

**Adopted Levels, Gammas**

$Q(\beta^-) = -19720.90$ ;  $S(n) = 19254.25$ ;  $S(p) = 3923.14$ ;  $Q(\alpha) = -5115.14$  (2021Wa16)  
 $S_{2n} = 34812$  keV 20,  $S_{2p} = 4523.3$  keV 4 (2021Wa16).

$^{18}\text{Ne}$  was observed for the first time by Gow and Alvarez in 1954 (1954Go17) using the  $^{19}\text{F}(p,2n)^{18}\text{Ne}$  reaction. This study was conducted at Berkeley linear accelerator facility (see the associated dataset). The decay curve of  $^{18}\text{Ne}_{g.s.}$  was measured. The positron end point energy and the  $^{18}\text{Ne}_{g.s.}$  half-life were deduced.

$^{18}\text{Ne}_{g.s.}(J^\pi=0^+)$   $\beta^+$  decays to: (1)  $^{18}\text{F}_{g.s.}(1^+)$  with  $Q_{EC}(g.s.) = 4444.21$  keV 68 (2020Ha30) and  $BR = 92.25\%$  13 (weighted average of 92.5% 2 (1970As06); 92.11% 21 (1975Ha21); and 92.12% 21 (2013Gr03)). (2)  $^{18}\text{F}^*(1041.55$  keV,  $0^+$ ) – superallowed Fermi decay with  $Q_{EC} = 3402.66$  keV 69 (2020Ha30) and  $BR = 7.70\%$  21 (weighted average of 9% 3 (1963Fr10); and 7.69% 21 (2020Ha30)). (3)  $^{18}\text{F}^*(1700.81$  keV,  $1^+$ ) with  $BR = 0.1866\%$  32 (weighted average of 0.17% 5 (1970As06); 0.23% 3 (1975Ha21); 0.19% 4 (1981Ad01) and E. G. Adelberger private communication to Fay Ajzenberg-Selove, see (1983Aj01)); 0.183% 6 (1982He04); 0.188% 6 (1983Ad03); and 0.187% 5 (2013Gr03)). (4)  $^{18}\text{F}^*(1080.54$  keV,  $0^-$ ) – the first forbidden decay with  $BR = 0.00219\%$  11 (weighted average of 0.00228% 17 (1975Ha21); 0.00214% 26 (1982He04); 0.00207% 28 (1983Ad03); and 0.00214% 25 (2013Gr03)). (1968Go05) estimated an upper limit of  $BR < 1.5\%$  for the  $^{18}\text{Ne}(\beta^+)^{18}\text{F}^*(2100.61$  keV,  $2^-)$  decay but this branch is not observed and may not exist, see (1982He04).

$^{18}\text{Ne}$  ( $T_z = -1$ ) is a superallowed  $\beta$  emitter. If its  $ft$  value can be estimated with sub-1% precision, the theoretical isospin symmetry breaking correction can be constrained. The uncertainty in  $ft$  for  $^{18}\text{Ne}$ , evaluated most recently by (2020Ha30), is dominated by the 2.7% fractional uncertainty in the branching ratio of the superallowed Fermi decay branch measured by (1975Ha21). This study provided the normalization ratio of 7.83% 21, with which the absolute branching ratios mentioned earlier are deduced. The branching ratio of the superallowed Fermi decay branch was remeasured in 2012 as 7.29% 5 (H. Bouzomita-Zran, *Mesure de précision de la décroissance super-premise de  $^{18}\text{Ne}$* , Ph.D. Thesis, Université de Caen Normandie, 2015, unpublished). The uncertainty was reduced to 0.7% (unpublished). A proposal (Tech. Rep. CERN-INTC-2016-051 INTC-P-481) was submitted in 2016 to ISOLDE and Neutron Time-of-Flight Committee at CERN to improve this measurement by a factor of  $\sim 2$  in order to achieve the required  $\pm 0.3\%$  precision. To reduce the contributions of the  $^{18}\text{Ne}$  and  $^{18}\text{F}$  ground-state masses to the uncertainty of the superallowed  $Q_{EC}$ , another proposal (Tech. Rep. CERN-INTC-2018-015 INTC-P-545) was submitted in 2018 to measure the  $Q_{EC}(^{18}\text{Ne}_{g.s.} \rightarrow ^{18}\text{F}_{g.s.})$  to a precision of about 20 eV, and thus improving the current uncertainty (2021Wa16) by a factor 30.

**Measurements:**

*Mass*: 1960Aj01, 1961To03, 1961Du02, 1963Fr10, 1994Ma14, 2008Ge07, 2017Se09. See also 2004BI20, A. Kellerbauer et al., AIP Conf. Proc. 831 (2006) 49.

$B(E2; 0^+_{g.s.} \rightarrow 2^+)$ : 1976Mc02, 1988Se04, 2000Ri15.

*RMS charge radius*: 2000Ne11, 2008Ge07, 2011Ma48, 2013An02: the average *rms* charge radius as defined by the evaluation of (2013An02) is  $R = 2.9714$  fm 76.

*Half-life*: 1954Go17: 1.6 s 2; 1959Du81: 1.25 s 20 (as cited in 1961Bu05); 1961Bu05: 1.46 s 7; 1961Ec02: 1.7 s 4; 1963Fr10, 1965Fr09: 1.47 s 10; 1970Al11: 1.67 s 2; 1970As06: 1.69 s 4; 1972Ha58: 1.655 s 25; 1975Al27: 1.669 s 4; 1975Ha21: 1.687 s 9; 1975Ha45: 1.682 s 15 (the average value); 2007Gr18: 1.6656 s 19; 2013Gr03: 1.6648 s 11; 2015La19 and A. Laffoley, *High precision half-life measurements for the superallowed Fermi beta emitters oxygen-14 and neon-18*, Ph.D. Thesis, University of Guelph, (2015): 1.66400 s +57–48. See also compilations and evaluations: 1969Ka41, 1970Mc23, 1973To04, 1975Ra37, 1975Ha45, 2005Ha27, 2005Ha65, 2009Ha12, 2012Ha46, 2015Ha07, 2016Pr01, 2020Ha30, 2023Se01.

*Superallowed  $\beta^+$  transition*: M. Eibach and M. Mougeot, *High-precision measurement of the  $^{18}\text{Ne}$  superallowed  $\beta$ -decay  $Q$ -value*, Tech. Rep. CERN-INTC-2018-015. INTC-P-545 (CERN, Geneva, 2018).

*$\beta^+$  decay*: 1954Go17, 1960Bu03, 1980LoZY, 1981Ad01, 1981Ba67, 1981BaZJ, 1981BoZY, 1981VoZY, 1982DaZZ, 1982He04, 1982HeZW, 1982VoZY, 1983Ad03, 1988La01, 1994Re24, 1997Eg02, 1998Br23, 1999Og03, 2001Be67, 2002Vo11, 2009BaZT.

**Theory:**

*Mass excess, particle separation and binding energies*: 1965Ry01, 1977Sh13, 1999Si13, 2002Gu10, 2010La06, 2013Ho01, 2013Xu15, 2015Mo16, 2018Fo04 (evaluation), 2018Is03 (evaluation), 2021Ma33, 2022Zo01, 2023Di08.

*2p decay*: 1996Be27, 2002Br22, 2003Ba99, 2004Ro26, 2005Pf02, 2005Ro23, 2005Ro41, 2005Pf01 (evaluation), 2007Be54, 2008Ch31, 2008BI03, 2009Yu04.

*Ground state properties*: 1968Be82, 1968Ar02, 1971KhZT, 1977Br03, 1979Va07, 1980Zh01, 1981OvZZ, 1982Ov01, 1982Se15, 1983AnZQ, 1984Sa37, 1987Po01, 1994Ci02, 1996Go38, 1996Gr21, 1996Re03, 1997Pa38, 1997Ch09, 1998La02, 1998Re07, 2001Oz04, 2002Fo11, 2002Gu10, 2002Mi14, 2003St22, 2004Sa58, 2004Ge02, 2004La24, 2004Sa58, 2005Ch71, 2005Ma98,

**Adopted Levels, Gammas (continued)**

2005Sa59, 2005Sa63, 2006Ma17, 2006Sa29, 2008Sc02, 2008Wi11, 2010Zh45, 2011Eb02, 2011Gu03, 2011Ro50, 2011Su14, 2012Ma12, 2013FeZW, 2013Xu15, 2014Ch39, 2014Va13, 2015Mo16, 2015Si12, 2016Wa14, 2016Ja03, 2016St12, 2017Ah08, 2019Ra09, 2019Sa38, 2019Sa58, 2020An13, 2020Pa38, 2020No10, 2021Am03, 2022Yu02, 2023Sa22.

*Calculated levels:* 1968Va24, 1969Ra28, 1970El08, 1970El23, 1972Ka01, 1982Zh01, 1987Ra01, 1987Wi11, 1989SuZT, 1989Fu01, 1990Av06, 1998Sh35, 2001Ra27, 2003Fo13, 2003Jh01, 2004Sa58, 2011Fo12, 2011YuZY, 2012GoZU, 2012Su28, 2013Ho01, 2013Ja13, 2013Sc14, 2014Ca21, 2014Sa30, 2014Yu02, 2016Wa14, 2019Oi01, 2019Pa38, 2019Wu12, 2023Ya06.

*Shell model and ab initio calculations:* 1965En02, 1969Be94, 1969Zu03, 1970El23, 1970Ha49, T. Engeland *et al.*, Nucl. Phys. A 181 (1972) 368, 1972Ka01, 1977He18, J. A. Harvey, J. Phys. Soc. Jpn. Suppl. 44 (1978) 127, A. M. Bernstein, V. R. Brown, and V. A. Madsen, Phys. Rev. Lett. 42 (1979) 425, 1982Br24, 1983Br29, 1984Wi17, 1985Br29, D. J. Rowe, Rept. Prog. Phys. 48 (1985) 1419, 1986An07, 1986An10, 1996Pa28, 1997Bo47, 1997Mi08, 1999Si13, 1999Va03, 2006Gu07, 2006Or01, 2007Ma54, 2007Wa30, 2008Ne13, 2008NeZX, 2012Po15, 2013La15, 2015La10, 2015Wu07, 2018Ji07, 2019Mi22, 2020Wi12, 2020Ma25, 2021Ka42, 2021Sa49, 2021Ya26, 2022Si03, 2022Zh57, 2023Sa22, J. G. Li, K. H. Li, N. Michel, H. H. Li, and W. Zuo, *Mechanisms of mirror energy difference for states exhibiting Thomas-Ehrman shift: Gamow shell model case studies of  $^{18}\text{Ne}^{18}\text{O}$  and  $^{19}\text{Ne}^{19}\text{O}$* , arXiv:2407.00884v1 [nucl-th] (July-2024) (unpublished).

*Superallowed  $\beta$  transition:* 1978Sz03, 2002To19, 2005Ha15, 2005Ha65, 2006Ha12, 2008To03, 2012Ha46, 2012Sa50, G. F. Grinyer *et al.*, Nucl. Instr. Meth. Phys. Res. A 741 (2014) 18 (GEANT4 simulation for  $^{18}\text{Ne}$  decay), 2015To02, 2022Xa01.

*$\beta^+$  decay:* 1976Lo01, 1977Az02, 1977To11, 1981Ha06, E. G. Adelberger, Comments Nucl. Part. Phys. 11 (1983) 189, P. G. Bizzeti, Riv. Nuovo Cim. vol 6, issue 12 (1983) 1-64, 1984Ha58, E. G. Adelberger and W. C. Haxton, Ann. Rev. Nucl. Part. Sci. 35 (1985) 501, 1986KiZR, I. S. Towner, Ann. Rev. Nucl. Part. Sci. 36 (1986) 115, 1987Ki03, 1991Ja13, 1992Ba22, 1992He12, 1996Ka04, 1999Va08, 1999Va25, 2002Va14, 2004Mc05, 2009Ha12, 2009Li22, 2010Li52, 2015El06, 2016Sa34, 2020Oh01, 2023Se05.

*Mirror and analog states:* 1969Mu09, 1971Bi12, 1987Ki03, 2020Br14, 2021Am03, 2023Li03.

*Giant multipole resonances:* 1994StZY, 2012Ma12, 2017Lv02.

*Other nuclear structure information:* 1972En03, 1972Ra08, 1976Sh04, 1977Sz03, 1979En05 (compilation), 1979Sa31, 1982Ri04 (E2 strengths), 1982La26 (compilation), 1985Al21, 1985An28 (compilation), B. G. Harvey, J. Phys. (Paris) 47 (1986) C4-29, 1986St15 (transition densities), 1988Tr02, 1992Ch50 (astrophysical resonance properties), 2004Su26 (B(E2) strengths), 2005Li48 (Gamow-Teller transitions), 2005Sa63 (B(E2) strengths), 2008He15, 2008Ti09 (spectroscopic factors and ANCs), 2009PeZW (B(E1) strengths), 2009Yu04 (Faddeev approach), 2011Ma18 (B(E1) distributions), 2012Ok02 (ANCs), 2017Pr04 (evaluated B(E2)), 2018Mi22 (M1 strengths), 2019Mu05 (ANCs), 2022Oh01, 2022Gu11, 2022Su17, 2023Fo05, 2023Xu10, 2024Ga05 (charge radius).

Other topics:

*Decay of trapped ions:* 2020Oh01.

*Other reactions that populated  $^{18}\text{Ne}$ :*

$^{12}\text{C}(^{18}\text{O}, ^{18}\text{Ne})^{12}\text{Be}$ : M. Takaki *et al.*, Proc. Conf. Advances in Radioactive Isotope Science (ARIS2014) JPS Conf. Proc. 6 (2015) 020038.

$^{18}\text{O}(^{12}\text{C}, ^{12}\text{Be}(0_2^+))^{18}\text{Ne}$ : 2015TaZY: populated the ground state of  $^{18}\text{Ne}$ .

$^{40}\text{Ca}(^{18}\text{O}, ^{18}\text{Ne}^*)^{40}\text{Ar}$ : 2015Ca24, 2016Ca12. These studies populated the  $^{18}\text{Ne}^*(1887\text{ keV}, 2^+)$  state. It was observed as unresolved and mixed with the  $^{40}\text{Ar}_{\text{g.s.}}$  and  $^{40}\text{Ar}^*(1.46\text{ MeV})$  state.

$^{116}\text{Sn}(^{18}\text{O}, ^{18}\text{Ne})^{116}\text{Cd}$ : 2019CaZW.

Previous  $^{18}\text{Ne}$  evaluations: 1959Aj76, 1972Aj02, 1978Aj03, 1981AjZY, 1983Aj01, 1987Aj02, 1978Aj03, 1987Co31, 1995Ti07.

 $^{18}\text{Ne}$  Levels

When possible, measured resonance energies in the center-of-mass have been used to deduced the corresponding  $E_x$  using either  $S_p=3923.1\text{ keV}$  or  $S_n=5115.1\text{ keV}$  from (2021Wa16). The given resonant reaction (A(b,c):res) determines which separation energy is used. These deduced  $E_x$  values are included in the recommended weighted average excitation energies given in the  $^{18}\text{Ne}$  Adopted Levels.

Cross Reference (XREF) Flags

A	$^{22}\text{Al}$ $\varepsilon\alpha$ decay:91.1 ms	K	$^9\text{Be}(^{20}\text{Mg},\text{X})$	U	$^{19}\text{F}(p,2n)$
B	$^{19}\text{Na}$ p decay	L	$^9\text{Be}(^{34}\text{Ar}, ^{18}\text{Ne}\gamma)$	V	$^{20}\text{Ne}(p,t)$
C	$^1\text{H}(^{17}\text{F},\gamma)$	M	$^{12}\text{C}(^{12}\text{C}, ^6\text{He})$	W	$^{27}\text{Al}(\pi^-, ^{18}\text{Ne}\gamma)$
D	$^1\text{H}(^{17}\text{F},p),(^{17}\text{F},2p),(^{17}\text{F},\alpha)$ :res	N	$^{14}\text{N}(^{17}\text{F}, ^{18}\text{Ne})$	X	$^{27}\text{Al}(p,\text{X}\gamma)$

<b>E</b>	<sup>1</sup> H( <sup>18</sup> Ne,p')	<b>O</b>	<sup>16</sup> O( <sup>3</sup> He,n)	<b>Y</b>	<sup>27</sup> Al( $\alpha$ , <sup>18</sup> Ne $\gamma$ ), <sup>28</sup> Si( $\alpha$ , <sup>18</sup> Ne $\gamma$ )
<b>F</b>	<sup>2</sup> H( <sup>17</sup> F,n)	<b>P</b>	<sup>16</sup> O( <sup>3</sup> He,n $\gamma$ )	<b>Z</b>	<sup>197</sup> Au( <sup>18</sup> Ne, <sup>18</sup> Ne'):coulex
<b>G</b>	<sup>4</sup> He( <sup>14</sup> O,p),( <sup>14</sup> O,2p):res	<b>Q</b>	<sup>16</sup> O( <sup>10</sup> B, <sup>8</sup> Li)	Others:	
<b>H</b>	<sup>4</sup> He( <sup>14</sup> O, $\alpha$ ):res	<b>R</b>	<sup>16</sup> O( <sup>11</sup> B, <sup>9</sup> Li)	<b>AA</b>	Si(p, <sup>18</sup> Ne)
<b>I</b>	<sup>9</sup> Be( <sup>17</sup> Ne, <sup>18</sup> Ne)	<b>S</b>	<sup>16</sup> O( <sup>12</sup> C, <sup>10</sup> Be)	<b>AB</b>	Pb( <sup>18</sup> Ne, <sup>18</sup> Ne'):coulex
<b>J</b>	<sup>9</sup> Be( <sup>18</sup> Ne, <sup>18</sup> Ne')	<b>T</b>	<sup>18</sup> O( $\pi^+$ , $\pi^-$ )		

E(level)	J <sup><math>\pi</math></sup>	T <sub>1/2</sub> or $\Gamma$	XREF			Comments
0	0 <sup>+</sup> <i>d</i>	1.66427 s 72	ABC EF	KLMNOP	STUVWXYZ	<p>XREF: Others: <b>AA</b>  <math>\% \epsilon + \% \beta^+ = 100</math> (1981Ad01)                      XREF: X(?)                      T=1 (1961Bu05, 1963Fr10, 1974Ne04, 1975Ha21, 1979Se08, 1981Ne09, 1981Ad01).                      T<sub>z</sub>=-1 (1968Gi09, 1975Ha21).                      T<sub>1/2</sub>: Weighted average (with external errors) of 1.6 s 2 (1954Go17); 1.73 s 42 (1961Ec02: from <math>\tau=2.5</math> s 6); 1.46 s 7 (1961Bu05); 1.47 s 10 (1963Fr10, 1965Fr09); 1.69 s 4 (1970As06); 1.67 s 2 (1970Al11); 1.669 s 4 (1975Al27); 1.687 s 9 (1975Ha21); 1.6648 s 11 (2013Gr03: includes the re-analysis of data from 2007Gr18); and 1.66400 s +57-48 (2015La19).                      See also T<sub>1/2</sub>=1.25 s 20 (1959Du81 as cited in 1961Bu05: this value is an outlier based on the Chauvenet's criterion); 1.655 s 25 (1972Ha58: a preliminary result preceding the value reported by (1975Ha21)); and 1.68 s (1969Ka41: a theoretical estimation). For the extensive evaluations by J. C. Hardy and I. S. Towner, see T<sub>1/2</sub>=1.682 s 15 (1975Ha45); 1.6670 s 17 (2009Ha12); 1.6654 s 11 (2015Ha07); and 1.66422 s 47 (2020Ha30).                      J<sup><math>\pi</math></sup>: From the zero-range DWBA analysis of (1996Ha26: see Fig. 5), which deduced L=0 from the neutron angular distributions corresponding to the strongly populated (via <sup>16</sup>O(<sup>3</sup>He,n)) <sup>18</sup>Ne<sub>g.s.</sub> (see footnote). This assignment is supported by various other DWBA analyses, mirror and isobaric analog states analyses, and Hauser-Feshbach calculations (see individual datasets).                      The A=18 <math>\beta</math>-decay mirror asymmetry: <math>\delta_{\text{exp}} = -0.86\% 80</math> (1975Al27). This is the asymmetry in the A=18 <math>\beta</math>-decay <i>ft</i> values, i.e., <math>\delta = [\log(ft^+)/\log(ft^-)] - 1</math>.                      Decays to the <sup>18</sup>F(g.s., 1042-, 1081-, and 1701-keV) states, see (1961Bu05, 1963Fr10, 1965Fr09, 1968Go05, 1970Al11, 1970As06, 1972Ha58, 1975Ha21, 1981Ad01, 1982He04, 1982DaZZ, 1983Ad03, 2013Gr03, 2020Ha30).                      %IT=100                      T=1 (1976Mc02, 1981Ne09)                      XREF: S(1.8E3)X(?)Y(?)                      E(level): Weighted average of 1880 keV 10 (1961To03); 1887.4 keV 2 (1968Gi09, 1969Ro08: evaluator performed a least-squares fit, with recoil correction, to the E<sub><math>\gamma</math></sub>); 1890 keV 20 (1969Ha38); 1894 keV 10 (1972Pa02); 1886 keV 10 (1974Ne04, 1981Ne09: (p,t)); 1886 keV 7 (1977Ev01); 1890 keV 19 (1978Ha10); 1886.5 keV 15 (deduced from <math>\Delta(^{18}\text{Ne}^*(2^+))=7204.1</math> keV 15 (1994Ma14) together with <math>\Delta(^{18}\text{Ne}_{\text{g.s.}})=5317.617</math> keV 363 (2021Wa16)); and 1887 keV 3 (2005Pa50). Note that E<sub>x</sub>=2000 keV 100 (1966Kr05) and 1830 keV 50 (1970Le08) are marked as outliers by the Chauvenet's criterion and are excluded. E<sub>x</sub>=1887 keV 1 (1972Gi01, 1980Li14) is excluded because it</p>
1887.4 2	2 <sup>+</sup>	0.47 ps 4	ABC EF	LMNOPQ	ST VWXYZ	<p>%IT=100                      T=1 (1976Mc02, 1981Ne09)                      XREF: S(1.8E3)X(?)Y(?)                      E(level): Weighted average of 1880 keV 10 (1961To03); 1887.4 keV 2 (1968Gi09, 1969Ro08: evaluator performed a least-squares fit, with recoil correction, to the E<sub><math>\gamma</math></sub>); 1890 keV 20 (1969Ha38); 1894 keV 10 (1972Pa02); 1886 keV 10 (1974Ne04, 1981Ne09: (p,t)); 1886 keV 7 (1977Ev01); 1890 keV 19 (1978Ha10); 1886.5 keV 15 (deduced from <math>\Delta(^{18}\text{Ne}^*(2^+))=7204.1</math> keV 15 (1994Ma14) together with <math>\Delta(^{18}\text{Ne}_{\text{g.s.}})=5317.617</math> keV 363 (2021Wa16)); and 1887 keV 3 (2005Pa50). Note that E<sub>x</sub>=2000 keV 100 (1966Kr05) and 1830 keV 50 (1970Le08) are marked as outliers by the Chauvenet's criterion and are excluded. E<sub>x</sub>=1887 keV 1 (1972Gi01, 1980Li14) is excluded because it</p>

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**Adopted Levels, Gammas (continued)** $^{18}\text{Ne}$  Levels (continued)

<u>E(level)</u>	<u>J<sup><math>\pi</math></sup></u>	<u>T<sub>1/2</sub> or <math>\Gamma</math></u>	<u>XREF</u>				<u>Comments</u>
							<p>was adopted by those authors from the <math>^{18}\text{Ne}</math> evaluation of (1978Aj03).</p> <p>T<sub>1/2</sub>: From <math>\tau=0.68</math> ps 6, which is the weighted average (with external errors and assuming statistical uncertainties) of <math>\tau=0.49</math> ps +17-9 (1968Gi09, 1969Ro08); <math>\tau=0.67</math> ps 6 (1976Mc02); and <math>\tau=0.77</math> ps +9-7 (2003Ri08). See also <math>\tau=0.63</math> ps 13 (sys.) (1974Mc17), which is excluded (see the <math>^{16}\text{O}(^3\text{He},n\gamma)</math> dataset for discussion).</p> <p>J<sup><math>\pi</math></sup>: From the coefficients of Legendre polynomial fits to the <math>\gamma</math>-ray angular correlations data measured by (1969Ro22). These uniquely determine J=2. The positive parity is preferred by (1969Ro22) from the lifetime measurement of (1968Gi09). This J<sup><math>\pi</math></sup> assignment is supported by various DWBA and mirror states analyses (see individual datasets).</p> <p><math>\delta=0.59284</math> (2005Gu03): theoretical quadrupole deformation parameter.</p> <p><math>\beta_C=0.450</math> 36 and <math>\beta_N=0.481</math> 39 (2000Ri15: using the optical model parameters of (1987Me05)). <math>\beta_C</math> and <math>\beta_N</math> are the Coulomb and nuclear deformation parameters, respectively. Using the optical model parameters of (1988Ba39), (2000Ri15) deduced <math>\beta_C=0.496</math> 40 and <math>\beta_N=0.503</math> 40. All these deformation values are obtained under the assumption that <math>b_n^F/b_p^F=0.820</math> for the <math>^{197}\text{Au}</math> target used, where <math>b_{n/p}^F</math> is the external field interaction strength of the probe F (which is <math>^{197}\text{Au}</math>) with neutrons or protons in the nucleus to be studied (<math>^{18}\text{Ne}</math>).</p> <p>The neutron and proton multipole matrix element for the empirical quadrupole densities are <math>M_n=6.18</math> fm<sup>2</sup> and <math>M_p=3.00</math> fm<sup>2</sup>, with <math>M_n/M_p=2.06</math> using the convention in which <math>B(E2; 0_{g.s.}^+ \rightarrow 2_1^+)=5M_p^2=45</math> fm<sup>4</sup> (1999Ri05). The empirical densities have <math>M_p/M_n &gt; Z/N</math> for <math>^{18}\text{Ne}</math> and <math>M_n/M_p &gt; N/Z</math> for <math>^{18}\text{O}</math> (1999Ri05). <math>M_p/M_n &gt; Z/N</math> is expected for low-lying quadrupole transitions in a closed neutron shell nucleus like <math>^{18}\text{Ne}</math> (1999Ri05).</p>
3376.4 4	4 <sup>+</sup>	3.05 ps 42	C	F	LMNOPQRS	VW	<p>%IT=100</p> <p>T=1 (1974An36,1981Ne09)</p> <p>E(level): Weighted average of 3362 keV 11 (1961To03); 3375 keV 30 (1969Ha38); 3376.4 keV 4 (1968Gi09, 1969Ro08: evaluator performed a least-squares fit to <math>E_\gamma</math> that took into account the recoil correction); 3360 keV 50 (1970Le08); 3375 keV 15 (1970Ad02); 3390 keV 14 (1972Pa02); 3375 keV 10 (1974Ne04, 1981Ne09: (p,t)); 3374 keV 7 (1977Ev01); 3380 keV 34 (1978Ha10); and 3376 keV 3 (2005Pa50).</p> <p>T<sub>1/2</sub>: From <math>\tau=4.4</math> ps 6 (1972Gi01). See also <math>\tau=1.9</math> ps +7-4 (1969Ro08) and <math>\tau=1.9</math> ps +10-4 (1968Gi09: the preliminary result published by the same authors before (1969Ro08)). Both of these values are measured via Doppler shift attenuation method. (1972Gi01) raised concern about the validity of the (1963Li17) stopping theory for light nuclei recoiling into high-Z materials with low velocities (used in deducing the aforementioned lifetimes), which cast doubt on the results of</p>

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**Adopted Levels, Gammas (continued)**

<sup>18</sup>Ne Levels (continued)

E(level)	J <sup>π</sup>	T <sub>1/2</sub> or Γ	XREF			Comments
3576.3 15	0 <sup>+</sup> <i>d</i>	2.8 ps 14	F	LM OP	V	<p>(1968Gi09, 1969Ro08) and may explain the inconsistencies between those values and the lifetime deduced by (1972Gi01).</p> <p>J<sup>π</sup>: From the nγ angular correlation measurement of (1970Sh04: studied the <sup>16</sup>O(<sup>3</sup>He,n)<sup>18</sup>Ne*→<sup>18</sup>Ne<sub>g.s.</sub>+γ reaction), which yielded a unique spin-parity assignment of J<sup>π</sup>=4<sup>+</sup>. This J<sup>π</sup> assignment is supported by various DWBA analyses and mirror states analyses (see individual datasets).</p> <p>%IT=100 T=1 (1981Ne09)</p> <p>E(level): Weighted average of 3576.5 keV 20 (1968Gi09, 1969Ro08: evaluator performed a least-squares fit to E<sub>γ</sub> that took into account the recoil correction); 3564 keV 20 (1970Ad02); 3576 keV 4 (1970Sh04); 3580 keV 10 (1974Ne04, 1981Ne09: (p,t)); and 3576 keV 3 (2005Pa50).</p> <p>T<sub>1/2</sub>: From τ=4 ps 2 deduced by (1972Gi01) by combining τ&gt;2 ps (1968Gi09, 1969Ro08: lower limit comes from the lack of Doppler shift observation for the 1689-keV γ ray from the decay of this state when using either of the CdO or SrO thick targets); and τ&lt;6 ps (1972Gi01). Evaluator notes that τ=4 ps 2 was proposed by (1972Gi01) and is not based on a decision made in this evaluation. It is a historically accepted value adopted by the previous <sup>18</sup>Ne evaluations ever since.</p> <p>J<sup>π</sup>: From the <sup>20</sup>Ne(p,t) measurement by (1981Ne09: see Fig. 14), which deduced J<sup>π</sup>=0<sup>+</sup> and L=0 through comparison of the triton angular distribution corresponding to this state with known L=0 transitions in the similar <sup>20</sup>Ne(p,t) measurements (1970Le08, 1970Fa17); mirror levels analysis; two-nucleon Coulomb shift analysis; and guided by the DWBA analysis of the <sup>20</sup>Ne(p,t) data of (1970Fa17). This assignment is supported by isobaric analog levels analysis, DWBA analyses, zero-range coupled-channel Born approximation calculations, and the nγ angular correlation of the <sup>16</sup>O(<sup>3</sup>He,n) reaction (see individual datasets and the footnote).</p> <p>(1970El23) and (1973Mc06) predicted that this state may have a pure 2p-0h configuration. The shell model calculations by (2022Ba39) indicate that this state is dominated by the two particle-hole excitation and couples to the L=0, n=4 α channel with a spectroscopic factor of 0.62 (from shell model).</p>
3616.5 6	2 <sup>+</sup> <i>d</i>	44 fs +2I-14	C F	LMNOP	T V Z	<p>%IT=100 T=1 (1970Sh04,1981Ne09) XREF: Z(?)</p> <p>E(level): Weighted average of 3608 keV 12 (1961To03); 3616.6 keV 6 (1968Gi09, 1969Ro08: evaluator performed a least-squares fit to E<sub>γ</sub> reported by (1968Gi09, 1969Ro08, 1969Ro22) that took into account the recoil correction); 3610 keV 15 (1970Ad02); 3612 keV 10 (1974Ne04, 1981Ne09: (p,t) using the Princeton Q3D spectrograph); 3603 keV 15 (1977Ev01); and 3616 keV 3 (2005Pa50).</p>

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Adopted Levels, Gammas (continued) $^{18}\text{Ne}$  Levels (continued)

<u>E(level)</u>	<u><math>J^\pi</math></u>	<u><math>T_{1/2}</math> or <math>\Gamma</math></u>	<u>XREF</u>				<u>Comments</u>	
4517 4	$1^-d$	9 keV 6	b	I	m	O	V	<p><math>T_{1/2}</math>: From <math>\tau=0.063</math> ps <math>+30-20</math> (1969Ro08). See also <math>\tau=0.06</math> ps <math>+3-2</math> (1968Gi09).</p> <p><math>\Gamma=1.05\times 10^{-2}</math> eV (1969Ro08: from <math>\tau=0.063</math> ps).</p> <p><math>J^\pi</math>: From the <math>^{20}\text{Ne}(p,t)</math> measurement by (1981Ne09: see Fig. 14), which deduced <math>J^\pi=2^+</math> and <math>L=2</math> through comparison of the triton angular distribution corresponding to this state with known <math>L=2</math> transitions in the similar <math>^{20}\text{Ne}(p,t)</math> measurements (1970Le08, 1970Fa17); mirror levels analysis; two-nucleon Coulomb shift analysis; and guided by the DWBA analysis of the <math>^{20}\text{Ne}(p,t)</math> data of (1970Fa17). In addition, the <math>n\gamma</math> angular correlation measurements of (1970Sh04) using the <math>^{16}\text{O}(^3\text{He},n)</math> reaction yielded a unique spin-parity assignment of <math>J^\pi=2^+</math>.</p> <p><math>J^\pi</math>: This assignment is supported by zero- and finite-range DWBA analyses, zero-range coupled-channel Born approximation calculations, isobaric analog levels analysis, mirror levels analysis, and measured <math>\gamma</math>-ray angular distribution and <math>n\gamma</math> angular correlations (see individual datasets).</p> <p><math>\Gamma_{p1}/\Gamma&lt;0.125</math> (2019Ch16)</p> <p>XREF: b(4481)m(4520)</p> <p>E(level): Weighted average of 4505 keV 15 (1970Ad02); 4530 keV 20 (1970Fa17); 4460 keV 50 (1970Le08); 4522 keV 10 (1974Ne04, 1981Ne09: (p,t) reaction); 4520 keV 1 (stat.) 7 (sys.) (1991Ga03); 4519 keV 1 (stat.) 4 (sys.) (2005Pa50); and 4514 keV 4 (2019Ch16). Note that <math>E_x=4460</math> keV 50 (1970Le08) is an outlier based on Chauvenet's criterion and is therefore excluded.</p> <p><math>T_{1/2}</math> or <math>\Gamma</math>: From (1991Ga03, 1999Pa07). See also <math>\Gamma\leq 20</math> keV (1981Ne09: (p,t), the result supersedes <math>\Gamma\leq 40</math> keV from an earlier (p,t) study by (1974Ne04)); and <math>\Gamma_p&lt;0.1</math> keV (1991Ga03: deduced using the measured proton spectroscopic factor of the mirror state in <math>^{18}\text{O}</math> from (1976Li01), and the single-particle width obtained from optical model calculations of (1991Ga03)). They assumed a negligible branch for the <math>^{18}\text{Ne}^*(4517\text{ keV})\rightarrow^{17}\text{F}^*(495\text{ keV})+p</math> decay such that <math>\Gamma\approx\Gamma_{p0}</math>. (1991Ga03) used <math>\Gamma_p&lt;0.1</math> keV to calculate the <math>^{17}\text{F}(p,\gamma)</math> reaction rate. They argued that the observed width of <math>\Gamma=9</math> keV 6 is consistent with zero [at <math>2\sigma</math>].</p> <p><math>\Gamma_{p1}/\Gamma&lt;0.125</math> (at <math>2\sigma</math> level) (2019Ch16), which mentions that there is a possibility for this result to be overestimated due to other sources of background that may have been unaccounted for, or from the overlap of some of the nearby states. Even though (2019Ch16) deduced an upper limit of 12.5% for the branching ratio of the decay of this state to <math>^{17}\text{F}^*(495\text{ keV})</math>, those authors expect the actual value to be extremely small as it is energetically more favorable for this state to proton decay to <math>^{17}\text{F}_{g.s.}</math> rather than to <math>^{17}\text{F}^*(495\text{ keV})</math>. A shell-model estimation of <math>\Gamma_{p1}/\Gamma_{\text{tot}}=1.32\times 10^{-6}</math> by (2019Ch16) confirms this.</p> <p><math>J^\pi</math>: From the <math>^{20}\text{Ne}(p,t)</math> measurement by (1981Ne09: see Fig. 14), which deduced <math>J^\pi=1^-</math> and <math>L=1</math> through comparison of the triton angular distribution corresponding to this state with known <math>L=1</math> transitions in the similar <math>^{20}\text{Ne}(p,t)</math> measurements</p>

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**Adopted Levels, Gammas (continued)**

<sup>18</sup>Ne Levels (continued)

E(level)	J <sup>π</sup>	T <sub>1/2</sub> or Γ	XREF				Comments
4524.0 21	3 <sup>+</sup>	18 keV 2	BCD	F	m	O	<p>(1970Le08, 1970Fa17); mirror levels analysis; two-nucleon Coulomb shift analysis; and guided by the DWBA analysis of the <sup>20</sup>Ne(p,t) data of (1970Fa17).                      J<sup>π</sup>: This assignment is supported by various DWBA analyses, Hauser-Feshbach calculations, isobaric analog states analysis, and Coulomb shift analysis (see individual datasets).                      This state predominantly decays through <sup>17</sup>F<sub>g.s.</sub>+p (2019Ch16).                      XREF: b(4481)m(4520)                      E(level): Weighted average of 4522.9 keV 25 (1999Ba49, 2000Bb04: from <sup>1</sup>H(<sup>17</sup>F,p):res E<sub>c.m.</sub>=599.8 keV 15 (stat.) 20 (sys.)); 4.52 MeV 5 (2001Go01: from <sup>1</sup>H(<sup>17</sup>F,p):res E<sub>c.m.</sub>=0.60 MeV 5); 4521 keV 25 (2010Ji02: from <sup>1</sup>H(<sup>17</sup>F,p):res E<sub>c.m.</sub>=598 keV 25); and 4527 keV 1 (stat.) 4 (sys.) (2005Pa50).                      T<sub>1/2</sub> or Γ: From Γ<sub>p</sub>≈Γ=18 keV 2 (stat.) 1 (sys.) (2000Bb04). See also Γ<sub>p</sub>≈Γ=17 keV 4 (sys.) (2005Pa50); and Γ<sub>p</sub>≈Γ=14.2 keV 3 (stat.) 11 (sys.) (2017Ku27: determined indirectly using C<sup>2</sup>S=0.78 2 (stat.) 6 (sys.) deduced from σ=15.3 mb 3 (stat.) 12 (sys.) measured for the J<sup>π</sup>=3<sup>+</sup> assignment).                      Γ<sub>γ</sub>=56 meV 24 (stat.) 30 (sys.) (2009Ch17, 2009Ch64, 2009ChZW: based on the direct measurement of ωγ=33 meV 14 (stat.) 17 (sys.) from the same study, and Γ<sub>p</sub>=18 keV 2 (stat.) 1 (sys.) from (2000Bb04) assuming J<sup>π</sup>=3<sup>+</sup>). See also Γ<sub>γ</sub>=25 meV 16 (2000Bb04: see Table V, where the value is taken from Γ<sub>γ</sub>(3<sub>1</sub><sup>+</sup>→2<sub>1</sub><sup>+</sup>) corresponding to the mirror level in <sup>18</sup>O, see (1991Ga03)).                      J<sup>π</sup>: From R-matrix analyses of (1999Ba49, 2000Bb04, 2000Ga50, 2001Ga18, 2001Go01, 2002Li66, 2010Ji02, and 2010Wa18). This assignment is supported by the coupled reactions channel calculations (2017Ku27) using FRESKO, mirror and analog states analysis, and DWBA analysis (see individual datasets).                      This state may decay via p+<sup>17</sup>F<sub>g.s.</sub> (2005De15).                      T=1 (1981Ne09)                      Γ<sub>p1</sub>/Γ&gt;0.16 (2019Ch16)                      E(level): Weighted average of 4590 keV 30 (1968To09); 4571 keV 15 (1970Ad02); 4592 keV 10 (1974Ne04, 1981Ne09: (p,t)); 4589 keV 1 (stat.) 7 (sys.) (1991Ga03); 4590 keV 1 (stat.) 4 (sys.) (2005Pa50); and 4594 keV 12 (2019Ch16).                      T<sub>1/2</sub> or Γ: Weighted average of Γ=2 keV +6-2 (1999Pa07: reported Γ=2 keV 6. The uncertainty band is changed to +6-2 keV to avoid having a negative width); and Γ=4 keV 4 (1991Ga03). See also Γ≤130 keV (1968To09); Γ≤40 keV (1970Ad02); and Γ≤20 keV (1981Ne09: (p,t), this result supersedes Γ≤40 keV reported in an earlier (p,t) measurement by (1974Ne04)).</p>
4590 4	0 <sup>+</sup> <sup>d</sup>	3 keV +4-2	B	I	M	O	V

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**Adopted Levels, Gammas (continued)** $^{18}\text{Ne}$  Levels (continued)

E(level)	$J^\pi$	$T_{1/2}$ or $\Gamma$	XREF	Comments
5100.5	$2^+$	45 keV	2 b D F M O T V	<p>See also <math>\Gamma_p=1</math> keV (1991Ga03): deduced for the state they observed at <math>E_x=4589</math> keV. This width was obtained using the experimentally determined proton spectroscopic factor of the mirror level in <math>^{18}\text{O}</math> (1976Li01) and the single-particle reduced width determined from an optical model calculation by (1991Ga03). <math>\Gamma_p=1</math> keV was used by those authors to determine the <math>^{17}\text{F}(p,\gamma)</math> reaction rate. It was assumed that <math>\Gamma \approx \Gamma_p</math>, where <math>\Gamma_p=1</math> keV was consistent with the observed width of <math>\Gamma=4</math> keV from (1991Ga03). These authors assumed that this level proton decays to the <math>^{17}\text{F}_{g.s.}</math>, which implies that <math>\Gamma \approx \Gamma_{p_0}</math>.</p> <p><math>\Gamma_{p_1}/\Gamma &gt; 0.16</math> (at <math>2\sigma</math> level) (2019Ch16).</p> <p><math>J^\pi</math>: From (1981Ne09), which used their <math>^{20}\text{Ne}(p,t)</math> data (see Fig. 14), and deduced <math>J^\pi=0^+</math> and <math>L=0</math> through comparison of the triton angular distribution corresponding to this state with the known <math>L=0</math> transitions in the similar <math>^{20}\text{Ne}(p,t)</math> measurements (1970Le08, 1970Fa17); mirror levels analysis; two-nucleon Coulomb shift analysis; and guided by the DWBA analysis of the <math>^{20}\text{Ne}(p,t)</math> data of (1970Fa17).</p> <p><math>J^\pi</math>: This assignment is supported by mirror and isobaric analog levels analysis, and various DWBA analyses (see individual datasets).</p> <p>Decays predominantly to <math>^{17}\text{F}^*(495 \text{ keV})+p</math> (2005De15, 2019Ch16: expects the decay to the ground state to also be significant).</p> <p>(1974Ne04, 1981Ne09, 1974Fo14) predicted a predominantly <math>s_{1/2}^2</math> character for this state.</p> <p>XREF: Others: AB</p> <p><math>T=1</math> (1981Ne09)</p> <p>XREF: b(5117)</p> <p><math>\Gamma_{2\text{He}}=1.8 \times 10^{-5}</math> eV (2001Go01).</p> <p>E(level): Weighted average of 5099 keV 10 (1981Ne09: (p,t): this result supersedes the <math>E_x=5095</math> keV 15 reported by an earlier (p,t) measurement by (1974Ne04)); 5075 keV 13 (1974Ne04, 1981Ne09: (<math>^3\text{He},n</math>)); 5106 keV 8 (1996Ha26: (<math>^3\text{He},n</math>)); 5115 keV 25 (1969Ha38); 5113 keV 30 (2010Ji02: from <math>^1\text{H}(^{17}\text{F},p)</math>:res <math>E_{c.m.}=1190</math> keV 30); and 5110 keV 30 (2011He09).</p> <p><math>T_{1/2}</math> or <math>\Gamma</math>: Weighted average of <math>\Gamma=40</math> keV 20 (1981Ne09: (p,t) using Q3D spectrograph); <math>\Gamma=50</math> keV 10 (1996Ha26: (<math>^3\text{He},n</math>)); <math>\Gamma=49</math> keV 6 (1996Ha26: (p,t) using K600 spectrograph); <math>\Gamma=45</math> keV 5 (1996Ha26: (p,t) using Q3D spectrograph); <math>\Gamma=45</math> keV 7 (1999Pa07); <math>\Gamma_p \approx \Gamma=45</math> keV 2 (2001Ga18, 2001Go01, 2002Li66, 2009He16, 2011He09); <math>\Gamma_p \approx \Gamma=42</math> keV 4 (2010Ji02); and <math>\Gamma_p \approx \Gamma=50</math> keV 8 (stat.) 8 (sys.) (2017Ku27: determined indirectly from measuring the proton spectroscopic factor from the <math>^2\text{H}(^{17}\text{F},n)</math> reaction). Evaluator assumed <math>\Gamma=\Gamma_p</math>, which is confirmed in (2017Ku27, 2020Br14: assigned the measured proton widths to the <math>2s_{1/2}</math> channel (see Section VII.B)). The <math>\Gamma_p</math> values deduced by (2010Ji02) and (2001Ga18, 2001Go01, 2002Li66, 2009He16, 2011He09) are based on an assumption that the width is entirely due to <math>L=0</math> proton emission to the <math>^{17}\text{F}_{g.s.}</math>, which is</p>

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Adopted Levels, Gammas (continued) $^{18}\text{Ne}$  Levels (continued)

<u>E(level)</u>	<u><math>J^\pi</math></u>	<u><math>T_{1/2}</math> or <math>\Gamma</math></u>	<u>XREF</u>							<u>Comments</u>	
5142 7	$3^-$	10 keV 5	b	D	I	M	O	T	V	Z	<p>confirmed by (2005De15). See also <math>\Gamma \leq 80</math> keV (1974Ne04: (p,t)); and <math>\Gamma \leq 60</math> keV (1974Ne04, 1981Ne09: (<math>^3\text{He},n</math>)).</p> <p><math>J^\pi</math>: From R-matrix analysis of (2000Ga50) and the zero-range DWBA analysis of (1999Pa07) using <math>L=2</math> (<math>^{20}\text{Ne}(p,t)</math> reaction).</p> <p><math>J^\pi</math>: This assignment is supported by the R-matrix analyses of (2001Ga18, 2001Go01, 2002Li66, 2009He16, 2010Ji02, 2010Wa18, and 2011He09), and the DWBA analysis of (1999Pa07: <math>L=2, J^\pi=2^+</math>).</p> <p>This state may decay via <math>^{17}\text{F}_{g.s.}+p</math> (2005De15).</p> <p>XREF: Others: AB</p> <p><math>T=1</math> (1981Ne09)</p> <p><math>\Gamma_{p1}/\Gamma &lt; 0.009</math> (2019Ch16)</p> <p>XREF: b(5117)</p> <p>E(level): Weighted average of 5150 keV 14 (1972Pa02); 5130 keV 10 (1977Ev01); 5135 keV 12 (1974Ne04, 1981Ne09: (<math>^3\text{He},n</math>)); 5151 keV 10 (1981Ne09: (p,t): this result supersedes <math>E_x=5149</math> keV 15 from an earlier (p,t) measurement by (1974Ne04)); 5153 keV 8 (1996Ha26: (<math>^3\text{He},n</math>)); and 5135 keV 2 (stat.) 7 (sys.) (2019Ch16: for systematic uncertainty, see text and/or the <math>^9\text{Be}(^{17}\text{Ne}, ^{18}\text{Ne})</math> dataset).</p> <p><math>T_{1/2}</math> or <math>\Gamma</math>: Weighted average of <math>\Gamma=25</math> keV 15 (1981Ne09: (p,t)); and <math>\Gamma=8</math> keV 5 (1999Pa07). See also <math>\Gamma \leq 60</math> keV (1974Ne04, 1981Ne09: (<math>^3\text{He},n</math>)); <math>\Gamma \leq 50</math> keV (1974Ne04: (p,t)); <math>\Gamma \leq 20</math> keV (1996Ha26: (<math>^3\text{He},n</math>)); <math>\Gamma \leq 20</math> keV (1996Ha26: (p,t) using the K600 spectrograph, see Table V); and <math>\Gamma \leq 15</math> keV (1996Ha26: (p,t) using the Q3D spectrograph, see Table V).</p> <p><math>\Gamma_{p1}/\Gamma &lt; 0.009</math> (2019Ch16: at <math>2\sigma</math> level).</p> <p><math>J^\pi</math>: From R-matrix analysis of (2000Ga50); zero-range DWBA analysis of (1977Ev01: see Fig. 4, <math>L=3</math> (not specifically mentioned) at incident energies of 15 and 18 MeV); and zero-range DWBA analysis of (1999Pa07: <math>L=3</math> from the <math>^{20}\text{Ne}(p,t)</math> reaction).</p> <p>Decays to <math>^{17}\text{F}+p</math> (2007Ra36, 2008SfZZ, 2008Ra12, 2010Gi05, and 2010Ra14: the final state in <math>^{17}\text{F}</math> is not specified). See also (2019Ch16: mentions that this state predominantly decays to <math>^{17}\text{F}_{g.s.}+p</math>).</p> <p>The shell-model calculations of (2022Ba39) predicts a prominent <math>\alpha</math>-cluster structure for this level with an <math>\alpha</math>-spectroscopic factor of 0.49.</p>
5461 4	$2^-$	6 keV 6	I	M	O	V					<p><math>\Gamma_{p1}/\Gamma &lt; 0.19</math> (2019Ch16)</p> <p>E(level): Weighted average of 5453 keV 10 (1974Ne04, 1981Ne09: (p,t)); 5467 keV 5 (1999Pa07); 5454 keV 8 (1996Ha26: (<math>^3\text{He},n</math>)); and 5457 keV 8 (2019Ch16).</p> <p><math>T_{1/2}</math> or <math>\Gamma</math>: From (1999Pa07). See also <math>\Gamma \leq 20</math> keV (1996Ha26: (<math>^3\text{He},n</math>)) and <math>\Gamma \leq 50</math> keV (1974Ne04, 1981Ne09: (p,t)).</p> <p><math>\Gamma_{p1}/\Gamma &lt; 0.19</math> (2019Ch16: at <math>2\sigma</math> level).</p> <p><math>J^\pi</math>: From (2019Ch16) considering the angular momentum selection rules for the <math>^9\text{Be}(^{17}\text{Ne}, ^{18}\text{Ne})</math> reaction. Given that the momentum mismatch due to the fast beam in that experiment favors neutron capture to <math>d_{3/2}</math> or <math>d_{5/2}</math> shells, (2019Ch16) assigned <math>J^\pi=2^-</math> guided by shell model calculations</p>

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**Adopted Levels, Gammas (continued)** $^{18}\text{Ne}$  Levels (continued)

<u>E(level)</u>	<u><math>J^\pi</math></u>	<u><math>T_{1/2}</math> or <math>\Gamma</math></u>	<u>XREF</u>	<u>Comments</u>
6135 <i>I</i>	$1^-$	53.0 keV <i>18</i>	<b>D G I M O Z</b>	<p>and the result of (1996Ha26), where <math>J^\pi=(2^-)</math> was assigned from <math>^{12}\text{C}(^{12}\text{C},^6\text{He})</math> based on the <math>^6\text{He}</math> angular distribution which peaked at backward angle. This was taken as a signature for an un-natural parity assignment by (1996Ha26).</p> <p><math>J^\pi</math>: This assignment is supported by the result of (1996Ha26: (<math>^3\text{He},n</math>)), where a combination of penetrability considerations, level widths, mirror levels analysis, and Woods-Saxon calculations of the Coulomb energy shifts were used to infer a <math>J^\pi=(2^-)</math>. The unnatural spin-parity assignment was given based on the fact that the measured neutron angular distribution was not forward peaked.</p> <p>Decays to <math>^{17}\text{F}_{g.s.}+p</math> (2019Ch16).</p> <p>XREF: Others: <b>AB</b></p> <p><math>\Gamma_{p0}/\Gamma=0.70</math> 4 (2012Ba28); <math>\Gamma_{p1}/\Gamma=0.30</math> 2 (2012Ba28)</p> <p><math>\Gamma_{p1}/\Gamma_{p0}=0.42</math> 3 (2012Ba28)</p> <p><math>\Gamma_\alpha=6.9</math> eV 20</p> <p><math>\Gamma_{^2\text{He}}=21</math> eV 3 (2001Go01).</p> <p><math>\Gamma_{2p}=57</math> eV 6 (2001Go01: assuming a democratic 3-body decay).</p> <p>E(level): Weighted average of 6150 keV <i>10</i> (1996Ha26: (<math>^3\text{He},n</math>)); 6150 keV <i>20</i> (1996Ha26: <math>^{12}\text{C}(^{12}\text{C},^6\text{He})</math>); 6.14 MeV <i>I</i> (2001Go01: from <math>^1\text{H}(^{17}\text{F},p)</math>:res <math>E_{c.m.}=2.22</math> MeV <i>I</i>); 6.18 MeV <i>6</i> (2009He16: from <math>^1\text{H}(^{17}\text{F},p')</math>:res <math>E_{c.m.}=2.26</math> MeV <i>6</i>); 6135 keV <i>I</i> (2012Ba28: from <math>^1\text{H}(^{17}\text{F},p')</math>:res <math>E_{c.m.}=2212</math> keV <i>I</i>); 6.15 MeV <i>8</i> (2012A111: see Table II); 6150 keV <i>30</i> (2014Hu16); and 6142 keV <i>5</i> (stat.) <i>8</i> (sys.) (L. E. Pratt, Ph.D. Thesis, 2014).</p> <p><math>T_{1/2}</math> or <math>\Gamma</math>: Weighted average of <math>\Gamma=50</math> keV <i>5</i> (2001Ga18, 2001Go01, 2002Li66); <math>\Gamma=53.7</math> keV <i>20</i> (2012Ba28: sum of <math>\Gamma_{p0}=37.8</math> keV <i>19</i> and <math>\Gamma_{p1}=15.9</math> keV <i>7</i> from their best fit, which supersedes the result of (2003B111)); <math>\Gamma=50</math> keV <i>15</i> (2014Hu16); and <math>\Gamma=45</math> keV <i>12</i> (L. E. Pratt, Ph.D. Thesis, 2014). See also <math>\Gamma\leq 40</math> keV (1996Ha26: (<math>^3\text{He},n</math>)). See also <math>\Gamma_{p1}/\Gamma&lt;0.21</math> (2012A111); <math>\Gamma=40</math> keV <i>10</i> (2010Ad02: theoretical value based on three-cluster generator coordinate method associated with the hyperspherical formalism); and <math>\Gamma_{p0}&gt;15</math> keV (L. E. Pratt, Ph.D. Thesis, 2014: at 90% confidence level).</p> <p><math>\Gamma_\alpha</math>: Weighted average (with external errors) of <math>\Gamma_\alpha=3.2</math> eV <math>+50-20</math> (2002Ha15); and <math>\Gamma_\alpha=8</math> eV <i>2</i> (2003B111). See also (1) <math>\Gamma_\alpha=3.9</math> eV <i>10</i> (2012Fo12: theoretical value calculated based on <math>S_\alpha=0.23</math> deduced from the mirror level assuming equal spectroscopic factors for mirror states); and (2) <math>\Gamma_\alpha\approx 2</math> eV (2012A111), which reported this width from a private communication of the authors with G. V. Rogachev, where the width was determined using the ANC method from the mirror level in <math>^{18}\text{O}</math> (E. D. Johnson, G. V. Rogachev, J. Mitchell, L. Miller, and K. W. Kemper, Phys. Rev. C 80 (2009) 045805).</p> <p>This state has a small partial width (<math>\Gamma_{2p}\sim 80</math> eV) for <math>2p</math> decay mode, including decay via <math>^2\text{He}</math>. The <math>2p</math>-proton decay</p>

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Adopted Levels, Gammas (continued) $^{18}\text{Ne}$  Levels (continued)

<u>E(level)</u>	<u><math>J^\pi</math></u>	<u><math>T_{1/2}</math> or <math>\Gamma</math></u>	<u>XREF</u>	<u>Comments</u>
6301.3	$3^-$	10 keV 7	D G i m O V	<p>mode proceeds through (1) a <math>^2\text{He}</math> (diproton) resonance leading to the <math>^{16}\text{O}_{g.s.}</math> 31% 7 of the time (2008Ra12, 2010Gi05, 2010Ra14); (2) 2p democratic three-body decay 66% 9 of the time (2008Ra12, 2010Gi05, 2010Ra14); and (3) 2p virtual sequential decay via the <math>^{17}\text{F}^*(3.1\text{ MeV}, 1/2^-)</math> state 3% 2 of the time (2008Ra12, 2010Gi05, 2010Ra14).</p> <p><math>J^\pi</math>: From the R-matrix analysis of (2014Hu16: L=1 from the <math>^1\text{H}(^{17}\text{F},p)</math> reaction).</p> <p><math>J^\pi</math>: Supported by R-matrix analyses of (2001Ga18, 2001Go01, 2002Li66, 2003Bi11, 2009He16, 2010He17, 2010Ji02, 2012Ba28, and L. E. Pratt Ph.D. Thesis 2014), and by a combination of zero-range DWBA analysis, penetrability considerations, level widths, mirror levels analysis, Woods-Saxon calculations of the Coulomb energy shifts, and Hauser-Feshbach statistical-model calculations of (1996Ha26). (2014Hu16) considered this state to have a 4p-2h configuration, where holes are in <math>1p_{3/2}</math> and particles are in <math>2s_{1/2}</math> or <math>1d_{3/2}</math> orbitals.</p> <p>(2009He16, 2010He17) measured <math>\gamma</math>-rays from the decay of this state to <math>^{17}\text{F}^*(495\text{ keV})</math> in coincidence with the <math>^{17}\text{F}+p</math> protons gated on the 495-keV <math>\gamma</math>-rays, and yielded <math>\omega\gamma_{(p,p')}=22\text{ keV } 7</math> from the total angle-integrated cross section. An enhanced <math>p_1</math> branch is preferred by (2009He16).</p> <p>For the valence proton pair that are emitted in the 2p-decay from this state, (2016Li45) deduced the p-p distances inside the <math>^{18}\text{Ne}^*(6.135\text{ MeV})</math> nucleus and obtained a p-p distance of <math>5.44\text{ fm} +19-17</math> assuming a Gaussian shape and by using the Hanbury-Brown Twiss interferometry analysis. This result may indicate a small opening angle between the proton pair emitted by the decay of the <math>^{18}\text{Ne}^*(6.135\text{ MeV})</math> state. This is the signature of the crossover of Bardeen-Cooper-Schrieffer pairing correlation to the Bose-Einstein condensation pairing correlation in the dilute nuclear matter, i.e., a 2p halo nucleus.</p> <p><math>\Gamma_{p_0}/\Gamma=100\ 2</math> (2012A111)</p> <p>XREF: i(6.3E3)m(6300)</p> <p>E(level): Weighted average of 6280 keV 20 (1970Fa17); 6326 keV 18 (1972Pa02); 6291 keV 30 (1974Ne04, 1981Ne09: (<math>^3\text{He},n</math>)); 6297 keV 10 (1974Ne04, 1981Ne09: (p,t)); 6300 keV 10 (1996Ha26: (<math>^3\text{He},n</math>)); 6286 keV 10 (1996Ha26: (p,t) using K600 spectrograph); 6305 keV 4 (1999Pa07); 6.30 MeV 5 (2012A111: see Table II); and 6280 keV 30 (2014Hu16).</p> <p><math>T_{1/2}</math> or <math>\Gamma</math>: Weighted average of <math>\Gamma=8\text{ keV } 7</math> (1999Pa07); and <math>\Gamma_p\approx\Gamma=20\text{ keV } 15</math> (2014Hu16: assumed <math>\Gamma=\Gamma_p</math>, see Table II). See also <math>\Gamma=180\text{ keV } 60</math> (1974Ne04, 1981Ne09: (<math>^3\text{He},n</math>)); <math>\Gamma\leq 60\text{ keV } (1974\text{Ne}04, 1981\text{Ne}09: (p,t))</math>; <math>\Gamma\leq 20\text{ keV } (1996\text{Ha}26: (p,t)</math> using the K600 spectrograph at Indiana University); and <math>\Gamma_{p_0}&lt;4\text{ keV}</math> (L. E. Pratt, Ph.D. Thesis, 2014: at 90% confidence level, unpublished).</p> <p><math>\Gamma_{p_1}/\Gamma</math>: (2019Ch16): the proton branching ratios for the members of the 6.3-MeV unresolved doublet, which consisted of <math>E_x=6279\text{ keV } 36</math> and <math>E_x=6369\text{ keV } 36</math>, are not given separately. (2019Ch16) gives <math>\Gamma_{p_1}/\Gamma&lt;0.12</math> (at <math>2\sigma</math> level) for the pair of these states. The <math>J^\pi</math> values of this pair were expected to be <math>3^-</math> and <math>2^-</math> with an undetermined order.</p>

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**Adopted Levels, Gammas (continued)**

<sup>18</sup>Ne Levels (continued)

<u>E(level)</u>	<u>J<sup>π</sup></u>	<u>T<sub>1/2</sub> or Γ</u>	<u>XREF</u>	<u>Comments</u>
6352 4	2 <sup>-</sup>	12 keV 5	D i m O V	<p>(2019Ch16) reported the doublet as E<sub>x</sub>~6.3 MeV with J<sup>π</sup>=(2<sup>-</sup>, 3<sup>-</sup>).</p> <p>J<sup>π</sup>: From R-matrix analysis of (2014Hu16: L=1 from the <sup>1</sup>H(<sup>17</sup>F,p) reaction) guided by the resonance parameters from (1996Ha26). These parameters were deduced by (1996Ha26) from a combination of Coulomb penetrability considerations, level widths, mirror levels analysis, and Woods-Saxon calculations of the Coulomb energy shifts.</p> <p>XREF: i(6.3E3)m(6300)</p> <p>E(level): Weighted average of 6353 keV 10 (1974Ne04, 1981Ne09: (p,t)); 6350 keV 10 (1996Ha26: (<sup>3</sup>He,n)); 6343 keV 20 (1996Ha26: measured at θ<sub>lab</sub>=6° using the K600 spectrograph); 6346 keV 10 (1996Ha26: measured at θ<sub>lab</sub>=11° using the K600 spectrograph); 6358 keV 5 (1999Pa07); 6.34 MeV 1 (2001Ga18, 2001Go01, 2002Li66: from <sup>1</sup>H(<sup>17</sup>F,p):res E<sub>c.m.</sub>=2.42 MeV 1); and 6350 keV 30 (2014Hu16).</p> <p>T<sub>1/2</sub> or Γ: Weighted average of Γ=18 keV 9 (1999Pa07) and Γ=10 keV 5 (2014Hu16). See also Γ≤60 keV (1974Ne04, 1981Ne09: (p,t)); Γ≈50 keV (2001Go01: evaluator notes the R-matrix fit does not describe all of the observed features of the data in the vicinity of this state); and Γ=45 keV 10 (1996Ha26: (p,t) using the K600 spectrograph at Indiana University). The last value disagrees (with 1σ) with the widths reported by (1999Pa07, 2014Hu16). We therefore excluded it.</p> <p>Γ<sub>p1</sub>/Γ&lt;0.12 (2019Ch16: at 2σ level). This result is the average branching ratio for an unresolved doublet reported at E<sub>x</sub>=6279 keV 36 and E<sub>x</sub>=6369 keV 36. The J<sup>π</sup> values were expected to be 3<sup>-</sup> and 2<sup>-</sup>, whose order was not determined. These authors report this doublet as E<sub>x</sub>~6.3 MeV with J<sup>π</sup>=(2<sup>-</sup>, 3<sup>-</sup>).</p> <p>J<sup>π</sup>: From the R-matrix analysis of (2014Hu16: L=1 from the <sup>1</sup>H(<sup>17</sup>F,p) reaction).</p> <p>(2014Hu16) indicates that this state can be expected to have an appreciable amplitude with a simple particle-hole component.</p>
6.85×10 <sup>3</sup> 11	(0 <sup>+</sup> )	50 keV 30	D G	<p>Γ<sub>α</sub>=149 eV (2014Hu16)</p> <p>XREF: G(7050)</p> <p>E(level): From (2014Hu16: the uncertainty is taken from abstract and tables as opposed to 100 keV reported in the text). Based on all the evidence discussed in (2014Hu16), they concluded that very likely a new state around 6.8 MeV exists in <sup>18</sup>Ne.</p> <p>E(level): See also E<sub>x</sub>=6.97 MeV from the R-matrix analysis of (2011He09) assuming a doublet (see text). Note also the shell model calculations of (2022Ba39) predicts the 0<sub>4</sub><sup>+</sup> state to be around 7.8 MeV. However, this calculation seems to predict the <sup>18</sup>Ne excitation energies to within 1 MeV from the experimentally known states.</p> <p>T<sub>1/2</sub> or Γ: From (2014Hu16).</p> <p>Γ<sub>α</sub>: Calculated by (2014Hu16) assuming J<sup>π</sup>=0<sup>+</sup> and</p>

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Adopted Levels, Gammas (continued) $^{18}\text{Ne}$  Levels (continued)

<u>E(level)</u>	<u>J<sup><math>\pi</math></sup></u>	<u>T<sub>1/2</sub> or <math>\Gamma</math></u>	<u>XREF</u>			<u>Comments</u>
7050 30	4 <sup>+</sup>	≤120 keV	D	H	O	<p><math>C^2S=0.01</math>.</p> <p>J<sup><math>\pi</math></sup>: From R-matrix analysis of (2014Hu16: J<sup><math>\pi</math></sup>=(0<sup>+</sup>,0<sup>-</sup>) with L=2 and L=3, respectively, from the <math>^1\text{H}(^{17}\text{F},\text{p})</math> reaction). However, (2014Hu16) prefers the J<sup><math>\pi</math></sup>=0<sup>+</sup> assignment guided by the potential evidence of this state being probably observed by (2004No14, 2004No18) in a direct <math>\alpha(^{14}\text{O},\text{p})</math> reaction measurement, in which case, the state most likely is of the natural-parity nature.</p> <p>If this state is a 0<sup>+</sup> state, it would be the head of the 6p-4h band (2003Fo13, 2011Fo12).</p> <p>XREF: Others: AB  <math>\Gamma_\alpha=40</math> eV 14 (2002Ha15)  <math>\Gamma_{p1}/\Gamma&lt;0.031</math> (2010Ba21)  XREF: H(8.2E3)O(?)</p> <p>E(level): From the (<math>^3\text{He},\text{n}</math>) study by (1996Ha26) assuming a doublet, for which the excitation energies of the members were reported as tentative (see below). See also 7062 keV 12 (1974Ne04, 1981Ne09: (<math>^3\text{He},\text{n}</math>)); 7051 keV 18 (1977Ev01); 7.16 MeV 15 (1999Ha14); 7.05 MeV 10 (2002Ha15); 7.06 MeV 4 (2012A111: see Table II); and 7.05 MeV 3 (2014Hu16). These measurements are not considered for deducing the energy of this state because they were all obtained by fitting this region of the spectra using one peak, and thus they each constitute an unresolved doublet.</p> <p>E(level): (1996Ha26) improved the fit to their (<math>^3\text{He},\text{n}</math>) spectrum near this energy range by considering a doublet in this region consisting of <math>E_x=7050</math> keV 30 and <math>E_x=7120</math> keV 30 both with <math>\Gamma\leq 120</math> keV. The reporting energies were tentative.</p> <p>T<sub>1/2</sub> or <math>\Gamma</math>: From (1996Ha26: assuming a doublet). See also <math>\Gamma=180</math> keV 50 (1974Ne04, 1981Ne09: (<math>^3\text{He},\text{n}</math>), only one state was considered at this energy, where a doublet exists); <math>\Gamma_p=90</math> keV 40 (2002Ha15: assuming <math>\Gamma=\Gamma_p</math>); and <math>\Gamma=95</math> keV 20 (2014Hu16).</p> <p><math>\Gamma_\alpha</math> is supported by <math>\Gamma_\alpha=22.6</math> eV 32 calculated by (2003Fo13) assuming mirror symmetry of spectroscopic factors.</p> <p><math>\Gamma_p</math>: See <math>\Gamma_p=64</math> keV 13 calculated by (2003Fo13) assuming mirror symmetry of spectroscopic factors.</p> <p><math>\Gamma_{p1}</math>: See <math>\Gamma_{p1}&lt;14</math> eV calculated by (2012Fo29). This work overthrew the experimental results of (2012A111) for this state, which were <math>\Gamma_{p0}/\Gamma=0.83</math> 3, <math>\Gamma_{p1}/\Gamma=0.16</math> 7, <math>\Gamma_\alpha/\Gamma\leq 0.01</math> (see Fig. 7), <math>\Gamma_{p'}/\Gamma_p=0.19</math>, and <math>\Gamma_\alpha/\Gamma_p\leq 0.01</math> (2012A111). (2012Fo29) calculated <math>\Gamma_{p1}/\Gamma_{p0}&lt;2\times 10^{-4}</math> for this state and argued that this level should not have a measurable p<sub>1</sub> decay because if this 4<sup>+</sup> state were to decay to <math>^{17}\text{F}^*(495</math> keV, 1/2<sup>+</sup>), the proton must carry an angular momentum of L=4, and such an appreciable g<sub>9/2</sub> strength would be very unlikely. Furthermore, because of the large centrifugal barrier the maximum width for such a transition is very small (in contrast to what was found by 2012A111). See also <math>\Gamma_{p'}&lt;1</math> keV (2002Ha15: proton branches not specified).</p> <p>J<sup><math>\pi</math></sup>: From the R-matrix analyses of (2014Hu16: L=2 from <math>^1\text{H}(^{17}\text{F},\text{p})</math> reaction), and (2011He09: deduced J<sup><math>\pi</math></sup>=4<sup>+</sup> with L=</p>

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Adopted Levels, Gammas (continued) $^{18}\text{Ne}$  Levels (continued)

<u>E(level)</u>	<u><math>T_{1/2}</math> or <math>\Gamma</math></u>	<u>XREF</u>	<u>Comments</u>
7120 20	$\leq 120$ keV	G M O Q	<p>from the <math>^1\text{H}(^{17}\text{F},\text{p})</math> reaction). This assignment is supported by (2000Fo19) based on the theoretical calculations of (1998Sh35) and the Coulomb shift analysis between the mirror levels, which ruled out the <math>J^\pi=1^-</math> assignment made by (1999Ha14: for the state observed at <math>E_x=7.16</math> MeV 15).</p> <p>The sequential 2p-decay via an intermediate <math>^{17}\text{F}</math> state is energetically possible for this state (2008Ra12, 2010Ra14). The decay via <math>^{16}\text{O}+2\text{p}</math> channel is also observed by (2007Ra36, 2008SfZZ, 2008Ra12, 2010Gi05, and 2010Ra14). (2008Ra12) mentions that the mode of 2p-decay is either via sequential decay or via 3-body democratic decay.</p> <p>Evaluator notes that (2022Ba39) reported a <math>J^\pi=4^+</math> level at (8.2 MeV 11), which was considered by those authors to be the same state as the <math>^{18}\text{Ne}^*(7050</math> keV, <math>4^+</math>) level. The 8.2-MeV state was not considered here because the data for this state are incomplete (2022Ba39). (2022Ba39) reports <math>\Gamma_p=60</math> keV for the 8.2-MeV level, which is consistent with what was calculated by (2003Fo13: see above). However, the <math>\Gamma_\alpha</math> deduced by (2022Ba39) is 30 keV, which is much larger than a few tens of eV reported by (2002Ha15, 2003Fo13: see above).</p> <p>XREF: O(?)Q(7200)</p> <p>E(level): From (1996Ha26: <math>^{12}\text{C}(^{12}\text{C},^6\text{He})</math>). Listed as a tentative state at (7120 keV 30) (1996Ha26: <math>(^3\text{He},\text{n})</math>: assuming a doublet). This state is a member of a close lying doublet. (1996Ha26) initially considered a single peak, whose excitation energy and width were deduced as <math>E_x=7070</math> keV 10 and <math>\Gamma=200</math> keV 40. However, the fit of the spectrum with two states, consisting of 7.05 MeV 3 and 7.12 MeV 3, resulted in a smaller <math>\chi^2</math>, and thus a better fit. The energy was reported as tentative. (1996Ha26) assumed the <math>E_x=7120</math> keV 20 level populated via the <math>^{12}\text{C}(^{12}\text{C},^6\text{He})</math> reaction was the same state populated by the <math>^{16}\text{O}(^3\text{He},\text{n})</math> reaction. (2012Fo29) argued that in the <math>E_x\sim 7</math> MeV energy region, there may be a state that could explain the <math>p_1</math> decay branch observed by (2012A111) and whose origin they mistook as the 7050 keV state. (2012Fo29) speculated that the <math>^{18}\text{Ne}^*(7.3</math> MeV) state may be the origin of this observed decay branch. (2004No14, 2004No18, 2006Ku17) observed evidence from the direct measurement of <math>^{14}\text{O}(\alpha,\text{p})</math>, which may support the proton decay to <math>^{17}\text{F}^*(495</math> keV) from a state in <math>^{18}\text{Ne}</math> around 7.1 MeV, but (2010Ba21) did not see any evidence after scanning this region for inelastic proton decay to <math>^{17}\text{F}</math>.</p> <p>The combination of the <math>^{12}\text{C}(^{12}\text{C},^6\text{He})</math> and <math>^{16}\text{O}(^3\text{He},\text{n})</math> data from (1996Ha26) is consistent with two levels at <math>E_x=7.05</math> MeV and <math>E_x=7.12</math> MeV. Evaluator notes that (1981Ne09) mentions that at incident energies above 11 MeV, some of their <math>(^3\text{He},\text{n})</math> spectra suggest that the state near 7.1 MeV has additional structure (see Fig. 5 of (1981Ne09)). Attempts to verify this were inconclusive, and data were treated as a structureless, broad state (with <math>\Gamma=180</math> keV 50).</p> <p><math>T_{1/2}</math> or <math>\Gamma</math>: From (1996Ha26: <math>(^3\text{He},\text{n})</math> assuming a doublet).</p>

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**Adopted Levels, Gammas (continued)**

<sup>18</sup>Ne Levels (continued)

<u>E(level)</u>	<u>J<sup>π</sup></u>	<u>T<sub>1/2</sub> or Γ</u>	<u>XREF</u>			<u>Comments</u>
7352 13	(2 <sup>+</sup> ,1 <sup>-</sup> )	70 keV 60	D	G	M O	<p>E(level): Weighted average of 7350 keV 20 (1996Ha26: <sup>12</sup>C(<sup>12</sup>C,<sup>6</sup>He)); 7350 keV 18 (1996Ha26: (<sup>3</sup>He,n)); and 7.40 MeV 6 (2002Ha15: from <sup>1</sup>H(<sup>17</sup>F,p):res E<sub>c.m.</sub>=3.48 MeV 6).</p> <p>E(level): Note that (1999Ha14) reported E<sub>x</sub>=7.37 MeV 6 corresponding to a resonance at E<sub>c.m.</sub>=3.48 MeV above the proton threshold in <sup>18</sup>Ne. The reported excitation energy is erroneous because assuming the use of AME-1995 (1995Au04) by (1999Ha14), converting the above mentioned E<sub>c.m.</sub> to E<sub>x</sub> would result in E<sub>x</sub>=E<sub>c.m.</sub>+S<sub>p</sub>(<sup>18</sup>Ne)=7.41 MeV, where S<sub>p</sub>(<sup>18</sup>Ne)=3933.9 keV 15 (1995Au04). Therefore, the 7.37-MeV level from (1999Ha14) was excluded. Evaluator notes that this state was populated weakly in (2002Ha15, 2015Ki07) and is structureless in both these datasets. (2015Ki07) had difficulty identifying this featureless state due to very poor statistics. Therefore, their result is excluded.</p> <p>T<sub>1/2</sub> or Γ: From (2002Ha15: deduced from R-matrix for J<sup>π</sup>=2<sup>+</sup>). See also Γ≤50 keV (1996Ha26: (<sup>3</sup>He,n)); Γ<sub>α</sub>=0.08 keV (1999Ha14: for J<sup>π</sup>=1<sup>-</sup>, data are featureless and look broad); and Γ=390 keV 40 (2015Ki07: sum of Γ<sub>p</sub>=387 keV 40 and Γ<sub>α</sub>=3.1 keV 2 deduced for J<sup>π</sup>=(1<sup>-</sup>), area under this state may be &lt;5 counts).</p> <p>J<sup>π</sup>: See (2011He09: J<sup>π</sup>=2<sup>+</sup> with L=2 from <sup>1</sup>H(<sup>17</sup>F,p), R-matrix); (2002Ha15: J<sup>π</sup>=(2<sup>+</sup>), claimed that this state must be a natural-parity state and speculated J<sup>π</sup>=(2<sup>+</sup>) based on Coulomb shift and mirror levels analysis); (1996Ha26: (<sup>3</sup>He,n), zero-range DWBA analysis with L=(1) and J<sup>π</sup>=(1<sup>-</sup>)); (1999Ha14: J<sup>π</sup>=1<sup>-</sup> based on a combination of penetrability considerations, level widths, mirror levels analysis, and Woods-Saxon calculations of the Coulomb energy shifts); and (2015Ki07: J<sup>π</sup>=(1<sup>-</sup>), R-matrix). See also (2000Fo09), who disputed J<sup>π</sup>=1<sup>-</sup> based on their mirror level analysis. Evaluator notes that J<sup>π</sup>=2<sup>+</sup> from (2011He09) may be the strongest evidence.</p>
7601 14	(0 <sup>+</sup> ,1 <sup>-</sup> )	75 keV 20	D	G	M	<p>Γ<sub>p</sub>=72 keV 20 (2002Ha15)            Γ<sub>α</sub>=1000 eV 120 (2002Ha15)            Γ<sub>p'</sub>≤2 keV (2002Ha15).</p> <p>E(level): Weighted average of 7620 keV 20 (1996Ha26: <sup>12</sup>C(<sup>12</sup>C,<sup>6</sup>He)); 7.61 MeV 5 (1999Ha14, 2002Ha15: from <sup>1</sup>H(<sup>17</sup>F,p):res E<sub>c.m.</sub>=3.69 MeV 5); and 7.58 MeV 2 (2015Ki07: poor statistics and relatively featureless peak). See also E<sub>x</sub>=7620 keV (2004No18, 2006Ku17); and E<sub>x</sub>=7.66 MeV with Γ(FWHM)=0.31 MeV (2007Fu09, 2008FuZZ).</p> <p>T<sub>1/2</sub> or Γ: The results are discrepant due to different J<sup>π</sup> values assigned. See Γ=75 keV 20 (2002Ha15: sum of Γ<sub>p</sub>=72 keV 20; Γ<sub>α</sub>=1000 eV 120; and Γ<sub>p'</sub>≤2 keV assuming J<sup>π</sup>=1<sup>-</sup>); and Γ=104 keV 26 (2015Ki07: sum of Γ<sub>p</sub>=102 keV 26 and Γ<sub>α</sub>=1.5 keV 5 assuming J<sup>π</sup>=0<sup>+</sup> using R-matrix). Evaluator adopted the results from</p>

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**Adopted Levels, Gammas (continued)**

<sup>18</sup>Ne Levels (continued)

<u>E(level)</u>	<u>J<sup>π</sup></u>	<u>T<sub>1/2</sub> or Γ</u>	<u>XREF</u>					<u>Comments</u>
7717 6	(2 <sup>-</sup> )	≤30 keV	D	G	M	O	V	<p>(2002Ha15) because the data of (2015Ki07) are featureless in this energy region and suffer from poor statistics. Therefore, a J<sup>π</sup>=1<sup>-</sup> assignment may not be improbable from these data (see Fig. 9). This assignment is also consistent with what was proposed by the theoretical work of (2000Fo19). Note that the results from (2002Ha15) are not based on an R-matrix fit. They were deduced by comparison of the excitation functions with R-matrix calculations for various spin assignments.</p> <p>Γ<sub>α</sub>: See also Γ<sub>α</sub>=1.2 keV (1999Ha14: deduced for J<sup>π</sup>=1<sup>-</sup>).</p> <p>J<sup>π</sup>: From (1999Ha14, 2002Ha15: J<sup>π</sup>=(1<sup>-</sup>) based on mirror levels and their Coulomb shift arguments); (2011He09: J<sup>π</sup>=1<sup>-</sup> based on R-matrix analysis with L=1 for a “groove-like” structure observed albeit at lower energy of E<sub>x</sub>~7.5 MeV); and (2015Ki07: J<sup>π</sup>=(0<sup>+</sup>) based on R-matrix analysis).</p> <p>J<sup>π</sup>: See also (1999Ha14: J<sup>π</sup>=(2<sup>+</sup>, 3<sup>-</sup>)). But (2000Fo19) ruled out both these assignments based on the theoretical calculations of (1998Sh35) and mirror levels arguments.</p> <p>XREF: G(?)</p> <p>E(level): Weighted average of 7712 keV 20 (1974Ne04, 1981Ne09: (<sup>3</sup>He,n)); 7713 keV 10 (1974Ne04, 1981Ne09: (p,t)); 7720 keV 10 (1996Ha26: (<sup>3</sup>He,n)); 7730 keV 20 (1996Ha26: <sup>12</sup>C(<sup>12</sup>C,<sup>6</sup>He)); 7.71 MeV 5 (2002Ha15: from <sup>1</sup>H(<sup>17</sup>F,p):res E<sub>c.m.</sub>=3.79 MeV 5); and 7.71 MeV 3 (2011He09). See also E<sub>x</sub>=7.72 MeV 2 (2015Ki07), whose width of Γ=281 keV 61 (2015Ki07: obtained via R-matrix) is too wide indicating that this state may be an unresolved group of states, which is thus excluded. Evaluator notes that the data of (2015Ki07) suffer from poor statistics, and (2015Ki07) reported partial and total widths which are collectively and systematically larger than other results found in the literature.</p> <p>T<sub>1/2</sub> or Γ: From (1996Ha26: (<sup>3</sup>He,n)). See also Γ≤50 keV (1974Ne04, 1981Ne09: (<sup>3</sup>He,n)); Γ≤60 keV (1974Ne04, 1981Ne09: (p,t)); and Γ=70 keV 25 (2002Ha15) deduced for J<sup>π</sup>=2<sup>-</sup>. Evaluator notes that (2002Ha15) reported Γ=70 keV 30 but this uncertainty is erroneous considering that it was obtained from the sum of Γ<sub>p</sub>=59 keV 25 and Γ<sub>p'</sub>=11 keV 5 (2002Ha15). The uncertainty in Γ was thus corrected to 25 keV. Also note that the data for this state are featureless.</p> <p>J<sup>π</sup>: (2001HaZP) deduced J<sup>π</sup>=(1<sup>+</sup>, 2<sup>-</sup>, 3<sup>+</sup>) based on R-matrix analysis. (2002Ha15) assumed J<sup>π</sup>=2<sup>-</sup> based on mirror levels and Coulomb shift arguments. (2011He09) deduced J<sup>π</sup>=(3<sup>-</sup>, 2<sup>-</sup>, 1<sup>-</sup>) from R-matrix analysis with L=3 for the <sup>1</sup>H(<sup>17</sup>F,p) reaction. Since the J<sup>π</sup>=2<sup>-</sup> assignment is shared between (2001HaZP, 2002Ha15, 2011He09), the evaluator assigned J<sup>π</sup>=(2<sup>-</sup>) to this state.</p>
7924 11	(1 <sup>-</sup> ,2 <sup>+</sup> )	40 keV 10	gh	m	o	s	z	<p>XREF: Others: AB</p>

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Adopted Levels, Gammas (continued) $^{18}\text{Ne}$  Levels (continued)

<u>E(level)</u>	<u>T<sub>1/2</sub> or <math>\Gamma</math></u>	<u>XREF</u>	<u>Comments</u>
			<p>XREF: g(7950)h(7.93E3)m(7940)O(7924)s(7900)z(7910)ab(7910)</p> <p>E(level): Weighted average (with external errors) of 7915 keV 12 (1974Ne04, 1981Ne09: (<math>^3\text{He},n</math>)); 7903 keV 15 (1977Ev01); and 7940 keV 10 (1996Ha26: (<math>^3\text{He},n</math>)). Evaluator notes that most likely there is a close lying doublet in this region. One of these members seems to be populated via the <math>^{16}\text{O}(\text{}^3\text{He},n)</math> reaction, while the other via <math>^{20}\text{Ne}(p,t)</math>. (1996Ha26) populated both states using these reactions. The two states were kept separate in the discussions (see section V.E) but were combined into one state when those authors presented their tabular results (see Table V) presumably because the doublet could not be distinguished based on the energies. Evaluator treated the 7924-keV and 7942-keV states as a doublet following the previous <math>^{18}\text{Ne}</math> evaluations, and because these states are populated via different reactions.</p> <p>E(level): See also 7940 keV 20 (1996Ha26: <math>^{12}\text{C}(\text{}^{12}\text{C},\text{}^6\text{He})</math>); 7950 keV (2004No18, 2006Ku17); 7910 keV (2009Ji02, 2008SfZZ, 2008Ra12, 2010Gi05, 2010Ra14); and 7900 keV (1988Kr11). Insufficient level properties prevent the placement of these levels in the Adopted Levels. See also 7950 keV 30 (2012Al11: see Table II): a wide neutron peak was observed, where the doublet is expected. This 7.95-MeV state is excluded from the Adopted Levels since the neutron time-of-flight resolution was not sufficient enough to separate the expected doublet.</p> <p>T<sub>1/2</sub> or <math>\Gamma</math>: From (1996Ha26: (<math>^3\text{He},n</math>)). See also <math>\Gamma \leq 50</math> keV (1974Ne04, 1981Ne09: (<math>^3\text{He},n</math>)).</p> <p>J<sup><math>\pi</math></sup>: From (1981Ne09: (<math>^3\text{He},n</math>)): J<sup><math>\pi</math></sup>=(1<sup>-</sup>,2<sup>+</sup>) based on comparison of the shape of neutron angular distribution data with the DWBA curves obtained with L=1,2). These assignments are supported by those deduced from the Coulomb excitation rules for the Pb(<math>^{18}\text{Ne}</math>, <math>^{18}\text{Ne}'</math>) reaction if what was populated is in fact this state. See (2008SfZZ, 2008Ra12, 2010Gi05, 2010Ra14).</p> <p>This state may be populated in the <math>^{16}\text{O}+2p</math> decay channel (2007Ra36, 2008SfZZ, 2008Ra12, 2010Gi05, and 2010Ra14). The sequential 2p-decay via an intermediate <math>^{17}\text{F}</math> state is energetically possible for this state (2008Ra12, 2010Ra14). The 2p-decay mode is suggested by (2008Ra12) to be either via sequential decay or 3-body democratic decay.</p>
7942 8	70 keV 20	gh m s V z	<p>XREF: Others: AB</p> <p>XREF: g(7950)h(7.93E3)m(7940)s(7900)z(7910)ab(7910)</p> <p>E(level): Weighted average of 7957 keV 25 (1972Pa02); 7949 keV 10 (1974Ne04, 1981Ne09: (p,t)); 7924 keV 20 (1996Ha26: (p,t) measured at <math>\theta_{\text{lab}}=6^\circ</math> using the K600 spectrograph); and 7920 keV 20 (1996Ha26: (p,t) measured at <math>\theta_{\text{lab}}=11^\circ</math> using the K600 spectrograph).</p> <p>See also (7930 keV 20) (2022Ba39: <math>\Gamma=75</math> keV, <math>\Gamma_\alpha=50</math> keV, <math>\Gamma_p=25</math> keV, J<sup><math>\pi</math></sup>=2<sup>+</sup> deduced from R-matrix analysis. This tentative level is excluded since it was introduced to keep the symmetry with <math>^{18}\text{O}</math>, and its data appear to be incomplete. Thus, the authors considered this state tentative); 7950 keV (2004No18, 2006Ku17); 7940 keV 20 (1996Ha26: <math>^{12}\text{C}(\text{}^{12}\text{C},\text{}^6\text{He})</math>); 7910 keV (2009Ji02, 2008SfZZ, 2008Ra12, 2010Gi05, 2010Ra14); 7900 keV (1988Kr11); and 7900 keV (1988Kr11).</p> <p>T<sub>1/2</sub> or <math>\Gamma</math>: From (1996Ha26: see the (p,t) reaction study using the K600 spectrograph at Indiana University). See also <math>\Gamma \leq 60</math> keV</p>

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**Adopted Levels, Gammas (continued)**

<sup>18</sup>Ne Levels (continued)

E(level)	J <sup>π</sup>	T <sub>1/2</sub> or Γ	XREF		Comments
8098 9		≤30 keV	G	M O	(1974Ne04, 1981Ne09: (p,t)), and 75 keV (2022Ba39: from Γ <sub>α</sub> +Γ <sub>p</sub> for J <sup>π</sup> =2 <sup>+</sup> ). Γ <sub>α</sub> /Γ=21 13 (2012A111) Γ <sub>p0</sub> /Γ=65 12 (2012A111) Γ <sub>p1</sub> /Γ=14 12 (2012A111) Γ <sub>p1</sub> /Γ <sub>p0</sub> =0.22 (2012A111) Γ <sub>α</sub> /Γ <sub>p</sub> =0.32 (2012A111) XREF: G(?) E(level): Weighted average (with external errors) of 8100 keV 14 (1974Ne04, 1981Ne09: ( <sup>3</sup> He,n): this state is a member of a resolved triplet with the 7717- and 7924-keV levels, see Figs. 6 and 7); 8070 keV 15 (1977Ev01); 8110 keV 10 (1996Ha26: ( <sup>3</sup> He,n)); and 8090 keV 30 (2012A111: see Table II). See also E <sub>x</sub> =8100 keV (2004No18, 2006Ku17); and E <sub>x</sub> =8.10 MeV 10 (2015Ki07). They deduced Γ <sub>p</sub> =298 keV 38, Γ <sub>α</sub> =40.4 keV 49, Γ=Γ <sub>p</sub> +Γ <sub>α</sub> =338 keV 38, and J <sup>π</sup> =(0 <sup>+</sup> ) for the 8.1-MeV state they observed based on R-matrix analysis. This state is too wide to be the same as the 8.1 MeV state measured via <sup>16</sup> O( <sup>3</sup> He,n) by (1981Ne09, 1996Ha26). Evaluator notes that the 8.1-MeV state in (2015Ki07) is most likely an unresolved state consisting of more than one level. T <sub>1/2</sub> or Γ: From (1996Ha26: ( <sup>3</sup> He,n)). See also Γ≤50 keV (1974Ne04, 1981Ne09: ( <sup>3</sup> He,n)).
8294 23			G	M Q	XREF: G(8300) E(level): Weighted average (with external errors) of 8300 keV 20 (1996Ha26: <sup>12</sup> C( <sup>12</sup> C, <sup>6</sup> He)); and 8200 keV 82 (1978Ha10: see Fig. 2). See also 8300 keV (2004No18, 2006Ku17).
8542 <sup>c</sup> 32	(1 <sup>-</sup> ,2 <sup>+</sup> ,3 <sup>-</sup> )		GH	M O	Z XREF: Others: AB XREF: H(8.71E3)M(8550) E(level): Weighted average (with external errors) of 8500 keV 30 (1974Ne04, 1981Ne09: ( <sup>3</sup> He,n)); 8550 keV 30 (1996Ha26: <sup>12</sup> C( <sup>12</sup> C, <sup>6</sup> He), this state has poor signal to noise ratio); 8.62 MeV 10 (2010Ha15: from <sup>4</sup> He( <sup>14</sup> O,α):res E <sub>c.m.</sub> =3.50 MeV 10); 8.50 MeV 10 (2015Ki07); and 8.76 MeV 8 (2022Ba39: from R-matrix analysis). See also E <sub>x</sub> =8.45 MeV (2007Fu09, 2008FuZZ); and E <sub>x</sub> =8.7 MeV (2008Fu07: from <sup>4</sup> He( <sup>14</sup> O,α):res E <sub>c.m.</sub> =3.60 MeV). T <sub>1/2</sub> or Γ: The results for the width of this state are discrepant: see Γ≤120 keV (1974Ne04, 1981Ne09: ( <sup>3</sup> He,n): evaluator notes that the width of this state seems to be underestimated, see Fig. 6 of (1981Ne09)); Γ=0.5 MeV and Γ <sub>α</sub> =260 keV (2008Fu07: for E <sub>x</sub> =8.7 MeV); Γ(FWHM)=0.47 MeV (2008FuZZ: for 8.45-MeV state observed by (2007Fu09, 2008FuZZ)); Γ=781 keV 31 (2010Ha15: sum of Γ <sub>α</sub> =615 keV 24 and Γ <sub>p</sub> =166 keV 20); Γ=630 keV 64 (2015Ki07: sum of Γ <sub>α</sub> =84.5 keV 210 and Γ <sub>p</sub> =546 keV 60); and Γ=870 keV (2022Ba39: sum of Γ <sub>α</sub> =440 keV and Γ <sub>p</sub> =430 keV).

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**Adopted Levels, Gammas (continued)** $^{18}\text{Ne}$  Levels (continued)

<u>E(level)</u>	<u><math>J^\pi</math></u>	<u><math>T_{1/2}</math> or <math>\Gamma</math></u>	<u>XREF</u>	<u>Comments</u>
				<p><math>J^\pi</math>: From the R-matrix analyses of (1) (2008Fu07): deduced <math>J^\pi=(1^-, 0^+)</math> for the 8.7-MeV state by taking into account the data of (2007Bu01). (2008Fu07) preferred the <math>J^\pi=1^-</math> assignment. Inclusion of <math>J^\pi=0^+</math> could not be excluded. (2) (2010Ha15): deduced <math>J^\pi=(1^-)</math>. Fitted the data using <math>J^\pi=0^+</math>, which caused a large energy shift for the strong resonance populated at 9.2 MeV. Therefore, (2010Ha15) suggested that the <math>J^\pi=1^-</math> assignment is more probable and ruled out <math>J^\pi=0^+</math>. (3) (2015Ki07): obtained <math>J^\pi=(1^-, 2^+)</math>. The <math>1^-</math> assignment led to a better fit with a slightly better <math>\chi^2</math>. (4) (2022Ba39): deduced <math>J^\pi=3^-</math>. See also (2007Ra36, 2007CaZT, 2008SfZZ, 2008Ra12, 2010Gi05, and 2010Ra14): <math>J^\pi=(1^-, 2^+)</math> based on the Coulomb excitation selection rules for the <math>\text{Pb}(^{18}\text{Ne}, ^{18}\text{Ne}')</math> reaction on the spin-zero target.</p> <p>(2008Ra12, 2010Gi05) observed <math>E_x=8500</math> keV state in the <math>^{16}\text{O}+2\text{p}</math> decay channel. Even though the sequential <math>2\text{p}</math>-decay via an intermediate <math>^{17}\text{F}</math> state is energetically possible for this state (2008Ra12, 2010Ra14), (2008Ra12) specifically mentions that this state is not observed in the <math>^{17}\text{F}+\text{p}</math> decay channel. The <math>1\text{p}</math> decay branching ratio is negligible for this state (2008Ra12). (2007Fu09, 2008FuZZ) observed evidence that suggests that this state decays to <math>^{16}\text{O}_{\text{g.s.}}</math> via <math>^2\text{He}</math> emission. This is supported by a predicted decay spectrum using the Faddeev approach. The angular momenta of <math>L=0,1,2,3</math> were assumed for the <math>^2\text{He}</math> relative to the <math>^{16}\text{O}</math> core when calculating the Faddeev model. The experimentally measured relative energy between the two protons emitted from this <math>^{18}\text{Ne}</math> level was best consistent with <math>L=3</math> (see Fig. 6 of (2008FuZZ)).</p>
8940? 20			M	<p>E(level): From (1996Ha26: <math>^{12}\text{C}(^{12}\text{C}, ^6\text{He})</math>): observed for the first time in this study. Evaluator notes that the signal to noise ratio for this state is poor.</p>
9111 25		<60 keV	I	<p>E(level): From (2019Ch16), which argues that this state is not the same as the 9.2-MeV level with <math>\Gamma=300</math> keV observed in (2008Fu07). (2019Ch16) suggests that the presence of a wide state nearby at 9.2 MeV along with the weak <math>\alpha</math>-cluster structure of the 9111-keV state (indicated by its much smaller decay width compared to the 9.2-MeV level) might have decreased the sensitivity of the <math>\alpha</math> scattering experiment performed by (2008Fu07) in detecting the 9111-keV state.</p> <p><math>T_{1/2}</math> or <math>\Gamma</math>: From (2019Ch16) at <math>1\sigma</math> level.</p> <p>(2019Ch16): this state decays to <math>^{14}\text{O}_{\text{g.s.}}+\alpha</math>. Due to low efficiency and poor resolution in (2019Ch16) when observing this state in the <math>\text{p}+^{17}\text{F}</math> decay channel, the sensitivity to detect evidence for the decay of this state via <math>\text{p}+^{17}\text{F}</math> is significantly reduced.</p>
$9.13\times 10^{3b}$ 2	$1^-$	990 keV	H	<p><math>\Gamma_\alpha=390</math> keV (2022Ba39); <math>\Gamma_{\text{p}}=600</math> keV (2022Ba39)</p> <p>E(level), <math>T_{1/2}</math> or <math>\Gamma, J^\pi</math>: From the multi-channel R-matrix analysis of (2022Ba39). Note that <math>\Gamma=\Gamma_{\text{p}}+\Gamma_\alpha</math>.</p> <p>E(level): Unlike the 9111-keV level, which may not have a strong <math>\alpha</math>-cluster structure (2019Ch16), this level presents a strong <math>\alpha</math>-cluster structure as reported by (2022Ba39).</p>

Continued on next page (footnotes at end of table)

**Adopted Levels, Gammas (continued)**

<sup>18</sup>Ne Levels (continued)

<u>E(level)</u>	<u>J<sup>π</sup></u>	<u>T<sub>1/2</sub> or Γ</u>	<u>XREF</u>			<u>Comments</u>
9197 <sup>bc</sup> 8	(2 <sup>+</sup> ,3 <sup>-</sup> )	490 keV 21	GH	M	V	<p>XREF: G(9.14E3)M(9.18E3)</p> <p>E(level): Weighted average of 9170 keV 30 (1970Fa17); 9215 keV 20 (1972Pa02); 9198 keV 10 (1974Ne04, 1981Ne09: (p,t)); 9180 keV 20 (1996Ha26: <sup>12</sup>C(<sup>12</sup>C,<sup>6</sup>He)); 9.22 MeV 4 (2010Ha15); 9.14 MeV 10 (2015Ki07: these authors paired this state with the 9.2-MeV state observed in the (p,t) measurements mentioned above); and 9.21 MeV 3 (2022Ba39). See also 9.2 MeV (2008Fu07) and 9.4 MeV (2007Fu09, 2008FuZZ: suggested that the 9.4-MeV state is likely the 9.2-MeV level, observed in the (p,t) measurements).</p> <p>T<sub>1/2</sub> or Γ: Results are discrepant: see (1) Γ=490 keV 21, which is the weighted average of (i) Γ=489 keV 22 (2010Ha15) obtained from summing Γ<sub>α</sub>=365 keV 18 and Γ<sub>p</sub>=124 keV 12; and (ii) Γ=495 keV 59 (2015Ki07) deduced from summing Γ<sub>α</sub>=27 keV 6 and Γ<sub>p</sub>=467.5 keV 590. Both of these results were obtained using R-matrix analysis for J<sup>π</sup>=3<sup>-</sup>. (2) Γ=540 keV (2022Ba39), which is the sum of Γ<sub>p</sub>=270 keV and Γ<sub>α</sub>=270 keV. These were obtained using R-matrix analysis for J<sup>π</sup>=2<sup>+</sup>. Evaluator notes that since J<sup>π</sup>=2<sup>+</sup> and 3<sup>-</sup> for a state populated by the <sup>14</sup>O+α interaction in these studies are associated with different angular momenta, the penetrability, partial widths, and the resulting total widths differ for these assignments. (3) Γ≤60 keV (1981Ne09) obtained from the (p,t) study. This result supersedes Γ≤50 keV by (1974Ne04). (4) Γ=0.3 MeV (2008Fu07) obtained from R-matrix for J<sup>π</sup>=3<sup>-</sup>. See also Γ<sub>α</sub>=180 keV (2007Fu09) and Γ(FWHM)=0.42 MeV (2008FuZZ).</p> <p>E(level),T<sub>1/2</sub> or Γ: These discrepant results may indicate the existence of a close lying doublet in this region. (2008Fu07) indicates that the 9.2-MeV state populated in their <sup>4</sup>He(<sup>14</sup>O,α) study shows an unusually large size of α-cluster configuration. This is supported by what is deduced by (2022Ba39). Assuming a doublet in this region, the presence of the wider state at similar energy may have reduced the sensitivity of the (2008Fu07, 2010Ha15, 2015Ki07, 2022Ba39) studies to detection of a level nearby with a smaller decay width. Therefore, it does not seem improbable that one of the members has a strong α-cluster structure causing it to be populated in the <sup>14</sup>O+α experiments, while the other may be a state with a weaker decay width populated mostly via the direct transfer reactions, whose spectra (albeit with low statistics) do not clearly show evidence for a wide peak. It could also be that the level at 9111 keV with smaller decay width is what was observed by (1974Ne04, 1981Ne09, 1970Fa17, 1972Pa02, 1996Ha26) measurements.</p> <p>J<sup>π</sup>: From the R-matrix analyses of (2008Fu07, 2010Ha15, 2015Ki07: J<sup>π</sup>=3<sup>-</sup>); and (2022Ba39: J<sup>π</sup>=</p>

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**Adopted Levels, Gammas (continued)**

<sup>18</sup>Ne Levels (continued)

<u>E(level)</u>	<u>J<sup>π</sup></u>	<u>T<sub>1/2</sub> or Γ</u>	<u>XREF</u>	<u>Comments</u>
9595 <sup>b</sup> 15	1 <sup>-</sup>	1640 keV	GH M	<p>The R-matrix fits of (2022Ba39) seems to be poorer than those of (2008Fu07, 2010Ha15, 2015Ki07). Also note that in the R-matrix analysis of (2015Ki07), J<sup>π</sup>=3<sup>-</sup> was fixed to obtain the best fit. Evaluator notes that if there is only one state in this region and its J<sup>π</sup> value is 3<sup>-</sup>, this casts doubt on the results of (2022Ba39) for some of the high-lying states in that analysis considering that they generally have low statistics, the R-matrix analysis is guided by mirror levels in <sup>18</sup>O, and the fits appear to be of low quality. If the J<sup>π</sup> assignment changes, the interference patterns and the global R-matrix analysis results would be different and the mirror levels would change. Evidence from (2007Fu09, 2008FuZZ) suggests that the 9.4-MeV state populated by these studies proton decays to <sup>17</sup>F*(3.1 MeV) and to <sup>17</sup>F*(3.86 MeV), see Fig. 5 of (2008FuZZ).</p> <p>Γ<sub>α</sub>=1120 keV; Γ<sub>p</sub>=520 keV (2022Ba39)</p> <p>E(level): Weighted average (width external errors) of 9580 keV 20 (1996Ha26: <sup>12</sup>C(<sup>12</sup>C,<sup>6</sup>He)); and 9.61 MeV 2 (2022Ba39). See 9.60 MeV 9 (2015Ki07): these data are featureless and those authors indicated that this state may be a superposition of two or more states. Therefore, this result was excluded.</p> <p>T<sub>1/2</sub> or Γ: From (2022Ba39: assuming Γ=Γ<sub>p</sub>+Γ<sub>α</sub>). See also Γ=628 keV 104 (2015Ki07: sum of Γ<sub>p</sub>=7.8 keV 66 and Γ<sub>α</sub>=620 keV 104). Evaluator notes that the data of (2015Ki07) are more or less flat. Also, the authors of (2015Ki07) acknowledged the possibility of more than one states in this region. We therefore adopt the results of (2022Ba39).</p> <p>J<sup>π</sup>: From the R-matrix analysis of (2022Ba39: J<sup>π</sup>=1<sup>-</sup>). See also J<sup>π</sup>=(1<sup>-</sup>, 0<sup>+</sup>) (2015Ki07): J<sup>π</sup>=1<sup>-</sup> yields to a fit with slightly better χ<sup>2</sup>.</p>
9.8×10 <sup>3</sup> ? <sup>b</sup> 3	0 <sup>+</sup>	4200 keV	H	<p>Γ<sub>α</sub>=4200 keV (2022Ba39)</p> <p>XREF: H(?)</p> <p>E(level),T<sub>1/2</sub> or Γ,J<sup>π</sup>: From the R-matrix analysis of (2022Ba39).</p> <p>E(level): (2022Ba39) reports that this state is a superradiant state that decays into the L=0, n=5 α-particle channel. Evaluator considered this state tentative because the spectra presented in (2022Ba39) show little indication of this state. Also, the analysis of (2022Ba39) for this state seems to be guided by those of (2014Av04, 2009Jo08) for the proposed <sup>18</sup>O mirror level. In those analyses, a very broad <sup>18</sup>O state was necessary to fit the <sup>14</sup>C+α excitation function. (2022Ba39) reports that the proton decay channel is highly suppressed.</p>
10.07×10 <sup>3</sup> 4	(1 <sup>-</sup> ,2 <sup>+</sup> )	302 keV 32	GH	<p>Γ<sub>p</sub>=94 keV 10</p>

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**Adopted Levels, Gammas (continued)**

<sup>18</sup>Ne Levels (continued)

E(level)	J <sup>π</sup>	T <sub>1/2</sub> or Γ	XREF	Comments
10.56×10 <sup>3b</sup> 4	1 <sup>-</sup>	380 keV	GH	<p>Γ<sub>α</sub>=207 keV 30                      E(level): Weighted average of 10.07 MeV 4 (2010Ha15: from <sup>4</sup>He(<sup>14</sup>O,α):res E<sub>c.m.</sub>=4.95 MeV 4); and 10.07 MeV 8 (2015Ki07). See also 10.12 MeV (2007Fu09, 2008FuZZ); and 10.1 MeV (2008Fu07: associated with E<sub>c.m.</sub>=5.0 MeV from <sup>4</sup>He(<sup>14</sup>O,α):res).                      T<sub>1/2</sub> or Γ: The width was deduced using R-matrix analyses, and thus depends on the J<sup>π</sup> assignment of this state. See Γ=302 keV 32 (2010Ha15: sum of Γ<sub>α</sub>=207 keV 30 and Γ<sub>p</sub>=95 keV 10 deduced for J<sup>π</sup>=1<sup>-</sup>); and Γ=92 keV 18 (2015Ki07: sum of Γ<sub>α</sub>=1.5 keV 8 and Γ<sub>p</sub>=90 keV 18 deduced for J<sup>π</sup>=2<sup>+</sup>). See also Γ=400 keV and Γ<sub>α</sub>=300 keV (2008Fu07) obtained from R-matrix for a J<sup>π</sup>=(1<sup>-</sup>) state at E<sub>x</sub>=10.1 MeV. We adopted the widths deduced by (2010Ha15) because the width deduced by (2015Ki07) for this state appears to be underestimated (see Fig. 11).                      Γ<sub>p</sub>: Weighted average of Γ<sub>p</sub>=95 keV 10 (2010Ha15) and 90 keV 18 (2015Ki07). Note that these values are deduced based on different J<sup>π</sup> values but they are consistent.                      J<sup>π</sup>: From the R-matrix analyses of (2008Fu07: J<sup>π</sup>=(1<sup>-</sup>); (2010Ha15: J<sup>π</sup>=1<sup>-</sup>); and (2015Ki07: J<sup>π</sup>=2<sup>+</sup> leading to a smaller χ<sup>2</sup> and better fit than that with J<sup>π</sup>=1<sup>-</sup>, see the solid black and dashed red lines in the bottom panel of Fig. 11).                      (2007Fu09, 2008FuZZ): evidence suggests that the state at 10120 keV (which is most likely the same state as the 10.07-MeV level) proton decays to <sup>17</sup>F*(3.1 MeV) and to <sup>17</sup>F*(3.86 MeV), see Fig. 5 of (2008FuZZ).                      XREF: Others: AB                      Γ<sub>α</sub>=320 keV; Γ<sub>p</sub>=60 keV (2022Ba39)                      XREF: ab(10700)                      E(level),T<sub>1/2</sub> or Γ,J<sup>π</sup>: From the R-matrix analysis of (2022Ba39).                      E(level): See also E<sub>x</sub>=10.66 MeV (2007Fu09); 10.6 (2008Fu07); and 10.49 MeV 2 (2010Ha15). The last two values are associated with the E<sub>c.m.</sub>=5.5 MeV, and E<sub>c.m.</sub>=5.37 MeV 2 from <sup>4</sup>He(<sup>14</sup>O,α):res, respectively. The study of (2022Ba39) has more angular coverage, and thus their reported excitation energy within this energy region was adopted.                      T<sub>1/2</sub> or Γ: See also Γ(FWHM)=0.73 (2008FuZZ); and Γ=0.2 MeV (2008Fu07).                      J<sup>π</sup>: See also (J≥2) from R-matrix analysis of (2008Fu07).                      (2007Fu09, 2008FuZZ): evidence suggests that this state proton decays to <sup>17</sup>F*(3.1 MeV) and to <sup>17</sup>F*(3.86 MeV) with a weaker branch, see Fig. 5 of (2008FuZZ).</p>
10.8×10 <sup>3b</sup> 1	2 <sup>+</sup>	1580 keV	H	<p>z XREF: Others: AB                      Γ<sub>α</sub>=1350 keV; Γ<sub>p</sub>=230 keV (2022Ba39)                      XREF: z(10900)ab(10700)                      E(level),T<sub>1/2</sub> or Γ,J<sup>π</sup>: From the R-matrix analysis of (2022Ba39).</p>

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**Adopted Levels, Gammas (continued)**

<sup>18</sup>Ne Levels (continued)

<u>E(level)</u>	<u>J<sup>π</sup></u>	<u>T<sub>1/2</sub> or Γ</u>	<u>XREF</u>	<u>Comments</u>
				E(level): See also E <sub>x</sub> =10900 keV (2009Ji02: from the complete reconstruction of the invariant mass of the <sup>16</sup> O+2p events observed in coincidence); and E <sub>x</sub> =10700 keV (2008SfZZ, 2008Ra12, 2010Gi05, 2010Ra14): observed in the <sup>16</sup> O+2p decay channel (see also 2007Ra36). The sequential 2p-decay via an intermediate <sup>17</sup> F state is energetically possible for this state (2008Ra12, 2010Ra14). The 1p decay branching ratio should be negligible for this state as it is not observed in the <sup>17</sup> F+p channel (2008Ra12). The 2p-decay will either occur via sequential decay or 3-body democratic decay (2008Ra12). J <sup>π</sup> : See also J <sup>π</sup> =(1 <sup>-</sup> , 2 <sup>+</sup> ) from (2008Ra12), who proposed these assignments based on Coulomb excitation selection rules.
11.0×10 <sup>3</sup> <sup>b</sup> 1	3 <sup>-</sup>	1130 keV	H	z Γ <sub>α</sub> =380 keV; Γ <sub>p</sub> =750 keV (2022Ba39) XREF: z(10900) E(level),T <sub>1/2</sub> or Γ,J <sup>π</sup> : From the R-matrix analysis of (2022Ba39).
11.23×10 <sup>3</sup> ? 8	6 <sup>+</sup>	15 keV	H	Γ <sub>α</sub> =5 keV; Γ <sub>p</sub> =10 keV (2022Ba39) XREF: H(?) E(level),T <sub>1/2</sub> or Γ,J <sup>π</sup> : From the R-matrix analysis of (2022Ba39).
11.31×10 <sup>3</sup> 4	5 <sup>-</sup>	65 keV	GH	E(level): This state was manually added by (2022Ba39) and the spin-parity assignment was varied until the data around E <sub>x</sub> =11-MeV excitation energy was reproduced by the best R-matrix fit. The statistics for this state are low in (2022Ba39), and more data are required to confirm the existence of this state. Therefore, (2022Ba39) presented it in parentheses and presumably considered it tentative. Γ <sub>α</sub> =15 keV; Γ <sub>p</sub> =50 keV (2022Ba39) E(level),T <sub>1/2</sub> or Γ,J <sup>π</sup> : From the R-matrix analysis of (2022Ba39).
11.66×10 <sup>3</sup> 8	1 <sup>-</sup>	360 keV	HI	E(level): See also 11.3 MeV (2008Fu07: from <sup>4</sup> He( <sup>14</sup> O,α):res E <sub>c.m.</sub> =6.2 MeV) and 11.29 MeV (2007Fu09, 2008FuZZ). T <sub>1/2</sub> or Γ: See also Γ=0.1 MeV (2008Fu07) and Γ=Γ(FWHM)=0.66 MeV (2008FuZZ). J <sup>π</sup> : See also the tentative assignment of (J≥4) from the R-matrix analysis of (2008Fu07). (2007Fu09, 2008FuZZ): evidence suggests that this state proton decays to <sup>17</sup> F*(3.1 MeV), <sup>17</sup> F*(3.86MeV) and <sup>17</sup> F*(5.22 MeV), see Fig. 5 of (2008FuZZ).
				z Γ <sub>α</sub> =310 keV; Γ <sub>p</sub> =50 keV (2022Ba39) XREF: H(11.74E3)I(11584)Z(11500) E(level): Unweighted average of 11584 keV 64 (2019Ch16: at 1σ level); and 11.74 MeV 5 (2022Ba39: from R-matrix analysis). See also 11500 keV from the complete reconstruction of the invariant mass of the <sup>16</sup> O+2p events observed in coincidence by a Coulomb excitation experiment of (2009Ji02); and E <sub>x</sub> =11.61 MeV 9 from (2010Ha15: associated with E <sub>c.m.</sub> =6.49

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**Adopted Levels, Gammas (continued)** $^{18}\text{Ne}$  Levels (continued)

<u>E(level)</u>	<u>J<sup>π</sup></u>	<u>T<sub>1/2</sub> or Γ</u>	<u>XREF</u>	<u>Comments</u>
				MeV 9 from $^4\text{He}(^{14}\text{O},\alpha)$ :res). T <sub>1/2</sub> or Γ,J <sup>π</sup> : From the R-matrix analysis of (2022Ba39). T <sub>1/2</sub> or Γ: See also Γ<650 keV (2019Ch16: at 1σ level). (2019Ch16): decays to $^{14}\text{O}+\alpha$ . Due to low efficiency and poor resolution when observing this state in the p+ $^{17}\text{F}$ decay channel, the sensitivity to detect evidence for the decay of this state via p+ $^{17}\text{F}$ is significantly reduced.
11.8×10 <sup>3</sup> <sup>b</sup> 2	6 <sup>+</sup>	260 keV	GH	Γα=40 keV; Γ <sub>p</sub> =220 keV (2022Ba39) E(level),T <sub>1/2</sub> or Γ,J <sup>π</sup> : From the R-matrix analysis of (2022Ba39). E(level): See also 11.8 MeV (2007Fu09, 2008Fu07: associated with a resonance at E <sub>c.m.</sub> =6.7 MeV in $^4\text{He}(^{14}\text{O},p)$ :res and $^4\text{He}(^{14}\text{O},\alpha)$ :res). T <sub>1/2</sub> or Γ: See also Γ(FWHM)=0.52 MeV from (2008FuZZ) and Γ=0.2 MeV (2008Fu07) for E <sub>x</sub> =11.8 MeV state observed in these studies. J <sup>π</sup> : See also the tentative assignment of J=(J≥3) (2008Fu07: for E <sub>x</sub> =11.8 MeV).
12.12×10 <sup>3</sup> 4	3 <sup>-</sup>	280 keV	H	Z Γα=180 keV; Γ <sub>p</sub> =100 keV (2022Ba39) E(level): Weighted average of 12.02 MeV 10 (2010Ha15: associated with E <sub>c.m.</sub> =6.90 MeV 10 from $^4\text{He}(^{14}\text{O},\alpha)$ :res); and 12.13 MeV 4 (2022Ba39). See also E <sub>x</sub> =12100 keV from the complete reconstruction of the invariant mass of the $^{16}\text{O}+2p$ events observed in coincidence by (2009Ji02). T <sub>1/2</sub> or Γ,J <sup>π</sup> : From the R-matrix analysis of (2022Ba39).
12.41×10 <sup>3</sup> <sup>b</sup> 9	6 <sup>+</sup>	350 keV	H	Γα=170 keV; Γ <sub>p</sub> =180 keV (2022Ba39) E(level): From (2010Ha15: associated with E <sub>c.m.</sub> =7.29 MeV 9 from $^4\text{He}(^{14}\text{O},\alpha)$ :res). See also 12.3 MeV (2008Fu07: associated with E <sub>c.m.</sub> =7.2 MeV from $^4\text{He}(^{14}\text{O},\alpha)$ :res); and 12.4 MeV 2 (2022Ba39). T <sub>1/2</sub> or Γ: From the R-matrix analysis of (2022Ba39). See also Γ=0.2 MeV (2008Fu07: for E <sub>x</sub> =12.3 MeV). J <sup>π</sup> : From the R-matrix analysis of (2022Ba39). See also (J≥4) from the R-matrix analysis of (2008Fu07: for E <sub>x</sub> =12.3 MeV).
12.45×10 <sup>3</sup> 2	(1 <sup>-</sup> ,2 <sup>-</sup> ,3 <sup>-</sup> )	390 keV	H	XREF: Others: AB Γα=180 keV; Γ <sub>p</sub> =210 keV (2022Ba39) E(level),T <sub>1/2</sub> or Γ: From the R-matrix analysis of (2022Ba39). E(level): See also 12500 keV (2008SfZZ, 2008Ra12, 2010Gi05, 2010Ra14). J <sup>π</sup> : From the R-matrix analysis of (2022Ba39: J <sup>π</sup> =3 <sup>-</sup> ); and based on the Coulomb excitation selection rules for the Pb( $^{18}\text{Ne},^{17}\text{F}+p$ ) and Pb( $^{18}\text{Ne},^{16}\text{O}+2p$ ) reactions on the spin zero target (2008Ra12: (J <sup>π</sup> =1 <sup>-</sup> , 2 <sup>+</sup> )).

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**Adopted Levels, Gammas (continued)**

<sup>18</sup>Ne Levels (continued)

<u>E(level)</u>	<u>J<sup>π</sup></u>	<u>T<sub>1/2</sub> or Γ</u>	<u>XREF</u>	<u>Comments</u>
12.7×10 <sup>3b</sup> 2	3 <sup>-</sup>	2240 keV	H	<p>The 12500-keV state mentioned above is populated in the <sup>16</sup>O+2p decay channel (2007Ra36, 2008SfZZ, 2008Ra12, 2010Gi05, and 2010Ra14). Its sequential 2p-decay via an intermediate <sup>17</sup>F state is energetically possible (2008Ra12, 2010Ra14). However, the 1p decay branching ratio should be negligible for this state as it is not observed in the <sup>17</sup>F+p channel (2008Ra12).</p> <p>Z Γα=2000 keV; Γ<sub>p</sub>=240 keV (2022Ba39)                      E(level),T<sub>1/2</sub> or Γ,J<sup>π</sup>: From the R-matrix analysis of (2022Ba39). Note that Γ=2300 keV was reported erroneously in Table I of (2022Ba39).                      E(level): See also E<sub>x</sub>=12700 keV deduced from the complete reconstruction of the invariant mass of the <sup>16</sup>O+2p events observed in coincidence by (2009Ji02). This state may be the same as the state reported above. No information about the width and other properties of the 12700-keV state is provided by (2009Ji02).</p>
12.87×10 <sup>3b</sup> 16	5 <sup>-</sup>	670 keV	H	<p>Γα=530 keV; Γ<sub>p</sub>=140 keV (2022Ba39)                      E(level): Weighted average of 12.82 MeV 25 (2010Ha15: associated with E<sub>c.m.</sub>=7.70 MeV 25 from <sup>4</sup>He(<sup>14</sup>O,α):res); and 12.9 MeV 2 (2022Ba39). See also 12.7 MeV (2008Fu07: associated with E<sub>c.m.</sub>=7.6 MeV from <sup>4</sup>He(<sup>14</sup>O,α):res).                      T<sub>1/2</sub> or Γ: From (2022Ba39). See also Γ=0.3 MeV (2008Fu07: for E<sub>x</sub>=12.7 MeV).                      J<sup>π</sup>: From the R-matrix analyses of (2008Fu07: (J≥5) for E<sub>x</sub>=12.7 MeV) and (2022Ba39: J<sup>π</sup>=5<sup>-</sup>).</p>
13.3×10 <sup>3b</sup> 3	4 <sup>+</sup>	870 keV	H	<p>Γα=850 keV; Γ<sub>p</sub>=20 keV (2022Ba39)                      E(level),T<sub>1/2</sub> or Γ,J<sup>π</sup>: From the R-matrix analysis of (2022Ba39).</p>
13.4×10 <sup>3b</sup> 2	2 <sup>+</sup>	1800 keV	H	<p>Γα=1750 keV; Γ<sub>p</sub>=50 keV (2022Ba39)                      E(level),T<sub>1/2</sub> or Γ,J<sup>π</sup>: From the R-matrix analysis of (2022Ba39).</p>
13.73×10 <sup>3b</sup> 1	1 <sup>-</sup>	1190 keV	H	<p>XREF: Others: AB                      Γα=780 keV; Γ<sub>p</sub>=410 keV (2022Ba39)                      E(level),T<sub>1/2</sub> or Γ,J<sup>π</sup>: From the R-matrix analysis of (2022Ba39).                      E(level): See also 13700 keV (2008SfZZ, 2008Ra12, 2010Gi05, 2010Ra14).                      T<sub>1/2</sub> or Γ: Note that an erroneous value of Γ=1200 keV was reported in Table I of (2022Ba39).                      J<sup>π</sup>: See also J<sup>π</sup>=(1<sup>-</sup>, 2<sup>+</sup>) proposed by (2008Ra12: for E<sub>x</sub>=13700 keV) based on the Coulomb excitation selection rules for the Pb(<sup>18</sup>Ne, <sup>17</sup>F+p) and Pb(<sup>18</sup>Ne, <sup>16</sup>O+2p) reactions on the spin zero target.                      The 13700-keV state measured by (2008SfZZ, 2008Ra12, 2010Gi05, 2010Ra14) is populated in the <sup>16</sup>O+2p decay channel (2007Ra36, 2008SfZZ, 2008Ra12, 2010Gi05, and 2010Ra14). Its sequential 2p-decay via an intermediate <sup>17</sup>F state is energetically possible (2008Ra12, 2010Ra14). The 1p decay branching ratio should be negligible for this state as it is not observed in the <sup>17</sup>F+p channel (2008Ra12). The</p>

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**Adopted Levels, Gammas (continued)**

<sup>18</sup>Ne Levels (continued)

<u>E(level)</u>	<u>J<sup>π</sup></u>	<u>T<sub>1/2</sub> or Γ</u>	<u>XREF</u>	<u>Comments</u>
13.79×10 <sup>3b</sup> 8	5 <sup>-</sup>	290 keV	H	2p-decay occurs either via sequential decay or via 3-body democratic decay (2008Ra12). Γ <sub>α</sub> =220 keV; Γ <sub>p</sub> =70 keV (2022Ba39) E(level),T <sub>1/2</sub> or Γ,J <sup>π</sup> : From the R-matrix analysis of (2022Ba39).
14.15×10 <sup>3b</sup> 21	4 <sup>+</sup>	630 keV	H	Γ <sub>α</sub> =380 keV; Γ <sub>p</sub> =250 keV (2022Ba39) E(level),T <sub>1/2</sub> or Γ,J <sup>π</sup> : From the multi-channel R-matrix analysis of (2022Ba39). Note that an erroneous value of Γ=620 keV was reported in Table I of (2022Ba39). E(level): See also E <sub>x</sub> =14.1 MeV (2008Fu07: associated with E <sub>c.m.</sub> =9.0 MeV from <sup>4</sup> He( <sup>14</sup> O,α):res).
14.6×10 <sup>3b</sup> 7	5 <sup>-</sup>	1180 keV	H	Γ <sub>α</sub> =520 keV; Γ <sub>p</sub> =660 keV (2022Ba39) E(level),J <sup>π</sup> ,T <sub>1/2</sub> or Γ: From R-matrix analysis of (2022Ba39). E(level): See also E <sub>x</sub> =14.5 MeV (2008Fu07: associated with E <sub>c.m.</sub> =9.4 MeV from <sup>4</sup> He( <sup>14</sup> O,α):res).
14.8×10 <sup>3b</sup> 2	3 <sup>-</sup>	5300 keV	H	Γ <sub>α</sub> =4000 keV; Γ <sub>p</sub> =1300 keV (2022Ba39) E(level),J <sup>π</sup> ,T <sub>1/2</sub> or Γ: From the R-matrix analysis of (2022Ba39). E(level): See also E <sub>x</sub> =15.0 MeV (2008Fu07: associated with E <sub>c.m.</sub> =9.9 MeV from <sup>4</sup> He( <sup>14</sup> O,α):res). This state appears to be broad but not as broad as the 14.8-MeV level reported by (2022Ba39).
14.9×10 <sup>3a</sup> 1	5 <sup>-</sup>	90 keV	H	Γ <sub>α</sub> =60 keV; Γ <sub>p</sub> =30 keV (2022Ba39) E(level),T <sub>1/2</sub> or Γ,J <sup>π</sup> : From the multi-channel R-matrix analysis of (2022Ba39).
16.26×10 <sup>3b</sup> 2	2 <sup>+</sup>	1100 keV	H	Γ <sub>α</sub> =1000 keV; Γ <sub>p</sub> =100 keV (2022Ba39) E(level),T <sub>1/2</sub> or Γ,J <sup>π</sup> : From the R-matrix analysis of (2022Ba39). E(level): This level was necessary to reproduce the structure observed by (2022Ba39) in their deduced <sup>14</sup> O+α excitation function between 16 and 17 MeV at various angles.
16794 29		328 keV 68	I	T=2 (2019Ch16) E(level),T <sub>1/2</sub> or Γ: From (2019Ch16): the state was observed in <sup>12</sup> C+α+2p invariant mass spectrum. The uncertainty was reported by (2019Ch16) as 20 keV in one instance. See also E <sub>x</sub> =16.5 MeV (2008Fu07: associated with E <sub>c.m.</sub> =11.4 MeV from <sup>4</sup> He( <sup>14</sup> O,α):res), which appears to be a broad state but not as broad as the 16.26-MeV level. (2019Ch16): this state appears to have an exotic decay involving isospin symmetry breaking α and proton decay branches: (1) p+ <sup>17</sup> F*(11.192 MeV, 1/2 <sup>-</sup> , T=3/2) → α+ <sup>13</sup> N*(2.365 MeV, 1/2 <sup>+</sup> ) → p+ <sup>12</sup> C <sub>g.s.</sub> , and (2) p+ <sup>17</sup> F*(11.192 MeV, 1/2 <sup>-</sup> , T=3/2) → p+ <sup>16</sup> O*(9.585 MeV, 1 <sup>-</sup> ) → α+ <sup>12</sup> C <sub>g.s.</sub> . An

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**Adopted Levels, Gammas (continued)**

<sup>18</sup>Ne Levels (continued)

E(level)	J <sup>π</sup>	T <sub>1/2</sub> or Γ	XREF	Comments
				additional smaller branch to the <sup>16</sup> O*(2 <sub>2</sub> <sup>+</sup> ) state, which then decays to the <sup>12</sup> C <sub>g.s.</sub> via α-emission cannot be ruled out. The branching ratio of the decay of the isobaric analog state in <sup>17</sup> F*(11.192 MeV), which is part of the exotic decay of this state, is estimated to be Γ <sub>α</sub> /Γ <sub>p</sub> =65% 9 (2019Ch16). Note that the experiment of (2019Ch16) had low efficiency and poor resolution for detecting the decay of this state in the p+ <sup>17</sup> F decay channel. Therefore, the sensitivity to detect any evidence for the p+ <sup>17</sup> F decay for this state is significantly reduced.
				(2019Ch16): using the isobaric multiplet mass equation for the J <sup>π</sup> =2 <sub>1</sub> <sup>-</sup> and 3 <sub>1</sub> <sup>-</sup> states in A=18 (T=2 multiplet), it appears that this state lines up (with a larger than expected deviation of 140 keV 34) with the J <sup>π</sup> =3 <sup>-</sup> analog states in <sup>18</sup> N, <sup>18</sup> O, and <sup>18</sup> Na. However, the intrinsic width of this state (328 keV 68) casts doubt on the J <sup>π</sup> =3 <sup>-</sup> assumption because in that case, its analog state in <sup>18</sup> Na*(0.83 MeV, 3 <sup>-</sup> ) has a much narrower width of Γ=42 keV 10 (see Adopted Levels of <sup>18</sup> Na in ENSDF). The state with a comparable width in <sup>18</sup> Na is the <sup>18</sup> Na*(0.59 MeV, 0 <sup>-</sup> ) state, whose J <sup>π</sup> assignment is not of interest and it occurs at 240 keV lower energy than the <sup>18</sup> Na*(0.83 MeV, 3 <sup>-</sup> ) state. So, (2019Ch16) reported that it is possible that the <sup>18</sup> Ne state reported here is a multiplet of a number of unresolved states of <sup>18</sup> Ne.
16.9×10 <sup>3</sup> <sup>ab</sup>	2 <sup>+</sup>	2400 keV	H	Γ <sub>α</sub> =1500 keV; Γ <sub>p</sub> =900 keV (2022Ba39) E(level),T <sub>1/2</sub> or Γ,J <sup>π</sup> : From the multi-channel R-matrix analysis of (2022Ba39).
20700				Z E(level): From (2010Xu11). Most likely decays via <sup>14</sup> O*+2α (2010Xu11).
23300				Z E(level): From (2010Xu11). Most likely decays via <sup>14</sup> O*+2α (2010Xu11).
26200				Z E(level): From (2010Xu11). Most likely decays via <sup>14</sup> O*+2α (2010Xu11).

<sup>a</sup> The data for the states located near the low- or high-energy edge of the excitation function measured by (2022Ba39) are incomplete. Also, due to the high thresholds in some detectors used in the experiment of (2022Ba39), the angular distributions in the excitation energy range from 7 to 8 MeV are incomplete. Therefore, (2022Ba39) report these states in parentheses.

<sup>b</sup> This level has a pronounced α-cluster structure reported by (2022Ba39), which is demonstrated with the large (>0.1) dimensionless reduced width (θ<sub>α</sub><sup>2</sup>).

<sup>c</sup> All the evidence presented here suggests that this state could be a superposition of more than one states.

<sup>d</sup> For a direct, one-step transfer via the (<sup>3</sup>He,n) or (p,t) reaction, in which compound nuclear processes can be neglected, on a target nucleus whose J<sup>π</sup> assignment is 0<sup>+</sup> (such as <sup>16</sup>O or <sup>20</sup>Ne), the double stripping selection rules require J=L and π=(-1)<sup>L</sup>. Therefore, the identification of L determines the spin and parity of the final state, particularly when the final state is strongly populated indicating the transfer of a diproton or a dineutron in a relative s=0 state.

**Adopted Levels, Gammas (continued)**

								$\gamma(^{18}\text{Ne})$		
$E_i(\text{level})$	$J_i^\pi$	$E_\gamma$	$I_\gamma^a$	$E_f$	$J_f^\pi$	Mult.	$\delta$	Comments		
1887.4	2 <sup>+</sup>	1887.3 2	100	0	0 <sup>+</sup>	E2		B(E2)(W.u.)=18.0 +17-14 E <sub>γ</sub> : From (1968Gi09, 1969Ro08). I <sub>γ</sub> : From (1968Gi09, 1969Ro08, 1969Ro22). Mult.: From (1974Mc17). δ=0 (mixing ratio): from (1969Ro08).		
3376.4	4 <sup>+</sup>	1488.9 3	100	1887.4	2 <sup>+</sup>	E2		B(E2)(W.u.)=9.1 +14-11 E <sub>γ</sub> : From (1968Gi09, 1969Ro08). Mult.: From (1972Gi01). See also E2/M3 (1969Ro08, 1969Ro22, 1970Sh04) with a mixing ratio of δ=0.04 3 from the weighted average of +0.06 7 (1969Ro08: see Table 2 assuming J=4); +0.00 4 (1969Ro22: see Fig. 3 assuming J=4); and +0.12 7 (1970Sh04: see Fig. 1). Note that mixing ratios deduced by (1970Sh04) and (1972Gi01) are based on the phase convention of (1967Ro21). I <sub>γ</sub> : From (1968Gi09, 1969Ro08, 1969Ro22: see Fig. 3, 1970Sh04: see Fig. 1). (1970Sh04) found that at θ <sub>γ,lab</sub> =90° the ratio of the yield of the 1.87-MeV to the 1.49-MeV γ rays is 1.01 4. This is consistent with J <sup>π</sup> =4 <sup>+</sup> assignment for the 3376.4-keV level because both of the γ-ray transitions involved in the 4 <sub>1</sub> <sup>+</sup> →2 <sub>1</sub> <sup>+</sup> →0 <sub>1</sub> <sup>+</sup> cascade have the same angular correlation with respect to the corresponding neutron groups independent of the reaction mechanism. For the unobserved decay branch from <sup>18</sup> Ne*(3376 keV)→ <sup>18</sup> Ne <sub>g.s.</sub> : I <sub>γ</sub> <1% (1969Ro22: see Fig. 3); I <sub>γ</sub> <1% (1970Sh04: see Fig. 1); and I <sub>γ</sub> <4% (1968Gi09, 1969Ro08). Therefore, we adopt I <sub>γ</sub> <1% for this branch.		
3576.3	0 <sup>+</sup>	1689 2	100	1887.4	2 <sup>+</sup>	E2		B(E2)(W.u.)=5.3 +44-18 E <sub>γ</sub> : From (1968Gi09, 1969Ro08). I <sub>γ</sub> : From (1968Gi09, 1969Ro08, 1969Ro22: see Fig. 3). Mult.: From (1972Gi01). The <sup>18</sup> Ne*(3576.3 keV)→ <sup>18</sup> Ne <sub>g.s.</sub> decay branch remains unobserved. The branching ratio is estimated to be I <sub>γ</sub> <5% (1969Ro22: see Fig. 3); and I <sub>γ</sub> <17% (1968Gi09, 1969Ro08). We, therefore, adopt I <sub>γ</sub> <5% for this branch.		
3616.5	2 <sup>+</sup>	1729.2 5	100 3	1887.4	2 <sup>+</sup>	M1+E2	0.05 7	B(M1)(W.u.)=0.088 +45-31; B(E2)(W.u.)<5.8 E <sub>γ</sub> : From (1968Gi09, 1969Ro08). I <sub>γ</sub> : I <sub>γ</sub> =90.9% 27 is the weighted average (with external errors) of 93% 2 (1969Ro22: see Fig. 3); and 87.5% 25 (1972Gi01). The resulting weighted average is normalized to 100%. Mult.: From (1969Ro08, 1970Sh04, 1972Gi01). (1969Ro08) calculated the matrix elements for E2 and M1 transitions to be  M  <sup>2</sup> <190 W.u. and 0.03< M  <sup>2</sup> <0.1, respectively. δ: Weighted average (with external errors) of -1.1 +10-3 (1969Ro08: see Table 2 assuming for J=2); -0.9 7 (1969Ro22: see Fig. 3); +0.09 7 (1970Sh04: see Fig. 1); and +0.03 9 (1972Gi01). See also δ=+0.06 6 computed by (1972Gi01) as the weighted average of the above mentioned values.		
		3614 3	10 3	0	0 <sup>+</sup>	E2		B(E2)(W.u.)=0.68 +38-28 E <sub>γ</sub> : From (1969Ro22).		

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**Adopted Levels, Gammas (continued)**

$\gamma(^{18}\text{Ne})$  (continued)

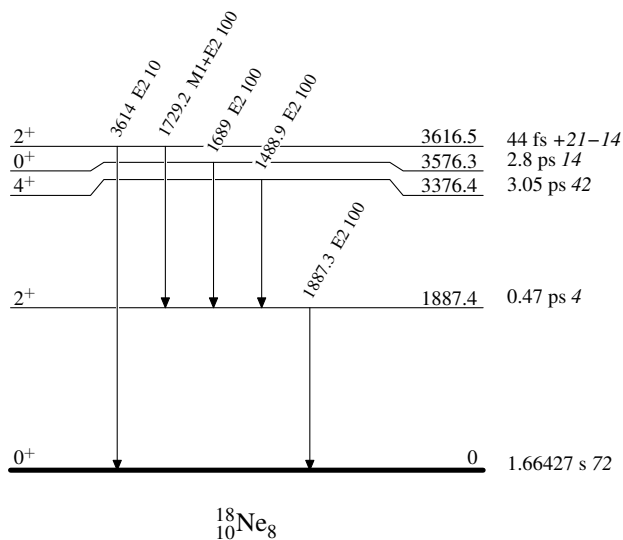
<u><math>E_i(\text{level})</math></u>	<u><math>E_\gamma</math></u>	<u>Comments</u>
		<p><math>I_\gamma</math>: <math>I_\gamma=9.2\%</math> 27 is the weighted average (with external errors) of 7% 2 (1969Ro22; see Fig. 3) and 12.5% 25 (1972Gi01). See also BR&lt;9% (1968Gi09, 1969Ro22); BR&lt;3% (1970Sh04; see Fig. 1). The resulting weighted average mentioned above is renormalized to deduce <math>I_\gamma=10\%</math> 3 given here.</p> <p>Mult.: From (1972Gi01).</p>

<sup>a</sup> Since (1968Gi09, 1969Ro08, 1969Ro22) considered the branching ratio of each observed branch as 100% and estimated an upper limit for the branching ratio of the unobserved branch for each level above the 1.89 MeV state, the evaluator renormalized the branching ratios from each level so they add to 100%.

**Adopted Levels, Gammas**

Level Scheme

Intensities: Relative photon branching from each level



**$^{22}\text{Al}$   $\varepsilon\alpha$  decay: 91.1 ms 1997BI03, 2021Wu10**

Parent:  $^{22}\text{Al}$ :  $E=0$ ;  $J^\pi=(4)^+$ ;  $T_{1/2}=91.1$  ms 5;  $Q(\varepsilon\alpha)=10.46\times 10^3$  syst; % $\varepsilon\alpha$  decay=0.038 17

$^{22}\text{Al}$ - $T_{1/2}$ : In (2006Ac04), the  $^{22}\text{Al}$  half-life was measured based on 3 different analyses, two of which are prone to errors (according to the authors). They recommended  $T_{1/2}=91.1$  ms 5 based on the error-weighted average half-life deduced from fits of decay time spectra in coincidence with various different proton groups. The recommended value is adopted in the latest ENSDF evaluation of  $^{22}\text{Al}$  (2015Ba27).

$^{22}\text{Al}$ - $J^\pi$ : Based on  $T=2$  isospin multiplet (1982Ca16) and from comparison of the measured  $\gamma$ -ray intensity, summed Gamow-Teller strength, and the delayed proton branching ratios accompanied by shell model calculations presented in (2006Ac04), the evaluator assigned  $J=(4)$ , which is consistent with the adopted (by 2015Ba27)  $J^\pi$  value in ENSDF and the  $J^\pi$  assignments presented in (1983Ca01, 1984Ca29, 1985Ja07, and 2021Wu10).

$^{22}\text{Al}$ - $Q(\varepsilon\alpha)$ : From  $Q(\varepsilon)(^{22}\text{Al})=18600$  (uncertainty is systematic: 2021Wa16) and  $S_\alpha(^{22}\text{Mg}_{\text{g.s.}})=8142.5$  4 (2021Wa16).

$^{22}\text{Al}$ -% $\varepsilon\alpha$  decay: From Adopted Levels of  $^{22}\text{Al}$  in (2015Ba27) and taken from (2006Ac04). See also  $\varepsilon\alpha=0.31$  % 9 (1997BI03), and  $\varepsilon\alpha=0.12$  % 1 (2021Wu10). The branching ratio deduced in (2006Ac04) was obtained from the intensity of the 1887-keV  $\gamma$  ray (from the  $\gamma$ -decay of the first excited state of  $^{18}\text{Ne}$  to  $^{18}\text{Ne}_{\text{g.s.}}$ ) observed in coincidence with the  $\beta$ -delayed  $\alpha$ -particle from the decay of  $^{22}\text{Mg}^*(\text{IAS})$  to  $^{18}\text{Ne}^*(1887$  keV).

1997BI03, 1997Cz02:  $^{22}\text{Al}(\beta^+)^{22}\text{Mg}^*(\alpha)^{18}\text{Ne}^*$   $E=74$  MeV/nucleon; implanted  $^{22}\text{Al}$  beam into a Si detector used as an entrance window (integrated in the cathode) of a Micro-Strip Gas Counter (MSGC). The particle-recoil and particle-particle coincidences from the  $^{22}\text{Al}$  decay were measured using these detectors as well as a Si detector downstream the MSGC. After collection of sufficient activity, the beam was switched off for 100 ms. Measured  $\beta$ -delayed protons-, two-protons-, and  $\alpha$ -emission spectra and  $E_p$  and  $E_\alpha$  for the  $\beta$ -delayed p, 2p, and  $\alpha$ -emissions. Deduced the half-life of  $^{22}\text{Al}$ ; discussed the  $J^\pi$  assignment of  $^{22}\text{Al}_{\text{g.s.}}$ ; deduced  $^{18}\text{Ne}^*(1887$  keV) level and its associated  $\beta$ -delayed  $\alpha$ -branching ratio; and measured the  $\beta$ -delayed  $\alpha$ -emission to the  $^{18}\text{Ne}^*(2_1^+)$  state from the isobaric analog state in  $^{22}\text{Mg}$ . The weaker  $\beta$ -delayed  $\alpha$ -decay branches were hindered because of the stronger transitions from contaminants.

2006Ac04:  $^{22}\text{Al}(\beta^+)^{22}\text{Mg}^*(\alpha)^{18}\text{Ne}^*$   $E=48$  MeV/nucleon; implanted  $^{22}\text{Al}$  beam into a Si telescope; identified the charged particles from the  $^{22}\text{Al}$  decay using a downstream set of three silicon detectors; detected  $\gamma$ -rays from the decay events by the EXOGAM HPGe clover detector in close geometry. Measured  $E_\gamma$ ,  $I_\gamma$ ,  $\beta$ ,  $\beta$ - $\gamma$  and ( $\beta$ -delayed particles)- $\gamma$  coincidences, branching ratios, and the  $^{22}\text{Al}$  half-life in beam-on/beam-off mode (120 ms of implantation, 300 ms beam-off). A GEANT Monte Carlo simulation, the  $^{22}\text{Al}$  decay scheme, comparisons with shell model calculations and with previous experimental results are presented. Observed the  $\beta$ -2p transition to the  $^{20}\text{Ne}^*(2_1^+)$  and the  $\beta$ - $\alpha$  decay to the  $^{18}\text{Ne}^*(2_1^+)$  state. To obtain the branching ratios for these transitions,  $\gamma$ -ray coincidence events were used. Deduced the mass excess of  $^{22}\text{Al}$  and discussed the  $J^\pi$  assignments of the measured  $^{22}\text{Mg}^*$  states.

2021Wu10:  $^{22}\text{Al}(\beta^+)^{22}\text{Mg}^*(\alpha)^{18}\text{Ne}^*$   $E$  not given; implanted  $^{22}\text{Al}$  into a position sensitive segmented Si detector array that composed of 3 DSSDs with different thicknesses. Downstream this array, 3 other silicon detectors identified the  $\beta$ -rays from the decay and vetoed the light beam contaminants. Measured the  $\beta$ -delayed  $\gamma$  rays by a  $\gamma$ -ray detector array consisting of 5 HPGe clover detectors surrounding the position sensitive Si array. Measured the  $\beta$ -delayed protons, 2p, and  $\alpha$ - particles,  $E_\beta$ ,  $E_\gamma$ ,  $I_\gamma$ ,  $\beta\gamma$  and  $\alpha$ - $\gamma$  coincidences, and decay curve of  $^{22}\text{Al}$ ; deduced level energies,  $J^\pi$  values,  $^{22}\text{Al}$  half-life, and branching ratios. The measured absolute branching ratios are summed to 91.6% 51. However, there are 8 unassigned transitions, which contribute to the missing branching ratios. These 8 transitions are, however, not in coincidence with any known  $\gamma$  rays in  $^{21}\text{Na}$  (from  $\beta p$  decay of  $^{22}\text{Al}$ ),  $^{20}\text{Ne}$  (from  $\beta 2p$  decay of  $^{22}\text{Al}$ ), or  $^{18}\text{Ne}$  (from  $\beta\alpha$  decay of  $^{22}\text{Al}$ ). Moreover, based on energy summation, these transitions cannot be connecting to the ground state in the above mentioned nuclei. The authors tentatively assigned them to  $\beta p$  decay of  $^{22}\text{Mg}^*$  states to  $^{21}\text{Na}_{\text{g.s.}}$ . Comparisons with shell model calculations are presented.

*Previously Known  $^{22}\text{Al}$  Decay Schemes:*

1983Ca01, 1983CaZU, 1983CaZT, 1984Ca29, 1984CaZV:  $^{24}\text{Mg}(^3\text{He}, p4n)$   $E=110$  MeV. In the experiments of (1983Ca01, 1984Ca29),  $^{22}\text{Al}$  recoils were stopped in a helium jet system, which was used to transport the  $^{22}\text{Al}$  activity to the counting chamber consisting of a Si  $\Delta E$ - $E$  telescope to measure  $\beta$ -delayed protons (from  $^{22}\text{Al}(\beta^+p)$ ) in coincidence at  $\theta_{\text{lab}}=0^\circ-70^\circ$ . These experiments only investigated the  $\beta$ -delayed 2p-decay of  $^{22}\text{Al}$ . The  $\beta$ -delayed  $\alpha$ -decay is not discussed. However, the authors present Fig. 3 (1983Ca01) and Fig. 1 (1984Ca29), in which the decay scheme of  $^{22}\text{Al}$  includes the  $\beta$ -delayed  $\alpha$ -decay branches to the ground and first excited states of  $^{18}\text{Ne}$ . No other information is provided.

<sup>22</sup>Al εα decay:91.1 ms    **1997BI03,2021Wu10 (continued)**

<sup>18</sup>Ne Levels

<u>E(level)<sup>a</sup></u>	<u>J<sup>π</sup><sup>a</sup></u>	<u>T<sub>1/2</sub><sup>a</sup></u>
0	0 <sup>+</sup>	1.66427 s
1887.4	2 <sup>+</sup>	0.47 ps

<sup>a</sup> From the <sup>18</sup>Ne Adopted Levels.

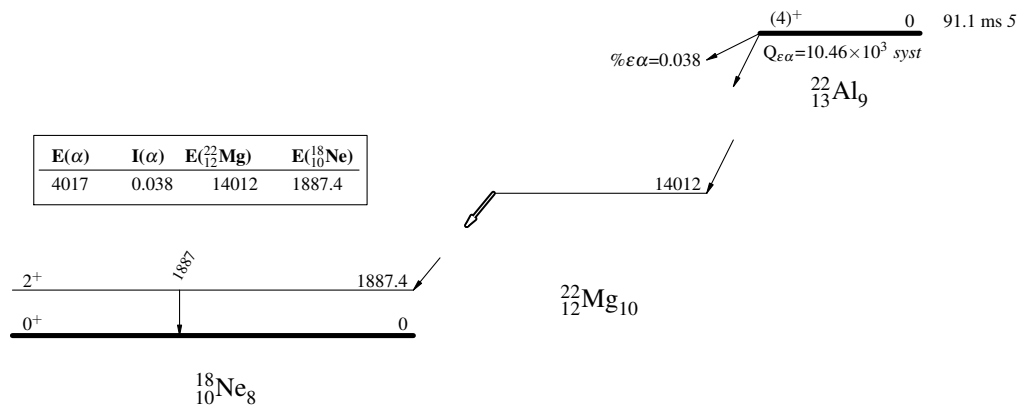
γ(<sup>18</sup>Ne)

<u>E<sub>γ</sub></u>	<u>E<sub>i</sub>(level)</u>	<u>J<sub>i</sub><sup>π</sup></u>	<u>E<sub>f</sub></u>	<u>J<sub>f</sub><sup>π</sup></u>	<u>Comments</u>
1887	1887.4	2 <sup>+</sup>	0	0 <sup>+</sup>	E <sub>γ</sub> : Measured in (2006Ac04, 2021Wu10). See also the <sup>18</sup> Ne Adopted Gammas. (1997BI03) did not measure any γ rays.

Delayed Alphas (<sup>18</sup>Ne)

<u>E(α)</u>	<u>E(<sup>18</sup>Ne)</u>	<u>I(α)<sup>a</sup></u>	<u>E(<sup>22</sup>Mg)</u>	<u>Comments</u>
4017 8	1887.4	0.038 17	14012	<p>E(α): Total decay energy given in the center-of-mass frame. This value is adopted from <sup>22</sup>Al Adopted Levels in (2015Ba27), which is taken from (2006Ac04). See also: E<sub>c.m.</sub>=3997 keV 40 deduced from E<sub>α,lab</sub>=3270 keV 40 (1997BI03); and E<sub>c.m.</sub>=4030 keV 10 (2021Wu10). Note that the β-delayed α-transition measured in (2006Ac04) was superimposed on a β-delayed proton transition. Using γ-α coincidence events, the β-delayed α-branch was distinguished. Also, note that in Table 1 of (2006Ac04), it is mentioned that the center-of-mass E<sub>α</sub> for this transition measured in (1997BI03) was 3997 keV 49 and that this is equivalent to the β-α transition measured by (1997BI03) at E=4.01 MeV 5. While (1997BI03) mentions that the measured E<sub>α,lab</sub>=3270 keV 40 corresponds to the Q-value of 4.01 MeV 5 for an α de-excitation of the <sup>22</sup>Mg*(IAS) towards the first excited state in <sup>18</sup>Ne. The evaluator cannot determine where the 49 keV uncertainty in E<sub>c.m.</sub>=3997 keV 49 value reported by (2006Ac04) for the measurement in (1997BI03) comes from. However, converting the E<sub>α,lab</sub>=3270 keV 40 (1997BI03) to the center-of-mass, the evaluator deduced E<sub>c.m.</sub>=3997 keV 40 for (1997BI03).</p> <p>I(α): Branching ratio per 100 decays of <sup>22</sup>Al from (2006Ac04), which is recommended by the Adopted Levels of <sup>22</sup>Al (2015Ba27).</p> <p>E(<sup>22</sup>Mg): 14012 keV 3 (2006Ac04) is the IAS of <sup>22</sup>Al<sub>g.s</sub> assuming J<sup>π</sup>=4<sup>+</sup>, see the Adopted Levels of <sup>22</sup>Al in (2015Ba27). See also 14046 keV 5 (2021Wu10) and 14027 keV 40 deduced from the reported E<sub>α,lab</sub>=3270 keV 40 (1997BI03).</p>

<sup>a</sup> Absolute intensity per 100 decays.

$^{22}\text{Al}$   $\varepsilon\alpha$  decay: 91.1 ms 1997BI03,2021Wu10Decay SchemeI( $\alpha$ ) Intensities: I( $\alpha$ ) per 100 parent decays

**<sup>19</sup>Na p decay 2003An02,2008Pe02**

Parent: <sup>19</sup>Na: E=0; J<sup>π</sup>=(5/2<sup>+</sup>); T<sub>1/2</sub><40 keV; Q(p)=-323 11; %p decay=100

<sup>19</sup>Na-T<sub>1/2</sub>: Label=Γ (keV)

<sup>19</sup>Na-E,J<sup>π</sup>,T<sub>1/2</sub>: From the Adopted Levels of <sup>19</sup>Na in ENSDF.

<sup>19</sup>Na-Q(p): From (2021Wa16).

<sup>19</sup>Na-%p decay: From Adopted Levels of <sup>19</sup>Na in the ENSDF database.

2003An02, 2003An28, 2004An28: <sup>1</sup>H(<sup>18</sup>Ne,<sup>19</sup>Na→p+<sup>18</sup>Ne), <sup>1</sup>H(<sup>18</sup>Ne,<sup>19</sup>Na→2p+<sup>17</sup>F) E=21, 23.5, and 28 MeV; measured the recoil protons using two segments of the Louvain-la-neuve Edinburg Detector Array (LEDA) Si array covering θ<sub>lab</sub>=4.9°-11.7° and θ<sub>lab</sub>=22.6°-29.9°. A J<sup>π</sup>=1/2<sup>+</sup> resonance was observed at E<sub>c.m.</sub>=1066 keV 3 corresponding to <sup>19</sup>Na\*(745 keV). The proton decay of this state to <sup>18</sup>Ne<sub>g.s.</sub> was measured.

2005De15, 2006DeZU: <sup>1</sup>H(<sup>18</sup>Ne,<sup>19</sup>Na→<sup>18</sup>Ne+p), <sup>1</sup>H(<sup>18</sup>Ne,<sup>19</sup>Na→2p+<sup>17</sup>F) E=7.2 MeV/nucleon; measured the excitation function of <sup>18</sup>Ne+p quasi-elastic scattering. The scattered protons were measured by a position sensitive ΔE-ΔE-E telescope covering θ<sub>lab</sub>=±4.5° with a resolution of 30 keV 10. Two peaks at E<sub>c.m.</sub>≈2400 and 3100 keV were observed on the excitation function of p(<sup>18</sup>Ne,p) elastic scattering, whose shapes, energies and intensities did not match any interpretation in the context of elastic scattering or shell model calculations for <sup>19</sup>Na states. An R-matrix calculation (using the ANARKI code) predicted the observed shapes and energies of these two peaks but not the observed intensities. It was necessary to consider inelastic scattering to the proton-unbound states of <sup>18</sup>Ne and the subsequent p-decay to <sup>17</sup>F. The two-proton decay analysis is consistent with <sup>19</sup>Na states at E<sub>x</sub>=5585, 5809 and 5815 keV that 2p decay, via <sup>18</sup>Ne\* intermediate states (see Fig. 8) to <sup>17</sup>F\*(0, 495 keV).

2006Sk09: <sup>1</sup>H(<sup>18</sup>Ne, <sup>19</sup>Na→<sup>18</sup>Ne+p) E=56 MeV. The <sup>18</sup>Ne beam was purified in the TwinSol magnetic analyzer and bombarded a thick (CH<sub>2</sub>)<sub>n</sub> target. Scattered protons were measured at θ<sub>lab</sub>=7.5°, 22.5°, and 37.5° with an energy resolution of ~30 keV. A <sup>19</sup>Na state at E<sub>x</sub>=0.74 MeV 3 was observed. No more <sup>19</sup>Na excited states at higher energies were observed.

2006AcZY, 2008Pe02: <sup>1</sup>H(<sup>18</sup>Ne,<sup>19</sup>Na→<sup>18</sup>Ne+p) E=66 MeV; measured the recoiling protons from the <sup>19</sup>Na decay using an annular ΔE-E Si telescope covering θ<sub>lab</sub>=4.7°-20.2° with an overall energy resolution of 105 keV. Elastic and inelastic scattering were measured at seven angles. Two states of <sup>19</sup>Na at E<sub>c.m.</sub>=2.78 and 3.09 MeV were measured and J<sup>π</sup> values of 5/2<sup>+</sup> and 3/2<sup>+</sup> were assumed, respectively. These states proton decay to <sup>18</sup>Ne<sub>g.s.</sub>.

<sup>18</sup>Ne Levels

Γ<sub>p1</sub> refers to the width of the proton transition for the <sup>19</sup>Na\*→p+<sup>18</sup>Ne decay (2005De15).

Γ<sub>p2</sub> refers to the width of the proton transition for the <sup>18</sup>Ne\*→p+<sup>17</sup>F decay (2005De15).

E(level)	J <sup>π</sup>	Γ (keV) <sup>b</sup>	E <sub>p2</sub> (c.m.) (keV) <sup>bc</sup>	Comments
0	0 <sup>+</sup>	1.66427 s		E(level): Populated by the proton decay of (1) the <sup>19</sup> Na state at E <sub>x</sub> =740 keV 30 (2006Sk09), which was also observed as a resonance at E <sub>c.m.</sub> (p+ <sup>18</sup> Ne)=1066 keV 3 (2003An02), and E <sub>c.m.</sub> (p+ <sup>18</sup> Ne)=1076 keV 6 (2005De15); (2) the <sup>19</sup> Na state at E <sub>x</sub> =4371 keV 10 (2005De15); and (3) the <sup>19</sup> Na state at E <sub>x</sub> =4903 keV 10 (2005De15). J <sup>π</sup> ,T <sub>1/2</sub> : From the <sup>18</sup> Ne Adopted Levels.
1887.4	2 <sup>+</sup>	0.47 ps		E(level): From the Adopted Levels of <sup>18</sup> Ne. This state is populated by the proton decay of (1) E <sub>x</sub> ( <sup>19</sup> Na)=2459 keV 32 (2008Pe02); and (2) E <sub>x</sub> ( <sup>19</sup> Na)=2769 keV 61 (2008Pe02). These two <sup>19</sup> Na states are observed by (2008Pe02) at E <sub>c.m.</sub> (p+ <sup>18</sup> Ne)=2.78 MeV 3 and 3.09 MeV 6, respectively. J <sup>π</sup> ,T <sub>1/2</sub> : From the <sup>18</sup> Ne Adopted Levels.
4121? 12		9 keV +54-9	200 12	E(level): (2005De15) observed a transition at E <sub>p1</sub> <sup>c.m.</sup> =1698 keV 75 corresponding to the proton decay of a <sup>19</sup> Na* state at E <sub>x</sub> =5499 keV 76 to a <sup>18</sup> Ne* state at E <sub>x</sub> =4121 keV 12, whose width was deduced as Γ=9 keV +54-9. However, the authors mentioned that no correspondence could be found between the <sup>18</sup> Ne*(4121 keV) state and any of the known <sup>18</sup> Ne states. The closest <sup>18</sup> Ne state has an excitation energy that differs by about 0.4-0.5 MeV. The evaluator

Continued on next page (footnotes at end of table)

$^{19}\text{Na}$  p decay 2003An02,2008Pe02 (continued) $^{18}\text{Ne}$  Levels (continued)

<u>E(level)</u>	<u><math>\Gamma</math> (keV)<sup>b</sup></u>	<u><math>E_{p_2}</math>(c.m.) (keV)<sup>bc</sup></u>	<u>Comments</u>
4481 11	27 keV +6-9	560 11	notes that the $^{19}\text{Na}^*(5499\text{ keV})$ state does not seem to correspond to any of the known $^{19}\text{Na}$ states either. Considering that the other transitions observed in this study lined up with the known levels in $^{19}\text{Na}$ and $^{18}\text{Ne}$ , the evaluator did not consider this state for the $^{18}\text{Ne}$ Adopted Levels. A decay to $^{17}\text{F}_{g.s.}$ with a proton transition width of $\Gamma_{p_2}=40\text{ keV}$ 34 was deduced by (2005De15) if this state belongs to $^{18}\text{Ne}$ . E(level): From (2005De15): reported that this state may be either the $^{18}\text{Ne}^*(4517\text{ keV}, 1^-)$ level, or the $^{18}\text{Ne}^*(4524\text{ keV}, 3^+)$ state. Due to uncertainty in identification of this state, we did not consider this state for the Adopted Levels. Decays to $^{17}\text{F}_{g.s.}$ with a proton transition width of $\Gamma_{p_2}=47\text{ keV}$ 4 (2005De15).
4590 <sup>a</sup>	0 keV +37-0	156 12	Decays to the $^{17}\text{F}^*(459\text{ keV})$ state with a proton transition width of $\Gamma_{p_2}=39\text{ keV}$ 15 (2005De15).
5117 11	33 keV +9-11	1196 11	E(level): From (2005De15): reported that this state may be either the $^{18}\text{Ne}^*(5100\text{ keV}, 2^+)$ level, or the $^{18}\text{Ne}^*(5142\text{ keV}, 3^-)$ state. Due to uncertainty in identification of this state, we did not consider this state for the Adopted Levels. Decays to $^{17}\text{F}_{g.s.}$ with a proton transition width of $\Gamma_{p_2}=51\text{ keV}$ 6 (2005De15).

<sup>a</sup> From the Adopted Levels of  $^{18}\text{Ne}$  assuming proton decay from the  $^{19}\text{Na}^*(5809\text{ keV})$  state to the  $^{18}\text{Ne}(4590\text{ keV})$  as suggested by (2005De15: see text and Fig. 8).

<sup>b</sup> From (2005De15).

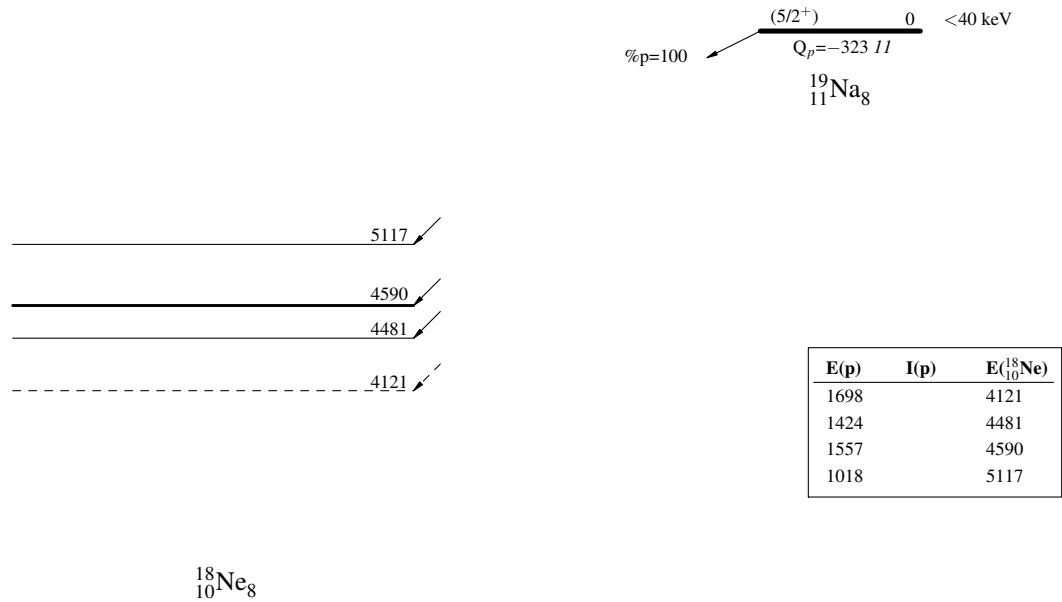
<sup>c</sup> This is the center-of-mass energy of the proton emitted from the  $^{18}\text{Ne}^*\rightarrow\text{p}+^{17}\text{F}_{g.s.}$  decay (2005De15).

Protons ( $^{18}\text{Ne}$ )

<u><math>E_{p_1}</math>(c.m.) (keV)<sup>ab</sup></u>	<u><math>E(^{18}\text{Ne})</math></u>	<u><math>E_x(^{19}\text{Na})</math> (keV)<sup>a</sup></u>	<u><math>\Gamma_{p_1}</math> (keV)<sup>a</sup></u>	<u>Comments</u>
1018 13	5117	5815	154 17	$E_x(^{19}\text{Na})$ (keV): $E_x(^{19}\text{Na})=5815\text{ keV}$ 17 with $\Gamma(^{19}\text{Na})=141\text{ keV}$ 18 (2005De15).
1424 30	4481	5585	697 72	$E_x(^{19}\text{Na})$ (keV): $E_x(^{19}\text{Na})=5585\text{ keV}$ 32 with $\Gamma(^{19}\text{Na})=695\text{ keV}$ 72 (2005De15).
1557 66	4590	5809	463 215	$E_x(^{19}\text{Na})$ (keV): $E_x(^{19}\text{Na})=5809\text{ keV}$ 76 with $\Gamma(^{19}\text{Na})=460\text{ keV}$ 215 (2005De15).
1698 75	4121?	5499	541 178	$E_x(^{19}\text{Na})$ (keV): $E_x(^{19}\text{Na})=5499\text{ keV}$ 76 with $\Gamma(^{19}\text{Na})=539\text{ keV}$ 180 (2005De15). Note that the energy of this $^{19}\text{Na}$ state is not in agreement within $1\sigma$ with any other $^{19}\text{Na}$ states.

<sup>a</sup> From (2005De15).

<sup>b</sup> This is the center-of-mass energy of the proton emitted from the  $^{19}\text{Na}^*\rightarrow\text{p}+^{18}\text{Ne}^*$  decay (2005De15).

**$^{19}\text{Na}$  p decay 2003An02,2008Pe02**Decay Scheme

$^1\text{H}(^{17}\text{F},\gamma)$  1987Wi11,2014A105

2005Fi01, K. Chipps, Ph.D. Thesis, Colorado School of Mines (2008), 2009Ch17, 2009Ch64, 2009Ba59, 2009ChZW, J. R. Beene *et al.*, J. Phys. G: Nucl. Part. Phys. 38 (2011) 024002:  $^1\text{H}(^{17}\text{F},\gamma)$   $E=10.83$  MeV; measured the  $\gamma$ - $^{18}\text{Ne}^*$  coincidences using a plastic scintillator array surrounding the target and an ionization chamber at the focal plane of the Daresbury Recoil Separator. Measured the resonance strength and deduced the partial  $\gamma$ -ray width of the 599.8-keV resonance using  $\Gamma_p=18$  keV 2 (stat.) 1 (sys.) from (2000Bb04). Reevaluated the  $^{17}\text{F}(p,\gamma)^{18}\text{Ne}$  reaction rate and discussed its astrophysical impact.

*Theory:*

2014A105:  $^{13}\text{C}(^{17}\text{O},^{18}\text{O})$  12 MeV/nucleon; the neutron transfer measurement was performed to study  $^{18}\text{O}$ , the mirror of  $^{18}\text{Ne}$ . The elastic scattering measurements were performed to extract the optical model parameters for the DWBA analysis of the neutron transfer data. The elastic scattering angular distributions were measured at  $\theta_{\text{lab}}=4^\circ-25^\circ$  using the MDM magnetic spectrometer. The same apparatus measured the neutron transfer data at  $\theta_{\text{lab}}=4^\circ-11^\circ$ . In a second set of measurements, a 216-MeV beam of  $^{18}\text{O}$  impinged on a  $^{12}\text{C}$  enriched target and the absolute elastic scattering cross section was measured at  $\theta_{\text{lab}}=4^\circ-22^\circ$ . The Asymptotic Normalization Coefficients were deduced from the DWBA analysis of the neutron transfer data. The ANCs were deduced for the  $^{18}\text{Ne}$  states assuming equality of the spectroscopic factors. The astrophysical S-factor and the  $^{17}\text{F}(p,\gamma)$  reaction rate are calculated, and the astrophysical implications are discussed.

*The  $^{18}\text{F}(p,\gamma)$  Astrophysical Reaction Rate:*

This subsection contains experimental and theoretical studies that are focused on the determination of the  $^{18}\text{F}(p,\gamma)$  astrophysical rate. The details of the experimental studies can be found in other sections. Only a summary of the important findings with regards to the reaction rate are mentioned here.

1979Wo07: Compiled, evaluated available semi-empirical thermonuclear reaction data for  $A=16-74$ . Parameterized analytic formulas are presented.

M. Wiescher *et al.*, Astrophys. J. 263 (1982) 891: The cross sections for direct proton capture transitions to two bound states in  $^{18}\text{Ne}$  at  $E_x=1887$  and 3616 keV were calculated using the direct capture model described by (1973Ro34). The total S-factor was computed. The resonant rate of the  $^{17}\text{F}(p,\gamma)$  reaction was calculated based on the contributions of two known proton resonances corresponding to the  $^{18}\text{Ne}^*(4.52$  MeV,  $1^-)$  and  $^{18}\text{Ne}^*(4.59$  MeV,  $0^+)$  levels. The total  $^{17}\text{F}(p,\gamma)$  reaction rate was calculated. Comparison with literature reaction rate is discussed.

1987Wi11, 1988Wi08: Constructed the  $T=1$  analog states in  $^{18}\text{O}$ ,  $^{18}\text{F}$  and  $^{18}\text{Ne}$ . From these, it was evident that a  $J^\pi=3^+$  proton resonance in  $^{18}\text{Ne}$  had not been observed experimentally. Calculated the excitation energy of this missing state using Thomas-Ehrman shift calculations (and obtained  $E_x=4.31$  MeV); and shell model calculations, which yielded  $E_x=4.33$  MeV. The authors deduced a value of  $E_x(^{18}\text{Ne})=4328$  keV 40 (with the uncertainty coming from the nuclear structure input); estimated  $\Gamma\sim\Gamma_p=5$  keV; and noted that these values lie sufficiently close to the  $^{17}\text{F}+p$  threshold that the  $3^+$  resonance would greatly enhance the  $^{17}\text{F}(p,\gamma)$  reaction rate. Proton and  $\gamma$ -ray partial widths, resonance strength, and non-resonant direct capture contribution were estimated for this  $s$ -wave resonance. Recalculated the  $^{17}\text{F}(p,\gamma)$  reaction rate.

1989Or02: A shell-model analysis of Coulomb energies of the  $A=10-55$  nuclei predicted the energy of the experimentally unobserved  $3^+$  state in  $^{18}\text{Ne}$  to be 4.47 MeV from estimating the Coulomb energy shift between  $^{18}\text{O}$  and  $^{18}\text{Ne}$  mirrors using the charge-dependent single-particle energies and two-body matrix elements.

1991Ga03: Estimated the energy of the experimentally unobserved  $3^+$  state to be 4.53 MeV with  $\Gamma=22$  keV by calculating the wave functions for a Woods-Saxon well and a  $2s_{1/2}$  resonance for  $^{17}\text{F}_{g.s.}+p$ . The authors then measured some excess counts at one angle, and attributed these counts to the missing  $3^+$  state, for which they inferred  $E_x=4561$  keV 9 (see the  $^{16}\text{O}(^3\text{He},n)$  section) and estimated its proton partial width to be  $\Gamma=25$  keV. From the mirror level, they found  $\Gamma_\gamma(3_1^+\rightarrow 2_1^+)=25$  meV 16,  $\Gamma_\gamma(3_1^+\rightarrow 2_2^+)=3.8$  meV 31,  $\Gamma_\gamma(3_1^+\rightarrow 4_1^+)=0.8$  meV 8. They also estimated the partial widths for the  $1_1^-$  and  $0_3^+$  states. The astrophysical S-factor at  $E_{c.m.}=100-800$  keV, and the  $^{17}\text{F}(p,\gamma)$  reaction rate for  $T=0.1-1$  GK were computed.

1992Ch50: Provides an extensive review of the  $^{17}\text{F}(p,\gamma)$  reaction rate and the structure of  $^{18}\text{Ne}$  based on the available data at the time.

1997Ba57: Calculated the astrophysical S-factor for the  $^{17}\text{F}(p,\gamma)$  reaction at  $E_{c.m.}=50-1000$  keV, and computed the REACLIB format for the  $^{17}\text{F}(p,\gamma)$  rate. Astrophysical implications are discussed.

1998Sh35: Computed Coulomb energies for positive-parity levels in the mirror nuclei and predicted the excitation energy and width of the astrophysically important  $3^+$  level at 4642 keV and  $\Gamma=42$  keV, respectively.

1999Ba49, 2000Bb04: Conclusively observed the astrophysically important  $3^+$  state by measuring the excitation function for the  $^{17}\text{F}(p,p)$  elastic scattering using a radioactive  $^{17}\text{F}$  beam (see the  $^1\text{H}(^{17}\text{F},p)$  section). The authors measured the excitation energy and the width of this state. The  $^{17}\text{F}(p,\gamma)$  resonant reaction rate, and the total reaction rate at  $T=0.1-2$  GK were computed. The properties of the resonances used in the rate calculation, the REACLIB format, and the astrophysical implications of this rate are

$^1\text{H}(^{17}\text{F},\gamma)$  1987Wi11,2014Ai05 (continued)

presented.

- S. T. Parete-Koon, M. Sc. Thesis, *Reaction Rate of  $^{17}\text{F}(p,\gamma)^{18}\text{Ne}$  and Its Implications for Nova Nucleosynthesis*, The University of Tennessee, Knoxville (2001): The  $^{17}\text{F}(p,\gamma)$  reaction rates of (1999Ba49, 1988Wi08, 1998Sh35) were used to perform nova nucleosynthesis calculations for 3 nova models, which are described and compared. The (1999Ba49) rate was observed to have a significant impact on the  $^{17}\text{O}$  yields.
- 2002Ii05: Recommended the reaction rate of (2000Bb04), varied this rate by one order of magnitude up and down, and studied its effect on nova nucleosynthesis.
- 2002SmZX: Performed nova nucleosynthesis calculations. Examined the influence on nova nucleosynthesis of two reaction rates:  $^{17}\text{F}(p,\gamma)$  and  $^{14}\text{O}(\alpha,2p)$ . Concluded that the  $^{17}\text{F}(p,\gamma)$  reaction rate plays a significant role on the production of radioisotopes that may be observable tracers of novae.
- 2003Pa54: Reviewed the  $^{17}\text{F}(p,\gamma)$  reaction rate, recalculated this rate for  $T=0.1-0.9$  GK based on the information from (1988Wi08, 1991Ga03, 1998Sh35, and 1999Ba49). Performed nova nucleosynthesis calculations for 3 different nova models and discussed the implications of the  $^{17}\text{F}(p,\gamma)$  reaction rate for nova nucleosynthesis.
- 2004De31: Calculated the  $^{17}\text{F}(p,\gamma)$  astrophysical S-factor for  $E_{c.m.}<3$  MeV using the generator coordinate method with an extended microscopic two-cluster model.
- 2004Du02: Investigated the  $^{17}\text{F}(p,\gamma)$  reaction rate using a two-cluster generator coordinate method. Estimated the  $^{18}\text{Ne}$  levels,  $J^\pi$  values, E2 and M1 reduced transition probabilities (in W.u.), and the corresponding  $\Gamma_\gamma$  and  $\Gamma_p$  widths for  $^{18}\text{Ne}$  resonances. Computed the astrophysical S-factor for  $E_{c.m.}=0.1-1.2$  MeV and the  $^{17}\text{F}(p,\gamma)$  reaction rate for  $T=0.1-2$  GK.
- 2005Pa50: Measured the astrophysically important  $3^+$  state in  $^{18}\text{Ne}$  and deduced  $E_x=4527$  keV  $4$  with  $\Gamma=17$  keV  $4$  (see the  $^{16}\text{O}(^3\text{He},n)$  section). Predicted that the  $\Gamma_\gamma$  for this state is negligible ( $\leq 1$  keV) and thus  $\Gamma=\Gamma_p$ . The authors recommended the  $^{17}\text{F}(p,\gamma)$  reaction rate of (2000Bb04).
- 2006Ch08: Calculated the  $^{17}\text{F}(p,\gamma)$  astrophysical S-factor at  $E_{c.m.}\leq 1$  MeV for the capture reaction from both the ground state and the first excited state in  $^{17}\text{F}$ , including E1, E2, and M1 transitions. Analyzed  $^{18}\text{Ne}$  level energies, widths, and spectroscopic factors using continuum shell model. Calculated the  $^{17}\text{F}(p,\gamma)$  reaction rate for  $T=0.1-2$  GK and presented comparison with previous rates.
- 2006De47: Calculated total and partial astrophysical S-factor at  $E_{c.m.}=0.05-1.1$  MeV for the E1, E2, and M1 multipolarities. Calculated  $\Gamma_p=21$  keV and  $\Gamma_\gamma=33$  meV for the astrophysically significant  $3^+$  state at around 4.5 MeV excitation energy. Reviewed and discussed the microscopic, R-matrix and other models. Presented comparison with data.
- 2009Ch17, 2009Ch64, 2009ChZW: Calculated the direct capture and resonant contributions to the total  $^{17}\text{F}(p,\gamma)$  reaction rate at  $T=0.1-0.6$  GK (2009Ch64) and  $0.1-1$  GK (2009Ch17, 2009ChZW). Presented the  $E_{c.m.}$ ,  $J^\pi$ ,  $\Gamma_p$  and  $\Gamma_\gamma$  for the resonances used. Parameterized the total reaction rate according to the REACLIB analytic form of (F. K. Thielemann, M. Arnould, and J. Truran, in *Advances in Nuclear Astrophysics*, edited by E. Vangioni-Flam et al. (Editions Frontières, Gif-sur-Yvette, 1987), p. 525). Presented a comparison with previous rates. Discussed the astrophysical implications of this rate for nova nucleosynthesis.
- 2010Ii04, 2010Ii06: Analyzed and evaluated the  $^{17}\text{F}(p,\gamma)$  direct capture, resonant and total reaction rate for  $T=0.01-10$  GK. Resonant properties for  $E_{c.m.}^{\text{res}}=596-2226$  keV are discussed.
- 2014Ai05: The astrophysical S-factor for the  $^{17}\text{F}(p,\gamma)$  reaction and the asymptotic normalization coefficients were calculated for the  $^{18}\text{Ne}^*(0, 1887, 3376, 3616$  keV) states using mirror analogy of the bound states in  $^{18}\text{O}$  and  $^{18}\text{Ne}$ . Deduced the resonant and total reaction rate for  $T=0.1-1$  GK. Presented the resonance parameters used to calculate the resonance reaction rate. Discussed the contribution of the direct capture rate to the total  $^{17}\text{F}(p,\gamma)$  reaction rate, and its consequences on the production of  $^{18}\text{F}$  at stellar energies in ONe novae.
- 2017Ku27: Calculated the asymptotic normalization coefficients. The direct capture cross sections together with the resulting astrophysical S-factors for each bound state were extracted at  $T=0.04-0.9$  GK using the RADCAP code. Deduced the resonant and total  $^{17}\text{F}(p,\gamma)$  reaction rate at the same temperature range significant for the hot CNO cycle in novae. Comparison with previous experimental results are presented.

 $^{18}\text{Ne}$  Levels

- (2014Ai05) calculated the ANCs for the  $^{18}\text{O}$  bound states using the  $^{13}\text{C}(^{17}\text{O}, ^{18}\text{O})^{12}\text{C}$  data; and estimated the ANCs for the bound states of  $^{18}\text{Ne}$  from analogy with the  $^{18}\text{O}$  mirror levels assuming the spectroscopic factors are the same for both members of the mirror pair.

Continued on next page (footnotes at end of table)

<sup>1</sup>H(<sup>17</sup>F,γ) 1987Wi11,2014AI05 (continued)

<sup>18</sup>Ne Levels (continued)

E(level) <sup>a</sup>	J <sup>π</sup> <sup>a</sup>	S(0) (keV.b) <sup>b</sup>	Comments
0	0 <sup>+</sup>	0.06 1	ANC=C <sup>2</sup> <sub>1d<sub>5/2</sub></sub> =12.2 fm <sup>-1</sup> 12 (2014AI05).
1887.4	2 <sup>+</sup>	0.61 11	ANC: C <sup>2</sup> <sub>1d<sub>5/2</sub></sub> =14.9 fm <sup>-1</sup> 21; C <sup>2</sup> <sub>1d<sub>3/2</sub></sub> =2.85 fm <sup>-1</sup> 32 (2014AI05).
3376.4	4 <sup>+</sup>	0.17 3	ANC=C <sup>2</sup> <sub>2s<sub>1/2</sub></sub> =2.73 fm <sup>-1</sup> 35 (2014AI05).
3616.5	2 <sup>+</sup>	1.34 24	ANC: C <sup>2</sup> <sub>1d<sub>5/2</sub></sub> =117 fm <sup>-1</sup> 20; C <sup>2</sup> <sub>1d<sub>3/2</sub></sub> =2.46 fm <sup>-1</sup> 33 (2014AI05).
4524.0	3 <sup>+</sup>		E(level): (2000Bb04) converted E <sub>c.m.</sub> =599.8 keV 15 (stat.) 20 (sys.) to E <sub>x</sub> =4523.7 keV 29 based on an outdated <sup>18</sup> Ne <sub>g.s.</sub> mass excess of 5316.8 keV 15 keV (1994Ma14). The updated value is 5317.617 keV 363 (2021Wa16), which leads to E <sub>x</sub> =4522.9 keV 25. J <sup>π</sup> : From R-matrix analysis of (2000Bb04). Also (1987Wi11,1988Wi08) deduced the same spin-parity assignment based on comparison of T=1 analog states in <sup>18</sup> O, <sup>18</sup> F, and <sup>18</sup> Ne. Γ <sub>p</sub> =18 keV 2 (stat.) 1 (sys.) (2000Bb04). Γ <sub>γ</sub> =56 meV 24 (stat.) 30 (sys.) (2009Ch17, 2009Ch64, 2009ChZW: calculated from the measured ωγ <sub>(p,γ)</sub> and Γ <sub>p</sub> ). ωγ <sub>(p,γ)</sub> =33 meV 14 (stat.) 17 (sys.) (2009Ch17, 2009Ch64, 2009ChZW, 2009Ba59). A 2σ upper limit of S(E) ≤65 keV.b was deduced from (2009Ch17, 2009Ch64) on the astrophysical S-factor of the <sup>17</sup> F(p,γ) reaction by measuring the p( <sup>17</sup> F,γ) yield off resonance at E <sub>lab</sub> =14.3 MeV (E <sub>c.m.</sub> =800 keV).

<sup>a</sup> From the <sup>18</sup>Ne Adopted Levels.

<sup>b</sup> From (2014AI05): the value of the total S-factor at zero energy is calculated as S<sub>1-17</sub>(0) =2.17 keV.b 37, which is 25% lower than S(0) =2.9 keV.b 4 computed by (1991Ga03).

γ(<sup>18</sup>Ne)

E <sub>γ</sub> <sup>a</sup>	E <sub>i</sub> (level)	J <sub>i</sub> <sup>π</sup>	E <sub>f</sub>	J <sub>f</sub> <sup>π</sup>
907.5 <sup>b</sup>	4524.0	3 <sup>+</sup>	3616.5	2 <sup>+</sup>
2636.4 <sup>b</sup>	4524.0	3 <sup>+</sup>	1887.4	2 <sup>+</sup>

<sup>a</sup> (2005Fi01, 2009Ch17, 2009Ch64, 2009Ba59, 2009ChZW) did not provide any information on the γ-ray transition(s) measured from the decay of the <sup>18</sup>Ne\*(4524 keV) state. Therefore, the γ-ray transitions presented above are deduced by the evaluator based on the analogy with the γ-ray transitions from the decay of the <sup>18</sup>O\*(5377.8 keV, 3<sup>+</sup>) mirror level (1995Ti07). The γ-ray energies given here are calculated from the <sup>18</sup>Ne level energy differences corrected for the recoil energy. Since these γ-ray energies are calculated, they are not included in the <sup>18</sup>Ne Adopted Gammas.

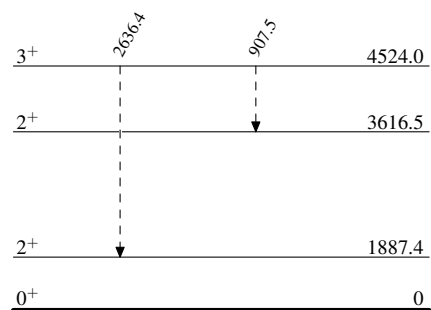
<sup>b</sup> Placement of transition in the level scheme is uncertain.

$^1\text{H}(^{17}\text{F},\gamma)$  **1987Wi11,2014Al05**

Legend

Level Scheme

-----▶  $\gamma$  Decay (Uncertain)



$^{18}_{10}\text{Ne}_8$

$^1\text{H}(^{17}\text{F,p}),(^{17}\text{F,2p}),(^{17}\text{F},\alpha):\text{res}$  1999Ba49,2020Br14

- 1999Ba49, 2000Bb04, J. R. Beene *et al.*, J. Phys. G: Nucl. Part. Phys. 38 (2011) 024002:  $^1\text{H}(^{17}\text{F,p})$  E=9-12 MeV; measured the proton spectra and angular distributions, and p- $^{17}\text{F}$  coincidences at  $\theta_{\text{lab}}=25^\circ-51^\circ$  (1999Ba49) and  $\theta_{\text{lab}}=15^\circ-35^\circ$  (2000Bb04) using the SIDAR array. Observed a previously unobserved s-wave proton resonance with  $J^\pi=3^+$  (deduced from R-matrix using the MULTI code) at  $E_{\text{c.m.}}=599.8$  keV 15 (stat.) 20 (sys.) corresponding to  $E_x=4523.7$  keV 29. Measured  $\Gamma=18$  keV 2 (stat.) 1 (sys.) for the  $3^+$  resonance and discussed its  $J^\pi$  assignment and the implications for astrophysical processes.
- 1998HaZQ, 1999Ha14:  $^1\text{H}(^{17}\text{F},\alpha)$   $E_{\text{c.m.}}=2.2-3.8$  MeV; measured the outgoing particles' energies, the  $^{14}\text{O}-\alpha$  coincidences and  $\sigma(E)$  using two position sensitive annular Si detectors covering  $\theta_{\text{lab}}\sim 13^\circ-25^\circ$  for the  $\alpha$ s and  $\theta_{\text{lab}}\sim 4^\circ-8^\circ$  for the  $^{14}\text{O}$  ions. Observed 3 resonances at  $E_x=7.60$  MeV 5, 7.37 MeV 6, and 7.16 MeV 15. Assigned  $J^\pi$  to these resonances based on mirror levels and Coulomb shift arguments. Deduced resonance strengths and  $\alpha$ -partial widths for these resonances. Discussed implications for astrophysical processes.
- 2000Ga50:  $^1\text{H}(^{17}\text{F,p})$  E=33 MeV; measured recoil proton spectra and the  $^{18}\text{Ne}$  excitation function using a position sensitive Si detector covering  $\theta_{\text{c.m.}}=160^\circ-180^\circ$ . Observed three proton resonances at  $E_{\text{c.m.}}=600, 1184$  and  $1231$  keV, for which  $J^\pi=3^+, 2^+$ , and  $3^-$  were deduced, respectively, based on an R-matrix analysis using the MULTI computer code.
- 2001Ga18, 2001Go01, 2002Li66:  $^1\text{H}(^{17}\text{F,p}), ^1\text{H}(^{17}\text{F,2p})$  E=33 and 44 MeV; measured protons, p-p coincidences, angular correlations, and the  $^{18}\text{Ne}$  excitation function using a  $\Delta E-E$  telescope that consisted of a position sensitive Si  $\Delta E$  detector covering  $\theta_{\text{lab}}=\pm 15^\circ$ , and a Si surface barrier E detector covering  $\theta_{\text{lab}}=\pm 10^\circ$ . The excitation function was analyzed with R-matrix using the MULTI code. (2001Ga18) deduced the properties of a  $^{18}\text{Ne}$  resonance at  $E_{\text{c.m.}}=2.22$  MeV 1 and considered the mode of decay to be a simultaneous two proton decay. (2001Go01, 2002Li66) deduced (using R-matrix) the properties of 4 of the  $^{18}\text{Ne}$  resonances, including the  $3^+$  state at  $E_{\text{c.m.}}\sim 600$  keV. (2001Go01) estimated via R-matrix the 2p partial decay widths for the states at 5.1 MeV and 6.15 MeV. Furthermore, (2001Go01) deduced the spectroscopic factors and branching ratios for 2p decay of the 6.15 MeV state assuming the diproton and the 3-body decay modes. (2001Go01) ruled out the 3-body decay and supported the correlated  $^2\text{He}$  decay from the 6.15-MeV state.
- 2000BaZV, 2001Bi06, 2003Bi11:  $^1\text{H}(^{17}\text{F,p}), ^1\text{H}(^{17}\text{F,p}'), ^1\text{H}(^{17}\text{F},\alpha)$  E=40.1-68.2 MeV; measured  $^{14}\text{O}-\alpha$  and p- $^{17}\text{F}$  coincidences, and  $\sigma(\theta)$  at 21 beam energies. The  $^{14}\text{O}$  and  $^{17}\text{F}$  recoils and the  $\alpha$ -particles were measured at  $\theta_{\text{lab}}=3.4^\circ-6.7^\circ$ ,  $\theta_{\text{lab}}=0^\circ$ , and  $\theta_{\text{lab}}=10.5^\circ-25.8^\circ$ , respectively, using arrays of position sensitive Si detectors. Four proton resonances in  $E_x(^{18}\text{Ne})=6-7$  MeV were observed in (2001Bi06, 2002BaZZ), and 13 proton resonances were observed in (2003Bi11). The latter work deduced (using R-matrix analysis) the resonance parameters for 5 resonances corresponding to  $E_x(^{18}\text{Ne})=6-7$  MeV, and discussed the  $^{14}\text{O}(\alpha,p)$  reaction rate. (2003Bi11) deduced a proton-decay branching ratio of  $\Gamma_{p'}/\Gamma_p=2.4$ , and  $\Gamma_{\text{tot}}\sim 58$  keV for the 6.15-MeV state. The large branch from the decay of this state to the  $^{17}\text{F}^*(495$  keV) state increased the astrophysical  $^{14}\text{O}(\alpha,p)^{17}\text{F}$  reaction rate by factors of 3 to 60 depending on the temperature.
- 2001HaZP:  $^1\text{H}(^{17}\text{F,p}), ^1\text{H}(^{17}\text{F,p}'), ^1\text{H}(^{17}\text{F},\alpha)$  E=54.8-70.3 MeV; measured the excitation functions of  $^{17}\text{F+p}$ ,  $\sigma_{(p,p')}$ , and  $\sigma_{(p,\alpha)}$ . Measured p-heavy recoil coincidences using a PPAC covering  $\theta_{\text{lab}}=1.5^\circ-6.5^\circ$  (for heavy ions) and an annular position sensitive Si  $\Delta E-E$  telescope covering  $\theta_{\text{lab}}=7^\circ-24.5^\circ$ . Six additional Si-strip detectors covered  $\theta_{\text{lab}}=32^\circ-56.5^\circ$ . Observed  $E_x(^{18}\text{Ne})=7.05$  MeV and deduced a tentative  $J^\pi=4^+$  based on R-matrix analysis and mirror levels arguments.
- 2001HaZQ:  $^1\text{H}(^{17}\text{F},^{17}\text{F}'), ^1\text{H}(^{17}\text{F,p}),$  and  $^1\text{H}(^{17}\text{F,p}')$   $E_{\text{c.m.}}=3-4$  MeV; measured excitation function of  $^{17}\text{F+p}$  elastic scattering at  $\theta_{\text{lab}}=52.5^\circ-56.5^\circ$ . Deduced an upper limit of  $\sim 5$  mb/sr for the inelastic cross section of  $E_x(^{18}\text{Ne})=7.05$  and 7.6 MeV. Observed a proton resonance at  $E_x(^{18}\text{Ne})=7.71$  MeV and deduced  $J^\pi=(1^+, 2^-, 3^+)$  based on the fact that this state was not populated by the (p, $\alpha$ ) reaction. Estimated that the contribution of the inelastic scattering to the  $^{14}\text{O}(\alpha,p)^{17}\text{F}$  reaction rate going through the  $^{18}\text{Ne}$  state at  $E_x=7-7.8$  MeV is less than 5%.
- 2002BaZZ:  $^1\text{H}(^{17}\text{F,p}),(^{17}\text{F},\alpha)$   $E_{\text{c.m.}}\approx 2-4$  MeV; measured yields, deduced astrophysical reaction rates for the  $^{17}\text{F}(p,\alpha)$  and  $^{14}\text{O}(\alpha,p)$ .
- 2002Ha15, 2004Ha58:  $^1\text{H}(^{17}\text{F,p}), ^1\text{H}(^{17}\text{F,p}'), ^1\text{H}(^{17}\text{F},\alpha)$  E=54.8-70.3 MeV; measured p- $^{17}\text{F}$  and  $\alpha$ - $^{17}\text{F}$  coincidences,  $\sigma(E,\theta)_{(p,\alpha)}$ , and  $\sigma(\theta)_{(p,p')}$  at a range of beam energies corresponding to  $E_{\text{c.m.}}=3.07-3.94$  MeV. The recoils were detected at  $\theta_{\text{lab}}=1.5^\circ-6.5^\circ$ , and the protons and  $\alpha$ -particles were measured at  $\theta_{\text{lab}}=7^\circ-24.5^\circ$  and  $32^\circ-56.5^\circ$  using an array of annular position sensitive Si detectors. Deduced an upper limit of 0.5-1 mb/sr for the  $^{17}\text{F}(p,p')$  cross section in the  $E_{\text{c.m.}}\sim 3.2$  MeV. Deduced excitation function for the elastic scattering. Extracted spectroscopic factors and resonance parameters for  $^{18}\text{Ne}$  states from the p( $^{17}\text{F},\alpha$ ) measurement. Calculated the  $^{14}\text{O}(\alpha,p)$  reaction rate and discussed its implication.
- 2009He16, 2010He17:  $^1\text{H}(^{17}\text{F,p}), ^1\text{H}(^{17}\text{F,p}')$  E=44.2 MeV; measured p- $\gamma$  coincidences from the  $^{18}\text{Ne}\rightarrow\text{p}+^{17}\text{F}^*(495$  keV) decay using  $\Delta E-E$  telescopes consisting of position sensitive Si detectors covering  $\theta_{\text{lab}}=15^\circ-50^\circ$  and the Miniball array (for  $\gamma$ -ray detection). The goal was to evaluate the contribution of the inelastic scattering to the astrophysical  $^{14}\text{O}(\alpha,p)^{17}\text{F}$  reaction rate. Deduced the  $^{18}\text{Ne}$  resonance parameters using R-matrix analysis. Comments were made on the  $\Gamma_{p_0}, \Gamma_{p_1}$  and  $\Gamma_\alpha$  for the  $^{18}\text{Ne}$  state at  $E_x\approx 6.2$  MeV. These studies found that the inelastic component would enhance the  $^{14}\text{O}(\alpha,p)$  reaction rate, contributing

$^1\text{H}(^{17}\text{F,p}),(^{17}\text{F,2p}),(^{17}\text{F},\alpha):\text{res}$  1999Ba49,2020Br14 (continued)

approximately equally to the ground-state component of the reaction rate, however not to the relative degree suggested in (2003B111).

- 2010Ji02:  $^1\text{H}(^{17}\text{F},\alpha)$ ,  $^1\text{H}(^{17}\text{F,p})$   $E=55.5$  MeV; measured the elastic scattering at  $E_{\text{c.m.}}=0.4-1.7$  MeV, and the (p, $\alpha$ ) channel at  $E_{\text{c.m.}}=2.23$  MeV. Measured protons and  $\alpha$ -particles, and the excitation function for the  $^{17}\text{F}+p$  elastic scattering, which was analyzed with a multilevel R-matrix code MULTI7. A  $\Delta E$ -E telescope, which consisted of a position sensitive Si  $\Delta E$  detector backed by a multi-guard silicon quadrant E-detector, was used at  $15^\circ$  for elastic scattering run and at  $\theta_{\text{lab}}=0^\circ$  for the (p, $\alpha$ ) run. Deduced the proton widths and average differential cross sections (systematic uncertainty of 5.6%). Discussed the  $^{14}\text{O}(\alpha,p)$  reaction rate.
- 2010Wa18:  $^1\text{H}(^{17}\text{F,p})$  E not given; measured protons using a position sensitive  $\Delta E$ -E telescope at  $\theta_{\text{lab}}=15^\circ$ . Deduced  $^{18}\text{Ne}$  states at 4.52 MeV,  $J^\pi=3^+$  and 5.11 MeV,  $J^\pi=2^+$  from the preliminary R-matrix analysis.
- 2010Ba21:  $^1\text{H}(^{17}\text{F,p})$ ,  $^1\text{H}(^{17}\text{F,p}')$   $E=52-58$  MeV; measured scattered protons and p- $^{17}\text{F}$  coincidences using the SIDAR array for protons and a gas-filled ionization counter for  $^{17}\text{F}$  ions. The objective was to search for a  $J^\pi=4^+$   $^{18}\text{Ne}$  resonance reported by (2004No18) at  $E_{\text{c.m.}}=1.95$  MeV in the  $^{14}\text{O}+\alpha$  frame ( $\sim 3.1$  MeV in the time-reversed  $^{17}\text{F}+p$  frame). This resonance was thought (2004No18) to populate the  $^{17}\text{F}^*(495\text{ keV})$  state with a large decay branching ratio. (2010Ba21) extracted Q-value spectra at different beam energies to search for inelastic events. No evidence of inelastic  $^{17}\text{F}^*(495\text{ keV})+p$  scattering was observed at any of the measured incident energies. An upper limit of  $\sim 10$  mb was set on the p( $^{17}\text{F,p}_1$ ) cross section at  $E_{\text{c.m.}}\sim 3.1$  MeV. Similar upper limits were obtained at a range of bombarding energies. Upper limits on the proton decay branching ratio from this resonance to the  $^{17}\text{F}^*(495\text{ keV})$  state are tabulated as a function of the assumed width of this resonance. This decay branching ratio was constrained to be less than 3.1%.
- 2011He09:  $^1\text{H}(^{17}\text{F,p})$   $E=4.22$  MeV/nucleon; measured energy spectra of the recoiled protons along with protons angular distributions using two  $\Delta E$ -E telescopes at  $\theta_{\text{lab}}=0^\circ$  and  $14^\circ$ . Observed several proton resonances in  $^{18}\text{Ne}$ . Deduced their resonant parameters using the R-matrix analysis. Identified a doublet structure around 7.10 MeV consisting of  $E_x(^{18}\text{Ne})=7.05$  MeV with  $J^\pi=2^+$  and  $E_x(^{18}\text{Ne})=7.12$  MeV with  $J^\pi=4^+$ . Calculated and discussed the  $^{14}\text{O}(\alpha,p)$  reaction rate.
- 2012Pa02:  $^1\text{H}(^{17}\text{F,p})$   $E=3.5$  and  $4.3$  MeV/nucleon; measured p- $^{17}\text{F}$  coincidences and the proton angular distributions at  $\theta_{\text{lab}}=11^\circ-65^\circ$  using the DINEX Si-detector array and a plastic scintillator covering  $\theta_{\text{lab}}=0^\circ-5^\circ$  to measure  $^{17}\text{F}$  ions. Deduced total reaction cross section for the quasi-elastic scattering since the inelastic excitation to the first excited state of  $^{17}\text{F}^*(495\text{ keV})$  was not resolved. Determined that the contribution of the inelastic excitation of the first excited state to the total cross section is less than 8%. Performed microscopic and macroscopic optical potential and DWBA analysis to probe a possible halo structure of  $^{17}\text{F}$ .
- 2012LiZY, L. E. Linhardt *et al.*, J. Phys.: Conf. Ser. 403 (2012) 012036:  $^1\text{H}(^{17}\text{F,p})$  and  $^1\text{H}(^{17}\text{F},\alpha)$  55 MeV; measured both these reactions simultaneously; measured thick target  $E_p$ ,  $I_p(\theta)$ ,  $E_\alpha$ ,  $I_\alpha(\theta)$  using the  $\Delta E$ -E DSSDs of ANASEN covering the angular range of  $\theta_{\text{lab}}=9.5^\circ-28^\circ$ ; measured heavy recoils, p-recoil and  $\alpha$ -recoil coincidences using the Heavy Ion Recoil Chamber downstream of ANASEN and at  $\theta_{\text{lab}}=0^\circ$  but with  $\theta_{\text{lab}}<1.4^\circ$  blocked; deduced unnormalized  $\sigma(E,\theta)$ , and proton yield vs.  $E_{\text{c.m.}}$ ; calculated  $\sigma(E,\theta)$  using R-matrix. Statistics were too low to draw conclusive results.
- 2014Hu16:  $^1\text{H}(^{17}\text{F,p})$   $E=3.6$  MeV/nucleon; measured the recoil protons from elastic scattering using three  $\Delta E$ -E Si telescopes at  $\theta_{\text{lab}}\approx 3^\circ$ ,  $10^\circ$  and  $18^\circ$ . Reconstructed the excitation function for the  $^{17}\text{F}+p$  elastic scattering. Analyzed the excitation function using multi-channel R-matrix and deduced the  $^{18}\text{Ne}$  level properties for 5 proton resonances observed, including a new state at  $E_x(^{18}\text{Ne})=6.85$  MeV. Discussed a detailed comparison of the present findings with the literature results. Calculated and analyzed the astrophysical  $^{14}\text{O}(\alpha,p)$  reaction rate.
- L. E. Pratt, Ph.D. Thesis, *Study of  $^{18}\text{Ne}$  using the Array for Nuclear Astrophysics and Structure with Exotic Nuclei*, Louisiana State University and Agricultural and Mechanical College (2014): p( $^{17}\text{F,p}$ )  $E_{\text{c.m.}}=2.053-2.985$  MeV  $E(^{17}\text{F})=55$  MeV; measured thick target  $E_p$  and  $I_p(\theta)$  using the RESOLUT facility and a  $\Delta E$ -E DSSD telescope covering the angular range of  $\theta_{\text{lab}}=8.0^\circ-24^\circ$ ; measured  $^{17}\text{F}$  recoils and p-recoil coincidences using the Heavy Ion Recoil Chamber at  $\theta_{\text{lab}}=0^\circ$  but with  $\theta_{\text{lab}}<1.3^\circ$  blocked; extracted  $^{18}\text{Ne}$  resonance properties for two states using an R-matrix fit to the measured  $\sigma(E,\theta)$ .

*Reanalysis of previous data:*

- 2010HeZX:  $^1\text{H}(^{17}\text{F,p})$ ,  $^1\text{H}(^{17}\text{F,2p})$   $E=33$  and  $44$  MeV. This article is not published in a peer reviewed journal. He *et al.* reanalyzed the data of the (2001Go01) experiment using multi-channel R-matrix. As a result, the  $J^\pi=1^-$  assignment made by (2001Go01) for the  $E_x(^{18}\text{Ne})=6.15$  MeV was overthrown. Instead He *et al.* assigned  $J^\pi=3^-$  to this state and  $J^\pi=1^-$  to another state at  $E_x(^{18}\text{Ne})=6.286$  MeV. The astrophysical consequences of these new assignments regarding the  $^{14}\text{O}(\alpha,p)$  reaction rate were discussed. Later on, both results of this work were overthrown by (2012Ba28, 2014Hu16).
- 2012Ba28:  $^1\text{H}(^{17}\text{F,p}')$   $E_{\text{c.m.}}=2-2.6$  MeV; re-analyzed  $\sigma(E,\theta)$  data from (2003B111) corresponding to  $E_x(^{18}\text{Ne})=6.15$  MeV to resolve discrepancies in the literature on the  $J^\pi$  assignment of the 6.15-MeV state in  $^{18}\text{Ne}$  and its  $\Gamma_p'/\Gamma_p$  branching ratio. Deduced  $^{18}\text{Ne}$  proton decay branching ratios from the 6.15-MeV level to the ground and first excited state in  $^{17}\text{F}$ , and  $p_0$  and  $p_1$

<sup>1</sup>H(<sup>17</sup>F,p),(<sup>17</sup>F,2p),(<sup>17</sup>F,α):res 1999Ba49,2020Br14 (continued)

widths using the multi-channel R-matrix code MULTI. Discussed  $J^\pi$  assignment of the 6.15-MeV level and the interpretation of the <sup>1</sup>H(<sup>17</sup>F,α) reaction measurements. The reanalysis of the (2003B111) data by (2012Ba28) resolved the literature discrepancies.

*Theory:*

- 2000Fo19: This work questioned some of the  $J^\pi$  assignments made in (1999Ha14). The questions were based on the theoretical results of (1998Sh35) and on the basis of the Coulomb shifts with respect to the analog states in the mirror nucleus <sup>18</sup>O. (2000Fo19) concluded that the states at 7.37 and 7.60 MeV, observed in (1999Ha14), cannot have  $J^\pi=4^+$  assignments, and the states at 7.16, observed in (1999Ha14), and 7.37 MeV cannot have  $J^\pi=1^-$  assignments. (2000Fo19) concluded that the state at 7.60 MeV could be a  $J^\pi=1^-$  state, and the 7.16-MeV state may be a  $J^\pi=4^+$  state.
- 2002Gr10: Calculated, using the R-matrix theory, the resonant <sup>17</sup>F(p,2p) production cross section on the  $E_x(^{18}\text{Ne})=6.15$  MeV resonance with  $J^\pi=1^-$  and deduced an upper limit of 310 mb. Assuming identical spectroscopic factors for the <sup>17</sup>F<sub>g.s.</sub>+p and <sup>17</sup>F\*(495 keV)+p channels, a branching ratio of  $\Gamma_{p_0}/\Gamma_{p_1} \sim 2$  was computed. This resulted in  $\Gamma_{p_0}/\Gamma \sim 2/3$ . Assuming  $S_{2p}=S_{1p}$  (2p and 1p decay spectroscopic factors), upper limits were estimated for various 2p decay branching ratios. Comparisons of these results to the experimental results of (2001Go01) are discussed. It was also argued that in addition to the 2p decay of the  $1^-$  resonance, the breakup of <sup>17</sup>F and the decay of a  $2^-$  resonance at higher energy could contribute to the 2p counts observed in (2001Go01) because of the use of a thick target.
- 2003Fo13: Calculated excitation energies and widths for astrophysically interesting <sup>18</sup>Ne states at  $E_x=7-8$  MeV. Presented, whenever possible, the information from mirror levels in <sup>18</sup>O.
- 2009Yu04: <sup>18</sup>Ne is considered as a cluster of two protons orbiting an <sup>16</sup>O core. The excitation energy spectrum of <sup>18</sup>Ne and the relative momentum distribution of the two protons emitted from the decay of the 6.15 MeV level of <sup>18</sup>Ne are calculated using the Faddeev approach using the CD-Bonn potential for the *pp* interaction. This study indicated that the probability of decay of the 6.15-MeV level via <sup>2</sup>He emission is half of that of the decay via three-body direct breakup involving an uncorrelated emission of the two protons.
- 2010Ad02: Investigated the structure and decay of the <sup>18</sup>Ne\*(6135 keV) state using a microscopic cluster model involving <sup>16</sup>O+p+p configurations. This description was used in the framework of the three-cluster generator coordinate method associated with the hyperspherical formalism. The authors analyzed the <sup>18</sup>Ne and <sup>18</sup>O low-lying states and determined the total width of the <sup>18</sup>Ne\*(6135 keV) level using the analytical continuation in the coupling constant method. They found  $\Gamma=40$  keV 10 keV, which is in fair agreement with experimental value of  $\Gamma=50$  keV 5 (2001Go01).
- 2012Ok02: Calculated asymptotic normalization coefficients and single-particle ANC as a function of the binding energy and orbital angular momentum, separation energies for pairs of nuclei, excitation energies and widths of the first excited states. Presented predictions of ANCs in mirror nuclei, and spectroscopic strengths in mirror pairs using the Gamow shell model and the real-energy and complex-energy continuum-shell-model approaches. Comparison with experimental data are presented.
- 2020Br14: Calculated ANCs for the first two  $2^+$  states and the width of the  $2_3^+$  states in <sup>18</sup>O and <sup>18</sup>Ne; investigated, using R-matrix calculations, the intuitive relationship between spectroscopic factors and single-particle wave functions and their physical counterparts, ANCs, and widths; presented comparison with experimental data. It was found that the ANC of the  $2_2^+$  state in <sup>18</sup>Ne deduced from the mirror state in <sup>18</sup>O is significantly larger than those found in previous work. Discussion on the astrophysical implications for the <sup>17</sup>F(p,γ) reaction rate is presented.

<sup>18</sup>Ne Levels

<u>E(level)</u>	<u>J<sup>π</sup></u>	<u>Γ</u>	<u>L</u>	<u>Comments</u>
4522.9 <sup>a</sup> 25	3 <sup>+</sup>	18 keV 2	0	<p><math>\Gamma_p=18</math> keV 2 (2010Ji02)</p> <p>E(level): From <math>E_{c.m.}=599.8</math> keV 25, which is the weighted average between <math>E_{c.m.}=599.8</math> keV 15 (stat.) 20 (sys.) (1999Ba49, 2000Bb04); <math>E_{c.m.}=0.60</math> MeV 5 (2001Go01); and <math>E_{c.m.}=598</math> keV 25 (2010Ji02). See also <math>E_{c.m.}=600</math> (2000Ga50).</p> <p>E(level): See also 4523.7 keV 29 (1999Ba49, 2000Bb04); 4.52 MeV 5 (2001Go01); and 4520 keV 25 (2010Ji02, 2010Wa18). These are deduced with outdated Q-values (for example, (1999Ba49) deduced 4523.7 keV 29 based on <sup>18</sup>Ne<sub>g.s.</sub> mass excess of 5316.8 keV 15 keV from (1994Ma14). The updated value is 5317.617 keV 363 (2021Wa16)).</p> <p>Γ: From <math>\Gamma=18</math> keV 2 (stat.) 1 (sys.) (1999Ba49, 2000Bb04). See also <math>\Gamma=18</math> keV 2 (2001Ga18, 2001Go01, 2002Li66); and <math>\Gamma=18</math> keV confirmed by the R-matrix analysis in (2000Ga50).</p>

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<sup>1</sup>H(<sup>17</sup>F,p),(<sup>17</sup>F,2p),(<sup>17</sup>F,α):res **1999Ba49,2020Br14 (continued)**

<sup>18</sup>Ne Levels (continued)

<u>E(level)</u>	<u>J<sup>π</sup></u>	<u>Γ</u>	<u>L</u>	<u>Comments</u>
5112 21	2 <sup>+</sup>	44 keV 2	0	<p>J<sup>π</sup>: From R-matrix analyses of (1999Ba49, 2000Bb04, 2000Ga50, 2001Ga18, 2001Go01, 2002Li66, 2010Ji02, and 2010Wa18).</p> <p>L: From (2000Ga50, 2010Ji02).</p> <p>Γ<sub>p</sub>=44 keV 2</p> <p>E(level): Weighted average of E<sub>x</sub>=5113 keV 30 (2010Ji02: from E<sub>c.m.</sub>=1190 keV 30); and E<sub>x</sub>=5110 keV 30 (2011He09). See also E<sub>x</sub>=5100 keV (2009He16); 5107 keV (2000Ga50: from E<sub>c.m.</sub>=1184 keV); 5103 keV (2001Go01: from E<sub>c.m.</sub>=1180 keV); and 5110 keV (2010Wa18). Note that the E<sub>c.m.</sub> reported by (2001Go01) was mistyped as 1.118 MeV. The correct value is 1.18 MeV confirmed from (2002Li66 and 2010HeZX).</p> <p>Γ<sub>p</sub>,Γ: Weighted average of Γ<sub>p</sub>=42 keV 4 (2010Ji02); and Γ<sub>p</sub>=45 keV 2 (2001Ga18, 2001Go01, 2002Li66, 2009He16, 2011He09). These were deduced from fits to elastic scattering data that appear to have assumed the width is entirely due to L=0 proton emission to the <sup>17</sup>F<sub>g.s.</sub>. Later on, (2020Br14: see Section VII.B) assigned these measured proton widths to the 2s<sub>1/2</sub> channel. Therefore, we assumed Γ=Γ<sub>p</sub>.</p> <p>Γ<sub>2He</sub>=1.8×10<sup>-5</sup> eV (2001Go01).</p> <p>J<sup>π</sup>: From the R-matrix analyses of (2000Ga50, 2001Ga18, 2001Go01, 2002Li66, 2009He16, 2010Ji02, 2010Wa18, and 2011He09).</p> <p>L: From (2010Ji02, 2011He09).</p>
5154 <sup>a</sup>	3 <sup>-</sup>			<p>E(level): From E<sub>c.m.</sub>=1231 keV (2000Ga50).</p> <p>J<sup>π</sup>: From (2000Ga50) based on R-matrix analysis.</p>
6135 1	1 <sup>-</sup>	53.0 keV 18	1	<p>Γα=6.9 eV 20</p> <p>Γ<sub>p0</sub>/Γ=0.70 4 (2012Ba28); Γ<sub>p1</sub>/Γ=0.30 2 (2012Ba28)</p> <p>Γ<sub>p1</sub>/Γ<sub>p0</sub>=0.42 3 (2012Ba28)</p> <p>E(level): Weighted average of 6.14 MeV 1 (2001Go01: from E<sub>c.m.</sub>=2.22 MeV 1); 6.18 MeV 6 (2009He16, 2010He17: from E<sub>c.m.</sub>=2.26 MeV 6); 6135 keV 1 (2012Ba28: from E<sub>c.m.</sub>=2212 keV 1); 6150 keV 30 (2014Hu16); and 6142 keV 5 (stat.) 8 (sys.) from (L. E. Pratt (Ph.D. Thesis, 2014)).</p> <p>E(level): See also 6150 keV (2001Bi06, 2001Ga18); 6.15 MeV (2002Ha15 and 2010Ji02: from E<sub>c.m.</sub>(<sup>14</sup>O+α)=1.04 MeV and E<sub>c.m.</sub>(p+<sup>17</sup>F)=2.23 MeV); 6137 keV (2003B111); and 6120 keV (2010HeZX: considered this state to be the same as the 6150 keV state observed in (1996Ha26)).</p> <p>E(level): This state is visible in the excitation function of <sup>1</sup>H(<sup>17</sup>F,p<sub>1</sub>γ) in (2009He16, 2010He17), when the spectrum is conditioned exclusively in coincidence with the γ-rays from the decay of <sup>17</sup>F*(495 keV).</p> <p>Γ: Weighted average of Γ=50 keV 5 (2001Ga18, 2001Go01, 2002Li66); Γ=53.7 keV 20 (2012Ba28: sum of Γ<sub>p0</sub>=37.8 keV 19 and Γ<sub>p1</sub>=15.9 keV 7 from their best R-matrix fit. (2014Hu16) mistakenly reported this sum as Γ=53.7 keV 26); Γ=50 keV 15 (2014Hu16); and Γ=45 keV 12 (L. E. Pratt, Ph.D. Thesis, 2014).</p> <p>Γ: See also 58 keV 2 (2003B111: this value is excluded because (2012Ba28) reanalyzed these data); Γ(res)≈120 keV 60 (2009He16: the experimental resolution is poor (80 keV) and the resonance width is not obtained from the observed width); and Γ=40 keV 10 calculated by (2010Ad02).</p> <p>Γ<sub>α</sub>: Weighted average (with external errors) of Γ<sub>α</sub>=8 eV 2 (2003B111) and Γ<sub>α</sub>=3.2 eV +50-20 (2002Ha15). See also the theoretical result of Γ<sub>α</sub>=3.9 eV 10 and S<sub>α</sub>=0.23 (spectroscopic factor) from (2012Fo12). These values are calculated for <sup>18</sup>Ne*(6135 keV, 1<sup>-</sup>) state from the mirror level at <sup>18</sup>O*(6.20 MeV, 1<sup>-</sup>) assuming equal spectroscopic factors for mirror states. See also (2012Ok02) for the theoretical ANC values.</p> <p>Γ<sub>p0</sub>: See also Γ<sub>p0</sub>&gt;15 keV at 90% confidence level (L. E. Pratt, Ph.D. Thesis, 2014).</p> <p>J<sup>π</sup>: From the R-matrix analyses of (2001Ga18, 2001Go01, 2002Li66, 2003B111, 2009He16, 2010He17, 2010Ji02, 2012Ba28, 2014Hu16, and L. E. Pratt Ph.D. Thesis 2014), and comparison of excitation function measured by (2002Ha15) with R-matrix calculations for J<sup>π</sup>=1<sup>-</sup>.</p> <p>J<sup>π</sup>: (2014Hu16) specifically ruled out the unnatural-parity J<sup>π</sup>=2<sup>-</sup> assignment made by (2010HeZX, unpublished) because such an assignment would be unlikely based on the discussions of the 2p-emission from this state (2001Go01, 2008Ra12). (2014Hu16) also</p>

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<sup>1</sup>H(<sup>17</sup>F,p),(<sup>17</sup>F,2p),(<sup>17</sup>F,α):res **1999Ba49,2020Br14 (continued)**

<sup>18</sup>Ne Levels (continued)

E(level)	J <sup>π</sup>	Γ	L	Comments
6280 <sup>a</sup> 30	3 <sup>-</sup>	20 keV 15	1	<p>ruled out the J<sup>π</sup>=3<sup>-</sup> assignment made by (2010HeZX) due to the large inelastic branch observed for this state in (2014Hu16: see Fig. 3(c)). (2014Hu16) considered this state to have a 4p-2h configuration, where h (holes) are in 1p<sub>3/2</sub> and p (particles) are in 2s<sub>1/2</sub> or 1d<sub>3/2</sub> orbitals.                      L: From (2014Hu16).                      ωγ<sub>(p,p')</sub>=22 keV 7 (2009He16). An enhanced p<sub>1</sub> branch is preferred by (2009He16).                      (2002Ha15): ωγ<sub>(p,α)</sub>=0.8 eV +12-5 and Θ<sub>α</sub><sup>2</sup>=0.19 +30-10, which is labeled as the spectroscopic factor in (2002Ha15).                      (2003B111) reported that the decay mode of this state is via proton decay to the <sup>17</sup>F*(495 keV, 1/2<sup>+</sup>) state. (2001Ga18, 2001Go01, 2002Li66) reported a 2p decay to <sup>16</sup>O<sub>g.s.</sub>(0<sup>+</sup>) with Γ<sub>2He</sub>=21 eV 3 (2001Go01) for decay via emission of a diproton and with Γ<sub>2p</sub>=57 eV 6 (2001Go01) assuming a 3-body decay. Because of limited angular coverage in these experiments, the data did not differentiate between simultaneous decay, diproton (<sup>2</sup>He) emission, or direct three-body decay. However, (2001Ga18) suggests that the mode of decay is most likely via simultaneous two proton emission, and (2001Go01) finds a 2p decay branching ratio of 4.2×10<sup>-4</sup> for the <sup>2</sup>He emission mode and 1.1×10<sup>-3</sup> assuming a three-body decay. (2001Go01) rules out the 3-body decay and supports a decay mode via the emission of <sup>2</sup>He. (2001Go01) estimated an spectroscopic factor of 0.35 for the 2p decay of this state and calculated and discussed the spectroscopic factors obtained if the decay is assumed to be of 3-body form.</p> <p>E(level): From (2014Hu16: corresponds to E<sub>c.m.</sub>=2.36 MeV. The resonance parameters of this state used in the R-matrix fit of (2014Hu16) were taken from (1996Ha26), which resulted in a good fit in (2014Hu16)). See also E<sub>x</sub>=6.29 MeV (2002Ha15: from E<sub>c.m.</sub>=2.37 MeV); 6240 keV (2010HeZX); and ≈6310 keV (2003B111).                      J<sup>π</sup>,Γ,L: From an R-matrix analysis by (2014Hu16).                      Γ<sub>p0</sub>&lt;4 keV from (L. E. Pratt, Ph.D. Thesis, 2014) at 90% confidence level.                      J<sup>π</sup>: See also (2002Ha15), where a comparison was made for the measured excitation function and the R-matrix calculations using J<sup>π</sup>=3<sup>-</sup>.                      ωγ<sub>(p,α)</sub>=0.2 eV (2002Ha15).</p>
6341 10	2 <sup>-</sup>	10 keV 5	1	<p>E(level): Weighted average of 6.34 MeV 1 (2001Ga18, 2001Go01, 2002Li66: from E<sub>c.m.</sub>=2.42 MeV 1); and 6350 keV 30 (2014Hu16). See also E<sub>x</sub>=6.35 MeV (2002Ha15: from E<sub>c.m.</sub>=2.43 MeV); ≈6310 keV (2003B111); 6320 keV (2010HeZX); and 6373 keV 8 (stat.) 8 (sys.) (L. E. Pratt, Ph.D. Thesis, 2014: this state was a 2<sup>-</sup> state, whose J<sup>π</sup>, energy and width were deduced from a phenomenological R-matrix calculation. The state was unresolved from the nearby 3<sup>-</sup> state at 6280 keV 30. Pratt set an upper limit on the proton partial width of the 3<sup>-</sup> state to the <sup>17</sup>F<sub>g.s.</sub> of Γ<sub>p</sub>&lt;4 keV at 90% confidence level).                      Γ,J<sup>π</sup>,L: From the R-matrix analysis of (2014Hu16).                      Γ: See also Γ≈50 keV (2001Go01: however, the R-matrix fit does not describe all of the observed features of the data in the vicinity of this state); and Γ=87 keV 15 deduced from an R-matrix analysis for the 6373 keV unresolved doublet observed in L. E. Pratt Ph.D. Thesis (2014).                      J<sup>π</sup>: See also (2002Ha15: comparison of excitation function with R-matrix calculations) and (2010HeZX: unpublished, R-matrix analysis).</p>
6.85×10 <sup>3</sup> 11	(0 <sup>+</sup> ,0 <sup>-</sup> )	50 keV 30	(2,3)	<p>Γα=149 eV (2014Hu16)                      E(level): From (2014Hu16). The energy uncertainty of this state observed in (2014Hu16) is sometimes mentioned as 100 keV in the text but in the abstract and tables, it is reported as 110 keV.                      E(level): Based on all the evidence discussed in (2014Hu16), they concluded that very likely a new state around 6.8 MeV exists in <sup>18</sup>Ne. In addition to those arguments, (2011He09) also argued that their R-matrix fit to the</p>

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<sup>1</sup>H(<sup>17</sup>F,p),(<sup>17</sup>F,2p),(<sup>17</sup>F,α):res **1999Ba49,2020Br14 (continued)**

<sup>18</sup>Ne Levels (continued)

E(level)	J <sup>π</sup>	Γ	L	Comments
7054 28	4 <sup>+</sup>	94 keV 20	2	<p>measured <sup>18</sup>Ne excitation function improved when considering a doublet near 7.1 MeV. Their best fit with a doublet resulted in two states at 6.97 MeV and 7.09 MeV with J<sup>π</sup>=2<sup>+</sup> (with L=2) and J<sup>π</sup>=4<sup>+</sup> (with L=2), respectively. However, they did not report an uncertainty for these excitation energies. (2011He09) mention in the text that the uncertainty in excitation energies were estimated to be 30 keV but it is not clear if this would still be the case for this doublet. (2011He09) did not suggest the energies of the doublet as their final result. Instead, they took the 7.05-MeV and 7.12-MeV for this doublet from (1996Ha26).</p> <p>Γ: From (2014Hu16).</p> <p>J<sup>π</sup>: From R-matrix analysis of (2014Hu16): J<sup>π</sup>=(0<sup>+</sup>,0<sup>-</sup>). (2014Hu16) prefers the J<sup>π</sup>=0<sup>+</sup> assignment for this state based on the evidence of this state potentially being populated in the direct α(<sup>14</sup>O,p) reaction in (2004No14, 2004No18).</p> <p>L: From (2014Hu16): L=2 for J<sup>π</sup>=0<sup>+</sup>, and L=3 for J<sup>π</sup>=0<sup>-</sup>, which is less preferred by (2014Hu16).</p> <p>ωγ(α,p)=149 eV assuming J<sup>π</sup>=0<sup>+</sup> and C<sup>2</sup>S=0.01 from (2014Hu16). These values together with Γ<sub>α</sub>=149 eV are calculated by (2014Hu16).</p> <p>Γ<sub>p</sub>=94 eV 20</p> <p>Γ<sub>α</sub>=40 eV 14 (2002Ha15)</p> <p>E(level): Weighted average of 7.16 MeV 15 (1999Ha14: associated with E<sub>c.m.</sub>=3.24 MeV); 7.05 MeV 10 (2002Ha15: from E<sub>c.m.</sub>=3.13 MeV 10); and 7.05 MeV 3 (2014Hu16: associated with E<sub>c.m.</sub>=3.13 MeV). See also ≈7070 keV (2001Bi06); 7050 keV (2001HaZP); 7050 (2001HaZQ); and 7092 keV (2003Bi11).</p> <p>Γ: Weighted average of Γ<sub>p</sub>=90 keV 40 (2002Ha15: Assuming Γ=Γ<sub>p</sub>) and Γ=95 keV 20 (2014Hu16). Evaluator assumed Γ≈Γ<sub>p</sub>.</p> <p>Γ<sub>p</sub>'&lt;1 keV (2002Ha15).</p> <p>J<sup>π</sup>: From (2001HaZQ: based on angular momentum selection rules); (2002Ha15: comparison of measured excitation function with R-matrix analysis); (2011He09: R-matrix analysis with L=2, see text); and (2014Hu16: R-matrix analysis with L=2). See also J<sup>π</sup>=(1<sup>-</sup>) (1999Ha14: mirror level and Coulomb shift analyses). This assignment was ruled out by (2000Fo19), who suggested J<sup>π</sup>=(4<sup>+</sup>) based on the theoretical calculations in (1998Sh35) and the Coulomb shift between mirror levels.</p> <p>L: From (2011He09: L=2 for J<sup>π</sup>=4<sup>+</sup>, see text); and (2014Hu16).</p> <p>Proton spectroscopic factor: Θ<sub>p</sub><sup>2</sup>=0.25 (2002Ha15) for J<sup>π</sup>=4<sup>+</sup>.</p> <p>The α-particle spectroscopic factor: Θ<sub>α</sub><sup>2</sup>=0.50 17 (2002Ha15: for J<sup>π</sup>=4<sup>+</sup>).</p> <p>ωγ(p,α)=29 eV 10 (2002Ha15: for J<sup>π</sup>=4<sup>+</sup>). Calculations performed by (2012Fo29) suggest that the resonance strength may be weaker.</p> <p>(2010Ba21) set an upper limit of ~10 mb for the p(<sup>17</sup>F,p<sub>1</sub>) cross section populating this state. (2010Ba21) set upper limits on the Γ<sub>p1</sub>/Γ<sub>p0</sub> as a function of assumed width and estimated that this branching ratio is less than 3.1%.</p>
7.40×10 <sup>3α</sup> 6	(2 <sup>+</sup> )	70 keV 60	2	<p>Γ<sub>α</sub>=40 eV 30 (2002Ha15)</p> <p>E(level): From (2002Ha15) using E<sub>c.m.</sub>=3.48 MeV 6. Note that (1999Ha14) reported E<sub>x</sub>=7.37 MeV 6 associated with E<sub>c.m.</sub>=3.48 MeV. However, this excitation energy appears to be computed wrongly. See also E<sub>x</sub>=7330 keV (2011He09); ≈7350 keV (2001Bi06); and 7323 keV (2003Bi11).</p> <p>Γ: From (2002Ha15).</p> <p>Γ<sub>α</sub>=40 eV 30 (2002Ha15: for J<sup>π</sup>=2<sup>+</sup>). See also (1999Ha14: Γ<sub>α</sub>=0.08 keV for J<sup>π</sup>=1<sup>-</sup> and Γ<sub>α</sub>=0.03 keV for J<sup>π</sup>=4<sup>-</sup>).</p> <p>J<sup>π</sup>: From (2011He09) based on R-matrix analysis with L=2 (see Fig. 7b). See also (2002Ha15), who makes no J<sup>π</sup> assignment for this state other than it must be natural parity, but by inspection of the mirror levels and Coulomb shift analysis, (2002Ha15) speculates it may be a 2<sup>+</sup> assignment; and J<sup>π</sup>=1<sup>-</sup> (1999Ha14) based on mirror level and Coulomb shift analyses. J<sup>π</sup>=1<sup>-</sup> was ruled out by (2000Fo19) based on the calculations of (1998Sh35) and mirror level arguments. For the same</p>

Continued on next page (footnotes at end of table)

<sup>1</sup>H(<sup>17</sup>F,p),(<sup>17</sup>F,2p),(<sup>17</sup>F,α):res **1999Ba49,2020Br14 (continued)**

<sup>18</sup>Ne Levels (continued)

<u>E(level)</u>	<u>J<sup>π</sup></u>	<u>Γ</u>	<u>L</u>	<u>Comments</u>
7.61×10 <sup>3</sup> <sup>a</sup> 5	(1 <sup>-</sup> )	75 keV 20	(1)	<p>reasons, (2000Fo19) also ruled out the J<sup>π</sup>=4<sup>+</sup> assignment made also by (1999Ha14).</p> <p>L: From (2011He09).</p> <p><math>\omega\gamma_{(p,\alpha)}</math>=18 eV 14 (2002Ha15: J<sup>π</sup>=2<sup>+</sup>). See also <math>\omega\gamma_{(p,\alpha)}</math>=23 eV 12 (1999Ha14: J<sup>π</sup>=1<sup>-</sup>).</p> <p><math>\Theta_{\alpha}^2</math>=0.004 3 (2002Ha15: J<sup>π</sup>=2<sup>+</sup>). <math>\Theta_{\alpha}^2</math> is labeled as the spectroscopic factor in (2002Ha15). See also <math>\Theta_{\alpha}^2</math>=0.002 for J<sup>π</sup>=1<sup>-</sup> assignment and <math>\Theta_{\alpha}^2</math>=0.09 for J<sup>π</sup>=4<sup>+</sup> assignment made by (1999Ha14).</p> <p><math>\Gamma_{\alpha}</math>=1.2 keV (1999Ha14); <math>\Gamma_{\alpha}</math>=1000 eV 120 (2002Ha15)</p> <p><math>\Gamma_p</math>=72 keV 20 (2002Ha15)</p> <p>E(level): From (2002Ha15) using E<sub>c.m.</sub>=3.69 MeV 5. Note that (1999Ha14) reported E<sub>x</sub>=7.60 MeV 5 associated with E<sub>c.m.</sub>=3.69 MeV. However, this excitation energy appears to be computed wrongly. See also E<sub>x</sub>≈7600 keV (2001BI06), 7584 keV (2003BI11), 7600 keV (2001HaZP), and (≈7500) keV (2011He09). (2011He09) describes this state as a “groove-like” structure, due to the interference with nearby resonances observed in the <sup>17</sup>F+p excitation function at E<sub>c.m.</sub>~3.6 MeV. Due to poor statistics in (2011He09), they found it difficult to fit this feature.</p> <p><math>\Gamma</math>: From <math>\Gamma=\Gamma_p+\Gamma_{\alpha}+\Gamma_{p'}</math>, where each partial width is from (2002Ha15) listed above; and <math>\Gamma_{p'}&lt;2</math> keV (2002Ha15).</p> <p>J<sup>π</sup>: From (1999Ha14, 2002Ha15: based on mirror levels and Coulomb shift arguments) and (2011He09: R-matrix analysis). Note that (1999Ha14) also assigned J<sup>π</sup>=(2<sup>+</sup>, 3<sup>-</sup>) to this state. However, (2000Fo19) suggested J<sup>π</sup>=(1<sup>-</sup>) for this state based on the theoretical calculations of (1998Sh35) and mirror levels arguments.</p> <p>L: From (2011He09).</p> <p><math>\omega\gamma_{(p,\alpha)}</math>=271 eV 30 is the weighted average of 300 eV 40 (1999Ha14: for J<sup>π</sup>=(1<sup>-</sup>)), and <math>\omega\gamma_{(p,\alpha)}</math>=255 eV 30 (2002Ha15: for J<sup>π</sup>=(1<sup>-</sup>)).</p> <p><math>\Theta_{\alpha}^2</math>=0.015 (1999Ha14: for J<sup>π</sup>=(1<sup>-</sup>)) and <math>\Theta_{\alpha}^2</math>=0.0130 15 (2002Ha15: for J<sup>π</sup>=(1<sup>-</sup>), this is labeled as the spectroscopic factor).</p> <p><math>\Theta_p^2</math>=0.034 (2002Ha15: for J<sup>π</sup>=(1<sup>-</sup>)).</p> <p>(2002Ha15) also considered J<sup>π</sup>=(2<sup>+</sup> and 3<sup>-</sup>) assignments for this state. As a result, (2002Ha15) estimated <math>\Gamma_{\alpha}</math>=610 eV 70 and extracted a spectroscopic factor of <math>\Theta_{\alpha}^2</math>=0.0200 25 assuming J<sup>π</sup>=(2<sup>+</sup>), and <math>\Gamma_{\alpha}</math>=440 eV 50 and <math>\Theta_{\alpha}^2</math>=0.070 8 assuming J<sup>π</sup>=(3<sup>-</sup>). These J<sup>π</sup> assignments are not favored.</p> <p>(1999Ha14) estimated <math>\Gamma_{\alpha}</math>=0.7 keV and <math>\Theta_{\alpha}^2</math>=0.026 for J<sup>π</sup>=2<sup>+</sup>; and <math>\Gamma_{\alpha}</math>=0.5 keV and <math>\Theta_{\alpha}^2</math>=0.09 for J<sup>π</sup>=3<sup>-</sup>. These J<sup>π</sup> assignments are not favored.</p>
7710 26	2 <sup>-</sup>	70 keV 25	3	<p><math>\Gamma_p</math>=59 keV 25 (2002Ha15)</p> <p>E(level): Weighted average of 7.71 MeV 5 (2002Ha15: from E<sub>c.m.</sub>=3.79 MeV 5); and 7710 keV 30 (2011He09). See also E<sub>x</sub>=7710 keV (2001HaZP).</p> <p><math>\Gamma</math>: From (2002Ha15); however, they report <math>\Gamma</math>=70 keV 30. The evaluator revised the uncertainty to be consistent with their reported partial widths: <math>\Gamma=\Gamma_p+\Gamma_{p'}=70</math> keV 25.</p> <p><math>\Gamma_{p'}=11</math> keV 5 (2002Ha15).</p> <p>J<sup>π</sup>: From (2001HaZP, 2002Ha15: assignment is based on mirror levels and Coulomb shift arguments) and (2011He09: R-matrix analysis).</p> <p>J<sup>π</sup>: See also J<sup>π</sup>=(1<sup>+</sup>, 2<sup>-</sup>, 3<sup>+</sup>) from the R-matrix analysis of (2001HaZP) and J<sup>π</sup>=(3<sup>-</sup>, 2<sup>-</sup>, 1<sup>-</sup>) from R-matrix analysis of (2011He09).</p> <p>L: From (2011He09).</p>

<sup>a</sup> The level energy is deduced from E<sub>x</sub>(<sup>18</sup>Ne)=E<sub>c.m.</sub>+q, where E<sub>c.m.</sub> is the resonance energy, and q is the Q-value of the <sup>17</sup>F+p resonant elastic scattering. To calculate the Q-value, the masses of <sup>17</sup>F, <sup>18</sup>Ne and p are taken from (2021Wa16: AME-2020).

$^1\text{H}(^{18}\text{Ne},\text{p}')$  1999Ri05,2019Mi21

**1999Ri05:**  $^1\text{H}(^{18}\text{Ne},\text{p}')$   $E=30$  MeV/nucleon; measured inelastic proton scattering for the  $0_{\text{g.s.}}^+ \rightarrow 2_1^+$  transition in inverse kinematics. Measured proton spectra,  $\sigma_{\text{inelastic}}(\theta)$ , and angular distributions ( $\theta_{\text{lab}}=65^\circ-80^\circ$ ) for protons scattered from the  $^{18}\text{Ne}_{\text{g.s.}}$  and  $^{18}\text{Ne}^*(1.89 \text{ MeV}, 2_1^+)$ . Deduced hadronic mirror symmetry, using folding model calculations, for quadrupole transitions in the  $s$ - $d$  shell nuclei. The theoretical results reproduced the experimental data very well, particularly for  $\theta_{\text{c.m.}} < 60^\circ$ . Comparison with  $n+^{18}\text{O}$  scattering are discussed.

*Theory:*

**2005Gu03:**  $^1\text{H}(^{18}\text{Ne},\text{p})$ ; investigated the experimental data obtained via low energy ( $E < 100$  MeV/nucleon) proton scattering on  $^{18}\text{Ne}$  (**1999Ri05**) and  $^{18}\text{O}$  (**1974Es02**) using folding model approach via two different effective NN interactions. Calculated  $\sigma(E,\theta)$  using folding model approach. Comparison of effective interactions are discussed. Recalculated the quadrupole deformations of  $^{18}\text{O}$  and  $^{18}\text{Ne}$  using the experimental  $B(E2)$  values from (**1987Ra01**). The results are  $\delta=0.33078$  and  $\delta=0.59284$  for  $^{18}\text{O}$  and  $^{18}\text{Ne}$ , respectively.

**2014Ja05:**  $^{18}\text{Ne}(\text{p},\text{p}')$ ; used the coupled-channel representation of the Gamow shell model to describe the low energy ( $E_{\text{c.m.}}=0.5-3$  MeV) experimental data obtained via elastic and inelastic scattering of protons on  $^{18}\text{Ne}$  at  $\theta_{\text{c.m.}}=105^\circ-180^\circ$  (**2006Sk09**, **2003An02**, and **2005De15**). Deduced the theoretical low-lying excited states of  $^{18}\text{Ne}$  and  $^{19}\text{Na}$ , the two proton separation energy for  $^{18}\text{Ne}$ , the  $\text{p}+^{18}\text{Ne}$  excitation function, and the elastic/inelastic differential cross sections in the  $^{18}\text{Ne}(\text{p},\text{p}')$  reaction, calculated in ( $sd$ - $p$ ) and ( $sd$ ) model spaces, for  $E_{\text{c.m.}}=0.1-5$  MeV. Comparison with experimental data are discussed.

**2019Mi21:**  $^{18}\text{Ne}(\text{p},\text{p})$ ; Calculated proton radial densities, binding energy, Coulomb energies of the ground and first few excited states, and energies and widths of the low-lying states of the isotones of  $^{16}\text{O}$ , including  $^{18}\text{Ne}$ , using Gamow shell model with the  $A$ -dependent EFT interaction. Calculated differential  $\sigma(E)$  for  $^{18}\text{Ne}(\text{p},\text{p})$  at  $E_{\text{c.m.}}=0.5-2.5$  MeV and  $\theta_{\text{c.m.}}=105^\circ-180^\circ$  using Gamow shell model and resonating group method with the  $A$ -dependent EFT interaction. Comparison with experimental data are discussed. The calculated excitation functions of the  $^{18}\text{Ne}(\text{p},\text{p})$  reaction compare well with experimental data (**2003An02**, **2005De15**) for all considered angles.

 $^{18}\text{Ne}$  Levels

$E(\text{level})^a$	$J\pi^a$	Comments
0	$0^+$	
$1.89 \times 10^3$	$2^+$	( <b>2005Gu03</b> ) calculated a quadrupole deformation parameter of $\delta=0.59284$ for this state. The neutron and proton multipole matrix element for the empirical quadrupole densities are $M_n=6.18 \text{ fm}^2$ and $M_p=3.00 \text{ fm}^2$ , with $M_n/M_p=2.06$ in the convention in which $B(E2; 0_{\text{g.s.}}^+ \rightarrow 2_1^+)=5M_p^2=45 \text{ fm}^4$ ( <b>1999Ri05</b> ). The empirical densities have $M_p/M_n > Z/N$ for $^{18}\text{Ne}$ and $M_n/M_p > N/Z$ for $^{18}\text{O}$ ( <b>1999Ri05</b> ). The result $M_p/M_n > Z/N$ is expected for low-lying quadrupole transitions in a closed neutron shell nucleus like $^{18}\text{Ne}$ ( <b>1999Ri05</b> ).

<sup>a</sup> From (**1999Ri05**).

<sup>2</sup>H(<sup>17</sup>F,n) 2017Ku27

**2017Ku27:** <sup>2</sup>H(<sup>17</sup>F,n)<sup>18</sup>Ne\*(p)<sup>17</sup>F E=95.5 MeV; measured the n-<sup>18</sup>Ne\*(→p+<sup>17</sup>F+γ) coincidences using the RESONEUT detector array at θ<sub>lab</sub>=90° covering θ<sub>c.m.</sub>=3°–10° (to measure neutrons with E=100-600 keV), an annular position sensitive silicon ΔE-E telescope covering θ<sub>lab</sub>=8°–21° (for protons), a cylindrical nine-fold segments position sensitive gas ionization chamber (for <sup>18</sup>Ne\* and <sup>17</sup>F ions), and a barrel-shaped array surrounding the target consisting of 20 position sensitive NaI(Tl) detectors (for γ rays). Deduced the <sup>18</sup>Ne excitation energies from a kinematic reconstruction and invariant mass analysis of the p+<sup>17</sup>F+γ events. Total cross sections of 15.3 mb 3 (stat.) 12 (sys.) and 2.30 mb 35 (stat.) 29 (sys.) were extracted for the prominent <sup>18</sup>Ne states populated at E<sub>c.m.</sub>=0.60 and 1.165 MeV, respectively. The neutron angular distributions were deduced from coupled reaction channel calculations using the FRESKO code. The spectroscopic factors and Asymptotic Normalization Coefficients were deduced for <sup>18</sup>Ne states. The astrophysical S-factors were deduced using the RADCAP code. The total S-factor for the <sup>17</sup>F(p,γ) reaction was deduced as S(0)=2.44 keV.b 97. D. W. Bardayan et al., AIP Conf. Proc. 2160 (2019) 070010; <sup>2</sup>H(<sup>17</sup>F,n) E=57.2 MeV; measured neutrons using the VANDLE and UMDSA arrays covering the angular ranges of θ<sub>lab</sub>=40°–170° and θ<sub>lab</sub>=18°–120°, respectively. The <sup>18</sup>Ne recoils were detected in a plastic scintillator downstream the target. This detector provided the reference signal for measuring the neutron time-of-flight. Analysis and results were not discussed.

<sup>18</sup>Ne Levels

The 2s<sub>1/2</sub> and 1d<sub>5/2</sub> ANC's were not independently determined in (2017Ku27). The ratio from the mirror nucleus was assumed. See also (2020Br14) for the theoretical ANC's.

E(level) <sup>a</sup>	J <sup>πc</sup>	L <sup>c</sup>	Comments
0			E(level): From (D. W. Bardayan et al., AIP Conf. Proc. 2160 (2019) 070010).
1888 <sup>b</sup>	2 <sup>+</sup>	0,2 <sup>d</sup>	E(level): See also 1887 keV (D. W. Bardayan et al., AIP Conf. Proc. 2160 (2019) 070010). C <sup>2</sup> S: Based on the measured differential cross section of dσ/dΩ <sub>c.m.</sub> =13.2 mb/sr 63 (stat.) 17 (sys.) at θ <sub>c.m.</sub> =11°: C <sup>2</sup> S(2s <sub>1/2</sub> )=0.22 11 (stat.) 3 (sys.) for l=0, and C <sup>2</sup> S(1d <sub>5/2</sub> )=0.88 42 (stat.) 11 (sys.) for l=2 contributions assuming the same mixing between l=0 and l=2 as that in the mirror reaction (2017Ku27). (2017Ku27): ANC(2s <sub>1/2</sub> )=22 fm <sup>-1</sup> 10 (stat.) 3 (sys.) assuming pure l=0 (from 2s <sub>1/2</sub> ) and with no l mixing. Assuming the same mixing between l=0 (2s <sub>1/2</sub> ) and l=2 (1d <sub>5/2</sub> ) as that in the mirror reaction: ANC(2s <sub>1/2</sub> )=16.0 fm <sup>-1</sup> 77 (stat.) 21 (sys.) for l=0 and ANC(1d <sub>5/2</sub> )=2.6 fm <sup>-1</sup> 12 (stat.) 3 (sys.) for l=2.
3376 <sup>b</sup>	4 <sup>+</sup>	2 <sup>d</sup>	C <sup>2</sup> S: C <sup>2</sup> S(1d <sub>5/2</sub> )=1.42 50 (stat.) 20 (sys.) (2017Ku27) based on dσ/dΩ <sub>c.m.</sub> =16.7 mb/sr 56 (stat.) 23 (sys.) at θ <sub>c.m.</sub> =8°. ANC(1d <sub>5/2</sub> )=2.8 fm <sup>-1</sup> 9 (stat.) 4 (sys.) (2017Ku27).
3576			E(level): Possibly populated but unresolved from the 3376-, 3576-, and 3616-keV states (see D. W. Bardayan et al., AIP Conf. Proc. 2160 (2019) 070010).
3616 <sup>b</sup>	2 <sup>+</sup>	0,2 <sup>d</sup>	E(level): (D. W. Bardayan et al., AIP Conf. Proc. 2160 (2019) 070010) observed a large peak, which was attributed to the unresolved states at 3376 keV, 3576 keV and 3616 keV (see Fig. 4). C <sup>2</sup> S: C <sup>2</sup> S(2s <sub>1/2</sub> )=0.41 14 (stat.) 6 (sys.) for l=0, and C <sup>2</sup> S(1d <sub>5/2</sub> )=0.76 26 (stat.) 11 (sys.) for l=2 contributions (based on dσ/dΩ <sub>c.m.</sub> =25.9 mb/sr 90 (stat.) 39 (sys.) at θ <sub>c.m.</sub> =8°) assuming the same mixing between l=0 and l=2 as that in the mirror reaction (2017Ku27). ANC(2s <sub>1/2</sub> )=188 fm <sup>-1</sup> 66 (stat.) 28 (sys.) (2017Ku27): assuming pure l=0 (from 2s <sub>1/2</sub> ) and with no l mixing. Assuming the same mixing between l=0 and l=2 as that in the mirror reaction (2017Ku27): ANC(2s <sub>1/2</sub> )=148 fm <sup>-1</sup> 52 (stat.) 22 (sys.) for l=0 and ANC(1d <sub>5/2</sub> )=3.1 fm <sup>-1</sup> 11 (stat.) 5 (sys.) for l=2.

Continued on next page (footnotes at end of table)

$^2\text{H}(^{17}\text{F},\text{n})$  **2017Ku27 (continued)** $^{18}\text{Ne}$  Levels (continued)

$E(\text{level})^a$	$J^\pi^c$	$\Gamma_p$ (keV)	$L^c$	$C^2S^e$	Comments
4523	$3^+$	14.2 keV <i>11</i>	0	0.79 <i>6</i>	E(level): The corresponding $E_{c.m.}=599.8$ keV was mentioned in (2017Ku27). See also 4561 keV (D. W. Bardayan et al., AIP Conf. Proc. 2160 (2019) 070010). $\Gamma_p=14.2$ keV <i>3</i> (stat.) <i>11</i> (sys.) (2017Ku27). $C^2S$ : Weighted average of $C^2S=0.78$ <i>2</i> (stat.) <i>6</i> (sys.) (2017Ku27: from the $p\text{-}^{17}\text{F}$ coincidence events using $\sigma=15.3$ mb <i>3</i> (stat.) <i>12</i> (sys.)); and $C^2S=0.84$ <i>10</i> (stat.) <i>10</i> (sys.) (2017Ku27: from the reconstructed $^{18}\text{Ne}$ excitation energy spectrum based on the neutron time-of-flight: $d\sigma/d\Omega_{c.m.}=41$ mb/sr <i>5</i> (stat.) <i>5</i> (sys.) at $\theta_{c.m.}=6^\circ$ using the coupled reaction channels calculations (see text) and assuming $J^\pi=3^+$ ).
$5.09\times 10^3$	$2^+$	50 keV <i>11</i>			E(level): The corresponding $E_{c.m.}=1.165$ keV was mentioned in (2017Ku27). $\Gamma_p=50$ keV <i>8</i> (stat.) <i>8</i> (sys.) (2017Ku27). $J^\pi$ : (2017Ku27) excludes $J^\pi=3^-$ because it would lead to a much smaller spectroscopic factor and a cross section too small to be observed in this experiment. $C^2S=0.20$ $+3-2$ (stat.) $+3-2$ (sys.) (2017Ku27) from the $p\text{-}^{17}\text{F}$ coincidences. $\sigma=2.30$ mb <i>35</i> (stat.) <i>29</i> (sys.) (2017Ku27).

<sup>a</sup> From (2017Ku27), unless noted otherwise.

<sup>b</sup> This state was observed in (2017Ku27) from the neutron time-of-flight spectrum when a gate on the  $\gamma$ -ray coincident events was applied.

<sup>c</sup> Deduced (1) for the proton unbound states ( $E_x(^{18}\text{Ne})>4$  MeV) from the coupled reactions channel calculations using FRESKO (2017Ku27), and (2) for the proton bound states ( $E_x(^{18}\text{Ne})<4$  MeV) from the Monte Carlo simulation of the correlation between the energies of the detected charged particle reaction products and the center-of-mass neutron emission angles (from the deuteron breakup). As a result, the simulated spectra of  $p\text{-}^{17}\text{F}$  energy distributions, assuming various angular momentum transfers, were used to fit the experimental spectra to find the best fit, and thus the best  $l$  value (2017Ku27).

<sup>d</sup> (2017Ku27) does not present the Monte Carlo fits, from which the angular momenta are deduced for the transfer reaction populating this state.

<sup>e</sup> An upper limit of  $C^2S\leq 0.1$  was estimated for the spectroscopic factors of potential additional low-lying resonances in  $^{18}\text{Ne}$  (2017Ku27).

**$^4\text{He}(^{14}\text{O},\text{p}),(^{14}\text{O},2\text{p})$ :res 1987Wi11,2018Na26**

- 2004No14, 2004No18, 2006Ku17:**  $^4\text{He}(^{14}\text{O},\text{p})$   $E=43$  MeV; measured protons by a  $\Delta E$ -E telescope at  $\theta_{\text{lab}}=0^\circ$ ; measured  $E_p$  and  $\sigma(E)$  for  $^{14}\text{O}(\alpha,\text{p})$  at  $E_{\text{c.m.}}(^{14}\text{O}+\alpha)=0.8$ -3.8 MeV ( $E_{\text{c.m.}}(^{17}\text{F}+\text{p})=2$ -4.8 MeV) using thick target yield technique; observed enhancements in the cross section near  $E_x(^{18}\text{Ne})=6.1, 7.1,$  and 7.4 MeV; observed for the first time a weak transition at  $E_{\text{c.m.}}(^{14}\text{O}+\alpha)=1.5$  MeV; discussed astrophysical implications and the  $^{14}\text{O}(\alpha,\text{p})$  reaction rate.
- 2007Fu09, 2008FuZZ:**  $^4\text{He}(^{14}\text{O},\text{X})^{16}\text{O}$   $E=66$  MeV; used the MARS recoil separator and measured protons emitted from the decay of  $^{18}\text{Ne}$  states using an array of 4 segmented Silicon detectors followed by a Silicon telescope at  $\theta_{\text{lab}}=0^\circ$ ; energy resolution was 200 keV (FWHM); measured  $E_p, \theta_p,$  p-p-coincidences; thick target technique; deduced  $^{18}\text{Ne}$  excitation function and decay cross sections; constructed Dalitz plots for the  $(\alpha,2\text{p})$  events assuming a sequential decay via  $^{18}\text{Ne}^* \rightarrow \text{p}_1 + ^{17}\text{F}^* \rightarrow \text{p}_1 + ^{16}\text{O}_{\text{g.s.}} + \text{p}_2$ ; dominant intensity of 2p events corresponded to the known  $^{17}\text{F}^*(3.10, 3.86, 5.22$  MeV); observed diproton decay of  $^{18}\text{Ne}^*(8.45$  MeV); calculated relative energy distribution for the two protons from the decay of the 8.45 MeV state using the Faddeev approach; observed 4 new states of  $^{18}\text{Ne}$  at 10.12, 10.66, 11.29, 11.8 MeV; discussed astrophysical implications for the  $^{14}\text{O}(\alpha,\text{p})$  reaction rate.
- 2015Ki07:**  $^4\text{He}(^{14}\text{O},\text{p}_{0,1,2,3})$   $E=33.8$  MeV; measured single protons and p-p coincidences at  $E_{\text{c.m.}}=2.1$ -5.3 MeV using a set of position sensitive  $\Delta E$ -E Si telescopes that covered  $\theta_{\text{lab}}=-12^\circ$ - $78^\circ$ ; data show much less statistics for the democratic 2p decay than for the sequential decay so the 2p events were excluded from the analysis but were considered in error estimations; it was generally possible to distinguish the  $^{14}\text{O}(\alpha,\text{p}_{0,1,2,3})$  groups; deduced excitation function of  $^{18}\text{Ne}$ ; analyzed the excitation function using SAMMY R-matrix code; performed shell model calculations to deduce spins and parities for the observed states above 8.1 MeV; identified  $^{18}\text{Ne}$  resonances significant to the  $^{14}\text{O}(\alpha,\text{p})$  astrophysical reaction rate; discussed astrophysical implications.
- 2023Pa44:**  $^4\text{He}(^{14}\text{O},\text{p})$   $E=3.845$  MeV/nucleon; measured  $\sigma(E)$  for the  $\alpha(^{14}\text{O},\text{p})^{17}\text{F}$  reaction around  $E_{\text{c.m.}}=7$  MeV using the upgraded TexAT active target chamber (TexAT\_v2) together with the MARS beamline. This study was carried out to commission TexAT\_v2. Analysis is in progress. The authors indicated that the direct cross section measurement of the  $\alpha(^{14}\text{O},\text{p})^{17}\text{F}$  reaction is proposed to be performed at the Center for Nuclear Study, RIKEN Nishina Center using the TexAT detector.

*Theory:*

- 2018Na26:** Calculated bound and resonant  $0^+$  levels, decay widths, monopole transition strengths, and Coulomb shifts for the mirror cluster  $\alpha+^{14}\text{O}$  system using the orthogonality condition model; results interpreted in terms of the extension of the Thomas-Ehrman shift (TES); comparison with experimental values; proposed combination of the cluster TES and the monopole transitions as experimental probe for cluster structure in mirror systems.

*The Astrophysical  $^{14}\text{O}(\alpha,\text{p})$  Reaction Rate:*

This subsection contains experimental and theoretical studies that are focused on the determination of the  $^{14}\text{O}(\alpha,\text{p})$  astrophysical rate. The details of the experimental studies can be found in other sections.

- R. K. Wallace and S. E. Woosley, *Astrophys. J. Suppl. Ser.* 45 (1981) 389: Calculated the  $^{14}\text{O}(\alpha,\text{p})$  reaction rate based on the resonant contribution from two  $\alpha$ -unbound levels at  $E_x=6.3$  and 6.35 MeV in  $^{18}\text{Ne}$ ; approximated the Hauser-Feshbach rate; deduced an analytical expression for the reaction rate.
- 1987Wi11:** Calculated the resonant and non-resonant contributions to the  $^{14}\text{O}(\alpha,\text{p})^{17}\text{F}$  and  $^{14}\text{O}(\alpha,\gamma)^{18}\text{Ne}$  reaction rates at 0.1-10 GK; calculated depletion rate ratios, S-factor, reaction  $\sigma$ , resonance energies, widths, spectroscopic factors, and resonance strengths.
- 1988Ca26, 1988Ca28:** Calculated an analytical expression for this reaction rate, which was used to obtain the rate from 0.001-10 GK.
- 1988Fu02, 1989Fu01:** Calculated the  $^{14}\text{O}(\alpha,\text{p})$  astrophysical reaction rate based on microscopic coupled-channel generator coordinate method; calculated reaction  $\sigma$  and the astrophysical S-factor vs.  $E$  for  $E_{\text{c.m.}}=0.4$ -4 MeV; deduced  $^{18}\text{Ne}$  resonance properties; pointed out the important contributions to the  $^{14}\text{O}(\alpha,\text{p})$  reaction rate by the direct capture process for temperatures  $T \leq 0.3$  GK; comparison with the results of (1987Wi11). (1989Fu01) included inelastic scattering of  $^{14}\text{O}+\alpha$  in this calculation and recalculated the S-factor.
- 1992Ch50:** Provides a review of the  $^{14}\text{O}(\alpha,\text{p})$  reaction rate and the structure of  $^{18}\text{Ne}$  based on the available data at the time.
- 1996Ha26:** Calculated astrophysical S-factor vs.  $E$  and the  $^{14}\text{O}(\alpha,\text{p})$  astrophysical reaction rate considering  $E_{\text{c.m.}} < 2.5$  MeV and for 0.1-1 GK; deduced the  $^{18}\text{Ne}$  resonance energies,  $J^\pi, C^2S_p, C^2S_\alpha, \Gamma_p, \Gamma_\alpha, \Gamma,$  and  $\omega\gamma_{(\alpha,\text{p})}$  for resonances with  $E_{\text{c.m.}} < 2.5$  MeV; discussed the astrophysical implications.
- 1997Ba57:** Calculated the  $^{14}\text{O}(\alpha,\text{p})$  and  $^{17}\text{F}(\text{p},\gamma)$  reaction rates for 0.1-1 GK based on the experimental data of (1991Ga03, 1996Ha26); calculated the S-factor for the  $^{17}\text{F}(\text{p},\gamma)$  reaction for  $E_{\text{c.m.}} \approx 30$ -1000 keV; deduced the REACLIB analytical expressions and parameters for these rates.
- 2002Ha15:** Analyzed data and deduced  $^{18}\text{Ne}$  resonance energies,  $J^\pi, \Gamma_p, \Gamma_\alpha, \Gamma_{p'}, \Gamma$  and  $\omega\gamma_{(\alpha,\text{p})}$  for 7 states with  $E_x=6.15$ -7.71 MeV; used these to calculate the  $^{14}\text{O}(\alpha,\text{p})$  resonant reaction rate for 0.5-3 GK; comparison with the rate of (1996Ha26)

<sup>4</sup>He(<sup>14</sup>O,P),(<sup>14</sup>O,2p):res 1987Wi11,2018Na26 (continued)

is presented.

2002Pi05: Recommended the rate of (1988Ca28).

Luc L. Dessieux, Jr., M. Sc. Thesis, *2p or Not 2p: The <sup>14</sup>O( $\alpha$ ,2p) <sup>16</sup>O Reaction Rate and Its Implications On Nova and X-ray Burst Nucleosynthesis*, The University of Tennessee, Knoxville (2002), and 2004Sm08: Evaluated the <sup>14</sup>O( $\alpha$ ,p) and <sup>14</sup>O( $\alpha$ ,2p) reaction rates at temperatures of interest for novae and type I X-ray bursts and discussed their astrophysical implications.

2003B111: Calculated the <sup>14</sup>O( $\alpha$ ,p) reaction rate for 0.1-1.5 GK incorporating the branch to the first excited state in <sup>17</sup>F; discussed the reaction rate on the basis of their experimental results; comparison with previous rates is presented.

2004No14, 2004No18, 2006Ku17: Discussed the <sup>14</sup>O( $\alpha$ ,p) reaction rate based on the results of their measurements (see the first subsection of this dataset).

2007Fu09, 2008FuZZ: Based on the measured properties of the <sup>14</sup>O+ $\alpha$  interaction, the authors disputed the assumptions made in (2004No18, 2006Ku17) for the interpretation of the <sup>14</sup>O( $\alpha$ , p) rate at astrophysical energies. On the contrary to what was stated in (2006Ku17) that the <sup>14</sup>O( $\alpha$ ,p) reaction dominates in the production of low energy protons, (2007Fu09, 2008FuZZ) concluded that the  $\alpha$ +<sup>14</sup>O interaction results in populating high energy <sup>18</sup>Ne resonances ( $E_x=7$ -12 MeV) with energies above the astrophysically significant energy region. The protons from the sequential decays (via proton-unbound <sup>17</sup>F levels) of these states, therefore, create a large background in the astrophysically important energy region, which would make it harder to distinguish <sup>18</sup>Ne proton decay paths.

2010Ha15: Discussed the <sup>14</sup>O( $\alpha$ ,p) reaction rate based on the results of their measurement (see <sup>4</sup>He(<sup>14</sup>O, $\alpha$ ) section).

2011He09: Calculated the total resonant <sup>14</sup>O( $\alpha$ ,p) reaction rate at T=0.5-3 GK. Presented the resonance properties ( $E_x$ ,  $J^\pi$  and  $\omega\gamma_{(\alpha,p)}$ ) for the resonances used. Comparison with previous rates is presented.

2012A111: Calculated the resonant <sup>14</sup>O( $\alpha$ ,p) reaction rate for 0.1-5 GK using 8 <sup>18</sup>Ne resonances with  $E_x=5.1$ -8.1 MeV; presented the recommended resonance energy,  $J^\pi$ ,  $\Gamma_\alpha$ ,  $\Gamma_p$ ,  $\Gamma$ ,  $\omega\gamma_{(\alpha,p)}$  for these resonances; comparison with previous rates; discussed the 2p decay of the 6.15-MeV <sup>18</sup>Ne state and its effect on the reaction rate; discussed the astrophysical implications.

2014Hu16: Recommended the resonance energy,  $J^\pi$ ,  $\Gamma_\alpha$ ,  $\Gamma_p$ ,  $\Gamma_{p'}$ ,  $\Gamma$ , and  $\omega\gamma_{(\alpha,p)}$  for 8 of the <sup>18</sup>Ne states with  $E_x=5.153$ -8.11 MeV; calculated the resonance <sup>14</sup>O( $\alpha$ ,p) reaction rate for 0.25-3.0 GK using these resonances; recommended the direct capture rate calculated by (1988Fu02); discussed the interferences between the direct and resonant captures for the <sup>18</sup>Ne\*(6.15 MeV) state; deduced an analytical expression for the reaction rate; discussed the astrophysical implications; comparison with previous reaction rates is presented.

2015Ki07: Deduced the resonance energies,  $\Gamma_\alpha$ ,  $\Gamma_p$ ,  $\omega\gamma_{(\alpha,p)}$ ,  $J^\pi$  for <sup>18</sup>Ne resonances corresponding to the states with  $E_x=7.35$ -8.10 MeV; calculated the <sup>14</sup>O( $\alpha$ ,p) resonant reaction rate for 0.5-4 GK; comparison with previous rates is presented.

<sup>18</sup>Ne Levels

(2007Fu09, 2008FuZZ) reported that the sequential 2p decays (<sup>18</sup>Ne\* $\rightarrow$ (<sup>17</sup>F\* $\rightarrow$ <sup>16</sup>O<sub>g.s.</sub>+p)+p) were dominant in the high energy region ( $E_x(^{18}\text{Ne}) > 8$  MeV).

E(level)	$J^\pi$ <sup>e</sup>	$\Gamma^c$	Comments
6150			E(level): From (2004No14, 2004No18, 2006Ku17).
6290			E(level): From (2004No18, 2006Ku17).
7050 <sup>a</sup>			(2004No14, 2004No18, 2006Ku17): evidence from the direct measurement of <sup>14</sup> O( $\alpha$ ,p) supports proton decay to <sup>17</sup> F*(495 keV).
7120 <sup>a</sup>			(2004No14, 2004No18, 2006Ku17): evidence from the direct measurement of <sup>14</sup> O( $\alpha$ ,p) supports proton decay to <sup>17</sup> F*(495 keV) but no such evidence is observed by (2010Ba21).
7.35 $\times$ 10 <sup>3b</sup>	3 (1 <sup>-</sup> )	390 keV 40	$\Gamma_\alpha=3.1$ keV 2; $\Gamma_p=387$ keV 40 (2015Ki07) E(level): See also 7350 keV (2004No18, 2006Ku17) and 7370 keV (2004No14). Note that (2015Ki07) had difficulty identifying this state due to poor statistics and claimed that the data for this state were featureless. However, their fit to the nearby states depended on the existence of this state and on its $J^\pi$ assignment. $E_{c.m.}(^{14}\text{O}+\alpha)=2.25$ MeV (2015Ki07). $\omega\gamma_{(\alpha,p)}=9.32$ keV (2015Ki07). The evaluator notes that the statistics for this state is very poor (only a few counts), which makes these results unreliable. Therefore, these results are excluded from the <sup>18</sup> Ne Adopted Levels.

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<sup>4</sup>He(<sup>14</sup>O,P),(<sup>14</sup>O,2p):res **1987Wi11,2018Na26 (continued)**

<sup>18</sup>Ne Levels (continued)

E(level)	J <sup>π</sup> <sub>e</sub>	Γ <sup>c</sup>	Comments
7.58×10 <sup>3</sup> <sup>b</sup> 2	(0 <sup>+</sup> )	104 keV 26	<p>Γ<sub>α</sub>=1.5 keV 5; Γ<sub>p</sub>=102 keV 26 (2015Ki07)                      E<sub>c.m.</sub>(<sup>14</sup>O+α)=2.46 MeV (2015Ki07). Evaluator notes that this state is relatively featureless and suffers from poor statistics.                      E(level): See also 7600 (2004No14); 7660 keV (2007Fu09, 2008FuZZ); and 7620 keV (2004No18, 2006Ku17).                      Γ: See also Γ(FWHM)=0.31 MeV from (2008FuZZ).                      ωγ<sub>(α,p)</sub>=1.52 keV (2015Ki07).                      (2015Ki07): this state could be a candidate for the mirror state of the <sup>18</sup>O(7.796 MeV, 0<sup>+</sup>) state, whose nature is proposed to be 6-particle-4-hole (6p-4h) (2011Fo12).                      σ=0.11 mb (2008FuZZ: deduced for 2p decay for the 7660-keV level).</p>
7.72×10 <sup>3</sup> ? <sup>b</sup> 2	(2 <sup>+</sup> ,3 <sup>-</sup> )	281 keV 61	<p>Γ<sub>α</sub>=1.9 keV 3; Γ<sub>p</sub>=279 keV 61 (2015Ki07)                      E(level): Evaluator notes that this state is too wide to be consistent with the 7.7-MeV state observed by others (see the <sup>18</sup>Ne Adopted Levels). This state, as well as the 8.1-MeV state from (2015Ki07) may be part of unresolved group of states. This is why these two states and their properties are reported here as tentative.                      E<sub>c.m.</sub>(<sup>14</sup>O+α)=2.61 MeV (2015Ki07).                      ωγ<sub>(α,p)</sub>=5.38 keV (2015Ki07).                      E(level): From (2004No18, 2006Ku17).</p>
7950 8.10×10 <sup>3</sup> ? <sup>b</sup> 10	(0 <sup>+</sup> )	338 keV 38	<p>Γ<sub>α</sub>=40.4 keV 49; Γ<sub>p</sub>=298 keV 38 (2015Ki07)                      E(level): See also 8100 keV (2004No18, 2006Ku17). Evaluator notes that this level is most likely an unresolved state, which is comprised of more than one level. (1981Ne09) observed a triplet at E<sub>x</sub>~8 MeV via <sup>16</sup>O(<sup>3</sup>He,n). Those authors did not specifically mention which states were part of the triplet. The evaluator estimated that the member states are the 7712-, 7915-, and 8100-keV levels as reported by (1981Ne09), see the discussion in the <sup>16</sup>O(<sup>3</sup>He,n) dataset. There is yet another state at 7949 keV as reported by (1981Ne09) but this state was not populated via <sup>16</sup>O(<sup>3</sup>He,n). Instead, <sup>20</sup>Ne(p,t) was used to populate it, and thus it is not part of this triplet. The three states constructing the triplet mentioned above were all assigned widths of up to ~50 keV by (1981Ne09). The 7949-keV state is presumed to be comparable in width but slightly wider. The 8.1-MeV state reported by (2015Ki07) is about 4 times as wide as each of the above mentioned states and is somewhat featureless (see Fig. 11 in (2015Ki07)). Therefore, it is conceivable to think that the 8.1-MeV state could be an unresolved peak, which is consisted of more than one peak.                      E<sub>c.m.</sub>(<sup>14</sup>O+α)=2.99 MeV (2015Ki07).                      J<sup>π</sup>: The 0<sup>+</sup> assignment in (2015Ki07) yielded the best χ<sup>2</sup> for fitting both the E<sub>x</sub>&lt;8.2 MeV and E<sub>x</sub>&gt;8.2 MeV regions.                      ωγ<sub>(α,p)</sub>=35.0 keV (2015Ki07) assuming a single state.                      E(level): From (2004No18, 2006Ku17).</p>
8300 8.50×10 <sup>3</sup> <sup>b</sup> 10	(1 <sup>-</sup> ,2 <sup>+</sup> )	630 keV 64	<p>Γ<sub>α</sub>=84.5 keV 210; Γ<sub>p</sub>=546 keV 60 (2015Ki07)                      E(level): See also 8450 keV (2007Fu09, 2008FuZZ) with Γ(FWHM)=0.47 MeV (2008FuZZ).                      E<sub>c.m.</sub>(<sup>14</sup>O+α)=3.39 MeV (2015Ki07).                      σ=0.73 mb (2008FuZZ) deduced for 2p decay of the state at 8450 keV.                      (2007Fu09, 2008FuZZ): evidence suggests that the state at 8450 keV decays to <sup>16</sup>O<sub>g.s.</sub> via <sup>2</sup>He emission. This is supported by a predicted decay spectrum using the Faddeev approach. The angular momenta of L=0,1,2,3 were assumed for the <sup>2</sup>He relative to the <sup>16</sup>O core when calculating the Faddeev model. The experimentally measured relative energy between the two protons emitted from the level at 8.45 MeV in <sup>18</sup>Ne was most consistent with L=3 (see Fig. 6 of (2008FuZZ)).</p>

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<sup>4</sup>He(<sup>14</sup>O,P),(<sup>14</sup>O,2p):res **1987Wi11,2018Na26 (continued)**

<sup>18</sup>Ne Levels (continued)

E(level)	J <sup>π</sup> <sup>e</sup>	Γ <sup>c</sup>	Comments
9.14×10 <sup>3</sup> <sup>b</sup> 10	3 <sup>-</sup>	494 keV 59	Γ <sub>α</sub> =27.0 keV 60; Γ <sub>p</sub> =467.5 keV 590 (2015Ki07) E <sub>c.m.</sub> ( <sup>14</sup> O+α)=4.03 MeV (2015Ki07). This study pairs the 9.14 MeV 10 state with the 9.2-MeV state observed in the (p,t) measurements. E(level): A state was observed in (2007Fu09) with E <sub>x</sub> =9.4 MeV, whose width was deduced as Γ(FWHM)=0.42 MeV (2008FuZZ). (2007Fu09) suggests that this state is likely to be the 9.2-MeV state observed in the (p,t) measurements. Evidence suggests that the 9.4-MeV state proton decays to <sup>17</sup> F*(3.1 MeV) and to <sup>17</sup> F*(3.86 MeV), see Fig. 5 of (2008FuZZ). σ=9.92 mb was deduced in (2008FuZZ) for the 2p decay of the 9.4-MeV level.
9.60×10 <sup>3</sup> <sup>b</sup> 9	(1 <sup>-</sup> ,0 <sup>+</sup> )	628 MeV 104	Γ <sub>α</sub> =620 keV 104; Γ <sub>p</sub> =7.8 keV 66 (2015Ki07) E <sub>c.m.</sub> ( <sup>14</sup> O+α)=4.49 MeV (2015Ki07). (2015Ki07): this state may be a superposition of two or more states. E(level): (2015Ki07) claims that this state was populated, for the first time, in their experiment. Note that (1996Ha26) observed a state at 9580 keV 20 using the <sup>12</sup> C( <sup>12</sup> C, <sup>6</sup> He) reaction, but the J <sup>π</sup> assignment was not deduced by (1996Ha26).
10.07×10 <sup>3</sup> <sup>b</sup> 8	(2 <sup>+</sup> ,1 <sup>-</sup> )	92 keV 18	Γ <sub>α</sub> =1.5 keV 8; Γ <sub>p</sub> =90 keV 18 (2015Ki07) E(level): This state was observed for the first time in (2015Ki07). See also 10.12 MeV (2007Fu09, 2008FuZZ): Γ(FWHM)=0.54 MeV observed for the first time in (2007Fu09). E <sub>c.m.</sub> ( <sup>14</sup> O+α)=4.96 MeV (2015Ki07). J <sup>π</sup> : The R-matrix analysis of (2015Ki07) with J <sup>π</sup> =2 <sup>+</sup> yields a slightly better χ <sup>2</sup> for the fit. σ=29.2 mb (2008FuZZ) for the 2p decay of the state at 10.12 MeV. (2007Fu09, 2008FuZZ): evidence suggests that the state at 10.12 MeV proton decays to <sup>17</sup> F*(3.1 MeV) and to <sup>17</sup> F*(3.86 MeV), see Fig. 5 of (2008FuZZ).
10660 <sup>d</sup>		0.73 MeV	Γ: From Γ(FWHM) obtained by (2008FuZZ). σ=25.9 mb (2008FuZZ) for the 2p decay of this state. (2007Fu09, 2008FuZZ): evidence suggests that this state proton decays to <sup>17</sup> F*(3.1 MeV) and to <sup>17</sup> F*(3.86 MeV) with a weaker branch, see Fig. 5 of (2008FuZZ).
11290 <sup>d</sup>		0.66 MeV	Γ: From Γ(FWHM) obtained by (2008FuZZ). σ=49.9 mb (2008FuZZ) for the 2p decay of this state. (2007Fu09, 2008FuZZ): evidence suggests that this state proton decays to <sup>17</sup> F*(3.1 MeV), <sup>17</sup> F*(3.86 MeV) and <sup>17</sup> F*(5.22 MeV), see Fig. 5 of (2008FuZZ).
11800 <sup>d</sup>		0.52 MeV	Γ: From Γ(FWHM) obtained by (2008FuZZ). σ=42.4 mb (2008FuZZ) for the 2p decay of this level.

<sup>a</sup> (2004No14, 2004No18): these studies observed a weak, previously unobserved transition at E<sub>c.m.</sub>(<sup>14</sup>O+α)=1.5 MeV, corresponding to E<sub>c.m.</sub>(<sup>17</sup>F+p)=2.7 MeV (2006Ku17). Since the <sup>17</sup>F+p elastic scattering measurement of (2001Bi06) did not reveal any <sup>18</sup>Ne state with a large proton width, and because the <sup>18</sup>Ne states in this energy region (near the α-threshold) cannot have a large α-width, (2006Ku17) ruled out the possibility that the observed transition at E<sub>c.m.</sub>(<sup>14</sup>O+α)=1.5 MeV could be a <sup>18</sup>Ne resonance. Instead, (2004No14, 2006Ku17) considered this transition to be an evidence supporting the proton decay of the <sup>18</sup>Ne state around 7.1 MeV to the <sup>17</sup>F\*(495 keV), which enhanced the deduced <sup>14</sup>O(α,p) reaction rate by 50% around 2 GK (2004No14). However, (2010Ba21) did not see any evidence of inelastic <sup>17</sup>F+p scattering in this energy region, and the decay branching ratio of Γ<sub>p</sub>/Γ<sub>p</sub> was constrained to be less than 0.03. (2014Hu16) observed a new state at 6.85 MeV, which may be what (2004No14, 2004No18) had observed at E<sub>c.m.</sub>(<sup>14</sup>O+α)=1.5 MeV.

<sup>b</sup> From (2015Ki07).

<sup>c</sup> Γ=Γ<sub>α</sub>+Γ<sub>p</sub> deduced from the R-matrix analysis of (2015Ki07) unless noted otherwise.

<sup>d</sup> This state was observed for the first time in (2007Fu09).

<sup>e</sup> From the R-matrix analysis of (2015Ki07).

<sup>4</sup>He(<sup>14</sup>O, $\alpha$ ):res 2008Fu07,2022Ba39

**2008Fu07:** <sup>4</sup>He(<sup>14</sup>O, $\alpha$ ) E=33, 42, and 57 MeV; measured the <sup>14</sup>O+ $\alpha$  elastic scattering excitation function using the MARS recoil spectrometer. Measured the reaction products using 4 large position sensitive Si detectors. Energy resolution was ~40 keV in the center-of-mass frame. Measured angular distributions of the  $\alpha$ -particles. The measured <sup>14</sup>O+ $\alpha$  excitation function was analyzed using R-matrix and shows  $\alpha$ -cluster structure in <sup>18</sup>Ne. Numerous <sup>18</sup>Ne resonances with E<sub>c.m.</sub>=3.6-11.4 MeV were measured. Authors concluded that there is a large increase in the radius of the  $\alpha$ -cluster states in <sup>18</sup>Ne. Comparisons between mirror levels in <sup>18</sup>O and <sup>18</sup>Ne are discussed.

**2010Ha15:** <sup>4</sup>He(<sup>14</sup>O, $\alpha$ ) E=24 and 35 MeV; measured the excitation function of the <sup>14</sup>O( $\alpha$ , $\alpha$ ) resonant elastic scattering and  $\sigma(\theta)$  (in inverse kinematics) using the thick target method. Energy range: E<sub>c.m.</sub>=2.1~8.0 MeV. The  $\alpha$ -particles were measured using a set of  $\Delta E$ -E telescopes consisting of position sensitive Si detectors and Si surface barrier detectors covering  $\theta_{lab}=0^\circ-70^\circ$ . Only the data collected by the telescope at 0° were used in this study. Energy resolution was 40 keV. A new state was observed at E<sub>c.m.</sub>=6900 keV. Deduced the <sup>18</sup>Ne resonance parameters for 3 resonances using an R-matrix analysis. The results are in agreement with the previous results obtained by (2008Fu07).

**2022Ba39:** <sup>4</sup>He(<sup>14</sup>O, $\alpha$ ) E=61.8 MeV; used the TexAT active target filled with <sup>4</sup>He(96%)+CO<sub>2</sub>(4%) gas mixture. The light reaction products were identified via  $\Delta E$ -E telescopes. Deduced the <sup>14</sup>O+ $\alpha$  resonant elastic scattering excitation function and the associated angular distributions. A multi-channel R-matrix analysis using the MINRMATRIX code was performed, which included the data of (2008Fu07) experiment with an assigned error of 30%. The dimensionless reduced  $\alpha$  and proton widths ( $\theta_\alpha^2$  and  $\theta_{(p_0+p_1)}^2$ ), and  $J^\pi$  were deduced from R-matrix. Discussed mirror levels and performed shell model calculations to deduce spectroscopic factors.

*Theory:*

A. Volya, M. Barbui, V. Z. Goldberg, and G. V. Rogachev, Commun. Phys. 5 (2022) 322: This theoretical article discusses superradiance in terms of continuum coupling. Analyzed the data of (2022Ba39) for <sup>18</sup>Ne and (2014Av04) for <sup>18</sup>O levels with a substantial reduced  $\alpha$  width; found that among the state populated, only one 0<sup>+</sup> state with E<sub>x</sub>=9.8 MeV 3 in <sup>18</sup>Ne and E<sub>x</sub>=9.9 MeV 1 in <sup>18</sup>O could be explained by the superradiance phenomenon.

<sup>18</sup>Ne Levels

(2022Ba39):  $\theta_p^2=(\gamma_{p_0}^2+\gamma_{p_1}^2)/\gamma_{SP}^2$ , where  $\gamma_{p_0}^2$  and  $\gamma_{p_1}^2$  are proton reduced partial widths for the channels populating the ground and the first excited states of <sup>17</sup>F, respectively.  $\theta_p^2$  is the proton dimensionless reduced width.

$\Gamma$ ,  $\Gamma_\alpha$ ,  $\Gamma_p$ ,  $\theta_\alpha^2$  and  $\theta_p^2$  are from R-matrix fits. The last two values are only provided by (2022Ba39), while the widths are provided for a few states in (2008Fu07, 2010Ha15) and for all states measured by (2022Ba39).

E(level) <sup>a</sup>	J <sup><math>\pi</math></sup> <sup>c</sup>	$\Gamma$	$\theta_\alpha^2$ <sup>e</sup>	Comments
7.93×10 <sup>3</sup> ? <sup>b</sup> 2	2 <sup>+</sup>	75 keV	0.12 5	$\Gamma_\alpha=50$ keV; $\Gamma_p=25$ keV (2022Ba39) E(level),J <sup><math>\pi</math></sup> , $\Gamma$ , $\theta_\alpha^2$ : From the multi-channel R-matrix analysis of (2022Ba39). E(level): (2022Ba39) introduced this state to keep the symmetry with <sup>18</sup> O. J <sup><math>\pi</math></sup> : Supported by mirror level analysis in (2022Ba39). $\theta_p^2=0.01$ (2022Ba39).
8.2×10 <sup>3</sup> ? <sup>b</sup> 11	4 <sup>+</sup>	90 keV	0.8 <sup>d</sup> 3	$\Gamma_\alpha=30$ keV; $\Gamma_p=60$ keV (2022Ba39) E(level),J <sup><math>\pi</math></sup> , $\Gamma$ , $\theta_\alpha^2$ : From the multi-channel R-matrix analysis of (2022Ba39). E(level): From E <sub>x</sub> =8.16 MeV +5-110 (2022Ba39). E(level): (2022Ba39) considered this state to be the same as the 4 <sup>+</sup> state established at 7.05 MeV, whose mirror is thought to be the 7.11 MeV state in <sup>18</sup> O (2002Ha15, 2022Ba39). However, due to high detector thresholds at some angles, the angular distribution measured by (2022Ba39) for this <sup>18</sup> Ne state is incomplete. Therefore (2022Ba39) considered their deduced energy as an upper limit. The evaluator considered this state tentative. J <sup><math>\pi</math></sup> : Supported by mirror level analysis in (2022Ba39). $\theta_p^2=0.03$ (2022Ba39).
8.71×10 <sup>3</sup> 7	(1 <sup>-</sup> ,3 <sup>-</sup> )		1.0 <sup>d</sup> 4	E(level): Weighted average (with external errors) of 8.62 MeV 10 (2010Ha15: from E <sub>c.m.</sub> =3.50 MeV 10); and 8.76 MeV 8 (2022Ba39). See also 8.7 MeV (2008Fu07: from E <sub>c.m.</sub> =3.6 MeV).

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<sup>4</sup>He(<sup>14</sup>O, $\alpha$ ):res **2008Fu07,2022Ba39 (continued)**

<sup>18</sup>Ne Levels (continued)

E(level) <sup>a</sup>	J <sup><math>\pi</math></sup> <sup>c</sup>	$\Gamma$	$\theta_{\alpha}^2$ <sup>e</sup>	Comments
9.13×10 <sup>3</sup> 2	1 <sup>-</sup>	990 keV	0.22 <sup>d</sup> 2	<p><math>\Gamma</math>: Results are discrepant and may depend on the J<sup><math>\pi</math></sup> assignment: see <math>\Gamma</math>=781 keV 3/ (2010Ha15: sum of <math>\Gamma_{\alpha}</math>=615 keV 24 and <math>\Gamma_p</math>=166 keV 20 deduced for J<sup><math>\pi</math></sup>=(1<sup>-</sup>); and <math>\Gamma</math>=870 keV (2022Ba39: sum of <math>\Gamma_{\alpha}</math>=440 keV and <math>\Gamma_p</math>=430 keV deduced for J<sup><math>\pi</math></sup>=3<sup>-</sup>). See also <math>\Gamma</math>=0.5 MeV and <math>\Gamma_{\alpha}</math>=260 keV (2008Fu07).</p> <p>J<sup><math>\pi</math></sup>: Based on the R-matrix fits of (1) (2008Fu07): deduced, taking into account the data of (2007Bu01), J<sup><math>\pi</math></sup>=(1<sup>-</sup>,0<sup>+</sup>). The J<sup><math>\pi</math></sup>=1<sup>-</sup> assignment was preferred. Inclusion of J<sup><math>\pi</math></sup>=0<sup>+</sup> could not be excluded. (2) (2010Ha15): deduced J<sup><math>\pi</math></sup>=(1<sup>-</sup>). J<sup><math>\pi</math></sup>=0<sup>+</sup> was tried but the resulting R-matrix fit largely shifted the energy of a strong 3<sup>-</sup> resonance at 9.2 MeV. Therefore, (2010Ha15) suggest that the J<sup><math>\pi</math></sup>=1<sup>-</sup> assignment for this state is more probable and rule out J<sup><math>\pi</math></sup>=0<sup>+</sup>. (3) (2022Ba39): deduced J<sup><math>\pi</math></sup>=3<sup>-</sup> from a multi-channel R-matrix fit and supported by a mirror level analysis.</p> <p><math>\theta_{\alpha}^2</math>: Deduced by (2022Ba39) for J<sup><math>\pi</math></sup>=3<sup>-</sup>.  <math>\theta_p^2</math>=0.03 (2022Ba39: for J<sup><math>\pi</math></sup>=3<sup>-</sup>).</p> <p><math>\Gamma_{\alpha}</math>=390 keV; <math>\Gamma_p</math>=600 keV (2022Ba39)</p> <p>E(level),<math>\Gamma</math>,J<sup><math>\pi</math></sup>,<math>\theta_{\alpha}^2</math>: From the multi-channel R-matrix analysis of (2022Ba39).</p> <p>J<sup><math>\pi</math></sup>: Supported by mirror level analysis in (2022Ba39).  <math>\theta_p^2</math>=0.11 (2022Ba39).</p>
9214 24	(2 <sup>+</sup> ,3 <sup>-</sup> )	489 keV 22	0.21 <sup>d</sup> 2	<p><math>\Gamma_p</math>=124 keV 12 (2010Ha15)  <math>\Gamma_{\alpha}</math>=365 keV 18 (2010Ha15)</p> <p>E(level): Weighted average of 9.22 MeV 4 (2010Ha15: from E<sub>c.m.</sub>=4.10 MeV 4) and 9.21 MeV 3 (2022Ba39). See also 9.2 MeV (2008Fu07: from E<sub>c.m.</sub>=4.1 MeV).</p> <p><math>\Gamma</math>: From (2010Ha15: deduced from an R-matrix fit for J<sup><math>\pi</math></sup>=3<sup>-</sup>). See also <math>\Gamma</math>=0.3 MeV and <math>\Gamma_{\alpha}</math>=180 keV (2008Fu07: deduced from an R-matrix fit for J<sup><math>\pi</math></sup>=3<sup>-</sup>); and <math>\Gamma</math>=540 keV (2022Ba39: sum of <math>\Gamma_{\alpha}</math>=270 keV and <math>\Gamma_p</math>=270 keV deduced from an R-matrix fit for a J<sup><math>\pi</math></sup>=2<sup>+</sup> assignment supported by mirror level analysis).</p> <p>J<sup><math>\pi</math></sup>: From the R-matrix analyses of (2008Fu07: J<sup><math>\pi</math></sup>=3<sup>-</sup>), (2010Ha15: J<sup><math>\pi</math></sup>=3<sup>-</sup>), and (2022Ba39: J<sup><math>\pi</math></sup>=2<sup>+</sup> supported by mirror levels analysis).</p> <p><math>\theta_{\alpha}^2</math>: From the R-matrix analysis of (2022Ba39) for J<sup><math>\pi</math></sup>=2<sup>+</sup>.  <math>\theta_p^2</math>=0.04 (2022Ba39) for J<sup><math>\pi</math></sup>=2<sup>+</sup>.</p>
9.61×10 <sup>3</sup> 2	1 <sup>-</sup>	1640 keV	0.52 <sup>d</sup> 5	<p>This state shows the evidence of being an <math>\alpha</math>-cluster state (2008Fu07).</p> <p><math>\Gamma_{\alpha}</math>=1120 keV; <math>\Gamma_p</math>=520 keV (2022Ba39)</p> <p>E(level),<math>\Gamma</math>,J<sup><math>\pi</math></sup>,<math>\theta_{\alpha}^2</math>: From the multi-channel R-matrix analysis of (2022Ba39).</p> <p>J<sup><math>\pi</math></sup>: Supported by mirror level analysis in (2022Ba39).  <math>\theta_p^2</math>=0.08 (2022Ba39).</p>
9.8×10 <sup>3</sup> ? 3	0 <sup>+</sup>	4200 keV	1.4 <sup>d</sup> 6	<p><math>\Gamma_{\alpha}</math>=4200 keV (2022Ba39)</p> <p>E(level),<math>\Gamma</math>,J<sup><math>\pi</math></sup>,<math>\theta_{\alpha}^2</math>: From the multi-channel R-matrix analysis of (2022Ba39).</p> <p>E(level): (2022Ba39) reports that this state is a superradiant state (see text for definition) that decays into the L=0, n=5 <math>\alpha</math>-particle channel. A simple <math>\alpha</math>+core potential model was used to calculate the phase shift for this broad L=0 state. The depth of the potential was tuned to obtain a relative motion wave function with n=5 nodes (as indicated by the shell model calculations performed in (2022Ba39)). The phase shift, <math>\sin^2(\theta_{ps})</math>, deduced from R-matrix and this simple potential model agreed well. The simple potential model reproduced the energy and the width of this broad state well, indicating that the description of this scattering feature in the R-matrix analysis of (2022Ba39) as an <math>\alpha</math>-particle plus <sup>14</sup>O core is valid.</p> <p>E(level): Evaluator considered this state tentative because the spectra presented in (2022Ba39) show little indication of this state. Also, the</p>

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<sup>4</sup>He(<sup>14</sup>O, $\alpha$ ):res **2008Fu07,2022Ba39 (continued)**

<sup>18</sup>Ne Levels (continued)

E(level) <sup>a</sup>	J <sup><math>\pi</math></sup> <sup>c</sup>	$\Gamma$	$\theta_{\alpha}^2$ <sup>e</sup>	Comments
10.07×10 <sup>3</sup> 4	1 <sup>-</sup>	302 keV 32		analysis of (2022Ba39) for this state seems to be guided by those of (2014Av04, 2009Jo08) for the proposed <sup>18</sup> O mirror level. In those analyses, a very broad <sup>18</sup> O state was necessary to fit the <sup>14</sup> C+ $\alpha$ excitation function. J <sup><math>\pi</math></sup> : Supported by mirror level analysis in (2022Ba39). (2022Ba39) reports that the proton decay channel is highly suppressed. $\Gamma_p$ =95 keV 10; $\Gamma_{\alpha}$ =207 keV 30 (2010Ha15) E(level): From (2010Ha15: associated with E <sub>c.m.</sub> =4.95 MeV 4). See also 10.1 MeV (2008Fu07: from E <sub>c.m.</sub> =5.0 MeV). E(level): (2008Fu07) reports that this state may be the mirror of the 1 <sup>-</sup> state in <sup>18</sup> O at 9.85 MeV 5. The presence of this <sup>18</sup> Ne state improved their R-matrix fit in the energy region near the tail of the <sup>18</sup> Ne*(9.2 MeV) state corresponding to the resonance at E <sub>c.m.</sub> =4.1 MeV. $\Gamma$ : From (2010Ha15). See also $\Gamma$ =0.4 MeV and $\Gamma_{\alpha}$ =300 keV (2008Fu07). J <sup><math>\pi</math></sup> : From the R-matrix analyses of (2008Fu07: J <sup><math>\pi</math></sup> =(1 <sup>-</sup> )) and (2010Ha15: J <sup><math>\pi</math></sup> =1 <sup>-</sup> ).
10.56×10 <sup>3</sup> 4	1 <sup>-</sup>	380 keV	0.11 <sup>d</sup> 5	$\Gamma_{\alpha}$ =320 keV; $\Gamma_p$ =60 keV (2022Ba39) E(level), $\Gamma$ ,J <sup><math>\pi</math></sup> , $\theta_{\alpha}^2$ : From the multi-channel R-matrix analysis of (2022Ba39). E(level): See also E <sub>x</sub> =10.49 keV 2 deduced from the R-matrix fit of (2010Ha15: associated with E <sub>c.m.</sub> =5.37 MeV 2); and E <sub>x</sub> =10.6 MeV deduced from the R-matrix analysis of (2008Fu07: associated with E <sub>c.m.</sub> =5.5 MeV). The study of (2022Ba39) has more angular coverage, and thus their reported excitation energy within this energy region is adopted. $\Gamma$ : See also $\Gamma$ =0.2 MeV obtained from R-matrix analysis of (2008Fu07) for E <sub>x</sub> =10.6 MeV. J <sup><math>\pi</math></sup> : Supported by mirror level analysis in (2022Ba39). See also the tentative assignment of (J <sup><math>\pi</math></sup> ≥2) from the R-matrix analysis of (2008Fu07) for the 10.6-MeV state mentioned above. $\theta_p^2$ =0.01 (2022Ba39).
10.8×10 <sup>3</sup> 1	2 <sup>+</sup>	1580 keV	0.55 <sup>d</sup> 3	$\Gamma_{\alpha}$ =1350 keV; $\Gamma_p$ =230 keV (2022Ba39) E(level), $\Gamma$ ,J <sup><math>\pi</math></sup> , $\theta_{\alpha}^2$ : From multi-channel R-matrix analysis of (2022Ba39). J <sup><math>\pi</math></sup> : Supported by mirror level analysis in (2022Ba39). $\theta_p^2$ =0.02 (2022Ba39).
11.0×10 <sup>3</sup> 1	3 <sup>-</sup>	1130 keV	0.21 <sup>d</sup> 7	$\Gamma_{\alpha}$ =380 keV; $\Gamma_p$ =750 keV (2022Ba39) E(level), $\Gamma$ ,J <sup><math>\pi</math></sup> , $\theta_{\alpha}^2$ : From the multi-channel R-matrix analysis of (2022Ba39). J <sup><math>\pi</math></sup> : Supported by mirror level analysis in (2022Ba39). $\theta_p^2$ =0.09 (2022Ba39).
11.23×10 <sup>3</sup> ? <sup>b</sup> 8	6 <sup>+</sup>	15 keV	0.04 3	$\Gamma_{\alpha}$ =5 keV; $\Gamma_p$ =10 keV (2022Ba39) E(level), $\Gamma$ ,J <sup><math>\pi</math></sup> , $\theta_{\alpha}^2$ : From the multi-channel R-matrix analysis of (2022Ba39). E(level): This state was manually added by (2022Ba39) and the spin-parity assignment was varied until the data around E <sub>x</sub> =11-MeV excitation energy was reproduced by the best R-matrix fit. The statistics for this state are low in (2022Ba39), and more data are required to confirm the existence of this state. Therefore, (2022Ba39) present it in parentheses and presumably considered it tentative. J <sup><math>\pi</math></sup> : Supported by mirror level analysis in (2022Ba39). $\theta_p^2$ =0.02 (2022Ba39).
11.31×10 <sup>3</sup> 4	5 <sup>-</sup>	65 keV	0.03 2	$\Gamma_{\alpha}$ =15 keV; $\Gamma_p$ =50 keV (2022Ba39) E(level), $\Gamma$ ,J <sup><math>\pi</math></sup> , $\theta_{\alpha}^2$ : From the multi-channel R-matrix analysis of (2022Ba39).

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<sup>4</sup>He(<sup>14</sup>O,α):res **2008Fu07,2022Ba39 (continued)**

<sup>18</sup>Ne Levels (continued)

E(level) <sup>a</sup>	J <sup>π</sup> <sup>c</sup>	Γ	θ <sub>α</sub> <sup>2e</sup>	Comments
11.74×10 <sup>3</sup> 5	1 <sup>-</sup>	360 keV	0.09 1	E(level): See also 11.3 MeV (2008Fu07: from E <sub>c.m.</sub> =6.2 MeV). Γ: See also Γ=0.1 MeV (2008Fu07: using R-matrix analysis). J <sup>π</sup> : Supported by mirror level analysis in (2022Ba39). See also (J≥4) from the R-matrix analysis of (2008Fu07). θ <sub>p</sub> <sup>2</sup> =0.02 (2022Ba39). Γα=310 keV; Γ <sub>p</sub> =50 keV (2022Ba39) E(level),Γ,J <sup>π</sup> ,θ <sub>α</sub> <sup>2</sup> : From the multi-channel R-matrix analysis of (2022Ba39). See also E <sub>x</sub> =11.61 MeV 9 deduced from the R-matrix fit (2010Ha15) and associated with E <sub>c.m.</sub> =6.49 MeV 9. J <sup>π</sup> : Supported by mirror level analysis in (2022Ba39). θ <sub>p</sub> <sup>2</sup> =0.01 (2022Ba39).
11.8×10 <sup>3</sup> 2	6 <sup>+</sup>	260 keV	0.23 <sup>d</sup> 7	Γα=40 keV; Γ <sub>p</sub> =220 keV (2022Ba39) E(level),Γ,J <sup>π</sup> ,θ <sub>α</sub> <sup>2</sup> : From the multi-channel R-matrix analysis of (2022Ba39). E(level): See also 11.8 MeV (2008Fu07: from E <sub>c.m.</sub> =6.7 MeV). Γ: See also Γ=0.2 MeV from the R-matrix fit of (2008Fu07). J <sup>π</sup> : Supported by mirror level analysis in (2022Ba39). See also (J≥3) from the R-matrix fit of (2008Fu07). θ <sub>p</sub> <sup>2</sup> =0.34 (2022Ba39).
12.12×10 <sup>3</sup> 4	3 <sup>-</sup>	280 keV	0.07 3	Γα=180 keV; Γ <sub>p</sub> =100 keV (2022Ba39) E(level): Weighted average of 12.02 MeV 10 (2010Ha15: from E <sub>c.m.</sub> =6.90 MeV 10); and 12.13 MeV 4 (2022Ba39). E(level): (2010Ha15) claims that this state was first observed in their experiment. However, a state was observed at 12100 keV from the complete reconstruction of the invariant mass of the <sup>16</sup> O+2p events observed in coincidence in (2009Ji02). Γ,J <sup>π</sup> ,θ <sub>α</sub> <sup>2</sup> : From the multi-channel R-matrix analysis of (2022Ba39). θ <sub>p</sub> <sup>2</sup> =0.01 (2022Ba39).
12.41×10 <sup>3</sup> 9	6 <sup>+</sup>	350 keV	0.56 <sup>d</sup> 26	Γα=170 keV; Γ <sub>p</sub> =180 keV (2022Ba39) E(level): From (2010Ha15: associated with E <sub>c.m.</sub> =7.29 MeV 9). See also 12.4 MeV 2 (2022Ba39); and 12.3 MeV (2008Fu07: from E <sub>c.m.</sub> =7.2 MeV). Γ: From the multi-channel R-matrix analysis of (2022Ba39). See also Γ=0.2 MeV deduced from the R-matrix fit of (2008Fu07). J <sup>π</sup> : From the R-matrix analysis of (2022Ba39) supported by their mirror analysis. See also (J≥4) from the R-matrix analysis of (2008Fu07). θ <sub>α</sub> <sup>2</sup> : From the R-matrix analysis of (2022Ba39). θ <sub>p</sub> <sup>2</sup> =0.22 (2022Ba39).
12.45×10 <sup>3</sup> 2	3 <sup>-</sup>	390 keV	0.07 3	Γα=180 keV; Γ <sub>p</sub> =210 keV (2022Ba39) E(level),Γ,J <sup>π</sup> ,θ <sub>α</sub> <sup>2</sup> : From the multi-channel R-matrix analysis of (2022Ba39). J <sup>π</sup> : Supported by mirror level analysis in (2022Ba39). θ <sub>p</sub> <sup>2</sup> =0.03 (2022Ba39).
12.7×10 <sup>3</sup> 2	3 <sup>-</sup>	2240 keV	0.7 <sup>d</sup> 2	Γα=2000 keV; Γ <sub>p</sub> =240 keV (2022Ba39) E(level),Γ,J <sup>π</sup> ,θ <sub>α</sub> <sup>2</sup> : From the multi-channel R-matrix analysis of (2022Ba39). Note that Γ=2300 keV was mistakenly reported in Table I of (2022Ba39). J <sup>π</sup> : Supported by mirror level analysis in (2022Ba39). θ <sub>p</sub> <sup>2</sup> =0.02 (2022Ba39).
12.87×10 <sup>3</sup> 16	5 <sup>-</sup>	670 keV	0.48 <sup>d</sup> 12	Γα=530 keV; Γ <sub>p</sub> =140 keV (2022Ba39) E(level): Weighted average of 12.82 MeV 25 (2010Ha15: from E <sub>c.m.</sub> =7.70 MeV 25); and 12.9 MeV 2 (2022Ba39). See also 12.7 MeV (2008Fu07: from E <sub>c.m.</sub> =7.6 MeV). Γ: From (2022Ba39). See also Γ=0.3 MeV (2008Fu07). J <sup>π</sup> : From the R-matrix analyses of (2008Fu07: (J≥5)); and (2022Ba39: J <sup>π</sup> =5 <sup>-</sup> supported by mirror level analysis). θ <sub>α</sub> <sup>2</sup> : From the multi-channel R-matrix analysis of (2022Ba39).

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<sup>4</sup>He(<sup>14</sup>O, $\alpha$ ):res **2008Fu07,2022Ba39** (continued)

<sup>18</sup>Ne Levels (continued)

E(level) <sup>a</sup>	J <sup><math>\pi</math></sup> <sup>c</sup>	$\Gamma$	$\theta_{\alpha}^2$ <sup>e</sup>	Comments
13.3×10 <sup>3</sup> 3	4 <sup>+</sup>	870 keV	0.37 <sup>d</sup> 4	$\theta_p^2=0.04$ (2022Ba39). $\Gamma\alpha=850$ keV; $\Gamma_p=20$ keV (2022Ba39) E(level), $\Gamma$ ,J <sup><math>\pi</math></sup> , $\theta_{\alpha}^2$ : From the multi-channel R-matrix analysis of (2022Ba39). J <sup><math>\pi</math></sup> : Supported by mirror level analysis in (2022Ba39). $\theta_p^2<0.01$ (2022Ba39).
13.4×10 <sup>3</sup> 2	2 <sup>+</sup>	1800 keV	0.45 <sup>d</sup> 8	$\Gamma\alpha=1750$ keV; $\Gamma_p=50$ keV (2022Ba39) E(level), $\Gamma$ ,J <sup><math>\pi</math></sup> , $\theta_{\alpha}^2$ : From the multi-channel R-matrix analysis of (2022Ba39). J <sup><math>\pi</math></sup> : Supported by mirror level analysis in (2022Ba39). $\theta_p^2<0.01$ (2022Ba39).
13.73×10 <sup>3</sup> 1	1 <sup>-</sup>	1190 keV	0.2 <sup>d</sup> 1	$\Gamma\alpha=780$ keV; $\Gamma_p=410$ keV (2022Ba39) E(level), $\Gamma$ ,J <sup><math>\pi</math></sup> , $\theta_{\alpha}^2$ : From the multi-channel R-matrix analysis of (2022Ba39). Note that $\Gamma=1200$ keV is mistakenly reported in Table I of (2022Ba39). J <sup><math>\pi</math></sup> : Supported by mirror level analysis in (2022Ba39). $\theta_p^2=0.04$ (2022Ba39).
13.79×10 <sup>3</sup> 8	5 <sup>-</sup>	290 keV	0.14 <sup>d</sup> 10	$\Gamma\alpha=220$ keV; $\Gamma_p=70$ keV (2022Ba39) E(level), $\Gamma$ ,J <sup><math>\pi</math></sup> , $\theta_{\alpha}^2$ : From the multi-channel R-matrix analysis of (2022Ba39). J <sup><math>\pi</math></sup> : Supported by mirror level analysis in (2022Ba39). $\theta_p^2=0.02$ (2022Ba39).
14.15×10 <sup>3</sup> 21	4 <sup>+</sup>	630 keV	0.14 <sup>d</sup> 10	$\Gamma\alpha=380$ keV; $\Gamma_p=250$ keV (2022Ba39) E(level), $\Gamma$ ,J <sup><math>\pi</math></sup> , $\theta_{\alpha}^2$ : From the multi-channel R-matrix analysis of (2022Ba39). Note that Table I of (2022Ba39) mistakenly reports $\Gamma=620$ keV. E(level): See also 14.1 MeV (2008Fu07: from E <sub>c.m.</sub> =9.0 MeV). J <sup><math>\pi</math></sup> : Supported by mirror level analysis in (2022Ba39). $\theta_p^2=0.03$ (2022Ba39).
14.6×10 <sup>3</sup> 7	5 <sup>-</sup>	1180 keV	0.27 <sup>d</sup> 20	$\Gamma\alpha=520$ keV; $\Gamma_p=660$ keV (2022Ba39) E(level), $\Gamma$ ,J <sup><math>\pi</math></sup> , $\theta_{\alpha}^2$ : From the multi-channel R-matrix analysis of (2022Ba39). E(level): See also E <sub>x</sub> =14.5 MeV (2008Fu07: from E <sub>c.m.</sub> =9.4 MeV). J <sup><math>\pi</math></sup> : Supported by mirror level analysis in (2022Ba39). $\theta_p^2=0.14$ (2022Ba39).
14.8×10 <sup>3</sup> 2	3 <sup>-</sup>	5300 keV	1.0 <sup>d</sup> 2	$\Gamma\alpha=4000$ keV; $\Gamma_p=1300$ keV (2022Ba39) E(level), $\Gamma$ ,J <sup><math>\pi</math></sup> , $\theta_{\alpha}^2$ : From the multi-channel R-matrix analysis of (2022Ba39). J <sup><math>\pi</math></sup> : Supported by mirror level analysis in (2022Ba39). $\theta_p^2=0.12$ (2022Ba39).
14.9×10 <sup>3</sup> <sup>b</sup> 1	5 <sup>-</sup>	90 keV	0.03 2	$\Gamma\alpha=60$ keV; $\Gamma_p=30$ keV (2022Ba39) E(level), $\Gamma$ ,J <sup><math>\pi</math></sup> , $\theta_{\alpha}^2$ : From the multi-channel R-matrix analysis of (2022Ba39). E(level): See also E <sub>x</sub> =15.0 MeV (2008Fu07: from E <sub>c.m.</sub> =9.9 MeV). J <sup><math>\pi</math></sup> : Supported by mirror level analysis in (2022Ba39). $\theta_p^2=0.01$ (2022Ba39).
16.26×10 <sup>3</sup> 2	2 <sup>+</sup>	1100 keV	0.2 <sup>d</sup> 1	$\Gamma\alpha=1000$ keV; $\Gamma_p=100$ keV (2022Ba39) E(level), $\Gamma$ ,J <sup><math>\pi</math></sup> , $\theta_{\alpha}^2$ : From the multi-channel R-matrix analysis of (2022Ba39). E(level): This level was necessary to reproduce the structure observed in the measured <sup>14</sup> O+ $\alpha$ excitation function between 16 and 17 MeV at various angles (2022Ba39). See also E <sub>x</sub> =16.5 MeV (2008Fu07: from E <sub>c.m.</sub> =11.4 MeV). J <sup><math>\pi</math></sup> : Supported by mirror level analysis in (2022Ba39). $\theta_p^2=0.01$ (2022Ba39).
16.9×10 <sup>3</sup> <sup>b</sup> 2	2 <sup>+</sup>	2400 keV	0.3 <sup>d</sup> 2	$\Gamma\alpha=1500$ keV; $\Gamma_p=900$ keV (2022Ba39) E(level), $\Gamma$ ,J <sup><math>\pi</math></sup> , $\theta_{\alpha}^2$ : From the multi-channel R-matrix analysis of (2022Ba39). J <sup><math>\pi</math></sup> : Supported by mirror level analysis in (2022Ba39). $\theta_p^2=0.07$ (2022Ba39).

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$^4\text{He}(^{14}\text{O},\alpha)$ :res 2008Fu07,2022Ba39 (continued) $^{18}\text{Ne}$  Levels (continued)

- <sup>a</sup> Level energies from (2008Fu07) and (2010Ha15) that are reported here are recalculated using  $E_x(^{18}\text{Ne})=E_{\text{c.m.}}+S_\alpha(^{18}\text{Ne})$ , where  $S_\alpha$  is the  $\alpha$ -separation energy for  $^{18}\text{Ne}$ , and  $E_{\text{c.m.}}$  values are from (2008Fu07) and/or (2010Ha15). To obtain  $S_\alpha$ , the masses of  $^{14}\text{O}$ ,  $^{18}\text{Ne}$  and  $^4\text{He}$  are taken from (2021Wa16: AME-2020).
- <sup>b</sup> The data for the states located near the low- or high-energy edge of the excitation function measured by (2022Ba39) are incomplete. Also, due to the high thresholds in some detectors used in the experiment of (2022Ba39), the angular distributions in the excitation energy range from 7 to 8 MeV are incomplete. Therefore, (2022Ba39) reported these states in parentheses and presumably considered them as tentative.
- <sup>c</sup> The lower limit spin estimations given by (2008Fu07) for the high energy  $^{18}\text{Ne}$  resonances are based on the assumption that the reduced width for the proton decay channel with the most favorable penetrability is  $\sim 10\%$  of the reduced width for the  $\alpha$ -decay channel. If this ratio changes to 15%, the estimated spin values from (2008Fu07) should be increased by at least one unit.
- <sup>d</sup> This level has a pronounced  $\alpha$ -cluster structure reported by (2022Ba39), which is demonstrated with the large ( $>0.1$ ) dimensionless reduced width,  $\theta_\alpha^2$ .
- <sup>e</sup> (2022Ba39):  $\theta_\alpha^2=\gamma_\alpha^2/\gamma_{\text{SP}}^2$ , where  $\gamma_\alpha^2$  is the  $\alpha$ -reduced partial width, and  $\gamma_{\text{SP}}^2=\hbar^2/\mu R^2$  is the single-particle limit calculated at channel radius  $R=5.2$  fm.  $\theta_\alpha^2$  is the  $\alpha$ -dimensionless reduced width.

<sup>9</sup>Be(<sup>17</sup>Ne,<sup>18</sup>Ne) 2019Ch16

2019Ch16: <sup>9</sup>Be(<sup>17</sup>Ne,X) E=58.2 MeV; measured the reaction products using the HiRA High-Resolution position sensitive ΔE-E telescope array covering  $\phi_{lab,zenith}=2^\circ$  to  $13.9^\circ$ . The target was surrounded by the  $\gamma$ -ray CAESAR CAESium iodide ARray covering  $\theta_{lab,polar}=57.5^\circ-122.4^\circ$  with a complete azimuthal coverage. Measured  $\gamma$ -particle, p-<sup>17</sup>F, and  $\alpha$ -<sup>14</sup>O coincidences. Used invariant mass spectroscopy and deduced the <sup>18</sup>Ne invariant mass excitation spectrum. Performed shell model calculations using OXBASH to obtain theoretical spectroscopic factors. Deduced branching ratios and  $\sigma$  for <sup>18</sup>Ne states.

<sup>18</sup>Ne Levels

A systematic uncertainty of  $\pm 15\%$  is added to the cross sections of the following states according to the discussions found in (2019Ch16).

E(level) <sup>g</sup>	J <sup><math>\pi</math>gh</sup>	$\Gamma_{p_1}/\Gamma^{gi}$	Comments
4514 <sup>b</sup> 4	1 <sup>-</sup>	<0.125 <sup>j</sup>	$\Gamma_{p_1}/\Gamma$ : (2019Ch16) mentions that there is a possibility for this result to be overestimated due to other sources of background that may have been unaccounted for, or from the overlap of some of the nearby states. Even though (2019Ch16) deduced an upper limit of 12.5% for the branching ratio of the decay of this state to <sup>17</sup> F*(495 keV), the authors expect the actual value to be extremely small as it is energetically more favorable for this state to proton decay to <sup>17</sup> F <sub>g.s.</sub> rather than to <sup>17</sup> F*(495 keV) level. A shell-model estimation of $\Gamma_{p_1}/\Gamma_{tot}=1.32\times 10^{-6}$ by (2019Ch16) confirms this hypothesis. $\sigma_{peak}=133 \mu b$ 8 (stat.) 20 (sys.) (2019Ch16). $C^2S(d_{3/2})=0.015$ and $C^2S(s_{1/2})=0.365$ (2019Ch16: both from shell model calculations). However, the <i>s</i> -wave transfer should be suppressed due to momentum mismatch. Note that the authors state that <i>either the effect of the momentum mismatch is not as large as expected, or these shell model predictions are in error.</i>
4594 <sup>a</sup> 12	0 <sup>+</sup>	>0.16 <sup>j</sup>	$\Gamma_{p_1}/\Gamma_{tot}=0.036$ (2019Ch16: from a shell model calculation). $\sigma_{peak}=11 \mu b$ 3 (stat.) 2 (sys.) (2019Ch16). In the text, this value was reported as $\sigma_{peak}=13 \mu b$ 3 (stat.) 2 (sys.). The authors also mention that this cross section is only for the observed branch from the decay to <sup>17</sup> F(495 keV). They estimate that the total cross section for this state must be less than 81 $\mu b$ . Considering the $\pm 15\%$ systematic uncertainty, this upper limit should be $\sigma_{tot}<69 \mu b$ . $C^2S(1p_{1/2})=0.66$ (2019Ch16: from shell model calculations). However, the larger momentum mismatch for <i>p</i> -wave capture should suppress this yield relative to those for <i>d</i> -wave capture.
5135 <sup>b</sup> 7	3 <sup>-</sup>	<0.009 <sup>j</sup>	E(level): The uncertainty in the excitation energy of this state deduced from the invariant mass of p+ <sup>17</sup> F is reported as 2 keV in Table IV of (2019Ch16). Furthermore, (2019Ch16) reports a $\pm 6.6$ keV systematic uncertainty (see text) for this level. So, the evaluator increased the uncertainty to 7 keV by adding the statistical and systematic uncertainties in quadrature such that $E_x=5135$ keV 2 (stat.) 7 (sys.). $J^\pi: J^\pi=2^+$ is ruled out because it is not expected to be populated by the <sup>9</sup> Be( <sup>17</sup> Ne, <sup>18</sup> Ne) reaction. $\Gamma_{p_1}/\Gamma_{tot}=3.6\times 10^{-4}$ (2019Ch16: from a shell model calculation). $\sigma_{peak}=1206 \mu b$ 20 (stat.) 181 (sys.) (2019Ch16). $C^2S(1d_{5/2})=0.65$ (2019Ch16: from shell model calculations).
5457 <sup>b</sup> 8	2 <sup>-</sup>	<0.19 <sup>j</sup>	$\Gamma_{p_1}/\Gamma_{tot}=0.0022$ (2019Ch16: from a shell model calculation). $\sigma_{peak}=186 \mu b$ 13 (stat.) 28 (sys.) (2019Ch16). $C^2S(1d_{5/2})=0.23$ and $C^2S(d_{3/2})=0.12$ (2019Ch16: both from shell model calculations).
6150 <sup>b</sup>	1 <sup>-</sup>	0.65 <sup>j</sup>	E(level): This energy was fixed to 6150 keV from (1995Ti07). $\Gamma_{p_1}/\Gamma$ : Fixed to $\Gamma_{p_1}/\Gamma=0.65$ from (2003B111). $\sigma_{peak}<46 \mu b$ : note that this upper limit is reported as 54 $\mu b$ at 2 $\sigma$ level (2019Ch16). Considering the 15% systematic uncertainty on this value suggested by (2019Ch16), the upper limit is altered by the evaluator to 46 $\mu b$ .
$\approx 6.3\times 10^3$ <sup>b</sup>	(2 <sup>-</sup> , 3 <sup>-</sup> )	<0.12 <sup>j</sup>	E(level): Likely a doublet consisting of $E_x=6279$ keV 36 and $E_x=6369$ keV 36 (2019Ch16).

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<sup>9</sup>Be(<sup>17</sup>Ne,<sup>18</sup>Ne) **2019Ch16 (continued)**

<sup>18</sup>Ne Levels (continued)

E(level) <sup>g</sup>	Γ <sup>g</sup>	Comments
		<p><math>\Gamma_{p_1}/\Gamma</math>: The reported upper limit branching ratio is for the pair of the two members of the 6.3-MeV unresolved doublet (see above).</p> <p><math>\sigma_{\text{peak}}=354 \mu\text{b}</math> 17 (stat.) 53 (sys.) (2019Ch16): this is the total cross section for the likely unresolved doublet states.</p>
9111 <sup>ce</sup> 25	<60 <sup>f</sup> keV	<p>E(level): (2019Ch16) argues that this state is not the same as the 9.2 MeV with <math>\Gamma=300</math> keV level observed in (2008Fu07), and that the 9.111-MeV state observed in (2019Ch16) does not have a strong <math>\alpha</math>-cluster structure contribution to be excited via <math>\alpha</math> scattering.</p> <p><math>\sigma_{\text{peak}}=52 \mu\text{b}</math> 5 (stat.) 8 (sys.) (2019Ch16).</p>
11584 <sup>ce</sup> 64	<650 <sup>f</sup> keV	<p><math>\sigma_{\text{peak}}\sim 18 \mu\text{b}</math> 3 (sys.) (2019Ch16).</p>
16794 <sup>de</sup> 29	328 keV 68	<p>T=2 (2019Ch16)</p> <p><math>\sigma_{\text{peak}}=182 \mu\text{b}</math> 11 (stat.) 27 (sys.) (2019Ch16).</p> <p>(2019Ch16): this state appears to have an exotic decay involving isospin symmetry breaking <math>\alpha</math> and proton decay branches: (1) <math>p+^{17}\text{F}^*(11.192 \text{ MeV}, 1/2^-, T=3/2) \rightarrow \alpha+^{13}\text{N}^*(2.365 \text{ MeV}, 1/2^+) \rightarrow p+^{12}\text{C}_{\text{g.s.}}</math>, and (2) <math>p+^{17}\text{F}^*(11.192 \text{ MeV}, 1/2^-, T=3/2) \rightarrow p+^{16}\text{O}^*(9.585 \text{ MeV}, 1^-) \rightarrow \alpha+^{12}\text{C}_{\text{g.s.}}</math>. An additional smaller branch to the <math>^{16}\text{O}^*(2_2^+)</math> state, which then decays to the <math>^{12}\text{C}_{\text{g.s.}}</math> via <math>\alpha</math>-emission cannot be ruled out. The branching ratio of the decay of the isobaric analog state in <math>^{17}\text{F}^*(11.192 \text{ MeV})</math>, which is part of the exotic decay of this state, is estimated to be <math>\Gamma_{\alpha}/\Gamma_p=65\%</math> 9 (2019Ch16).</p> <p>(2019Ch16): using the isobaric multiplet mass equation for the <math>J^\pi=2_1^-</math> and <math>3_1^-</math> states in A=18 (T=2 multiplet), it appears that this state lines up (with a larger than expected deviation of 140 keV 34) with the <math>J^\pi=3^-</math> analog states in <sup>18</sup>N, <sup>18</sup>O, and <sup>18</sup>Na. However, the intrinsic width of this state (328 keV 68) casts doubt on the <math>J^\pi=3^-</math> assumption because in that case, its analog state in <sup>18</sup>Na*(0.83 MeV, 3<sup>-</sup>) has a much narrower width of <math>\Gamma=42</math> keV 10 (see Adopted Levels of <sup>18</sup>Na in ENSDF). The state with a comparable width in <sup>18</sup>Na is the <sup>18</sup>Na*(0.59 MeV, 0<sup>-</sup>) state, whose <math>J^\pi</math> assignment is not of interest and it occurs at 240 keV lower energy than the <sup>18</sup>Na*(0.83 MeV, 3<sup>-</sup>) state. So, (2019Ch16) reported that it is possible that the <sup>18</sup>Ne state reported here is a multiplet of a number of unresolved states of <sup>18</sup>Ne.</p>

<sup>a</sup> Decays to <sup>17</sup>F\*(495 keV)+p.

<sup>b</sup> Decays to <sup>17</sup>F<sub>g.s.</sub>+p.

<sup>c</sup> Decays to <sup>14</sup>O<sub>g.s.</sub>+ $\alpha$ .

<sup>d</sup> Observed in the <sup>12</sup>C+ $\alpha$ +2p decay channel.

<sup>e</sup> Due to low efficiency and poor resolution for observing this state in the p+<sup>17</sup>F decay channel, the sensitivity to detect evidence for the decay of this state via p+<sup>17</sup>F is significantly reduced (2019Ch16).

<sup>f</sup> At 1 $\sigma$  level.

<sup>g</sup> From (2019Ch16).

<sup>h</sup> From comparison with <sup>18</sup>O mirror levels, comparison with prior measurements, and by considering the angular momentum selection rules for the <sup>9</sup>Be+<sup>17</sup>Ne reaction given that the momentum mismatch (due to fast beam's higher energy) favors neutron capture to  $d_{3/2}$  or  $d_{5/2}$  shells.

<sup>i</sup> Branching ratio for the decay of <sup>18</sup>Ne\* state via <sup>17</sup>F\*(495 keV)+p channel. (2019Ch16) reports that these results are probably an overestimation of these excited state branches as other [not accounted for] sources of background are present.

<sup>j</sup> At 2 $\sigma$  level.

$^9\text{Be}(^{18}\text{Ne}, ^{18}\text{Ne}')$  2001ZeZZ

**2001ZeZZ:**  $^9\text{Be}(^{18}\text{Ne}, ^{18}\text{Ne}\rightarrow\text{p}+^{17}\text{F})$ ,  $^9\text{Be}(^{18}\text{Ne}, ^{18}\text{Ne}\rightarrow 2\text{p}+^{16}\text{O})$   $E\approx 30$ -40 MeV/nucleon; measured p- $^{17}\text{F}$  coincidences. The 2p emission from  $^{18}\text{Ne}^*$  was measured via detecting triple p-p- $^{16}\text{O}$  coincidences measured by the MUST detector assembly and the SPEG spectrometer. Deduced the  $^{18}\text{Ne}$  invariant mass and the excitation function of  $^{18}\text{Ne}$ . The measured excitation energy and angular distributions of protons and decay fragments agree well with the predictions of a break-up model calculation based on solving the time-dependent Schrödinger equation. The incomplete reconstruction of the missing mass prevented detection of any  $^2\text{He}$  emission from the  $^{18}\text{Ne}^*(6.15\text{-MeV})$  state. So this study can neither confirm or negate the results of (2001Go01) regarding to the diproton decay of the 6.15-MeV state in  $^{18}\text{Ne}$ .

 $^{18}\text{Ne}$  Levels

<u>E(level)<sup>a</sup></u>	<u><math>\Gamma</math> (MeV)<sup>a</sup></u>	<u>Comments</u>
$4.91\times 10^3$ 1	0.74 MeV 2	E(level): From reconstruction of the $^{18}\text{Ne}$ missing mass via detecting the proton- $^{17}\text{F}$ coincidences. (2001ZeZZ) reports that this state corresponds to a mixture of the $^{18}\text{Ne}$ excited states located between 4.52 MeV and 5.45 MeV. A simulation carried out assuming that the observed state is solely from the proton decay of the resonant state at 5.11 MeV gave rise to a peak of approximately 300 keV wide. The broad width suggests multiple unresolved states are populated. Therefore, this result is not included in the Adopted Levels.

<sup>a</sup> From (2001ZeZZ).

$^9\text{Be}(^{20}\text{Mg},\text{X})$  [2004Ze05](#),[2010Mu12](#)

[2004Ze05](#):  $^9\text{Be}(^{20}\text{Mg}, ^{19}\text{Na})$   $E=43$  MeV/nucleon; studied breakup of  $^{19}\text{Na}$  into  $p+^{18}\text{Ne}$ ; measured the energy and scattering angle of the recoiling protons using the SPEG spectrometer and the MUST detector array covering  $\theta_{\text{lab}}=2^\circ-25^\circ$ . The  $^{18}\text{Ne}$  decay particles were measured using the focal plane detector of the SPEC spectrograph located at  $0^\circ$  covering  $\theta_{\text{lab}}=\pm 2^\circ$  in both horizontal and vertical directions. Deduced the invariant mass of  $^{18}\text{Ne}+p$  events originated from the decay of an unresolved  $^{19}\text{Na}$  state at 0.16 MeV *II*. The experimental resolution was 250 keV *50*.

[2010Mu12](#):  $^9\text{Be}(^{20}\text{Mg},\text{X})$   $E=450$  MeV/nucleon; investigated the  $2p$  decay of  $^{20}\text{Mg}$  and  $1p$  decay of  $^{19}\text{Na}$ . The trajectories of protons and the respective heavy ion particles, originating from the in-flight decay of their parent state, were measured using the Projectile Fragment Separator at GSI together with a tracking technique utilizing microstrip detectors. Reconstructed the angular correlations of the decay fragments. No momenta were measured. Energies and widths of the parent states were deduced using GEANT simulations. From  $^{18}\text{Ne}+2p$  events measured in coincidence, the  $(p_1-^{18}\text{Ne})$ - $(p_2-^{18}\text{Ne})$  angular correlations were deduced.

 $^{18}\text{Ne}$  Levels

<u>E(level)</u>	<u>Comments</u>
0	E(level): The $^{18}\text{Ne}_{\text{g.s.}}$ is populated from the $1p$ decay of $^{19}\text{Na}_{\text{g.s.}}$ ( <a href="#">2010Mu12</a> ), and from the in-flight proton decay of a state observed at 0.16 MeV <i>II</i> , which is the unresolved contribution of $^{19}\text{Na}_{\text{g.s.}}$ and $^{19}\text{Na}^*(120 \text{ keV})$ ( <a href="#">2004Ze05</a> ).

$^9\text{Be}(^{34}\text{Ar}, ^{18}\text{Ne}\gamma)$  2006Ob03

**2006Ob03:**  $^9\text{Be}(^{34}\text{Ar}, ^{18}\text{Ne}\gamma)$   $E \approx 94$ -110 MeV/nucleon; measured  $E_\gamma$ ,  $I_\gamma$ , particle- $\gamma$  coincidences, energy loss, and time-of-flight of charged particles using the S800 spectrometer's focal plane detection system. The beam was a cocktail of  $^{24}\text{Mg}$ ,  $^{25}\text{Al}$ ,  $^{26}\text{Si}$ , and  $^{34}\text{Ar}$  ions. Deduced the relative population of excited states of the  $sd$ -shell nuclei produced by fragmentation. Discussed nondissipative population. Performed shell model calculations using the Oxbash code. Deduced reaction mechanisms.

 $^{18}\text{Ne}$  Levels

The relative populations (combining the statistical feeding with the nondissipative population) of  $^{18}\text{Ne}_{g.s.}$  from the interaction of  $^9\text{Be}$  with  $^{24}\text{Mg}$ ,  $^{25}\text{Al}$ ,  $^{26}\text{Si}$ , and  $^{34}\text{Ar}$  beams at  $E_{\text{lab}}=94, 102, 109,$  and  $110$  MeV/nucleon, respectively, were deduced as  $P_k=0.8, 0.3, 0,$  and  $0.2,$  respectively (2006Ob03).

The weights of the single-particle component for the interaction of  $^9\text{Be}$  with  $^{24}\text{Mg}$ ,  $^{25}\text{Al}$ ,  $^{26}\text{Si}$ , and  $^{34}\text{Ar}$  beams at  $E_{\text{lab}}=94, 102, 109,$  and  $110$  MeV/nucleon, respectively, were deduced as  $\alpha=0.0\ 8, 0.0\ 9, 0.4\ 6,$  and  $0.0\ 8,$  respectively (2006Ob03).

<u><math>E(\text{level})^a</math></u>	<u><math>J^\pi{}^a</math></u>	<u><math>P_k</math> (%)<sup>b</sup></u>
0	$0^+$	20
1887.4	$2^+$	40
3376.4	$4^+$	26
3576.3	$0^+$	4
3616.5	$2^+$	10

<sup>a</sup> From the  $^{18}\text{Ne}$  Adopted Levels.

<sup>b</sup> The relative population of  $^{18}\text{Ne}$  in a particular state obtained from (2006Ob03).  $^{18}\text{Ne}$  is populated from interaction of  $^{34}\text{Ar}$  at 110 MeV/nucleon with a  $^9\text{Be}$  target. The given values are estimated by the evaluator based on Fig. 4 in (2006Ob03).

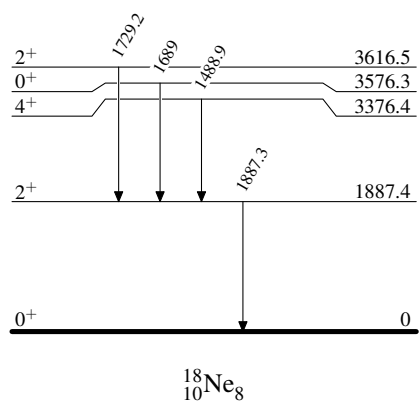
 $\gamma(^{18}\text{Ne})$ 

<u><math>E_\gamma{}^a</math></u>	<u><math>E_i(\text{level})</math></u>	<u><math>J_i^\pi</math></u>	<u><math>E_f</math></u>	<u><math>J_f^\pi</math></u>
1488.9	3376.4	$4^+$	1887.4	$2^+$
1689	3576.3	$0^+$	1887.4	$2^+$
1729.2	3616.5	$2^+$	1887.4	$2^+$
1887.3	1887.4	$2^+$	0	$0^+$

<sup>a</sup> From the  $^{18}\text{Ne}$  Adopted Gammas. Note that no information is provided by (2006Ob03) regarding the measured  $^{18}\text{Ne}$   $\gamma$ -ray transitions, their energies and intensities. The authors only mention that the highest  $\gamma$ -ray energy observed for all populated transitions (not specific to  $^{18}\text{Ne}$ ) was 2.5 MeV.

$^9\text{Be}(^{34}\text{Ar},^{18}\text{Ne}\gamma)$  2006Ob03

Level Scheme



$^{12}\text{C}(^{12}\text{C},^6\text{He})$  **1992HaZZ,1996Ha26**

**1992HaZZ, 1996Ha26:**  $^{12}\text{C}(^{12}\text{C},^6\text{He})$  E=80 MeV; measured  $^6\text{He}$  ejectiles at the focal plane of an Enge split-pole spectrograph at  $\theta_{\text{lab}}=1^\circ, 2^\circ, 4^\circ, 6^\circ, 7^\circ,$  and  $10^\circ$ . Energy resolution was  $\Delta E \sim 70$  keV (FWHM) at all angles except at  $\theta_{\text{lab}}=1^\circ$ , where the resolution was  $\sim 100$  keV (FWHM). Deduced  $^{18}\text{Ne}$  excited states, differential cross sections, and  $^6\text{He}$  angular distributions.  $(d\sigma/d\Omega)_{\text{max}} \sim 1 \mu\text{b/sr}$  was reported. Performed Hauser-Feshbach calculations using the STATIS code to compute the compound nucleus cross sections for the  $^{12}\text{C}(^{12}\text{C},^6\text{He})$  reaction. Most angular distributions did not present clear features that could be used to deduce reliable  $J^\pi$  values.

 $^{18}\text{Ne}$  Levels

E(level) <sup>a</sup>	$J^\pi$ <sup>h</sup>	Comments
$0^{bd}$	$(0^+)^i$	
$1.89 \times 10^3^{bd}$	$(2^+)^i$	
$3.38 \times 10^3^{bd}$		
$3.58 \times 10^3^{bc}$		
$3.62 \times 10^3^{bc}$		
$4.52 \times 10^3^e$		
$4.56 \times 10^3^e$		E(level): This energy must have come from the previous $^{18}\text{Ne}$ evaluation (1995Ti07) and originally reported by (1991Ga03). Note that this state was observed at $E_{\text{beam}}=10.9$ MeV and only at one angle of $\theta_{\text{lab}}=124.7^\circ$ . (2005Pa50) saw no evidence for this level and suggested that it is likely that the experiment of (1991Ga03), whose resolution was a factor of 2 poorer, was unable to resolve the states observed in (2005Pa50) at 4519 keV and 4527 keV.
$4.59 \times 10^3^e$		
$5.11 \times 10^3^f$		
$5.15 \times 10^3^f$		
$5.45 \times 10^3^d$	$(2^-)^i$	$J^\pi$ : The angular distribution of this state populated by the $^{12}\text{C}(^{12}\text{C},^6\text{He})$ reaction has the characteristics of an unnatural-parity state, with very weak population at forward angles peaking at backward angles.
$6.15 \times 10^3$	$2^-$	
$6.30 \times 10^3^{dg}$		
$7.12 \times 10^3$		
$7.35 \times 10^3$	$2^-$	
$7.62 \times 10^3$		
$7.73 \times 10^3$		
$7.94 \times 10^3$		
$8.11 \times 10^3^d$		
$8.30 \times 10^3$		
$8.45 \times 10^3?$	$3$	E(level): This tentative state, if exists, has poor statistics and is not even labeled on the spectrum shown in Fig. 6 of (1996Ha26). Therefore, it was not considered for the Adopted Levels.
$8.55 \times 10^3$		
$8.94 \times 10^3$		
$9.18 \times 10^3$		
$9.58 \times 10^3$		

<sup>a</sup> From (1996Ha26: weighted average values of the excitation energies measured at  $\theta_{\text{lab}}=2^\circ, 4^\circ, 6^\circ, 7^\circ,$  and  $10^\circ$ ).

<sup>b</sup> From Figs. 6 and 7 of (1996Ha26).

<sup>c</sup> The 3.58 MeV and 3.62 MeV doublet could not be resolved (see Fig. 6 of (1996Ha26)).

<sup>d</sup>  $E_x$  used as a calibration point in (1996Ha26).

<sup>e</sup> The 4.52-4.56-4.59-MeV triplet states were unresolved (see Fig. 6 of (1996Ha26)).

<sup>f</sup> The 5.11 MeV and 5.15 MeV doublet could not be resolved (see Fig. 6 of (1996Ha26)).

<sup>g</sup> The 6.30 MeV and 6.35 MeV doublet could not be resolved (see Table II of (1996Ha26)). The calibration favored the 6.30 MeV state, and thus this value was used as a calibration point.

<sup>h</sup> From (1996Ha26) based on Hauser-Feshbach statistical-model calculations (using the STATIS computer code) compared to the

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 ${}^{12}\text{C}({}^{12}\text{C}, {}^6\text{He})$  [1992HaZZ,1996Ha26](#) (continued) ${}^{18}\text{Ne}$  Levels (continued)

experimental angular distributions for the  ${}^{18}\text{Ne}$  states populated in the  ${}^{12}\text{C}({}^{12}\text{C}, {}^6\text{He})$  reaction at  $E_{\text{lab}}=80$  MeV.  
<sup>i</sup> From Fig. 8 of [\(1996Ha26\)](#).

$^{14}\text{N}(^{17}\text{F}, ^{18}\text{Ne})$  2003BI12,2004BI21

2003BI12, 2004BI21:  $^{14}\text{N}(^{17}\text{F}, ^{17}\text{F}), ^{14}\text{N}(^{17}\text{F}, ^{18}\text{Ne})$  E=170 MeV; measured the reaction products by a pair of position sensitive  $\Delta E$ -E silicon telescopes covering  $\theta_{\text{lab}}=2^\circ-9^\circ$ . Measured  $\gamma$ - $^{18}\text{Ne}$  coincidences using the CLARION array that consisted of 11 segmented clover Ge-detectors. Deduced the differential cross sections of the  $^{14}\text{N}(^{17}\text{F}, ^{18}\text{Ne})^{13}\text{C}$  reaction populating  $^{18}\text{Ne}$  states by gating charged particles on individual  $\gamma$ -ray transitions. The  $J^\pi$  values for strongest transitions were deduced using DWBA analysis, which is discussed in detail.

 $^{18}\text{Ne}$  Levels

<u>E(level)<sup>a</sup></u>	<u>J<sup><math>\pi</math></sup><sup>a</sup></u>	<u>L</u>	<u>Comments</u>
0	0 <sup>+</sup>		
1887.4	2 <sup>+</sup>		
3376.4	4 <sup>+</sup>	2	E(level),J <sup><math>\pi</math></sup> ,L: From (2004BI21). L and J are determined from a DWBA analysis (using a $d_{5/2}$ proton transfer to populate the 3376 keV state in $^{18}\text{Ne}$ ), and by comparison with the single particle neutron amplitude in $^{18}\text{O}$ . The spectroscopic amplitudes for the 4 <sup>+</sup> state are reported in (2004BI21) to be about 30% larger than expected.
3616.5	2 <sup>+</sup>		

<sup>a</sup> From the Adopted Levels of  $^{18}\text{Ne}$  unless otherwise noted.

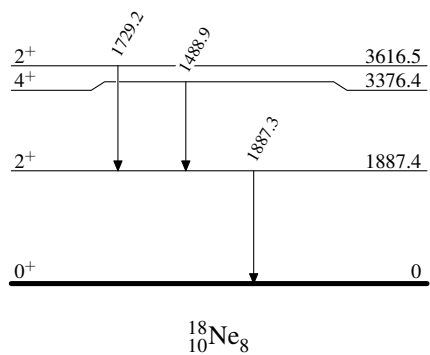
 $\gamma(^{18}\text{Ne})$ 

<u>E<sub><math>\gamma</math></sub><sup>a</sup></u>	<u>E<sub>i</sub>(level)</u>	<u>J<sub>i</sub><sup><math>\pi</math></sup></u>	<u>E<sub>f</sub></u>	<u>J<sub>f</sub><sup><math>\pi</math></sup></u>
1488.9	3376.4	4 <sup>+</sup>	1887.4	2 <sup>+</sup>
1729.2	3616.5	2 <sup>+</sup>	1887.4	2 <sup>+</sup>
1887.3	1887.4	2 <sup>+</sup>	0	0 <sup>+</sup>

<sup>a</sup> The  $\gamma$ -rays were observed in (2003BI12: see Fig. 1); however, the authors did not present the  $\gamma$ -ray energies or the excitation energies of the states involved in those transitions. The  $\gamma$ -ray energies are therefore taken from the Adopted Gammas of  $^{18}\text{Ne}$ .

$^{14}\text{N}(^{17}\text{F},^{18}\text{Ne})$  2003B112,2004B121

Level Scheme



$^{16}\text{O}(^3\text{He},n)$  **1953Ku08,2012Fo29**

- 1953Ku08:**  $^{16}\text{O}(^3\text{He},n)^{18}\text{Ne}(\beta^+)^{18}\text{F}$ ,  $^{16}\text{O}(^3\text{He},p)$   $E=21$  MeV; measured the  $^{18}\text{F}$  radiative decay and evaluated the relative cross sections of the  $^3\text{He}+\text{natO}$  and  $^3\text{He}+\text{natNi}$  reactions.
- 1960Aj01:**  $^{16}\text{O}(^3\text{He},n)$ ; measured the mass of  $^{18}\text{Ne}$ .
- 1960Aj03:**  $^{16}\text{O}(^3\text{He},n)$   $E=5.51$  MeV; measured  $E_n$  using emulsions plates mounted at  $\theta_{\text{lab}}=0^\circ, 15^\circ, 30^\circ, 45^\circ, 90^\circ,$  and  $135^\circ$ ; populated  $^{18}\text{Ne}_{\text{g.s.}}$ ; measured  $\sigma(\theta)$  for  $^{18}\text{Ne}_{\text{g.s.}}$ ; deduced  $Q_{\text{g.s.}}=-3.19$  MeV 4; deduced mass( $^{18}\text{Ne}$ )=18.00570 amu 4 and mass excess( $^{18}\text{Ne}$ )=10.64 MeV 4; deduced  $d\sigma/d\Omega(\theta=0^\circ)=1.6$  mb/sr 3 for the  $^{16}\text{O}(^3\text{He},n)^{18}\text{Ne}_{\text{g.s.}}$  reaction. No evidence for the existence of the  $^{18}\text{Ne}^*(114 \text{ keV } 15)$  proposed by (1959Du81) was found.
- 1961Du02:**  $^{16}\text{O}(^3\text{He},n)$   $E=4.5$  and  $5.6$  MeV; measured the excitation energy spectrum of the  $^{16}\text{O}(^3\text{He},n)$  reaction, and the yield of fast neutrons as well as the ratio of slow-to-fast neutrons as a function of the incident energy; measured the ground state threshold energy of 3811 keV 15 for the  $^{16}\text{O}(^3\text{He},n)$  reaction (published in (1959Du81)); interpreted the observed break in the excitation curve at 3.95 MeV as a resonance in the compound nucleus ( $^{19}\text{Ne}$ ); deduced  $m=18.011446$  amu 14 and  $\Delta M=10.658$  MeV 13 for the atomic mass and mass excess of  $^{18}\text{Ne}$ , respectively; deduced  $Q_{\text{g.s.}}=-3206$  keV 13; deduced the end-point positron energy of 3423 keV 2 for the decay of  $^{18}\text{Ne}_{\text{g.s.}}$  to  $^{18}\text{F}_{\text{g.s.}}$ .  
. No excited state of  $^{18}\text{Ne}$  was observed and the authors ruled out the  $E_x=114$  keV 15 state proposed by (1959Du81).
- 1961Ga01:**  $^{16}\text{O}(^3\text{He},n)$   $E=5.6$  and  $6.09$  MeV; measured neutrons using a pulsed beam time-of-flight neutron spectrometer; measured  $\sigma(\theta)$  of  $n_0$  group at  $\theta_{\text{c.m.}}=5^\circ-175^\circ$ . Angular distributions were observed to be forward peaked. The neutron angular distribution data were fitted with double-stripping theoretical cross sections based on the zero order spherical Bessel functions formalism of (1960Ne21). Good agreement was obtained with the theoretical prediction for  $l=0$  double stripping. This led to the  $J^\pi=0^+$  assignment for the  $^{18}\text{Ne}_{\text{g.s.}}$ ; however a knock-out mechanism could not be excluded.
- 1961To03:**  $^{16}\text{O}(^3\text{He},n)$   $E\leq 10$  MeV; measured the  $^{18}\text{Ne}$  excitation energy spectra for  $E(^3\text{He})=2-5.7$  MeV using two long  $\text{BF}_3$  counters at  $\theta_{\text{lab}}=0^\circ$  and  $90^\circ$ ; measured the time-of-flight spectrum of the  $^{16}\text{O}(^3\text{He},n)$  reaction at  $\theta_{\text{lab}}=20^\circ, 25^\circ,$  and  $35^\circ$ ; deduced  $Q_{\text{g.s.}}=-3199$  keV 6 and ground state threshold energy of 3802 keV 7 for the  $^{16}\text{O}(^3\text{He},n)$  reaction; deduced  $\Delta M=10.649$  MeV 8 and an end point energy of 3439 keV 12 for the  $^{18}\text{Ne}_{\text{g.s.}}\rightarrow^{18}\text{F}^*(1042 \text{ keV})+\beta^+$ ; confirmed the existence of no excited state below  $E_x=1.5$  MeV in  $^{18}\text{Ne}$ ; deduced 3 excited levels in  $^{18}\text{Ne}$  at  $E_x=1880$  keV 10, 3362 keV 11, and 3608 keV 12 from the measured ratio of slow-to-fast neutrons at incident energies of 3.5-10 MeV; deduced  $Q$ -values of  $-5079$  keV 8,  $-6561$  keV 9, and  $-6807$  keV 10 for the three measured excited states, respectively.
- 1962Ma61:**  $^{16}\text{O}(^3\text{He},n)$   $E=1-31$  MeV; measured the induced radioactivity from the activation by calibrated end-window proportional counters and NaI scintillators; measured the combined cross section of the  $^{16}\text{O}(^3\text{He},p)$  and  $^{16}\text{O}(^3\text{He},n)$  reactions; the summed cross section was highest at 7.7 MeV incident energy and was measured to be  $\sigma=400$  mb for the  $^{16}\text{O}(^3\text{He},n)^{18}\text{Ne}_{\text{g.s.}}$  reaction. The authors deduced  $Q_{\text{g.s.}}=-3000$  keV.
- 1964Br13:**  $^{16}\text{O}(^3\text{He},n)$   $E=25.4$  MeV; measured neutrons with  $E_n=0-25$  MeV at  $\theta_{\text{lab}}=0^\circ$  using a liquid hydrogen bubble chamber at 26 K; measured  $\sigma(E_n,\theta)$  and deduced  $d\sigma/d\Omega(\theta_{\text{lab}}=0^\circ)=2.0$  mb/sr 4; observed 5 levels of  $^{18}\text{Ne}$  at  $E_x=0, 1.88$  MeV, 3.36 MeV, 3.61 MeV, and either one or a group of levels at 5.2 MeV 3; deduced upper limits of 15.8 MeV and 16.4 MeV on the neutron energies from the  $^{16}\text{O}(^3\text{He},n2p)$  and  $^{16}\text{O}(^3\text{He},np)$  reactions, respectively. These reactions produced a continuum in the neutron spectrum.
- 1965Br42:**  $^{16}\text{O}(^3\text{He},n)$   $E=4.9-31$  MeV; measured products of various  $^3\text{He}$  induced reactions; measured the combined cross section of  $^{16}\text{O}(^3\text{He},p)$  and  $^{16}\text{O}(^3\text{He},n)$  reactions; estimated that the cross section of the latter reaction populating  $^{18}\text{Ne}_{\text{g.s.}}$  is  $\sigma=20$  mb.
- 1966Kr05:**  $^{16}\text{O}(^3\text{He},n)$   $E=11$  MeV; measured neutrons with a double scatter time-of-flight spectrometer with 1 MeV resolution; measured  $\sigma(E_n,\theta)$  at 8 angles between  $\theta_{\text{lab}}=6^\circ-50^\circ$  and deduced  $(d\sigma/d\Omega)_{\text{c.m.}}^{\text{max}}=21$  mb/sr 4 at  $\theta_{\text{c.m.}}\sim 15^\circ$ ; populated  $^{18}\text{Ne}_{\text{g.s.}}$  and  $^{18}\text{Ne}^*(1.88 \text{ MeV})$ . Using the plane wave double stripping theory of (1960Ne21), the authors deduced  $L=0$  and  $L=2$ , and  $J^\pi=0^+$  and  $J^\pi=2^+$  for these states, respectively.
- 1967Mc03:**  $^{16}\text{O}(^3\text{He},n)$   $E=4.9, 5.2,$  and  $5.6$  MeV; measured neutrons using a time-of-flight neutron spectrometer that consisted of a NE-213 liquid scintillator coupled to a PMT and long counters placed at  $\theta_{\text{lab}}=90^\circ$  and  $120^\circ$ ; measured  $\sigma(E;E_n,\theta)$  for  $^{16}\text{O}(^3\text{He},n_0)$ ; performed a plane wave Born approximation calculation and deduced  $L=0$  for  $^{18}\text{Ne}_{\text{g.s.}}$ .
- 1968Sh09:**  $^{16}\text{O}(^3\text{He},n)$   $E=8.5, 9, 9.5,$  and  $10$  MeV; measured neutrons using a time-of-flight spectrometer that consisted of a Pilot B scintillator coupled to a PMT; populated  $^{18}\text{Ne}$  levels at  $E_x=0, 1.88, 3.36, 3.61,$  and  $4.55$  MeV; measured  $\sigma(E_n,\theta)$  for  $^{18}\text{Ne}_{\text{g.s.}}$  at 10 MeV. Energy resolution: 70-300 keV.
- 1968To09,** J. H. Towle and G. J. Wall, Conf. on Low and medium energy nuclear physics, A. E. R. E., Harwell, March 1968:  
 $^{16}\text{O}(^3\text{He},n)$   $E=9.15-10.55$  MeV; measured neutrons using a neutron time-of-flight spectrometer that consisted of a liquid NE-213 scintillator coupled to 2 PMTs; measured  $\sigma(E;E_n,\theta)$  at  $\theta_{\text{c.m.}}=0^\circ-150^\circ$ ; measured  $^{18}\text{Ne}$  excitation energy spectrum at  $\theta_{\text{lab}}=20^\circ$ ; deduced  $^{18}\text{Ne}$  level energies, L, J, and  $\pi$  for the  $^{18}\text{Ne}(0, 1.88, 3.36, 3.61, 4.59 \text{ MeV})$  states from a double stripping DWBA analysis.

**$^{16}\text{O}(^3\text{He},n)$  1953Ku08,2012Fo29 (continued)**

- 1970Ad02:**  $^{16}\text{O}(^3\text{He},n)$   $E=8.84\text{--}13.5$  MeV; measured neutrons using a time-of-flight spectrometer consisting of a Pilot B plastic scintillator placed at  $\theta_{\text{lab}}=0^\circ\text{--}150^\circ$ ; energy resolution was  $<50$  keV for 1 MeV neutrons; measured  $\sigma(E;E_n,\theta)$  at  $E=9, 9.5, 10.5, 11.5,$  and  $12.5$  MeV; deduced  $^{18}\text{Ne}$  levels, L and  $J^\pi$  for the states up to  $E_x=5.14$  MeV. Comparisons with  $(^3\text{He},p)$  and  $(t,p)$  reactions are discussed.
- 1971NeZR, 1974Ne04:**  $^{16}\text{O}(^3\text{He},n)$   $E=10\text{--}20$  MeV; measured neutrons using a time-of-flight spectrometer; measured  $\sigma(E_n,\theta)$ ; deduced  $^{18}\text{Ne}$  level energies up to  $E_x=8.5$  MeV, L and  $J^\pi$  for the  $^{18}\text{Ne}^*(4513, 4587$  keV) states; discussed mirror states and calculated their Coulomb shift; discussed two-nucleon configurations for the  $0_3^+$  state in  $^{18}\text{Ne}$ ; models that assign most of the  $s_{1/2}$  strength to the  $^{18}\text{Ne}(0_3^+)$  state (**1969Be94, 1970E123**) rather than to the  $^{18}\text{Ne}(0_2^+)$  level (**1965En02, 1969Zu03, 1972Ka01**) are preferred.
- 1974PeZO, 1975Pe11:**  $^{16}\text{O}(^3\text{He},n)$   $E=18.3$  MeV; measured neutrons using a neutron time-of-flight spectrometer at  $\theta_{\text{lab}}=0^\circ\text{--}45^\circ$  with a resolution of 120 keV (FWHM); measured  $\sigma(E_n,\theta)$ ; deduced  $^{18}\text{Ne}$  level energies, L, and  $J^\pi$  values for the ground and first excited states using a zero-range DWBA analysis via DWUCK4.
- 1977Ev01:**  $^{16}\text{O}(^3\text{He},n)$   $E=15, 18,$  and  $21$  MeV; measured neutrons using the Munich neutron time-of-flight spectrometer with six counters at  $\theta_{\text{lab}}=0^\circ\text{--}40^\circ$  and two NE-213 scintillators at  $\theta_{\text{lab}}=5^\circ$  and  $15^\circ$ ; measured  $\sigma(E_n,\theta)$ ; deduced  $^{18}\text{Ne}$  level energies for the states with  $E_x\leq 8070$  keV; deduced  $J^\pi$  values using a zero-range DWBA analysis via DWUCK2; comparison with shell model calculations and the two-proton amplitudes used in the DWUCK analysis are presented.
- 1981Ne09:**  $^{16}\text{O}(^3\text{He},n)$   $E=10\text{--}22$  MeV; measured neutrons using a time-of-flight spectrometer that consisted of a plastic scintillator; measured  $\sigma(E_n,\theta)$  for  $\theta_{\text{c.m.}}=0^\circ\text{--}150^\circ$ ; deduced  $^{18}\text{Ne}$  level energies, widths, and  $J^\pi$  values (using a DWBA analysis with the code JULIE) for states with  $E_x\leq 8100$  keV; calculated two-particle Coulomb energy shifts for  $A=18, T=1$  states and found that the difference between the excitation energy of the 4.59-MeV  $0^+$  state and the analog state in  $^{18}\text{O}$  could be accounted for by a double Thomas-Ehrman shift, which gives strong evidence for the predominantly  $s_{1/2}$  character of these states.
- 1989GaZW, 1990GaZR, 1990GaZW, 1991Ga03:**  $^{16}\text{O}(^3\text{He},n)$   $E=9.5\text{--}10.5, 11,$  and  $12$  MeV; measured neutrons using a time-of-flight spectrometer consisting of plastic scintillators; measured  $\sigma(E_n,\theta)$  at  $\theta_{\text{lab}}=0^\circ, 42^\circ,$  and  $126^\circ$  ( $E_{\text{beam}}=9.8\text{--}11$  MeV); at  $\theta_{\text{lab}}=0^\circ$  and  $35^\circ$  ( $E_{\text{beam}}=10.5, 11$  and  $12$  MeV); and at  $\theta_{\text{lab}}=0^\circ$  and  $124.7^\circ$  ( $E_{\text{beam}}=10.9$  MeV); observed evidence at  $\theta_{\text{lab}}=124.7^\circ$  for a previously unresolved level in the form of excess counts that could not be attributed to background or any source other than  $^{18}\text{Ne}$ . Using the  $^{18}\text{Ne}$  mass excess of 5319 keV 5 (**1987Aj02**), an excitation energy of 4561 keV 9 was inferred for this missing  $3^+$  state by (**1991Ga03**). Deduced  $^{18}\text{Ne}$  level energies, Q-values and  $J^\pi$  values for the  $^{18}\text{Ne}^*(0, 1887, 3376, 3576, 3616, 4520, 4561,$  and  $4589$  keV) states; deduced widths for the  $^{18}\text{Ne}^*(4520, 4561,$  and  $4589$  keV) states; computed the  $^{17}\text{F}(p,\gamma)$  resonance properties, reaction rate, and the astrophysical S-factor; discussed the astrophysical implications.
- 1994Ma14:**  $^{16}\text{O}(^3\text{He},n)$   $E=7.31$  MeV; measured the neutrons corresponding to the  $^{18}\text{Ne}^*(0, 1.89, 3.38$  MeV) states using a time-of-flight spectrometer consisting of two liquid scintillators at  $\theta_{\text{lab}}=0^\circ$  and  $8.75^\circ$ ; deduced  $^{18}\text{Ne}$  level energies and Q-values for the states at  $E_x=0, 1.89$  MeV, and  $3.38$  MeV; deduced mass excesses for the  $^{18}\text{Ne}^*(0, 1.89$  MeV) states.
- 1996Ha26:**  $^{16}\text{O}(^3\text{He},n)$   $E=10.9\text{--}14.5$  MeV; measured neutrons using a time-of-flight spectrometer consisting of 3 liquid scintillators, one fixed at  $\theta_{\text{lab}}=0^\circ$ , the other two at  $\theta_{\text{lab}}=11^\circ, 23^\circ, 34^\circ, 47^\circ, 64^\circ,$  and  $79^\circ$ ; measured  $\sigma(\theta)$  at  $E_{\text{lab}}=14.5$  MeV; deduced  $^{18}\text{Ne}$  level energies,  $\Gamma$ , and  $J^\pi$  values for the  $E_x\leq 8110$  keV states. The  $J^\pi$  values were deduced using a combination of penetrability considerations (i.e., generally a larger width is expected for a state that decays via a proton carrying a lower orbital angular momentum than a state emitting a proton with a higher angular momentum) as well as zero-range DWBA analysis using DWUCK4. The authors calculated the Coulomb shifts and widths for all states of  $^{18}\text{Ne}$  up to  $E_x=7.6$  MeV; calculated the  $^{14}\text{O}(\alpha,p)$  reaction rate and the astrophysical S-factor and discussed the astrophysical implications.
- 2005Pa50:**  $^{16}\text{O}(^3\text{He},n)$   $E=9.9$  MeV at  $\theta_{\text{beam}}=0^\circ, 10.1$  MeV at  $\theta=30^\circ,$  and  $10.4$  MeV at  $\theta=60^\circ$ ; measured neutron energy spectra using an array of two plastic and one NE-213 liquid scintillators; measured  $\sigma(\theta)$ ; energy resolutions: 10, 12, and 16 keV for the aforementioned beam energies, respectively. The goal was to resolve the discrepancy between (**1991Ga03**) and (**2000Bb04**) regarding the excitation energy and width of the  $^{18}\text{Ne}^*(3_1^+)$  state. Deduced  $^{18}\text{Ne}$  level properties for the  $^{18}\text{Ne}^*(0, 1887, 3376, 3576, 3616, 4519, 4527,$  and  $4590$  keV) states; performed Hauser-Feshbach calculations to compare with the experimental differential cross sections for all the observed levels.
- 2010AIZZ, 2010Ta17, 2012A111:**  $^{16}\text{O}(^3\text{He},n)$   $E=15$  MeV; measured  $E(\text{particle})$  for the charged-particles from the decay of  $^{18}\text{Ne}^*$  resonances at  $E_x=5.1\text{--}8.09$  MeV using the LESA array that consisted of 4 Si-pad detectors covering  $\theta_{\text{lab}}=90^\circ\text{--}150^\circ$ ; measured neutrons time-of-flight using 16 liquid scintillators covering  $\theta_{\text{lab}}=11^\circ$  to  $39^\circ$ ; measured  $I_{p/\alpha}(\theta), E_n, I_n(\theta),$  p-n coincidences and  $\alpha$ -n coincidences; considered only the p, p',  $^2\text{He}$  and  $\alpha$ -decay from the populated  $^{18}\text{Ne}^*(5.1, 6.15, 6.30, 7.06, 7.95,$  and  $8.09$  MeV) levels to the  $^{17}\text{F}(0, 495$  keV) states and to  $^{16}\text{O}_{g.s.}$ ; performed a complete, event-by-event kinematics reconstruction to deduce  $^{18}\text{Ne}$  states; measured angular distributions of the protons from the  $^{18}\text{Ne}^*(p_0+^{17}\text{F}_{g.s.})$  decay channels. (**2012A111**) deduced level decay branching ratios for  $p_0$  (to  $^{17}\text{F}_{g.s.}$ ), p' (to  $^{17}\text{F}(495$  keV)), 2p and  $\alpha$  decay modes (to  $^{16}\text{O}_{g.s.}$ ); discussed the astrophysical reaction rate for  $^{14}\text{O}(\alpha,p)$ ; comparison with literature results are given. Some of the branching ratios deduced by (**2012A111**) are

**$^{16}\text{O}(^3\text{He},n)$  1953Ku08,2012Fo29 (continued)**

disputed in the literature. See for example (2012Fo29, 2019Ch16, and 2020Br14).

The  $^{16}\text{O}(^3\text{He},n)$  Studies with Relevant Information on the  $^{18}\text{Ne}(\beta^+)^{18}\text{F}$  Decay:

- 1959Du81, 1959Du83:**  $^{16}\text{O}(\text{He},n)$ ; measured the yield of slow-to-fast neutrons; deduced the excitation curve of  $^{18}\text{Ne}$  as a function of bombarding energy; observed an upward break in the excitation curve at 3.95 MeV, which was interpreted as the threshold for a possible new excited state in  $^{18}\text{Ne}$  at 114 keV 15; measured the threshold energy for the  $^{16}\text{O}(^3\text{He},n)$  reaction to be 3.811 MeV 15; deduced the half-life of  $^{18}\text{Ne}_{\text{g.s.}}$  as  $T_{1/2}=1.25$  s 20, see (1961Bu05). The state at  $E_x=114$  keV was later voided (see above).
- 1960Bu03:**  $^{16}\text{O}(\text{He},n)$ ; measured the decay of  $^{18}\text{Ne}_{\text{g.s.}}(\beta^+)^{18}\text{F}_{\text{g.s.}}$ . This study was the first to indicate that  $^{18}\text{Ne}$  decays by positron emission to the 1.04- and 1.70-MeV levels of  $^{18}\text{F}$ .
- 1961Ec02:**  $^{16}\text{O}(^3\text{He},n)$   $E=5.2$  MeV; measured the  $\gamma$ -rays from the  $^{18}\text{Ne}_{\text{g.s.}}(\beta^+)^{18}\text{F}^*\rightarrow\gamma+^{18}\text{F}_{\text{g.s.}}$  decay at  $\theta_{\text{lab}}=90^\circ$  using a lead-shielded NaI(Tl) detector. The beam was switched on and off every 2, 10, and 50 seconds using a shutter downstream the accelerator. This study only observed the superallowed decay branch, and its  $\beta$ -delayed  $\gamma$ -ray energy was measured as  $E_\gamma=1035$  keV 10. Its intensity decreased with the lifetime of  $^{18}\text{Ne}_{\text{g.s.}}$ , which was deduced as  $\tau=2.5$  s 6.
- 1961Bu05:**  $^{16}\text{O}(^3\text{He},n)$   $E=5.2$  MeV; measured  $E_\gamma=1041$  keV 5 for the superallowed  $\beta$ -delayed  $\gamma$ -ray transition using a NaI(Tl) crystal. The  $\gamma$ -ray energy was measured relative to the  $^{22}\text{Na}$   $\gamma$ -ray at  $E_\gamma=1273.6$  keV 16. Deduced  $T_{1/2}(^{18}\text{Ne}_{\text{g.s.}})=1.46$  s 7 by observing the annihilation radiation due to  $^{18}\text{Ne}$  positron decay; measured branching ratios of 93% 2 and 7% 2 for the  $^{18}\text{Ne}_{\text{g.s.}}(\beta)^{18}\text{F}_{\text{g.s.}}$  and  $^{18}\text{Ne}_{\text{g.s.}}(\beta)^{18}\text{F}^*(1041$  keV) decay branches, respectively, by a comparison of the intensities of the photopeaks of the annihilation radiation and that of the 1.04-MeV  $\gamma$ -ray. Using the results of (1959Du81), the authors deduced the end point energy of 3423 keV 13 for the positrons from the  $^{18}\text{Ne}_{\text{g.s.}}(\beta^+)^{18}\text{F}_{\text{g.s.}}$  decay.
- 1963Fr10, 1965Fr09:**  $^{16}\text{O}(^3\text{He},n)$   $E=5.2$  MeV; measured the positrons from the  $^{18}\text{Ne}_{\text{g.s.}}(\beta^+)^{18}\text{F}_{\text{g.s.}}$  decay by focusing them onto a bell-type Geiger-Muller counter using a Siegbahn-Slätis intermediate-image spectrometer (with a resolution of 4%). The activated target was moved outside the spectrometer and the  $\beta$ -delayed  $\gamma$ -rays were measured using a NaI crystal with a resolution of 8% at 661 keV. Deduced  $T_{1/2}(^{18}\text{Ne}_{\text{g.s.}})=1.47$  s 10. Measured  $E_\gamma=1035$  keV 20 for the superallowed  $\beta$ -delayed  $\gamma$ -ray transition. The branching ratios and the positron end-point energies were measured to be 91% 3 and 3416 keV 9, and 9% 3 and 2373 keV 11 for the  $^{18}\text{Ne}_{\text{g.s.}}(\beta)^{18}\text{F}_{\text{g.s.}}$  and superallowed decay branches, respectively. Deduced  $\log ft$  values, and  $^{18}\text{Ne}$  mass excess of 10.651 MeV 10.
- 1967Mi02:**  $^{16}\text{O}(^3\text{He},n_0)$   $E=10$ -12 MeV; the  $^{18}\text{Ne}_{\text{g.s.}}$  was populated as a contaminant in various spectra due to the oxygen contamination in the targets.
- 1968Go05:**  $^{16}\text{O}(^3\text{He},n)$   $E=5.6$  MeV; populated the  $^{18}\text{Ne}_{\text{g.s.}}$  and measured the  $\beta$ -delayed  $\gamma$ -rays from the decay of  $^{18}\text{Ne}_{\text{g.s.}}(\beta)^{18}\text{F}^*(\gamma)^{18}\text{F}$  using a Ge(Li) detector. Measured  $E_\gamma=1043$  keV 1 for the  $\gamma$ -ray transition following the superallowed decay branch. Deduced the branching ratios and  $\log ft$  values for the  $^{18}\text{Ne}$  decay to the  $^{18}\text{F}^*(1.08, 1.70, 2.10$  MeV) states. The deduced branching ratios are reported as <0.7%, <0.9%, and <1.5%, respectively.
- 1970Al11:**  $^{16}\text{O}(^3\text{He},n)$   $E=5.5$ -MeV; measured  $\beta$ -rays from the  $^{18}\text{Ne}_{\text{g.s.}}(\beta)^{18}\text{F}$  decay using a plastic scintillator with beam cycles of 4 s beam on, and 102 s beam off. Deduced  $T_{1/2}$  for the  $^{18}\text{Ne}_{\text{g.s.}}$  in 3 separate measurements and obtained  $T_{1/2}=1.701$  s 32, 1.650 s 33, and 1.658 s 25; deduced the recommended half-life of 1.67 s 2; deduced  $\log ft$ , and a branching ratio of 92.4% 17 for the  $^{18}\text{Ne}_{\text{g.s.}}(\beta)^{18}\text{F}_{\text{g.s.}}$  decay branch.
- 1970As06:**  $^{16}\text{O}(^3\text{He},n)$   $E=10$ -11 MeV; measured the positron decay of  $^{18}\text{Ne}_{\text{g.s.}}$ : measured  $I_\gamma$  for the  $\beta$ -delayed  $\gamma$ -ray transitions from the  $^{18}\text{F}^*(1042, 1700$  keV) states using a Ge(Li) detector with an energy resolution of 3 keV at 1.33 MeV; deduced  $T_{1/2}=1.69$  s 4 for  $^{18}\text{Ne}_{\text{g.s.}}$ ; deduced  $I_\beta$ , branching ratios and  $\log ft$  for the  $\beta^+$  decay branches to  $^{18}\text{F}^*(1042, 1700$  keV). The resulting branching ratios are 92.5% 2 for the ground state branch, 7.3% 2 for the superallowed branch, and 0.17% 5 for the  $^{18}\text{Ne}_{\text{g.s.}}(\beta^+)^{18}\text{F}^*(1700$  keV) branch.
- 1972Ha58:**  $^{16}\text{O}(^3\text{He},n)$   $E=12$  MeV; measured the  $\beta$ -delayed  $\gamma$ -rays from the  $^{18}\text{Ne}_{\text{g.s.}}(\beta^+)^{18}\text{F}^*$  decay using a Ge(Li) detector. Deduced  $T_{1/2}=1655$  ms 25 for  $^{18}\text{Ne}_{\text{g.s.}}$ ; obtained a branching ratio of 7.65% 26 for the superallowed decay branch; and deduced  $\log ft$ . The half-life deduced in (1975Ha21) supersedes the preliminary result of (1972Ha58).
- 1975Al27:**  $^{16}\text{O}(^3\text{He},n)$   $E=5.7$  MeV; measured the  $\beta$ -decay of  $^{18}\text{Ne}_{\text{g.s.}}$  using two NE102 plastic scintillators. The half-life of  $^{18}\text{Ne}_{\text{g.s.}}$  was deduced as  $T_{1/2}=1.669$  s 4 by multi-scaling at 0.1 s/channel for 300-350 channels. The authors deduced  $A=18$   $\beta$ -decay mirror asymmetry of  $\delta_{\text{exp}}=-0.86\%$  80, which is the asymmetry in the  $\beta$ -decay  $ft$  values, i.e.,  $\delta=[\log(ft^+)/\log(ft^-)]-1$ .
- 1975Ha21:**  $^{16}\text{O}(^3\text{He},n)$   $E=12$  MeV; measured the  $\beta$ -delayed  $\gamma$ -rays from the decay of  $^{18}\text{Ne}$  using a Ge(Li) detector. Measured  $E_\gamma=659.4$  keV 10, 1041.3 keV 10, and 1699.6 keV 20 with relative intensities (2.1% 3, 100%, and 0.71% 17, respectively); measured absolute branching ratios of 92.11% 21, 7.66% 21, and 0.23% 3, respectively, for the decay to the  $^{18}\text{F}^*(0, 1042, 1700$  keV) states. Deduced  $E_{\text{max}}(\beta)=2383.0$  keV 47, and  $T_{1/2}=1687$  s 9 for  $^{18}\text{Ne}_{\text{g.s.}}$  extracted by comparing the resultant decay curve with a single component exponential using least squares method; deduced  $\log ft$  values for each decay branch; determined the corrected  $Ft$  value.

[1981Ad01](#):  $^{16}\text{O}(^3\text{He},n)$  E=12 MeV; measured the energy and intensity of the  $\beta$ -delayed  $\gamma$ -rays from the  $^{18}\text{Ne}(\beta)^{18}\text{F}^*$  decay using

<sup>16</sup>O(<sup>3</sup>He,n) 1953Ku08,2012Fo29 (continued)

a Ge(Li) detector. Data collection started 0.1 seconds after each beam bombardment ended and continued for 1.7 seconds. Observed <sup>18</sup>F  $\gamma$ -rays at 659-, 1042-, 1081-, and 1700-keV. Measured the branching ratio of the <sup>18</sup>Ne<sub>g.s.</sub>( $\beta$ )<sup>18</sup>F\*(1081 keV) decay for the first time. Deduced  $I_\gamma=100.0$ ,  $1.71 \times 10^{-2}$  41, and 2.47 5 for the transitions to the 1042-, 1081-, and 1700-keV levels in <sup>18</sup>F, respectively. Deduced  $Ft$  value for the <sup>18</sup>Ne(<sub>g.s.</sub>, 0<sup>+</sup>) $\rightarrow$ <sup>18</sup>F(1081, 0<sup>-</sup>) branch; deduced the strength of the parity non-conserving  $\pi$ -exchange NN interaction.

1982He04: <sup>16</sup>O(<sup>3</sup>He,n) E=15 and 18 MeV; measured  $E_\gamma$  and  $I_\gamma$  for the  $\beta$ -delayed  $\gamma$ -rays from the decay of <sup>18</sup>F\* states using a Ge(Li) detector with a NaI anti-Compton shield. The <sup>18</sup>F  $\gamma$ -rays of 659-, 1042-, 1081-, and 1700-keV were observed. A  $\gamma$ -ray with  $E_\gamma=1164$  keV was observed, which could be the <sup>18</sup>F\*(2100 keV, 2<sup>-</sup>) $\rightarrow$ <sup>18</sup>F\*(937 keV, 3<sup>+</sup>)+ $\gamma$  transition but the authors were doubtful that the 2100-keV state could be fed by the  $\beta^+$  decay of <sup>18</sup>Ne (see also (1968Go05)). Deduced  $Ft$  and the strength of the parity non-conserving  $\pi$ -exchange NN interaction. Deduced <sup>18</sup>F levels, and absolute branching ratios for the  $\beta$ -decay branches to the <sup>18</sup>F\*(1042, 1081, 1700 keV) states. The results are 7.70% 21,  $2.14 \times 10^{-3}$ % 26, and 0.183% 6, respectively.

1982DaZZ, 1983Ad03: <sup>16</sup>O(<sup>3</sup>He,n) E=12 MeV; measured  $E_\gamma$  and  $I_\gamma$  of the  $\beta$ -delayed  $\gamma$ -rays corresponding to the decays from the <sup>18</sup>F\*(1042, 1081, and 1700 keV) states using a shielded Ge(Li) detector. Deduced absolute branching ratios of 92.11% 21, 7.70% 21,  $2.07 \times 10^{-3}$ % 28, and 0.188 6 for the <sup>18</sup>Ne<sub>g.s.</sub>

( $\beta^+$ )<sup>18</sup>F\*(0, 1042, 1081, 1700 keV) decay branches, respectively. Deduced  $Ft$  values. Discussed the  $\pi$ -exchange contribution to the parity non-conserving NN force and weak pion coupling constant. Comparison to shell model calculations are provided.

2002Vo11: <sup>16</sup>O(<sup>3</sup>He,n) E=10 MeV; measured  $E_\gamma$  and  $\beta$ - $\gamma$  coincidences using 14 Si(Li) and 2 HPGe-detectors; deduced  $\beta$ - $\nu$  angular correlation coefficient ( $\alpha=+1.06$  19) and an upper limit for the presence of a scalar interaction.

Theory:

1964He06: X(<sup>3</sup>He,n) E=20 MeV; discussed the two-nucleon stripping reactions with a particular reference to the (<sup>3</sup>He,n) reaction.

Three models (plane wave and distorted wave Born approximations, and a simple diffraction model) are studied and compared. DWBA is used to calculate absolute differential cross sections to various final states for the (<sup>3</sup>He,n) reaction on <sup>12</sup>C, <sup>16</sup>O, Ni, and Sn targets at 20 MeV incident <sup>3</sup>He ions. Comparison with experimental data is made where available and an agreement is found. To further such comparisons, summed cross sections were computed to several low-lying states of the final nucleus. Spectroscopic weights are obtained for pure and mixed configurations of single-particle wave functions.

2012Fo29: <sup>16</sup>O(<sup>3</sup>He,n); reviewed and compared the available experimental and theoretical properties of the <sup>18</sup>Ne\*(7.06 MeV, 4<sup>+</sup>) state; calculated an upper limit of  $2 \times 10^{-4}$  for the  $p_1/p_0$  decay branching ratio for the state mentioned above. Therefore, the author disputed the  $p_1/p_0$  decay branching ratio for this state deduced by (2012A111); discussed the problems with the  $p_1$  branching ratio obtained by (2012A111) and concluded that the reported (by 2012A111)  $p_1$  decay must be from a nearby state – perhaps at  $E_x=7.37$  MeV.

Others:

1977Fi13: <sup>16</sup>O(<sup>3</sup>He,p), <sup>16</sup>O(<sup>3</sup>He,n) E=14-41 MeV; measured  $\sigma(E)$  for production of radio isotope <sup>18</sup>F used for gamma scintigraphy for imaging bones and bony lesions. Cross sections of these reactions are given as a function of incident energy.

1991Gu05: <sup>16</sup>O(<sup>3</sup>He,n) E=36 MeV; reviewed the available data (at the time) on the production of <sup>18</sup>F<sub>g.s.</sub>; included a discussion of and recommendations for production techniques in the context of proton emission tomography. This work presented the <sup>18</sup>F production yield per 2h irradiation at E=36 MeV from (1983Kn11 and 1977Fi13).

<sup>18</sup>Ne Levels

The neutron angular distribution data of (1968To09) show very similar patterns at different beam energies, which are indicative of direct reaction mechanism, except for the broad resonance at 3.36 MeV.

( $d\sigma/d\Omega$ )<sub>tot.,lab}</sub>=84 mb/sr for 5 MeV< $E_{lab}$ <35 MeV and at  $\theta_{lab}=0^\circ$  (1964Br13: see Table 2).

E(level)	J $\pi^a$	T <sub>1/2</sub> or $\Gamma$	L <sup>abc</sup>	Relative C <sup>2</sup> S <sup>d</sup>	Comments
0	0 <sup>+</sup>	1.671 s 6	0	1	$\% \epsilon + \% \beta^+ = 100$ T=1 (1961Bu05,1963Fr10,1975Ha21,1981Ne09,1981Ad01) T <sub>z</sub> =-1 (1968Gi09, 1975Ha21). E(level): From (1959Du81, 1960Aj03, 1961Bu05, 1961Du02, 1961Ga01, 1961To03, 1962Ma61, 1964Br13 (see Fig. 10 and the text), 1965Br42, 1966Kr05, 1967Mc03, 1967Mi02, 1968Sh09, 1968To09, 1970Ad02,

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<sup>16</sup>O(<sup>3</sup>He,n) **1953Ku08,2012Fo29 (continued)**

<sup>18</sup>Ne Levels (continued)

<u>E(level)</u>	<u>J<sup>π</sup>a</u>	<u>L<sup>abc</sup></u>	<u>Relative C<sup>2</sup>S<sup>d</sup></u>	<u>Comments</u>
1886.5 13	2 <sup>+</sup>	2	0.74	<p>1975Pe11, 1977Ev01, 1981Ne09, 1991Ga03 (used as a calibration point), 1994Ma14, 1996Ha26, 2005Pa50, 2010AIZZ, 2010Ta17, and 2012A111). A tentative state was observed by (1959Du81) at 114 keV 15, the existence of which was ruled out by (1960Aj03, 1961Du02).</p> <p>T<sub>1/2</sub>: Weighted average (with external errors) of 1.46 s 7 (1961Bu05); 1.73 s 42 (1961Ec02: from τ=2.5 s 6); 1.47 s 10 (1963Fr10, 1965Fr09); 1.69 s 4 (1970As06); 1.67 s 2 (1970A111); 1.669 s 4 (1975A127); and 1.687 s 9 (1975Ha21). Note that the 1.25 s 20 (1959Du81, see 1961Bu05) value is marked as an outlier by Chauvenet's criterion, and thus is excluded.</p> <p>T<sub>1/2</sub>: If the 1.46 s 7 (1961Bu05) and 1.47 s 10 (1963Fr10, 1965Fr09) values are excluded from the weighted average, the χ<sup>2</sup>/ν improves from 2.8 to 0.89, and the weighted average is 1.672 s 4.</p> <p>J<sup>π</sup>,L: From the plane wave Born approximation calculations of (1961Ga01, 1966Kr05, and 1967Mc03: see Fig. 13, at E(<sup>3</sup>He)=5.6 MeV); and the zero-range DWBA analyses of (1968Sh09, 1968To09, 1970Ad02, 1975Pe11, 1977Ev01, 1981Ne09, and 1996Ha26), all of which assign L=0 and J<sup>π</sup>=0<sup>+</sup>. Note that the DWBA fit of (1977Ev01) and the measured neutron angular distributions data for this state diverge at θ<sub>c.m.</sub>&gt;20°.</p> <p>Mass of <sup>18</sup>Ne: 18.00570 amu 4 (1960Aj03); and 18.011446 amu 14 (1961Du02: based on <sup>16</sup>O mass as the standard).</p> <p>Mass excess of <sup>18</sup>Ne: 10.64 MeV 4 (1960Aj03); 10658 keV 13 (1961Du02: based on <sup>16</sup>O mass as the standard); 10649 keV 8 (1961To03); 10651 keV 10 (1963Fr10); and 5316.8 keV 15 (1994Ma14: inferred by measuring the energy loss of <sup>3</sup>He ions through the target at E<sub>lab</sub>(<sup>3</sup>He)=7.31 MeV and by using E<sub>x</sub>(<sup>18</sup>Ne)=1887.3 keV 2 from (1987Aj02). The energy loss was determined by measuring the <sup>16</sup>O(α,γ) excitation function over the narrow resonance at E<sub>α</sub>=6928 keV 4 (1987Aj02)).</p> <p>Q(<sup>16</sup>He,n)<sup>18</sup>Ne<sub>g.s.</sub>: -3190 keV 4 (1960Aj03); -3206 keV 13 (1961Du02); -3199 keV 6 (1961To03: weighted average between Q=-3199 keV 20 measured from the neutron time-of-flight spectrum and Q=-3199 keV 6 measured using a calibrated NMR to accurately obtain the beam energy); -3000 (1962Ma61); -3196 keV (1991Ga03); and -3194.0 keV 15 (1994Ma14).</p> <p>Threshold energy(<sup>16</sup>O(<sup>3</sup>He,n)<sup>18</sup>Ne<sub>g.s.</sub>): 3811 keV 15 (1961Du02); and 3802 keV 7 (1961To03).</p> <p>dσ/dΩ(θ=0°)=1.6 mb/sr 3 for the <sup>16</sup>O(<sup>3</sup>He,n)<sup>18</sup>Ne<sub>g.s.</sub> reaction at 5.5 MeV (1960Aj03).</p> <p>For the <sup>16</sup>O(<sup>3</sup>He,n)<sup>18</sup>Ne<sub>g.s.</sub> reaction: σ=400 mb at E(<sup>3</sup>He)=7.7 MeV (1962Ma61); and σ=20 mb (1965Br42).</p> <p>dσ/dΩ(θ<sub>lab</sub>=0°)=2.0 mb/sr 4 at E=25.4 MeV (1964Br13).</p> <p>dσ/dΩ<sub>c.m.</sub><sup>max</sup>=21 mb/sr 4 at θ<sub>c.m.</sub>~15° at 2.54 MeV (1966Kr05).</p> <p>dσ/dΩ<sub>c.m.</sub>(θ<sub>c.m.</sub>=0°)=3.65 mb/sr at E=15 MeV (1977Ev01).</p> <p>dσ/dΩ<sub>c.m.</sub>(θ<sub>c.m.</sub>=0°)=3.69 mb/sr at E=18 MeV (1977Ev01).</p> <p>dσ/dΩ<sub>c.m.</sub>(θ<sub>c.m.</sub>=0°)=2.40 mb/sr at E=21 MeV (1977Ev01).</p> <p>(1967Mc03): performed plane wave Born approximation calculations to fit the σ(E<sub>n</sub>, θ) measured at 3 beam energies. The cross sections obtained at backward angles were inconsistent with those obtained by (1961Ga01).</p> <p>T=1 (1981Ne09)</p> <p>E(level): Weighted average of 1880 keV 10 (1961To03); 2.0 MeV 1 (1966Kr05); 1886 keV 7 (1977Ev01); 1886.5 keV 15 (1994Ma14: from Δ(<sup>18</sup>Ne*(2<sup>+</sup>))=7204.1 keV 15); and 1887 keV 3 (2005Pa50). Note that Δ<sub>ex</sub>=Δ<sub>g.s.</sub>+E<sub>x</sub>, where Δ<sub>ex</sub> is the mass excess for an excited state at E<sub>x</sub> and Δ<sub>g.s.</sub> is the</p>

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<sup>16</sup>O(<sup>3</sup>He,n) **1953Ku08,2012Fo29 (continued)**

<sup>18</sup>Ne Levels (continued)

<u>E(level)</u>	<u>J<sup>π</sup><sup>a</sup></u>	<u>T<sub>1/2</sub> or Γ</u>	<u>L<sup>abc</sup></u>	<u>Relative C<sup>2</sup>S<sup>d</sup></u>	<u>Comments</u>
3375.3	(4 <sup>+</sup> )	<30 keV	(4)	1.54	<p>ground state mass excess that is Δ<sub>g.s.</sub>(<sup>18</sup>Ne)=5317.617 keV 363 (2021Wa16). Note that the E<sub>x</sub>=2.0 MeV <i>l</i> was considered an outlier by the Chauvenet criterion, and thus excluded.</p> <p>E(level): See also 1880 keV (1964Br13, 1968Sh09, 1968To09); 1.89 MeV (1970Ad02, 1975Pe11, 1994Ma14, 1996Ha26, 2010AIZZ, 2010Ta17, 2012A111); 1887.3 keV (1981Ne09: this state was used as a calibration point, whose energy was taken from (1969Ro08)); 1887 keV (1991Ga03: this state was used as a calibration point).</p> <p>J<sup>π</sup>,L: From plane wave Born approximation calculations of (1966Kr05) using the (1960Ne21) formalism; and the zero-range DWBA analyses of (1968To09, 1970Ad02, 1975Pe11, 1977Ev01, 1981Ne09, 1996Ha26). All of these studies assigned J<sup>π</sup>=2<sup>+</sup> and L=2 to this state. Note that the DWBA curves of (1970Ad02: J<sup>π</sup>=2<sup>+</sup>) fail to reproduce the deep minimum observed at forward angles, which is most pronounced around 10 MeV. At 9.5 MeV, the neutron angular distribution data were indicative of a resonance-like structure due to the compound nuclear reaction contributions. The neutron angular distribution for this state measured by (1970Ad02) disagrees with that of (1966Kr05) in magnitude and shape.</p> <p>Mass excess for the 2<sub>1</sub><sup>+</sup> state=7204.1 keV 15 (1994Ma14).</p> <p>Q-value=-5079 keV 8 (1961To03); and -5083 keV (1991Ga03).</p> <p>Threshold energy=6038 keV 9 (1961To03).</p> <p>dσ/dΩ<sub>c.m.</sub>=11 mb/sr 2 at θ<sub>c.m.</sub>~15° and E<sub>lab</sub>=11 MeV (1966Kr05).</p> <p>σ<sub>rel</sub>=1.8 2 at E<sub>lab</sub>=18.3 MeV (1975Pe11). This cross section is reported relative to that of the <sup>16</sup>O(<sup>3</sup>He,n)<sup>18</sup>Ne<sub>g.s.</sub>. The same relative cross section calculated by (1975Pe11) using shell model is 0.76.</p> <p>dσ/dΩ<sub>c.m.</sub>(θ<sub>c.m.</sub>=0°)=4.55 mb/sr at E=15 MeV (1977Ev01).</p> <p>dσ/dΩ<sub>c.m.</sub>(θ<sub>c.m.</sub>=0°)=6.80 mb/sr at E=18 MeV (1977Ev01).</p> <p>dσ/dΩ<sub>c.m.</sub>(θ<sub>c.m.</sub>=0°)=6.15 mb/sr at E=21 MeV (1977Ev01).</p> <p>E(level): Weighted average of 3362 keV 11 (1961To03); 3375 keV 15 (1970Ad02); 3374 keV 7 (1977Ev01); and 3376 keV 3 (2005Pa50). See also 3360 keV (1964Br13, 1968Sh09, 1968To09); 3376.2 keV (1981Ne09: this state was used as a calibration point, whose energy was taken from (1969Ro08)); 3376 keV (1991Ga03: this state was used as a calibration point); and 3380 keV (1994Ma14).</p> <p>(1968Sh09, M. H. Shapiro et al., Bull. Amer. Phys. Soc. 13 (1968) 698) suggested that the 3.36 MeV level in <sup>18</sup>Ne is a closely spaced doublet, see (1968Gi09).</p> <p>T<sub>1/2</sub> or Γ: From (1970Ad02).</p> <p>J<sup>π</sup>,L: From the zero-range DWBA analyses of (1968To09: J<sup>π</sup>=(4<sup>+</sup>) and L=(4)); (1970Ad02: J<sup>π</sup>=(4<sup>+</sup>)); and (1977Ev01: J<sup>π</sup>=4<sup>+</sup> but the agreement between the DWBA fits and the data at E(<sup>3</sup>He)=15 MeV and 18 MeV is not good). See also a similar assignment from (1991Ga03: J<sup>π</sup>=4<sup>+</sup> from the analysis of mirror states in <sup>18</sup>Ne and <sup>18</sup>O).</p> <p>Note that (1968To09) suggested that this state may be an indication of high spin modes of excitation in <sup>19</sup>Ne compound nucleus in the region of 16.5 MeV because the neutron angular distributions for this state were not consistent with direct reaction mechanism (see also (1970Ad02), E(<sup>3</sup>He)=9.5 MeV), and thus DWBA analysis failed to describe the data well. The authors pointed out that the DWBA analysis is further complicated due to the potential presence</p>

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<sup>16</sup>O(<sup>3</sup>He,n) **1953Ku08,2012Fo29** (continued)

<sup>18</sup>Ne Levels (continued)

<u>E(level)</u>	<u>J<sup>π</sup><sup>a</sup></u>	<u>T<sub>1/2</sub> or Γ</u>	<u>L<sup>abc</sup></u>	<u>Relative C<sup>2</sup>S<sup>d</sup></u>	<u>Comments</u>
3576 3	(0 <sup>+</sup> )		(0)	<0.6	<p>of an unresolved 0<sup>+</sup> state in the vicinity of this state in their data, which may explain their observed high cross section for <math>\theta_{c.m.} &lt; 30^\circ</math>. Q-value=-6561 keV 9 (1961To03); -6572 keV (1991Ga03); and -6568 keV 2 (1994Ma14: using the Q<sub>g.s.</sub> and E<sub>x</sub>=3376.2 keV 4 from (1987Aj02)).</p> <p>Threshold energy=7800 keV 10 (1961To03).  <math>d\sigma/d\Omega_{c.m.}(\theta_{c.m.}=0^\circ)=3.30</math> mb/sr at E=15 MeV (1977Ev01).  <math>d\sigma/d\Omega_{c.m.}(\theta_{c.m.}=0^\circ)=2.62</math> mb/sr at E=18 MeV (1977Ev01).  <math>d\sigma/d\Omega_{c.m.}(\theta_{c.m.}=0^\circ)=3.50</math> mb/sr at E=21 MeV (1977Ev01).                      E(level): Weighted average of 3564 keV 20 (1970Ad02); and 3576 keV 3 (2005Pa50). See also 3576 keV (1991Ga03: this state was used as a calibration point); and 3.5 MeV (2010AIZZ, 2010Ta17, 2012A111).</p> <p>J<sup>π</sup>: From (1970Ad02: recommended J<sup>π</sup>=0<sup>+</sup> from the isobaric analog levels analysis and supported by L=2 DWBA fit to the 3.564+3.610 MeV unresolved states, see below). See also (1991Ga03: from the analysis of mirror states in <sup>18</sup>Ne and <sup>18</sup>O).</p> <p>L: (1970Ad02): a zero-range DWBA fit with L=2 was fitted to the combined cross sections of the unresolved 3564- and 3610-keV doublet measured at E=9, 9.5, 10.5 and 11.5 MeV, which implied that one member of the doublet (presumably a 0<sup>+</sup> state with L=0) was weakly populated, as expected by comparison with the <sup>16</sup>O(t, p) reaction.</p> <p>Q-value=-6772 keV (1991Ga03).                      (1977Ev01) predicted that <math>(d\sigma/d\Omega)_{c.m.} &lt; 300</math> <math>\mu</math>b/sr at <math>\theta_{c.m.} = 0^\circ</math> (at E(<sup>3</sup>He)=15, 18, and 21 MeV) for the 0<sup>+</sup> state at 3576 keV, which remained unobserved in (1977Ev01). The cross section value is deduced compared to <math>(d\sigma/d\Omega)_{c.m.}=3.6</math> mb/sr for the ground-state transition at E(<sup>3</sup>He)=18 MeV.                      (1970E123, 1973Mc06) predicted that this state may have a pure 2p-0h configuration.</p>
3615 3	2 <sup>+</sup>		2	0.22	<p>E(level): Weighted average of 3608 keV 12 (1961To03); 3610 keV 15 (1970Ad02); 3603 keV 15 (1977Ev01); and 3616 keV 3 (2005Pa50). See also 3610 keV (1964Br13, 1968Sh09, 1968To09); 3616.4 keV (1981Ne09: the state was used as calibration and its energy was taken from (1969Ro08)); and 3616 keV (1991Ga03: this state was used as a calibration point).</p> <p>J<sup>π</sup>,L: From the zero-range DWBA analyses of (1968To09: J<sup>π</sup>=2<sup>+</sup> and L=2, see Fig. 11) and (1977Ev01: J<sup>π</sup>=2<sup>+</sup>, see Fig. 4 and E(<sup>3</sup>He)=15 MeV). See also a similar assignment from (1991Ga03: J<sup>π</sup>=2<sup>+</sup> from the analysis of mirror states in <sup>18</sup>Ne and <sup>18</sup>O).</p> <p>Q-value=-6807 keV 10 (1961To03); and -6812 keV (1991Ga03).                      Threshold energy=8092 keV 11 (1961To03).  <math>d\sigma/d\Omega_{c.m.}(\theta_{c.m.}=0^\circ)=0.85</math> mb/sr at E=15 MeV (1977Ev01).  <math>d\sigma/d\Omega_{c.m.}(\theta_{c.m.}=0^\circ)=0.92</math> mb/sr at E=18 MeV (1977Ev01).  <math>d\sigma/d\Omega_{c.m.}(\theta_{c.m.}=0^\circ)=0.55</math> mb/sr at E=21 MeV (1977Ev01).</p>
4518 4	1 <sup>-</sup>	9 keV 6	1		<p>E(level): Weighted average of 4505 keV 15 (1970Ad02); 4520 keV 1 (stat.) 7 (sys.) (1991Ga03: this excitation energy was computed using a <sup>18</sup>Ne mass excess of 5319 keV 5 (1987Aj02). The current <sup>18</sup>Ne mass excess is 5317.617 keV 363 (2021Wa16), which is consistent with the one used by the authors, so the evaluator did not re-scale this excitation energy); and 4519 keV 1 (stat.) 4 (sys.) (2005Pa50).</p> <p>E(level): See also 4513 keV 13 (1974Ne04: this state is an unresolved doublet. The width of the peak was found to increase as <math>\theta_{lab}</math> was changed from 20° to 30°, and the excitation energy appeared to</p>

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<sup>16</sup>O(<sup>3</sup>He,n) **1953Ku08,2012Fo29 (continued)**

<sup>18</sup>Ne Levels (continued)

<u>E(level)</u>	<u>J<sup>π</sup></u> <sup>a</sup>	<u>T<sub>1/2</sub> or Γ</u>	<u>Comments</u>
			<p>decrease by about 30 keV. This indicated that at forward angles the bulk of the strength was due to the higher-lying member of the doublet; at larger angles, where the observed cross section was small, neither of the states dominated); 4537 keV <i>10</i> (1977Ev01: this state is an unresolved doublet, whose reported energy is the mean energy of the doublet); 4513 keV <i>13</i> (1981Ne09: this state is a member of a doublet. At <math>\theta_{c.m.}=0^\circ</math>, the population of this doublet is dominated by the higher-lying member of the doublet and that at large angles the two contributions become comparable); and 4.5 MeV (2010AIZZ, 2010Ta17, 2012A111).</p> <p>(1970Ad02, E<sub>x</sub>=4505 keV <i>15</i>): the authors could not eliminate the <sup>17</sup>O(<sup>3</sup>He,n) reaction as the source for populating this state. However, this would imply an unreasonable cross section of 500 mb/sr at <math>\theta_{c.m.}=0^\circ</math> and E(<sup>3</sup>He)=12.5 MeV. So, the authors concluded that this state belonged to <sup>18</sup>Ne. This study also pointed out that this state may be the mirror of the <sup>18</sup>O*(4.455 MeV, 1<sup>-</sup>) state, in which case the large displacement between this state and its mirror would be due to a double Thomas-Ehrman shift.</p> <p>T<sub>1/2</sub> or Γ: From (1991Ga03). See also Γ≤40 keV (1970Ad02: deduced from folding the line shape of the corresponding neutron group with a negligible intrinsic width into a Breit-Wigner curve).</p> <p>T<sub>1/2</sub> or Γ: See also (1991Ga03): deduced Γ<sub>p</sub>&lt;0.1 keV for this state using the measured proton spectroscopic factor of the mirror state in <sup>18</sup>O from (1976Li01) and the single-particle width deduced from optical model calculations of (1991Ga03). They assumed a negligible branch for the <sup>18</sup>Ne*(4518 keV)→<sup>17</sup>F*(495 keV)+p decay such that Γ≈Γ<sub>p0</sub>. (1991Ga03) used Γ<sub>p</sub>&lt;0.1 keV (as opposed to their experimentally determined value of Γ<sub>tot</sub>=9 keV <i>6</i>) to calculate the <sup>17</sup>F(p,γ) reaction rate. They argued that the observed width of Γ=9 keV <i>6</i> is consistent with zero [at 2σ], and therefore deduced Γ<sub>p</sub>&lt;0.1 keV from the mirror level.</p> <p>J<sup>π</sup>,L: From the zero-range DWBA analysis of (1977Ev01) using DWUCK2 with L=1. The authors assigned J<sup>π</sup>=0<sup>+</sup>, 1<sup>-</sup> to this state but only present the L=1 fits (see Fig. 4). The agreements between DWBA fits and the neutron angular distribution data at E(<sup>3</sup>He)=15 MeV and 18 MeV are very good for L=1. L=0 fits are not presented; however, the authors reported J<sup>π</sup>=0<sup>+</sup> and 1<sup>-</sup> because this state was expected to be an unresolved doublet. The evaluator adopted J<sup>π</sup>=1<sup>-</sup> with L=1 from these data and the other supporting evidence mentioned below.</p> <p>J<sup>π</sup>,L: See also (1970Ad02: J<sup>π</sup>=(0<sup>+</sup>, 1<sup>-</sup>) deduced from the analog levels analysis); (1981Ne09: J<sup>π</sup>=(0<sup>+</sup>, 1<sup>-</sup>) from DWBA analysis with L=0 and L=1); (1991Ga03: J<sup>π</sup>=1<sup>-</sup> from the analysis of mirror states in <sup>18</sup>Ne and <sup>18</sup>O); and (2005Pa50: J=1 from comparison of the measured differential cross sections to those predicted by the Hauser-Feshbach theory, which is sensitive to J but not to π changes).</p> <p>(2005Pa50): Figs. 4 and 5 show measured and Hauser-Feshbach differential cross sections of the observed states in graphical formats per beam energy.</p> <p>Q-value=-7716 keV <i>1</i> (stat.) <i>5</i> (sys.) (1991Ga03).</p>
4527.4	3 <sup>+</sup>	17 keV <i>4</i>	<p>E(level): From E<sub>x</sub>=4527 keV <i>1</i> (stat.) <i>4</i> (sys.) (2005Pa50). See also 4537 keV <i>10</i> (1977Ev01: this state is identified as an unresolved doublet, whose reported energy is the mean energy of the doublet); and 4561 keV <i>6</i> (stat.) <i>7</i> (sys.) (1991Ga03: this excitation energy was computed using a <sup>18</sup>Ne mass excess of 5319 keV <i>5</i> (1987Aj02). The current <sup>18</sup>Ne mass excess is 5317.617 keV <i>363</i> (2021Wa16), which is consistent with the one used by the authors, so the evaluator did not re-scale this excitation energy. Also note that this state was only observed at E<sub>beam</sub>=10.9 MeV and at <math>\theta_{lab}=124.7^\circ</math>). (2005Pa50) saw no evidence for this level and suggested that it is likely that the experiment of (1991Ga03), whose resolution was a factor of 2 poorer, was unable to resolve the states observed in (2005Pa50) at 4519 keV and 4527 keV.</p> <p>T<sub>1/2</sub> or Γ: From (2005Pa50). The error on the width is dominated by the systematic uncertainty (2005Pa50). See also Γ=25 keV (1991Ga03: not measured but estimated from a Woods-Saxon calculation for E<sub>x</sub>=4561 keV <i>9</i>).</p>

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<sup>16</sup>O(<sup>3</sup>He,n) 1953Ku08,2012Fo29 (continued)

<sup>18</sup>Ne Levels (continued)

<u>E(level)</u>	<u>J<sup>π</sup><sub>a</sub></u>	<u>T<sub>1/2</sub> or Γ</u>	<u>L<sup>abc</sup></u>	<u>Comments</u>
4589 <sup>e</sup> 4	0 <sup>+</sup>	4 keV 4	0	<p>(1991Ga03) recommended <math>\Gamma_\gamma(3_1^+ \rightarrow 2_1^+) = 25</math> meV 16, <math>\Gamma_\gamma(3_1^+ \rightarrow 2_2^+) = 3.8</math> meV 31, and <math>\Gamma_\gamma(3_1^+ \rightarrow 4_1^+) = 0.8</math> meV 8. Under the assumption that the <sup>18</sup>Ne B(M1) transitions are identical to those in <sup>18</sup>O, (1991Ga03) deduced the lower-value <math>\gamma</math>-ray partial widths mentioned above. The higher values were deduced by assuming that the actual B(M1) transitions could be twice as large as the shell-model predictions obtained from a private communication between the authors and B. A. Brown.</p> <p>J<sup>π</sup>,L: From (2005Pa50): J=3 from comparing the measured differential cross sections to the Hauser-Feshbach predicted ones); and (1991Ga03): J<sup>π</sup>=3<sup>+</sup> from the analysis of mirror states in <sup>18</sup>Ne and <sup>18</sup>O).</p> <p>Q-value=-7757 keV 6 (stat.) 5 (sys.) (1991Ga03: assuming E<sub>x</sub>=4561 keV 9). T=1 (1974Ne04,1981Ne09)</p> <p>E(level): Weighted average of 4590 keV 30 (1968To09); 4571 keV 15 (1970Ad02); 4589 keV 1 (stat.) 7 (sys.) (1991Ga03: this excitation energy was computed using a <sup>18</sup>Ne mass excess of 5319 keV 5 (1987Aj02). The current <sup>18</sup>Ne mass excess is 5317.617 keV 363 (2021Wa16), which is consistent with the one used by the authors, so the evaluator did not re-scale this excitation energy); and 4590 keV 1 (stat.) 4 (sys.) (2005Pa50).</p> <p>E(level): See also 4550 keV (1968Sh09); 4587 keV 13 (1974Ne04: this state is identified as an unresolved doublet. The width of the peak was found to increase as <math>\theta_{lab}</math> was changed from 20° to 30°, and the excitation energy appeared to decrease by about 30 keV. This indicated that at forward angles the bulk of the strength was due to the higher-lying member of the doublet; at larger angles, where the observed cross section was small, neither of the states dominated); and 4587 keV 13 (1981Ne09: this state is a member of a doublet. At <math>\theta_{c.m.} = 0^\circ</math>, the population of this doublet is dominated by the higher-lying member of the doublet and at large angles the two contributions become comparable).</p> <p>(1970Ad02): the <sup>17</sup>O(<sup>3</sup>He,n) reaction could not be eliminated as the source for the production of this state; however, this would imply an unreasonably large cross section of 500 mb/sr at <math>\theta_{c.m.} = 0^\circ</math> and E(<sup>3</sup>He)=12.5 MeV. So, the authors concluded that this state belonged to <sup>18</sup>Ne. They also mentioned that this state may be the mirror to the <sup>18</sup>O*(5336 keV,0<sup>+</sup>) state, in which case the large shift is due to the double Thomas-Ehrman shift.</p> <p>T<sub>1/2</sub> or Γ: From Γ=4 keV 4 measured by (1991Ga03). See also Γ≤130 keV (1968To09: the width of the corresponding neutron group); Γ≤40 keV (1970Ad02: deduced by folding the line shape of the corresponding neutron group with a negligible intrinsic width into a Breit-Wigner curve); and Γ<sub>p</sub>=1 keV (1991Ga03). This value was obtained for the state populated at E<sub>x</sub>=4589 keV. Its Γ<sub>p</sub>=1 keV width was deduced using the experimentally determined proton spectroscopic factor of the mirror level in <sup>18</sup>O (1976Li01) and the single-particle reduced width, which was determined from an optical model calculation by (1991Ga03). Γ<sub>p</sub>=1 keV was used by the authors to deduce the <sup>17</sup>F(p,γ) reaction rate. It was assumed that Γ≈Γ<sub>p</sub>, where Γ<sub>p</sub>=1 keV is consistent with the observed width of Γ=4 keV 4. (1991Ga03) assumed that this level proton decays to the <sup>17</sup>F<sub>g.s.</sub>, which implies that Γ≈Γ<sub>p0</sub>.</p> <p>J<sup>π</sup>: From the DWBA analyses of (1) (1974Ne04): these data are not presented but the authors mention that the DWBA analysis favors L=0 for the higher energy state in the 4.5-MeV doublet (this state). This is confirmed with the presented DWBA analysis of this state using their <sup>20</sup>Ne(p,t) data. (2) (1981Ne09): J<sup>π</sup>=(0<sup>+</sup>, 1<sup>-</sup>) and L=(0,1). (3) (1991Ga03): J<sup>π</sup>=0<sup>+</sup> from mirror state analysis. (4) (2005Pa50): deduced J=0 by comparing the measured differential cross sections to the Hauser-Feshbach predicted cross sections. The evaluator adopted J<sup>π</sup>=0<sup>+</sup> and L=0 because the 1<sup>-</sup> state in this energy range is established to be at E<sub>x</sub>=4519 keV as reported by (2005Pa50). (2005Pa50) presents the measured and Hauser-Feshbach differential cross sections of</p>

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<sup>16</sup>O(<sup>3</sup>He,n) **1953Ku08,2012Fo29 (continued)**

<sup>18</sup>Ne Levels (continued)

<u>E(level)</u>	<u>J<sup>π</sup><sub>a</sub></u>	<u>T<sub>1/2</sub> or Γ</u>	<u>L<sub>abc</sub></u>	<u>Comments</u>
5098 14	2 <sup>+</sup>	50 keV 10	(2,3)	<p>the observed states in graphical formats per beam energy (see Figs. 4 and 5). Q-value=-7785 keV 1 (stat.) 5 (sys.) (1991Ga03).</p> <p>(1977Ev01): the mean energy of the 4.5-MeV doublet shows that at E(<sup>3</sup>He)=18 MeV the 0<sup>+</sup> and 1<sup>-</sup> states are almost equally populated implying a cross section of (dσ/dΩ)<sub>c.m.</sub>=1 mb/sr at θ<sub>c.m.</sub>=0° for the 0<sup>+</sup> member of the doublet.</p> <p>(1981Ne09): predicted a predominantly s<sub>1/2</sub><sup>2</sup> character for this state.</p> <p>E(level): Weighted average (with external errors) of 5106 keV 8 (1996Ha26); and 5075 keV 13 (1974Ne04, 1981Ne09: this state is a member of a doublet. The population of this doublet is dominated by the lower-lying member (this state) at small angles).</p> <p>E(level): See also 5.2 MeV 3 (1964Br13: indicated that this state may be formed by a group of unresolved neutrons); 5.14 MeV 2 (1970Ad02: may be an unresolved doublet); 5.15 MeV (2010AlZZ, 2010Ta17); and 5.10 MeV 10 (2012A111: an unresolved doublet, see Table II. Note that Fig. 6 and Table I both report this excitation energy as 5.15 MeV).</p> <p>T<sub>1/2</sub> or Γ: From (1996Ha26). See also Γ=100 keV 40 (1970Ad02: deduced by folding the line shape of the corresponding neutron group with a negligible intrinsic width into a Breit-Wigner curve. The state observed was an unresolved doublet so this measurement is excluded); and Γ≤60 keV (1974Ne04, 1981Ne09). (2012A111) reported Γ<sub>p0</sub>/Γ=89% 3, Γ<sub>p1</sub>/Γ=11% 4, and Γ<sub>p1</sub>/Γ<sub>p0</sub>=0.124. However, (2020Br14) argues these branching ratios are for a combination of the 5.10- and 5.15-MeV states, which remained unresolved in (2012A111). If the <sup>18</sup>Ne*(5097 keV, 2<sup>+</sup>) state were to decay to <sup>17</sup>F*(495 keV, 1/2<sup>+</sup>), the proton must carry an angular momentum of L=2. Considering the Coulomb barrier associated with this decay, (2020Br14) suggested that the Γ<sub>p1</sub> branch observed by (2012A111) cannot involve the <sup>18</sup>Ne*(5097 keV, 2<sup>+</sup>) state. See also (2019Ch16), which discussed the Γ<sub>p1</sub>/Γ=11% 4 result of (2012A111) that is in disagreement with Γ<sub>p1</sub>/Γ&lt;0.009 deduced in (2019Ch16).</p> <p>J<sup>π</sup>,L: From the DWBA analyses of (1970Ad02: J<sup>π</sup>=2<sup>+</sup>, 3<sup>-</sup> and L=2,3); (1981Ne09: J<sup>π</sup>=(2<sup>+</sup>, 3<sup>-</sup>) and L=2,3); and (1996Ha26: J<sup>π</sup>=2<sup>+</sup> from a combination of Coulomb barrier penetrability considerations, level widths, mirror levels analysis, and Woods-Saxon calculations of the Coulomb energy shifts).</p> <p>(2012A111): a<sub>0</sub>=1506.90, a<sub>2</sub>=-819.45, a<sub>4</sub>=-547.42, and a<sub>6</sub>=-802.13, where a<sub>i</sub> are the Legendre polynomial fit coefficients for the measured proton's (from the decay of <sup>18</sup>Ne state) angular distribution.</p>
5142 8	3 <sup>-</sup>	≤20 keV	(2,3)	<p>E(level): Weighted average (with external errors) of 5130 keV 10 (1977Ev01); 5135 keV 12 (1974Ne04, 1981Ne09: this state is a member of a doublet. The population of this doublet is dominated by the higher-lying member (this state) at small angles); and 5153 keV 8 (1996Ha26).</p> <p>E(level): See also 5.2 MeV 3 (1964Br13: possibly a group of unresolved levels); and 5.14 MeV 20 (1970Ad02: this state is an unresolved doublet).</p> <p>(1977Ev01): the measured energy of 5130 keV 10 corresponds to an unresolved doublet, whose reported energy is the mean energy of the members of the doublet. However, this energy was observed to be more or less constant as a function of incident energy, and it showed a small shift with angle. These were indicative that most likely only one member of the doublet (5.14-MeV state) was populated in their experiment.</p> <p>T<sub>1/2</sub> or Γ: From (1996Ha26). See also Γ≤60 keV (1974Ne04, 1981Ne09); Γ=100 keV 40 (1970Ad02: deduced for a state that is unresolved from another nearby state).</p> <p>J<sup>π</sup>,L: From (1977Ev01: J<sup>π</sup>=3<sup>-</sup> from the zero-range DWBA analysis. L is not given but the evaluator assigned L=3 from the selection rules. The agreement between the DWBA fit and the neutron angular distribution data at E(<sup>3</sup>He)=15 MeV and 18 MeV is very good); (1981Ne09: J<sup>π</sup>=(2<sup>+</sup>, 3<sup>-</sup>) from DWBA analysis with L=2,3);</p>

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<sup>16</sup>O(<sup>3</sup>He,n) **1953Ku08,2012Fo29 (continued)**

<sup>18</sup>Ne Levels (continued)

E(level)	J <sup>π</sup> <sup>a</sup>	T <sub>1/2</sub> or Γ	L <sup>abc</sup>	Comments
5454 8	(2 <sup>-</sup> )	≤20 keV		and (1996Ha26: J <sup>π</sup> =3 <sup>-</sup> from a combination of penetrability considerations, level widths, mirror levels analysis, and Woods-Saxon calculations of the Coulomb energy shifts). E(level),T <sub>1/2</sub> or Γ: From (1996Ha26). J <sup>π</sup> ,L: From (1996Ha26: based on a combination of penetrability considerations, level widths, mirror levels analysis, and Woods-Saxon calculations of the Coulomb energy shifts. The un-natural spin-parity assignment was assigned because the neutron angular distribution was not forward peaked).
6150 <sup>f</sup> 10	(1 <sup>-</sup> )	≤40 keV	(1)	Γ <sub>p0</sub> /Γ≤0.52 Γ <sub>p1</sub> /Γ≤0.21 (2012A111) E(level): Weighted average of 6150 keV 10 (1996Ha26) and 6.15 MeV 8 (2012A111: see Table II). See also 6.1 MeV (2010AIZZ, 2010Ta17). T <sub>1/2</sub> or Γ: From (1996Ha26). (2012A111) deduced Γ <sub>2He</sub> /Γ≤0.27. The authors reported an excess of counts in the energy region corresponding to the 2p-decay channel for this state. This is not a direct evidence for 2p decay since (2012A111) did not detect the two individual protons from the decay of this state. (2012A111) reported Γ <sub>α</sub> ≈2 eV from a private communication of the authors with G. V. Rogachev. This width was determined from the ANC deduced for the mirror level in <sup>18</sup> O (see also (2009Jo07)). With this and the other branching ratios deduced by (2012A111), the evaluator determined Γ <sub>p0</sub> /Γ≤0.52. This value implies Γ <sub>p1</sub> /Γ <sub>p0</sub> ≤0.40, which disagrees with Γ <sub>p1</sub> /Γ <sub>p0</sub> ≤0.27 reported in Table IV of (2012A111). The evaluator assumed that the latter value is erroneous based on Γ <sub>p1</sub> =15.9 keV 7 and Γ <sub>p0</sub> =37.8 keV 19 deduced by (2012Ba28: from <sup>17</sup> F(p,p') data of (2003B111)). (2012A111): upper limits for branching ratios are estimated at 95% confidence level using a Bayesian approach assuming that the net excess of counts were from real decay events. J <sup>π</sup> ,L: From (1996Ha26: J <sup>π</sup> =(1 <sup>-</sup> ) from a combination of zero-range DWBA analysis, penetrability considerations, level widths, mirror levels analysis, and Woods-Saxon calculations of the Coulomb energy shifts. The DWBA fits with L=0, L=1, and L=2 are presented; however, these fits do not describe the measured neutron angular distribution data well). The evaluator selected a tentative L=(1) as the best l-value for this case. (2012A111): a <sub>0</sub> =194.80, a <sub>2</sub> =-43.05, a <sub>4</sub> =-22.06, and a <sub>6</sub> =-94.73, where a <sub>i</sub> are the Legendre polynomial fit coefficients for the measured proton's (from proton decay of this state) angular distribution.
6299 9	(3 <sup>-</sup> )	180 keV 60		Γ <sub>p0</sub> /Γ=1.00 2 (2012A111) E(level): Weighted average of 6291 keV 30 (1974Ne04, 1981Ne09); 6300 keV 10 (1996Ha26); and 6.30 MeV 5 (2012A111: Table II). See also 6.3 MeV (2010AIZZ, 2010Ta17). T <sub>1/2</sub> or Γ: From (1974Ne04, 1981Ne09). J <sup>π</sup> : From (1996Ha26: J <sup>π</sup> =(3 <sup>-</sup> ) deduced from a combination of penetrability considerations, level widths, mirror levels analysis, and Woods-Saxon calculations of the Coulomb energy shifts). (2012A111): a <sub>0</sub> =532.94, a <sub>2</sub> =-193.96, a <sub>4</sub> =111.55, and a <sub>6</sub> =0, where a <sub>i</sub> are the Legendre polynomial fit coefficients for the measured proton's (from proton decay of this state) angular distribution.
6350 10	(2 <sup>-</sup> )			E(level): From (1996Ha26). J <sup>π</sup> : From (1996Ha26: J <sup>π</sup> =(2 <sup>-</sup> ), deduced from a combination of penetrability considerations, level widths, mirror levels analysis, and Woods-Saxon calculations of the Coulomb energy shifts).
7050? 30	(1 <sup>-</sup> ,2 <sup>+</sup> ,4 <sup>+</sup> )	≤120 keV	1,2	E(level): From (1996Ha26): assuming a doublet. This state is the lower energy member of a doublet and was reported as a tentative state, see

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<sup>16</sup>O(<sup>3</sup>He,n) **1953Ku08,2012Fo29 (continued)**

<sup>18</sup>Ne Levels (continued)

<u>E(level)</u>	<u>J<sup>π</sup><sub>a</sub></u>	<u>T<sub>1/2</sub> or Γ</u>	<u>L<sub>abc</sub></u>	<u>Comments</u>
				below. See also 7062 keV <i>12</i> (1974Ne04, 1981Ne09); 7051 keV <i>18</i> (1977Ev01); 7.0 MeV (2010AlZZ, 2010Ta17); and 7.06 MeV <i>4</i> (2012A111: Table II). These states are not considered because they were all fitted using a single peak, and thus constitute an unresolved doublet.
				E(level): (1996Ha26): this level may be a member of a close lying doublet. Considering a single peak, (1996Ha26) deduced E <sub>x</sub> =7070 keV <i>10</i> and Γ=200 keV <i>40</i> for this state. However, the fit to the spectrum considering two states (a doublet) resulted in a smaller χ <sup>2</sup> , and was thus a better fit. As a result, two tentative states were deduced at (7050 keV <i>30</i> ) and (7120 keV <i>30</i> ), both of which with Γ≤120 keV.
				T <sub>1/2</sub> or Γ: From (1996Ha26) considering a doublet. See also Γ=180 keV <i>50</i> (1974Ne04, 1981Ne09); and Γ=200 keV <i>40</i> (1996Ha26) considering a single state.
				Γ <sub>α</sub> =22.6 eV <i>32</i> and Γ <sub>p</sub> =64 keV <i>13</i> are calculated by (2003Fo13) assuming mirror symmetry of spectroscopic factors and J <sup>π</sup> =4 <sup>+</sup> .
				Γ <sub>p1</sub> <14 eV and Γ <sub>p1</sub> /Γ <sub>p0</sub> <2×10 <sup>-4</sup> are calculated by (2012Fo29). This work disputed the validity and overthrew the following experimental branching ratios deduced by (2012A111) for this state: Γ <sub>p0</sub> /Γ=0.83 <i>3</i> , Γ <sub>p1</sub> /Γ=0.16 <i>7</i> , Γ <sub>α</sub> /Γ≤0.01 (see Fig. 7), Γ <sub>p'</sub> /Γ <sub>p</sub> =0.19, and Γ <sub>α</sub> /Γ <sub>p</sub> ≤0.01 (2012A111).
				J <sup>π</sup> ,L: From (1977Ev01: J <sup>π</sup> =2 <sup>+</sup> from the zero-range DWBA analysis. L is not given but the evaluator assigned L=2 from this DWBA analysis. The agreement between DWBA fit and the neutron angular distribution data at 15 and 18 MeV incident energies is very good); (1981Ne09: J <sup>π</sup> =(1 <sup>-</sup> , 2 <sup>+</sup> ) from DWBA analysis with L=1,2. L=2 (and thus J <sup>π</sup> =2 <sup>+</sup> ) was preferred based on the reaction mechanism); (1996Ha26: (J <sup>π</sup> =4 <sup>+</sup> ) from a combination of penetrability considerations, level widths, mirror levels analysis, and Woods-Saxon calculations of the Coulomb energy shifts); and (2000Fo19: J <sup>π</sup> =4 <sup>+</sup> predicted from shell model calculations).
				(2012A111): a <sub>0</sub> =1554.26, a <sub>2</sub> =-109.72, a <sub>4</sub> =-1230.54, and a <sub>6</sub> =-589.35, where a <sub>i</sub> are the Legendre polynomial fit coefficients for the measured proton's (from proton decay of this state) angular distribution.
				(1981Ne09) suggests that this state may contain substantial d <sub>3/2</sub> strength.
				(2012Fo29) reports this state to be of four-particle two-hole (4p-2h) configuration, i. e., (sd) <sup>4</sup> (1p) <sup>-2</sup> , and calculated Γ <sub>sp</sub> (l=4)=0.68 keV for the proton decay of <sup>18</sup> Ne*(7.06 MeV, 4 <sup>+</sup> )→p+ <sup>17</sup> F*(495 keV, 1/2 <sup>+</sup> ). (2012Fo29) assumed C <sup>2</sup> S=0.01-0.02 for this <sup>18</sup> Ne state and calculated the Γ <sub>p1</sub> indicated above, which yields a Γ <sub>p1</sub> /Γ <sub>p0</sub> branching ratio of less than 2×10 <sup>-4</sup> . This value disagrees with the Γ <sub>p1</sub> /Γ <sub>p0</sub> =0.19 deduced by (2012A111).
7120? <sup>f</sup> <i>30</i>		≤120 keV		E(level): From (1996Ha26): this level is a member of a close lying doublet. (1996Ha26) considered a single peak in this region and deduced E <sub>x</sub> =7070 keV <i>10</i> and Γ=200 keV <i>40</i> . However, the fit with two states (a doublet) led to a smaller χ <sup>2</sup> , and was thus a better fit. Consequently, (1996Ha26) obtained two tentative states: E <sub>x</sub> =(7050 keV <i>30</i> ) and (7120 keV <i>30</i> ) both with Γ≤120 keV.
				E(level): The combination of the <sup>12</sup> C( <sup>12</sup> C, <sup>6</sup> He) <sup>18</sup> Ne data from (1996Ha26) together with the evidence reported previously is consistent with two levels at E <sub>x</sub> =7.05 MeV and E <sub>x</sub> =7.12 MeV.
				T <sub>1/2</sub> or Γ: From (1996Ha26) considering a doublet.
7350 <sup>f</sup> <i>18</i>	(1 <sup>-</sup> )	≤50 keV	(1)	E(level),T <sub>1/2</sub> or Γ: From (1996Ha26).
				J <sup>π</sup> ,L: (1996Ha26: J <sup>π</sup> =(0 <sup>+</sup> , 1 <sup>-</sup> , 2 <sup>+</sup> )): from a zero-range DWBA analysis with L=(0,1, 2). However, from a combination of Coulomb penetrability considerations, level widths, mirror levels analysis, and Woods-Saxon calculations of the Coulomb energy shifts, (1996Ha26) assigned J <sup>π</sup> =(1 <sup>-</sup> ) to this state.
7718 <i>9</i>		≤30 keV		E(level): Weighted average of 7712 keV <i>20</i> (1974Ne04, 1981Ne09); and 7720 keV <i>10</i> (1996Ha26). (1981Ne09) observed a triplet of states near 8 MeV. These states were unresolved at 14.5 MeV incident energy (see the last peak in Fig.

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<sup>16</sup>O(<sup>3</sup>He,n) **1953Ku08,2012Fo29** (continued)

<sup>18</sup>Ne Levels (continued)

<u>E(level)</u>	<u>J<sup>π</sup><sub>a</sub></u>	<u>T<sub>1/2</sub> or Γ</u>	<u>L<sup>abc</sup></u>	<u>Comments</u>
7924 11	(1 <sup>-</sup> ,2 <sup>+</sup> )	40 keV 10	(1,2)	<p>5). However, at 16.1 MeV incident energy, these 3 states are more or less resolved at <math>\theta_{lab}=5^\circ</math> (see Fig. 6) and very well separated at <math>\theta_{lab}=25^\circ</math>. (1981Ne09) does not report which states construct the triplet and only mentions “an 8-MeV triplet”. The neutron energy spectra presented in (1981Ne09) is in logarithmic scale, which makes it harder to reliably determine which states are included in the triplet. Evaluator notes that the 7062-keV state is a strongly populated, broad peak in (1981Ne09: see Fig. 8). Based on that, we estimated that the 3 states constructing the triplet are most likely the 7712-keV, 7915-keV, and 8100-keV states, all of which were estimated to have <math>\Gamma \leq 50</math> keV. Note that the 7949-keV state observed in (1981Ne09) via <sup>20</sup>Ne(p,t) measurement is not part of this triplet because this latter state was not populated via the <sup>16</sup>O(<sup>3</sup>He,n) reaction, so no neutron peak in the triplet can be associated with that state. Moreover, no evidence of the state at E<sub>x</sub>=8294 keV (see the <sup>18</sup>Ne Adopted Levels) is mentioned in (1981Ne09). Therefore, the <sup>18</sup>Ne*(7718 keV) level recommended here is most likely one of the members of this triplet.</p> <p>T<sub>1/2</sub> or Γ: From (1996Ha26). See also <math>\Gamma \leq 50</math> keV (1974Ne04, 1981Ne09).</p> <p>E(level): Weighted average (with external errors) of 7915 keV 12 (1974Ne04, 1981Ne09); 7903 keV 15 (1977Ev01); and 7940 keV 10 (1996Ha26).</p> <p>Evaluator notes that in this region, a close lying doublet is expected. See also 7.9 MeV (2010AIZZ, 2010Ta17), and 7950 keV 30 (2012A111: Table II). This state was excluded since the poor neutron time-of-flight resolution of (2012A111) was not sufficient enough to separate the doublet, and a wide neutron peak is observed, where this doublet is expected.</p> <p>E(level): This state is most likely another member of the 8-MeV triplet observed in (1981Ne09) discussed above.</p> <p>T<sub>1/2</sub> or Γ: From (1996Ha26). See also <math>\Gamma \leq 50</math> keV (1974Ne04, 1981Ne09).</p> <p>J<sup>π</sup>,L: From (1981Ne09: J<sup>π</sup>=(1<sup>-</sup>,2<sup>+</sup>) based on comparison of the shape of neutron angular distribution data with the DWBA curves obtained with L=1,2). See also (1996Ha26): J<sup>π</sup>=(1<sup>-</sup>,2<sup>+</sup>,3<sup>-</sup>) from zero-range DWBA analysis with L=1,2,3, respectively. These DWBA fits do not seem to describe the measured neutron angular distribution data well.</p> <p>(2012A111) deduced branching ratios of <math>\Gamma_{p_0}/\Gamma=64\%</math> 8, <math>\Gamma_{p_1}/\Gamma=16\%</math> 10, and <math>\Gamma_{\alpha}/\Gamma=20\%</math> 9 for this state. However, there is a close doublet expected in this region. But (2012A111) appears to have ignored this. They used <math>\Gamma=55</math> keV 20 keV and deduced <math>\Gamma_{p'}/\Gamma_p=0.25</math> and <math>\Gamma_{\alpha}/\Gamma_p=0.31</math> in addition to branching ratios mentioned before. The <math>\Gamma_{tot}</math> used must have been the unweighted average (with an inflated uncertainty by 5 keV) of <math>\Gamma=40</math> keV 10 from (1996Ha26: (<sup>3</sup>He,n) data) and <math>\Gamma=70</math> keV 20 from (1996Ha26: (p,t) data using the K600 spectrograph). However, the state observed in the (p,t) measurement with a larger width is most likely the higher energy member of the doublet. So, these results are unreliable. The evaluator notes that (1996Ha26) also did not consider the doublet as separate states when presenting their results in tabular format (presumably because the deduced energies were indistinguishable) but they seem to acknowledge the doublet in their discussions (see section V.E in that article).</p> <p>(2012A111) observed, for the first time, the <math>\alpha</math>-decay from the level measured at 7950 keV 30 with a significant branching ratio. However, as mentioned above, it is not clear which of the members of this doublet is responsible for this.</p> <p>(2012A111): <math>a_0=1116.96</math>, <math>a_2=-18.64</math>, <math>a_4=-428.29</math>, and <math>a_6=-495.91</math>, where <math>a_i</math> are the Legendre polynomial fit coefficients for the measured angular distribution of protons from the decay of this state. Evaluator notes that these results may be unreliable due to reasons mentioned above.</p>
8098 9		$\leq 30$ keV		<p><math>\Gamma_{p_0}/\Gamma=0.65</math> 12 (2012A111)  <math>\Gamma_{p_1}/\Gamma=0.14</math> 12 (2012A111)  <math>\Gamma_{\alpha}/\Gamma=0.21</math> 13 (2012A111)</p>

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$^{16}\text{O}(^3\text{He},n)$  **1953Ku08,2012Fo29 (continued)** $^{18}\text{Ne}$  Levels (continued)

E(level)	$T_{1/2}$ or $\Gamma$	Comments
		$\Gamma\alpha/\Gamma_p=0.32$ (2012A111)
		E(level): Weighted average (with external errors) of 8100 keV 14 (1974Ne04, 1981Ne09); 8070 keV 15 (1977Ev01); 8110 keV 10 (1996Ha26); and 8090 keV 30 (2012A111: Table II). See also 8.1 MeV (2010AIZZ, 2010Ta17). Evaluator notes that this state is most likely a member of the 8-MeV triplet reported by (1981Ne09) based on their $^{16}\text{O}(^3\text{He},n)$ data (see Figs. 6 and 7).
		$T_{1/2}$ or $\Gamma$ : From (1996Ha26). See also $\Gamma\leq 50$ keV (1974Ne04, 1981Ne09).
		$\Gamma_p/\Gamma_p=0.22$ (2012A111).
		(2012A111): $a_0=642.28$ , $a_2=-47.26$ , $a_4=-276.58$ , and $a_6=-299.72$ , where $a_i$ are the Legendre polynomial fit coefficients for the measured proton's (from proton decay of this state) angular distribution.
8500 30	$\leq 120$ keV	E(level), $T_{1/2}$ or $\Gamma$ : From (1974Ne04).

<sup>a</sup> (1968Sh09): the double stripping selection rules for the  $(^3\text{He},n)$  reactions require  $J_f=L$  and  $\pi_f=(-1)^L$  when a target nucleus with  $J^\pi=0^+$  is bombarded and a direct, one-step diproton in a relative  $s=0$  state is transferred. Here,  $J_f$  and  $\pi_f$  are the spin and parity of the final nucleus and  $L$  is the transferred orbital angular momentum.

<sup>b</sup> (1970Ad02): the  $L=2$  transitions in the DWBA calculations do not reproduce the forward angle dip in the data but the agreement improves with the increase of the bombarding energy, as it does for the  $L=4$  transitions. Note that although there is evidence that compound nuclear effects are not completely negligible in the energy region studied in this work, the simplified DWBA calculations appear to be in rough quantitative agreement with the measured angular distributions.

<sup>c</sup> The angular momentum transfer is not given by (1977Ev01) except that of the state at 4537 keV. So,  $L$  is deduced by the evaluator based on the angular momentum selection rules for the  $^{16}\text{O}(^3\text{He},n)$  reaction for each state with reported DWBA analysis from (1977Ev01: see Fig. 4).

<sup>d</sup> From (1970Ad02): the relative spectroscopic factors for the  $^{16}\text{O}(^3\text{He},n)$  reaction are obtained at various incident energies between 9-12.5 MeV and for two sets of optical potential models (see Tables 5 and 6). (1970Ad02) has arbitrarily set the spectroscopic factor equal to unity for the transition to the  $^{18}\text{Ne}_{g.s.}$  measured at  $E(^3\text{He})=11.5$  MeV. The values given here are the relative spectroscopic factors obtained from a consistent analysis of the  $^{16}\text{O}(t,p)$ ,  $^{16}\text{O}(^3\text{He},p)$ , and  $^{16}\text{O}(^3\text{He},n)$  reactions and for optical potential model A.

<sup>e</sup> This state was first observed in (1968To09).

<sup>f</sup> This state was first observed in (1996Ha26).

$^{16}\text{O}(^3\text{He},n\gamma)$  **1968Gi09,2003Ta13**

- 1968Gi09:**  $^{16}\text{O}(^3\text{He},n\gamma)$   $E=9.2, 12$  and  $13.2$  MeV; measured  $n\gamma$  coincidences using a Ge(Li) at  $\theta_{\text{lab}}=90^\circ$  and an NE-213 liquid scintillator at  $\theta_{\text{lab}}=0^\circ$ ; measured  $\gamma$ -rays and their angular correlations from the de-exciting  $^{18}\text{Ne}^*$  levels at 1887-, 3376-, 3576-, and 3616 keV; deduced lifetimes of these states using the Doppler shift attenuation method; deduced  $J^\pi$  assignments using the mirror level analysis.
- 1969Ro08:**  $^{16}\text{O}(^3\text{He},n\gamma)$   $E=8.5-13.15$  MeV; part of the results of this experiment was published in (1968Gi09). Measured  $n\gamma$  and  $\gamma\gamma$  coincidences using rotatable Ge(Li) detectors (resolution=8 keV at 1.84 MeV (FWHM)), a NaI detector, and a NE-213 liquid scintillator at  $\theta_{\text{lab}}=0^\circ$ ; measured  $\sigma(E_\gamma, \theta(n\gamma))$ . Measured  $E_\gamma=1887.3$  keV 2, 1488.9 keV 3, 1689 keV 2, 1729.2 keV 5. Measured lifetimes of the 1887-, 3376-, 3576-, and 3616-keV states using the Doppler shift attenuation method. Measured  $\gamma$ -branching ratios using  $n\gamma$  coincidences with the NaI or a Ge(Li) detector at  $55^\circ$  and at  $E_{\text{lab}}=12$  MeV,  $\gamma$ -ray angular distributions at 8.5 MeV, and  $\gamma$ -ray angular correlations at 8.5 and 12 MeV; deduced  $^{18}\text{Ne}$  level energies,  $J$ , and  $\delta$  (mixing ratios); calculated transition rates in  $^{18}\text{Ne}$  based on shell model.
- 1969Ro22:**  $^{16}\text{O}(^3\text{He},n\gamma)$   $E=9.5-11.5$  MeV; measured  $n\gamma$  coincidences using 3 Ge(Li) detectors and a NE-213 scintillator at  $\theta_{\text{lab}}=0^\circ$ ; measured the  $\gamma$ -ray from the decay of the 3616-keV state directly to the ground state; measured  $n\gamma\gamma$  coincidences using a Ge(Li) and 4 NaI detectors; measured  $\sigma(E; E_n, E_{\gamma_1}, E_{\gamma_2}, \theta(n\gamma))$ ; deduced  $^{18}\text{Ne}$  levels at 1887-, 3376-, 3576-, and 3616-keV; deduced  $\gamma$ -branching,  $J$ ,  $\pi$ , and  $\delta$  (mixing ratios); confirmed the results of (1968Gi09, 1969Ro08) regarding to the existence of the level at 3576 keV and its 1689-keV  $\gamma$ -ray from the decay to the 1887-keV state.
- 1969Be31:**  $^{24}\text{Mg}(^3\text{He},n\gamma)$   $E=5.5, 7.8,$  and  $10$  MeV. The first excited state of  $^{18}\text{Ne}$  was also populated due to oxygen contamination of the enriched  $^{24}\text{Mg}$  self-supporting target. The  $\gamma$ -ray from the de-excitation of the 1887-keV state in  $^{18}\text{Ne}$  to the ground state was observed.
- 1970Sh04:**  $^{16}\text{O}(^3\text{He},n\gamma)$   $E=9$  and  $10$  MeV; measured  $\sigma(E; E_n)$ ,  $n\gamma$  coincidences,  $n\gamma(\theta)$  using a  $\gamma$ -ray time-of-flight technique employing a Ge(Li) (and a NaI(Tl)) counter at  $\theta_{\text{lab}}=90^\circ$  and a NE-102 plastic scintillator at  $\theta_{\text{lab}}=0^\circ$  and  $40^\circ$ , measured  $n\gamma$  correlations from the  $^{18}\text{Ne}^*(3626$  keV,  $2_2^+$ ) and  $^{18}\text{Ne}^*(3383$  keV,  $4_1^+)$  states using a  $\text{WO}_3$  target and the Ge(Li) at  $\theta_{\text{lab}}=55^\circ, 90^\circ, 105^\circ, 125^\circ, 135^\circ$  and  $145^\circ$ ; combined this information with lifetime measurements of (1968Gi09, 1969Ro08) to deduce the isoscalar and isovector matrix elements involved in the decay of  $2_2^+$  levels of the  $A=18$  triad; measured  $^{18}\text{Ne}$   $\gamma$ -rays at 1890 keV 2, 1466 keV 2, 1493 keV 2, 1689 keV 2, 1736 keV 2, and 3630 keV 2; deduced  $^{18}\text{Ne}$  levels at 1890 keV 2, 3383 keV 4, 3576 keV 4, and 3623 keV 4; deduced  $J, \pi, \gamma$ -branching ratios, and  $\delta$  (mixing ratios) for the observed transitions.
- 1971Ro18:**  $^{16}\text{O}(^3\text{He},n\gamma)$   $E=10.3$  MeV; measured  $n\gamma$  coincidences for the triplet states at  $E_x \sim 3.5$  MeV using the Oxford  $\gamma$ -neutron time-of-flight spectrometer consisting of a large Ge(Li) and a large scintillator; measured  $\sigma(E_n, E_\gamma)$ ; found no evidence for the 1466 keV  $\gamma$ -ray observed in (1970Sh04) and attributed the origin of this  $\gamma$ -ray to the Compton scattering from the 1736-keV  $\gamma$ -ray; deduced the  $\gamma$ -decay of the triplet excited states of  $^{18}\text{Ne}$  at  $E_x \sim 3.5$  MeV; confirmed that the 3576-keV state is the  $0_2^+$  state; deduced the branching ratio and mixing ratio of the  $3616 \rightarrow 1887$  keV transition but these are not published here.
- 1972Gi01:**  $^{16}\text{O}(^3\text{He},n\gamma)$   $E=10.3-10.8$  MeV; measured  $n\gamma$  coincidences using a Ge(Li) detector with 2.3 keV resolution at 1.33 MeV and by neutron time-of-flight method using a NE-213 liquid scintillator at  $\theta_{\text{lab}}=0^\circ$ ; The Ge(Li) detector was placed at  $\theta_{\text{lab}}=90^\circ, 115^\circ, 125^\circ, 135^\circ, 140^\circ,$  and  $145^\circ$  to measure the  $n\gamma$  angular correlations and the  $\gamma$ -ray decay scheme; measured lifetimes of the 3376- and 3576-keV states via the Doppler-shift recoil distance method with the Ge(Li) detector at  $\theta_{\text{lab}}=0^\circ$  and the scintillator at  $\theta_{\text{lab}}=30^\circ$ ; measured  $\sigma(\theta)$  for the 1887-, 1729-, and 3616-keV  $\gamma$ -rays; deduced  $^{18}\text{Ne}$  levels, branching ratios, and  $\gamma$ -mixing ratios for the  $^{18}\text{Ne}^*(1887, 3376, 3576, 3616$  keV) states.
- 1974Mc17:**  $^{16}\text{O}(^3\text{He},n\gamma)$   $E=7.5$  and  $9$  MeV; measured  $E_\gamma=1490-, 1690-, 1730-, 1890-,$  and  $3620$ -keV and  $I_\gamma$  a Ge(Li) detector placed at  $\theta_{\text{lab}}=0^\circ, 90^\circ,$  and  $135^\circ$ ; measured  $n\gamma$  and  $\gamma\gamma$  coincidences using a NE-213 liquid scintillator at  $\theta_{\text{lab}}=0^\circ$  and 2 Ge(Li) detectors at  $\theta_{\text{lab}}=45^\circ$  and  $135^\circ$ ; Ge(Li) detectors with resolution of 3.5 keV at 1.88 MeV; measured the lifetime of the 1.89-MeV state of  $^{18}\text{Ne}$  using the Doppler shift attenuation method using the stopping powers of (1963Li17); transition rates in the  $^{18}\text{Ne}$  and  $^{18}\text{O}$  mirror nuclei are compared with theoretical predictions.
- 1976Mc02:**  $^3\text{He}(^{16}\text{O},n\gamma)$   $E=38$  MeV; measured  $n\gamma$  coincidences using a Ge(Li) and a NE-213 liquid scintillator both at  $\theta_{\text{lab}}=0^\circ$ ; remeasured the lifetime of the  $^{18}\text{Ne}^*(1890$  keV) state using Doppler broadened line shape analysis; used inverse kinematics to produce high velocity ( $v/c=6\%$ ) recoils, for which accurate stopping powers had been measured by (1976Fo20). Deduced level energy, lifetime and  $B(E2)$  for the 1890 keV state. The lifetime was determined using a method which is insensitive to the systematic uncertainties arising from stopping powers.
- 2003Ri08:**  $^3\text{He}(^{16}\text{O},n\gamma)$   $E=38$  MeV. The goal was to resolve the discrepancy between  $B(E2: 0_{g.s.}^+ \rightarrow 2_1^+)$  deduced from (2000Ri15: see section  $^{197}\text{Au}(^{18}\text{Ne}, ^{18}\text{Ne}'): \text{COULEX}$ ) and the  $B(E2: 2_1^+ \rightarrow 0_{g.s.}^+)$  deduced by (1976Mc02). Measured  $E_\gamma, I_\gamma, n\gamma$  coincidences for the  $^{18}\text{Ne}^*(2_1^+)$  state using 2 large clover Ge detectors with Compton suppression both at  $\theta_{\text{lab}}=135^\circ$  and a NE-213 liquid scintillator at  $\theta_{\text{lab}}=0^\circ$ ; measured the lifetime of the  $^{18}\text{Ne}(2_1^+)$  state using Doppler shift attenuation method; deduced  $B(E2: 0_{g.s.}^+ \rightarrow 2_1^+)$ ; performed a semi-microscopic reanalysis of the intermediate energy  $^{18}\text{Ne}+^{197}\text{Au}$  scattering data of (2000Ri15) to resolve the aforementioned discrepancy; discussed comparison with previous results.

<sup>16</sup>O(<sup>3</sup>He,n $\gamma$ ) **1968Gi09,2003Ta13 (continued)**

**2003Ta13:** <sup>16</sup>O(<sup>3</sup>He,n $\gamma$ ) E=3.7-36 MeV; measured E $\gamma$ =1489 keV and 1887 keV; measured I $\gamma$ ,  $\sigma(\theta)$  using 4 large Compton suppressed HPGe detectors at  $\theta_{lab}$ =90°, 112.5°, 135°, and 157.5°; deduced  $\gamma$ -ray production  $\sigma(E)$  of the 1887-keV  $\gamma$ -ray from the de-excitation of <sup>18</sup>Ne\*(1.89 MeV) state. These cross sections are given in numerical format as a function of laboratory energy. The astrophysical implications for solar flares and  $\gamma$ -ray astronomy are discussed.

<sup>18</sup>Ne Levels

Cross sections measured by (2003Ta13) are uncertain by 13-17%.

The  $\gamma$ -ray energies (and thus the deduced excitation energies) from (1970Sh04) are consistently higher than all other  $\gamma$ -ray measurements except for the E $\chi$ =3576 keV. Thus, these results are not used due to potentially unknown systematic uncertainties.

E(level)	J $\pi$	T <sub>1/2</sub>	Comments
0	0 <sup>+</sup>		E(level): The ground state was populated indirectly via the $\gamma$ -decay of the first excited state in (1968Gi09, 1969Be31, 1969Ro08, 1969Ro22, 1970Sh04, 1971Ro18, 1971Gi02, 1974Mc17, 1976Mc02, 2003Ri08, 2003Ta13). J $\pi$ : From the <sup>18</sup> Ne Adopted Levels. T $\chi$ =-1 (1968Gi09). T=1 (1976Mc02)
1887.4 <sup>a</sup> 2	2 <sup>+</sup> <sup>c</sup>	0.47 ps 4	E(level): From recoil correction of E $\gamma$ =1887.3 keV 2 (1968Gi09, 1969Ro08). See also excitation energies deduced that appear to neglect the <sup>18</sup> Ne recoil corrections: E $\chi$ =1887.3 keV 2 (1968Gi09, 1969Ro08); E $\chi$ =1887 keV (1969Ro22, 1971Ro18, 1972Gi01, 2003Ri08, 2003Ta13); E $\chi$ =1890 keV 2 (1970Sh04); and E $\chi$ =1890 keV (1974Mc17, 1976Mc02). T <sub>1/2</sub> : From $\tau$ =0.68 ps 6, which is the weighted average (with external errors) of (1) $\tau$ =0.49 ps +17-9 (1968Gi09); deduced $\tau$ =0.45 ps +22-15 and $\tau$ =0.37 ps 14 using thick SrO and CdO targets, respectively, and recommended $\tau$ =0.49 ps +17-9 (see the footnote of Table 1 in (1968Gi09)). A year later, (1969Ro08) obtained $\tau$ =0.44 ps +24-16 and $\tau$ =0.54 ps +24-10 using a thin WO <sub>3</sub> target on gold and lead backings, respectively, and again recommended $\tau$ =0.49 ps +17-9; (2) $\tau$ =0.67 ps 6 (1976Mc02); and (3) $\tau$ =0.77 ps +9-7 (2003Ri08). T <sub>1/2</sub> : See also $\tau$ =0.63 ps 13 (sys.) (1974Mc17): they measured the lifetime using Doppler shift attenuation method. They acknowledged that for low recoil velocities ( $v/c \leq 1\%$ , which was the case), the lifetime was uncertain to the extent of about $\pm 20\%$ , and this uncertainty was systematic arising from lack of experimental stopping powers and the inadequacies of the theoretical stopping powers deduced by (1963Li17). (1976Mc02) re-measured this lifetime using inverse kinematics to increase the velocity of the recoils, for which more accurate stopping powers were measured. This measurement used Doppler broadened line shape analysis, which is insensitive to the systematic uncertainties arising from stopping powers. Consequently, (1976Mc02) were able to remeasure the lifetime of this state more accurately. We therefore excluded $\tau$ =0.63 ps 13 (sys.) (1974Mc17). J $\pi$ : From (1969Ro22): J=2 uniquely determined from the coefficients of the Legendre polynomial fits to the $\gamma$ -ray angular correlations data). The positive parity is preferred by (1969Ro22) from the lifetime measurement of (1968Gi09). This assignment is also supported by the mirror levels analysis of (1970Sh04). (1971Ro18) also recommended the J $\pi$ =2 <sup>+</sup> assignment for this state.
3376.4 <sup>a</sup> 4	4 <sup>+</sup> <sup>c</sup>	3.05 ps 42	E(level): From recoil correction of E $\gamma$ =1488.9 keV 3 (1968Gi09, 1969Ro08). See also excitation energies deduced that appear to neglect the <sup>18</sup> Ne recoil corrections: 3376.2 keV 4 (1968Gi09, 1969Ro08); 3376 keV (1969Ro22, 1971Ro18, 1972Gi01, 2003Ta13); and 3383 keV 4 (1970Sh04). E(level): (1968Gi09) did not find any evidence to support the suggestion of (Shapiro et al., Bull. Amer. Phys. Soc. 13 (1968) 698) concerning the doublet nature of the 3376 keV state. T <sub>1/2</sub> : From $\tau$ =4.4 ps 6 (1972Gi01). Note that this lifetime is consistent with $\tau$ =4.3 ps (1966Be29: calculated); 4.1 ps; and 4.7 ps (private communication of T. Engeland and P. J. Ellis with the authors of (1972Gi01): lifetimes were calculated assuming the two-particle configuration model). T <sub>1/2</sub> : See also $\tau$ =1.9 ps +7-4 (1969Ro08) and $\tau$ =1.9 ps +10-4 (1968Gi09: the preliminary result published by the same authors before (1969Ro08)). Both of these values are measured

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$^{16}\text{O}(^3\text{He},n\gamma)$  **1968Gi09,2003Ta13 (continued)** $^{18}\text{Ne}$  Levels (continued)

E(level)	$J^\pi$	$T_{1/2}$	Comments
3576.5 <sup>ab</sup> 20	0 <sup>+</sup> c	2.8 ps 14	<p>via Doppler shift attenuation method. (1972Gi01) raised concern about the validity of the (1963Li17) stopping theory for light nuclei recoiling into high-Z materials with low velocities (used in deducing the aforementioned lifetimes), which cast doubt on the results of (1968Gi09, 1969Ro08) and may explain the inconsistencies between those values and the lifetime deduced by (1972Gi01).</p> <p><math>\Gamma=0.15</math> meV: from the lifetime deduced by (1972Gi01: see Table 1). See also similar calculated values of: <math>\Gamma=0.15</math> meV (1966Be29) as cited in (1969Ro08); <math>\Gamma=0.14</math> meV (1968Ar02) as cited in (1969Ro08); and <math>\Gamma=0.16</math> meV (private communication with T. Engeland and P. J. Ellis and the authors of (1972Gi01)).</p> <p><math>J^\pi</math>: <math>J=2,4</math> from the measured angular correlations in (1969Ro08, 1969Ro22). Both of these assignments are compatible with the lifetime measurement of (1968Gi09, 1969Ro08). However, (1969Ro08) selected <math>J^\pi=4^+</math> based on their mirror levels analysis. (1969Ro22) ruled out <math>J=2</math> and made the <math>J^\pi=4^+</math> assignment tentative. Furthermore, the <math>n\gamma</math> angular correlation measurements of (1970Sh04) yielded a unique spin-parity assignment of <math>J^\pi=4^+</math> for this level. The angular correlation data were fitted simultaneously for the 1493-keV and 1890-keV <math>\gamma</math>-rays observed by (1970Sh04) using the code of Warburton (1965Po01). (1971Ro18) also recommended the <math>J^\pi=4^+</math> assignment for this state.</p> <p>E(level): From recoil correction of <math>E_\gamma=1689</math> keV 2 (1968Gi09, 1969Ro08). See also excitation energies deduced that appear to neglect the <math>^{18}\text{Ne}</math> recoil corrections: 3576.3 keV 20 (1968Gi09, 1969Ro08); 3576 keV (1969Ro22, 1971Ro18, 1972Gi01); and 3576 keV 4 (1970Sh04).</p> <p><math>T_{1/2}</math>: From <math>\tau=4</math> ps 2 (1972Gi01). (1968Gi09, 1969Ro08) deduced <math>\tau&gt;2</math> ps. This lower limit comes from the lack of observation of Doppler shift for the 1689 keV <math>\gamma</math> ray from this state when either a CdO or SrO thick target was used to populate this state. (1972Gi01) obtained <math>\tau&lt;6</math> ps, combined their result with the <math>\tau&gt;2</math> ps from (1968Gi09, 1969Ro08), and deduced <math>\tau=4</math> ps 2 for this state. Note that this value is inconsistent with the calculated values of <math>\tau=13</math> ps (1966Be29) or 16 ps (private communication of T. Engeland and P. J. Ellis with the authors of (1972Gi01)). <math>\tau=4</math> ps 2 (1972Gi01) was historically accepted by the previous ENSDF evaluators, and thus it is also adopted here.</p> <p><math>\Gamma=0.16</math> meV: from (1972Gi01: see Table 1). This value should be compared to <math>\Gamma=0.05</math> meV (1966Be29) as cited in (1969Ro08); <math>\Gamma=0.03</math> meV (1968Ar02) as cited in (1969Ro08); and <math>\Gamma=0.04</math> meV (private communication of T. Engeland and P. J. Ellis with the authors of (1972Gi01)).</p> <p><math>J^\pi</math>: Out of <math>J\leq 4</math> deduced from the measured angular correlations in (1969Ro08), <math>J^\pi=0^+</math> is selected by (1969Ro08) based on the mirror levels analysis by (1969Ro08). The <math>n\gamma</math> angular correlation measured by (1969Ro22) for the 3576 keV <math>\rightarrow</math> 1887 keV <math>\gamma</math>-ray transition was isotropic, and thus not in disagreement with the suggested <math>J^\pi=0^+</math> assignment for the 3576 keV state (1968Gi09, 1969Ro08). (1971Ro18) also recommended the <math>J^\pi=0^+</math> assignment for this state.</p>
3616.6 <sup>a</sup> 6	2 <sup>+</sup> c	44 fs +2I-14	<p><math>T=1</math> (1970Sh04)</p> <p>E(level): From the least-squares fit to <math>E_\gamma</math>, which includes nuclear recoil corrections. See also excitation energies that appear to not be corrected for the recoil energy: 3616.4 keV 6 (1968Gi09, 1969Ro08: simply adding <math>E_\gamma=1887.3</math> keV 2 and <math>E_\gamma=1729.2</math> keV 5 to follow what was done by these studies to deduce <math>E_x</math>, one would obtain <math>E_x=3616.5</math> keV 5. It is not clear why the energy was reported in (1968Gi09, 1969Ro08) as <math>E_x=3616.4</math> keV 6); 3616 keV (1969Ro22); 3623 keV 4 (1970Sh04); and 3616 keV (1971Ro18).</p> <p><math>T_{1/2}</math>: From <math>\tau=0.063</math> ps +30-20 (1969Ro08: the analysis of the 1.73 MeV <math>\gamma</math>-ray observed using the thick SrO and CdO targets yielded lifetimes of <math>\tau=0.074</math> ps +60-40 and <math>\tau=0.059</math> ps +40-30, respectively. (1969Ro08) then recommended the lifetime of <math>\tau=0.063</math> ps +30-20). See also a similar value of <math>\tau=0.06</math> ps +3-2 from (1968Gi09).</p> <p><math>\Gamma=1.05\times 10^{-2}</math> from the recommended lifetime deduced by (1969Ro08).</p> <p><math>J^\pi</math>: From the <math>n\gamma</math> angular correlation measurements of (1970Sh04), which yielded a unique spin-parity assignment of <math>J^\pi=2^+</math> for this level. The angular correlation data were fitted simultaneously for the 1736-keV and 1890-keV <math>\gamma</math> rays observed by (1970Sh04)</p>

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<sup>16</sup>O(<sup>3</sup>He,n $\gamma$ ) **1968Gi09,2003Ta13 (continued)**

<sup>18</sup>Ne Levels (continued)

<u>E(level)</u>	<u>J<math>\pi</math></u>	<u>T<sub>1/2</sub></u>	<u>Comments</u>
			using the code of Warburton (1965Po01). J $\pi$ : See similar assignments from (1969Ro08): J $\pi$ =2 <sup>+</sup> based on the E2 sum rules of (1968Ar02). The lifetime measurement together with the ground state decay from this state exclude J=4); (1969Ro22: J=2,4 but J=4 is excluded as mentioned previously. A positive parity is selected based on lifetime measurement by (1969Ro08) and mixing ratio from (1969Ro22)); and (1972Gi01: J $\pi$ =2 <sup>+</sup> ). (1972Gi01) reports a population parameter p>0.75 at 10.3 MeV bombarding energy. It is not clear what this parameter refers to.
			<sup>a</sup> It appears that none of the above mentioned experiments considered the <sup>18</sup> Ne recoil energies when calculating the excitation energies. Instead, it appears that the excitation energies were calculated simply by adding the Doppler shift corrected $\gamma$ -ray energies from the decay cascades to deduce the excitation energies. This is true for all the previous evaluations of <sup>18</sup> Ne. Therefore, the evaluator corrected the excitation energies of all the bound states of <sup>18</sup> Ne by performing a least-squares fit to E $\gamma$ , which also takes into account the nuclear recoil energies.
			<sup>b</sup> This state was observed in (1968Gi09) for the first time via measuring the $\gamma$ -ray decay to the first excited state confirmed by the n $\gamma$ coincidences measurement in (1968Gi09).
			<sup>c</sup> Supported by the mirror analysis of (1968Gi09); and the measured $\gamma$ -ray angular correlations by (1969Ro08). The latter were fitted with the theoretical distributions taken from (O. Häusser, J. S. Lopes, H. J. Rose and R. D. Gill, University of Oxford Laboratory Report (1966)) for a number of assumed spins involved in the $\gamma$ -ray transitions. (1969Ro08) deduced a <sub>2</sub> and a <sub>4</sub> coefficients of Legendre polynomials and used them together with the sum rules of (1968Ar02) for the E2 transitions and the mirror levels in <sup>18</sup> O to deduced one final spin for the excited states, which are reported here.

$\gamma$ (<sup>18</sup>Ne)

In (1970Sh04),  $\gamma$ -ray de-excitation data were quoted in terms of the relative intensities for  $\theta_\gamma=90^\circ$  and  $\theta_n=0^\circ$  whenever a transition was observed definitely.

The results from (1976Mc02) for the B(E2: 2<sub>1</sub><sup>+</sup> $\rightarrow$ 0<sub>g.s.</sub><sup>+</sup>) transitions confirm the presence of two-body contributions to the effective E2 transition operator. (1970Ha75, 1970Ha49) predicted two-body contributions of the order of 25% to the E2 transition strengths in <sup>18</sup>Ne.

<u>E<sub>i</sub>(level)</u>	<u>J<math>\pi</math><sub>i</sub></u>	<u>E<math>\gamma</math><sup>a</sup></u>	<u>I<math>\gamma</math></u>	<u>E<sub>f</sub></u>	<u>J<math>\pi</math><sub>f</sub></u>	<u>Mult.</u>	<u>Comments</u>
1887.4	2 <sup>+</sup>	1887.3 2	100	0	0 <sup>+</sup>	E2	B(E2)(W.u.)=18.0 +17-14 E $\gamma$ : From (1968Gi09, 1969Ro08). See also 1890 keV (1969Be31, 1974Mc17, 1976Mc02); 1887 keV (1969Ro22, 1971Ro18, 1972Gi01, 2003Ta13); and 1890 keV 2 (1970Sh04). I $\gamma$ : From (1968Gi09, 1969Ro08, 1969Ro22). Mult.: From (1974Mc17). $\delta=0$ (mixing ratio) from (1969Ro08). (1969Ro08): deduced coefficients of Legendre polynomials from the $\gamma$ -ray angular distributions. These are: a <sub>2</sub> =0.44 3 and a <sub>4</sub> =-0.33 5 (E <sub>lab</sub> not given). (1969Ro22): deduced a <sub>2</sub> =0.31 9 and a <sub>4</sub> =-0.92 7 from the measured $\gamma$ -ray angular correlations at E <sub>lab</sub> =9.5 MeV. These coefficients uniquely determine J=2 for the <sup>18</sup> Ne*(1887 keV) level. (2003Ta13): deduced values of a <sub>2</sub> /a <sub>0</sub> =0.40 and a <sub>4</sub> /a <sub>0</sub> =-0.15 23 from the measured angular distribution, for the 1887 keV $\rightarrow$ g.s. transition, averaged over E <sub>lab</sub> =6-30 MeV. (1976Mc02) calculated an experimental value of B(E2:2 <sub>1</sub> <sup>+</sup> $\rightarrow$ 0 <sub>1</sub> <sup>+</sup> )=52 e <sup>2</sup> fm <sup>4</sup> 5 for the 1887 keV $\rightarrow$ g.s. transition using $\tau=0.66$ ps 6. [This value was deduced by (1976Mc02) as the weighted average of $\tau=0.63$ ps 13

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<sup>16</sup>O(<sup>3</sup>He,n $\gamma$ ) **1968Gi09,2003Ta13 (continued)**

$\gamma$ (<sup>18</sup>Ne) (continued)

<u>E<sub>i</sub>(level)</u>	<u>J<sub>i</sub><sup><math>\pi</math></sup></u>	<u>E<sub><math>\gamma</math></sub><sup><i>a</i></sup></u>	<u>I<sub><math>\gamma</math></sub></u>	<u>E<sub>f</sub></u>	<u>J<sub>f</sub><sup><math>\pi</math></sup></u>	<u>Mult.</u>	<u>Comments</u>
3376.4	4 <sup>+</sup>	1488.9 3	100	1887.4	2 <sup>+</sup>	E2	<p>(1974Mc17); <math>\tau=0.67</math> ps 6 (1976Mc02); and <math>\tau=0.49</math> ps +17-9 (1969Ro08). Evaluator notes that even though the uncertainty in <math>\tau=0.63</math> ps 13 (1974Mc17) was systematic, (1976Mc02) appears to have ignored that, and we cannot reproduce the weighted average obtained by (1976Mc02).] The deduced B(E2) value should be compared with calculated values of B(E2)=32 e<sup>2</sup>fm<sup>4</sup> (T. Engeland and P. J. Ellis, Nucl. Phys. A 181 (1972) 368: from shell model); B(E2)=40 e<sup>2</sup>fm<sup>4</sup> (1976Mc02: calculated assuming that the wave functions for the states in <sup>18</sup>Ne have the same structure as the corresponding T=1 states in <sup>18</sup>O); B(E2)=52 e<sup>2</sup>fm<sup>4</sup> (1976Mc02: from the phenomenological estimates of (1970Ha75, 1970Ha49) for the two-body part of the effective transition operator); and B(E2)=48 e<sup>2</sup>fm<sup>4</sup> (1976Mc02: from the realistic reaction matrix elements of (F. C. Khanna, M. Harvey, D. W. L. Sprung and A. Jopko, The two body force in nuclei, ed. S. M. Austin and G. M. Crawley (Plenum Press, New York, 1972) p. 229)). (2003Ri08): deduced, using the measured lifetime of 0.77 ps +9-7, B(E2: 0<sub>g.s.</sub><sup>+</sup>→2<sub>1</sub><sup>+</sup>)=222 e<sup>2</sup>fm<sup>4</sup> 20, which is consistent with B(E2: 0<sub>g.s.</sub><sup>+</sup>→2<sub>1</sub><sup>+</sup>)=260 e<sup>2</sup>fm<sup>4</sup> 25 (1976Mc02). Both of these values are inconsistent with B(E2: 0<sub>g.s.</sub><sup>+</sup>→2<sub>1</sub><sup>+</sup>)=113 e<sup>2</sup>fm<sup>4</sup> 18 (2000Ri15) and B(E2: 0<sub>g.s.</sub><sup>+</sup>→2<sub>1</sub><sup>+</sup>)=137 e<sup>2</sup>fm<sup>4</sup> 22 (2000Ri15). Note that the B(E2: 0<sub>g.s.</sub><sup>+</sup>→2<sub>1</sub><sup>+</sup>)=222 e<sup>2</sup>fm<sup>4</sup> 20 from (2003Ri08), in turn, yields a proton matrix element M<sub>p</sub>(<sup>18</sup>Ne)=0.149 7 (2006ChZY). By adopting the mirror hypothesis, (2003Ri08) deduced B(E2: 0<sub>g.s.</sub><sup>+</sup>→2<sub>1</sub><sup>+</sup>)=190 e<sup>2</sup>fm<sup>4</sup> 14 from the <sup>18</sup>O empirical neutron transition density. This calculation yields an integrated cross section of 52.7 mb for the excitation of the first 2<sup>+</sup> state of <sup>18</sup>Ne. This cross section is very close to the measured value of 40 mb 11 from (2000Ri15). (2003Ta13): a broad resonance like structure dominates the <sup>16</sup>O(<sup>3</sup>He, n<math>\gamma</math><sub>1887</sub>)<sup>18</sup>Ne* excitation function at E<sub>lab</sub>~9.5 MeV, which corresponds to an excitation energy of ~16.4 MeV in the compound nucleus <sup>19</sup>Ne. A narrower resonance was also observed at E<sub>lab</sub>~6.5 MeV, which could correspond to the 13.8-MeV level of <sup>19</sup>Ne (1995Ti07). Maximum production cross section for this transition was reported as ~65 mb at E<sub>lab</sub>=10 MeV (2003Ta13). B(E2)(W.u.)=9.1 +15-11</p> <p>E<sub><math>\gamma</math></sub>: From (1968Gi09, 1969Ro08). See also 1489 keV (1969Ro22, 1971Ro18, 1972Gi01, 2003Ta13); and 1493 keV 2 (1970Sh04). Mult.: From (1972Gi01). See also E2/M3 (1969Ro08, 1969Ro22, 1970Sh04) with a mixing ratio of <math>\delta=0.04</math> 3 determined from the weighted average of +0.06 7 (1969Ro08: see Table 2 assuming J=4); +0.00 4 (1969Ro22: see Fig. 3 assuming J=4); and +0.12 7 (1970Sh04: see Fig. 1). See also <math>\delta=+8</math> 3 (1969Ro08: see Table 2 assuming J=4). (1969Ro08) mentions that the latter value may be excluded because this value together with the measured lifetime by (1969Ro08) would imply an enormously enhanced M3 matrix element (<math>\approx 10^4</math>). Note that (1970Sh04) and (1972Gi01) both used the phase convention of (1967Ro21) to deduce their mixing ratios. The uncertainty in the mixing ratio of (1970Sh04) is statistical.</p> <p>I<sub><math>\gamma</math></sub>: From (1968Gi09, 1969Ro08, 1969Ro22: see Fig. 3), and (1970Sh04: see Fig. 1). (1969Ro08) deduced coefficients of Legendre polynomials from the <math>\gamma</math>-ray angular distributions: a<sub>2</sub>=0.37 6 and a<sub>4</sub>=-0.28 9. (1969Ro22) deduced a<sub>2</sub>=0.22 9 and a<sub>4</sub>=-0.20 10 at E<sub>lab</sub>=10 MeV; a<sub>2</sub>=0.61 10 and a<sub>4</sub>=-0.11 11 at E<sub>lab</sub>=10.2 MeV; and a<sub>2</sub>=0.38 10 and a<sub>4</sub>=</p>

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<sup>16</sup>O(<sup>3</sup>He,n $\gamma$ ) **1968Gi09,2003Ta13 (continued)**

$\gamma$ (<sup>18</sup>Ne) (continued)

<u>E<sub>i</sub>(level)</u>	<u>J<sub>i</sub><sup><math>\pi</math></sup></u>	<u>E<sub><math>\gamma</math></sub><sup><i>a</i></sup></u>	<u>I<sub><math>\gamma</math></sub></u>	<u>E<sub>f</sub></u>	<u>J<sub>f</sub><sup><math>\pi</math></sup></u>	<u>Mult.</u>	<u>Comments</u>
3576.5	0 <sup>+</sup>	1689.2	100	1887.4	2 <sup>+</sup>	E2	<p>12 at E<sub>lab</sub>=11.5 MeV from the measured <math>\gamma</math>-ray angular correlations for the 1488.9-keV transition.</p> <p>The fit to the n<math>\gamma</math> angular correlation data of (1970Sh04) with J=4 is the best fit with 0.1% confidence level (1970Sh04: see Fig. 9).</p> <p>Using <math>\tau=4.4</math> ps (see 1974Mc17) for the <sup>18</sup>Ne*(3380 keV) state, (1976Mc02) calculated an experimental value of B(E2: 4<sub>1</sub><sup>+</sup>→2<sub>1</sub><sup>+</sup>)=25 e<sup>2</sup>fm<sup>4</sup> (3 for this transition. This value should be compared with calculated values of B(E2)=26 e<sup>2</sup>fm<sup>4</sup> (T. Engeland and P. J. Ellis, Nucl. Phys. A 181 (1972) 368: from shell model); B(E2)=26 e<sup>2</sup>fm<sup>4</sup> (1976Mc02: calculated assuming that the wave functions for the states in <sup>18</sup>Ne have the same structure as the corresponding T=1 states in <sup>18</sup>O); B(E2)=33 e<sup>2</sup>fm<sup>4</sup> (1976Mc02: from the phenomenological estimates of (1970Ha75, 1970Ha49) for the two-body part of the effective transition operator); and B(E2)=26 e<sup>2</sup>fm<sup>4</sup> (1976Mc02: from the realistic reaction matrix elements of (F. C. Khanna, M. Harvey, D. W. L. Sprung and A. Jopko, The two body force in nuclei, ed. S. M. Austin and G. M. Crawley (Plenum Press, New York, 1972) p. 229)).</p> <p>(1970Sh04) found that at <math>\theta_{\gamma,lab}=90^\circ</math> the ratio of the yield of the 1.87-MeV to the 1.49-MeV <math>\gamma</math> rays is 1.01 (4). This is consistent with J<sup><math>\pi</math></sup>=4<sup>+</sup> assignment for the 3376.4-keV level because both of the <math>\gamma</math>-ray transitions involved in the 4<sub>1</sub><sup>+</sup>→2<sub>1</sub><sup>+</sup>→0<sub>1</sub><sup>+</sup> cascade have the same angular correlation with respect to the corresponding neutron groups independent of the reaction mechanism.</p> <p>The ground state decay branch (3376 keV → g.s.) was not observed. The branching ratio for this unobserved branch was estimated to be &lt;1% (1969Ro22: see Fig. 3); &lt;1% (1970Sh04: see Fig. 1); and &lt;4% (1968Gi09, 1969Ro08).</p> <p>B(E2)(W.u.)=5.3 (46-18)</p> <p>E<sub><math>\gamma</math></sub>: From (1968Gi09, 1969Ro08). See also 1689 keV (1969Ro22, 1971Ro18, 1972Gi01); and 1689 keV (1970Sh04: which is most likely what was reported by (1969Ro08)).</p> <p>E<sub><math>\gamma</math></sub>: This <math>\gamma</math> ray was first observed by (1968Gi09, 1969Ro08). (1969Ro22) confirmed that this <math>\gamma</math> ray belongs to <sup>18</sup>Ne by using n<math>\gamma\gamma</math> coincidences gating on the 1887-keV <math>\gamma</math> ray.</p> <p>I<sub><math>\gamma</math></sub>: From (1968Gi09, 1969Ro08, 1969Ro22: see Fig. 3).</p> <p>Mult.: From (1972Gi01).</p> <p>(1969Ro08) deduced coefficients of Legendre polynomials from the <math>\gamma</math>-ray angular distributions: a<sub>2</sub>=0.0 (3), a<sub>4</sub>=0.0 (5).</p> <p>(1969Ro22) deduced a<sub>2</sub>=0.0 (3) and a<sub>4</sub>=-0.1 (6) at E<sub>lab</sub>=11.5 MeV from the measured <math>\gamma</math>-ray angular correlations.</p> <p>Assuming <math>\tau=4</math> ps (1972Gi01), (1974Mc17) calculated B(E2: 0<sub>2</sub><sup>+</sup>→2<sub>1</sub><sup>+</sup>)=14.5 e<sup>2</sup>fm<sup>4</sup> (74) for this transition. This value should be compared with B(E2)=3.36 e<sup>2</sup>fm<sup>4</sup> calculated by (T. Engeland and P. J. Ellis, Nucl. Phys. A 181 (1972) 368).</p> <p>The decay branch from the 3576-keV state to the ground state was not observed. The branching ratio for this unobserved branch was estimated to be &lt;5% (1969Ro22: see Fig. 3); and &lt;17% (1968Gi09, 1969Ro08).</p>

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<sup>16</sup>O(<sup>3</sup>He,n $\gamma$ ) **1968Gi09,2003Ta13 (continued)**

$\gamma(^{18}\text{Ne})$  (continued)

$E_i(\text{level})$	$J_i^\pi$	$E_\gamma^a$	$I_\gamma$	$E_f$	$J_f^\pi$	Mult.	$\delta$	Comments
3616.6	2 <sup>+</sup>	1729.2 5	91 3	1887.4	2 <sup>+</sup>	M1+E2	0.05 7	<p>B(M1)(W.u.)=0.088 +45-31; B(E2)(W.u.)&lt;5.8  <math>E_\gamma</math>: From (1968Gi09, 1969Ro08). See also 1729 keV (1969Ro22, 1971Ro18, 1972Gi01); and 1736 keV 2 (1970Sh04).  <math>I_\gamma</math>: Weighted average (rounded to the nearest integer) of 93% 2 (1969Ro22: see Fig. 3) and 87.5% 25 (1972Gi01). See also 100% (1968Gi09, 1969Ro08, 1970Sh04: see Fig. 1).  <math>\delta</math>: Weighted average (with external errors) of -1.1 +10-3 (1969Ro08: see Table 2 assuming J=2); -0.9 7 (1969Ro22: see Fig. 3); +0.09 7 (1970Sh04: see Fig. 1; used the phase convention of (1967Ro21) to deduce the mixing ratio. The uncertainty in this mixing ratio is statistical); and +0.03 9 (1972Gi01: the mixing ratio was determined following the convention of (1967Ro21)). See also <math>\delta</math>=0.06 6 deduced by (1972Gi01) as the weighted average of the same values mentioned above.  Mult.: From (1969Ro08, 1970Sh04, 1972Gi01). (1969Ro08) calculated the matrix elements for E2 and M1 transitions as <math> M ^2 &lt; 190</math> W.u. and <math>0.03 &lt;  M ^2 &lt; 0.1</math>, respectively. (1969Ro08) deduced coefficients of Legendre polynomials from the <math>\gamma</math>-ray angular distributions: <math>a_2=0.74</math> 11, <math>a_4=-0.13</math> 17.  (1969Ro22) deduced <math>a_2=0.48</math> 22 and <math>a_4=0.02</math> 26 at <math>E_{\text{lab}}=10</math> MeV; <math>a_2=0.35</math> 18 and <math>a_4=-0.69</math> 19 at <math>E_{\text{lab}}=10.2</math> MeV; and <math>a_2=0.62</math> 17 and <math>a_4=-0.34</math> 25 at <math>E_{\text{lab}}=11.5</math> MeV from the measured <math>\gamma</math>-ray angular correlations.  <math>\Gamma=9.1</math> meV was calculated by (1972Gi01) for this transition using the mixing ratio of +0.06 6 (1972Gi01: see the comment on <math>\delta</math>) and the lifetime of the 3616-keV state from (1972Gi01). This width should be compared with <math>\Gamma=9.4</math> meV (1966Be29) as cited in (1969Ro08) and <math>\Gamma=6.7</math> meV (private communication of T. Engeland and P. J. Ellis with the authors of (1972Gi01)).  Assuming <math>\delta=+0.06</math> 6 and BR=87.5% 25 deduced from the results of (1972Gi01), (1974Mc17) calculated <math>B(E2: 2_2^+ \rightarrow 2_1^+)=2.6</math> e<sup>2</sup>fm<sup>4</sup> +77-27 for this transition. This value should be compared with the calculated values of B(E2)=30.5 e<sup>2</sup>fm<sup>4</sup> (1970Ha49: based on wave functions of (1969Be94) without two-body contributions), B(E2)=22.14 e<sup>2</sup>fm<sup>4</sup> (T. Engeland and P. J. Ellis, Nucl. Phys. A 181 (1972) 368), and B(E2)=36 e<sup>2</sup>fm<sup>4</sup> (1970Ha49).  Using <math>\tau=0.063</math> ps +30-20 (1968Gi09), (1974Mc17) calculated B(M1)=0.00170 e<sup>2</sup>fm<sup>2</sup> +77-53, which should be compared with B(M1)=0.0012 e<sup>2</sup>fm<sup>2</sup> calculated by (T. Engeland and P. J. Ellis, Nucl. Phys. A 181 (1972) 368).  B(E2)(W.u.)=0.68 +37-29  <math>E_\gamma</math>: From (1969Ro22). See also 3630 keV 2 (1970Sh04); and 3616 keV (1972Gi01, 1971Ro18: this <math>\gamma</math>-ray was observed in this experiment. This is confirmed in the text but not shown on the Fig. 2).  <math>E_\gamma</math>: (1969Ro22): confirmed that this <math>\gamma</math>-ray belongs to the 3617-keV <sup>18</sup>Ne state because the energy of the photopeak and double-escape peak from the decay of this</p>
		3614 3	9 3	0	0 <sup>+</sup>	E2		

Continued on next page (footnotes at end of table)

$^{16}\text{O}(^3\text{He},n\gamma)$  1968Gi09,2003Ta13 (continued) $\gamma(^{18}\text{Ne})$  (continued) $E_i(\text{level})$   $E_\gamma^a$ 

Comments

state fit the excitation energy of this level within the errors.

$I_\gamma$ : Weighted average (rounded to the nearest integer) of 7% 2 (1969Ro22: see Fig. 3, deduced from measurement of angular correlations using a NaI counter at 10.2 MeV); and 12.5% 25 (1972Gi01). See also BR<9% (1968Gi09, 1969Ro22); BR<3% (1970Sh04: see Fig. 1). Note that (1969Ro22) deduced branching ratio of 8% 2 from  $n\gamma$ -coincidence measurement using Ge(Li) detector. They recommended the value of 7% 2 deduced from angular correlations. However, later on, (1972Gi01) argued that the 7% 2 branching ratio reported by (1969Ro22) is a calculated value and not from measurement. It is not clear to the evaluator if this opinion is correct.

Mult.: From (1972Gi01).

Using the branching ratio for this transition and the lifetime of the 3616-keV state from (1972Gi01), they calculated  $\Gamma=1.4$  meV for this transition. This value should be compared with the theoretical values of  $\Gamma=0.4$  meV from (1966Be29) as cited in (1969Ro08);  $\Gamma=0.6$  meV from (1968Ar02) as cited in (1969Ro08); and  $\Gamma=0.64$  meV (private communication of T. Engeland and P. J. Ellis with the authors of (1972Gi01)).

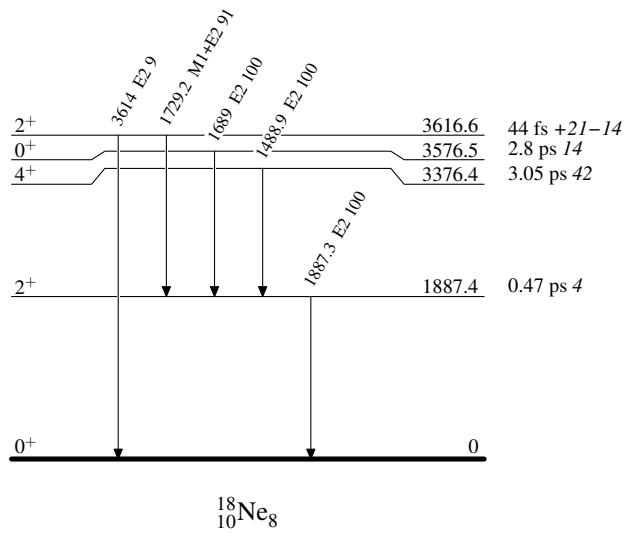
Assuming BR=12.5 % 25 (1972Gi01), (1974Mc17) calculated  $B(E2: 2_2^+ \rightarrow 0_1^+) = 2.5 \text{ e}^2\text{fm}^4$  +13-10 for this transition. This value should be compared with the calculated values of  $B(E2)=1.68 \text{ e}^2\text{fm}^4$  (1970Ha49: based on wave functions of (1969Be94) without two-body contributions),  $B(E2)=1.26 \text{ e}^2\text{fm}^4$  (T. Engeland and P. J. Ellis, Nucl. Phys. A 181 (1972) 368), and  $B(E2)=2.77 \text{ e}^2\text{fm}^4$  (1970Ha49).

<sup>a</sup> The  $\gamma$ -ray energies (and thus the deduced excitation energies) from (1970Sh04) are consistently higher than all other  $\gamma$ -ray measurements reported here. Due to potentially unknown systematic uncertainties, the evaluator did not consider the  $\gamma$ -ray energies reported by (1970Sh04) in finding the adopted  $E_\gamma$  and  $E_x$  energies.

$^{16}\text{O}(^3\text{He},n\gamma)$  1968Gi09,2003Ta13

## Level Scheme

Intensities: % photon branching from each level



$^{16}\text{O}(^{10}\text{B}, ^8\text{Li})$  1977HaYB,1983Os07

1977HaYB:  $^{16}\text{O}(^{10}\text{B}, ^8\text{Li})$  E=100 MeV; measured yields.

1978Ha10:  $^{16}\text{O}(^{10}\text{B}, ^8\text{Li})$  E=100 MeV; measured the reaction products using a  $\Delta\text{E-E}$  Si telescope with an energy resolution of  $\Delta\text{E}(\text{FWHM})=300\text{-}400$  keV. Measured  $\sigma(\theta)$  and a few excited levels of  $^{18}\text{Ne}$  at 1890 keV 19, 3380 keV 34, 7200 keV 72, and 8200 keV 82. Measured the angular distribution of the  $^{18}\text{Ne}^*(3380\text{ keV})$  state at  $\theta_{\text{c.m.}} \sim 17^\circ\text{-}35^\circ$ , which was analyzed using finite range DWBA analysis via the SATURN and MARS codes. Deduced the spectroscopic factor and compared the result with that obtained using shell model calculations. The authors concluded that the  $(^{10}\text{B}, ^8\text{Li})$  reaction selectively populates the high spin states.

Theory:

1976ToZV:  $^{16}\text{O}(^{10}\text{B}, ^8\text{Li})$  E=100 MeV.

1983Os07:  $^{16}\text{O}(^{10}\text{B}, ^8\text{Li})$  E=100 MeV; developed an expression for the DWBA differential cross sections of heavy ion reactions with two nucleon transfer taking into account the finite range effects. Analyzed the experimental  $\sigma(\theta)$  (1978Ha10) for  $^{16}\text{O}(^{10}\text{B}, ^8\text{Li})$  at 100 MeV. Deduced optical model parameters for the finite range DWBA calculations performed using the LAJOLLA code. Deduced the spectroscopic factors. The theoretical calculations reproduced the experimental measurements of the differential cross sections both in shape and in magnitude.

 $^{18}\text{Ne}$  Levels

<u>E(level)<sup>a</sup></u>	<u>J<sup><math>\pi</math></sup></u>	<u>C<sup>2</sup>S<sup>c</sup></u>	<u>Comments</u>
1890 <sup>b</sup> 19	2 <sup>+</sup>		J <sup><math>\pi</math></sup> : From Fig. 2 of (1978Ha10), measured at $\theta_{\text{lab}}=10.8^\circ$ . J <sup><math>\pi</math></sup> is determined from the exact finite range DWBA calculation performed in (1978Ha10) but L is not given.
3380 34	4 <sup>+</sup>	0.50 13	J <sup><math>\pi</math></sup> ,C <sup>2</sup> S: Determined from the exact finite range DWBA calculation performed in (1978Ha10). The agreement with the data is very good except at $\theta_{\text{c.m.}}=35^\circ$ (see Fig. 5). The orbital angular momentum for the transfer is not provided. This state is strongly populated (see Fig. 2), and it is mentioned in (1978Ha10) that the results of the exact finite-range DWBA showed that only those states which have shell model configuration of the target nucleus coupled to an $s=0$ , T=1 proton pair are strongly populated for A=18 nuclei. (1978Ha10) deduced the ratio between experimental to theoretical cluster spectroscopic factor for this state and found that $S_{\text{exp}}/S_{\text{theo}}=2.50\ 63$ , where the theoretical spectroscopic factor is calculated to be $S_{\text{theo}}=0.199$ using shell model wave functions from (1976La13). (1978Ha10) reported that this rather large ratio may be caused by an interference between $s=0$ and $s=1$ transfer [the proton pair may be transferred in a relative $s=1$ state], which could enhance the population strength of this state (1978Ha10). A similar theoretical finite range DWBA calculation performed by (1983Os07) reports $\Delta L=3,4$ . Evaluator notes that $\Delta L=3$ most likely indicates that the two protons are transferred from two different shells with a relative L=1, whereas $\Delta L=4$ refers to a diproton transfer in a relative $s=0$ state. C <sup>2</sup> S: (1978Ha10): $\sigma_{\text{exp}}(\theta)=C_1^2S_1C_2^2S_2\sigma_{\text{DWBA}}$ for 2p transfer. Therefore, the normalization factor is $N=C_1^2S_1C_2^2S_2$ . $N=0.095\ 24$ (1978Ha10). Assuming $C_1^2S_1=0.191$ (1978Ha10), $C_2^2S_2=0.50\ 13$ (1978Ha10). C <sup>2</sup> S: (1978Ha10): shell model wave functions from (1976La13) (constrained-II set) assumed for this state in $^{18}\text{Ne}$ is: $0.986 d_{5/2}^2\rangle+0.151 d_{5/2}d_{3/2}\rangle$ . The corresponding amplitude of the leading SU <sub>3</sub> term in the transformed wave function is 0.576 (1978Ha10). C <sup>2</sup> S: See also $S_{\text{theoretical}}=0.6531$ (1983Os07).
7200 <sup>b</sup> 72			E(level): Due to insufficient information, this state was not considered for the $^{18}\text{Ne}$ Adopted Levels. However, based on the excitation energy, we paired this level with the 7120-keV state in the Adopted Levels.
8200 <sup>b</sup> 82			

<sup>a</sup> From (1978Ha10). An uncertainty of 1% due to calibration is added to the excitation energies based on what is reported in the text of (1978Ha10).

<sup>b</sup> From Fig. 2 of (1978Ha10), measured at  $\theta_{\text{lab}}=10.8^\circ$ .

<sup>c</sup> Cluster spectroscopic factor from (1978Ha10).

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$^{16}\text{O}(^{11}\text{B},^9\text{Li})$  1979Ra10

**1979Ra10:**  $^{16}\text{O}(^{11}\text{B},^9\text{Li})$  E=115 MeV; measured the  $^9\text{Li}$  ejectiles using a  $\Delta\text{E}-\Delta\text{E}-\text{E}$  telescope with an overall energy resolution of  $\sim 250$  keV. This two-proton transfer reaction populated only one state of  $^{18}\text{Ne}$  at 3.38 MeV.

$^{18}\text{Ne}$  Levels

<u>E(level)<sup>a</sup></u>	<u>J<math>\pi</math><sup>a</sup></u>
3376.4	4 <sup>+</sup>

<sup>a</sup> From the  $^{18}\text{Ne}$  Adopted Levels.

<sup>16</sup>O(<sup>12</sup>C, <sup>10</sup>Be) 1972Sc21, 1988Me10

**1972Sc21:** <sup>16</sup>O(<sup>12</sup>C, <sup>10</sup>B) E=114 MeV; measured the reaction products, from <sup>6</sup>Li to <sup>13</sup>C, using a solid state ΔE-E telescope covering  $\theta_{lab}=7^\circ-35^\circ$ . Energy resolution was ΔE(FWHM)=300 keV. Measured charged particle spectra. The mechanism of the reactions appears to be dominated by a surface interaction. The experimenters concluded that the reactions caused by heavy ions with incident energies of ~10 MeV/nucleon tend to populate high-spin excited states with stretched particle configurations. In the case of two-proton transfer, the exclusion principle allows only states of even spin with T=1.

**1974An36:** <sup>16</sup>O(<sup>12</sup>C, <sup>10</sup>B) E=114 MeV; measured the reaction products using a telescope that consisted of ΔE-ΔE-E fully depleted Si surface barrier detectors in anti-coincidence with a final Si veto detector. The experimental energy resolution was 400 keV (FWHM). Angular distributions were measured at  $\theta_{lab}=6^\circ-30^\circ$ . The observed cross section for a transfer of two protons was on the order of 0.02 mb/sr. Reaction mechanism, and spectroscopic amplitudes are discussed. The experimenters report that the excitation of <sup>10</sup>Be is mostly obscured and conclude that this heavy-ion transfer reaction selectively populates high spin states by transferring particles into the *sd* shell coupling to the maximum possible spin.

**1988Kr11, 1988Me10:** <sup>16</sup>O(<sup>12</sup>C, <sup>10</sup>B) E=480 MeV; measured the reaction products using the SPEG spectrometer and its associated focal plane equipment resulting in an energy resolution of 200 keV. The angular distributions of the most strongly populated excited states in various residual nuclei, including <sup>18</sup>Ne, were measured (for the case of <sup>18</sup>Ne states, at  $\theta_{lab}=2^\circ-6^\circ$ ). For the residual nuclei other than <sup>18</sup>Ne, these distributions were analyzed using the exact finite range DWBA with the PTOLEMY code. The <sup>18</sup>Ne states were unresolved from the <sup>30</sup>S excited states populated by the (<sup>12</sup>C, <sup>10</sup>Be) reaction on the Si content of the target. Shell model calculations were performed to explain the observed levels.

<sup>18</sup>Ne Levels

E(level)	J <sup>π</sup>	Comments
0 <sup>a</sup>	0 <sup>+</sup> <sup>b</sup>	E(level),J <sup>π</sup> : From Fig. 3(c) of (1972Sc21), Fig. 5(b) of (1974An36), and Fig. 3 of (1988Kr11).
1.8×10 <sup>3a</sup>	2 <sup>+</sup> <sup>b</sup>	E(level),J <sup>π</sup> : From Fig. 3 of (1988Kr11). It is not clear if the J <sup>π</sup> assignment was independently determined.
3380 <sup>a</sup>	4 <sup>+</sup>	T=1 (1974An36) E(level),J <sup>π</sup> : From Fig. 3(c) of (1972Sc21), Fig. 5(b) of (1974An36), and Fig. 3 of (1988Kr11). E(level): See also 3.4 MeV (1988Kr11, 1988Me10). E(level),J <sup>π</sup> : The shell model calculation of (1988Kr11) predicted the 4 <sub>1</sub> <sup>+</sup> state in <sup>18</sup> Ne to be at 3.32 MeV with a configuration of 1d <sub>5/2</sub> <sup>2</sup> . The evaluator assumed the J <sup>π</sup> assignment is from the shell model calculation in (1988Kr11). This state, formed by 2p transfer on <sup>16</sup> O, has a configuration of (d <sub>5/2</sub> ) <sup>2</sup> (1972Sc21, 1970Ad02). (1988Kr11): the <sup>18</sup> Ne state at 3.4 MeV appears to be wide (see Fig. 3). This is because in the data analysis, the position of the focal plane is reconstructed for the Si target and not for the O target, which causes the <sup>18</sup> Ne states to suffer from kinematics broadening (out of focus).
7.9×10 <sup>3</sup>	(4 <sup>+</sup> )	E(level),J <sup>π</sup> : From Fig. 3 of (1988Kr11). E(level),J <sup>π</sup> : The shell model calculation of (1988Kr11) predicted the 4 <sub>2</sub> <sup>+</sup> state in <sup>18</sup> Ne to be at 8.32 MeV with a configuration of 1d <sub>5/2</sub> <sup>1</sup> 1d <sub>3/2</sub> <sup>1</sup> . So, the evaluator assumed the J <sup>π</sup> assignment is from the shell model calculation in (1988Kr11).

<sup>a</sup> From (1988Kr11): these states were unresolved and mixed with a <sup>30</sup>S\* excited state with E<sub>x</sub>~5.1-8.3 MeV. The (<sup>12</sup>C, <sup>10</sup>Be) reactions on the Si and O contents of the SiO<sub>2</sub> target, as well as poor energy resolution made the spectra of <sup>18</sup>Ne and <sup>30</sup>S in (1988Kr11) complicated. However, different angular kinematic shifts of the <sup>10</sup>Be reaction products, arising either from a reaction on the O or on the Si, allowed partial disentanglement of the two reactions.

<sup>b</sup> It is not clear from (1972Sc21) and (1974An36) if the reported J<sup>π</sup> assignment is based on the shell model calculations, or from the literature. In (1988Kr11), finite range DWBA was used but no angular distribution data are presented or discussed for the populated <sup>18</sup>Ne states. So, it is not clear if the reported J<sup>π</sup> assignments in (1988Kr11) are from the DWBA calculations or from shell model calculations.

$^{18}\text{O}(\pi^+, \pi^-)$  **1974LiZR, 2007Ke07**

- 1968Ch46:**  $^{18}\text{O}(\pi^\pm, \pi^\mp)$  E=80-280 MeV; measured the activation cross sections for reactions of pions with light nuclei, including  $^{18}\text{O}$  over the energy range of 80 to 280 MeV. No  $^{18}\text{Ne}$  state was observed. An upper limit on the  $^{18}\text{O}(\pi^+, \pi^-)^{18}\text{Ne}_{\text{g.s.}}$  cross section was set to  $\sigma < 0.1$  mb.
- 1974LiZR:**  $^{18}\text{O}(\pi^+, \pi^-)$ ; measured  $\sigma$ .
- 1977Ma02, 1977MaYB:**  $^{18}\text{O}(\pi^+, \pi^-)$  E=95-139 MeV (**1977MaYB**), E=139 MeV (**1977Ma02**); measured the  $\pi^-$  particles using the focal plane detection system of the low-energy pion beamline of the Los Alamos Meson Physics Facility, which was used as a spectrometer. The detection system consisted of 3 helical wire proportional chambers, 3 plastic Cherenkov counters, and 5 scintillator counters to measure the  $\pi^-$  trajectories, energies and time-of-flight. The intrinsic experimental resolution was 4 MeV. The  $^{18}\text{Ne}_{\text{g.s.}}$  was observed at  $E_{\pi^-}=130$  MeV. The differential cross section at  $\theta_{\text{c.m.}}=0^\circ$  was deduced to be  $d\sigma/d\Omega_{\text{lab}}(0^\circ)=1.78$   $\mu\text{b/sr}$  30. Comparison between this result and theoretical calculations are presented.
- 1977Pe12:**  $^{18}\text{O}(\pi^+, \pi^-)$  E=148 and 187 MeV; used the SIN  $\pi\text{M1}$  beamline for tuning  $\pi^+$  beam and pion spectrometer for tuning the  $\pi^-$  ejectiles; resolutions were 0.7 MeV at 148 MeV, and 1.1 MeV at 187 MeV; the experiments were performed at  $\theta_{\text{lab}}=18^\circ$ ; a series of multi-wire proportional counters and scintillators were used to measure the momenta and scattering angles; measured differential cross sections normalized to the measured  $^{12}\text{C}$  elastic scattering data; deduced  $d\sigma/d\Omega_{\text{lab}}(\theta_{\text{lab}}=18^\circ, E=148 \text{ MeV})=0.30$   $\mu\text{b/sr}$  10 and  $d\sigma/d\Omega_{\text{lab}}(\theta_{\text{lab}}=18^\circ, E=187 \text{ MeV})=0.21$   $\mu\text{b/sr}$  8 for the  $^{18}\text{O}(\pi^+, \pi^-)^{18}\text{Ne}_{\text{g.s.}}$ ; upper limits were set for the cross section of the first excited state of  $^{18}\text{Ne}$  (unresolved from  $^{18}\text{Ne}_{\text{g.s.}}$ ):  $d\sigma/d\Omega_{\text{lab}}(\theta_{\text{lab}}=18^\circ, E=148 \text{ MeV}) < 70$  nb/sr and  $d\sigma/d\Omega_{\text{lab}}(\theta_{\text{lab}}=18^\circ, E=187 \text{ MeV}) \sim 120$  nb/sr for  $^{18}\text{Ne}^*(1.89 \text{ MeV})$  level. The authors deduced the laboratory differential cross section by integrating over the double charge exchange continuum and the excited states of  $^{18}\text{Ne}$  up to 20 MeV excitation energy and obtained  $d\sigma/d\Omega_{\text{lab}}=3.8$   $\mu\text{b/sr}$  70 and 3.0  $\mu\text{b/sr}$  5 for  $\theta_{\text{lab}}=18^\circ$  and E=148 MeV and 187 MeV, respectively.
- 1978Bu09:**  $^{18}\text{O}(\pi^+, \pi^-)$  E=95, 126, and 139 MeV; used the low energy pion channel at the Los Alamos Meson Physics Facility. The experimental setup and detection system was identical to that of (**1977Ma02**). The authors state that the (**1977Ma02**) publication is the initial results of this experiment. Energy resolution was 4 MeV (FWHM). Laboratory differential cross sections for the  $^{18}\text{O}(\pi^+, \pi^-)^{18}\text{Ne}_{\text{g.s.}}$  reaction at  $\theta_{\text{lab}}=0^\circ$  were deduced to be  $d\sigma/d\Omega_{\text{lab}}(\theta_{\text{lab}}=0^\circ)=2.00$   $\mu\text{b/sr}$  34 at E=139 MeV,  $d\sigma/d\Omega_{\text{lab}}(\theta_{\text{lab}}=0^\circ)=2.19$   $\mu\text{b/sr}$  44 at E=126 MeV, and  $d\sigma/d\Omega_{\text{lab}}(\theta_{\text{lab}}=0^\circ)=1.67$   $\mu\text{b/sr}$  38 at E=95 MeV. The result at 139 MeV is consistent with that of (**1977Ma02**). Comparison between the deduced ground state cross section and various theoretical models are presented and discussed. A conclusion is made that the calculations based on first-order optical equations are an incomplete representation for  $^{18}\text{Ne}_{\text{g.s.}}$ , and that higher-order processes contribute significantly to the  $^{18}\text{O}(\pi^+, \pi^-)^{18}\text{Ne}_{\text{g.s.}}$  reaction. The (**1977Ma02**) presents the initial results of (**1978Bu09**).
- 1978SeZU:**  $^{18}\text{O}(\pi^+, \pi^-)$  E not given; measured absolute  $\sigma$ .
- 1979Gr18, 1979GrZG:**  $^{18}\text{O}(\pi^+, \pi^-)$  E=164 and 292 MeV; measured the ground state angular distribution at 164 MeV and  $\theta_{\text{lab}}=5^\circ-33^\circ$ ; measured the excitation function of the  $^{18}\text{O}(\pi^+, \pi^-)^{18}\text{Ne}$  reaction at  $\theta_{\text{lab}}=5^\circ$  using the EPICS pion spectrometer facility at LAMPF and a time-of-flight and a freon gas Cherenkov detector to reject electrons in the spectrometer's focal plane; The excitation function shows the ground and first excited states of  $^{18}\text{Ne}$ . The first excited state is populated with relatively high statistics. This excitation function covers, for the first time, the full region of the (3,3)  $\pi$ -nucleon resonance (aka  $\Delta_{33}$  resonance). In addition,  $d\sigma/d\Omega_{\text{lab}}(\theta_{\text{lab}}=5^\circ)$  was measured as a function of incident energy from 80 to 292 MeV. Cross section varied between 0.8  $\mu\text{b/sr}$  at 80 MeV to 2.5  $\mu\text{b/sr}$  at 292 MeV. These data were compared with calculations using a local Laplacian potential (**1974Mi22**), and a fixed scatterer model (W. R. Gibbs, B. F. Gibson, A. T. Hess and G. J. Stephenson, private communication). The agreement between these calculations and the data is poor but the former model predicts the overall shape better.
- 1979Se08,** Los Alamos Scientific Laboratory Report No. LA-7892-C, 1979, p. 201 (unpublished):  $^{18}\text{O}(\pi^+, \pi^-)$  E=164 MeV; used the EPICS pion spectrometer facility at LAMPF; energy resolution: 600 – 800 keV (FWHM); (**1979Se08**) is the first measurement ever of angular distributions for double charge exchange transitions to a discrete excited nuclear state; measured angular distributions at  $\theta_{\text{lab}}=13^\circ, 18^\circ, 23^\circ, 30^\circ,$  and  $45^\circ$ . The angular distribution for the transition to the  $^{18}\text{Ne}_{\text{g.s.}}$  monotonically decrease from 5.8  $\mu\text{b/sr}$  around  $\theta_{\text{c.m.}}=13^\circ$  (see the errata) to 2.5  $\mu\text{b/sr}$  at  $\theta_{\text{c.m.}}=45^\circ$ . Measured  $\pi^+$  elastic scattering yields between  $13^\circ$  and  $45^\circ$ ; used these data and those of (**1978Iv01, 1979Iv03**) to deduce an average normalization for the absolute cross section; measured  $\sigma(\theta)$  for the ground and the  $2_1^+$  states in  $^{18}\text{Ne}$ ; placed an upper limit of  $\sim 200$  nb/sr for populating the  $^{18}\text{Ne}^*(2_1^+)$  state at  $\theta_{\text{c.m.}}=0^\circ$ ; discussed strengths and shortcomings of theoretical models used (**1976Mi23, 1978Sp07, 1978Os02**) to describe measured angular distributions; the agreement between the data and these models were poor; argued that a large radius (4.8 fm) is required for  $^{18}\text{O}$  to theoretically produce the first minima of the measured angular distributions at  $\theta_{\text{c.m.}} \sim 21^\circ$ ; populated analog and non-analog  $^{18}\text{Ne}$  states.
- 1980GrZZ:**  $^{18}\text{O}(\pi^+, \pi^-)$  E=164 and 292 MeV; measured  $\sigma(\theta)$ . Deduced double-isobaric analog transitions relative to non-analog transitions in  $^{18}\text{Ne}$  and investigated their energy dependence.
- 1981GrZS:**  $^{18}\text{O}(\pi^+, \pi^-)$  E=100-290 MeV; measured  $d\sigma/d\Omega(^{18}\text{Ne}_{\text{g.s.}})$  and  $d\sigma/d\Omega(^{18}\text{Ne}(2_1^+))$  at  $\theta_{\text{lab}}=5^\circ$  as a function of incident energy for E=80-310 MeV using the EPICS pion spectrometer facility. Deduced reaction mechanism and structure effects.

$^{18}\text{O}(\pi^+, \pi^-)$  **1974LiZR,2007Ke07 (continued)**

- 1982Gr02,1982GrZV:**  $^{18}\text{O}(\pi^+, \pi^-)$  E=80-292 MeV; used the EPICS spectrometer facility; measured angular distributions for  $^{18}\text{Ne}_{\text{g.s.}}$  at  $\theta_{\text{lab}}=5^\circ-35^\circ$ ; measured  $\sigma(\theta)$  vs. E for  $^{18}\text{Ne}_{\text{g.s.}}$  and observed that the cross section peaks near 130 MeV, dips near 170 MeV, and shows a smooth rise above that energy, which is in contrast with the theoretical predictions (1975Li04, 1980Ge09, G. A. Miller, Bull. Am. Phys. Soc. 25 (1981) 731). (1982Gr02) showed that the  $\sigma(\theta)$  vs. E for the ground state of  $^{18}\text{Ne}$  can be explained by adding the direct double-isobaric analog transition (DIAT) amplitude (quasi-elastic amplitude) and non-DIAT amplitude, which is the sum of all processes that can change any two neutrons into any two protons without violating the Pauli principle. The interference of these two amplitudes gives a good account of the  $\sigma(\theta)$  vs. E data throughout the energy range. This model also explains the  $^{18}\text{Ne}_{\text{g.s.}}$  angular distributions at 164 and 292 MeV: strong interference with non-DIAT amplitude changes the location of the minimum to lower angles at 164 MeV incident energy.
- 1982Gr28:**  $^{18}\text{O}(\pi^+, \pi^-)$  E=100-300 MeV; a systematic investigation via  $(\pi^+, \pi^-)$  on  $^9\text{Be}$ ,  $^{12,13}\text{C}$ ,  $^{16,18}\text{O}$ ,  $^{24,26}\text{Mg}$ ,  $^{32}\text{S}$ , and  $^{209}\text{Bi}$ . The EPICS pion facility and its associated detection system at LAMPF were used. Energy resolution was  $\sim 150$  keV. Angular distributions were measured at  $\theta_{\text{lab}}=5^\circ-33^\circ$  for  $^{18}\text{Ne}_{\text{g.s.}}$  (at E=164 and 292 MeV) and the  $^{18}\text{Ne}(2_1^+)$  state (at 164 MeV). At the latter incident energy, the angular distribution of  $^{18}\text{Ne}_{\text{g.s.}}$  shows a variation in the cross section from  $\sim 1$   $\mu\text{b/sr}$  at  $5^\circ$  falling into a minimum (40 nb/sr) at  $20^\circ$  followed by a rise to  $\sim 250$  nb/sr at  $33^\circ$ . At 292 MeV, the position of the minimum is shifted outwards to near  $25^\circ$ . The angular distribution of the  $2_1^+$  state has a shape consistent with a  $\Delta L=2$  transition, in agreement with the result of (1979Se08). The missing mass spectrum of the  $^{18}\text{Ne}$  was deduced. The excitation functions ( $d\sigma/d\Omega_{\text{lab}}(E)$ ) were measured for  $^{18}\text{Ne}(\text{g.s.}, \text{and } 2_1^+)$  levels at  $\theta_{\text{lab}}=5^\circ$  and E=80-320 MeV. The authors discuss the result of a second-order optical model with isovector and isotensor terms, developed by (M. B. Johnson and E. R. Siciliano, Bull. Am. Phys. Soc. 25 (1980) 741), which fits very well the angular distribution of  $^{18}\text{Ne}_{\text{g.s.}}$  at 164 MeV.
- 1983AnZT:**  $^{18}\text{O}(\pi^+, \pi^-)$  E=65 MeV; measured  $\sigma(E_\pi)$ ; deduced reaction  $\sigma(\theta)$ .
- 1984MoZU:**  $^{18}\text{O}(\pi^+, \pi^-)$  E=140, 200 MeV; measured  $\sigma(\theta)$ . Deduced  $^{18}\text{Ne}$  analog double charge exchange excitation energy dependence.
- 1985Al15,1985AlZV,1985GiZX:**  $^{18}\text{O}(\pi^+, \pi^-)$  E=50 MeV; measured  $d\sigma/d\Omega(\theta)$  for the double isobaric analog state (DIAS) using the M13 pion channel and the QQD spectrometer at TRIUMF. The differential cross sections were measured at  $\theta_{\text{lab}}=22^\circ, 32^\circ, 42^\circ, 52^\circ, 92^\circ, \text{and } 122^\circ$ . The detection system consisted of 4 two-dimensional multi-wire proportional chambers with which the momenta of the  $\pi^-$  ejectiles were measured. The resolution was 1 MeV. The cross section for populating  $^{18}\text{Ne}_{\text{g.s.}}$  at  $\theta_{\text{c.m.}}=0^\circ$  at 50 MeV was deduced to be 5.3  $\mu\text{b/sr}$ , and a total angle integrated cross section was deduced as 16.7  $\mu\text{b}$ . Comparison with  $^{14}\text{C}(\pi^+, \pi^-)^{14}\text{O}_{\text{g.s.}}$  at 50 MeV, and the A-dependence of the cross section at 50, 164 and 292 MeV are discussed.
- 1985Se08, 1985SeZZ:**  $^{18}\text{O}(\pi^+, \pi^-)$  E=100-292 MeV; used the EPICS facility at LAMPF and its associated detection system. Measured the differential cross sections of the  $^{18}\text{O}(\pi^+, \pi^-)$  reaction populating the  $^{18}\text{Ne}_{\text{g.s.}}$  and  $^{18}\text{Ne}(2_1^+)$  states as a function of pion incident energy and momentum transfer. Performed calculations representing the lowest-order sequential charge exchange through the intermediate analog state using the PIESDEX code for  $E_\pi=180-292$  MeV. This model describes the measured angular distribution of the differential cross sections of  $^{18}\text{Ne}_{\text{g.s.}}$  very well at  $E_\pi=230$  and 292 MeV. But it fails to explain the data at  $E_\pi=180$  and 200 MeV. For these lower energies, the angular distributions exhibit a minima at forward angles, which is the evidence for a different reaction mechanism involving higher-order dynamic effects.
- 1986AnZX:**  $^{18}\text{O}(\pi^+, \pi^-)$  E=24-80 MeV; measured the differential cross sections of the DIAT from the  $^{18}\text{O}(\pi^+, \pi^-)$  reaction at forward angles for different energies using the QQD-spectrometer at the pion channels M13 and M11 of TRIUMF. The results together with those of (1982Gr28, 1985Se08) indicate that this cross section peaks at forward angles at low energies and that the shape of its angular distribution differs for  $E_\pi < 65$  MeV and  $E_\pi > 65$  MeV.
- 1986AnZY:**  $^{18}\text{O}(\pi^+, \pi^-)$  E=22, 33, 64 MeV; measured  $\sigma(\theta)$ ; deduced reaction mechanism and energy dependence of the  $^{18}\text{O}(\pi^+, \pi^-)$  reaction populating the DIAS ( $^{18}\text{Ne}_{\text{g.s.}}$ ).
- 1989Wi02:**  $^{18}\text{O}(\pi^+, \pi^-)$  E=300, 400, 500 MeV; used the Large Acceptance Spectrometer at the P<sup>3</sup> high energy channel of LAMPF. The energy resolution was 2.8 MeV (FWHM) at 500 MeV. Measured the differential cross sections of the  $^{18}\text{O}(\pi^+, \pi^-)$  reaction as a function of energy at  $\theta_{\text{lab}}=5^\circ$  and as a function of center-of-mass angle. Due to poor energy resolution,  $^{18}\text{Ne}_{\text{g.s.}}$  could not be resolved from the contributions from the  $2_1^+$  state at 1.89 MeV and the next triple excited states at  $\sim 3.5$  MeV. The angular distribution of the cross section was measured, which was affected by the contributions of the  $^{18}\text{Ne}$  excited states. Comparison with literature is presented, and the results are discussed.
- 1992JoZZ, 1993Jo03:**  $^{18}\text{O}(\pi^+, \pi^-)$  E=350-440 MeV; measured the excitation function of the  $^{18}\text{O}(\pi^+, \pi^-)$  reaction, populating the DIAS, for momentum transfers of  $q=0, 105$  and 210 MeV/c. The experiment was performed using the Large Acceptance Spectrometer at the P<sup>3</sup> high energy channel of LAMPF with configuration, target and detection system identical to the ones used in (1989Wi02). The energy resolution was 2.3 MeV (FWHM).  $^{18}\text{O}(\pi^+, \pi^-)^{18}\text{Ne}(\text{DIAS})$  was measured at  $\theta_{\text{lab}}=5^\circ$  and for fixed momentum transfers of  $q=105$  and 210 MeV/c. The DIAS state could not be resolved from the next 4 excited states up to 3.6 MeV in excitation energy. The missing mass spectrum was deduced. Presented evidence for the observation of a structure near the  $\eta$

$^{18}\text{O}(\pi^+, \pi^-)$  **1974LiZR,2007Ke07 (continued)**

production threshold. However, poor statistics prevented the authors to make a conclusive argument.

*Theory:*

- 1965Pa21:**  $^{18}\text{O}(\pi^+, \pi^-)$ ; calculated  $d\sigma/d\Omega$  at  $0^\circ$ , for  $^{18}\text{Ne}_{\text{g.s.}}$ , as a function of incident pion momentum (in units of  $m_\pi$ ) using shell model without the spin-orbit coupling effects. The authors used plane wave Born approximation and Chew-Low model.
- 1965Ko25:**  $^{18}\text{O}(\pi^+, \pi^-)$   $E=20\text{--}40$  MeV; calculated the double charge exchange cross sections for pions with low incident energies. The authors considered the pion scattering on nucleon pairs from light targets using the second Born approximation via a semi-phenomenological  $s$ -wave pion-nucleon interaction. The resultant cross sections were deduced to be  $\sim 7 \mu\text{b/sr}$ .
- 1968Da32:**  $^{18}\text{O}(\pi^+, \pi^-)$ ; calculated the differential cross section of the double charge exchange process as a function of the momentum transfer and of the excitation energy of the residual nucleus.
- 1974Mi22, 1976Mi23:**  $^{18}\text{O}(\pi^+, \pi^-)$ ; calculated two nucleon short range correlations and angle transformation related to the Kisslinger and local Laplacian potentials (**1974Mi22:** off-shell), which are used for the framework of a coupled-channel optical model. This model only considered analog transitions between pure  $d_{5/2}^2$  states.
- 1974Ka07:**  $^{18}\text{O}(\pi^+, \pi^-)$   $E=180$  MeV; calculated  $\sigma(E)$  using a fixed scatterer model, which included elastic multiple scattering corrections to infinite order.
- 1975Li04:**  $^{18}\text{O}(\pi^+, \pi^-)$   $E < 550$  MeV; calculated  $\sigma(E)$ ,  $\sigma(E, \theta=0^\circ)$  and  $\sigma(\theta)$  using an Eikonalized distorted wave formulation obtained from the Glauber calculations. The calculated  $\sigma(E)$  shows a minimum near 130 MeV and a maximum near the (3,3) resonance energy. The  $\sigma(\theta)$  distributions are forward peaked.
- 1976HeZU:**  $^{18}\text{O}(\pi^+, \pi^-)$ ; calculated  $\sigma$ .
- 1977Le16:**  $^{18}\text{O}(\pi^+, \pi^-)$ ; investigated the effects of nuclear structure, such as pairing correlations in the nuclear wave functions, on the total double charge exchange cross section using Glauber calculations. This was an attempt to explain the experimental ratio deduced for the  $d\sigma/d\Omega(^{18}\text{Ne}_{\text{g.s.}})$  to  $d\sigma/d\Omega(^{16}\text{Ne}_{\text{g.s.}})$ , both of which were populated by the  $(\pi^+, \pi^-)$  reactions.
- 1978Os02:**  $^{18}\text{O}(\pi^+, \pi^-)$   $E=187\text{--}190$  MeV; calculated  $\sigma(\theta)$  using the Glauber model formalism with a  $d_{5/2}, s_{1/2}$  basis for  $A=18$  wave functions. The results were sensitive to the anti-symmetry of the nuclear wave function and details of the nuclear surface.
- 1978Sp07:**  $^{18}\text{O}(\pi^+, \pi^-)$   $E=100, 139, 187$  MeV; calculated  $\sigma(\theta)$  for the ground state of  $^{18}\text{Ne}$  using optical model assuming that a single intermediate state in  $^{18}\text{F}$  contributes. These single particle states were considered to be the  $0_1^+$ ,  $2_1^+$  and  $4_1^+$  states of  $^{18}\text{F}$ , whose contributions seem to be important at  $E=100\text{--}200$  MeV. The authors emphasized on the importance of non-analog contributions to the double charge exchange scattering amplitude for populating a double isobaric analog state. However, their model did not explain the slope of the measured cross sections from  $0^\circ\text{--}18^\circ$  (**1977Ma02, 1977Pe12, 1978Bu09**).
- 1979RoZN:**  $^{18}\text{O}(\pi^+, \pi^-)$   $E \approx 100$  MeV; calculated  $\sigma(\theta)$  using pion-nucleus optical model and first-order multiple scattering theory. Los Alamos Scientific Laboratory Report No. LA-7892-C, 1979, p. 343 (unpublished), **1980Jo06:**  $^{18}\text{O}(\pi^+, \pi^-)$   $E=180, 164$  MeV; calculated  $\sigma(\theta)$  of pion single and double charge exchange to analog states. Calculations were performed using the geometrical Eikonal approximation. The theoretical angular distributions were deduced using the Bessel functions with a cross section scaling factor of  $A^{-10/3}$ . This model was designed to consider  $T \geq 1$  nuclei and was limited to the region of  $p$ -wave dominance. This model failed to reproduce the observed angular distribution of the  $^{18}\text{O}(\pi^+, \pi^-)^{18}\text{Ne}_{\text{g.s.}}$  reaction.
- 1981Li04:**  $^{18}\text{O}(\pi^+, \pi^-)$   $E=162$  MeV; calculated  $\sigma(\theta)$  using the closure approximation, following the procedure of (**1977Le16**), to sum the two-step contributions from all the intermediate states of  $^{18}\text{F}$ . This study was performed to try to describe the measured results of (**1979Se08**: a minimum was observed around  $\theta_{\text{c.m.}}=13^\circ$  in the angular distribution of  $^{18}\text{Ne}_{\text{g.s.}}$ ). However, the calculated first minimum of the differential cross section of the  $^{18}\text{O}(\pi^+, \pi^-)^{18}\text{Ne}_{\text{g.s.}}$  is at  $30^\circ$ , which is much smaller than that produced by the optical-model calculation of (**1974Mi22**).
- X. Liu, Z. Wu, Z. Huang, and Y. Li, *Sci. Sin.* 24 (1981) 789:  $^{18}\text{O}(\pi^+, \pi^-)$ ; another study using Glauber calculation.
- M. B. Johnson and E. R. Siciliano, *Bull. Am. Phys. Soc.* 25 (1980) 741:  $^{18}\text{O}(\pi^+, \pi^-)$ ; demonstrated that the pion-nucleus elastic, single, and double charge exchange scattering to isobaric analog states can be systematically described by including isoscalar, isovector, and isotensor correlation terms in the optical potential. Calculations were performed using the Kisslinger optical potential, which assumes a zero range for the pion-nucleon interaction. The inclusion of an isotensor component in the optical potential significantly altered the shape of the resultant angular distribution for  $^{18}\text{O}(\pi^+, \pi^-)^{18}\text{Ne}_{\text{g.s.}}$ . The result agrees very well with the shape of the measured angular distribution of (**1979Se08**); however, the minimum deduced by this calculation is  $\sim 20^\circ$  higher. The authors concluded that this measurement suggests the presence of an isotensor interaction, and the effects of including finite-range pion-nucleon form factors must also be understood.
- 1981McZU:**  $^{18}\text{O}(\pi^+, \pi^-)$   $E=164$  MeV; calculated  $\sigma(\theta)$ ; investigated the finite-range effects suggested by (M. B. Johnson and E. R. Siciliano, *Bull. Am. Phys. Soc.* 25 (1980) 741) by performing the lowest-order optical potential calculations in momentum space for a number of different off-shell pion-nucleon models; deduced nuclear density pion-nucleon interaction dependence. The theoretical angular distribution deduced from this study for  $^{18}\text{O}(\pi^+, \pi^-)^{18}\text{Ne}_{\text{g.s.}}$  at 164 MeV shows no qualitative difference between the

$^{18}\text{O}(\pi^+, \pi^-)$  [1974LiZR,2007Ke07](#) (continued)

zero-range calculation and the lowest-order finite-range calculation performed in this study. They both miss the observed minimum by  $\sim 20^\circ$ . The authors concluded that some important piece of physics, such as higher-order terms in the optical potential, must have been ignored in all the theoretical work up to then.

- [1981Mi09](#):  $^{18}\text{O}(\pi^+, \pi^-)$  E=80-300 MeV; analyzed  $\sigma(\theta, E)$  using a simple sequential single charge exchange model. They concluded that the measured cross sections of double charge exchange reactions at relatively high energies (E>250 MeV) can be confidently described by two subsequent single charge exchange. However, at energies in the vicinity of the pion-nucleon  $\Delta_{33}$  resonance, this simple model fails, which is a strong evidence that the double charge exchange reaction at these energies proceed via two nucleon processes (such as true pion absorption).
- [1982LiZP](#):  $^{18}\text{O}(\pi^+, \pi^-)$  E=164, 292 MeV; analyzed  $\sigma(\theta)$  using sequential single charge exchange, which did not reproduce the data observed for  $^{18}\text{Ne}_{g.s.}$  ([1979Se08](#), [1979Gr18](#)). These data showed a minimum at around  $\theta_{c.m.}=13^\circ$ . But up to this point, none of the above mentioned theories could produce a minimum at an angle lower than  $\theta_{c.m.}=30^\circ$ . Using the same model that was used in ([1981Li02](#)) involving coupled-channel formalism, the authors included two-nucleon processes such as true pion absorption. As a result, the theoretical angular distributions of the  $^{18}\text{O}(\pi^+, \pi^-)^{18}\text{Ne}_{g.s.}$  reaction displayed minima at  $23^\circ$  at 164 MeV and at  $22^\circ$  at 292 MeV. The results were in much better agreement with the data of ([1979Se08](#), [1979Gr18](#)). Using an inert  $^{16}\text{O}$  core could not move the minimum at 164 MeV closer to the measured value of  $\theta_{c.m.}=13^\circ$  ([1979Se08](#)). The authors then assumed an  $^{18}\text{O}$  core polarization and introduced into the valence neutron wave function of  $^{18}\text{O}$  a collective state component arising from 4p-2h excitation. Consequently, the minimum in the resultant angular distributions moved closer to the measured data, and the theoretical  $\sigma(\theta)$  described the data well.
- [1983FoZX](#):  $^{18}\text{O}(\pi^+, \pi^-)$  E=164 MeV; analyzed  $\sigma(\theta)$  using the two-amplitude model.
- [1983Ho02](#):  $^{18}\text{O}(\pi^+, \pi^-)$  E=164 MeV; calculated  $\sigma(\theta)$  using the optical model and isobar dynamics. This model included a Lane potential term, which incorporates the effects of  $\Delta$  charge exchange to account for processes ignored by the sequential charge exchange models. The resultant theoretical cross sections did not satisfactorily reproduce the data of ([1979Se08](#), [1979Gr18](#)). The authors concluded that the double charge exchange reaction mechanism must include effects such as short range correlations, spin-flip terms, core polarization, inclusion of recoils and delta-particles in the nuclear wave function.
- [1983Jo06](#):  $^{18}\text{O}(\pi^+, \pi^-)$  E=164, 180 MeV; calculated  $\sigma(\theta)$  using second-order optical potential, Klein-Gordon equation, and Eikonal theory in an isospin invariant framework. The authors emphasized the necessity of the distinction between nuclear structure and reaction dynamics in the optical potential so that these effects manifest themselves differently in the deduced cross section. Discussed the effects of the inclusion of isotensor term to properly account for the reaction dynamics. This model agrees with the experimental data on the relative variation of the zero-degree cross section for the single and double charge exchange reactions throughout the periodic table.
- [1983Li08](#):  $^{18}\text{O}(\pi^+, \pi^-)$  E=50-300 MeV; calculated  $\sigma(\theta)$  vs. E using coupled-channel diffractive scattering theory with the inclusion of the higher-order processes. The authors deduced reaction mechanism, and discussed the roles that nuclear structure and two-nucleon processes play in the double charge exchange reaction mechanism. This model considers core-excitation and reflects the effects of true pion absorption. It therefore provides a good prediction of the measured angular distributions at 164 MeV, and the measured excitation function of  $^{18}\text{Ne}_{g.s.}$ .
- [1983Os09](#):  $^{18}\text{O}(\pi^+, \pi^-)$  E=130-250 MeV; described reaction mechanism by taking into account the virtual  $\Delta$  mesons in the nuclear medium and investigating the effects of meson exchange currents; deduced  $\sigma(E, \theta)$  for the DIAS at 130-250 MeV. It appears that at E<130 MeV and E>250 MeV, the corrections to the cross section from meson exchange current can be larger than 50%, and thus these effects have to be included to enable accurate calculations of the double charge exchange amplitudes.
- [1984Gr27](#):  $^{18}\text{O}(\pi^+, \pi^-)$  E=165 MeV; calculated  $\sigma(\theta, A)$  using phenomenological analysis and second-order optical model calculations. According to this study, the anomalous position of the minima in the angular distribution of the  $^{18}\text{Ne}_{g.s.}$  is attributed to the interference with higher-order terms (due to two-nucleon processes) in the pion-nucleus optical potential. In this approach, the magnitudes of the isovector and isotensor terms were adjusted to fit the available data on the single charge exchange reactions at  $\theta_{c.m.}=0^\circ$  and on the double charge exchange reaction populating  $^{18}\text{Ne}_{g.s.}$  at  $\theta_{c.m.}=5^\circ$ . The resulting optical model parameters provide good predictions of the measured angular-distribution shapes.
- [1984Jo01](#):  $^{18}\text{O}(\pi^+, \pi^-)$  E=100-300 MeV; calculated  $\sigma(\theta=0^\circ)$  vs. E; constructed double charge exchange cross sections from the solution of the Klein-Gordon equation for the pion; investigated the effects of direct meson-isobar interactions and found out conclusively that the inclusion of the  $\Delta$ -particles in the wave functions has a negligible effect on the energy region near the  $\Delta_{33}$  resonance in the double charge exchange reactions populating the DIAS. Inclusion of these terms improves agreement with the experimental data below the  $\Delta_{33}$  resonance. Data at the higher energies cannot be described by a simple combination of sequential pion-nucleon scattering plus a direct meson-nucleus interaction.
- [1984Ka26](#):  $^{18}\text{O}(\pi^+, \pi^-)$  E=164 MeV; calculated  $\sigma(\theta)$  using  $\Delta$ -hole and non-local  $\pi$ -nucleon T-matrix formalisms and closure approximation; discussed  $\Delta$ -nucleon interaction and the role of  $\Delta$  recoil and the non-analog intermediate states in  $^{18}\text{F}$ . The

$^{18}\text{O}(\pi^+, \pi^-)$  **1974LiZR,2007Ke07 (continued)**

deduced angular distribution has more or less a similar shape to the measured data of (1979Gr18, 1979Se08) but the location of the minimum is not exactly reproduced.

- 1985Gi01:**  $^{18}\text{O}(\pi^+, \pi^-)$   $E=164$  MeV; calculated  $\sigma(\theta)$  using the two-amplitude model to describe the anomalous excitation function measured by (1982Gr28) near 160 MeV and the angular distribution for  $^{18}\text{Ne}_{g.s.}$ . The authors suggested that the unusual behavior of these measured distributions arises from non-double-analog processes. To describe the measured angular distribution of  $^{18}\text{Ne}_{g.s.}$ : the authors parameterized the non-analog amplitude using Bessel functions, and Legendre polynomial expansion. They then added the analog amplitude produced by Eikonal approximation of (1980Jo06) to each of the parameterized non-analog amplitudes. These were used to fit the measured (by 1982Gr28) angular distribution. The fit consisting of the non-analog parameterization using Legendre polynomials describes the data very well (see Fig. 5 of (1985Gi01)). To describe the measured excitation function at  $\theta_{\text{lab}}=5^\circ$  for  $^{18}\text{Ne}_{g.s.}$ , the authors achieved an excellent fit of the data using the sum of double charge exchange analog amplitude (produced by the simple sequential single charge exchange (1981Mi09)) and the analog amplitude produced by the Eikonal approximation of (1980Jo06) together with either of the non-analog parameterized amplitudes. The fits with both parameterizations describe the data very well.
- 1985Gm01:**  $^{18}\text{O}(\pi^+, \pi^-)$   $E\approx 100-340$  MeV; calculated  $\sigma(\theta)$  vs.  $E$  using coupled-channel and distorted-wave impulse approximation (DWIA). Both these calculations are performed under the same kinematical and dynamical assumptions in constructing the corresponding transition matrix elements. This model is used to explain the  $d\sigma/d\Omega(E)$  for  $^{18}\text{O}(\pi^+, \pi^-)^{18}\text{Ne}_{g.s.}$ . However, the model cannot describe the experimentally observed (at  $\theta_{\text{lab}}=5^\circ$ ) minimum in the cross section. The minimum that this model produces occurs at much larger angles. The authors concluded that core excitation is important to be able to understand the double-charge exchange reaction mechanism populating the double analog states.
- 1986Fo06:**  $^{18}\text{O}(\pi^+, \pi^-)$   $E=292$  MeV,  $\theta_{\text{lab}}=5^\circ$ ; analyzed  $\sigma(E)$  for  $^{18}\text{Ne}_{g.s.}$ ; deduced reaction mechanism using two-amplitude model. The authors assume that the double charge exchange amplitude for a  $T=1$  nucleus is the sum of a double isobaric analog transition amplitude (DIAT) and a non-DIAT amplitude. The calculations are insensitive to the relative phase. They conclude that at 292 MeV, the cross section of the  $^{18}\text{O}(\pi^+, \pi^-)^{18}\text{Ne}_{g.s.}$  reaction contains contributions from two distinct amplitudes, one varying as  $A^{-5/3}$ , the other as  $A^{-2/3}$ . The relative phase between the two amplitude is  $\sim 95^\circ$  at 292 MeV and seems to be independent of  $A$ . For the double charge exchange on  $^{18}\text{O}$ , the ratio of analog to nonanalog amplitudes is 1.087 at 292 MeV. This calculation predicts the cross section for the  $^{18}\text{O}(\pi^+, \pi^-)^{18}\text{Ne}_{g.s.}$  reaction at 292 MeV and  $\theta_{\text{lab}}=5^\circ$  to be  $2.47 \mu\text{b}/\text{sr}$ , which is consistent with the experimentally deduced value of  $2.40 \mu\text{b}/\text{sr}$  (1982Gr28).
- 1986Ge06:**  $^{18}\text{O}(\pi^+, \pi^-)$   $E=50$  MeV; calculated  $\sigma(\theta)$ ; deduced  $\sigma(E)$  for  $^{18}\text{Ne}_{g.s.}$  using coupled-channels approach with the inclusion of the long range shape correlations and quadrupole coupling to the first  $2^+$  state in  $^{18}\text{F}$ . The authors used a Kisslinger optical potential model with further corrections for  $s$ -wave pion absorption and for Fermi averaging of the  $\pi$ -nucleus amplitudes. The integrated cross sections for mass-18 were deduced. The authors conclude that by adjusting the pion-nucleus exchange currents when the quadrupole couplings are included, the agreement between the calculated and observed double charge exchange dataset improves.
- 1986Jo04:**  $^{18}\text{O}(\pi^+, \pi^-)$   $E\approx 20-320$  MeV; calculated double isobaric analog state excitation's  $\sigma(\theta)$  vs.  $E$  using the six-quark cluster model to calculate their contributions on pion double charge exchange. It is assumed that the two excess neutrons in  $^{18}\text{Ne}_{g.s.}$  on which the double charge exchange takes place reside in a  $(1d_{5/2})^2$  configuration. The resulting cross sections are roughly a factor of 2 smaller than the experimentally deduced ones. The authors conclude that the direct  $\pi$  coupling to the interior region quarks and long term mesonic corrections should be included in the quark cluster models in order to improve the agreement between the data and theoretical calculations.
- 1986Os06:**  $^{18}\text{O}(\pi^+, \pi^-)$ ; discussed pion pole and pion contact terms for the double charge-exchange reactions in the context of distorted wave born approximation.
- 1987Ka39:**  $^{18}\text{O}(\pi^+, \pi^-)$   $E=50, 164$  MeV; calculated  $\sigma(\theta)$  using a semi-microscopic model for the double charge exchange reactions. The double charge-exchange amplitude is separated into sequential and non-sequential amplitudes that interfere with one another. The pion distortion is based on delta-hole optical potential. This model is able to describe the experimentally deduced (1985A115)  $^{18}\text{O}(\pi^+, \pi^-)^{18}\text{Ne}_{g.s.}$  cross section at 50 MeV but fails to reproduce the energy and angular dependence of this cross-section in the medium energy region.
- 1987Mi02:**  $^{18}\text{O}(\pi^+, \pi^-)$ ; computed the effects of a mechanism in which the double charge exchange reaction proceeds via pion absorption and emission on a six-quark bag.
- 1987Ha29:**  $^{18}\text{O}(\pi^+, \pi^-)$ ; predicted a narrow ( $\Gamma\sim 10$  MeV) resonance structure, related to the strongly bound  $\eta$ -nucleus system, in the excitation function of the  $(\pi^+, \pi^-)$  double charge exchange reactions at a pion kinetic energy of  $\sim 419$  MeV.
- 1988Os02:**  $^{18}\text{O}(\pi^+, \pi^-)$   $E=130-230$  MeV; calculated  $\sigma(\theta)$ . The authors investigated the contribution of the  $\Delta$  interaction to the pion-induced double-charge exchange reaction to isobaric analogue states at energies around the  $\Delta_{33}$  resonance region and compared it to the conventional mechanisms involving two sequential single charge exchange steps.

$^{18}\text{O}(\pi^+, \pi^-)$  **1974LiZR,2007Ke07 (continued)**

- 1988Yu04**, Yu, Cai and Ma, Sao Paulo (1989) 9:  $^{18}\text{O}(\pi^+, \pi^-)$   $E=164, 292$  MeV; calculated  $\sigma(\theta)$  by including the effect of the second kind of meson exchange currents. The authors found out that meson exchange currents decrease the  $^{18}\text{O}(\pi^+, \pi^-)^{18}\text{Ne}_{g.s.}$  cross sections at low energies and increase it at the energies higher than 180 MeV. The theoretical results has a minimum at  $30^\circ$ , which is far away from the experimentally observed minimum at  $13^\circ$  (**1979Se08**). The authors concluded that even though these effects are important, the second kind of meson exchange currents do not provide a better understanding of the location of the minimum in the experimental differential cross section at 164 MeV.
- Ching *et al.*, Commun. Theor. Phys. 11 (1989) 171:  $^{18}\text{O}(\pi^+, \pi^-)$   $E=50$  MeV; calculated  $\sigma(\theta)$ . The authors used two-nucleon pion absorption-emission mechanism to describe the pion double charge exchange reaction at low energies.
- 1989Ch21**:  $^{18}\text{O}(\pi^+, \pi^-)$   $E=24-79$  MeV; calculated  $\sigma(\theta)$  using quark-antiquark annihilation mechanism to calculate the short-range contribution to the pion double charge exchange reaction. The authors found that this process contributes significantly to the double charge exchange reaction and can account for most of the cross section of the  $^{18}\text{Ne}_{g.s.}$  double isobaric analog state in the forward angles at low pion incident energies. However, their model did not well describe the experimental data (provided by R. R. Johnson via private communication).
- 1989Fo02**:  $^{18}\text{O}(\pi^+, \pi^-)$   $E \approx 100-300$  MeV; calculated  $\sigma(\theta)$  using a two-amplitude model. The author discussed the relative magnitudes, the relative phase between them, and their interferences at different pion energies and scattering angles. The model used in this study reproduces the experimental data of (**1982Gr28**, **1985Se08**) very well.
- 1989Wi20**:  $^{18}\text{O}(\pi^+, \pi^-)$   $E=164$  MeV; calculated  $\sigma(\theta)$ . They investigated in detail the  $\Delta$ -nucleus interactions contributing to the double charge exchange reaction populating the double isobaric analog state. They studied the model dependence and nuclear structure sensitivity of various processes which are responsible for the  $\Delta$ -nucleus interaction.
- 1990Ch14**, Ching, Ho and Zou, Panic XII (1990) Paper III-77:  $^{18}\text{O}(\pi^+, \pi^-)$   $E \leq 300$  MeV; calculated  $d\sigma/d\Omega(E)$  at  $\theta_{\text{lab}}=0^\circ$  by combining the contribution of two-nucleon pion absorption-emission mechanism (in the framework of distorted wave impulse approximation) with the conventional two sequential single charge exchange mechanism to describe the pion induced double charge exchange reaction. As a result, the agreement between the data and theoretical results is improved at low energy. Deduced new pion absorption-emission mechanism role.
- 1990Ch27**:  $^{18}\text{O}(\pi^+, \pi^-)$   $E \approx 20-300$  MeV; calculated  $d\sigma/d\Omega(E)$  at  $\theta_{\text{lab}}=0^\circ$  by using operator expansion approach for the pion absorption-emission mechanism. This method is used to avoid truncating higher order terms. Therefore, this work was the continuation of that of (**1990Ch14**) to investigate the influence of all highly excited states in the intermediate  $^{18}\text{F}$  nucleus. The authors concluded that these excited states do not play an important role in the double charge exchange reaction. They stated that the two-nucleon pion absorption-emission mechanism together with the two sequential single charge exchange can account for the anomalous, large, forward cross section of  $^{18}\text{O}(\pi^+, \pi^-)^{18}\text{Ne}_{g.s.}$  at the low energies. Their theoretical cross section distortion reproduces the shape of the observed data at low energy but the magnitude of their cross section does not describe the measurements.
- 1990MaZW**:  $^{18}\text{O}(\pi^+, \pi^-)$   $E$  in the region of  $\Delta$  resonance; deduced the influence of quark effects on double charge exchange mechanism. Analyzed the measurements using a hybrid quark hadron model.
- 1992Ma46**:  $^{18}\text{O}(\pi^+, \pi^-)$ ;  $E=164$  MeV; calculated  $\sigma(\theta)$ ; deduced dibaryon effects and its role in double charge exchange mechanism.
- 1992Os05**:  $^{18}\text{O}(\pi^+, \pi^-)$   $E=164$  MeV; calculated  $\sigma(\theta)$  by evaluating the pion absorption contribution near  $E_\pi=50$  MeV. Near the  $\Delta_{33}$  resonance region, the corrections due to pion absorption are small. The most noticeable effect from this contribution is a small shift of the minimum in the cross section at smaller angles. This shift is however not big enough to reproduce the experimental data (**1979Gr18**, **1979Se08**).
- 1993Bi10**:  $^{18}\text{O}(\pi^+, \pi^-)$   $E \approx 20-300$  MeV; analyzed  $\sigma(\theta)$  vs.  $E$ . The authors discussed that the anomalous energy dependence of the cross section of  $^{18}\text{O}(\pi^+, \pi^-)^{18}\text{Ne}_{g.s.}$  at  $E_\pi=50$  MeV may be explained by a narrow resonance in the  $\pi\text{NN}$  subsystem with  $J^\pi=0^-$  and a mass of 2.065 GeV.
- 1993Gi03**:  $^{18}\text{O}(\pi^+, \pi^-)$ ;  $E=100-300$  MeV; calculated  $\sigma(\theta)$ ; the contribution of sequential charge exchange and delta-nucleon charge exchange is examined. It is found that the nonanalog double charge exchange cannot be quantitatively understood in terms of these two reaction mechanisms. The authors recommended that the contributions of the double spin-flip to the sequential single charge exchange be considered.
- 1993Os01**:  $^{18}\text{O}(\pi^+, \pi^-)$   $E=200-1400$  MeV; calculated differential cross sections at  $\theta_{\text{lab}}=0^\circ$  and excitation function at  $\theta_{\text{lab}}=5^\circ$  for double charge exchange on  $^{14}\text{C}$  and  $^{18}\text{O}$  using a zero-parameter Glauber theory that includes spin-flip and pion absorption. The wave functions are calculated using the Glasgow shell model code. The authors compared their theoretical results with the experimental data of (**1989Wi02**) at  $E_\pi=300-525$  MeV. The authors found that theory reproduces the shape of the excitation function but is about a factor of 3 too large compared with experiment. The effects of medium polarization on the isovector pion operator were calculated. As a result of isovector normalization, the theoretical center-of-mass differential cross sections at  $\theta_{\text{lab}}=5^\circ$  reproduces the experimental results of (**1989Wi02**) very well.

<sup>18</sup>O( $\pi^+, \pi^-$ ) 1974LiZR,2007Ke07 (continued)

- 1993Os07:** <sup>18</sup>O( $\pi^+, \pi^-$ ) E=400 MeV; calculated  $\sigma(\theta)$  using a microscopic, parameter free Glauber approach. The authors considered corrections in the single and double charge exchange amplitudes due to the medium polarization from an isospin-flip spin-nonflip source. This kind of mechanism dominates these reactions at energies near  $\Delta(3/2,3/2)$  resonance. The authors discuss their theoretical calculations for the <sup>18</sup>O( $\pi^+, \pi^-$ ) reaction populating the non-analog excited states of <sup>18</sup>Ne at 1.89 MeV and 3.56 MeV.
- 1993Os09:** <sup>18</sup>O( $\pi^+, \pi^-$ ) E=300-525 MeV; compiled and reviewed theoretical  $\sigma(\theta)$ .
- 1993Wa30:** <sup>18</sup>O( $\pi^+, \pi^-$ ) E $\leq$ 300 MeV; analyzed  $\sigma(\theta)$  available data and deduced  $\pi$ NN-system resonance parameters.
- 1995Ma58:** <sup>18</sup>O( $\pi^+, \pi^-$ ) E=164 MeV; calculated  $\sigma(\theta)$  using a hybrid quark hadron model. In this model, the dominant mechanisms contributing to the double charge exchange reactions are the six-quark cluster mechanisms (short range) in the interior quark region, and the conventional two-nucleon mechanisms (long range) in the exterior hadronic region. This model seems to be able to reproduce the experimental data of (1979Se08, 1979Gr18).
- 1996Al15:** <sup>18</sup>O( $\pi^+, \pi^-$ ) E=0.4-1.4 GeV; calculated  $\sigma(\theta)$  vs. E by evaluating the sequential single charge-exchange and meson exchange currents. The authors state that the contribution of the meson-exchange currents becomes relevant at  $E_\pi > 600$  MeV.
- 2003Wu09:** <sup>18</sup>O( $\pi^+, \pi^-$ ) E=20-220 MeV; calculated  $\sigma(\theta)$  for double isobaric analog state transition in <sup>18</sup>Ne and the ground states transitions in <sup>16</sup>O( $\pi^+, \pi^-$ )<sup>16</sup>Ne and <sup>40</sup>Ca( $\pi^+, \pi^-$ )<sup>40</sup>Ti ; deduced configuration mixing effects. The authors emphasized on the importance of nuclear structure effects on the double charge exchange reactions.
- 2007Ke07:** <sup>18</sup>O( $\pi^+, \pi^-$ ) E=600-1400 MeV; calculated  $\sigma(E, \theta)$  using a composite-meson model. The authors discussed the contribution of meson exchange current in double charge exchange reaction mechanism.

*Informative Reviews of Experiments and Theory:*

- 1979Al35,** S. J. Greene, The Positive-Pion Double Charge Exchange Reaction, Los Alamos National Laboratory Report No. LA8891-T (1981), R. A. Gilman, Systematics of Pion Double Charge Exchange, Thesis, Los Alamos National Laboratory Report No. LA-10524-T (1985), **1983Os09, 1988Se13, 1993Jo16.**

*See also:*

- E. Aslanides, T. Bressani, M. Caria, *et al.*, Proc. Int. Conf. on Nucleus-Nucleus Collisions, 26 September-1 October (1982), East Lansing, MI, USA (1982) 2.
- X.-H. Liu and Y.-G. Li, Phys. Energ. Fortis Phys. Nucl. 7 (1983) 197.
- Bauer *et al.*, 10<sup>th</sup> Int. Conf. on Particles and Nuclei, 30 July-3 August (1984), Heidelberg (1984) F21.
- H. W. Baer and G. A. Miller, Comments Nucl. Part. Phys. 15 (1986) 269.
- B. Parker, K. Seth and R. Soundranayagam, Panic (1987) 356.
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- Strottman, Fund. Symm. and Nucl. Struct., Eds. Ginocchio and Rosen, in Santa Fe, NM 1988 (World Scientific: 1989) 247.

<sup>18</sup>Ne Levels

(1977Pe12): the laboratory differential cross section was deduced by integrating over the double charge exchange continuum and the excited states of <sup>18</sup>Ne up to 20 MeV excitation energy. The results are:  $d\sigma/d\Omega_{lab} = 3.8 \mu\text{b/sr}$  70 and  $3.0 \mu\text{b/sr}$  5 for E-148 MeV and 187 MeV, respectively, and at  $\theta_{lab} = 18^\circ$ .

E(level) <sup>a</sup>	J <sup><math>\pi</math></sup> <sup>c</sup>	Comments
0	0 <sup>+</sup>	T=1 (1979Se08) E(level): In the <sup>18</sup> O( $\pi^+, \pi^-$ ) <sup>18</sup> Ne <sub>g.s.</sub> reaction, the final state is the $\Delta T_z = 2$ , isobaric analog state of <sup>18</sup> O <sub>g.s.</sub> . E(level): Populated in (1977Ma02, 1977Pe12, 1978Bu09, 1979Gr18, 1979Se08, 1982Gr02, 1982Gr28, 1985Al15, 1985Se08, 1989Wi02, 1992JoZZ, and 1993Jo03). J <sup><math>\pi</math></sup> : This state, when populated via the <sup>18</sup> O( $\pi^+, \pi^-$ ) reaction, is the double isobaric analog state, which makes it a 0 <sup>+</sup> state. Moreover, (1979Se08) stated that the measured angular distribution of this state populated via the <sup>18</sup> O( $\pi^+, \pi^-$ ) reaction shows an apparent diffractive shape characteristic of L=0 transfer, which is evidence for the J <sup><math>\pi</math></sup> =0 <sup>+</sup> assignment.
1886	2 <sup>+</sup>	E(level): From an unweighted average of the energies reported by (1977Pe12: 1890 keV); (1979Gr18: 1880 keV); (1979Se08: 1890 keV); (1981GrZS: 1880 keV); (1982Gr28: 1880 keV); (1985Al15: 1890 keV); and (1985Se08: 1890 keV) and rounded to the nearest integer.

Continued on next page (footnotes at end of table)

$^{18}\text{O}(\pi^+, \pi^-)$  **1974LiZR,2007Ke07 (continued)** $^{18}\text{Ne}$  Levels (continued)

E(level) <sup>a</sup>	J <sup><math>\pi</math></sup> <sup>c</sup>	Comments
		J <sup><math>\pi</math></sup> : From (1979Gr18, 1979Se08, 1982Gr28, and 1985Se08). Note that none of these studies actually measured the J <sup><math>\pi</math></sup> value for this state. The evaluator speculates that the reported J <sup><math>\pi</math></sup> =2 <sup>+</sup> for this state in these studies come from the established $^{18}\text{Ne}$ Adopted Levels in ENSDF (1978Aj03 and 1983Aj01). (1979Se08) stated that the measured angular distribution of this state populated via the $^{18}\text{O}(\pi^+, \pi^-)$ reaction shows an apparent diffractive shape characteristic of L=2 transfer, which is evidence for the J <sup><math>\pi</math></sup> =2 <sup>+</sup> assignment. Also, the measured angular distribution (by 1982Gr28) of this state has a shape consistent with a $\Delta L=2$ transition, in agreement with the result of (1979Se08).
3.62×10 <sup>3</sup>	2 <sup>+</sup> <sup>d</sup>	E(level): From (1979Se08).
5.09×10 <sup>3</sup> <sup>b</sup>	3 <sup>-</sup> <sup>d</sup>	E(level): From (1979Se08).
5.14×10 <sup>3</sup> <sup>b</sup>	3 <sup>-</sup> <sup>d</sup>	E(level): From (1979Se08).

<sup>a</sup> (1979Se08): the uncertainty in the excitation energies reported in this work may be 30%.

<sup>b</sup> (1979Se08): these states are not resolved.

<sup>c</sup> (1979Se08): the measured angular distributions (at 164 MeV) for the double isobaric analog state ( $^{18}\text{Ne}_{g.s.}$ ) and for the  $^{18}\text{Ne}(2^+)$  state showed apparent diffractive shapes, characteristic of L=0 and L=2 transfers, respectively, observed in surface dominated direct reactions. These are in contrast to the flat, featureless distributions expected from two consecutive uncorrelated steps of single charge exchange.

<sup>d</sup> (1979Se08) did not measure the J <sup>$\pi$</sup>  assignment of this state, so the evaluator speculates that the reported J <sup>$\pi$</sup> =2<sup>+</sup> and 3<sup>-</sup> assignments most likely come from the  $^{18}\text{Ne}$  Adopted Levels established in (1978Aj03).

$^{19}\text{F}(\text{p},2\text{n})$  1954Go17

**1954Go17:**  $^{19}\text{F}(\text{p},2\text{n})$  E not given. This study reports the first observation of  $^{18}\text{Ne}$  (see also [2012Th01](#)). A proton beam (E not given) impinged on a teflon and a LiF crystal target. Beam was on for a “*short time*”, and positrons were counted during beam off time using a  $180^\circ$  magnetic spectrograph to deflect the positrons  $180^\circ$  away from the target. Measured positrons coincidences using two proportional counters facing each other. Measured a single  $\beta^+$  branch of the maximum energy of 3.2 MeV, which was attributed to the positron decay of  $^{18}\text{Ne}$  to the ground state of  $^{18}\text{F}$ . Measured  $^{18}\text{Ne}_{\text{g.s.}}$  decay curve and half-life ( $T_{1/2}=1.6$  s). Deduced a  $\log ft$  value of 2.9.

**2003An02, 2003An28, 2004An28, 2006AcZY, 2008Pe02:**  $^{19}\text{F}(\text{p},2\text{n})$  E=21, 23.5, 25, 28 MeV;  $^1\text{H}, ^{\text{nat}}\text{C}(^{18}\text{Ne},\text{p})$  E=66 MeV; and  $^1\text{H}(^{18}\text{Ne}, ^{18}\text{Ne}), ^1\text{H}(^{18}\text{Ne}, ^{18}\text{Ne}')$  E=66 MeV. These studies focused on  $^{19}\text{Na}$  states and their proton decay to  $^{18}\text{Ne}$ . In order to carry out these experiments, a beam of  $^{18}\text{Ne}_{\text{g.s.}}$  was produced using the  $^{19}\text{F}(\text{p},2\text{n})$  reaction.

 $^{18}\text{Ne}$  Levels

<u>E(level)<sup>a</sup></u>	<u><math>T_{1/2}</math><sup>a</sup></u>
0	1.6 s

<sup>a</sup> From ([1954Go17](#)).

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 $^{20}\text{Ne}(\text{p,t})$  **1969Ha38,2017Ch32**

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- D. K. Olsen and R. E. Brown, John H. Williams Laboratory of Nuclear Physics, University of Minnesota Report No. COO-1265-67, 1968, p. 86 (unpublished):  $^{20}\text{Ne}(\text{p,t})$   $E=40$  MeV; measured tritons using 32 surface barrier detectors placed on the focal plane of a spectrometer (no information is given on its type). The energy resolution was 150-200 keV (FWHM). The ground state of  $^{18}\text{Ne}$  was observed. The triton angular distribution corresponding to  $^{18}\text{Ne}_{\text{g.s.}}$  was measured at  $\theta_{\text{lab}}=8^\circ-75^\circ$ .
- 1969Ha38:**  $^{20}\text{Ne}(\text{p,t})$   $E=45$  MeV; measured the reaction products using two telescopes consisting of a phosphorus diffused silicon  $\Delta E$  counter and a Si(Li) E counter mounted on opposite sides of the scattering chamber operating in coincidence mode. The energy resolution was 100-130 keV (FWHM). Tritons were measured at  $\theta_{\text{lab}}=22.3^\circ, 26.8^\circ, \text{ and } 41^\circ$ .  $^{18}\text{Ne}$  levels were deduced at 1890 keV  $20$ , 3375 keV  $30$ , 3588 keV  $25$ , 4580 keV  $30$ , and 5115 keV  $25$ . Comparisons with the reported energies from previous experiments are presented. The angular distributions of tritons corresponding to  $^{18}\text{Ne}_{\text{g.s.}}$  were measured at  $\theta_{\text{c.m.}}=10^\circ-40^\circ$ . Angular momentum transfers were deduced by DWBA analysis. Coulomb displacement energies for the  $A=18$  multiplet were calculated using two sets of equations: one derived in low-seniority  $j$ - $j$  coupling limit, and the other in the Wigner supermultiplet scheme. The results are discussed and compared with the previous theoretical calculations in (**1968Be82**).
- 1970Fa17:**  $^{20}\text{Ne}(\text{p,t})$   $E=42.6$  MeV. The reaction products' detection system was comprised of a  $\Delta E$ -E telescope consisting of a silicon surface barrier  $\Delta E$  and a Si(Li) E detector. The energy resolution was 140 keV. The excitation energy spectrum of  $^{18}\text{Ne}$  (up to  $E_x=9170$  keV  $30$ ) and the tritons angular distributions at  $\theta_{\text{c.m.}}=10^\circ-80^\circ$  were measured. A finite range DWBA analysis was performed to deduce  $L, J^\pi$ , and the two-nucleon spectroscopic amplitudes. Comparison with  $^{18}\text{O}$  mirror levels are presented. The spectroscopic amplitudes deduced by (**1967Ku09**: includes  $1d_{5/2}$  and  $2s_{1/2}$  configurations) used in the DWBA calculations of (**1970Fa17**) resulted in good agreement with all the five lowest  $^{18}\text{Ne}$  states except for the  $4_1^+$  level.
- 1970Le08:**  $^{20}\text{Ne}(\text{p,t})$   $E=50$  MeV; momentum analyzed the reaction products using a  $n=1/2$  magnetic spectrometer (J. Bonn *et al.*, Rutherford Laboratory Report No. RHEL/R136, 1966 (unpublished), p. 141). The focal plane detector consisted of a sonic spark chamber backed by a  $\Delta E$ -E scintillator telescope. Energy resolution was 120 keV (FWHM). The  $^{18}\text{Ne}$  excitation energy spectrum up to  $E_x=6.34$  MeV was measured at  $\theta_{\text{lab}}=15^\circ-50^\circ$ . The triton angular distributions were measured at  $\theta_{\text{lab}}=15^\circ-50^\circ$ . Finite-range DWBA calculations were performed to deduce the transferred angular momenta and the  $J^\pi$  values. The spectroscopic amplitudes were deduced for the  $^{20}\text{Ne}(\text{p,t})$  reaction at 50 MeV.
- 1971PaZX, 1972Pa02:**  $^{20}\text{Ne}(\text{p,t})$   $E=45$  MeV; identified the reaction products using a  $\Delta E$ -E telescope consisting of silicon surface barrier detectors. The energy resolution was 90 keV (FWHM). Measured the excitation energy spectrum of  $^{18}\text{Ne}$  (up to  $E_x=9215$  MeV) and triton angular distributions of the strongly populated levels at  $\theta_{\text{c.m.}}\sim 10^\circ-120^\circ$ . The transferred angular momenta, and  $J^\pi$  values were deduced by finite-range DWBA calculations using the JULIE code. Comparison with the previously assigned  $J^\pi$  values and known level energies are presented.
- 1974Ne04:**  $^{20}\text{Ne}(\text{p,t})$   $E=41.8$  MeV; detected tritons at  $\theta_{\text{lab}}=10^\circ-45^\circ$  using a solid state telescope. The experimental resolution was 50 keV. The authors were interested to study a doublet in  $^{18}\text{Ne}$  at  $E_x\sim 4.5$  MeV that consisted of a  $0^+$  state and a  $1^-$  state based on mirror analysis (**1970Ad02**). The  $^{18}\text{Ne}$  excitation energy spectrum was measured up to  $E_x=9198$  MeV, and two states at 4522 keV  $10$  and 4592 keV  $10$  were observed among others. The triton angular distributions corresponding to these two states were measured. Level energies,  $J, \pi$ , and  $L$  were deduced based on comparisons of the shapes of triton angular distributions and the previously published results.
- 1974OIZQ, 1975OI03:**  $^{20}\text{Ne}(\text{p,t})$   $E=39.8$  MeV; momentum analyzed the reaction products using a magnetic spectrometer with an array of 32 Si surface barrier detectors on the focal plane. Deduced  $^{18}\text{Ne}$  excitation energies for states up to 5140 keV. Measured triton angular distributions at  $\theta_{\text{c.m.}}\sim 10^\circ-85^\circ$ . The energy resolution was 100 keV. Deduced the two-neutron spectroscopic amplitudes for the  $2s_{1/2}, 1d_{3/2}$  and  $1d_{5/2}$  sub shells. Performed zero-range coupled-channel Born approximation calculations using the JUPITOR-1 and MARS codes; and DWBA calculations (using the MARS code). Deduced the rotational and vibrational deformation parameters for the  $T=1$  excited states in mass-18.
- 1981Ne09:**  $^{20}\text{Ne}(\text{p,t})$   $E=41.8$  MeV; measured the reaction products using a  $\Delta E$ -E telescope; measured the angular distributions of tritons at  $\theta_{\text{lab}}=10^\circ-40^\circ$ ; deduced  $^{18}\text{Ne}$  excitation energies up to  $E_x=9198$  keV. Comparison with previous  $^{20}\text{Ne}(\text{p,t})$  and  $^{16}\text{O}({}^3\text{He},n)$  experiments, and the mirror levels in  $^{18}\text{O}$  and  $^{18}\text{Ne}$  are discussed. The authors calculated the Coulomb shifts for the  $^{18}\text{Ne}$  states from the ground state to the  $0_3^+$  state. The authors recommended wave functions that place most of the  $s_{1/2}^2$  strength in the  $0_3^+$  state observed at 4.5 MeV in  $^{18}\text{Ne}$ , such as the wave functions of (**1969Be94, 1972En03, and 1970E123**). The authors concluded that the existence of three  $0^+$  and three  $2^+$  states at low excitation energy and the observation of enhanced E2 transition rates in  $^{18}\text{Ne}$  suggest the presence of deformed configurations in this region. They assigned the deformed strength to the  $0_2^+$  state. As a by-product of the remeasurement of the  $^{18}\text{Ne}$  mass (F. P. Calaprice, S. J. Freedman, and A. V. Nero, private communication, unpublished), the doublets at  $E_x(^{18}\text{Ne})=4.5$  MeV and 5.1 MeV, as well as the triplet at  $E_x\sim 3.5$  MeV were remeasured using the  $^{20}\text{Ne}(\text{p,t})$  reaction at 41.8 MeV beam energy. The tritons were measured using the high resolution Princeton Q3D spectrograph. With this latter measurement, the members of the 3.5-MeV triplet and those of the 4.5-MeV and 5.1-MeV doublets were resolved (see Fig. 13 of **1981Ne09**). The authors deduced  $E_x=4522$  keV  $10$  and  $E_x=4592$  keV  $10$  states and  $\Gamma=40$  keV  $20$  and  $\Gamma=25$  keV
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$^{20}\text{Ne}(\text{p,t})$  1969Ha38,2017Ch32 (continued)

15 for the 5099 keV  $10$  and 5151 keV  $10$  states, respectively.

- 1995La27:**  $^{nat}\text{Ne}(\text{p,X})$   $E=25-67.5$  MeV. This study focused on the commercial production of  $^{18}\text{F}$  as a source for positron emission tomography purposes. Several reaction channels contributed to the total production cross section of  $^{18}\text{F}_{\text{g.s.}}$ . As a by-product,  $^{18}\text{Ne}_{\text{g.s.}}$  was produced via the (p,t), (p,dn), and (p,p2n) reactions on  $^{20}\text{Ne}$ ; the (p,4n), (p,p3n), (p,d2n), and (p,tn) reactions on  $^{21}\text{Ne}$ ; and the (p,d3n), (p,p4n), (p,t2n), and (p, $\alpha$ n) reactions on  $^{22}\text{Ne}$ . The results and recommendations for production of  $^{18}\text{F}$  are discussed. Single, cumulative and saturation yields of  $^{18}\text{F}$  were discussed.
- 1996Ha26:**  $^{20}\text{Ne}(\text{p,t})$   $E=88.4$  and  $40$  MeV. Performed two separate experiments: in the first experiment, a 88.4-MeV proton beam from the Indiana University Cyclotron Facility bombarded a  $^{20}\text{Ne}$  implanted target. The tritons were measured at  $\theta_{\text{lab}}=6^\circ-11^\circ$  using the high resolution K600 spectrometer, and its associated focal plane detectors, in dispersion matching mode. The energy resolution was 20-25 keV. The  $^{18}\text{Ne}$  states with  $E_x=0\sim 8$  MeV were observed in this experiment. In the second experiment, a 40-MeV proton beam from the Princeton AVF cyclotron bombarded the  $^{20}\text{Ne}$  implanted target. Tritons were measured at  $\theta_{\text{lab}}=10^\circ$  and  $20^\circ$  using the Princeton Q3D spectrograph, with an energy resolution of 15 keV. The  $^{18}\text{Ne}$  excited states with  $E_x<6$  MeV were observed. With the Q3D spectrograph, the authors easily resolved the doublets at 4.5 MeV and 5.1 MeV (see Fig. 11). There was no indication in any of these experiments of a missing state with  $J^\pi=3^+$  proposed by (1988Wi08). With these two experiments, the  $^{18}\text{Ne}$  level energies and widths were deduced.
- 1996Ro11:**  $^{nat}\text{Ne}(\text{p,X})$   $E=19-38$  and  $41$  MeV. This study also focused on the production cross section of  $^{18}\text{F}$  for medical purposes. The authors measured the residual  $^{18}\text{F}$  yields and calculated thick target saturation yields. Comparison with the results of (1995La27) are discussed. The authors concluded that  $^{18}\text{F}$  can be produced with high yield using proton energies above 40 MeV.
- 1998PaZZ, 1998PaZR, 1998KuZX, 1999Pa07:**  $^{20}\text{Ne}(\text{p,t})$   $E=35$  MeV; measured the tritons using a high resolution Q2D magnetic spectrograph. The energy resolution was 12 keV. Measured the excitation energies of  $^{18}\text{Ne}$  from  $E_x=4520$  keV to  $E_x=6358$  keV. Owing to the high resolution achieved in this study, the member states of the 3 doublets near 4.5 MeV, 5.1 MeV and 6.3 MeV were all fully resolved. Measured the triton angular distributions for the members of the 5.1 MeV doublet at  $\theta_{\text{c.m.}}=15^\circ-90^\circ$ . DWBA calculations were performed using DWUCK4; and J,  $\pi$ , and L were deduced for these two states. The widths of the unbound members of these 3 closely spaced doublets were deduced. Comparison with the previous results are discussed. The authors searched for the missing  $3^+$  state proposed by (1988Wi08) at 4.33 MeV and found no conclusive evidence for such a state.
- 2017Ch32:**  $^{20}\text{Ne}(\text{p,t})$  E not given. A proton beam impinged upon a neon jet gas target using the JENSA instrument (2014Ch56). The preliminary experimental program is outlined.

*Theory:*

- 1969So08:**  $^{20}\text{Ne}(\text{p,t})$ ; investigated pairing type correlations in the structure of even-N nuclei; calculated neutron pairing strength, collective boson Hamiltonian, and neutron pairing type states (zero seniority) for  $^{18}\text{Ne}$  and suggested that  $^{18}\text{Ne}$  may be slightly deformed due to the observation of a weak  $0^+$  state populated (via the  $^{20}\text{Ne}(\text{p,t})$  reaction: 1970Le08) at approximately twice the  $2^+_1$  energy.
- 1973OIZU:**  $^{20}\text{Ne}(\text{p,t})$ ; calculated  $\sigma(\theta)$ .

 $^{18}\text{Ne}$  Levels

T: From (1974Ne04, 1981Ne09) unless otherwise noted.

(1972Pa02) deduced their excitation energies using the  $^{18}\text{Ne}$  mass excess of 5319.3 keV 47 from (1965Ma54). This could explain why the excitation energies reported by (1972Pa02) are on average  $\sim 10$  keV higher than those deduced by (1974Ne04).

The overall normalization uncertainty for the measured cross sections in (1972Pa02) is about  $\pm 5\%$ .

The overall normalization uncertainty of about  $\pm 10\%$  should be added in quadrature to the error bars shown on the experimental data points in Fig. 4 of (1970Fa17).

The differential cross sections measured in (1975OI03) have a relative uncertainty of  $\pm 4\%$ . The absolute cross sections have a 5% uncertainty (standard deviation).

(1981Ne09): measured cross sections have 15% uncertainty.

(1981Ne09): from the measured triton angular distributions, the relative intensities deduced by (1981Ne09) are:  $\sigma(0^+)/\sigma(0^+_1)\sim 12$  and  $\sigma(2^+)/\sigma(2^+_1)\sim 4$ .

<sup>20</sup>Ne(p,t) **1969Ha38,2017Ch32 (continued)**

<sup>18</sup>Ne Levels (continued)

E(level)	J <sup>π</sup> f	L	Comments
0 <sup>a</sup>	0 <sup>+</sup> d <sup>e</sup>	0 <sup>g</sup>	T=1 E(level): Populated in (1969Ha38, 1970Fa17, 1970Le08, 1972Pa02, 1974Ne04, 1975OI03, 1981Ne09, 1995La27, and 1996Ro11). J <sup>π</sup> : From the DWBA analyses of (1969Ha38, 1970Fa17, 1970Le08, 1972Pa02: finite-range DWBA), and the zero-range coupled-channel Born approximation calculations of (1975OI03). L: From the DWBA analyses of (1969Ha38, 1970Fa17, 1970Le08: finite-range DWBA). S <sub>2n</sub> =28.50 MeV (1970Fa17). (1975OI03) measured dσ/dΩ <sub>c.m.</sub> =747 μb/sr for <sup>18</sup> Ne <sub>g.s.</sub> at the first maximum near θ <sub>c.m.</sub> =30° and at E <sub>p</sub> =39.8 MeV. This result is in agreement with the 650-750 μb/sr cross sections measured at E <sub>p</sub> =42.6 MeV (1970Fa17), 45 MeV (1969Ha38, 1972Pa02), and 50 MeV (1970Le08).
1889 <sup>a</sup> 7	2 <sup>+</sup> e	2 <sup>g</sup>	T=1 (1981Ne09) E(level): Weighted average of 1890 keV 20 (1969Ha38); 1830 keV 50 (1970Le08); 1894 keV 10 (1972Pa02); and 1886 keV 10 (1974Ne04, 1981Ne09). See also E <sub>x</sub> =1887 keV (1970Fa17) and 1890 keV (1975OI03). J <sup>π</sup> : From the DWBA analyses of (1970Fa17, 1970Le08, 1972Pa02: finite-range DWBA) and the zero-range coupled-channel Born approximation calculations of (1975OI03). L: From the finite-range DWBA analyses of (1970Fa17, 1970Le08). σ/σ <sub>g.s.</sub> (θ <sub>lab</sub> =30°)=0.42 (1970Le08) at E <sub>p</sub> =50 MeV.
3379 <sup>ab</sup> 8	4 <sup>+</sup> e	4 <sup>g</sup>	T=1 E(level): Weighted average of 3375 keV 30 (1969Ha38); 3360 keV 50 (1970Le08); 3390 keV 14 (1972Pa02); and 3375 keV 10 (1974Ne04, 1981Ne09). See also E <sub>x</sub> =3376 keV (1970Fa17); 3380 keV (1975OI03); and 3376 keV (see Fig. 13 of (1981Ne09): from the remeasurement of this state using the Princeton Q3D spectrograph). E(level): (1972Pa02) paired their level observed at 3390 keV 14 to the level in <sup>18</sup> Ne with E <sub>x</sub> =3376.2 keV 4, which is the weighted average of the energies reported for this state in (1970Fa17, 1968To09, 1970Le08, and 1969Ro08). J <sup>π</sup> : From the DWBA analyses of (1970Fa17, 1970Le08, 1972Pa02: J <sup>π</sup> =(4 <sup>+</sup> ) from finite-range DWBA) and the zero-range coupled-channel Born approximation calculations of (1975OI03). Note that the DWBA fits performed by (1970Le08) and (1972Pa02) with L=4 for J <sup>π</sup> =4 <sup>+</sup> do not well describe the measured triton angular distribution data corresponding to this state. J <sup>π</sup> : (1972Pa02) considered the 1d <sub>5/2</sub> sub-shell for the two transferred neutrons. L: From the finite-range DWBA analyses of (1970Fa17, 1970Le08). σ/σ <sub>g.s.</sub> (θ <sub>lab</sub> =30°)=0.06 (1970Le08) at E <sub>p</sub> =50 MeV.
3580 <sup>ab</sup> 10	(0 <sup>+</sup> ) <sup>e</sup>	0 <sup>g</sup>	T=1 E(level): From (1974Ne04, 1981Ne09). See also E <sub>x</sub> =3588 keV 25 (1969Ha38: unresolved doublet consisting of a (0 <sup>+</sup> ) state at 3576.3 keV and the 2 <sup>(+)</sup> state at 3616.4 keV with the energies from (1968Gi09)); 3576 keV (1970Fa17: an unresolved doublet); 3580 keV 50 (1970Le08: an unresolved doublet consisting of a 0 <sup>+</sup> and a 2 <sup>+</sup> state at 3.59 MeV and 3.63 MeV, respectively); 3614 keV 13 (1972Pa02: see below); 3580 keV (1975OI03); and 3576 keV (see Fig. 13 of (1981Ne09): from the remeasurement of this state using the Princeton Q3D spectrograph). E(level): There were known, 0 <sup>+</sup> and 2 <sup>+</sup> states at E <sub>x</sub> =3576.3 keV 20 and 3616.4 keV 6 (see 1968Gi09). (1972Pa02) observed a level at 3614 keV 13, which was thought to be an unresolved doublet consisting of the 0 <sup>+</sup> and 2 <sup>+</sup> levels mentioned above. The evaluator notes that the level energies measured by (1972Pa02) seem to be on average ~10 keV higher than those of (1974Ne04), so there may be ~10 keV systematic uncertainty that was not considered by (1972Pa02). They paired the E <sub>x</sub> =3614 keV 13 level to the known 0 <sup>+</sup> state at E <sub>x</sub> =3576 keV and stated that the level observed at 3614 keV may have been the 0 <sup>+</sup> state populated more strongly because the DWBA fit (by 1972Pa02) with L=0 and s <sup>2</sup> <sub>1/2</sub> shell configuration appeared to describe the triton angular distribution of the 3614-keV level better than that with L=2 and d <sup>2</sup> <sub>5/2</sub> shell configuration (see Fig. 8). J <sup>π</sup> ,L: From the finite-range DWBA analyses of (1970Fa17: J <sup>π</sup> =0 <sup>+</sup> +2 <sup>+</sup> (an unresolved doublet) with L=0+2); (1970Le08: J <sup>π</sup> =0 <sup>+</sup> +2 <sup>+</sup> (an unresolved doublet) but L=0 was preferred due to a better DWBA fit); (1972Pa02: J <sup>π</sup> =(0 <sup>+</sup> ) with L=0 preferred due to a better DWBA fit); and the zero-range coupled-channel Born approximation calculations of (1975OI03: J <sup>π</sup> =0 <sup>+</sup> with L=0). (1970Le08): σ/σ <sub>g.s.</sub> (θ <sub>lab</sub> =30°)=0.11 for L=0 and 0.05 for L=2 at E <sub>p</sub> =50 MeV.

Continued on next page (footnotes at end of table)

<sup>20</sup>Ne(p,t) **1969Ha38,2017Ch32 (continued)**

<sup>18</sup>Ne Levels (continued)

E(level)	J <sup>π</sup> f	Γ (keV) <sup>c</sup>	L	Comments
3612 <sup>b</sup> 10	(2 <sup>+</sup> ) <sup>e</sup>		8	T=1 E(level): From (1974Ne04, 1981Ne09): state resolved using the high resolution Princeton Q3D spectrograph). See also E <sub>x</sub> =3616 keV (1970Fa17: unresolved doublet); 3620 keV (1975OI03); and 3616 keV (1981Ne09: Fig. 13 from a remeasurement of this state using the Princeton spectrograph). J <sup>π</sup> : From (1975OI03), who assigned a J <sup>π</sup> =(2 <sup>+</sup> ) to this state based on comparison of the cross section with a zero-range coupled-channel Born approximation calculation. S <sub>2n</sub> =32.12 MeV (1970Fa17).
4522 <sup>b</sup> 9	1 <sup>-de</sup>	9 keV 6	1 <sup>g</sup>	E(level): Weighted average of 4530 keV 20 (1970Fa17); 4460 keV 50 (1970Le08); and 4522 keV 10 (1974Ne04, 1981Ne09). See also E <sub>x</sub> =4576 keV (1972Pa02: a (0 <sup>+</sup> , 1 <sup>-</sup> ) unresolved doublet with L=0,1); 4560 (1975OI03); 4519 keV (1981Ne09: remeasured by the Princeton Q3D spectrograph, see Fig. 13); and 4520 (1999Pa07). Γ (keV): From (1999Pa07). See also Γ≤20 keV (1981Ne09), which supersedes Γ≤40 keV (1974Ne04). J <sup>π</sup> : From the DWBA analyses of (1970Fa17) and (1972Pa02: finite-range DWBA). (1972Pa02): the DWBA fit was obtained considering the two transferred neutrons from the 1p <sub>1/2</sub> and 2s <sub>1/2</sub> sub shells (see Fig. 8). L: From (1970Fa17) and (1970Le08), where L=1 was deduced. (1970Fa17) ruled out L=0 transfer for population of this state due to an observed minimum at θ <sub>c.m.</sub> =25° in the triton angular distribution corresponding to this state, which would have not been seen if this state had J=0. Furthermore, note that the angular distribution for the tritons corresponding to the population of this state agrees well with an L=1 transfer (1974Ne04, see Fig. 2). A minimum is observed at θ <sub>c.m.</sub> =25°, in agreement with what was observed in (1970Fa17). S <sub>2n</sub> =33.03 MeV (1970Fa17). σ/σ <sub>g.s.</sub> (θ <sub>lab</sub> =30°)=0.16 (1970Le08) at E <sub>p</sub> =50 MeV.
4592 10	0 <sup>+</sup> <sup>de</sup>	2 keV +6-2	0 <sup>g</sup>	T=1 E(level): From (1974Ne04, 1981Ne09). See also E <sub>x</sub> =4580 keV 30 (1969Ha38: an unresolved state); 4576 keV (1972Pa02: (0 <sup>+</sup> , 1 <sup>-</sup> ) unresolved doublet with L=0,1); 5120 keV 50 (1970Le08: an unresolved doublet with J <sup>π</sup> =0 <sup>+</sup> , 2 <sup>+</sup> ); 4590 (1981Ne09: see Fig. 13, from the remeasurement of this state using the Princeton Q3D spectrograph); and 4589 keV (1999Pa07). Γ (keV): From (1999Pa07), which reported Γ=2 keV 6. The uncertainty was changed to +6-2 keV by the evaluator to avoid having a negative width. See also Γ≤20 keV (1981Ne09), which supersedes Γ≤40 keV (1974Ne04). J <sup>π</sup> ,L: From (1974Ne04): triton angular distribution corresponding to the 4.59-MeV state has the characteristics of L=0 in that a minimum occurs at θ <sub>c.m.</sub> <25°. A predominantly s <sub>1/2</sub> <sup>2</sup> configuration was assigned to this state based on its large downward shift with respect to the analog state in <sup>18</sup> O (1974Ne04).
5101 9	2 <sup>+</sup>	46 keV 3	2	T=1 E(level): Weighted average of 5115 keV 25 (1969Ha38); and 5099 keV 10 (1981Ne09), which supersedes the 5095 keV 15 result by (1974Ne04). See also E <sub>x</sub> =5100 keV 20 (1970Fa17: an unresolved doublet with J <sup>π</sup> =2 <sup>+</sup> , 3 <sup>-</sup> members); 5085 keV (1981Ne09: see Fig. 13, remeasurement by the Princeton Q3D spectrograph); 5095 keV (1996Ha26: used as energy calibration); and 5106 keV (1999Pa07). Γ (keV): Weighted average of 49 keV 6 (1996Ha26: the (p,t) reaction using the K600 spectrograph at the Indiana University); 45 keV 5 (1996Ha26: the (p,t) reaction study using the Q3D spectrograph at Princeton University); 40 keV 20 (1981Ne09: from the remeasurement of this state using the Princeton Q3D spectrograph); and 45 keV 7 (1999Pa07). See also Γ≤80 keV (1974Ne04). J <sup>π</sup> ,L: From the DWBA analysis of (1999Pa07). See also (1970Le08), where the triton angular distribution corresponding to the population of this state could be

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<sup>20</sup>Ne(p,t) **1969Ha38,2017Ch32 (continued)**

<sup>18</sup>Ne Levels (continued)

<u>E(level)</u>	<u>J<sup>π</sup>f</u>	<u>Γ (keV)<sup>c</sup></u>	<u>L</u>	<u>Comments</u>
5151 <sup>a</sup> 8	3 <sup>-</sup>	10 keV 5	3	<p>fitted equally well with L=0, L=2, and L=3 momentum transfers; and (1970Fa17), where the triton angular distribution was best fitted with a sum of L=2+3.</p> <p>T=1</p> <p>E(level): Weighted average of 5150 keV 14 (1972Pa02); and 5151 keV 10 (1981Ne09), which supersedes the 5149 keV 5 (1974Ne04). See also E<sub>x</sub>=5120 keV 50 (1970Le08: this level was believed to be composed of more than one states); 5140 (1975OI03: see Fig. 1); 5140 keV (1981Ne09: see Fig. 13 from remeasurement using the Princeton Q3D spectrograph); 5150 keV (1996Ha26: used as energy calibration); and 5153 keV (1999Pa07).</p> <p>(1972Pa02) paired the level observed at 5150 keV 14 to the level in <sup>18</sup>Ne with E<sub>x</sub>=5120 keV reported in (1970Le08, 1970Ad02).</p> <p>Γ (keV): Weighted average of 25 keV 15 (1981Ne09); and 8 keV 5 (1999Pa07). See also Γ≤50 keV (1974Ne04); Γ≤20 keV (1996Ha26: from the (p,t) study using the K600 spectrograph in Indiana University, see Table V); and Γ≤15 (1996Ha26: from the (p,t) study using the Princeton Q3D spectrograph, see Table V).</p> <p>J<sup>π</sup>,L: From the DWBA analysis by (1999Pa07). See also (1970Le08), where σ(E<sub>t</sub>,θ) could be fitted, using finite-range DWBA calculations, equally well with L=0, L=2, and L=3 momentum transfers.</p> <p>σ/σ<sub>g.s.</sub>(θ<sub>lab</sub>=30°)=0.24 (1970Le08) at E<sub>p</sub>=50 MeV.</p>
5464 6		6 keV 6		<p>E(level): Weighted average (with external errors) of 5453 keV 10 (1974Ne04, 1981Ne09) and 5467 keV 5 (1999Pa07). See also E<sub>x</sub>≈5360 keV (1970Fa17: very weakly populated state).</p>
6302 <sup>a</sup> 4	(4 <sup>+</sup> )	8 keV 7	(4)	<p>Γ (keV): From (1999Pa07). See also Γ≤50 keV (1974Ne04, 1981Ne09).</p> <p>E(level): Weighted average (with external errors) of 6280 keV 20 (1970Fa17); 6326 keV 18 (1972Pa02); 6297 keV 10 (1974Ne04, 1981Ne09); 6286 keV 10 (1996Ha26: from the (p,t) study using the K600 spectrograph at Indiana University); and 6305 keV 4 (1999Pa07). See also 6340 keV 50 (1970Le08: thought to be composed of more than one states).</p> <p>Γ (keV): From (1999Pa07). See also Γ≤60 keV (1974Ne04, 1981Ne09); and Γ≤20 keV (1996Ha26: from the (p,t) reaction study using the K600 spectrograph at Indiana University).</p> <p>J<sup>π</sup>,L: From (1970Fa17: deduced from a finite-range DWBA analysis; however, the DWBA curve does not really describe the data well. Therefore, the evaluator made the L value tentative).</p>
6355 4		30 keV 13		<p>E(level): Weighted average of 6353 keV 10 (1974Ne04, 1981Ne09); 6343 keV 20 (1996Ha26: measured at θ<sub>lab</sub>=6° using the K600 spectrograph at Indiana University); 6346 keV 10 (1996Ha26: measured at θ<sub>lab</sub>=11° using the K600 spectrograph at Indiana University); and 6358 keV 5 (1999Pa07). See also 6340 keV 50 (1970Le08: this level was believed to be composed of more than one states).</p> <p>Γ (keV): Weighted average of 45 keV 10 (1996Ha26: from the (p,t) reaction study using the K600 spectrograph at Indiana University); and 18 keV 9 (1999Pa07). See also Γ≤60 keV (1974Ne04, 1981Ne09).</p> <p>σ/σ<sub>g.s.</sub>(θ<sub>lab</sub>=30°)=0.06 (1970Le08) at E<sub>p</sub>=50 MeV.</p>
7713 10 7942 8		≤60 keV 70 keV 20		<p>E(level),Γ (keV): From (1974Ne04, 1981Ne09).</p> <p>E(level): Weighted average of 7957 keV 25 (1972Pa02); 7949 keV 10 (1974Ne04, 1981Ne09); 7924 keV 20 (1996Ha26: measured at θ<sub>lab</sub>=6° using the K600 spectrograph at Indiana University); and 7920 keV 20 (1996Ha26: measured at θ<sub>lab</sub>=11° using the K600 spectrograph in Indiana University). See also, 7920 keV 20 (1996Ha26: Table V).</p> <p>Γ (keV): From (1996Ha26: from the (p,t) reaction study using the K600 spectrograph at Indiana University). See also Γ≤60 keV (1974Ne04, 1981Ne09).</p>
9199 9		≤60 keV		<p>E(level): Weighted average of 9170 keV 30 (1970Fa17); 9215 keV 20 (1972Pa02); and 9198 keV 10 (1974Ne04, 1981Ne09).</p> <p>Γ (keV): From (1981Ne09), which supersedes Γ≤50 keV (1974Ne04).</p>

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 $^{20}\text{Ne}(\text{p,t})$  **1969Ha38,2017Ch32 (continued)**

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 $^{18}\text{Ne}$  Levels (continued)

- <sup>a</sup> This level was strongly populated in (1972Pa02), and  $\sigma(E_t, \theta)$ , where t=triton, was measured at  $\theta_{\text{c.m.}} \sim 10^\circ - 120^\circ$ .
- <sup>b</sup> (1981Ne09): this state was remeasured by (F. P. Calaprice, S. J. Freedman, and A. V. Nero, private communication) using the  $^{20}\text{Ne}(\text{p,t})$  reaction with a 41.8 MeV proton beam. In this additional experiment, tritons were measured using the high resolution Princeton Q3D spectrograph. As a result, the constituent states in the 4.5-MeV and 5.1-MeV doublets, as well as those of the triplet around 3.5 MeV were resolved (1981Ne09: Fig. 13). The widths of the members of the doublet at 5.1 MeV reported by (1981Ne09) are from this additional measurement, which is published together with (1981Ne09).
- <sup>c</sup> (1999Pa07): the instrumental width was extracted from a particle bound state in  $^{18}\text{Ne}$  at  $E_x=3616$  keV. It was assumed that the instrumental spreads are Gaussian distributions, but the proton resonance structures are Lorentzian distributions. Hence, these two different functions were convoluted for each state, in order to deduce their intrinsic widths.
- <sup>d</sup> See similar results in (1974Ne04), where the triton angular distributions were analyzed without a DWBA analysis. These authors assigned  $J^\pi$  values and inferred the transferred angular momentum, L, based on arguments on whether or not the shape of distributions have the characteristics of a certain angular momentum transfer. These educated guesses were guided by the results of the previous studies of these states.
- <sup>e</sup> See also (1981Ne09), where similar  $J^\pi$  was deduced through comparison with the known states, mirror level and two-nucleon Coulomb shift analysis.
- <sup>f</sup> (1970Le08) specified that to deduce J from L, they assumed  $J=L+S$  (see footnote (a) under Table IV).
- <sup>g</sup> See also (1981Ne09), which deduced similar L-values from comparison with the data of (1970Le08, 1970Fa17). The authors of (1981Ne09) appear to have been guided by the same DWBA calculations performed in (1970Fa17) due to the proximity of the beam energies in these two experiments.

$^{27}\text{Al}(\pi^-, ^{18}\text{Ne}\gamma)$  1976Li18,1978Li18

1976Li18, 1978Li18:  $^{27}\text{Al}(\pi^-, X\gamma)$  E=230-235 MeV; measured prompt  $\gamma$  rays from the de-exciting reaction products using a Ge(Li) detector at  $\theta_{\text{lab}}=90^\circ$  surrounded by a cup-shaped Compton suppressed scintillator. Measured beam- $\gamma$  coincidences; resolution was 5 keV at 1 MeV in (1976Li18) and 4 keV for  $E_\gamma=0.3$ -6.4 MeV in (1978Li18). Measured  $\gamma$  yields. Deduced production  $\sigma$  for multi-nucleon removal,  $\sigma(E_\gamma)$  and nuclear recoil momenta.

$^{18}\text{Ne}$  Levels

E(level) <sup>a</sup>	J $\pi$ <sup>a</sup>	$\sigma$ (mb) <sup>b</sup>	Comments
0			
1887.4	2 <sup>+</sup>	<3.3	The $\gamma$ -ray transition from 1887 keV→g.s. was observed in (1976Li18) (see Table II) but the $\gamma$ -ray energy is not reported.
3376.4	4 <sup>+</sup>	2.1 5	The $\gamma$ -ray transition from 3376 keV→1887 keV was observed in (1976Li18) (see Table II) but the $\gamma$ -ray energy is not reported. $\sigma$ (mb): The production cross section was corrected for $\gamma$ feeding from higher states known to be excited in (1976Li18). These higher energy states are not reported in (1976Li18). $\sigma$ (mb): See also 2.1 mb 5 (1978Li18).

<sup>a</sup> From the  $^{18}\text{Ne}$  Adopted Levels.

<sup>b</sup> This is the cross section for production of a particular state by direct excitation and/or by feeding from higher states (1976Li18).

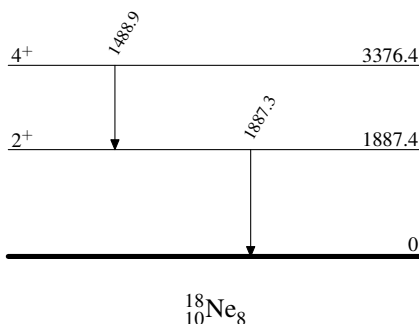
$\gamma(^{18}\text{Ne})$

$E_\gamma$ <sup>a</sup>	$E_i$ (level)	J $\pi$ <sub>i</sub>	$E_f$	J $\pi$ <sub>f</sub>
1488.9	3376.4	4 <sup>+</sup>	1887.4	2 <sup>+</sup>
1887.3	1887.4	2 <sup>+</sup>	0	

<sup>a</sup> From the  $^{18}\text{Ne}$  Adopted Gammas.

$^{27}\text{Al}(\pi^-, ^{18}\text{Ne}\gamma)$  1976Li18,1978Li18

Level Scheme



$^{27}\text{Al}(p,X\gamma)$  1997Vo03

**1997Vo03:**  $^{27}\text{Al}(p,X\gamma)$   $E=800$  MeV; measured the production cross sections for  $^{18}\text{Ne}$  and 47 other nuclei; measured the prompt and delayed  $\gamma$  rays from the decay of these nuclei using a HPGe detector (energy resolution=3 keV at FWHM) placed 30 m away from the target at  $\theta_{\text{lab}}=150^\circ$ . Compared the data with literature and semi-empirical systematics and quantum molecular dynamics calculations. Deduced upper limits of  $\sigma < 1.7$  mb and  $\sigma < 0.05$  mb for the  $^{18}\text{Ne}_{\text{g.s.}}$  production from  $^{27}\text{Al}+p$  at  $E_p=800$  MeV, and for the  $^{18}\text{Ne}^*(1887 \text{ keV})$  state by considering the prompt  $^{18}\text{Ne}(2_1^+ \rightarrow \text{g.s.})$  transition, respectively. This study assumes that at  $E_p=800$  MeV, well over 90% of all  $\gamma$ -ray cascades in even-even nuclei proceed through the  $2_1^+ \rightarrow \text{g.s.}$  transition because of the large average spin of the residual nuclei cascading downwards. It is also assumed that the  $2_1^+ \rightarrow \text{g.s.}$  transition is isotropic at  $E_p=800$  MeV.

 $^{18}\text{Ne}$  Levels

<u><math>E(\text{level})^a</math></u>	<u><math>J^\pi^a</math></u>	<u><math>\sigma</math> (mb)<sup>b</sup></u>	<u>Comments</u>
0?	$0^+$	$< 1.7$	$\sigma$ (mb): Deduced from $^{18}\text{Ne}(\beta^+)^{18}\text{F}^*(1042 \text{ keV}) \rightarrow ^{18}\text{F}_{\text{g.s.}}$ : $E_\gamma=1041 \text{ keV}$ and $I_\gamma=7.9\%$ (1997Vo03).
1887.4?	$2^+$	$< 0.05$	E(level): Since the cross sections given here are upper limits, the evaluator assumed the level energy and its $\gamma$ -ray transition to the $^{18}\text{Ne}_{\text{g.s.}}$ tentative. $\sigma$ (mb): Deduced from intensity of the prompt $2_1^+ \rightarrow \text{g.s.}$ transition in $^{18}\text{Ne}$ (1997Vo03).

<sup>a</sup> From the  $^{18}\text{Ne}$  Adopted Levels.

<sup>b</sup>  $^{18}\text{Ne}$  production cross section from (1997Vo03).

 $\gamma(^{18}\text{Ne})$ 

<u><math>E_\gamma^a</math></u>	<u><math>E_i(\text{level})</math></u>	<u><math>J_i^\pi</math></u>	<u><math>E_f</math></u>	<u><math>J_f^\pi</math></u>
1887.3 <sup>b</sup>	1887.4?	$2^+$	0?	$0^+$

<sup>a</sup> From the  $^{18}\text{Ne}$  Adopted Gammas.

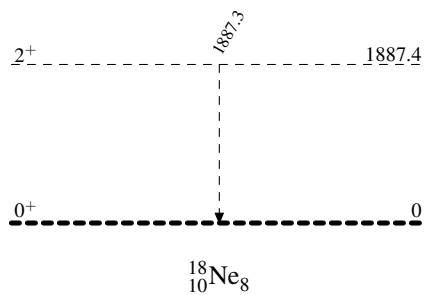
<sup>b</sup> Placement of transition in the level scheme is uncertain.

$^{27}\text{Al}(\text{p},\text{X}\gamma)$  1997Vo03

Legend

Level Scheme

-----►  $\gamma$  Decay (Uncertain)



<sup>27</sup>Al( $\alpha$ ,<sup>18</sup>Ne $\gamma$ ),<sup>28</sup>Si( $\alpha$ ,<sup>18</sup>Ne $\gamma$ ) 1979GI01,2001Na02

**1979GI01:** Inclusive <sup>27</sup>Al( $\alpha$ ,X $\gamma$ ) E=140 MeV; target mounted at 45°; performed in-beam  $\gamma$ -ray spectroscopy to study prompt and  $\beta$ -delayed  $\gamma$  rays using a Ge(Li) detector (energy resolution of 2 keV at 1 MeV) located at  $\theta_{lab}=90^\circ$ . Measured lowest energy  $\gamma$  rays using a planar intrinsic Ge detector (energy resolution of <1 keV at <0.5 MeV). Identified the nuclei produced through measuring  $E_\gamma$ , and determined production  $\sigma$  for specific levels in the residual nuclei. Measured Doppler broadening  $\sigma(\theta,E)$  for discrete energy groups corresponding to p, d, t, <sup>3</sup>He, and  $\alpha$  ejectiles assuming isotropic  $\gamma$ -ray emission. Also measured light reaction products using rotatable Si  $\Delta E$ - $\Delta E$  and NaI-E, and Si  $\Delta E$ -E telescopes, respectively.

**1980Li14:** <sup>27</sup>Al( $\alpha$ ,X $\gamma$ ),<sup>28</sup>Si( $\alpha$ ,X $\gamma$ ) E=180 MeV/nucleon; targets mounted at  $\theta_{lab}=45^\circ$ ; measured prompt  $\gamma$  rays from the decay of the populated residual nuclei,  $E_\gamma$  and  $I_\gamma$  from the decaying nuclei, and  $\gamma$ -recoil coincidences using a Compton suppressed Ge(Li) detector at  $\theta_{lab}=90^\circ$  and a scintillator  $\Delta E$ -E telescope. Deduced the momenta of the residual nuclei from Doppler broadening. Deduced <sup>18</sup>Ne levels and the production  $\sigma$  assuming that the  $\gamma$  rays were emitted isotropically. Comparison between the interactions of  $\alpha$  and pion beams with <sup>27</sup>Al and <sup>28</sup>Si targets, as well as the calculation of the spallation yield are discussed.

*Theory:*

**2001Na02:** <sup>nat</sup>Si(p,X)<sup>18</sup>Ne E=20–110 MeV; calculated excitation functions of several nuclei from p+<sup>nat</sup>Si interactions using the ALICE code. The aim was to investigate radiation damage to Si (including quartz beam viewers) from structural changes inflicted by the residual nuclei produced from the activation of Si by energetic protons. Comparisons with experimental data are discussed for a few of these nuclei, for which data are available. The formation cross section of <sup>18</sup>Ne from the <sup>nat</sup>Si(p,X) reaction was estimated to be less than 0.1 mb for proton incident energies of 70-110 MeV (see Fig. 8 of (2001Na02)).

<sup>18</sup>Ne Levels

<u>E(level)<sup>b</sup></u>	<u>J<sup><math>\pi</math></sup></u>	<u>Total Production Cross Section <math>\sigma_{total}</math> (mb)<sup>a</sup></u>	<u>Comments</u>
0			
1887? 1	2 <sup>+</sup>	<0.8	<p>E(level): Since the cross sections given here are upper limits, the evaluator assumed the level energy and its <math>\gamma</math>-ray transition to the <sup>18</sup>Ne<sub>g.s.</sub> tentative.</p> <p>Total Production Cross Section <math>\sigma_{total}</math> (mb): From (1980Li14): <math>\sigma_{ex}&lt;0.8</math> mb for <math>\alpha+^{27}</math>Al. For <math>\alpha+^{28}</math>Si: <math>\sigma_{tot}&lt;0.6</math> mb and <math>\sigma_{ex}&lt;0.6</math> mb.</p> <p>Total Production Cross Section <math>\sigma_{total}</math> (mb): See also <math>\sigma_x \leq 0.4</math> mb (1979GI01), where <math>\sigma_x</math> is the cross section for production of a particular state by direct excitation and/or by <math>\gamma</math> feeding from unidentified higher lying states. <math>\gamma</math> feeding by transitions from identified higher lying states was subtracted. In (1979GI01), no <math>\gamma</math> rays from the decay of <sup>18</sup>Ne, produced by the <sup>27</sup>Al(<math>\alpha</math>,X<math>\gamma</math>) reaction, were observed. Therefore, only an upper limit for the production of the reported excited state was determined.</p> <p>(2001Na02) calculated the formation cross section of <sup>18</sup>Ne from the <sup>nat</sup>Si(p,X) reaction. The result was less than 0.1 mb for proton incident energies of 70-110 MeV (see Fig. 8 of (2001Na02)).</p>

<sup>a</sup> From (1980Li14):  $\sigma_{tot}$  is the cross section for production of the excited state, including the  $\gamma$  ray feeding from higher excited states.  $\sigma_{ex}$  is  $\sigma_{total}$  corrected for the  $\gamma$  ray feeding from the populated, known higher excited states.

<sup>b</sup> Taken by (1979GI01, 1980Li14) from the Adopted Levels of <sup>18</sup>Ne in (1978Aj03).

$^{27}\text{Al}(\alpha, ^{18}\text{Ne}\gamma), ^{28}\text{Si}(\alpha, ^{18}\text{Ne}\gamma)$  1979GI01,2001Na02 (continued) $\gamma(^{18}\text{Ne})$ 

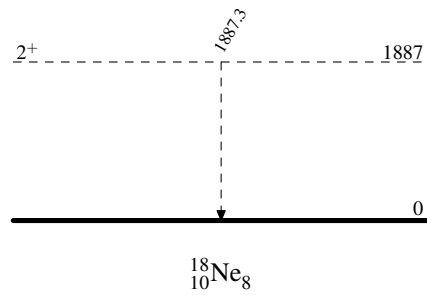
$E_\gamma^a$	$E_i(\text{level})$	$J_i^\pi$	$E_f$
1887.3 <sup>b</sup>	1887?	2 <sup>+</sup>	0

<sup>a</sup> From the  $^{18}\text{Ne}$  Adopted Gammas.

<sup>b</sup> Placement of transition in the level scheme is uncertain.

 $^{27}\text{Al}(\alpha, ^{18}\text{Ne}\gamma), ^{28}\text{Si}(\alpha, ^{18}\text{Ne}\gamma)$  1979GI01,2001Na02

Legend

Level Scheme-----►  $\gamma$  Decay (Uncertain)

<sup>197</sup>Au(<sup>18</sup>Ne,<sup>18</sup>Ne'):coulex 2000Ri15,2016Li45

- 2000Ri15:** <sup>197</sup>Au(<sup>18</sup>Ne,<sup>18</sup>Ne'), <sup>197</sup>Au(<sup>18</sup>O,<sup>18</sup>O') E=60 and 46 MeV/nucleon, respectively. The <sup>18</sup>Ne and <sup>18</sup>O beams were slowed down in the gold target and stopped in a cylindrical fast/slow plastic phoswich detector located at  $\theta_{lab}=0^\circ$  subtending  $\theta_{lab}=0^\circ-4^\circ$ . Measured  $\gamma$  rays from decays of the Coulomb excited states in coincidence with beam particles using an array of 10 position sensitive NaI(Tl) detectors subtending  $\theta_{lab}=56.5^\circ-123.5^\circ$ . Measured  $E_\gamma$  and  $I_\gamma$ . Deduced the integrated  $\sigma$  for the excitation of the  $2_1^+$  state in <sup>18</sup>Ne in the forward angle. Analyzed data using a macroscopic model that included both Coulomb and nuclear excitation mechanisms. Deduced  $B(E2:0_1^+ \rightarrow 2_1^+)$ , as well as the Coulomb and nuclear deformation parameters of  $\beta_C=0.450$  36 and  $\beta_N=0.481$  39, respectively.
- 2009Ji02, 2010Li33, 2011LiZV, 2016Li45:** <sup>197</sup>Au(<sup>18</sup>Ne,<sup>18</sup>Ne' $\rightarrow$ <sup>16</sup>O+2p) E $\approx$ 65 MeV/A (deduced from LISE++); studied the in-flight decay of <sup>18</sup>Ne excited states populated via Coulomb excitation and detected in coincidence with the heavy fragments and light decay products. These were measured using a position sensitive telescope with 6 Si  $\Delta E$  detectors followed by an array of stopping CsI crystals that covered a maximum opening angle of  $\pm 13.2^\circ$ . Measured the relative momenta, angular and energy correlations of the proton pairs (from <sup>18</sup>Ne\* $\rightarrow$ <sup>16</sup>O+2p decay) in the center-of-mass system. The experimental energy resolution was 200-400 keV. Deduced the invariant mass of the <sup>16</sup>O<sub>g.s.</sub>+2p from the complete kinematics reconstruction of these decay events. Simulations and data support diproton decay of the <sup>18</sup>Ne\*(6.15 MeV) state. No obvious diproton emission was found for higher-lying <sup>18</sup>Ne states.
- The <sup>18</sup>Ne beam energy of 65 MeV/nucleon is estimated by the evaluator from the incident <sup>20</sup>Ne primary beam energy of 78.24 MeV/nucleon (2009Ji02) on the <sup>9</sup>Be target using LISE++ computer code.
- 2010Xu11:** <sup>197</sup>Au(<sup>18</sup>Ne,<sup>18</sup>Ne') E=51.8 MeV/nucleon; measured momenta of <sup>18</sup>Ne\* decay products using a position sensitive telescope along  $\theta_{lab}=0^\circ$  that covered  $\theta_{lab}=\pm 11^\circ$ . The array comprised several position sensitive  $\Delta E$  detectors and a stopping E layer of CsI. Deduced the excitation function of <sup>18</sup>Ne. The resolutions of the experimental setup were  $\sim 500$  keV at FWHM for  $E_x$ ,  $5^\circ$  for  $\theta_{c.m.}^\alpha$ , and 5 MeV/c for the c.m. relative momentum of the two  $\alpha$ -particles. Deduced the c.m. relative angular correlations and momenta between the  $\alpha$  pairs from the decay of the <sup>18</sup>Ne\* states. The decay mechanism that best describes the data is a sequential decay via the <sup>14</sup>O\* intermediate states.

<sup>18</sup>Ne Levels

E(level)	J <sup><math>\pi</math></sup>	Comments
0 <sup>a</sup>	0 <sup>+a</sup>	
1887.4 <sup>a</sup>	2 <sup>+a</sup>	(2000Ri15): deduced $\sigma=45$ mb 6 for the production of the 1887 keV $\gamma$ ray in <sup>18</sup> Ne assuming a $\gamma$ -ray angular distribution corresponding to a pure E2 transition and by integrating over $\theta_{lab}=0^\circ-4^\circ$ . The authors noted that this cross section may not be identical to that for directly exciting the <sup>18</sup> Ne*( $2_1^+$ ) state via scattering. This is because the latter state can be fed by $\gamma$ decays from higher-lying states. A total cross section of 40 mb 11 was deduced, using coupled channels calculations via the ECIS88 code, for directly populating the $2_1^+$ state in <sup>18</sup> Ne. (2000Ri15): using the optical model parameters of (1987Me05), the Coulomb and nuclear deformation parameters were deduced as $\beta_C=0.450$ 36 and $\beta_N=0.481$ 39, respectively. These resulted in $B(E2:0_1^+ \rightarrow 2_1^+)=113$ e <sup>2</sup> fm <sup>4</sup> 18 and $M_p=10.6$ fm <sup>2</sup> 9. (2000Ri15): using the optical model parameters of (1988Ba39), the above-mentioned values were deduced to be: $\beta_C=0.496$ 40, $\beta_N=0.503$ 40, $B(E2:0_1^+ \rightarrow 2_1^+)=137$ e <sup>2</sup> fm <sup>4</sup> 22, and $M_p=11.7$ fm <sup>2</sup> 9. Both the above-mentioned groups of results are under the assumption that $b_n^F/b_p^F=0.820$ for <sup>197</sup> Au, where $b_n^F$ is the external field interaction strength of the probe F (which is <sup>197</sup> Au) with neutrons or protons in <sup>18</sup> Ne. If <sup>197</sup> Au is assumed to be an isoscalar probe ( $b_n^F/b_p^F=1$ ), then $B(E2:0_{g.s.}^+ \rightarrow 2_1^+)$ increases by 0.4% (2000Ri15).
3616.5 <sup>a</sup>	2 <sup>+a</sup>	(2000Ri15) speculated that even though the 1729-keV $\gamma$ ray was not observed in the projectile frame spectrum, it would have been possible that the <sup>18</sup> Ne*(3616.5 keV, $2_2^+$ ) state would be significantly populated in their measurement specially when the <sup>18</sup> O*( $2_2^+$ ) state was strongly populated. Using GEANT simulations, an upper limit of 10 mb was deduced for production $\sigma$ of the 1729-keV $\gamma$ ray from the decay of the <sup>18</sup> Ne*( $2_2^+$ ) state to the <sup>18</sup> Ne*( $2_1^+$ ) state.
5150 <sup>b</sup>		
6150 <sup>b</sup>		Mode of decay: <sup>2</sup> He (diproton) decay to <sup>16</sup> O <sub>g.s.</sub> (2009Ji02, 2011LiZV, 2016Li45). (2016Li45) performed a Hanbury-Brown Twiss interferometry analysis to probe the space-time character of <sup>18</sup> Ne assuming a Gaussian shape. As a result, the p-p distances inside <sup>18</sup> Ne nucleus (for the valence proton

Continued on next page (footnotes at end of table)

$^{197}\text{Au}(^{18}\text{Ne}, ^{18}\text{Ne}'):\text{coulex}$  2000Ri15,2016Li45 (continued) $^{18}\text{Ne}$  Levels (continued)

<u>E(level)</u>	<u>Comments</u>
	pair that are emitted in the 2p-decay) was determined to be 5.44 fm +19–17. This result may indicate a small opening angle between the proton pair, a signature of the crossover of Bardeen-Cooper-Schrieffer (BCS) pairing correlation to the Bose-Einstein Condensation (BEC) pairing correlation in the dilute nuclear matter, i.e., a 2p halo nucleus.
7060 <sup>b</sup>	
7910 <sup>b</sup>	
8500 <sup>b</sup>	
9600 <sup>b</sup>	
10900 <sup>b</sup>	
11500 <sup>b</sup>	
12100 <sup>b</sup>	
12700 <sup>b</sup>	
20700 <sup>c</sup>	(2010Xu11): mode of decay is most likely via $^{14}\text{O}^* + 2\alpha$ (2010Xu11).
23300 <sup>c</sup>	(2010Xu11): mode of decay is most likely via $^{14}\text{O}^* + 2\alpha$ (2010Xu11).
26200 <sup>c</sup>	(2010Xu11): mode of decay is most likely via $^{14}\text{O}^* + 2\alpha$ (2010Xu11).

<sup>a</sup> From the  $^{18}\text{Ne}$  Adopted Levels.<sup>b</sup> From the complete reconstruction of the invariant mass of the  $^{16}\text{O}+2\text{p}$  events observed in coincidence in (2009Ji02).<sup>c</sup> From (2010Xu11). $\gamma(^{18}\text{Ne})$ 

<u><math>E_\gamma</math></u>	<u><math>E_i(\text{level})</math></u>	<u><math>J_i^\pi</math></u>	<u><math>E_f</math></u>	<u><math>J_f^\pi</math></u>
1729.2 <sup>ab</sup>	3616.5?	2 <sup>+</sup>	1887.4	2 <sup>+</sup>
1887.3 <sup>a</sup>	1887.4	2 <sup>+</sup>	0	0 <sup>+</sup>

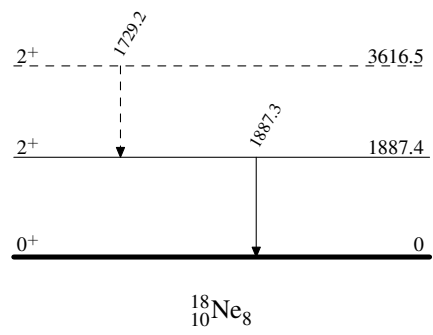
<sup>a</sup> From the  $^{18}\text{Ne}$  Adopted Gammas.<sup>b</sup> Placement of transition in the level scheme is uncertain.

$^{197}\text{Au}(^{18}\text{Ne}, ^{18}\text{Ne}'):\text{coulex}$  2000Ri15,2016Li45

Legend

Level Scheme

-----►  $\gamma$  Decay (Uncertain)



Si(p,  $^{18}\text{Ne}$ ) 2005Ba87, 2017DuZU

**2005Ba87, 2007Gr18, 2013Gr03:** SiC(p,  $^{18}\text{Ne}$ ) E=30 keV (2005Ba87, 2007Gr18) and E=60 keV (2013Gr03); implanted the  $^{18}\text{Ne}$  beam into a movable mylar backed aluminum tape placed in the mutual center of  $8\pi$  spectrometer and Scintillating Electron-Positron Tagging Array (SCEPTAR). Measured  $\beta$ - $\gamma$  coincidences. Measured the level of  $^{18}\text{F}$  and  $\text{H}^{17}\text{F}$  contaminants, whose decays are not followed by a prompt  $\gamma$  ray, using SCEPTAR. Measured the 1042-keV  $\gamma$  rays following the superallowed  $\beta$ -decay of  $^{18}\text{Ne}^*$ . In (2005Ba87, 2007Gr18), the implantation took 7 seconds followed by 40 s  $\gamma$ -ray counting before the tape was moved 1.5 m away to stop counting, and the cycle repeated. In (2013Gr03), such cycles consisted of 2.5, 5, or 7 s of background counting, 120 s of implantation, 40 s counting followed by 1 s for moving the tape outside the detection array. Deduced the relative  $\gamma$ -ray intensities,  $\beta$ -decay branching ratios, and the half-life of  $^{18}\text{Ne}$ . The result of (2013Gr03) supersedes that of (2007Gr18). The results of (2005Ba87) were preliminary and should not be used.

**2014LaZV, 2015La19, 2017DuZU:** SiC(p,  $^{18}\text{Ne}$ ) E=30 keV; measured the half-life of  $^{18}\text{Ne}$  in two independent  $\beta^+$ -counting measurements:

A 30-keV  $^{18}\text{Ne}$  beam was implanted in the thick aluminum layer of a single-sided aluminized Mylar tape (2014LaZV). Once a sufficient amount of  $^{18}\text{Ne}$  activity was implanted, the beam was deflected, and the tape was transferred to the center of a  $4\pi$  continuous-flow gas proportional counter for counting. Ions were implanted in 440 beam-on, beam-off cycles, each consisting of a 0.5 s of implantation followed by 1.5-4.5 s for cooling, 2 s for transfer to the counting station and 40 s ( $\approx 24$  half-lives) of  $\beta$ -counting. In this experiment, a cold-transfer line was used between the spallation target and the ion source to reduce the  $^{18}\text{F}$  beam contaminant to undetectable levels.

In the second experiment, the cold-transfer line was not utilized. This resulted in a higher intensity  $\approx 4.8 \times 10^5$   $^{18}\text{Ne}$  ions/s beam with a  $1 \times 10^6$   $^{18}\text{F}$  ions/s contaminant. In this case, the beam was implanted in the same kind of tape but at 20 keV during a total of 813 beam-on beam-off cycles. The  $\beta$ -counting was carried out with a different  $4\pi$  gas proportional counter at lower operating voltage. The  $^{18}\text{Ne}$  half life was measured independently in both experiments.

 $^{18}\text{Ne}$  Levels

E(level) <sup>a</sup>	J $\pi$ <sup>a</sup>	T <sub>1/2</sub> <sup>b</sup>	Comments
0	0 <sup>+</sup>	1.66415 s +57-48	% $\epsilon$ +% $\beta^+$ =100 (1981Ad01) Decays to the $^{18}\text{F}$ (g.s., 1042-, 1081-, and 1701-keV) states (2013Gr03).

<sup>a</sup> From the  $^{18}\text{Ne}$  Adopted Levels.

<sup>b</sup> From the weighted average of T<sub>1/2</sub>=1.6648 s // (2013Gr03) and T<sub>1/2</sub>=1.66400 s +57-48 (2015La19). The evaluator assumed that the uncertainties are systematic, and therefore cannot decrease.

**Pb(<sup>18</sup>Ne,<sup>18</sup>Ne'):coulex 2007Ra36,2010Gi05**

2007Ra36, 2007CaZT, 2008SfZZ, 2008Ra12, 2010Ra14, 2010RaZZ, 2010Gi05: Pb(<sup>18</sup>Ne,<sup>17</sup>F+p) and Pb(<sup>18</sup>Ne,<sup>16</sup>O+2p) E=32–35 MeV/nucleon; targets: <sup>207</sup>Pb (2007Ra36) and <sup>nat</sup>Pb (other studies); measured the angles, energies and velocities of heavy reaction and light decay products in coincidence using two Si-CsI hodoscopes covering an angular range of  $\theta_{lab}=\pm 4.5^\circ$  to  $\pm 16.5^\circ$  (2007Ra36),  $\theta_{lab}=0^\circ-20^\circ$  in (2007CaZT), and  $\theta_{lab}=\pm 5^\circ$  to  $\pm 21.5^\circ$  in (2008SfZZ, 2008Ra12, 2010Gi05, and 2010Ra14, 2010RaZZ). Deduced the invariant mass from a reconstruction of the <sup>17</sup>F+p and <sup>16</sup>O+2p complete decay kinematics in the center-of-mass frame. The experimental energy resolution varied between 250 keV (2007Ra36) to 500 keV (other studies). The particle decay of the observed states are discussed.

*Theory:*

2007Be54: <sup>208</sup>Pb(<sup>18</sup>Ne,<sup>18</sup>Ne'); Coulomb excitation of low-lying states of unstable, light and medium heavy nuclei in intermediate collision energies of interest to radioactive beam facilities is investigated. Coulomb excitation cross sections of numerous projectiles incident on Pb and Au targets at laboratory bombarding energies of 10, 20, 30, 50, 100, 200, 500 MeV/nucleon and retardation effects are calculated. B(E1:J<sub>g.s.</sub>→J<sub>f</sub>), B(E2:J<sub>g.s.</sub>→J<sub>f</sub>), or B(M1:J<sub>g.s.</sub>→J<sub>f</sub>) are obtained for the lowest-lying transitions of various reaction products, including <sup>18</sup>Ne. Comparison with data are discussed. The calculated Coulomb excitation cross section for <sup>18</sup>Ne\*(1.89 MeV) is very large (615 mb at 10 MeV/nucleon, reducing to 22.1 mb at 500 MeV/nucleon). B(E2:0<sub>1</sub><sup>+</sup>→2<sub>1</sub><sup>+</sup>)= 248 e<sup>2</sup>fm<sup>4</sup> is calculated by (2007Be54).

N. Yu, E. Maglione and L. S. Ferreira, Nucl. Sci. Tech., 24 (2013) 050517 and 2024Fe02: Used the shell model interaction of (2011Bo20) to fit the experimentally obtained excitation energies of (2008Ra12). Assuming <sup>18</sup>Ne as a spherical nucleus, in 2013, the authors deduced excited states with negative parity, some of which are narrow resonances with excitation energies above 10 MeV. These theoretically calculated states decay preferentially by one proton emission to <sup>17</sup>F\*, and are therefore possible candidates for a sequential two-proton decay.

<sup>18</sup>Ne Levels

(2008Ra12) determined branching ratios for the decay of the <sup>18</sup>Ne\*(>6.5 MeV) states: 64% 7 for 3-body direct break up involving an uncorrelated emission of two protons (usually referred to as democratic emission), 30% 4 for true sequential decay via the <sup>17</sup>F(3.1 MeV, 1/2<sup>-</sup>) state, and 6% 2 for <sup>2</sup>He decay.

E(level) <sup>a</sup>	J <sup>π</sup> <sup>b</sup>	Comments
5090 <sup>c</sup>	2 <sup>+</sup>	E(level): From (2008SfZZ, 2008Ra12, 2010Gi05, and 2010Ra14). See also 5110 keV (2007Ra36).
5150 <sup>c</sup>	2 <sup>+</sup>	E(level): From (2007Ra36, 2008SfZZ, 2008Ra12, 2010Gi05, and 2010Ra14).
6150 <sup>cd</sup>	1 <sup>-</sup>	E(level): Observed in both <sup>17</sup> F+p and <sup>16</sup> O+2p decay channels (2007Ra36, 2008SfZZ, 2008Ra12, 2010Gi05, and 2010Ra14) but not resolved from the neighboring states. The cross section of the <sup>17</sup> F+p decay channel in the excitation energy region of 6 MeV was extracted in (2007CaZT) to be of the order of 20 mb 10. This state has various decay modes (see the Adopted Levels), including 2p decay mode. The 2-proton decay mode proceeds through (1) a <sup>2</sup> He (diproton) resonance leading to the <sup>16</sup> O <sub>g.s.</sub> 31% 7 of the time (2008Ra12, 2010Gi05, 2010Ra14); (2) 2p democratic three-body decay 66% 9 of the time (2008Ra12, 2010Gi05, 2010Ra14); and (3) 2p virtual sequential decay via the <sup>17</sup> F*(3.1 MeV, 1/2 <sup>-</sup> ) state 3% 2 of the time (2008Ra12, 2010Gi05, 2010Ra14). The first experimental proof for diproton emission from this state comes from a combination of (2008SfZZ, 2008Ra12) analyses.
7060 <sup>deg</sup>	(1 <sup>-</sup> ,2 <sup>+</sup> )	E(level): From (2007Ra36, 2008SfZZ, 2008Ra12, 2010Gi05, 2010Ra14). Note that this state is mistakenly labeled as 7.59 MeV (instead of 7.059 MeV) in (2007Ra36). In this study, it is shown on Fig. 7 that this state is populated via the <sup>17</sup> F+p decay channel. The higher statistics of the studies later carried out by (2008Ra12, 2010Gi05) indicate that this state is also populated in the <sup>16</sup> O+2p channel.
7910 <sup>deg</sup>	(1 <sup>-</sup> ,2 <sup>+</sup> )	E(level): From (2008SfZZ, 2008Ra12, 2010Gi05, 2010Ra14).
8500 <sup>def</sup>	(1 <sup>-</sup> ,2 <sup>+</sup> )	E(level): From (2007Ra36, 2008SfZZ, 2008Ra12, 2010Gi05, 2010Ra14). In (2007Ra36), it is shown on Fig. 7 that this state is populated via the <sup>17</sup> F+p channel. The higher statistics of the studies by (2008Ra12, 2010Gi05) carried out later indicate that this state was populated in the <sup>16</sup> O+2p channel. (2008Ra12) specifically mentions that <i>this state is not observed in the <sup>17</sup>F+p decay channel.</i> J <sup>π</sup> : From (2007Ra36, 2008Ra12).

Continued on next page (footnotes at end of table)

**Pb( $^{18}\text{Ne}, ^{18}\text{Ne}'$ ):coulex 2007Ra36,2010Gi05 (continued)** $^{18}\text{Ne}$  Levels (continued)

<u>E(level)<sup>a</sup></u>	<u>J<sup><math>\pi</math></sup><sup>b</sup></u>	<u>Comments</u>
10700 <sup>defg</sup>	(1 <sup>-</sup> ,2 <sup>+</sup> )	This state is a candidate for diproton decay (2008Ra12). E(level): From (2008SfZZ, 2008Ra12, 2010Gi05, 2010Ra14). J <sup><math>\pi</math></sup> : From (2008Ra12).
12500 <sup>def</sup>	(1 <sup>-</sup> ,2 <sup>+</sup> )	E(level): From (2008SfZZ, 2008Ra12, 2010Gi05, 2010Ra14). J <sup><math>\pi</math></sup> : From (2008Ra12).
13700 <sup>defg</sup>	(1 <sup>-</sup> ,2 <sup>+</sup> )	E(level): From (2008SfZZ, 2008Ra12, 2010Gi05, 2010Ra14). J <sup><math>\pi</math></sup> : From (2008Ra12).

<sup>a</sup> From invariant mass spectra of  $^{18}\text{Ne}$  created from the  $^{16}\text{O}+2\text{p}$  and  $^{17}\text{F}+\text{p}$  events (2007Ra36, 2007CaZT, 2008SfZZ, 2008Ra12, 2010Gi05, and 2010Ra14).

<sup>b</sup> It is assumed by the evaluator that the reported J <sup>$\pi$</sup>  in (2007Ra36, 2007CaZT, 2008SfZZ, 2008Ra12, 2010Gi05, and 2010Ra14) are based on the Coulomb excitation selection rules for spin zero targets (J <sup>$\pi$</sup> =1<sup>-</sup> and 2<sup>+</sup> for E1 and E2 transitions, respectively).

<sup>c</sup> This state is populated in the  $^{17}\text{F}+\text{p}$  decay channel (2007Ra36, 2008SfZZ, 2008Ra12, 2010Gi05, and 2010Ra14).

<sup>d</sup> This state is populated in the  $^{16}\text{O}+2\text{p}$  decay channel (2007Ra36, 2008SfZZ, 2008Ra12, 2010Gi05, and 2010Ra14).

<sup>e</sup> The sequential 2p-decay via an intermediate  $^{17}\text{F}$  state is energetically possible for this state (2008Ra12, 2010Ra14).

<sup>f</sup> The 1p decay branching ratio should be negligible for this state as it is not observed in the  $^{17}\text{F}+\text{p}$  channel (2008Ra12).

<sup>g</sup> Mode of 2p-decay from (2008Ra12): either sequential decay or 3-body democratic decay.

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