

Adopted Levels

Type	Author	History	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell		NDS 198,1 (2024)	1-Aug-2024

S(n)=17770 10; S(p)=1512 10; Q( $\alpha$ )=-8220 10 (2021Wa16)  
 S<sub>2n</sub>=40770 60; S<sub>2p</sub>=2112 10; Q( $\epsilon$ p)=15826 10 (2021Wa16).

Theoretical studies:

Level properties and model analyses:

1978Gu10, 1987Sa15, 2001Sa06, 2001Su10, 2002Sa12, 2008Sh16, 2010Ti04, 2011Sh21, 2013Ti05, 2013Ma60, 2016Pa05, 2017Br02, 2020So01, 2022Zo01, 2023Me02.

Charge symmetry in mirror nuclei:

1971Bl12, 1973Sa25, 1974Ch46, 1999Ba21, 2021Ca23, 2023Se01.

Magnetic moments:

1999Ba21, 2003Su04, 2003Su28, 2013De06, 2016Me17, 2021Ca23.

Analyzed  $\beta$ -decay,  $\beta$ -p decay data.

1973Ha77, 1977Ce05, 1977Ri08, 1993Ch06.

Solar and cosmogenic production rates:

2006Li57, 2018Ge07, 2019Zh29.

In the early studies of (1984Se15, 1993Wa07) using  $^{13}\text{C}(\pi^+, \pi^-)$ , the levels observed in the excitation spectrum appeared as broad groups with excitation energies around  $E_x=3, 4.5, 6$  and  $8.7$  MeV. In the later work of (2007GuZW), using  $^{16}\text{O}(^3\text{He}, ^6\text{He})$ , more structures are observed revealing a collection of narrower states. Finally, in the seminal work of (2021Ch45), analysis of the decay mechanism further resolved the groups observed by (2007GuZW) into narrower states that dominantly proton decay to different  $^{12}\text{N}$  states.

 $^{13}\text{O}$  LevelsCross Reference (XREF) Flags

<b>A</b>	$^1\text{H}(^{12}\text{N}, \text{p})$ :res	<b>F</b>	$^9\text{Be}(^{16}\text{O}, ^{13}\text{O})$	<b>K</b>	$^{14}\text{N}(\text{p}, 2\text{n})$
<b>B</b>	$^1\text{H}(^{14}\text{O}, \text{d})$	<b>G</b>	$^{12}\text{C}(\text{p}, \pi^-)$	<b>L</b>	$^{14}\text{N}(^{12}\text{N}, ^{13}\text{O})$
<b>C</b>	$^2\text{H}(^{12}\text{N}, ^{13}\text{O})$	<b>H</b>	$^{12}\text{C}(^{15}\text{O}, ^{13}\text{O})$	<b>M</b>	$^{16}\text{O}(^3\text{He}, ^6\text{He})$
<b>D</b>	$^2\text{H}(^{14}\text{O}, \text{t})$	<b>I</b>	$^{13}\text{C}(\pi^+, \pi^-)$	<b>N</b>	$^{28}\text{Si}(^{13}\text{O}, \text{X})$
<b>E</b>	$^9\text{Be}(^{13}\text{O}, ^{13}\text{O}), (^{13}\text{O}, \text{p})^{12}\text{N}$	<b>J</b>	$^{13}\text{C}(^{11}\text{B}, ^{11}\text{Li})$	<b>O</b>	$^{208}\text{Pb}(^{13}\text{O}, ^{13}\text{O})$

E(level)	$J^\pi$	$T_{1/2}$ or $\Gamma$	XREF	Comments
0.0	$3/2^-$	8.58 ms 5	BCD FGHIJKLMNO	$\% \epsilon + \% \beta^+ = 100$ ; $\% \beta^+ \text{p} = 11.3$ 23 (2005Kn02) $T = 3/2$ $\mu = 1.3891$ 3 (1996Ma38, 2019StZV) $Q = 0.0111$ 8 (2016St14, 2021StZZ) $Q$ : From reanalysis of (1999Ma46). $J^\pi$ : Allowed $ft$ values to $^{13}\text{N}$ $J^\pi = 1/2^-, 3/2^-, 5/2^-$ states (1970Es03). $T_{1/2}$ : From weighted average of 8.7 ms 4 (1965Mc09), 8.95 ms 20 (1970Es03) and 8.55 ms 5 (1990As01).
2428 <sup>†</sup> 18	$1/2^+ \&$	358 keV 19	AB E G M	$\% \text{p} = 100$

Continued on next page (footnotes at end of table)

**Adopted Levels (continued)** $^{13}\text{O}$  Levels (continued)

E(level)	J <sup>π</sup>	T <sub>1/2</sub> or Γ	XREF	Comments
3006 <sup>†</sup> 13	3/2 <sup>+</sup> &	55 keV 19	E i	<p>XREF: A(2.69E3)B(2.8E3)G(2.82E3)M(2650).  E(level),J<sup>π</sup>,Γ: From (2021Ch45) <sup>9</sup>Be(<sup>13</sup>O,<sup>13</sup>O). See also E<sub>x</sub>=2400 keV 50 (1991Go13,1991GoZR) <sup>16</sup>O(<sup>3</sup>He,<sup>6</sup>He), E<sub>x</sub>=2690 keV 50 (2007Sk02) <sup>1</sup>H(<sup>12</sup>N,p), and E<sub>x</sub>=2690 keV 50 from the (2007GuZW: ΔE estimated by evaluator) <sup>16</sup>O(<sup>3</sup>He,<sup>6</sup>He) conference proceedings. Other values reported near this energy are E<sub>x</sub>=2.82 MeV 24 (1978Co15) <sup>12</sup>C(p,π<sup>-</sup>) and E<sub>x</sub>=2.8 MeV 3 (2012Su21) <sup>1</sup>H(<sup>14</sup>O,d).  Γ: See also Γ=0.45 MeV 10 (2007Sk02), &lt;300 keV (2012Su21) and &lt;100 keV (2007GuZW: est.).  %<i>p</i>=100  XREF: i(2.75E3).  E(level),J<sup>π</sup>,Γ: From (2021Ch45) <sup>9</sup>Be(<sup>13</sup>O,<sup>13</sup>O). See also E<sub>x</sub>=2956 keV 15 and Γ&lt;50 keV (2013So11) <sup>9</sup>Be(<sup>13</sup>O,<sup>13</sup>O). Ambiguity exists in the level energies obtained from the <sup>13</sup>C(π<sup>+</sup>,π<sup>-</sup>) reaction. A narrow resonance is reported in (1984Se15) with E<sub>x</sub>=2.75 MeV 4 and in (1993Wa07) with 3.10 MeV 7; we associate these observations with either or both of the E<sub>x</sub>=3006 keV and 3051 keV Adopted Levels of this evaluation.  %<i>p</i>=100  XREF: i(2.75E3)m(3120).  E(level),J<sup>π</sup>,Γ: From (2021Ch45) <sup>9</sup>Be(<sup>13</sup>O,<sup>13</sup>O). See also E<sub>x</sub>=3025 keV 16 and Γ&lt;50 keV (2013So11) <sup>9</sup>Be(<sup>13</sup>O,<sup>13</sup>O) and E<sub>x</sub>=3038 keV 9 (2019We11) <sup>9</sup>Be(<sup>13</sup>O,<sup>13</sup>O). Also see E<sub>x</sub>=2750 keV 40 (1984Se15) and 3100 keV 70 (1993Wa07) both from <sup>13</sup>C(π<sup>+</sup>,π<sup>-</sup>), and 3120 keV 50 (2007GuZW:ΔE est.) <sup>16</sup>O(<sup>3</sup>He,<sup>6</sup>He).  Γ: See also ≈0.43 MeV (2007GuZW:est.).  XREF: m(3120).  E(level),J<sup>π</sup>,Γ: From R-matrix analysis in (2007Sk02) <sup>1</sup>H(<sup>12</sup>N,p). See also E<sub>x</sub>=3120 keV 50 and Γ=0.43 MeV 10 (2007GuZW:est.) <sup>16</sup>O(<sup>3</sup>He,<sup>6</sup>He).  E(level): This level is listed because of the significant energy difference between 3290 and the nearest level at E<sub>x</sub>=3051 keV and because of the broad width of the group reported in (2007GuZW) that may suggest both groups were populated in that study. But, its existence is rather uncertain.</p>
3051 <sup>‡</sup> 16	5/2 <sup>+</sup> &	54 keV 19	E i m	
3290 <sup>?</sup> @ 50	(1/2,3/2) <sup>-</sup>	75 keV 30	A m	
3692 <sup>†</sup> 13	7/2 <sup>+</sup> &	53 keV 21	E m	<p>%<i>p</i>=100  XREF: m(3800).  E(level),J<sup>π</sup>,Γ: From (2021Ch45) <sup>9</sup>Be(<sup>13</sup>O,<sup>13</sup>O). See also E<sub>x</sub>=3669 keV 13 and Γ&lt;50 keV (2013So11) <sup>9</sup>Be(<sup>13</sup>O,<sup>13</sup>O), E<sub>x</sub>=3701 keV 10 (2019We11) <sup>9</sup>Be(<sup>13</sup>O,<sup>13</sup>O). Also see E<sub>x</sub>=3800 keV 50 and Γ≈160 keV (2007GuZW: ΔE and Γ est.) <sup>16</sup>O(<sup>3</sup>He,<sup>6</sup>He) where the unresolved <sup>13</sup>O*(3692+3721) states may have been observed.  %<i>p</i>=100</p>
3721 <sup>#</sup> 16	(3/2 <sup>+</sup> ,5/2 <sup>+</sup> ,5/2 <sup>-</sup> ) &	10 keV +19-10	E m	

Continued on next page (footnotes at end of table)

**Adopted Levels (continued)** $^{13}\text{O}$  Levels (continued)

E(level)	$J^\pi$	$T_{1/2}$ or $\Gamma$	XREF	Comments
				XREF: m(3800). E(level), $J^\pi$ , $\Gamma$ : From (2021Ch45) $^9\text{Be}(^{13}\text{O},^{13}\text{O})$ . See also $E_x=3800$ keV 50 and $\Gamma\approx 160$ keV (2007GuZW: $\Delta E$ and $\Gamma$ est.) $^{16}\text{O}(^3\text{He},^6\text{He})$ where the unresolved $^{13}\text{O}^*(3692+3721)$ states may have been observed.
4287 <sup>†</sup> 13	$(3/2^+, 5/2^+)$ &	170 keV 25	B E I M	%p=100 XREF: I(4210)M(4410). E(level), $J^\pi$ , $\Gamma$ : From (2021Ch45) $^9\text{Be}(^{13}\text{O},^{13}\text{O})$ . E(level): See also $E_x=4.21$ MeV (1984Se15) and 4500 keV 90 (1993Wa07) discrepant values reported in $^{13}\text{C}(\pi^+, \pi^-)$ , 4.2 MeV 3 (2012Su21) $^1\text{H}(^{14}\text{O}, d)$ and 4410 keV 50 (2007GuZW: $\Delta E$ est.) $^{16}\text{O}(^3\text{He},^6\text{He})$ . $J^\pi$ : See also $(1/2^-, 3/2, 5/2^+)$ (2012Su21) and $(1/2^-)$ from (1993Wa07). $\Gamma$ : See also $\Gamma=0.6$ MeV 4 (1993Wa07), $<500$ keV (2012Su21) and $\approx 0.43$ MeV (2007GuZW: est.).
4866 <sup>‡</sup> 20	$(1/2^+, 1/2^-, 3/2^-)$ &	103 keV 37	E	%p=100 E(level), $J^\pi$ , $\Gamma$ : From (2021Ch45) $^9\text{Be}(^{13}\text{O},^{13}\text{O})$ .
4892 <sup>†</sup> 25	$7/2^+$ &	323 keV 27	E M	%p=100 E(level), $J^\pi$ , $\Gamma$ : From (2021Ch45) $^9\text{Be}(^{13}\text{O},^{13}\text{O})$ . See also $E_x=4.95$ MeV 10 and $\Gamma\approx 280$ keV (2007GuZW: $\Delta E$ and $\Gamma$ estimated by evaluator.) $^{16}\text{O}(^3\text{He},^6\text{He})$ .
5483 <sup>#</sup> 17	$7/2^-$ &	204 keV 41	E	%p=100 E(level), $J^\pi$ , $\Gamma$ : From (2021Ch45) $^9\text{Be}(^{13}\text{O},^{13}\text{O})$ .
5951 <sup>‡</sup> 18	$(7/2^+, 7/2^-)$ &	875 keV 68	E IJ M	%p=100 XREF: J(6E3). E(level), $J^\pi$ , $\Gamma$ : From (2021Ch45) $^9\text{Be}(^{13}\text{O},^{13}\text{O})$ . E(level): (2021Ch45) suggests two states in this region: one at $E_x=5951$ keV 18 along with a questionable state at $\approx 6.2$ MeV; both have broad widths of around 1 MeV. Other reactions have reported broad states near $E_x\approx 6$ MeV, but none have suggested or resolved two states. We associate all firm states reported in this region with the lower level reported in (2021Ch45), but highlight that the associations may be different if both states are found to exist. Other energies reported near $E_x=6$ MeV are 6020 keV 80 (1984Se15) and 6100 keV 90 (1993Wa07) both from $^{13}\text{C}(\pi^+, \pi^-)$ , 6.00 MeV 10 (2007GuZW: $\Delta E$ est.) $^{16}\text{O}(^3\text{He},^6\text{He})$ and 6 MeV (2007TaZR) $^{13}\text{C}(^{11}\text{B}, ^{11}\text{Li})$ . $\Gamma$ : Other reported widths are $\Gamma\approx 1.2$ MeV (1984Se15) and $\Gamma=0.6$ MeV 4 (1993Wa07) from $^{13}\text{C}(\pi^+, \pi^-)$ ; (1984Se15) suggest the group may correspond to one or more unresolved states. See also $\Gamma\approx 1.0$ MeV (2007GuZW: est.).
$\approx 6.2\times 10^3$ ? <sup>#</sup>			E	%p=100 $T_{1/2}$ or $\Gamma$ : $\Gamma=\text{BROAD}$ . E(level), $T_{1/2}$ or $\Gamma$ : From (2021Ch45) $^9\text{Be}(^{13}\text{O},^{13}\text{O})$ .

Continued on next page (footnotes at end of table)

**Adopted Levels (continued)** $^{13}\text{O}$  Levels (continued)

E(level)	$T_{1/2}$ or $\Gamma$	XREF	Comments
$6.90 \times 10^3$ @ 10	$\approx 160$ keV	<b>M</b>	From (2007GuZW): $\Delta E$ and $\Gamma$ est.) $^{16}\text{O}(^3\text{He}, ^6\text{He})$ .
$8.7 \times 10^3$ @ 2	3.1 MeV 5	<b>IJ</b>	E(level), $\Gamma$ : From (1993Wa07) $^{13}\text{C}(\pi^+, \pi^-)$ . See also $E_x=8.8$ MeV 5 and $\Gamma=3.0$ MeV 6 (1991Mo02) and $E_x=8.8$ MeV (2007TaZR) $^{13}\text{C}(^{11}\text{B}, ^{11}\text{Li})$ . E(level): Suggested GDR@IAS (GDR built on isobaric analog states) see (2007TaZR, 1984Se15).

<sup>†</sup> Decays to  $p+^{12}\text{N}_{\text{g.s.}}$ . See details in (2021Ch45)  $^9\text{Be}(^{13}\text{O}, ^{13}\text{O})$ .

<sup>‡</sup> Decays to  $p+^{12}\text{N}(961 \text{ keV}; 2^+)$ . See details in (2021Ch45)  $^9\text{Be}(^{13}\text{O}, ^{13}\text{O})$ .

# Decays to  $p+^{12}\text{N}(1.19 \text{ MeV}; 2^-)$ . See details in (2021Ch45)  $^9\text{Be}(^{13}\text{O}, ^{13}\text{O})$ .

@ Decay mode not specified.

& From (2021Ch45) analysis of the  $m$  sub-state distributions obtained by comparison of measured  $^{12}\text{N}+p$  angular distributions with those expected for proton decay via the relevant  $s$ -,  $p$ - and  $d$ -wave components. Angular distributions are found that uniquely identify  $J^\pi$  values.

$^1\text{H}(^{12}\text{N,p})$ :res [2007Sk02](#)

Type	Author	History	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell		NDS 198,1 (2024)	1-Aug-2024

[2003Te09](#), [2003Te12](#):  $^1\text{H}(^{12}\text{N,p})$   $E=3.9$  MeV/nucleon; Used two parallel-plate avalanche counters to tag events by nuclide and to monitor angular spread. Si detectors measured recoil proton spectra. Deduced resonance at  $E_p \approx 4.5$  MeV ( $E_x \approx 2.7$  MeV).

[2007Sk02](#):  $^1\text{H}(^{12}\text{N,p})$  produced the 46 MeV  $^{12}\text{N}^{7+}$  beam via  $^{10}\text{B}(^3\text{He,n})$  reaction at  $E(^{10}\text{B})=43$  MeV. Used a  $\text{CH}_2$  polyethylene target. At  $E(\text{c.m.})=0.8\text{-}2.7$  MeV, measured elastic scattering  $E_p$  excitation at  $\theta=7.5^\circ$ ,  $22.5^\circ$  and  $37.5^\circ$  using three Si  $\Delta E$ -E detectors. Deduced  $^{13}\text{O}$  resonance energies,  $J^\pi$  and  $\Gamma$  using R-matrix analysis.

 $^{13}\text{O}$  Levels

$E(\text{level})^\ddagger$	$J^\pi{}^\dagger{}^\ddagger$	$\Gamma^\ddagger$	$L^\dagger$	Comments
$2.69 \times 10^3$ 5	$1/2^+$	0.45 MeV 10	0	$\Gamma=\Gamma_p$ . See related discussion on ANCs and widths in ( <a href="#">2015Mu08</a> , <a href="#">2017Mu06</a> , <a href="#">2022Mu07</a> ).
3290 50	$[1/2^-, 3/2^-]$	75 keV 30	1	$E(\text{level})$ : Possible mirror of a shell model predicted $(1/2^-, 3/2^-)$ state in $^{13}\text{B}$ at $E_x \approx 4$ MeV.

<sup>†</sup> From shape of resonance and R-matrix analysis assuming a only a single-proton decay channel. The following three distant resonances were included in the R-matrix analysis to fit the background: 4550,  $3/2^-$ ,  $\Gamma=0.24$  MeV; 5000,  $3/2^+$ ,  $\Gamma=0.78$  MeV; 5700,  $3/2^+$ ,  $\Gamma=2.0$  MeV.

<sup>‡</sup> From [2007Sk02](#).

$^1\text{H}(^{14}\text{O},\text{d})$  2012Su21

Type	Author	History	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell		NDS 198,1 (2024)	1-Aug-2024

2012Su21: XUNDL dataset compiled by TUNL, 2012.

The authors measured  $^{14}\text{O}(\text{p},\text{d})$  at  $E(^{14}\text{O})=51$  MeV/nucleon using a hydrogen gas target mounted in the SPEG/GANIL target chamber and using position sensitive Si strip arrays to detect the deuteron recoils (MUST2 and RIKEN Si telescope). The energy and angular distributions of deuterons were measured in coincidence with  $^{13}\text{O}$  and  $^{12}\text{N}$  (from  $^{13}\text{O}^* \rightarrow ^{12}\text{N} + \text{p}$ ) recoils. A distorted wave analysis of the angular distributions is given as well as a discussion on the breakdown of  $Z=8$  shell closure.

2023Po05:  $^1\text{H}(^{14}\text{O}, ^{13}\text{O})$   $E=94$  MeV/nucleon at RIKEN/RIBF; they also studied  $^1\text{H}(^{14}\text{O}, ^{13}\text{N})$ . Measured the parallel momentum distributions and reaction cross sections. Analyzed quasifree knockout and other mechanisms. Deduced  $S=3.42$  in DWIA analysis.

 $^{13}\text{O}$  Levels

$E(\text{level})^\dagger$	$J^\pi^\dagger$	$T_{1/2}$ or $\Gamma^\dagger$	$L^\dagger$	$S$	Comments
0.0	$3/2^-$	8.58 ms 5	1	2.1 4	$T_{1/2}$ : From Adopted Levels. $E(\text{level})$ : Observed at $E_x=-0.2$ MeV 3.
$2.8 \times 10^3$ 3	$1/2^+, (1/2^- \text{ to } 5/2^+)$	$<0.3$ MeV	0,(1,2)		$J^\pi=1/2^+, (1/2^-, 3/2^-, 3/2^+, 5/2^+)$ . The authors suggest this state corresponds to the 2.7 MeV $J^\pi=1/2^+$ level of (2007Sk02), though participation of a second $\Delta L=1$ or 2 state can not be ruled out. Discussion on the spectroscopic factors for the various doublet combination is given in Table 1.
$4.2 \times 10^3$ 3	$(1/2^-, 3/2, 5/2^+)$	$<0.5$ MeV	(1,2)		Discussion on the spectroscopic factors is given in Table 1.

$^\dagger$  From (2021Su21). Note: systematic uncertainty of 0.2 MeV is included.

---

 $^2\text{H}(^{12}\text{N}, ^{13}\text{O})$  [2013Gu04](#)

---

Type	Author	History	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell		NDS 198,1 (2024)	1-Aug-2024

[2013Gu04](#): XUNDL dataset compiled by TUNL, 2013.

A beam of 72 MeV  $^{12}\text{N}$  ions was produced via the  $^3\text{He}(^{10}\text{B}, ^{12}\text{N})$  reaction at the RIKEN RI Beam facility. The trajectory of beam particles was tracked onto a 1.5 mg/cm<sup>2</sup> deuterated polyethylene foil, where  $^2\text{H}(^{12}\text{N}, ^{13}\text{O})$  reactions occurred. Interacting  $^{12}\text{N}$  ions were identified by their time of flight relative to the cyclotron rf. The  $^{13}\text{O}$  ejectiles were identified by  $\Delta\text{E-E}$  in a telescope array. The data are normalized by the  $^2\text{H}(^{12}\text{N}, ^{12}\text{N})$  elastic scattering reaction. The code FRESCO was used to analyze the cross section angular distributions and to deduce the ANC's. Values of  $(C_{p1/2})^2=3.4 \text{ fm}^{-1}$  13 and  $(C_{p3/2})^2=0.54 \text{ fm}^{-1}$  20 yield a total ANC of  $(C_{\text{tot}})^2=3.9 \text{ fm}^{-1}$  13. An earlier measurement at RIKEN is mentioned in ([2010LiZW](#)).

Discussion is given on the astrophysical implications to the  $^1\text{H}(^{12}\text{N}, ^{13}\text{O})$  reaction. See also ([2022Du11](#)).

---

 $^{13}\text{O}$  Levels

---

$\text{E(level)}^\dagger$	$J^\pi^\dagger$
0.0	$3/2^-$

<sup>†</sup> From Adopted Levels.

$^2\text{H}(^{14}\text{O},\text{t})$  2013FI01

Type	Author	History	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell		NDS 198,1 (2024)	1-Aug-2024

2013FI01: XUNDL dataset compiled by TUNL, 2013.

A 18.1 MeV/nucleon  $^{14}\text{O}$  beam was produced at the GANIL/SPIRAL facility. The beam impinged on a 1.5 mg/cm<sup>2</sup> CD<sub>2</sub> target (elastic scattering) or a 8.5 mg/cm<sup>2</sup> CD<sub>2</sub> target ((d,t)) and the light recoil nuclei were detected in one of six MUST2 array telescopes: four telescopes covered  $\theta_{\text{cm}} \approx 15\text{-}70^\circ$  for the nucleon transfer reactions while the other two were near  $\theta_{\text{lab}} \approx 90^\circ$  and were used to extend the elastic measurements.

The angular distributions were analyzed using the FRESKO code. Spectroscopic factors are deduced using both phenomenological and microscopic overlap functions and compared with literature results for  $^{16}\text{O}(\text{d},^3\text{He})$ , (d,t) and  $^{18}\text{O}(\text{d},^3\text{He})$ . See further analysis in (2018FI03).

 $^{13}\text{O}$  Levels

E(level)	$J^\pi$ <sup>†</sup>	Comments
0.0	$3/2^-$	C <sup>2</sup> S(phenomenological)=1.69 17 (experimental) 20 (analysis). C <sup>2</sup> S(microscopic)=1.89 19 (experimental) 22 (analysis).

<sup>†</sup> From FRESKO analysis of spectroscopic factors.



$^9\text{Be}(^{13}\text{O}, ^{13}\text{O}), (^{13}\text{O}, \text{p})^{12}\text{N}$  2013So11, 1996Oz01

Type	Author	History	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell		NDS 198,1 (2024)	1-Aug-2024

1996Oz01, 2001Oz04:  $^9\text{Be}$ , C,  $^{27}\text{Al}(^{13}\text{O}, ^{13}\text{O})$   $E \approx 730$  MeV. Measured interaction cross section. Deduced p, charge, neutron and matter r.m.s. radii of 2.56 fm 5, 2.68 fm 5, 2.48 fm 5 and 2.53 fm 5, respectively.

2013So11: XUNDL data set compiled by TUNL, 2013.

A beam of  $E(^{13}\text{O})=30.3$  MeV/nucleon ions, produced via  $^1\text{H}(^{14}\text{N}, ^{13}\text{O})$  reaction at the Texas A&M MARS facility, impinged on a 45.6 mg/cm<sup>2</sup>  $^9\text{Be}$  target. Breakup particles were detected in a 10 cm $\times$  10 cm segmented  $\Delta E$ -E telescope located on the beam axis, 18 cm from the target.

Momentum analysis of the breakup particles permitted the kinematic reconstruction of the invariant mass and determination of excitation energies for  $^{12}\text{N}^*$  and  $^{13}\text{O}^*$  states involved in the reactions. The intrinsic width resolution was roughly 50 keV and there was a 10 keV systematic uncertainty in the invariant mass energy. The excitation spectra of  $\text{p}+^{12}\text{N}$  and  $2\text{p}+^{11}\text{C}$  events were analyzed to deduce  $^{13}\text{O}$  excited states.

A single state was observed at  $E_x=2956$  keV 10 in the  $\text{p}+^{12}\text{N}$  relative energy spectrum, while two states at  $E_x=3025$  keV 6 and 3669 keV 3 were found in the  $2\text{p}+^{11}\text{C}$  spectrum (uncertainty is statistical only, systematic uncertainty is 10 keV). The widths of  $^{13}\text{O}$  states were found consistent with the system resolution, hence narrow widths of  $\Gamma < 50$  keV are assumed.

Analysis of the Jacobi T and Y systems provides insight into the decay mechanism for the 3-body breakup systems; the decays are consistent with sequential decay mainly through  $E_x=0.96$  and 1.18 MeV unbound states in  $^{12}\text{N}$ .

2019We11:  $^9\text{Be}(^{13}\text{O}, ^{13}\text{O})$ , the authors of (2013So11) measured the excitation spectra of particle unbound nuclides produced in the breakup  $^{13}\text{O}$  ions on a  $^9\text{Be}$  target, the emphasis was on  $^{11,12}\text{N}$  and  $^{12}\text{O}$ , but some new information on  $^{13}\text{O}$  was presented.

A beam of 69.5 MeV/nucleon  $^{13}\text{O}$  ions, from the NSCL/A1900 fragment separator, was purified in the Radio Frequency Fragment Separator before impinging on a 1 mm thick  $^9\text{Be}$  target. The reaction products were detected using the HiRA High-Resolution position sensitive  $\Delta E$ -E telescope array, which covered the polar angles  $\theta_{\text{lab}}=2.1^\circ$  to  $12.1^\circ$ . Peaks corresponding to  $^{13}\text{O}^*$  (3038 9, 3701 10) were reported. These values are consistent with (2013So11) but more precise. See related discussion in (2019Ka50).

2021Ch45: XUNDL dataset compiled by TUNL (2022).

The authors of (2013So11, 2019We11) reported new results on unbound  $^{13}\text{O}$  states and analyzed the associated decay proton angular distributions to obtain information on the spin values.

A beam of 69.5 MeV/nucleon  $^{13}\text{O}$  ions from the NSCL/A1900 fragment separator was purified in the Radio Frequency Fragment Separator before impinging on a 1 mm thick  $^9\text{Be}$  target. The reaction products were detected using the HiRA High-Resolution position sensitive  $\Delta E$ -E telescope array, which covered the polar angles  $\theta_{\text{lab}}=2.1^\circ$  to  $12.4^\circ$ . The invariant-mass spectra were obtained for states decaying to  $\text{p}+^{12}\text{N}_{\text{g.s.}}$  and  $2\text{p}+^{11}\text{C}$  (resulting from  $\text{p}+^{12}\text{N}(1.19 \text{ MeV}; 2^-)$  and  $\text{p}+^{12}\text{N}(961 \text{ keV}; 2^+)$  events).

Events corresponding to low target excitations were selected, since these events are thought to possess a strong spin alignment in the ejectile that should be sensitive to the excited state's spin value. Additionally, the breakup events having the decay protons emitted perpendicular to the beam axis were preferentially selected to enhance the excitation energy resolution. Five states were observed in the  $\text{p}+^{12}\text{N}_{\text{g.s.}}$  spectrum, three states were observed in the  $\text{p}+^{12}\text{N}(961 \text{ keV}; 2^+)$  spectrum, two states were observed in the  $\text{p}+^{12}\text{N}(1.19 \text{ MeV}; 2^-)$  spectrum, and evidence for a third, difficult to interpret, broad state was also observed in the  $\text{p}+^{12}\text{N}(1.19 \text{ MeV}; 2^-)$  decay channel.

The decay proton angular distributions were analyzed and compared with a model based on DWBA calculations to gain insight into sensitivity for constraining spin values of the excited states. The model analyzed the  $m$ -state distribution dependence for small-angle, and all-angle scattering of the  $^{13}\text{O}$  ejectiles. Using the  $m$ -state distributions, angular distributions were calculated for  $s$ -,  $p$ - and  $d$ -wave components that are expected in proton emission from  $^{13}\text{O}$ . The angular distributions showed a differentiable dependence for  $J$  and  $\pi$  values, and they were compared with the measured  $^{13}\text{O} \rightarrow ^{12}\text{N}+\text{p}$  angular distributions to obtain  $J^\pi$  values given below.

The present results are found in reasonable agreement with prior reports. In a few instances, states at similar excitation energies are found in the different decay modes; these states are assigned to different close-lying levels with different  $J^\pi$  values based on the analysis of the decay proton angular distributions. See discussion in text.

note: In the initial publication, Table 1 was found to have inconsistencies between the  $E^*$  and  $E_{\text{c.m.}}$  values given. These values were corrected in September 2022 following a private communication with R.J. Charity (June 14, 2022). However, inconsistencies persist in the published  $\Delta E$  values; in the present analysis  $\Delta E$  values are obtained beginning with the uncertainties on  $E_{\text{c.m.}}$  values. Also, the discussion indicates  $J^\pi=7/2^+$  for peak 3, the Table I contains a typographical error.

$^9\text{Be}(^{13}\text{O}, ^{13}\text{O}), (^{13}\text{O}, \text{p}^{12}\text{N})$  **2013So11,1996Oz01 (continued)** $^{13}\text{O}$  Levels

E(level)	$J^\pi$ <sup>‡</sup>	$\Gamma$ <sup>†</sup>	$E_{\text{c.m.}}(\text{p}+^{12}\text{N})$ (keV) <sup>†</sup>	Comments
2428 <sup>#</sup> 18	1/2 <sup>+</sup>	358 keV 19	916 14	
3006 <sup>#</sup> 13	3/2 <sup>+</sup>	55 keV 19	1494 8	E(level): See also 2956 keV 15 (2013So11).
3051 <sup>@</sup> 16	5/2 <sup>+</sup>	54 keV 19	578 11	E(level): See also 3025 keV 16 (2013So11) and 3038 keV 9 (2019We11).
3692 <sup>#</sup> 13	7/2 <sup>+</sup>	53 keV 21	2180 8	E(level): See also 3669 keV 13 (2013So11) and 3701 keV 10 (2019We11).
3721 <sup>&amp;</sup> 16	(3/2 <sup>+</sup> , 5/2 <sup>+</sup> , 5/2 <sup>-</sup> )	10 keV +19-10	1019 11	
4287 <sup>#</sup> 13	(3/2 <sup>+</sup> , 5/2 <sup>+</sup> )	170 keV 25	2775 9	
4866 <sup>@</sup> 20	(1/2 <sup>+</sup> , 1/2 <sup>-</sup> , 3/2 <sup>-</sup> )	103 keV 37	2393 16	
4892 <sup>#</sup> 25	7/2 <sup>+</sup>	323 keV 27	3380 23	
5483 <sup>&amp;</sup> 17	7/2 <sup>-</sup>	204 keV 41	2781 11	
5951 <sup>@</sup> 18	(7/2 <sup>+</sup> , 7/2 <sup>-</sup> )	875 keV 68	3478 14	
$\approx 6.2 \times 10^3$ ? <sup>&amp;</sup>		1.2 MeV	$\approx 3500$	$\Gamma$ : From (1984Se15).

<sup>†</sup> From (2021Ch45). An 8 keV systematic uncertainty is combined in quadrature to the  $\Delta E_{\text{c.m.}}$  decay energy values of Table 1 (labeled  $\Delta E_{\text{p}}$  in that table).

<sup>‡</sup> From (2021Ch45) analysis of the  $m$  sub-state distributions obtained by comparison of measured  $^{12}\text{N}+\text{p}$  angular distributions with those expected for proton decay via the relevant  $s$ -,  $p$ - and  $d$ -wave components.

<sup>#</sup>  $E = S(\text{p}) + E_{\text{cm}}(\text{p} + ^{12}\text{N}_{\text{g.s.}}) = 1512 \text{ keV } 10 + E_{\text{c.m.}}(\text{p} + ^{12}\text{N})$ .

<sup>@</sup>  $E = S(\text{p}) + E_{\text{cm}}(\text{p} + ^{12}\text{N}(961 \text{ keV}; 2^+)) = 1512 \text{ keV } 10 + E_{\text{c.m.}}(\text{p} + ^{12}\text{N}) + 961 \text{ keV } 5$ .

<sup>&</sup>  $E = S(\text{p}) + E_{\text{cm}}(\text{p} + ^{12}\text{N}(1.19 \text{ MeV}; 2^-)) = 1512 \text{ keV } 10 + E_{\text{c.m.}}(\text{p} + ^{12}\text{N}) + 1190 \text{ keV } 7$ .

<u><math>^9\text{Be}(^{16}\text{O}, ^{13}\text{O})</math></u>				
Type	Author	History	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell		NDS 198,1 (2024)	1-Aug-2024
<a href="#">1996Ma38</a> , <a href="#">1999Ma46</a> , <a href="#">1999Sa75</a> : $^9\text{Be}(^{16}\text{O}, ^{13}\text{O})$ , studied $\beta$ -NQR and $\beta$ -NMR. Deduced $\text{ABS}(\mu(^{13}\text{O}))=1.3891\ \mu_{\text{N}}$ <sup>3</sup> ( <a href="#">1996Ma38</a> ) and $\text{ABS}(\text{Q}(^{13}\text{O}))=11.0\ \text{mb}$ <i>13</i> ( <a href="#">1999Ma46</a> , <a href="#">1999Sa75</a> ).				
See preliminary and conference results in ( <a href="#">1996MaZQ</a> , <a href="#">1998MaZK</a> , <a href="#">2002Ma43</a> ).				
See theoretical analyses in ( <a href="#">1999Ki27</a> , <a href="#">1999Ki28</a> , <a href="#">2003Sm02</a> , <a href="#">2003Su04</a> , <a href="#">2003Su28</a> ).				

<u><math>^{13}\text{O}</math> Levels</u>
<u>E(level)</u>
0

$^{12}\text{C}(\text{p},\pi^-)$     **1978Co15,1980Ho20**

Type	Author	History	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell		NDS 198,1 (2024)	1-Aug-2024

**1978Co15:**  $^{12}\text{C}(\text{p},\pi^-)$  E=613 MeV from the Saclay synchrotron Saturne; measured  $\pi$  yields using the SPES I high-resolution magnetic spectrometer at  $\theta=5^\circ$ ,  $15^\circ$ ,  $25^\circ$  and  $35^\circ$ . Deduced level at  $E_x=2.82$  MeV 24, enhancement at  $\approx 5.5$  MeV (450 keV energy resolution). No Q dependence on angular distribution.

**1980Ho20:**  $^{12}\text{C}(\text{p},\pi^-)$  E=200 MeV from Indiana University Cyclotron Facility; measured  $\sigma(\theta)$  for  $^{13}\text{O}_{\text{g.s.}}$ , deduced structure and reaction process interplay.

**1982Ja05:**  $^{12}\text{C}(\text{pol. p},\pi^-)$  E=205 MeV from the Indiana University Cyclotron Facility; measured  $\sigma(E(\pi))$ ,  $\sigma(\theta)$ , and  $A_y$  vs  $\theta$  from  $\theta(\text{c.m.})=31^\circ$  to  $153^\circ$  using the quadrupole-quadrupole split-pole spectrometer. Analyzed  $^{13}\text{O}_{\text{g.s.}}$ .

**1985Bi04:**  $^{12}\text{C}(\text{p},\pi^-)$  E= 180, 201 MeV from the Orsay synchrocyclotron, measured  $\sigma(\theta, E(\pi))$ . Deduced  $\sigma_{\text{total}}$ .

**1988Ab05:**  $^{12}\text{C}(\text{p},\pi^-)$  E=997(5) MeV, measured  $\sigma(\theta)$  vs.  $\pi$  momentum from 75-950 MeV/c at  $\theta=0^\circ$  and  $57.8^\circ$ . Used two magnetic spectrometers  $\pi 1$  and  $\pi 2$  with angular acceptance of 0.01 sr. Total RMS error for normalisation of the differential cross section was 6% and 11% for  $0^\circ$  and  $57.8^\circ$ , respectively.

**1992Ho03:**  $^{12}\text{C}(\text{p},\pi^-)$  E=186, 204 MeV,  $\theta(\text{c.m.})=155^\circ-180^\circ$ . Observed  $\pi'$ s emitted in backward direction corresponding to  $^{13}\text{O}_{\text{g.s.}}$ .

**2002Ha02:**  $^{12}\text{C}(\text{pol. p},\pi^-)$  E=250, 300, 350 MeV, proton polarization of about 0.7 from the atomic beam-type polarized ion source at the Research Center for Nuclear Physics in Osaka University. Measured  $\sigma(\theta)$  and analyzing powers using spectrometer LAS. Focal plane detectors consisted of two vertical drift chambers and two  $\Delta E$  trigger scintillators. 10% data acquisition deadtime. Most background was from  $\mu$  produced from  $\pi$ -decay. Less than 5% overall systematic uncertainties. Comparison with DWBA.

See also (theory) ([1981Bu18](#), [1984Gu27](#), [1985Co11](#), [1991Ku07](#), [1992Be37](#), [1992No01](#), [1998No08](#), [2018No02](#)).

 $^{13}\text{O}$  Levels

E(level) <sup>†</sup>	J $\pi$ <sup>‡</sup>
0	(3/2 <sup>-</sup> )
$2.82 \times 10^3$ 24	

<sup>†</sup> From [1978Co15](#).

<sup>‡</sup> From [1980Ho20](#).

<sup>12</sup>C(<sup>15</sup>O,<sup>13</sup>O)    [2022Bo01](#)

Type	Author	History	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell		NDS 198,1 (2024)	1-Aug-2024

[2022Bo01](#): <sup>12</sup>C(<sup>15</sup>O,<sup>13</sup>O) E=349 MeV/nucleon. Measured fragmentation yields for nuclei produced in the fragmentation of <sup>15</sup>O. In addition they measured the production yields of <sup>12</sup>C(<sup>13</sup>O,X) at E=397 MeV/nucleon for X=<sup>7,9</sup>Be, <sup>8,10,11</sup>B, <sup>9,10,11,12</sup>C and <sup>12</sup>N.

<sup>13</sup>O Levels

E(level)  
0

$^{13}\text{C}(\pi^+, \pi^-)$  1993Wa07

Type	Author	History	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell		NDS 198,1 (2024)	1-Aug-2024

**1980Bu15:**  $^{13}\text{C}(\pi^+, \pi^-)$  E=180 MeV,  $\theta=5^\circ$ , measured  $\sigma(\theta)$  and Q. Used the Energetic Pion Channel and EPICS spectrometer to separate pions.

**1984Se15, 1985SeZY:**  $^{13}\text{C}(\pi^+, \pi^-)$  E=164, 292 MeV, measured  $\sigma(E(\pi), \theta)$ , missing mass spectrum. Used a 90% isotopic pure  $^{13}\text{C}$  target. Normalized yields with  $^1\text{H}(\pi^+, \pi^+)$  at  $50^\circ$  and compared with phase-shift analysis. Found  $\Delta E \approx 0.9$  and 0.5 MeV FWHM resolution of missing mass spectra for thick and thin targets. The pions were separated using the EPICS spectrometer. Deduced  $^{13}\text{O}$  levels. Excited state peaks appear significantly narrower than the ground state peak, which is surprising. The energies of the observed peaks appear to be shifted lower by  $\approx 300$  keV when compared with (1993Wa07), while the g.s. seems to have a high-energy tail. The ground state and other levels are reported at  $E_x=2.75$  MeV 4, 4.21 MeV and 6.02 MeV 8.

**1989Mo09:**  $^{13}\text{C}(\pi^+, \pi^-)$  E=292 MeV,  $\theta=5^\circ$ , measured  $\sigma(\theta)$ .  $^{13}\text{O}$  deduced GDR built on IAS.

**1990GI09:**  $^{13}\text{C}(\pi^+, \pi^-)$  E=132 MeV, compiled data.

**1990Mo02:**  $^{13}\text{C}(\pi^+, \pi^-)$  E=292 MeV,  $\theta=5^\circ$ , measured  $\sigma(\theta)$ .  $^{13}\text{O}$  deduced GDR built on IAS. 90% enriched  $^{13}\text{C}$  target.

**1991Mo02:**  $^{13}\text{C}(\pi^+, \pi^-)$  E=292 MeV,  $\theta=18^\circ$ , measured  $\sigma(\theta(\pi), E(\pi))$ . 90% isotopic pure  $^{13}\text{C}$  target.  $^{13}\text{O}$  deduced giant resonances,  $\Gamma$ , ISPIN.

**1993Wa07:**  $^{13}\text{C}(\pi^+, \pi^-)$  E=140-295 MeV, measured  $\sigma(\theta)$  vs E using EPICS at LAMPF. 90% isotopic pure  $^{13}\text{C}$  target. Deduced levels,  $\Gamma$ , configurations from missing mass spectra. Analyzed level structures at  $E_{\pi^+}=140, 180, 220, 260, 295$  MeV. The ground state and other levels are reported at  $E_x=3.10$  MeV 7, 4.50 MeV 9, 6.10 MeV 9 and 8.7 MeV 2. The ground state width is reported at  $\Gamma=0.40$  MeV 6, even though the state is known to have  $\Gamma < 1$  eV. Other widths for the excited states are reported as  $\Gamma=0.6$  MeV 4, 0.6 MeV 4, 0.6 MeV 4 and 3.1 MeV 5, respectively.

**1994Mo04, 1994Mo44:**  $^{13}\text{C}(\pi^+, \pi^-)$  E=295 MeV, compiled, reviewed  $\sigma(\theta)$ . Deduced GDR excitation.

**1996Mo03:**  $^{13}\text{C}(\pi^+, \pi^-)$  E=140-295 MeV,  $\theta=18^\circ$  measured  $\sigma(\theta)$ . Analyzed various results.

See theoretical analysis in (1991Ku07).

*Discussion:* The level structures observed in  $^{13}\text{C}(\pi^+, \pi^-)$  are best resolved in (1984Se15), though they did not report uncertainties for some of their results. On the other hand, (1993Wa07) also utilized EPICS at LANSCE for their measurement, and they did report experimental uncertainties, but they reported rather unreliable width values such as  $\Gamma_{\text{g.s.}}=400$  keV 60. A further complication is that the reported excitation energies of (1984Se15) are systematically lower than those in (1993Wa07) suggesting the data sets should not simply be averaged. We select the excitation energies and widths of (1984Se15) for the lower-lying states since they appear better resolved, and we note that (1993Wa07) was focused on the  $E_x=8.7$  MeV GDR@IAS resonance.

 $^{13}\text{O}$  Levels

E(level) <sup>†</sup>	$J^\pi$	$\Gamma^\dagger$	Comments
0	(3/2 <sup>-</sup> )		E(level): Q(g.s.)=-18.9 MeV 1 (1993Wa07, 1991Mo02). $\Gamma$ : The value $\Gamma=400$ keV 60 is reported in (1993Wa07), but this would imply a particle unbound level.
$2.75 \times 10^3$ 4			$\Gamma$ : NARROW. E(level): From $E_x=2.75$ MeV 4 in (1984Se15). See also $E_x=3.10$ MeV 9 from Q=-22.0 MeV 6 (1993Wa07). $\Gamma$ : In (1984Se15) a peak with a narrower width than the g.s. is observed; subsequent results from (2021Ch45) $^9\text{Be}(^{13}\text{O}, ^{13}\text{O})$ support the existence of narrow states ( $\approx 50$ keV) in this region. The other width reported for this state is $\Gamma=0.60$ MeV 40 (1993Wa07).
4210	(1/2 <sup>-</sup> )		E(level): From (1984Se15). See also $E_x=4500$ keV 90 from Q=-23.4 MeV (1993Wa07). $J^\pi$ : Based on similarities with $^{12}\text{C}(\pi^+, \pi^-)^{12}\text{O}$ (g.s.) and $^{14}\text{C}(\pi^+, \pi^-)^{17}\text{O}$ (5.9 MeV) (1984Se15). $\Gamma$ : In (1984Se15) a peak with a similar width to the g.s. is observed. The only width reported for this state in $^{13}\text{C}(\pi^+, \pi^-)$ is $\Gamma=0.60$ MeV 40 in (1993Wa07).
6020 80		$\approx 1.2$ MeV	E(level): From (1984Se15). See also $E_x=6.10$ MeV 9 from Q=-25.0 MeV 8 (1993Wa07) and see also 5.1 MeV from Q=-24.0 MeV 5 in (1991Mo02).

Continued on next page (footnotes at end of table)

---

 $^{13}\text{C}(\pi^+, \pi^-)$  [1993Wa07](#) (continued)

---

 $^{13}\text{O}$  Levels (continued)

---

<u>E(level)<sup>†</sup></u>	<u><math>\Gamma</math><sup>†</sup></u>	<u>Comments</u>
$8.7 \times 10^3$ 2	3.1 MeV 5	$\Gamma$ : From ( <a href="#">1984Se15</a> ). The other width reported for this state is $\Gamma=0.60$ MeV 40 ( <a href="#">1993Wa07</a> ). E(level), $\Gamma$ : From $Q=-27.6$ MeV 2 ( <a href="#">1993Wa07</a> ). See also $Q=-27.7$ MeV 5 and $\Gamma=3.0$ MeV 6 ( <a href="#">1991Mo02</a> ), and $Q=-27.4$ MeV 5 and $\Gamma=2$ MeV 1 ( <a href="#">1989Mo09</a> ). Suggested GDR $\otimes$ IAS resonance.

<sup>†</sup> From ([1984Se15](#)).

<u><math>^{13}\text{C}(^{11}\text{B},^{11}\text{Li})</math></u>				
Type	Author	History	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell		NDS 198,1 (2024)	1-Aug-2024

[2007TaZR](#):  $^{13}\text{C}(^{11}\text{B},^{11}\text{Li})$  E=758 MeV, measured  $^{13}\text{O}$  excitation spectrum at RCNP Grand Raiden spectrometer. Peaks are suggested in the spectrum, and results are compared with the  $^{13}\text{C}(\pi^+,\pi^-)$  spectrum. The ground state is observed and there may be some evidence of levels at  $E_x=25.0$  and  $27.5$  MeV. Comments on the GDR $\otimes$ IAS (GDR built on isobaric analog states) are given.

<u><math>^{13}\text{O}</math> Levels</u>	
E(level)	Comments
0	
$6\times 10^3?$	
$8.8\times 10^3?$	E(level): Possibly the GDR $\otimes$ IAS.



<sup>14</sup> N(p,2n)				
Type	Author	History	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell		NDS 198,1 (2024)	1-Aug-2024
<a href="#">1963Ba63</a> : Study of residual decays from a <sup>14</sup> N(p,2n) study at the McGill synchrocyclotron. The <sup>13</sup> O nucleus was discovered based on observed β-p branches. See also ( <a href="#">2012Th01</a> ).				
<a href="#">1965Mc09</a> : <sup>14</sup> N(p,2n) E=50 MeV; deduced <sup>13</sup> O β-p branches with E <sub>p</sub> =6.06 and 6.65 MeV. T <sub>1/2</sub> =8.7 ms 4.				
<a href="#">1970Es03</a> , <a href="#">1971EsZR</a> : <sup>14</sup> N(p,2n) E=43 MeV; measured nine <sup>13</sup> O β-p branches and T <sub>1/2</sub> =8.95 ms 20.				
<a href="#">1983AsZZ</a> , <a href="#">1984MiZR</a> , <a href="#">1990As01</a> : <sup>14</sup> N(p,2n) E=45 MeV; studied <sup>13</sup> O decay. Reported T <sub>1/2</sub> =8.50 ms 10 ( <a href="#">1984MiZR</a> ); T <sub>1/2</sub> =8.55 ms 5 ( <a href="#">1984MiZR</a> , <a href="#">1990As01</a> ).				
<a href="#">2005Kn02,2014Te01</a> : <sup>14</sup> N(p,2n) deduced <sup>13</sup> O β-p branches.				

<sup>13</sup> O Levels		
E(level)	T <sub>1/2</sub>	Comments
0	8.55 ms 5	T <sub>1/2</sub> : From ( <a href="#">1990As01</a> ).

<u><sup>14</sup>N(<sup>12</sup>N,<sup>13</sup>O)</u>				
Type	Author	History	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell		NDS 198,1 (2024)	1-Aug-2024
<a href="#">2009Ba09</a> : <sup>14</sup> N( <sup>12</sup> N, <sup>13</sup> O) E=12 MeV/nucleon; measured particle spectra, angular distributions at TAMU/MARS spectrometer. DWBA analysis of elastic scattering channel to obtain <sup>12</sup> N(p,γ) ANC. Analyzed astrophysical reaction rate.				
<u><sup>13</sup>O Levels</u>				
E(level)				
0				

$^{16}\text{O}(^3\text{He},^6\text{He})$  1991Go13,2007GuZW

Type	Author	History	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell		NDS 198,1 (2024)	1-Aug-2024

1966Ce02:  $^{16}\text{O}(^3\text{He},^6\text{He})$  E=65.3,  $\theta=10\text{-}20^\circ$ ; deduced mass excess of 23.11 MeV 7.

1970Me11:  $^{16}\text{O}(^3\text{He},^6\text{He})$  E=65-75 MeV; measured M=23.107 MeV 15 at the 88-inch using  $\Delta\text{E-E}$  telescopes. Compared IMME.

1970Tr05, 1970TrZX, 1971Tr03:  $^{16}\text{O}(^3\text{He},^6\text{He})$  E=68-70 MeV, measured Q=-30.506 MeV 13 and  $\Delta\text{M}=23.103$  MeV 14.

Identification of particles using a position-sensitive Si surface-barrier detector in Enge spectrometer. Compared IMME.

1991Go13, 1991GoZR:  $^{16}\text{O}(^3\text{He},^6\text{He})$  E=76.6 MeV. Used a gas target, solid  $\text{SiO}_2$ , and  $\text{W}_2\text{O}_5$  targets to increase reliability.

Collected spectra at  $\theta=5^\circ$  on a cooled semiconductor detector. Deduced levels. The article shows a spectrum with levels indicated and the text gives energy uncertainties around 50 keV, but the levels are not well resolved from other features. The peak fits appear drawn by hand via  $\chi$ -by-eye technique. States at  $E_x=2.4$  MeV 5 and 2.9 MeV 5 are deduced.

2007GuZW:  $^{16}\text{O}(^3\text{He},^6\text{He})$  E=79.90 MeV; measured excitation spectra for  $\theta=7^\circ$  to  $24^\circ$  with  $\Delta\text{E}\approx 250$  keV (FWHM). Only one figure is shown for  $\theta=12^\circ$  where several peaks are observed with widths that are typically 2-3 times broader than the ground state width. The data were collected along with  $^{20}\text{Ne}(^3\text{He},^6\text{He})$  data that were published in (1998Gu10); the  $^{16}\text{O}(^3\text{He},^6\text{He})$  data appear only in (2007GuZW). By comparison with (1998Gu10) the peak energy resolution is estimated below by the evaluator.

The measured angular distributions disagreed with DWBA calculations which may indicate higher order effects, sequential transfer and core excitations should be considered.

 $^{13}\text{O}$  Levels

E(level) <sup>†</sup>	J <sup>π</sup> @	Γ&	Comments
0			
2650 <sup>‡</sup>	(5/2 <sup>+</sup> )	<100 keV	E(level): See also $E_x=2.40$ MeV 5 (1991Go13,1991GoZR). Γ: The $\approx 250$ keV width observed in the spectrum suggests $\Gamma < 100$ keV.
3120 <sup>‡</sup>	(1/2 <sup>-</sup> )	$\approx 0.43$ MeV	E(level): See also $E_x=2.90$ MeV 5 (1991Go13,1991GoZR). Γ: $\approx 500$ keV observed width.
3800 <sup>‡</sup>		$\approx 160$ keV	Γ: $\approx 300$ keV observed width.
4410 <sup>‡</sup>		$\approx 0.43$ MeV	Γ: $\approx 500$ keV observed width.
$4.95 \times 10^3$ <sup>#</sup>		$\approx 280$ keV	Γ: $\approx 375$ keV observed width.
$6.00 \times 10^3$ <sup>#</sup>		$\approx 1.0$ MeV	Γ: $\approx 1$ MeV observed width.
$6.90 \times 10^3$ <sup>#</sup>		$\approx 160$ keV	Γ: $\approx 300$ keV observed width.

<sup>†</sup> From (2007GuZW). As the evaluation progressed it became clear that these level parameters would be more reliable if data from all nine angles had been analyzed and reported in a journal article. The weight given to these data and their uncertainties (deduced by the evaluator) is somewhat dismissed.

<sup>‡</sup>  $\Delta\text{E}\approx 50$  keV is estimated by the evaluator.

<sup>#</sup>  $\Delta\text{E}\approx 100$  keV is estimated by the evaluator.

@ Listed in (1991Go13,1991GoZR).

& The  $\Gamma$  values are estimated by the evaluator by subtracting the FWHM=250 keV resolution from the width observed in the Figure 2 spectrum of (2007GuZW).

<sup>28</sup> Si( <sup>13</sup> O,X)				
Type	Author	History	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell		NDS 198,1 (2024)	1-Aug-2024

[2006Wa18](#): <sup>28</sup>Si(<sup>13</sup>O,X) E=22.5-46.8 MeV; measured total  $\sigma_{\text{reaction}}$  and  $\sigma_{1p}$ , Glauber model analysis. Deduced proton, neutron and matter radii of 2.81, 2.47 and 2.69 fm, respectively. Deduced spectroscopic factors. See other estimates of the <sup>13</sup>O nuclear density in ([2005Ji04](#), [2017Ah08](#)).

<sup>13</sup> O Levels
E(level)
0

$^{208}\text{Pb}(^{13}\text{O}, ^{13}\text{O})$  [2022Wa16](#)

Type	Author	History	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell		NDS 198,1 (2024)	1-Aug-2024

[2022Wa16](#): XUNDL dataset compiled at TUNL (2022).

The authors measured elastic scattering of the  $^{13}\text{O}$  and  $^{13}\text{B}$  mirror nuclei on  $^{208}\text{Pb}$  and analyzed the nuclear densities obtained from optical model analyses.

A beam of 413 MeV  $^{13}\text{O}$  ions from the HIRFL in Lanzhou impinged on a 12.24 mg/cm<sup>2</sup> thick  $^{208}\text{Pb}$  target. Scattered  $^{13}\text{O}$  ions were momentum analyzed using an array of four position sensitive  $\Delta E$ -E Si-detector telescopes that covered  $\theta \approx 3^\circ$  to  $27^\circ$ .

Differential cross sections were analyzed for  $\theta_{\text{lab}} = 4^\circ$  to  $15^\circ$ . Only the ground state is bound in  $^{13}\text{O}$ , and participation of any  $^{208}\text{Pb}$  excited states was unresolved.

The data were analysed using two optical model approaches: first, using the double-folding Sao Paulo potential-2 ([2021Ch70](#)), and second using the single-folding Xu and Pang potential model ([2013Xu06](#)). The data are reasonably fit using standard global parameterization inputs. The discussion gives details on an approach for obtaining the proton, neutron and matter rms radii. A comparison of the results may suggest a thin proton skin for  $^{13}\text{O}$ .

 $^{13}\text{O}$  Levels

E(level)	Comments
0	$\langle r_p^2 \rangle^{1/2} = 3.095$ fm, $\langle r_n^2 \rangle^{1/2} = 2.670$ fm, $\langle r_m^2 \rangle^{1/2} = 2.939$ rm.