Adopted Levels

S(n)=2.323×10^4 *8*; S(p)=−1.51×10^3 *7*; Q(α)=−9.92×10^3 *8* 2012Wa38

Highlighted theoretical analyses:

2011Fo02: Reanalyzed data on ^{15}C levels populated in ^{13}C(t,p)^{15}C and interpreted results to revise predictions on ^{15}F levels.

2010Mu03: Parameters of the lowest Jπ=1/2$^+$ and 5/2$^+$ states were analyzed via the S-matrix pole method.

2015Gr04: Analysis, which focused on ^{16}Ne, found the ^{15}F ground state should lie near E$_{res}$(p+^{14}O)=1.39 to 1.42 MeV.

2006Ca08, 2015Fr04: Analyzed the ^{14}C+n system and then used multichannel algebraic scattering theory to predict resonances in the mirror ^{15}F nucleus. See also 2007Ca31.

2005Ba73: A microscopic cluster model was developed that was tuned to the ^{14}C+n system and used to predict the ^{14}O+p scattering reaction and ^{15}F resonances. Results are compaired and found in agreement with an R-matrix analysis of experimental observations.

2005Fo10: The lowest T=3/2 and Jπ=1/2$^+$ and 5/2$^+$ states of the A=15 quartet are analyzed in a (0+2)$\hbar\omega$ shell model.

2006Fo16: The definition of resonance energy is explored by considering three different parameters that may define the position: "(a) the energy at which the appropriate cross section peaks, (b) the energy at which the nuclear phase shift has the value $\delta=\pi/2$, and (c) the energy at which the magnitude of the internal wave function or the derivative of the phase shift dδ/dE is a maximum." Then, discussion on various A=15 and 16 states and analysis of the IMME mass relation are used to constrain predicted values for poorly known ^{15}O, ^{15}F and ^{16}F states.

General theoretical analyses:

Other theoretical analyses relevant to ^{15}F include general calculations on mass and structure properties in (1978Gu10,1993Po11,2008Qi04,2013Ci04). More detailed analyses considering pairs of mirror nuclides, Coulomb shifts, Thomas-Ehrman shifts and other detailed relationships are found in (1988Co15,1995Fo18,1997Gr18,1999Og11,1999Ts06,2013Fo22).

Other experimental results:

^{15}F is not strongly populated in ^{12}C(^{3}He,π^-) reactions at E(^{3}He)=283 MeV (1986Mi25) or 235 MeV (1984Bi08).

^{15}F Levels

Cross Reference (XREF) Flags

A	^{1}H(^{14}O,p):NSCL	F	^{16}O(^{14}N,^{15}C)
B	^{1}H(^{14}O,p):Texas	G	^{20}Ne(^{3}He,^{8}Li):NSCL
C	^{1}H(^{14}O,p):LBNL	H	^{20}Ne(^{3}He,^{8}Li):LBNL
D	^{1}H(^{14}O,p):GANIL		
E	^{9}Be(^{16}Ne,^{15}F)		

E(level)	J$^\pi$	Γ	E(p+^{14}O)$_{cm}$ (keV)	XREF	Comments
0	1/2$^+$	660 keV *20*	1.28×10^3 *4*	ABCDEFGH	%p=100 E(level): The value E$_{res}$=1.28 MeV *4* is adopted; excited state energies are calculated using this value. The weighted average of all reported resonance energy values is 1.28 MeV *2* (external uncertainty); this value compares with the Rajeval technique value (1.29 MeV *3*) and the Method of Best Representation (see 2014Bi13) value (1.37 MeV *13*). A critical scrutiny of some of the data may suggest exclusion of some results, such as those from (1978Be26,1978Ke06,2008Mu13), but these have little impact on the values deduced using the weighted average or Rajeval techniques. Γ: The values Γ>900 keV (1978Be26) and $\Gamma\approx$1200 keV (2003Pe23) are not considered, and a 20% uncertainty is assigned to $\Gamma\approx$700 keV from 2004Go15. This yields the weighted average Γ=660 keV *20*.
1.52×10^3 *5*	5/2$^+$	300 keV *13*	2798 *24*	ABCDEFGH	%p=100 E(level): The value E$_{res}$=2798 keV *24* is deduced using

Continued on next page (footnotes at end of table)

Adopted Levels (continued)

^{15}F Levels (continued)

E(level)	J^{π}	Γ	E(p+^{14}O)$_{cm}$ (keV)	XREF	Comments
					the Method of Best Representation; this value is accepted. This compares with the weighted average of all values, E_{res}=2785 keV *10*, and the value deduced using the Rajeval technique, 2797 keV *11*. An analysis was carried out in 2016De15 that recommended 2794 keV *16*. Γ: from the weighted average of all values.
3.48×10^3 *4*	1/2$^-$	36 keV *15*	4757 *12*	DEF	%p=100 E(level),Γ: from 2016De15.
5.1×10^3 *2*	(3/2$^-$,5/2$^-$)	0.2 MeV *2*	6.4×10^3 *2*	EF	%p=100 Γ_p=0.2 MeV *2* (2009Mu09,2010Mu12) E(level),Γ: from (2009Mu09,2010Mu12). J^{π}: 3/2$^-$ favored from arguments based on the mirror ^{15}C nucleus.
6.5×10^3 *2*	(3/2$^+$,5/2$^+$)	0.4 MeV *4*	7.8×10^3 *2*	E	%p=100 Γ_p=0.4 MeV *4* (2009Mu09,2010Mu12) E(level),Γ: from (2009Mu09,2010Mu12).

^{1}H(^{14}O,p):NSCL 2003Pe23

2003Pe23:

The authors evaluated the ^{1}H(^{14}O,p) elastic scattering reaction in Thick Target Inverse Kinematics (TTIK). E_{res}, E_x and Γ were deduced from the analysis.

A beam of 115 MeV/nucleon ^{14}O ions, produced by fragmentation of an ^{16}O beam at the NSCL, was degraded in energy to obtain an 8 MeV/nucleon beam. This low energy beam impinged on a 181.3 μm polyethylene target that stopped the beam. Protons from elastic scattering reactions were detected around θ=0° in a ΔE-E (75.3 μm and 1000 μm) Si detector telescope. The excitation function was analyzed using the VLADCS potential model code to deduce resonance energies.

^{15}F Levels

E(level)	J^{π}	Γ	E(p+^{14}O)$_{cm}$ (keV)	Comments
0	$1/2^{+}$	≈1.2 MeV	1.51×10^{3} *11*	E(level): mass excess=16.81 MeV *11*.
1.34×10^{3} *12*	$5/2^{+}$	≈340 keV	2853 *45*	

^{1}H(^{14}O,p):Texas 2004Go15

2004Go15:

The authors evaluated the ^{1}H(^{14}O,p) elastic scattering reaction in Thick Target Inverse Kinematics (TTIK). E_{res}, E_x, Γ and Jπ were deduced from the analysis.

A beam of ^{14}O ions, produced by fragmentation of an ^{14}N beam on a hydrogen target at the Texas A&M University Cyclotron Institute, was degraded in energy to obtain 80.6 MeV beam. The low-energy beam impinged on a thick CH_4 gas target that provided a low background when compared with other approaches. Protons from elastic scattering reactions were detected at θ=0°, +9.2°, +16.5° and −7.5° in a ΔE-E Si detector telescope. The excitation function was analyzed using a Woods-Saxon potential model to deduce resonance energies.

^{15}F Levels

E(level)	J$^{\pi}$	Γ	E(p+^{14}O)$_{cm}$ (keV)	Comments
0	1/2^{+}	0.7 MeV	≈1.29×10^{3}	E(level): The authors give a discussion on the s-wave scattering, which highlights a difference between the resonance peak cross section energy (1.29 MeV *+8-6*) and the maximum of the wavefunction amplitude (1.45 MeV *+16-1*). This effect also impacts the Γ value, which is observed with FWHM≈1.2 MeV.
≈1.5×10^{3}	5/2^{+}	0.325 MeV *60*	2795 *45*	

^{1}H(^{14}O,p):LBNL 2005Gu25

2005Gu25:

The authors evaluated the ^{1}H(^{14}O,p) elastic scattering reaction in Thick Target Inverse Kinematics (TTIK). E_{res}, E_x, Γ and Jπ were deduced for the ground and first excited states.

A beam of 120 MeV/nucleon ^{14}O ions, produced at the LBNL 88-Inch Cyclotron in the BEARS system, impinged on a target consisting of a Ni degrader followed by a thick 18.4 mg/cm^2 polyethylene foil that stopped the beam. Protons from elastic scattering reactions were detected around θ_{lab}=0° (±5°) in a ΔE-E Si detector telescope. The experimental resolution was about 60 keV. Two peaks were observed in the spectrum, which was analyzed using an R-matrix formalism.

The disappearance of the Z=8 proton magic number for odd Z nuclei, T_Z=−3/2, was discussed in light of the measured energy of $^{15}F_{g.s.}$.

^{15}F Levels

E(level)	Jπ	Γ	L	E(p+^{14}O)$_{cm}$ (keV)	Comments
0	1/2$^+$	0.67 MeV *17*	0	1.23×10^3 *5*	Γ: The measured width was Γ=0.5-0.84 MeV.
1.58×10^3 *5*	5/2$^+$	0.30 MeV *6*	2	2.81×10^3 *2*	

^{1}H(^{14}O,p):GANIL 2016De15,2014St14

The authors used the ^{14}O(p,p)^{14}O elastic scattering reaction, in thick target inverse kinematics, to populate resonant states in ^{15}F. The measured excitation function was analyzed via R-matrix formalism, and E_{res}, E_x, Γ and Jπ values were deduced.

Beams of ^{14}O ions were produced at the GANIL SPIRAL1 facility by fragmenting ^{20}Ne ions on a carbon target, and the ions were reaccelerated to 5.91 MeV/nucleon using the CIME cyclotron. The beam was purified in the LISE spectrometer before impinging on a stack of three 50 μm thick polypropylene targets that stopped the beam. Protons from elastic scattering reactions were detected at θ_{cm}=180° (θ_{lab}=±2.2°) in a ΔE-E (Si-SiLi) detector telescope. The energy resolution of the telescope was measured using ^{14}N beams to populate ^{15}O states; an energy resolution of σ_{cm}=7 keV *2* was deduced for ^{15}F resonances.

The data was analyzed via the thick target inverse kinematics method and evaluated using the AZURE2 R-matrix code. In (2016De15) the properties of three resonances are briefly discussed guided by Gamow Shell model calculations; in an earlier published result (2014St14) only two resonances are evaluated, and their energies are slightly higher.

^{15}F Levels

E(level)	Jπ	Γ	E(p+^{14}O)$_{cm}$ (keV)	Comments
0	1/2$^+$	0.38 MeV *21*	1270 *14*	E(level): This resonance was observed at E_R=1270 keV *10*(stat) *10*(sys). Γ: The observed width was Γ=376 keV *70*(stat) *+200−0*(sys).
1493 *19*	5/2$^+$	305 keV *12*	2763 *13*	E(level): This level was deduced from E_R=2763 keV *9*(stat) *10*(sys) with E_R=1270 keV *10*(stat) *10*(sys) for the g.s. In 2016De15, the authors note that using the statistical procedure outlined by the Particle Data Group to evaluate all reported energies for this resonance they find E_R=2794 keV *16* and Γ=301 keV *16* for this state.
3487 *18*	1/2$^-$	36 keV *15*	4757 *12*	E(level): This level was deduced from E_R=4757 keV *6*(stat) *10*(sys) with E_R=1270 keV *10*(stat) *10*(sys) for the g.s.

^{9}Be(^{16}Ne,^{15}F) 2010Mu12,2009Mu09,2008Mu13

2010Mu12,2009Mu09,2008Mu13:

The authors evaluated the decay product particle correlations for one-proton decays of ^{15}F, ^{16}Ne, ^{19}Na and two-proton decays of ^{15}F, ^{16}Ne and ^{20}Mg. Angular correlations were measured; momenta were not measured; hence properties of excited states are deduced based on GEANT simulations of the p-HI (Heavy Ion) and (p_1-HI)(p_2-HI) angular correlations.

A 591 MeV/nucleon beam of ^{24}Mg, from the SIS facility at GSI, was used to produce a beam of 410 MeV/nucleon ^{17}Ne in the FRS. The beam of ^{16}Ne was produced by (^{17}Ne,^{16}Ne) on a ^{9}Be target. The (p_1-^{14}O)(p_2-^{14}O) angular correlations were analyzed to determine: the decay mode (2p or sequential proton decay), and the excitation energies of states involved in the reactions.

^{15}F Levels

E(level)	J^{π}	$T_{1/2}$	E(p+^{14}O)$_{cm}$ (MeV)[†]	Comments
0	$1/2^+$		1.5 *1*	E(level): This group of counts is observed in (p_1-^{14}O)(p_2-^{14}O) correlations from ^{16}Ne breakup.
1.3×10^3 *1*	$5/2^+$	0.4 MeV *1*	2.80 *5*	Γ_p=0.4 MeV *1* (2010Mu12) E(level): This group is observed in (p_1-^{14}O)(p_2-^{14}O) correlations from ^{16}Ne breakup.
3.4×10^3 *2*	$(1/2^-)$	0.2 MeV *2*	4.9 *2*	Γ_p=0.2 MeV *2* (2009Mu09,2010Mu12) E(level): This group is observed in (p_1-^{14}O)(p_2-^{14}O) correlations from ^{16}Ne breakup.
4.9×10^3 *2*	$(3/2^-,5/2^-)$	0.2 MeV *2*	6.4 *2*	Γ_p=0.2 MeV *2* (2009Mu09,2010Mu12) E(level): This group is observed in (p_1-^{14}O)(p_2-^{14}O) correlations from ^{16}Ne breakup. J^{π}: $3/2^-$ favored from arguments based on the mirror ^{15}C nucleus.
6.3×10^3 *2*	$(3/2^+,5/2^+)$	0.4 MeV *4*	7.8 *2*	Γ_p=0.4 MeV *4* (2009Mu09,2010Mu12) E(level): from Q_{2p}(^{15}F)=3.2 MeV *2* group observed in (p_1-^{13}N)(p_2-^{13}N) correlations. This group is associated with decay via the ^{14}O $J\pi=2^+$ state at E_x=6.59 MeV. Decay to the $^{14}O_{g.s.}$ is weak, with an upper limit of decay via $^{14}O_{g.s.}/^{14}O(2^+)<0.2$. The state corresponds to Q_{1p}(^{15}F)=7.8 MeV *2*.

[†] From 2009Mu09.

^{16}O(^{14}N,^{15}C) 2004Le12,2003Le26

2004Le12:

The authors studied the excitation spectrum of the ^{15}F nucleus using the ^{16}O(^{14}N,^{15}C)^{15}F reaction. Angular distributions were analyzed using the FRESCO code.

A beam of 30 MeV/nucleon ^{14}N, from the GANIL facility, impinged on a 0.60 mg/cm^2 thick V_2O_5 foil located at the SPEG spectrometer target position. The reaction products were measured at θ_{lab}=2.5°±1.2°.

Three peaks were observed in the energy spectrum and were fitted using Breit-Wigner line-shapes that were folded with the resolution of FWHM=360 keV. A group of counts near E_{res}=6.8 MeV is indicated in the sepectrum, but not analyzed.

In (2003Le26) only the ground and first excited states were analyzed leading to slightly lower resonance energies and slightly different widths.

^{15}F Levels

E(level)	J^π	Γ	E(p+^{14}O)$_{cm}$ (MeV)	Comments
0	$1/2^+$	≈0.6 MeV	1.56 *13*	Γ: The observed width was Γ=0.6 MeV *+8-4*.
1.24×10^3 *14*	$5/2^+$	0.38 MeV *10*	2.80 *5*	
3.24×10^3 *13*	$(1/2^-)$	0.15 MeV *10*	4.80 *1*	
≈5.2×10^3?			6.8	

^{20}Ne(^{3}He,^{8}Li):NSCL 1978Be26

1978Be26:

The authors studied the level structure of ^{15}F populated using the ^{20}Ne(^{3}He,^{8}Li) reaction. The resulting excitation spectrum shows evidence for the ground and first excited states.

A beam of 74.5 MeV ^{3}He ions impinged on 150-200 torr of enriched (99.95%) ^{20}Ne gas in cells that were located in the Enge spectrometer target chamber at Michigan State University. Data collected at 10° used a gas cell with 0.45 mg/cm^2 Mylar foil windows, while data collected at 9°, 11°, and 13° used a gas cell with a 2.2 mg/cm^2 Ni foil exit window. ^{8}Li was detected in the focal plane of the spectrometer. The peaks were analyzed to obtain Q-values, mass excesses and widths.

The peaks were fitted by Gaussian shapes.

The authors also evaluated the IMME parameters for the A=15 T=3/2 analog states.

^{15}F Levels

E(level)	J^{π}	Γ	E(p+^{14}O)$_{cm}$ (keV)	Comments
0	1/2$^+$	>900 keV	1.6×10^3 *2*	E(level): mass excess=16.9 MeV *2*. The lack of a minimum between the ground and first excited states makes a mass excess determination difficult. Likewise, the lack of an angular momentum barrier for the $s_{1/2}$ state results in a large tail toward higher energies and complicates quantification of the width.
1.2×10^3 *2*	5/2$^+$	240 keV *30*	2802 2 *5*	E(level): mass excess=18.088 MeV *25*. The value for this resonance energy is sometimes not rigorously deduced; see for example 2005Fo10 who list E_{res}=2.8 MeV with 200 keV uncertainty. This value has been carried over into other analyses. The resonance energy is derivable with 25 keV resolution using the known p and ^{14}O mass excesses.

^{20}Ne(^{3}He,^{8}Li):LBNL 1978Ke06

1978Ke06:

The authors evaluated the excitation spectrum of the ^{15}F nucleus using the ^{20}Ne(^{3}He,^{8}Li) reaction to obtain reaction Q values, mass excesses and decay widths of states.

Beams of 88 and 75 MeV/nucleon ^{3}He ions from the LBNL 88-Inch Cyclotron impinged on an enriched (>99.5%) 1.2±0.4 mg/cm^{2} ^{20}Ne gas target. The ^{8}Li reaction products were detected in the focal plane of a QSD spectrometer positioned at θ=9°. The peaks were analyzed to obtain Q-value and mass excesses.

The authors also evaluated the IMME parameters for the A=15 T=3/2 analog states.

^{15}F Levels

E(level)	J^{π}	Γ	E(p+^{14}O)$_{cm}$ (MeV)	Comments
0	1/2^{+}	0.8 MeV *3*	1.37 *18*	E(level): The Q-value is Q=−29.73 MeV *18* and mass excess=16.67 MeV *18*.
1.3×10^{3} *2*	5/2^{+}	0.5 MeV *2*	2.67 *10*	E(level): The resonance energy is not rigorously discussed in the text; the Q-value to the state is not given. Instead the comment, "the excitation energy of the first excited state is 1.3±0.1 MeV" is given in the text. The evaluator assumes the mass excess is then Δm=(16.67+1.30)±0.10 MeV=17.97±0.10 MeV, which corresponds to a resonance energy E_{res}=2.67±0.10 MeV. E(level): In a comparison to the mirror nucleus, the excitation energy is 500 keV higher than the excitation energy of the first excited state in ^{15}C.

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