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

	History		
Type	Author	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}Be, C, ^{27}Al(^{13}O,^{13}O) E≈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}O)=30.3 MeV/nucleon ions, produced via ^{1}H(^{14}N,^{13}O) reaction at the Texas A&M MARS facility, impinged on a 45.6 mg/cm^2 ^{9}Be target. Breakup particles were detected in a 10 cm× 10 cm segmented ΔE-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}N* and ^{13}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 p+^{12}N and 2p+^{11}C events were analyzed to deduce ^{13}O excited states.

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

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

A beam of 69.5 MeV/nucleon ^{13}O ions, from the NSCL/A1900 fragment separator, was purified in the Radio Frequency Fragment Separator before impinging on a 1 mm thick ^{9}Be target. The reaction products were detected using the HiRA High-Resolution position sensitive ΔE-E telescope array, which covered the polar angles θ_{lab}=2.1° to 12.1°. Peaks corresponding to ^{13}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}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}O ions from the NSCL/A1900 fragment separator was purified in the Radio Frequency Fragment Separator before impinging on a 1 mm thick ^{9}Be target. The reaction products were detected using the HiRA High-Resolution position sensitive ΔE-E telescope array, which covered the polar angles θ_{lab}=2.1° to 12.4°. The invariant-mass spectra were obtained for states decaying to p+^{12}N$_{g.s.}$ and 2p+^{11}C (resulting from p+^{12}N(1.19 MeV:2$^-$) and p+^{12}N(961 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 p+^{12}N$_{g.s.}$ spectrum, three states were observed in the p+^{12}N(961 keV:2$^+$) spectrum, two states were observed in the p+^{12}N(1.19 MeV:2$^-$) spectrum, and evidence for a third, difficult to interpret, broad state was also observed in the p+^{12}N(1.19 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}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}O. The angular distributions showed a differentiable dependence for J and π values, and they were compaired with the measured ^{13}O→^{12}N+p angular distributions to obtain J^π 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 $E_{c.m.}$ 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 ΔE values; in the present analysis ΔE values are obtained beginning with the uncertainties on $E_{c.m.}$ values. Also, the discussion indicates J^π=7/2$^+$ for peak 3, the Table I contains a typographycal error.

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

^{13}O Levels

E(level)	J^{π} ‡	Γ †	$E_{c.m.}(p+^{12}N)$ (keV) †	Comments
2428# *18*	$1/2^+$	358 keV *19*	916 *14*	
3006# *13*	$3/2^+$	55 keV *19*	1494 *8*	E(level): See also 2956 keV *15* (2013So11).
3051@ *16*	$5/2^+$	54 keV *19*	578 *11*	E(level): See also 3025 keV *16* (2013So11) and 3038 keV *9* (2019We11).
3692# *13*	$7/2^+$	53 keV *21*	2180 *8*	E(level): See also 3669 keV *13* (2013So11) and 3701 keV *10* (2019We11).
3721& *16*	$(3/2^+,5/2^+,5/2^-)$	10 keV *+19−10*	1019 *11*	
4287# *13*	$(3/2^+,5/2^+)$	170 keV *25*	2775 *9*	
4866@ *20*	$(1/2^+,1/2^-,3/2^-)$	103 keV *37*	2393 *16*	
4892# *25*	$7/2^+$	323 keV *27*	3380 *23*	
5483& *17*	$7/2^-$	204 keV *41*	2781 *11*	
5951@ *18*	$(7/2^+,7/2^-)$	875 keV *68*	3478 *14*	
$\approx 6.2\times10^3$?&		1.2 MeV	≈3500	Γ: From (1984Se15).

† From (2021Ch45). An 8 keV systematic uncertainty is combined in quadrature to the $\Delta E_{c.m.}$ decay energy values of Table 1 (labled ΔE_p in that table).

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

$E=S(p)+E_{cm}(p+^{12}N_{g.s.})=1512$ keV *10* + $E_{c.m.}(p+^{12}N)$.

@ $E=S(p)+E_{cm}(p+^{12}N(961\ keV{:}2^+))=1512$ keV *10* + $E_{c.m.}(p+^{12}N)$ + 961 keV *5*.

& $E=S(p)+E_{cm}(p+^{12}N(1.19\ MeV{:}2^-))=1512$ keV *10* + $E_{c.m.}(p+^{12}N)$ + 1190 keV *7*.