MeV). See (86AJ04).
[i] From (a) and (84ST10, 85HA01).
[j] From (a) and (84ST10).
[k] See also (85HA01).
[l] (85HA01).
[m] Observed only in ^{19}F(^{3}He, ^{6}He).
[n] Decays to ^{15}O$_{g.s.}$ by proton emission (84ST10).
[o] Decays to ^{15}O*(6.18) (84ST10).

Table 16.32
Energy levels of ^{16}Ne

E_x (MeV $\pm$ keV)	$J^\pi; T$	$\Gamma_{c.m.}$ (keV)	Decay	Reactions
0	$0^+; 2$	122 ± 37	p	1, 2
1.69 ± 0.07	$(2^+); 2$		(p)	2

References

(Closed 31 December 1992)

References are arranged and designated by the year of publication followed by the first two letters of the first-mentioned author's name and then by two additional characters. Most of the references appear in National Nuclear Data Center files and have NNDC key numbers ending in numeric characters. Otherwise, TUNL key numbers were assigned with the last two characters of the form 1A, 1B, etc.

59AJ76 AJZENBERG-SELOVE AND LAURITSEN, NUCL. PHYS. 11 (1959) 1

60WI1A WILKINSON, NUCL. SPECTROSCOPY B, ED. F. AJZENBERG-SELOVE (ACADEMIC PRESS, NY, 1960)

66KE16 KELSON AND GARVEY, PHYS. LETT. 23 (1966) 689

66LA04 LAURITSEN AND AJZENBERG-SELOVE, NUCL. PHYS. 78 (1966) 1

68AJ02 AJZENBERG-SELOVE AND LAURITSEN, NUCL. PHYS. A114 (1968) 1

69AD02 ADELBERGER, MCDONALD AND BARNES, NUCL. PHYS. A124 (1969) 49

70AD1A ADELBERGER, NERO AND MCDONALD, NUCL. PHYS. A143 (1970) 97

70AH02 AHRENS ET AL, PHYS. LETT. B31 (1970) 570

70AJ04 AJZENBERG-SELOVE, NUCL. PHYS. A152 (1970) 1

70DU04 DURAY AND BROWNE, PHYS. REV. C1 (1970) 776

71AJ02 AJZENBERG-SELOVE, NUCL. PHYS. A166 (1971) 1

71BO02 BOHNE ET AL, NUCL. PHYS. A160 (1971) 257

71HA05 HARDY ET AL, PHYS. REV. C3 (1971) 700

71TO08 TOWNER, WARBURTON AND GARVEY, ANN. PHYS. 66 (1971) 674

72AJ02 AJZENBERG-SELOVE, NUCL. PHYS. A190 (1972) 1

73AD1A ADELBERGER, IN PROC. OF THE INT. CONG. ON NUCL. PHYS., FLORENCE, AUGUST-SEPT. 1983, VOL. 2, EDITORS: P. BLASI AND R.A. RICCI; TIPOGRAFIA COMPOSITORI BOLOGNA (1983) 499

74AJ01 AJZENBERG-SELOVE AND LAURITSEN, NUCL. PHYS. A227 (1974) 1

74BO05 BOWMAN ET AL, PHYS. REV. C9 (1974) 836

74MI21 MINAMISONO ET AL, NUCL. PHYS. A236 (1974) 416

74TH01 THIBAULT AND KLAPISCH, PHYS. REV. C9 (1974) 793

75AJ02 AJZENBERG-SELOVE, NUCL. PHYS. A248 (1975) 1

75HA06 HARAKEH, PAUL AND SNOVER, PHYS. REV. C11 (1975) 998

75HA07 HARAKEH, PAUL AND GORODETZKY, PHYS. REV. C11 (1975) 1008

76AJ04 AJZENBERG-SELOVE, NUCL. PHYS. A268 (1976) 1

76AL02 ALBURGER AND WILKINSON, PHYS. REV. C13 (1976) 835

76HI09 HINTERBERGER ET AL, NUCL. PHYS. A263 (1976) 460

76MC11 MC DONALD, ALEXANDER AND HAUSSER, NUCL. PHYS. A273 (1976) 464

77AJ02 AJZENBERG-SELOVE, NUCL. PHYS. A281 (1977) 1

77CH16 CHEW, NUCL. PHYS. A283 (1977) 445

77CH19 CHEW ET AL, NUCL. PHYS. A286 (1977) 451

77MA10 MAIRLE ET AL, NUCL. PHYS. A280 (1977) 97

77MA1B MARTZ ET AL, INT. CONF. NUCL. STRUC., TOKYO (1977) 177

77MC05 MC DONALD ET AL, NUCL. PHYS. A281 (1977) 325

77NO06 NORUM, BERGSTROM AND CAPLAN, NUCL. PHYS. A289 (1977) 275

78AJ03 AJZENBERG-SELOVE, NUCL. PHYS. A300 (1978) 1

78AR15 ARTEMOV ET AL, YAD. FIZ. 28 (1978) 288

77BA59 BALAMUTH ET AL, NUCL. PHYS. A290 (1977) 65

78CH09 CHEW ET AL, NUCL. PHYS. A298 (1978) 19

78CH19 CHEW AND LOWE, NUCL. PHYS. A306 (1978) 125

78CL08 CLARK, KEMPER AND FOX, PHYS. REV. C18 (1978) 1262

78FO27 FORTUNE, MIDDLETON AND BILANIUK, PHYS. REV. C18 (1978) 1920

78GU05 GUICHON ET AL, Z. PHYS. A285 (1978) 183
78GU07 GUICHON, GIFFON AND SAMOUR, PHYS. LETT. B74 (1978) 15
78KE06 KEKELIS ET AL, PHYS. REV. C17 (1978) 1929
78KI01 KIM ET AL, NUCL. PHYS. A297 (1978) 301
78KU1A KUBODERA, DELORME AND RHO, PHYS. REV. LETT. 40 (1978) 755
78LEZA LEDERER AND SHIRLEY, TABLE OF ISOTOPES, JOHN WILEY PUBS. (1978)
78OC01 O'CONNELL AND HANNA, PHYS. REV. C17 (1978) 892
79AJ01 AJZENBERG-SELOVE, NUCL. PHYS. A320 (1979) A
79BR04 BRADLOW ET AL, NUCL. PHYS. A314 (1979) 207
79CL10 CLARK, JOHNSTON AND OPHEL, AUST. J. PHYS. 32 (1979) 283
79CU1A CUJEC, WU AND BARNES, PHYS. LETT. B89 (1979) 151
79EN1A ENDT, AT. NUCL. DATA TABLES 23 (1979) 3
79FO14 FORTUNE ET AL, PHYS. REV. C20 (1979) 1228
79GU06 GUICHON ET AL, PHYS. REV. C19 (1979) 987
79KO26 KOESTER, KNOPF AND WASCHKOWSKI, Z. PHYS. A292 (1979) 95
79MO04 MOYLE ET AL, PHYS. REV. C19 (1979) 631
79SA29 SANDERS, MARTZ AND PARKER, PHYS. REV. C20 (1979) 1743
79SC07 SCHWALLER ET AL, NUCL. PHYS. A316 (1979) 317
79VE02 VENTURA ET AL, PHYS. REV. C19 (1979) 1705
80AJ01 AJZENBERG-SELOVE, NUCL. PHYS. A336 (1980) 1
80BU15 BURLESON ET AL, PHYS. REV. C22 (1980) 1180
80CU08 CUNSOLO ET AL, PHYS. REV. C21 (1980) 2345
80HO13 HOLTKAMP ET AL, PHYS. REV. LETT. 45 (1980) 420
80HO18 HOSONO ET AL, NUCL. PHYS. A343 (1980) 234
80JO1A JOHNSON ET AL, NUCL. CROSS SECTIONS FOR TECH. (NBS) (1980) 807
80JU01 JURY ET AL, PHYS. REV. C21 (1980) 503
80LI05 LINCK, KRAUS AND BLATT, PHYS. REV. C21 (1980) 791
81AJ01 AJZENBERG-SELOVE, NUCL. PHYS. A360 (1981) 1
81CU11 CUNSOLO ET AL, PHYS. REV. C24 (1981) 2127
81HI01 HINTERBERGER ET AL, NUCL. PHYS. A352 (1981) 93
81JA1A JARCZYK ET AL, NUCL. PHYS. A369 (1981) 191
81LI23 LISOWSKI ET AL, PHYS. REV. C24 (1981) 1852
81MA1A MAIRLE ET AL, NUCL. PHYS. A393 (1981) 413
81MUZQ MUGHABGHAB, DIVADEENAM AND HOLDEN, NEUTRON CROSS SECTIONS 1A (1981)
81NA14 NARAYANASWAMY ET AL, PHYS. REV. C24 (1981) 2727
81OV02 OVERWAY ET AL, NUCL. PHYS. A366 (1981) 299
81SA07 SANDORFI ET AL, PHYS. REV. LETT. 46 (1981) 884
81TO16 TOWNER AND KAHANA, NUCL. PHYS. A372 (1981) 331
82AB04 ABDEL-WAHAB ET AL, CAN. J. PHYS. 60 (1982) 1595
82AJ01 AJZENBERG-SELOVE, NUCL. PHYS. A375 (1982) 1
82AR20 ARTEMOV ET AL, SOV. J. NUCL. PHYS. 36 (1982) 779
82AV1A AVERYANOV, GOLUBEV AND SADOVI, SOV. J. NUCL. PHYS. 35 (1982) 484
82BA03 BANGERT ET AL, NUCL. PHYS. A376 (1982) 15
82CH07 CHAN ET AL, PHYS. REV. C25 (1982) 1410
82CUZZ CURTIN, WILDENTHAL AND BROWN, BULL. AM. PHYS. SOC. 27 (1982) 696
82FI10 FIFIELD ET AL, NUCL. PHYS. A385 (1982) 505
82HA1A HAIGHT, PROC. 4TH INT. SYMP. GRENOBLE 1981 (IOP 1982) 510
82HE07 HEUSCH ET AL, PHYS. REV. C26 (1982) 542
82HI01 HICKS, PHYS. REV. C25 (1982) 695
82KA12 KARBAN ET AL, PHYS. LETT. B112 (1982) 433
82KA30 KARADZHEV ET AL, YAD. FIZ. 36 (1982) 308
82KU14 KUEHNER ET AL, PHYS. LETT. B115 (1982) 437
82MA11 MADEY ET AL, PHYS. REV. C25 (1982) 1715

82NE04 NEEDHAM ET AL, NUCL. PHYS. A385 (1982) 349
82OL01 OLNESS ET AL, NUCL. PHYS. A373 (1982) 13
82RE06 REDDER ET AL, Z. PHYS. A305 (1982) 325
82REZZ REES ET AL, BULL. AM. PHYS. SOC. 27 (1982) 509
82VE04 VERMEER AND POLETTI, J. PHYS. G8 (1982) 743
82VE13 VERNOTTE ET AL, NUCL. PHYS. A390 (1982) 285
82WE16 WEST AND SHERWOOD, ANN. NUCL. ENERGY 9 (1982) 551
83AJ01 AJZENBERG-SELOVE, NUCL. PHYS. A392 (1983) 1
83ANZQ ANDO, UNO AND YAMADA, JAERI-M-83-025 (1983)
83AR12 ARTEMOV ET AL, SOV. J. NUCL. PHYS. 37 (1983) 643
83BR11 BRAUN AND FRIED, Z. PHYS. A311 (1983) 173
83BY03 BYRD ET AL, NUCL. PHYS. A410 (1983) 29
83CU02 CUNSOLO ET AL, PHYS. LETT. B124 (1983) 439
83CU04 CUNSOLO ET AL, LETT. NUOVO CIM. 38 (1983) 87
83DA22 DAVE AND GOULD, PHYS. REV. C28 (1983) 2212
83DE1A DETRAZ, NUCL. PHYS. A409 (1983) C353
83GA03 GAGLIARDI ET AL, PHYS. REV. C27 (1983) 1353
83GA18 GAGLIARDI ET AL, PHYS. REV. C28 (1983) 2423
83IN02 INGRAM ET AL, PHYS. REV. C27 (1983) 1578
83KE06 KEMPER ET AL, NUCL. PHYS. A405 (1983) 348
83KO1A KONDRATIEV ET AL, IN MOSCOW (1983) 326
83KU14 KUCHLER ET AL, NUCL. PHYS. A406 (1983) 473
83LE25 LEAVITT ET AL, NUCL. PHYS. A410 (1983) 93
83PUZZ PUGH ET AL, BULL. AM. PHYS. SOC. 28 (1983) 690
83RA1B RANGACHARYULU ET AL, NUCL. PHYS. A406 (1983) 493
83RA29 RANGACHARYULU ET AL, CAN. J. PHYS. 61 (1983) 1486
83SCZR SCHALLER ET AL, BULL. AM. PHYS. SOC. 28 (1983) 997
83SN03 SNOVER ET AL, PHYS. REV. C2 (1983) 1837
83TRZZ TRAIL ET AL, BULL. AM. PHYS. SOC. 28 (1983) 658
83WA29 WATSON ET AL, NUCL. INSTRUM. METHODS PHYS. RES. 215 (1983) 413
83WO01 WOODWARD, TRIBBLE AND TANNER, PHYS. REV. C27 (1983) 27
84AJ01 AJZENBERG-SELOVE, NUCL. PHYS. A413 (1984) 1
84AM04 AMOS ET AL, NUCL. PHYS. A413 (1984) 255
84AS03 ASHER ET AL, J. PHYS. G10 (1984) 1079
84BA24 BARKER, AUST. J. PHYS. 37 (1984) 17
84BI03 BILLOWES ET AL, NUCL. PHYS. A413 (1984) 503
84BL17 BLILIE ET AL, PHYS. REV. C30 (1984) 1989
84BR03 BRADY ET AL, J. PHYS. G10 (1984) 363
84CA39 CARDELLA ET AL, LETT. NUOVO CIM. 41 (1984) 429
84DA18 DARDEN ET AL, NUCL. PHYS. A429 (1984) 218
84DE1A DE BIEVRE ET AL, J. PHYS. CHEM. REF. DATA 13 (1984) 809
84GA1A GARVEY, PROC. INTL. SYMP. AT OSAKA, WORLD SCIENTIFIC (1984) 193
84HO17 HOSONO ET AL, PHYS. REV. C30 (1984) 746
84NE1A NEMETS, RUDCHIK AND CHUVILSKI, PROC. 34TH MTG. NUCL. SPECTROSCOPY STRUC. AT. NUCL., ALMA ATA, USSR, NAUKA (1984) 334
84ST10 STERRENBURG ET AL, NUCL. PHYS. A420 (1984) 257
84VA06 VAN HEES AND GLAUDEMANS, Z. PHYS. A315 (1984) 223
84WA07 WARBURTON, ALBURGER AND MILLENER, PHYS. REV. C29 (1984) 2281
85AD1A ADELBERGER AND HAXTON, ANN. REV. NUCL. PART. SCI. 35 (1985) 501
85AJ01 AJZENBERG-SELOVE, NUCL. PHYS. A449 (1985) 1
85AN28 ANTONY ET AL, AT. DATA NUCL. DATA TABLES 33 (1985) 447
85BE1A BECKERMAN, PHYS. REP. 129 (1985) 145
85BE31 HEIDELBERG-SACLAY COLLABORATION, PHYS. LETT. B158 (1985) 19
85BLZZ BLAND ET AL, BULL. AM. PHYS. SOC. 30 (1985) 1163

85BO1A BOAL, ADV. NUCL. PHYS. 15 (1985) 85
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85HA01 HAMANN, NUCL. PHYS. A433 (1985) 198
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85HY1A HYDE-WRIGHT, PH.D. THESIS (1985) 1
85JA17 JARJIS, NUCL. INSTRUM. METHODS PHYS. RES. B12 (1985) 331
85JU02 JURY ET AL, PHYS. REV. C32 (1985) 1817
85KH10 KHALIL, SHALABY AND EL-KERIEM, FIZIKA 17 (1985) 465
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85PO10 POPPELIER, WOOD AND GLAUDEMANS, PHYS. LETT. B157 (1985) 120
85PU1A PUGH, MIT, PH.D. THESIS (1985)
85SH1A SHITIKOVA, SOV. J. PART. AND NUCL. 16 (1985) 364
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85VA1A VAN DER WERF, HARAKEH AND STERRENBURG, KVI-582 (1985)
85VO12 VON REDEN ET AL, PHYS. REV. C32 (1985) 1465
85WA02 WAPSTRA AND AUDI, NUCL. PHYS. A432 (1985) 1
85WA24 WATSON ET AL, PHYS. REV. LETT. 55 (1985) 1369
86AB06 ABUL-MAGD, FRIEDMAN AND HUFNER, PHYS. REV. C34 (1986) 113
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86AJ04 AJZENBERG-SELOVE, NUCL. PHYS. A460 (1986) 1
86AL22 ALTMAN ET AL, PHYS. REV. C34 (1986) 1757
86AL25 ALEKLETT ET AL, PHYS. SCR. 34 (1986) 489
86ALZN ALLCOCK ET AL, INT. CONF. NUCL. PHYS., HARROGATE, UK, IOP (1986) 46
86AN07 ANTONY, BRITZ AND PAPE, AT. DATA NUCL. DATA TABLES 34 (1986) 279
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86AN30 ANDREWS ET AL, NUCL. PHYS. A459 (1986) 317
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86AV1A AVDEICHIKOV ET AL, SOV. J. NUCL. PHYS. 44 (1986) 282
86AY01 AYOUB, J. PHYS. G12 (1986) 859
86BA13 BAYMAN ET AL, NUCL. PHYS. A452 (1986) 513
86BA1C BAER AND MILLER, COMMENTS NUCL. PART. PHYS. 15 (1986) 269
86BA1D BARRETTE, J. PHYSIQUE 47 (1986) C4
86BA1E BAUR AND BERTULANI, PHYS. REV. C34 (1986) 1654
86BA1H BANDO, CZECH. J. PHYS. 36 (1986) 915
86BA1M BABA ET AL, NUCL. DATA FOR BASIC & APPLIED SCIENCE, EDITED BY P.G. YOUNG, PUBL. GORDON & BREACH (1986) 223
86BA1N BAUHOFF, AT. DATA NUCL. DATA TABLES 35 (1986) 429
86BA50 BAUR, BERTULANI AND REBEL, NUCL. PHYS. A458 (1986) 188
86BA69 BAYE, NUCL. PHYS. A460 (1986) 581
86BA78 BANG ET AL, PHYS. SCR. 34 (1986) 541
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86BE1F BERGE AND AMOS, PROC. 11TH AINSE NUCL. PHYS. CONF. AT MELBOURNE (1986) 19
86BE22 BENHAR AND CLERI, PHYS. REV. C34 (1986) 1134
86BE23 BENHAR ET AL, PHYS. LETT. B177 (1986) 135
86BE35 BELOZYOROV ET AL, NUCL. PHYS. A460 (1986) 352
86BE42 BERDNIKOV ET AL, SOV. J. NUCL. PHYS. 44 (1986) 562
86BI1A BIMBOT ET AL, J. PHYSIQUE 47 (1986) C4-241
86BL04 BLUMEL AND DIETRICH, NUCL. PHYS. A454 (1986) 691
86BL08 BLATT ET AL, PHYS. REV. LETT. 57 (1986) 819
86BO1A BOIKOVA ET AL, SOV. J. NUCL. PHYS. 43 (1986) 173
86BO1B BOGDANOV ET AL, JETP LETT. 44 (1986) 391
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86BR23 BRAGIN, SOV. J. NUCL. PHYS. 44 (1986) 61
86BR25 BRANDAN ET AL, PHYS. REV. C34 (1986) 1484
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86BU02 BUTI ET AL, PHYS. REV. C33 (1986) 755
86CA19 CATFORD ET AL, NUCL. INSTRUM. METHODS PHYS. RES. A247 (1986) 367
86CA24 CARRAGHER ET AL, NUCL. PHYS. A460 (1986) 341
86CA27 CARCHIDI, WILDENTHAL AND BROWN, PHYS. REV. C34 (1986) 2280
86CE04 CERNIGOI ET AL, NUCL. PHYS. A456 (1986) 599
86CH1I CHRIEN, AIP CONF. PROC. 150 (1986) 325
86CH1J CHANT, AIP CONF. PROC. 142 (1986) 246
86CH20 CHAUDHURI AND SINHA, NUCL. PHYS. A455 (1986) 169
86CH27 CHITWOOD ET AL, PHYS. REV. C34 (1986) 858
86CH38 CHAUDHURI, NUCL. PHYS. A459 (1986) 417
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86CH41 CHAPURAN ET AL, PHYS. REV. C34 (1986) 2358
86CH44 CHRISTOV, DELCHEV AND SHITIKOVA, BULG. J. PHYS. 13 (1986) 26
86CL03 CLARKE AND COOK, NUCL. PHYS. A458 (1986) 137
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86CO28 COOPER AND MATSUYAMA, NUCL. PHYS. A460 (1986) 699
86CU01 CURTIN ET AL, PHYS. REV. LETT. 56 (1986) 34
86CU02 CUJEC ET AL, NUCL. PHYS. A453 (1986) 505
86DE11 DESPLANQUES AND NOGUERA, PHYS. LETT. B173 (1986) 23
86DE15 DEUTCHMAN, NORBURY AND TOWNSEND, NUCL. PHYS. A454 (1986) 733
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86DE40 DENG AND CHEN, CHIN. J. NUCL. PHYS. 8 (1986) 207
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86DR03 DRUMM ET AL, NUCL. PHYS. A448 (1986) 93
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86DU15 DUBAR ET AL, IZV. AKAD. NAUK SSSR SER. FIZ. 50 (1986) 2034
86ED03 EDEN AND ASSAFIRI, AUST. J. PHYS. 39 (1986) 871
86EK1A EKUNI ET AL, REP. JOINT SEMINAR ON HEAVY-ION NUCL. PHYS. AND NUCL. CHEM., JAERI (1986) 48

86ESZV ESWARAN ET AL, INT. CONF. NUCL. PHYS., HARROGATE, UK, IOP (1986) 271
86FA1A FAESSLER ET AL, J. PHYSIQUE 47 (1986) C4
86FI1A FILIMONOV, CZECH. J. PHYS. 36 (1986) 431
86FI1B FILIPPONE, ANN. REV. NUCL. PART. SCI. 36 (1986) 717
86FR04 FREEMAN ET AL, PHYS. REV. C33 (1986) 1275
86FR10 FRIEDMAN AND LICHTENSTADT, NUCL. PHYS. A455 (1986) 573
86FR20 FRIEDMAN, KALBERMANN AND BATTY, PHYS. REV. C34 (1986) 2244
86FU1B FURNSTAHL, AIP CONF. PROC. 142 (1986) 376
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86GA13 GAZIS ET AL, PHYS. REV. C34 (1986) 872
86GA14 GAL AND KLIEB, PHYS. REV. C34 (1986) 956
86GA1H GAL, AIP CONF. PROC. 150 (1986) 127
86GA1I GAARDE, INT. CONF. NUCL. PHYS., HARROGATE, UK, IOP (1986) 173
86GA24 GAY, DENNIS AND FLETCHER, PHYS. REV. C34 (1986) 2144
86GA31 GAREEV ET AL, IZV. AKAD. NAUK SSSR SER. FIZ. 50 (1986) 865
86GI13 GILMAN ET AL, PHYS. REV. C34 (1986) 1895
86GI15 GILAD ET AL, PHYS. REV. LETT. 57 (1986) 2637
86GL1A GLAUDEMANS, AIP CONF. PROC. 142 (1986) 316
86GM02 GMITRO AND OVCHINNIKOVA, CZECH. J. PHYS. 36 (1986) 390
86GO16 CONCHAR ET AL, SOV. J. NUCL. PHYS. 43 (1986) 907
86GU05 GULKAROV AND VAKIL, SOV. J. NUCL. PHYS. 43 (1986) 515
86GU1C GUPTA, MALIK AND SULTANA, IN HEIDELBERG (1986) 55
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86HA1B HARVEY, J. PHYSIQUE 47 (1986) C4-29
86HA1E HARNEY, RICHTER AND WEIDENMULLER, REV. MOD. PHYS. 58 (1986) 607
86HA1F HAAS ET AL, INT. CONF. NUCL. PHYS., HARROGATE, UK, IOP (1986) C184
86HA26 HAUSMANN AND WEISE, Z. PHYS. A324 (1986) 355
86HA30 HARAKEH ET AL, PHYS. LETT. B176 (1986) 297
86HA39 HALDERSON, NING AND PHILPOTT, NUCL. PHYS. A458 (1986) 605
86HE1A HE ET AL, INT. CONF. NUCL. PHYS., HARROGATE, UK, IOP (1986) C51
86HE26 HEFTER AND MITROPOLSKY, NUOVO CIM. A95 (1986) 63
86HI07 HINO, J. PHYS. G12 (1986) L255
86HO18 HODGSON, CAN. J. PHYS. 64 (1986) 653
86HO33 HORIUCHI, WADA AND YABANA, PROG. THEOR. PHYS. 76 (1986) 837
86HU1A HUBERT ET AL, J. PHYSIQUE 47 (1986) C4-229
86IK03 IKEZOE ET AL, NUCL. PHYS. A456 (1986) 298
86IS04 ISERI AND KAWAI, PHYS. REV. C34 (1986) 38
86IS09 ISHKHANOV, KAPITONOV AND MOKEEV, IZV. AKAD. NAUK SSSR SER. FIZ. 50 (1986) 1974
86JE1A JEAN ET AL, INT. CONF. NUCL. PHYS., HARROGATE, UK, IOP (1986) C179
86KA1A KAWAI, KAMIMURA AND TAKESAKO, PROG. THEOR. PHYS. SUPPL. 89 (1986) 118
86KA1B KAMIMURA ET AL, PROG. THEOR. PHYS. SUPPL. 89 (1986) 1
86KE15 KENNETT, PRESTWICH AND TSAI, NUCL. INSTRUM. METHODS PHYS. RES. A247 (1986) 420
86KH1A KHUBEIS, BULL. AM. PHYS. SOC. 31 (1986) 1285
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86KI1D KISHIMOTO, AIP CONF. PROC. 150 (1986) 921
86KL06 KLEINWACHTER AND ROTTER, J. PHYS. G12 (1986) 821
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86KO22 KOHLER ET AL, PHYS. LETT. B176 (1986) 327
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86KU15 KUDO AND MIYAZAKI, PHYS. REV. C34 (1986) 1192
86KY1A KYLE ET AL, BULL. AM. PHYS. SOC. 31 (1986) 1204
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86LE22 LEEB AND SCHMID, FEW-BODY SYST. 1 (1986) 203
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86LI1B LIU AND HAIDER, AIP CONF. PROC. 150 (1986) 930
86LI1C LINDGREN ET AL, AIP CONF. PROC. 142 (1986) 133
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86MA13 MATEJA ET AL, PHYS. REV. C33 (1986) 1307
86MA16 MARTOFF ET AL, CZECH. J. PHYS. 36 (1986) 378
86MA19 MATEJA ET AL, PHYS. REV. C33 (1986) 1649
86MA1C MAJLING ET AL, NUCL. PHYS. A450 (1986) 189C
86MA1E MATTEUCCI, ASTROPHYS. J. 305 (1986) L81
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86MA1O MACDONALD ET AL, INT. CONF. NUCL. PHYS., HARROGATE, UK, IOP (1986) C214
86MA32 MATSUOKA ET AL, NUCL. PHYS. A455 (1986) 413
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86MA48 MANLEY ET AL, PHYS. REV. C34 (1986) 1214
86MAZE MAVROMATIS, INT. CONF. NUCL. PHYS., HARROGATE, UK, IOP (1986) 191
86MC10 MC DONALD ET AL, NUCL. PHYS. A456 (1986) 577
86MC13 MCNEIL ET AL, PHYS. REV. C34 (1986) 746
86ME06 MERMAZ ET AL, NUCL. PHYS. A456 (1986) 186
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86MEZX MEIRAV ET AL, INT. CONF. NUCL. PHYS., HARROGATE, UK, IOP (1986) A2
86MI22 MILEK AND REIF, NUCL. PHYS. A458 (1986) 354
86MI24 MIKULAS ET AL, NUOVO CIM. A93 (1986) 135
86MO1A MOTOBA, CZECH. J. PHYS. 36 (1986) 435
86MO27 MOTOBAYASHI ET AL, PHYS. REV. C34 (1986) 2365
86MU1A MUSKET, BULL. AM. PHYS. SOC. 31 (1986) 1294
86NA14 NAVARRO AND KRIVINE, NUCL. PHYS. A457 (1986) 731
86NA1B NAMBOODIRI ET AL, J. PHYSIQUE 47 (1986) C4-101
86NU01 NURZYNSKI ET AL, J. PHYS. G12 (1986) 383
86NU1A NURZYNSKI ET AL, PROC. 11TH AINSE NUCL. PHYS. CONF. AT MELBOURNE (1986) 26
86OR03 ORLANDINI, TRAINI AND ERICSON, PHYS. LETT. 179B (1986) 201
86OR1A O'REILLY AND THOMPSON, 11TH AINSE NUCL. PHYS. CONF. IN MELBOURNE (1986) 56
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86OS03 OSET AND VICENTE-VACAS, NUCL. PHYS. A454 (1986) 637
86OS08 OSTROUMOV, LOSHCHAKOV AND VDOVIN, IZV. AKAD. NAUK SSSR SER. FIZ. 50 (1986) 916
86OU01 OUICHAOUI ET AL, NUOVO CIM. A94 (1986) 133
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86PE1E PETROVICH, CARR AND MC MANUS, ANN. REV. NUCL. PART. SCI. 36 (1986) 29

86PE1G PETRASCU ET AL, STUD. CERCET. FIZ. 38 (1986) 825
86PE22 PERRY, PHYS. LETT. B182 (1986) 269
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86PO06 POENARU ET AL, AT. DATA NUCL. DATA TABLES 34 (1986) 423
86PO14 POTOKAR AND RAMSAK, PHYS. REV. C34 (1986) 2338
86PO1D POYARKOV AND SIZOV, PROC. 36TH MTG. NUCL. SPECTROSCOPY STRUC. AT. NUCL., KHARKOV, USSR, NAUKA (1986) 275
86QU1A QIU, ZHANG AND HUANG, SCI. SIN. A29 (1986) 1283
86RAZI RAE, KEELING AND ALLCOCK, INT. CONF. NUCL. PHYS., HARROGATE, UK, IOP (1986) 227
86RO1C RONDON ET AL, NUCL. DATA FOR BASIC & APPLIED SCIENCE, EDITED BY P.G. YOUNG, PUBL. GORDON & BREACH (1986) 763
86RO1F ROMERO, BRADY AND SUBRAMANIAN, NUCL. DATA FOR BASIC & APPLIED SCIENCE, EDITED BY P.G. YOUNG, PUBL. GORDON & BREACH (1986) 687
86RO23 ROHMANN ET AL, Z. PHYS. A325 (1986) 261
86RO26 ROTTER, J. PHYS. G12 (1986) 1407
86RYZZ RYBARCYK ET AL, BULL. AM. PHYS. SOC. 31 (1986) 1209
86SA1D SAKURAGI, YAHIRO AND KAMIMURA, PROG. THEOR. PHYS. SUPPL. 89 (1986) 136
86SA24 SAMANTA ET AL, PHYS. REV. C34 (1986) 1610
86SA25 SANDERS ET AL, PHYS. REV. C34 (1986) 1746
86SA30 SATO AND OKUHARA, PHYS. REV. C34 (1986) 2171
86SC28 SCHOLZ, RICKEN AND KUHLMANN, Z. PHYS. A325 (1986) 203
86SC29 SCHMIDT ET AL, PHYS. LETT. B180 (1986) 9
86SCZX SCHUMACHER ET AL, BULL. AM. PHYS. SOC. 31 (1986) 1220
86SH10 SHIMOURA ET AL, NUCL. PHYS. A452 (1986) 123
86SH1F SHEN ET AL, CHIN. PHYS. 6 (1986) 80
86SH25 SHIVAKUMAR ET AL, PHYS. REV. LETT. 57 (1986) 1211
86SHZY SHIVAKUMAR ET AL, BULL. AM. PHYS. SOC. 31 (1986) 1111
86SI11 SICILIANO ET AL, PHYS. REV. C34 (1986) 267
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86SM1A SMITH AND LAMBERT, ASTROPHYS. J. 311 (1986) 843
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86SO10 SOBOTKA ET AL, PHYS. REV. C34 (1986) 917
86ST13 STOITSOV, PETKOV AND SIMITROVA, IZV. AKAD. NAUK SSSR SER. FIZ. 50 (1986) 2071
86ST1A STEADMAN AND RHOADES-BROWN, ANN. REV. NUCL. PART. SCI. 36 (1986) 649
86SU06 SUZUKI AND HECHT, NUCL. PHYS. A455 (1986) 315
86SU13 SUZUKI AND OKAMOTO, PROG. THEOR. PHYS. 75 (1986) 1388
86SU15 SUBRAMANIAN ET AL, PHYS. REV. C34 (1986) 1580
86SU16 SUZUKI AND OKAMOTO, PROG. THEOR. PHYS. 76 (1986) 127
86SU1G SUGIMITSU ET AL, JAERI (1986) 74
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86TK01 TKACHEV, IZV. AKAD. NAUK SSSR SER. FIZ. 50 (1986) 1949
86TO13 TOMASELLI, BECK AND RICHTER, NUCL. PHYS. A459 (1986) 279
86TO14 TOHYAMA AND MOSEL, NUCL. PHYS. A459 (1986) 711
86TO16 TONDEUR, BERDICHEVSKY AND FARINE, Z. PHYS. A325 (1986) 405
86TO1A TOWNER, CZECH. J. PHYS. 36 (1986) 360
86TO1D TOWNER, ANN. REV. NUCL. PART. SCI. 36 (1986) 115
86TOZQ TOWNER, INT. CONF. NUCL. PHYS., HARROGATE, UK, IOP (1986) D6
86TR1C TRURAN AND LIVIO, ASTROPHYS. J. 308 (1986) 721
86UM02 UMAR, STRAYER AND REINHARD, PHYS. REV. LETT. 56 (1986) 2793
86VA18 VAN ENGELEN ET AL, Z. PHYS. A324 (1986) 121
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86VD04 VDOVIN ET AL, IZV. AKAD. NAUK SSSR SER. FIZ. 50 (1986) 936
86VD1C VDOVIN ET AL, PROC. 36TH MTG. NUCL. SPECTROSCOPY STRUC. AT. NUCL., KHARKOV, USSR, NAUKA (1986) 290
86VI08 VITTURE AND DASSO, NUCL. PHYS. A458 (1986) 157
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86VO10 VON REDEN ET AL, PHYS. REV. C34 (1986) 375
86WA1C WADA, INT. CONF. NUCL. PHYS., HARROGATE, UK, IOP (1986) C189
86WA1D WALECKA, INT. CONF. NUCL. PHYS., HARROGATE, UK, IOP (1986) 285
86WAZM WADA AND HORIUCHI, INT. CONF. NUCL. PHYS., HARROGATE, UK, IOP (1986) 376
86WE1B WEIGMANN, NUCL. DATA FOR BASIC & APPLIED SCIENCE, EDITED BY P.G. YOUNG, PUBL. GORDON & BREACH (1986) 853
86WH03 WHISNANT, PHYS. REV. C34 (1986) 262
86WO1A WOOSLEY AND WEAVER, ANN. REV. ASTRON. ASTROPHYS. 24 (1986) 205
86WU03 WU, CHIN. J. NUCL. PHYS. 8 (1986) 147
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86YA16 YAMAGUCHI, NAGATA AND MICHIYAMA, PROG. THEOR. PHYS. 76 (1986) 1289
86YA1B YAZICI AND IRVINE, INT. CONF. NUCL. PHYS., HARROGATE, UK, IOP (1986) B144
86YE1A YE ET AL, CHIN. PHYS. 6 (1986) 139
86YE1B YE AND VAN SEN, J. PHYS. SOC. JPN. SUPPL. 55 (1986) 948
86ZA06 ZAVARZINA AND STEPANOV, SOV. J. NUCL. PHYS. 43 (1986) 543
86ZA1A ZAIKOV ET AL, NUCL. INSTRUM. METHODS PHYS. RES. B17 (1986) 97
86ZE1B ZELENSKAYA ET AL, PROC. 36TH MTG. NUCL. SPECTROSCOPY STRUC. AT. NUCL., KHARKOV, USSR, NAUKA (1986) 335
86ZI08 ZIJDERHAND AND VAN DER LEUN, NUCL. PHYS. A460 (1986) 181
87AB03 ABELE ET AL, Z. PHYS. A326 (1987) 373
87AB21 ABOUZI ET AL, NUOVO CIM. A97 (1987) 753
87AD04 ADACHI AND VON GERAMB, NUCL. PHYS. A470 (1987) 461
87AD1A ADAMS AND TYLKA, BULL. AM. PHYS. SOC. 32 (1987) 1066
87AG1A AGAKISHIEV ET AL, SOV. J. NUCL. PHYS. 45 (1987) 852
87AJ02 AJZENBERG-SELOVE, NUCL. PHYS. A475 (1987) 1
87AL1B ALTAS, ASTROPHYS. SPACE SCI. 134 (1987) 85
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88AL1K AL-KOFAHI ET AL, BULL. AM. PHYS. SOC. 33 (1988) 1730
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88AY03 AYIK, SHAPIRA AND SHIVAKUMAR, PHYS. REV. C38 (1988) 2610
88AZZZ AZIZ ET AL, BULL. AM. PHYS. SOC. 33 (1988) 961
88BA15 BAYE AND DESCOUVEMONT, NUCL. PHYS. A481 (1988) 445
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88BE1D BECCHETTI ET AL, 5TH INTL. CONF. ON CLUSTERING IN NUCLEI (KYOTO, JAPAN 1988)
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88BE57 BEREZHNOY, MIKHAJLUK AND PILIPENKO, IZV. AKAD. NAUK SSSR 52 (1988) 2185
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88BL10 BLUNDEN AND MCCORQUODALE , PHYS. REV. C38 (1988) 1861
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88BO10 BOZZOLO, CIVITARESE AND VARY, PHYS. REV. C37 (1988) 1240
88BO13 BORDERIE ET AL, PHYS. LETT. B205 (1988) 26
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88BO39 BORGE ET AL, NUCL. PHYS. A490 (1988) 287
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88BR04 BRANDAN, PHYS. REV. LETT. 60 (1988) 784
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88CA07 CAVINATO, MARAGONI AND SARUIS, Z. PHYS. A239 (1988) 463
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88CIZZ CISKOWSKI ET AL, BULL. AM. PHYS. SOC. 33 (1988) 1583
88CL03 CLAUSEN, PETERSON AND LINDGREN, PHYS. REV. C38 (1988) 589
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88CO1G CO ET AL, NUCL. PHYS. A485 (1988) 463
88CS01 CSEH AND LEVAI, PHYS. REV. C38 (1988) 972
88CU1A CUMMINGS, CHRISTIAN AND STONE, BULL. AM. PHYS. SOC. 33 (1988) 1069
88DA11 DATTA ET AL, J. PHYS. G14 (1988) 937
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88DE1A DEYOUNG ET AL, BULL. AM. PHYS. SOC. 33 (1988) 928
88DE22 DE BOER ET AL, J. PHYS. G14 (1988) L131
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88ER04 ERNST AND DHUGA, PHYS. REV. C37 (1988) 2651
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88FE1A FERRANDO ET AL, PHYS. REV. C37 (1988) 1490
88FEZX FELDMAN ET AL, BULL. AM. PHYS. SOC. 33 (1988) 1570
88FI01 FIASE ET AL, J. PHYS. G14 (1988) 27
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88FR14 FRICKE, BRANDAN AND MCVOY, PHYS. REV. C38 (1988) 682
88FR15 FREEMAN ET AL, PHYS. REV. C38 (1988) 1081
88FR19 FRISCHKNECHT ET AL, PHYS. REV. C38 (1988) 1996
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88FU02 FUNCK AND LANGANKE, NUCL. PHYS. A480 (1988) 188
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88GA11 GAZES ET AL, PHYS. LETT. B208 (1988) 194
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88GA1A GAL, NUCL. PHYS. A479 (1988) 97C
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88GN1A GNADE, BULL. AM. PHYS. SOC. 33 (1988) 1759
88GO11 GOMEZ DEL CAMPO ET AL, PHYS. REV. LETT. 61 (1988) 290
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88GR1E GRAM, AIP CONF. PROC. 163 (1988) 79
88GR32 GRIDNEV, SUBBOTIN AND FADEEV, IZV. AKAD. NAUK SSSR 52 (1988) 2262
88GU03 GUL'KAROV, MANSUROV AND KHOMICH, SOV. J. NUCL. PHYS. 47 (1988) 25
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88GU14 GULKAROV AND MANSUROV, IZV. AKAD. NAUK SSSR 52 (1988) 878
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88HA22 HAXTON, PHYS. REV. C37 (1988) 2660
88HA2A HASSANI ET AL, HELV. PHYS. ACTA 61 (1988) 1130
88HA41 HAYANO, NUCL. PHYS. A478 (1988) 113C
88HAZS HARMON ET AL, BULL. AM. PHYS. SOC. 33 (1988) 1572
88HE06 HEBBARD ET AL, NUCL. PHYS. A481 (1988) 161
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88HU02 HUBER ET AL, PHYS. REV. C37 (1988) 215
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88HYZY HYMAN ET AL, BULL. AM. PHYS. SOC. 33 (1988) 1607
88HYZZ HYMAN ET AL, BULL. AM. PHYS. SOC. 33 (1988) 902
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88IM02 IMANISHI, MISONO AND VON OERTZEN, PHYS. LETT. B210 (1988) 35
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88JA09 JASSELETTE, CUGNON AND VANDERMEULEN, NUCL. PHYS. A484 (1988) 542
88JA14 JARCZYK ET AL, ACTA PHYS. POL. B19 (1988) 951
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88JU02 JULIEN ET AL, Z. PHYS. A330 (1988) 83
88KA08 KALANTAR-NAYESTANAKI ET AL, PHYS. REV. LETT. 60 (1988) 1707
88KA13 KABIR, KERMODE AND ROWLEY, NUCL. PHYS. A481 (1988) 94
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88KA1Z KATO, FUKATSU AND TANAKA, PROG. THEOR. PHYS. 80 (1988) 663
88KA39 KAYUMOV, MUKHAMEDZHANOV AND YARMUKHAMEDOV, SOV. J. NUCL. PHYS. 48 (1988) 268
88KE07 KEMPER ET AL, PHYS. REV. C38 (1988) 2664
88KH01 KHANKHASAYEV AND SAPOZHNIKOV, PHYS. LETT. B201 (1988) 17
88KH1B KHAN ET AL, BULL. AM. PHYS. SOC. 33 (1988) 963
88KI02 KITAZAWA AND IGASHIRA, J. PHYS. G14 (1988) S215

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88KO18 KOESTER ET AL, Z. PHYS. A330 (1988) 387
88KO1S KOWALSKI, PROC. INTL. SYMPOSIUM ON MODERN DEVELOPMENTS IN NUCL. PHYS., NOVOSIBIRSK, USSR, 1987 (WORLD SCI. 1988), P. 391
88KO1U KOVAR ET AL, PROC. TEXAS A&M SYMPOSIUM ON HOT NUCLEI 1987 (SINGAPORE: WORLD SCI. 1988), P. 392
88KO23 KOHMURA, OHNAKA AND GILLET, NUCL. PHYS. A486 (1988) 253
88KO27 KOBOS, BRANDAN AND SATCHLER, NUCL. PHYS. A487 (1988) 457
88KR09 KRIVINE ET AL, NUCL. PHYS. A481 (1988) 781
88KR11 KRAUS ET AL, PHYS. REV. C37 (1988) 2529
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88LI13 LIPPARINI AND STRINGARI, NUCL. PHYS. A482 (1988) 205C
88LI1O LI, HIGH ENERGY PHYS. NUCL. PHYS.12 (1988) 501
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88LO07 LOTZ AND SHERIF, PHYS. LETT. B210 (1988) 45
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88MA05 MACKINTOSH, COOPER AND IOANNIDES, NUCL. PHYS. A476 (1988) 287
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88MA09 MATSUYAMA AND YAZAKI, NUCL. PHYS. A477 (1988) 673
88MA1G MAJLING ET AL, PHYS. LETT. B202 (1988) 489
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88MA31 MACKINTOSH, IOANNIDES AND COOPER, NUCL. PHYS. A483 (1988) 195
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88MA53 MAIRLE, KNOPFLE AND SEEGER, NUCL. PHYS. A490 (1988) 371
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88MC03 MCDERMOTT ET AL, PHYS. REV. LETT. 61 (1988) 814
88MCZT MCLANE, DUNFOR AND ROSE, NEUTRON CROSS SECTIONS, VOL. 2, NEUTRON CROSS SECTION CURVES (ACADEMIC PRESS, INC. 1988)
88ME09 MERCHANT AND ISIDRO FILHO, PHYS. REV. C38 (1988) 1911
88ME1H MENCHACA-ROCHA ET AL, PROC. TEXAS A & M SYMPOSIUM ON HOT NUCLEI 1987 (SINGAPORE: WORLD SCI. 1988), P. 479
88MEZX MELLEMA ET AL, BULL. AM. PHYS. SOC. 33 (1988) 1570
88MI1I MISHRAM, SATPATHY AND SATPATHY, J. PHYS. G14 (1988) 1115
88MI1J MILLENER, AIP CONF. PROC. 163 (1988) 402
88MI1N MILLENER, DOVER AND GAL, PHYS. REV. C38 (1988) 2700
88MI25 MILEK AND REIF, SOV. J. NUCL. PHYS. 48 (1988) 237
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88MU08 MUELLER ET AL, Z. PHYS. A330 (1988) 63
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88OS05 OSMAN, ANN. PHYS. 45 (1988) 379
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88OT04 OTTENSTEIN, WALLACE AND TJON, PHYS. REV. C38 (1988) 2272
88OT05 OTTENSTEIN, WALLACE AND TJON, PHYS. REV. C38 (1988) 2289
88PA05 PACHECO, MAGLIONE AND BROGLIA, PHYS. REV. C37 (1988) 2257
88PA1H PACHECO AND MACHADO, ASTRON. J. 96 (1988) 365
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88PR05 PRICE AND WALKER, PHYS. REV. C38 (1988) 2860
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88RE1A REINHARD ET AL, PHYS. REV. C37 (1988) 1026
88RE1E REAMES, ASTROPHYS. J. 330 (1988) L71
88RO01 ROUSSEL-CHOMAS ET AL, NUCL. PHYS. A477 (1988) 345
88RO09 ROTTER, J. PHYS. G14 (1988) 857
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88RY03 RYCKEBUSCH ET AL, NUCL. PHYS. A476 (1988) 237
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88SA1B SALTZBERG ET AL, BULL. AM. PHYS. SOC. 33 (1988) 988
88SA24 SALCEDO ET AL, NUCL. PHYS. A484 (1988) 557
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88SAZY SAHA ET AL, BULL. AM. PHYS. SOC. 33 (1988) 1022
88SC14 SCHUMACHER ET AL, PHYS. REV. C38 (1988) 2205
88SE11 SEVERIJNS ET AL, HYPERFINE INTERACT. 43 (1988) 415
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88SEZU SEIFERT ET AL, BULL. AM. PHYS. SOC. 33 (1988) 1570
88SH03 SHIVAKUMAR ET AL, PHYS. REV. C37 (1988) 652
88SH05 SHARMA, JAIN AND SHYAM, PHYS. REV. C37 (1988) 873
88SH07 SHEPARD ET AL, PHYS. REV. C37 (1988) 1130
88SH1E SHVEDOV, NEMETS AND RUDCHIK, PROC. 38TH MTG. NUCL. SPECTROSCOPY STRUC. AT. NUCL., BAKU, USSR, NAUKA (1988) 351
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88TA1P TANG AND ZHENG, HIGH ENERGY PHYS. NUCL. PHYS. 12 (1988) 455
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88TE03 TERLAU ET AL, Z. PHYS. A330 (1988) 303
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88THZZ THIEL ET AL, BULL. AM. PHYS. SOC. 33 (1988) 1562
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88TO1C TOWNER, AIP CONF. PROC. 164 (1988) 593
88TRZY TRCKA ET AL, BULL. AM. PHYS. SOC. 33 (1988) 1101
88TRZZ TRICE ET AL, BULL. AM. PHYS. SOC. 33 (1988) 1023
88UM1A UMEZAWA ET AL, NUCL. INSTRUM. METHODS PHYS. RES. B33 (1988) 634
88UT02 UTSUNOMIYA AND SCHMITT, NUCL. PHYS. A487 (1988) 162
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88WA1E WARBURTON, INTERACTIONS AND STRUCTURES IN NUCLEI, PROC. IN HONOR OF D.H. WILKINSON, SUSSEX, 9/87; ADAM HILGER PUBL. (1988) P. 81
88WA31 WADA AND HORIUCHI, PROG. THEOR. PHYS. 80 (1988) 488
88WE17 WEITZENFELDER ET AL, NUCL. PHYS. A489 (1988) 125
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88WI1B WILLIAMS ET AL, BULL. AM. PHYS. SOC. 33 (1988) 1131
88WI1F WILLIAMS ET AL, BULL. AM. PHYS. SOC. 33 (1988) 1591
88WI1I WILLIAMS ET AL, BULL. AM. PHYS. SOC. 33 (1988) 1472
88WO04 WOLTERS, VAN HEES AND GLAUDEMANS, EUROPHYS. LETT. 5 (1988) 7
88WO09 WOUTERS ET AL, Z. PHYS. A331 (1988) 229
88WU1A WU, CHIN. PHYS. 8 (1988) 213
88YA08 YAHNE AND ONLEY, PHYS. REV. C38 (1988) 813
88YE1A YE ET AL, CHIN. PHYS. 8 (1988) 188
88ZA06 ZAVARZINA AND STEPANOV, SOV. J. PART. NUCLEI 19 (1988) 404
88ZH07 ZHENG, BERDICHEVSKY AND ZAMICK, PHYS. REV. C38 (1988) 437
88ZH1G ZHU ET AL, HIGH ENERGY PHYS. NUCL. PHYS. 12 (1988) 799
89AB1J ABIA AND REBOLO, ASTROPHYS. J. 347 (1989) 186
89AD1B ADAMOVICH ET AL, PHYS. REV. C40 (1989) 66
89AL1D ALEKSANDROV ET AL, TASHKENT (1989) 377
89AN10 ANTONOV ET AL, NUOVO CIM. A101 (1989) 639
89AR02 ARAKELYAN, DAVTYAN AND MATINYAN, SOV. J. NUCL. PHYS. 49 (1989) 55
89BA06 BANDO ET AL, PHYS. REV. C39 (1989) 587
89BA1E BANDO ET AL, NUCL. PHYS. A501 (1989) 900

89BA2N BANDO, NUOVO CIM. A102 (1989) 627
89BA2P BAHCALL, NEUTRINO ASTROPHYS. (PUBL. CAMBRIDGE UNIV. PRESS 1989)
89BA2S BAUR AND WEBER, NUCL. PHYS. A504 (1989) 352
89BA60 BARKER AND WOODS, AUST. J. PHYS. 42 (1989) 233
89BA63 BATUSOV ET AL, SOV. J. NUCL. PHYS. 49 (1989) 777
89BE02 BENNHOLD AND WRIGHT, PHYS. REV. C39 (1989) 927
89BE11 BENNHOLD, PHYS. REV. C39 (1989) 1944
89BE14 BEISE ET AL, PHYS. REV. LETT. 62 (1989) 2593
89BE17 BECK ET AL, PHYS. REV. C39 (1989) 2202
89BE2H BENCIVENNI ET AL, ASTROPHYS. J. 71 (1989) 109
89BEZC BEHR ET AL, BULL. AM. PHYS. SOC. 34 (1989) 1832
89BI1A BINI ET AL, WEIN 89 (1989) PAPER PG04
89BLZZ BLUMENTHAL ET AL, BULL. AM. PHYS. SOC. 34 (1989) 1155
89BO01 BOGAERT ET AL, PHYS. REV. C39 (1989) 265
89BOYU BORZOV AND TERTICHNY, TASHKENT (1989) 427
89BR14 BRANCUS ET AL, Z. PHYS. A333 (1989) 71
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89CA04 CAUVIN, GILLET AND KOHMURA, PHYS. LETT. B219 (1989) 35
89CA11 CAPLAR, KOROLIJA AND CINDRO, NUCL. PHYS. A495 (1989) 185C
89CA13 CAVINATO, MARANGONI AND SARUIS, NUCL. PHYS. A496 (1989) 108
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89CA25 CATFORD ET AL, NUCL. PHYS. A503 (1989) 263
89CEZZ CEBRA ET AL, BULL. AM. PHYS. SOC. 34 (1989) 1221
89CH04 CHANT AND ROOS, PHYS. REV. C39 (1989) 957
89CH13 CHOUDHURY AND GUO, PHYS. REV. C39 (1989) 1883
89CH1X CHEN AND LI, ASTROPHYS. SPACE SCI. 158 (1989) 153
89CH24 CHIAPPARINI AND GATTONE, PHYS. LETT. B224 (1989) 243
89CH31 CHUMBALOV, ERAMZHYAN AND KAMALOV, CZECH. J. PHYS. 39 (1989) 853
89CH32 CHRIEN, CZECH. J. PHYS. 39 (1989) 914
89CU03 CUJEC, HUNYADI AND SZOGHY, PHYS. REV. C39 (1989) 1326
89CU1E CUMMINGS, STONE AND WEBBER, BULL. AM. PHYS. SOC. 34 (1989) 1171
89DA1C DABROWSKI, ACTA PHYS. POL. B20 (1989) 61
89DE02 DEYOUNG ET AL, PHYS. REV. C39 (1989) 128
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89DE22 DE BOER ET AL, J. PHYS. G15 (1989) L177
89DO04 DOBES, PHYS. LETT. B222 (1989) 315
89DO05 DONNELLY, KRONENBERG AND VAN ORDEN, NUCL. PHYS. A494 (1989) 365
89DO1I DOVER ET AL, PHYS. REP. 184 (1989) 1
89DR1C DRECHSEL AND GIANNINI, REP. PROG. PHYS. 52 (1989) 1083
89EL01 EL-SHABSHIRY, FAESSLER AND ISMAIL, J. PHYS. G15 (1989) L59
89EL02 ELSTER AND TANDY, PHYS. REV. C40 (1989) 881
89ES06 ESWARAN ET AL, PHYS. REV. C39 (1989) 1856
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89FE07 FERNANDEZ, LOPEZ-ARIAS AND PRIETO, Z. PHYS. A334 (1989) 349
89FE1F FELDMEIER, SCHONHOFEN AND CUBERO, NUCL. PHYS. A495 (1989) 337C
89FEZV FELDMAN ET AL, BULL. AM. PHYS. SOC. 34 (1989) 1232
89FI03 FILHO ET AL, PHYS. REV. C39 (1989) 884
89FI04 FINK ET AL, PHYS. LETT. B218 (1989) 277
89FI05 FIELDS ET AL, PHYS. LETT. B220 (1989) 356
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89FR04 FREEMAN ET AL, PHYS. REV. C39 (1989) 1335
89FU01 FUNCK, GRUND AND LANGANKE, Z. PHYS. A332 (1989) 109
89FU02 FUKUGITA ET AL, ASTROPHYS. J. 337 (1989) L59
89FU05 FURNSTAHL AND PRICE, PHYS. REV. C40 (1989) 1398
89FU10 FULTON ET AL, PHYS. LETT. B232 (1989) 56
89FU1J FUKAHORI, JAERI-M 89-047 (1989)
89FU1N FUKATSU, KATO AND TANAKA, PROG. THEOR. PHYS. 81 (1989) 738
89GA04 GATTONE AND VARY, PHYS. LETT. B219 (1989) 22
89GA05 GAO AND KONDO, PHYS. LETT. B219 (1989) 40
89GA09 GARCIA-RECIO ET AL, PHYS. LETT. B222 (1989) 329
89GA26 GAREEV ET AL, SOV. J. PART. NUCL. 20 (1989) 547
89GE1A GELBKE, NUCL. PHYS. A495 (1989) 27C
89GO1F GONG AND TOHYAMA, BULL. AM. PHYS. SOC. 34 (1989) 1156
89GR05 GRION ET AL, NUCL. PHYS. A492 (1989) 509
89GR06 GRAM ET AL, PHYS. REV. LETT. 62 (1989) 1837
89GR13 GROTOWSKI ET AL, PHYS. LETT. B223 (1989) 287
89GR1J GREINER ET AL, TREATISE ON HEAVY-ION SCI., VOL. 8, ED. BROMLEY (PLENUM PUBL. CORP. 1989) P. 641
89GU06 GULKAROV AND KUPRIKOV, SOV. J. NUCL. PHYS. 49 (1989) 21
89GU1I GUESSOUM AND GOULD, ASTROPHYS. J. 345 (1989) 356
89GU1J GUESSOUM, ASTROPHYS. J. 345 (1989) 363
89GU1Q GUPTA AND WEBBER, ASTROPHYS. J. 340 (1989) 1124
89HA07 HAUSMANN AND WEISE, NUCL. PHYS. A491 (1989) 598
89HA24 HASSAN, COMSAN AND TAGELDIN, ANN. PHYS. 46 (1989) 207
89HA29 HAUSMANN AND WEISE, NUOVO CIM. A102 (1989) 421
89HA32 HALDERSON, PHYS. REV. C40 (1989) 2173
89HAZY HAYES, FRIAR AND STROTTMAN, BULL. AM. PHYS. SOC. 34 (1989) 1187
89HE04 HEATON ET AL, NUCL. INSTRUM. METHODS PHYS. RES. A276 (1989) 529
89HE21 HEISELBERG ET AL, PHYS. SCR. 40 (1989) 141
89HO10 HONG ET AL, PHYS. REV. C39 (1989) 2061
89HU1C HUANG AND YEN, PHYS. REV. C40 (1989) 635
89HY1B HYMAN ET AL, BULL. AM. PHYS. SOC. 34 (1989) 1568
89JE07 JELITTO ET AL, Z. PHYS. A332 (1989) 317
89JI1A JIN, ARNETT AND CHAKRABARTI, ASTROPHYS. J. 336 (1989) 572
89JI1D JIANG ET AL, PHYS. REV. C40 (1989) R1857
89JO1B JOHNSON, CZECH. J. PHYS. 39 (1989) 822
89KA02 KALEN ET AL, PHYS. REV. C39 (1989) 340
89KA24 KAPPELER, BEER AND WISSHAK, REP. PROG. PHYS. 52 (1989) 945
89KA28 KAMERDZHIEV AND TKACHEV, Z. PHYS. A334 (1989) 19
89KA35 KATKHAT, IZV. AKAD. NAUK SSSR 53 (1989) 103
89KA37 KALBERMANN ET AL, NUCL. PHYS. A503 (1989) 632
89KE03 KELLY ET AL, PHYS. REV. C39 (1989) 1222
89KE05 KELLY, PHYS. REV. C39 (1989) 2120
89KEZZ KELLOGG, VOGELAAR AND KAVANAGH, BULL. AM. PHYS. SOC. 34 (1989) 1192
89KH01 KHANKHASAYEV AND TOPILSKAYA, PHYS. LETT. B217 (1989) 14
89KH1E KHANKHASAYEV, CZECH. J. PHYS. 39 (1989) 836
89KO10 KOIDE ET AL, PHYS. REV. C39 (1989) 1636
89KO23 KONDO, ROBSON AND SMITH, PHYS. LETT. B227 (1989) 310
89KO29 KOVASH ET AL, PHYS. REV. C40 (1989) R1093
89KO2A KOLDE, SAO PAULO (1989) 326
89KO37 KOUTROULOS, J. PHYS. G15 (1989) 1659
89KO55 KOZYR AND SOKOLOV, BULL. ACAD. SCI. USSR 53 (1989) 194
89KRZX KRYGER AND KOLATA, BULL. AM. PHYS. SOC. 34 (1989) 1156

89KU30 KUZNICHENKO, MOLEV AND ONYSHCHENKO, IZV. AKAD. NAUK SSSR SER. FIZ. 53 (1989) 2211
89KU31 KURGALIN AND CHUVILSKY, UKR. FIZ. ZH. SSSR 34 (1989) 1157
89LA19 LANDRE ET AL, PHYS. REV. C40 (1989) 1972
89LA1G LANG AND WERNTZ, BULL. AM. PHYS. SOC. 34 (1989) 1186
89LA1I LANSKOI, SOV. J. NUCL. PHYS. 49 (1989) 41
89LE12 LEBRUN ET AL, PHYS. LETT. B223 (1989) 139
89LE16 LEWITOWICZ ET AL, NUCL. PHYS. A496 (1989) 477
89LE23 LENZI, VITTURI AND ZARDI, PHYS. REV. C40 (1989) 2114
89LE24 LEE ET AL, PHYS. REV. C40 (1989) 2585
89LH02 L'HUILLIER AND VAN GIAI, PHYS. REV. C39 (1989) 2022
89LI01 LI AND XU, PHYS. REV. C39 (1989) 276
89LI1G LIPPARINI AND STRINGARI, PHYS. REP. 175 (1989) 103
89LI1H LIU, LONDERGAN AND WALKER, PHYS. REV. C40 (1989) 832
89LI1I LIVIO ET AL, NATURE 340 (1989) 281
89MA06 MASSEN AND PANOS, J. PHYS. G15 (1989) 311
89MA08 MAASS, MAY AND SCHEID, PHYS. REV. C39 (1989) 1201
89MA23 MALAGUTI ET AL, NUOVO CIM. A101 (1989) 517
89MA30 MARES AND ZOFKA, Z. PHYS. A333 (1989) 209
89MA41 MALECKI, PICOZZA AND HODGSON, NUOVO CIM. A101 (1989) 1045
89MA45 MAJKA ET AL, PHYS. REV. C40 (1989) 2124
89MC05 MCNEIL ET AL, PHYS. REV. C40 (1989) 399
89ME10 MEIRAV ET AL, PHYS. REV. C40 (1989) 843
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89MI06 MICHEL, KONDO AND REIDEMEISTER, PHYS. LETT. B220 (1989) 479
89MI1K MIAO AND CHAO, NUCL. PHYS. A494 (1989) 620
89MO17 MOTOBA, NUOVO CIM. A102 (1989) 345
89NA01 NAVARRO AND ROIG, PHYS. REV. C39 (1989) 302
89NE02 NEDJADI AND ROOK, J. PHYS. G15 (1989) 589
89OB1B OBERHUMMER, HERNDL AND LEEB, KERNTECHNIK 53 (1989) 211
89OR02 ORMAND AND BROWN, NUCL. PHYS. A491 (1989) 1
89OR07 O'REILLY, ZUBANOV AND THOMPSON, PHYS. REV. C40 (1989) 59
89PI01 PIEKAREWICZ AND WALKER, PHYS. REV. C39 (1989) 1
89PI07 PICKLESIMER AND VAN ORDEN, PHYS. REV. C40 (1989) 290
89PI11 PILE, NUOVO CIM. A102 (1989) 413
89PI1F PIEPER, BULL. AM. PHYS. SOC. 34 (1989) 1149
89PLZU PLAVKO, TASHKENT (1989) 289
89PO05 POPLAVSKY, SOV. J. NUCL. PHYS. 49 (1989) 253
89PO06 PORILE ET AL, PHYS. REV. C39 (1989) 1914
89PO07 POULIOT ET AL, PHYS. LETT. B223 (1989) 16
89PO1K POPPELIER, PH.D. THESIS, UNIV. OF UTRECHT (1989)
89RA02 RAY, PHYS. REV. C39 (1989) 1170
89RA15 RAY AND SHEPARD, PHYS. REV. C40 (1989) 237
89RA16 RAMAN ET AL, AT. DATA NUCL. DATA TABLES 42 (1989) 1
89RA17 RAGHAVAN, AT. DATA NUCL. DATA TABLES 42 (1989) 189
89RE08 REUTER ET AL, PHYS. LETT. B230 (1989) 16
89RE1C REINHARD, REP. PROG. PHYS. 52 (1989) 439
89RI1E RISKA, PHYS. REP. 181 (1989) 207
89RY01 RYCKEBUSCH ET AL, PHYS. LETT. B216 (1989) 252
89RY06 RYCKEBUSCH ET AL, NUCL. PHYS. A503 (1989) 694
89SA10 SAINT-LAURENT ET AL, Z. PHYS. A332 (1989) 457
89SA14 SARMA AND SINGH, Z. PHYS. A333 (1989) 299
89SAZZ SAWAFTA ET AL, BULL. AM. PHYS. SOC. 34 (1989) 1141
89SC1I SCHMIDT ET AL, PHYS. LETT. B229 (1989) 197

89SE06 SEMJONOV ET AL, PHYS. REV. C40 (1989) 463
89SE07 SEVERIJNS ET AL, PHYS. REV. LETT. 63 (1989) 1050
89SH13 SHIGEHARA, SHIMIZU AND ARIMA, NUCL. PHYS. A492 (1989) 388
89SH27 SHEPARD, ROST AND MCNEIL, PHYS. REV. C40 (1989) 2320
89SI09 SIBIRTSEV AND TREBUKHOVSKII, SOV. J. NUCL. PHYS. 49 (1989) 622
89SP01 SPEAR, AT. DATA NUCL. DATA TABLES 42 (1989) 55
89SP1G SPITE, BARBUY AND SPITE, ASTRON. ASTROPHYS. 222 (1989) 35
89ST08 STILIARIS ET AL, PHYS. LETT. B223 (1989) 291
89SU01 SUZUKI AND HARA, PHYS. REV. C39 (1989) 658
89SU05 SURAUD, PI AND SCHUCK, NUCL. PHYS. A492 (1989) 294
89SU1I SURAUD, GREGOIRE AND TAMAIN, PROG. PART. NUCL. PHYS. 23 (1989) 357
89TA04 TANABE, KOHNE AND BENNHOLD, PHYS. REV. C39 (1989) 741
89TA16 TAMURA ET AL, PHYS. REV. C40 (1989) R479
89TA17 TAMURA ET AL, PHYS. REV. C40 (1989) R483
89TA19 TAMURA ET AL, NUOVO CIM. A102 (1989) 575
89TA1T TANAKA, PHYS. LETT. B227 (1989) 195
89TA1Y TANAKA ET AL, NATURE 341 (1989) 727
89TA24 TAN AND GU, J. PHYS. G15 (1989) 1699
89TA26 TAKAHARA ET AL, NUCL. PHYS. A504 (1989) 167, WEIN 89 (1989) PAPER PD03
89TE02 TERRASI ET AL, PHYS. REV. C40 (1989) 742
89TE06 TERRANOVA, DE LIMA AND PINHEIRO FILHO, EUROPHYS. LETT. 9 (1989) 523
89TH1B THIEL AND PARK, BULL. AM. PHYS. SOC. 34 (1989) 1156
89TH1C THIELEMANN AND WIESCHER, TOKYO (1988) 27
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89TO11 TOKI ET AL, NUCL. PHYS. A501 (1989) 653
89VA04 VAN VERST ET AL, PHYS. REV. C39 (1989) 853
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89VI09 VILLARI ET AL, NUCL. PHYS. A501 (1989) 605
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89VI1E VINOGRADOVA ET AL, TASHKENT (1989) 556
89VO19 VOLOSHCHUK ET AL, UKR. FIZ. ZH. 34 (1989) 511
89VO1F VOLKOV, TREATISE ON HEAVY-ION SCIENCE, VOL. 8, ED. D.A. BROMLEY, (PLENUM PUBL. CORP. 1989), P. 101
89WA06 WARBURTON AND MILLENER, PHYS. REV. C39 (1989) 1120
89WA16 WA KITWANGA ET AL, PHYS. REV. C40 (1989) 35
89WA26 WARNER ET AL, NUCL. PHYS. A503 (1989) 161
89WAZZ WATSON ET AL, BULL. AM. PHYS. SOC. 34 (1989) 1142
89WE1E WEFEL ET AL, BULL. AM. PHYS. SOC. 34 (1989) 1137
89WE1I WELLER ET AL, SAO PAULO (1989) 8
89WI1E WIESCHER ET AL, ASTROPHYS. J. 343 (1989) 352
89WI20 WIRZBA ET AL, PHYS. REV. C40 (1989) 2745
89WU1C WU, YANG AND LI, HIGH ENERGY PHYS. NUCL. PHYS. 13 (1989) 75
89WUZZ WUOSMAA AND ZURMUHLE, BULL. AM. PHYS. SOC. 34 (1989) 1187
89YA15 YAMAGUCHI, YABANA AND HORIUCHI, PROG. THEOR. PHYS. 82 (1989) 217
89YI1A YIN ET AL, CHIN. PHYS. 9 (1989) 1045
89YO02 YOKOYAMA ET AL, Z. PHYS. A332 (1989) 71
89YO09 YOKOTA ET AL, Z. PHYS. A333 (1989) 379
89ZHZY ZHOU ET AL, BULL. AM. PHYS. SOC. 34 (1989) 1800
89ZO1A ZOFKA, CZECH. J. PHYS. 39 (1989) 925
89ZUZZ ZURMUHLE ET AL, BULL. AM. PHYS. SOC. 34 (1989) 1810
90AB07 ABBONDANNO ET AL, J. PHYS. G16 (1990) 1517
90AB10 ABBONDANNO ET AL, PHYS. LETT. B249 (1990) 396
90AB1D ABRAAMYAN ET AL, SOV. J. NUCL. PHYS. 51 (1990) 94
90AB1E ABIA, CANAL AND ISERN, ASTROPHYS. AND SPACE SCI. 170 (1990) 361

90AB1G ABEL ET AL, NUCL. INSTRUM. METHODS PHYS. RES. B45 (1990) 100
90ADZT ADODIN ET AL, LENINGRAD (1990) 321
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90AJ01 AJZENBERG-SELOVE, NUCL. PHYS. A506 (1990) 1
90AL05 ALAM AND MALIK, PHYS. LETT. B237 (1990) 14
90AM06 AMUSYA ET AL, SOV. J. NUCL. PHYS. 52 (1990) 796
90AR03 ARELLANO, BRIEVA AND LOVE, PHYS. REV. C41 (1990) 2188
90AR11 ARELLANO, BRIEVA AND LOVE, PHYS. REV. C42 (1990) 652
90AS06 ASHEROVA, SMIRNOV AND FURSA, BULL. ACAD. SCI. USSR 54 (1990) 131
90AZZY AZZONZ AND BENDJABALLAH, BULL. AM. PHYS. SOC. 35 (1990) 1720
90BA1M BARTHE ET AL, NUCL. INSTRUM. METHODS PHYS. RES. B45 (1990) 105
90BA1Z BARONI ET AL, NUCL. PHYS. A516 (1990) 673
90BL16 BLOKHINTSEV ET AL, BULL. ACAD. SCI. USSR 54 (1990) 190
90BL1H BLECHER ET AL, NUCL. PHYS. B PROC. SUPPL. 13 (1990) 322
90BL1K BLAES ET AL, ASTROPHYS. J. 363 (1990) 612
90BO01 BOHNE ET AL, PHYS. REV. C41 (1990) R5
90BO1X BONETTI AND CHIESA, MOD. PHYS. LETT. A5 (1990) 619
90BO31 BOFFI ET AL, NUCL. PHYS. A518 (1990) 639
90BR1Q BROWN, BULL. AM. PHYS. SOC. 35 (1990) 940
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90BU27 BUBALLA ET AL, NUCL. PHYS. A517 (1990) 61
90CA09 CANNATA, DEDONDER AND GIBBS, PHYS. REV. C41 (1990) 1637
90CA32 CARSTANJEN ET AL, NUCL. INSTRUM. METHODS PHYS. RES. B51 (1990) 152
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90CH13 CHIANG, OSET AND DE CORDOBA, NUCL. PHYS. A510 (1990) 591
90CO19 COKER AND RAY, PHYS. REV. C42 (1990) 659
90CO29 COOPER AND MACKINTOSH, NUCL. PHYS. A517 (1990) 285
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90DA03 DASMAHAPATRA ET AL, NUCL. PHYS. A509 (1990) 393
90DA14 DAWSON AND FURNSTAHL, PHYS. REV. C42 (1990) 2009
90DA1Q DARWISH ET AL, APPL. RADIAT. ISOT. 41 (1990) 1177
90DE16 DE WITT HUBERTS, J. PHYS. G16 (1990) 507
90DE1M DEGTYARENKO ET AL, Z. PHYS. A335 (1990) 231
90DE35 DE PAULA AND CANTO, PHYS. REV. C42 (1990) 2628
90EL01 ELSTER ET AL, PHYS. REV. C41 (1990) 814
90ER09 ERMER ET AL, COLLOQ. PHYS. C6 (1990) 431
90FEZY FELDMAN ET AL, BULL. AM. PHYS. SOC. 35 (1990) 1038
90FU06 FUJIMOTO, NUCL. INSTRUM. METHODS PHYS. RES. B45 (1990) 49
90GL02 GLEISSL ET AL, ANN. PHYSIQUE 197 (1990) 205
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90HA35 HAXTON AND JOHNSON, PHYS. REV. LETT. 65 (1990) 1325
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90HO1I HOLLOWELL AND IBEN, ASTROPHYS. J. 349 (1990) 208
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90HO24 HOCH AND MANAKOS, Z. PHYS. A337 (1990) 383
90IM01 IMANISHI, MISONO AND VON OERTZEN, PHYS. LETT. B241 (1990) 13
90IR01 IRMSCHER, BUCHAL AND STRITZKER, NUCL. INSTRUM. METHODS PHYS. RES. B51 (1990) 442
90JI02 JI ET AL, PHYS. REV. C41 (1990) 1736
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90KE03 KELLY ET AL, PHYS. REV. C41 (1990) 2504

90KH04 KHOSLA, MALIK AND GUPTA, NUCL. PHYS. A513 (1990) 115
90KH05 KHAN AND BERES, PHYS. REV. C42 (1990) 1768
90KO18 KONDO, MICHEL AND REIDEMEISTER, PHYS. LETT. 242B (1990) 340
90KO1X KONG ET AL, CHIN. PHYS. LETT. 7 (1990) 212
90KO2C KOZNICHENKO ET AL, ACTA PHYS. POL. B21 (1990) 1031
90KO36 KOHNO AND TANABE, NUCL. PHYS. A519 (1990) 755
90KR14 KRYGER ET AL, PHYS. REV. LETT. 65 (1990) 2118
90KR16 KRUPPA AND KATO, PROG. THEOR. PHYS. (KYOTO) 84 (1990) 1145
90KR1D KRAKAUER ET AL, PANIC XII (1990) PAPER XV-8
90LA1J LANDRE ET AL, ASTRON. ASTROPHYS. 240 (1990) 85
90LI10 LI AND CHEN, PHYS. REV. C41 (1990) 2449
90LI1Q LI, YANG AND WU, HIGH ENERGY PHYS. NUCL. PHYS. 14 (1990) 407
90LO11 LOMBARD, J. PHYS. G16 (1990) 1311
90LO20 LOTZ AND SHERIF, J. PHYS. IV COLLOQ. C6 (1990) 495
90MA63 MASSEN, J. PHYS. G16 (1990) 1713
90MC06 MCNEILL AND JURY, PHYS. REV. C42 (1990) 2234
90MEZV MELLENDORF ET AL, BULL. AM. PHYS. SOC. 35 (1990) 1680
90MO1K MORGENSTERN, BULL. AM. PHYS. SOC. 35 (1990) 1634
90MO36 MORSE, PHYS. LETT. B251 (1990) 241
90MU15 MUTHER, MACHLEIDT AND BROCKMANN, PHYS. REV. C42 (1990) 1981
90NA15 NAKANO ET AL, PHYS. LETT. B240 (1990) 301
90NE12 NEDJADI AND ROOK, PHYS. LETT. B247 (1990) 485
90OH04 OHNUMA ET AL, NUCL. PHYS. A514 (1990) 273
90OL01 OLSSON, RAMSTROM AND TROSTELL, NUCL. PHYS. A509 (1990) 161
90OP01 OPPER ET AL, J. PHYS. IV COLLOQ. C6 (1990) 607
90PAZW PADALINO ET AL, BULL. AM. PHYS. SOC. 35 (1990) 1664
90PH02 PHAM AND DE SWINIARSKI, NUOVO CIM. A103 (1990) 375
90PI05 PISKOR AND SCHAFERLINGOVA, NUCL. PHYS. A510 (1990) 301
90PO04 POPLAVSKII, SOV. J. NUCL. PHYS. 51 (1990) 799
90RA12 RAY, PHYS. REV. C41 (1990) 2816
90RE16 REN AND XU, PHYS. LETT. B252 (1990) 311
90RE1E REED AND HAIDER, BULL. AM. PHYS. SOC. 35 (1990) 947
90RO1C ROLFS AND BARNES, ANN. REV. NUCL. PART. SCI. 40 (1990) 45
90SA1O SATCHLER, PROC. 1989 INTL. NUCL. PHYS. CONF., SAO PAULO, BRASIL (SINGAPORE: WORLD SCI. 1990) VOL. 2, P. 541
90SA27 SAHA ET AL, PHYS. REV. C42 (1990) 922
90SE04 SETH ET AL, PHYS. REV. C41 (1990) 2800
90SE11 SEIDL ET AL, PHYS. REV. C42 (1990) 1929
90SE1H SERGEEV, BULL. ACAD. SCI. USSR 54 (1990) 193
90SH10 SHIGEHARA, SHIMIZU AND ARIMA, NUCL. PHYS. A510 (1990) 106
90SH1D SHIBATA ET AL, REPORT JAERI-M 90-012, JPN. ATOMIC ENERGY RES INST., TOKAI, IBARAKI, JPN, FEB. 1990
90SL01 SLAVOV ET AL, J. PHYS. G16 (1990) 395
90SN1A SNOVER, BULL. AM. PHYS. SOC. 35 (1990) 1032
90TA21 TANG, SRINIVASAN AND AZZIZ, PHYS. REV. C42 (1990) 1598
90TA31 ZHENQIANG AND YUNTING, CHIN. J. NUCL. PHYS. 12 91990) 201
90TH1D THIEL, J. PHYS. G16 (1990) 867
90TJ01 TJON, J. PHYS. IV COLLOQ. C6 (1990) 111
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90TR02 TRCKA ET AL, PHYS. REV. C41 (1990) 2134
90VA07 VAN HOOREBEKE ET AL, PHYS. REV. C42 (1990) R1179
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90WA01 WADA, YAMAGUCHI AND HORIUCHI, PHYS. REV. C41 (1990) 160
90WE10 WEISS ET AL, NUCL. INSTRUM. METHODS PHYS. RES. A292 (1990) 359

90WO09 WOLTERS, VAN HEES and GLAUDEMANS, PHYS. REV. C42 (1990) 2053
90WO10 WOLTERS, VAN HEES and GLAUDEMANS, PHYS. REV. C42 (1990) 2062
90XE01 XENOULIS ET AL, NUCL. PHYS. A516 (1990) 108
90YE02 YENNELLO ET AL, PHYS. REV. C41 (1990) 79
90ZHZV ZHENG AND ZAMICK, BULL. AM. PHYS. SOC. 35 (1990) 1651
91AB1C ABADA AND VAUTHERIN, PHYS. LETT. B258 (1991) 1
91AB1F ABLEEV ET AL, Z. PHYS. A340 (1991) 191
91AJ01 AJZENBERG-SELOVE, NUCL. PHYS. A523 (1991) 1
91AL02 ALBERICO, DEPACE AND PIGNONE, NUCL. PHYS. A523 (1991) 488
91AN1E ANDERS ET AL, ASTROPHYS. J. 373 (1991) L77
91AR06 ARENDS ET AL, NUCL. PHYS. A526 (1991) 479
91AR11 ARELLANO, LOVE AND BRIEVA, PHYS. REV. C43 (1991) 2734
91AR1K ARELLANO, BRIEVA AND LOVE, PROC. OF THE XIV SYMP. ON NUCLEAR PHYSICS 1991 (1991) 19
91BA1K BARKER AND KAJINO, AUST. J. PHYS. 44 (1991) 369
91BA1M BARHAI AND AKHAURY, CZECH. J. PHYS. 41 (1991) 536
91BA44 BATTY ET AL, NUCL. PHYS. A535 (1991) 548
91BAZW BARRETO ET AL, BULL. AM. PHYS. SOC. 36 (1991) 1272
91BE01 BENNHOLD, PHYS. REV. C43 (1991) 775
91BE05 BERTULANI AND HUSSEIN, NUCL. PHYS. A524 (1991) 306
91BE1E BEREZHNOY, MIKHAILYUK AND PILIPENKO, MOD. PHYS. LETT. A6 (1991) 775
91BE45 BEREZHNOY, MIKHAILYUK AND PILIPENKO, ACTA PHYS. POL. B22 (1991) 873
91BL14 BLUNDEN AND KIM, NUCL. PHYS. A531 (1991) 461
91BO02 BOOTEN ET AL, PHYS. REV. C43 (1991) 335
91BO10 BOFFI AND RADICI, NUCL. PHYS. A526 (1991) 602
91BO26 BOFFI, BRACCI AND CHRISTILLIN, NUOVO CIM. A104 (1991) 843
91BO29 BOFFI AND GIANNINI, NUCL. PHYS. A533 (1991) 441
91BO39 BOERSMA, MALFLIET AND SCHOLTEN, PHYS. LETT. B269 (1991) 1
91CA1C CARLSON, NUCL. PHYS. A522 (1991) 185
91CE09 CENTELLES ET AL, J. PHYS. G17 (1991) L193
91CH28 CHINN, ELSTER AND THALER, PHYS. REV. C44 (1991) 1569
91CH39 CHINITZ ET AL, PHYS. REV. LETT. 67 (1991) 568
91CI08 CIEPLY ET AL, PHYS. REV. C44 (1991) 713
91CO12 COON AND JAQUA, PHYS. REV. C44 (1991) 203
91CO13 COWLEY ET AL, PHYS. REV. C44 (1991) 329
91CR04 CRESPO, JOHNSON AND TOSTEVIN, PHYS. REV. C44 (1991) R1735
91CR06 CROFT, NUCL. INSTRUM. METHODS PHYS. RES. A307 (1991 353
91CR1A CRECCA AND WALKER, PHYS. REV. C43 (1991) 1709
91CS01 CSEH, LEVAI AND KATO, PHYS. REV. C43 (1991) 165
91DA05 DASMAHAPATRA ET AL, NUCL. PHYS. A526 (1991) 395
91DE11 DEANGELIS AND GATOFF, PHYS. REV. C43 (1991) 2747
91DE15 DESCOUVEMONT, PHYS. REV. C44 (1991) 306
91DU04 DUMITRESCU, NUCL. PHYS. A535 (1991) 94
91ER03 ERMER ET AL, NUCL. PHYS. A533 (1991) 71
91ES1B ESMAEL AND ABOU STEIT, J. PHYS. G17 (1991) 1755
91FE06 FETISOV ET AL, Z. PHYS. A339 (1991) 399
91FI08 FIRK, J. PHYS. G17 (1991) 1739
91FL01 FLANDERS ET AL, PHYS. REV. C43 (1991) 2103
91GA03 GARCIA ET AL, PHYS. REV. C43 (1991) 2012
91GA07 GARCIA-RECIO ET AL, NUCL. PHYS. A526 (1991) 685
91GL03 GLOWACKA ET AL, NUCL. PHYS. A534 (1991) 349
91GM02 GMUCA, J. PHYS. G17 (1991) 1115
91GO12 GORBATOV ET AL, SOV. J. NUCL. PHYS. 53 (1991) 425
91GO1F GOKALP AND YILMAZ, DOGA TURK FIZ. ASTROFIZ. DERG. 15 (1991) 402

91GO1G GOKALP, YALCIN AND YILMAZ, DOGA TURK FIZ. ASTROFIZ. DERG. 15 (1991) 374
91GO25 GONCHAROV ET AL, SOV. J. NUCL. PHYS. 54 (1991) 552
91HA15 HATSUDA, HOGAASEN AND PRAKASH, PHYS. REV. LETT. 66 (1991) 2851
91HE16 HERNDL ET AL, PHYS. REV. C44 (1991) R952
91HI05 HICKS ET AL, PHYS. REV. C43 (1991) 2554
91HO03 HOIBRATEN ET AL, PHYS. REV. C43 (1991) 1255
91HU10 HUMBLET, FILIPPONE AND KOONIN, PHYS. REV. C44 (1991) 2530
91IS1D ISKRA, XXTH INT. SYMP. ON NUCL. PHYS., CASTLE GAUSSIG, WORLD SCIENTIFIC (1991) 51
91KA09 KAWAHIGASHI AND ICHIMURA, PROG. THEOR. PHYS. 85 (1991) 829
91KA12 KARADZHEV ET AL, SOV. J. NUCL. PHYS. 53 (1991) 204
91KA19 KANEKO, LEMERE AND TANG, PHYS. REV. C44 (1991) 1588
91KA22 KAKI, NUCL. PHYS. A531 (1991) 478
91KE02 KELLY ET AL, PHYS. REV. C43 (1991) 1272
91KH08 KHOA ET AL, PHYS. LETT. B260 (1991) 278
91KI08 KING ET AL, PHYS. REV. C44 (1991) 1077
91KN03 KNIEST ET AL, PHYS. REV. C44 (1991) 491
91KN04 KNOBLES AND UDAGAWA, NUCL. PHYS. A533 (1991) 189
91KO18 KOEPF AND RING, Z. PHYS. A339 (1991) 81
91KO1C KONG AND LIU, CHIN. PHYS. 11 (1991) 345
91KO1P KOEHLER AND O'BRIEN, AIP CONF. PROC. 238 (1991) 892
91KO23 KOEPF, SHARMA AND RING, NUCL. PHYS. A533 (1991) 95
91KO31 KOEHLER AND GRAFF, PHYS. REV. C44 (1991) 2788
91KO40 KOZYR, IZV. AKAD. NAUK SSSR 55 (1991) 144
91LA02 LAGU AND SINGH, NUCL. PHYS. A528 (1991) 525
91LE06 LEMAIRE ET AL, PHYS. REV. C43 (1991) 2711
91LE13 LEBEDEV AND TRYASUCHEV, J. PHYS. G17 (1991) 1197
91LE14 LEIDEMANN, ORLANDINI AND TRAINI, PHYS. REV. C44 (1991) 1705
91LI25 LICHTENHALER ET AL, PHYS. REV. C44 (1991) 1152
91LI28 LIU ET AL, NUCL. PHYS. A534 (1991) 25
91LI29 LIU ET AL, NUCL. PHYS. A534 (1991) 48
91LI41 LI, ZHAO AND FANG, CHIN. J. NUCL. PHYS. 13 (1991) 223
91MA29 MAJUMDAR, SAMANTA AND SAMADDAR, J. PHYS. G17 (1991) 1387
91MA33 MAVROMATIS, ELLIS AND MUTHER, NUCL. PHYS. A530 (1991) 251
91MA39 MACGREGOR ET AL, NUCL. PHYS. A533 (1991) 269
91MC08 MCGLONE AND JOHNSON, NUCL. INSTRUM. METHODS PHYS. RES. B61 (1991) 201
91MO1B MOTAROU ET AL, PHYS. REV. C44 (1991) 365
91MU04 MUTHER AND SKOURAS, J. PHYS. G17 (1991) L27
91NA05 NAVILIAT-CUNCIC ET AL, J. PHYS. G17 (1991) 919
91NI02 NIEVES ET AL, PHYS. REV. C43 (1991) 1937
91OM03 OMAR, SAAD AND DARWISH, APPL. RADIAT. ISOT. 42 (1991) 823
91OR01 ORR ET AL, PHYS. LETT. B258 (1991) 29
91OR02 ORYU ET AL, NUCL. PHYS. A534 (1991) 221
91OW01 OWENS, MATTHEWS AND ADAMS, J. PHYS. G17 (1991) 261
91PA06 PACATI AND RADICI, PHYS. LETT. B257 (1991) 263
91PA1C PAVLENKO, ASTRON. ZH. 68 (1991) 431
91PH01 PHAM, NUOVO CIM. A104 (1991) 1455
91PI07 PILE ET AL, PHYS. REV. LETT. 66 (1991) 2585
91RA14 RASHDAN, FAESSLER AND WADIA, J. PHYS. G17 (1991) 1401
91RA1C RAITERI ET AL, ASTROPHYS. J. 371 (1991) 665
91RE02 REEDER ET AL, PHYS. REV. C44 (1991) 1435
91RU1B RUAN, CHIN. J. NUCL. PHYS. 13 (1991) 377
91SA1F SAGE, MAUERSBERGER AND HENKEL, ASTRON. ASTROPHYS. 249 (1991) 31

91SA20 SAMANTA AND MUKHERJEE, PHYS. REV. C44 (1991) 2233
91SC26 SCHMID, MUTHER AND MACHLEIDT, NUCL. PHYS. A530 (1991) 14
91SE12 SEMENOV ET AL, SOV. J. NUCL. PHYS. 54 (1991) 429
91SH08 SHEN, FENG AND ZHUO, PHYS. REV. C43 (1991) 2773
91SH1F SHELINE, SOOD AND RAGNARSSON, INT. J. MOD. PHYS. A6 (1991) 5057
91SK02 SKOURAS AND MUTHER, NUCL. PHYS. A534 (1991) 128
91TA11 TAZAWA AND ABE, PROG. THEOR. PHYS. 85 (1991) 567
91TE03 TERUYA, DE TOLEDO PIZA AND DIAS, PHYS. REV. C44 (1991) 537
91TH04 THIEL, PARK AND SCHEID, J. PHYS. G17 (1991) 1237
91TO03 TOKI ET AL, NUCL. PHYS. A524 (1991) 633
91UM01 UMAR ET AL, PHYS. REV. C44 (1991) 2512
91VA1F VARIAMOV ET AL, BULL. ACAD. SCI. 55 (1991) 137
91VO02 VOEGLER ET AL, PHYS. REV. C43 (1991) 2172
91YA08 YAMAGUCHI, PHYS. REV. C44 (1991) 1171
91ZH05 ZHU, MANG AND RING, PHYS. LETT. B254 (1991) 325
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91ZH16 ZHANG AND ONLEY, PHYS. REV. C44 (1991) 1915
91ZH17 ZHANG AND ONLEY, PHYS. REV. C44 (1991) 2230
92AV1B AVOTINA, EROKHINA AND LEMBERG, SOV. J. NUCL. PHYS. 55 (1992) 1777
92BA31 BAUER ET AL, PHYS. REV. C46 (1992) R20
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92BE03 BEREZHNOY, MIKHAILYUK AND PILIPENKO, J. PHYS. G18 (1992) 85
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92BO04 BORROMEO ET AL, NUCL. PHYS. A539 (1992) 189
92BO07 BOFFI ET AL, NUCL. PHYS. A539 (1992) 597
92BR05 BRUNE AND KAVANAGH, PHYS. REV. C45 (1992) 1382
92CA04 CARRASCO AND OSET, NUCL. PHYS. A536 (1992) 445
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92CR05 CRESPO, JOHNSON AND TOSTEVIN, PHYS. REV. C46 (1992) 279
92DA19 D'ARRIGO ET AL, NUCL. PHYS. A549 (1992) 375
92DE06 DE BLASIO ET AL, PHYS. REV. LETT. 68 (1992) 1663
92EN02 ENDISCH ET AL, NUCL. INSTRUM. METHODS PHYS. RES. B62 (1992) 513
92FA04 FALLAVIER ET AL, NUCL. INSTRUM. METHODS PHYS. RES. B64 (1992) 83
92FR05 FRITSCH ET AL, PHYS. REV. LETT 68 (1992) 1667
92GO07 GOKALP AND YILMAZ, NUOVO CIM. 105 (1992) 695
92IG01 IGASHIRA, KITAZAWA AND TAKAURA, NUCL. PHYS. A536 (1992) 285
92JA04 JAIN, PHYS. REV. C45 (1992) 2387
92JA13 JAQUA ET AL, PHYS. REV. C46 (1992) 2333
92KA1K KANEKO AND TANG, PHYS. LETT. B296 (1992) 285
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92KW01 KWASNIEWICZ AND JARCZYK, NUCL. PHYS. A541 (1992) 193
92LA01 LAYMON, BROWN AND BALAMUTH, PHYS. REV. C45 (1992) R576
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92LU01 LUDWIG ET AL, PHYS. LETT. B274 (1992) 275
92MA09 MACK ET AL, PHYS. REV. C45 (1992) 1767
92MA45 MARCOS, VAN GIAI AND SAVUSHKIN, NUCL. PHYS. A549 (1992) 143
92MI01 MILLENER, HAYES AND STROTTMAN, PHYS. REV. C45 (1992) 473
92MI1H MINAMISONO ET AL, HYPERFINE INTERACT. 73 (1992) 347
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92OL02 OLKHOVSKY AND DOROSHKO, EUROPHYS. LETT. 18 (1992) 483
92PH01 PHAM ET AL, PHYS. REV. C46 (1992) 621
92PY1A PYYKKÖ, Z. NATURFORSCH. A47 (1992) 189

92QI02	QI ET AL, CHIN. J. NUCL. PHYS. 14 (1992) 15
92RY02	RYCKEBUSCH ET AL, PHYS. LETT. B291 (1992) 213
92SA1F	SARANGI AND SATPATHY, PRAMANA 39 (1992) 279
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