^{13}O $\varepsilon+\beta^+$ decay 2005Kn02

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

Parent: ^{13}O: E=0; J$^\pi$=3/2$^-$; $T_{1/2}$=8.58 ms *5*; Q(ε)=17770 *10*; %ε+%β^+ decay=100

All daughter levels deexcite mainly by proton decay, except the ground state. The 3501 keV level has a small %Iγ=0.0011 branch compared to it's main %p≈100 decay. Consequently, there is no observable γ emission following ^{13}O β^+ decay.

1965Mc09: ^{13}O(β+p), [from ^{14}N(p,2n)], measured delayed p spectrum; analyzed proton groups at E_p=6.06 and 6.65 MeV; deduced E_x=8.77 *4* and 9.49 *4* MeV.

1970Es03: ^{13}O(β+p), [from ^{14}N(p,2n)], measured delayed p spectrum, analyzed E_p groups; deduced I_p, E_p, I_p, I_β and Log ft. (*Expected but not observed).

$E_{c.m.}$=1.565 MeV from ^{13}N*(3.509) with I_{rel}=100;

$E_{c.m.}$=1.01(*) MeV and 5.48 MeV *5* from ^{13}N*(7.387) with I_{rel}=0.33 *10*;

$E_{c.m.}$=2.56 MeV *5* and 6.98 MeV from ^{13}N*(8.92) with I_{rel}=1.5 *3* and 3.5 *3*, resp.;

$E_{c.m.}$=3.12 MeV *5* and 7.58 MeV from ^{13}N*(9.52) with I_{rel}=0.43 *15* and 0.8 *1*, resp.;

and $E_{c.m.}$=3.97 *5* and 8.41(*) MeV from ^{13}N*(10.35) with I_{rel}=0.13 *7*.

1990As01: ^{13}O(β+p) [from ^{14}N(p,2n)], measured β delayed I_p, E_p, I_p, I_β.

$E_{c.m.}$=1.568 MeV from ^{13}N*(3.511) with I_{p_rel}=100;

$E_{c.m.}$=0.994 MeV and 5.433 MeV ^{13}N*(7.387) with I_{p_rel}=1.7 *8* and 0.17 *7*, resp.;

$E_{c.m.}$=2.536 MeV and 6.975 MeV from ^{13}N*(8.918) with I_{p_rel}=1.44 *25* and 4.83 *51*, resp.;

$E_{c.m.}$=3.094 MeV and 7.533 MeV from ^{13}N*(9.476) with I_{p_rel}=0.61 *15* and 0.98 *14*, resp.;

$E_{c.m.}$=3.97 MeV *5* and 8.42 MeV from ^{13}N*(10.36) with I_{p_rel}=0.12 *8* and 0.05 *3*. resp. Analyzed total Iβ along with I_p from ^{13}N*(3.51) to obtain an absolute I_p(3.51)=Iβ(3.51)=9.8% *20*; this implies Iβ(g.s.)=89.2% *22*.

2005Kn02: ^{13}O ions were produced at the IGISOL facility via the ^{14}N(p,2n)reaction by impinging an E_p=45 MeV beam on a 1 mg/cm^2 target. The ^{13}O ions recoiled out of the target and were collected in a helium carrier gas which delivered them to the mass separator. The ions were then implanted into a 30 μg/cm^2 carbon foil. The implantation target was surrounded by three position sensitive ΔE-E Si detector telescopes, which triggered the DAQ; the ISOLDE Si ball was not included in the trigger due to a high sensitivity to β particles.

The delayed-proton energy spectrum was analyzed using Breit-Wigner shapes, the analysis deduced relative Ip and I_β values, which were normalized to I_p(3.51)=Iβ(3.51)=9.8% *20* from (1990As01).

The (2005Kn02) data set has the highest statistical relevance and covers a broader energy range than other measurements (1965Mc09, 1970Es03, 1990As01). Furthermore, the discussion on the line-shape analysis suggests the results of (2005Kn02) should be adopted. Noteworthy differences between other measurements are for decay from ^{13}N*(8.918); (2005Kn02) observe a stronger p_1 branch than earlier measurements. Second, no evidence is seen for decay of ^{13}N*(10.360); the difference is attributed to the more sophisticated line-shape analysis in (2005Kn02).

A subtle note to understanding the (2005Kn02) manuscript: in Table 2 for %Iβ for ^{13}N*(15.065), the value includes unobserved contributions from γ decay, proton decay and α decay.

2023Bi03,2024Bi01: A 15.1 MeV ^{13}O beam from the Texas A&M MARS facility was implanted into the TexAT TPC. The β-delayed charged-particle emission events producing 3αp events were analyzed. A total of 149 events (%β3αp≈0.078 *6*) mainly included decay via ^{13}N*→p+[^{12}C*(7.65 MeV)→α+^{8}Be$_{g.s.}$] and ^{13}N*→α+[^{9}B*→p+^{8}Be$_{g.s.}$]; three low-lying ^{9}B states appear to be involved.

From the 149 3αp events, 102 events were fully reconstructed. The remaining 47 events were incomplete, for example, because they involved high energy α-particles that could not be fully characterized by the active volume of the TexAT TPC, for example, feeding to high-lying states that decay to ^{9}B$_{g.s.}$+α. In general, the decay energy was deduced using momentum conservation and the excitation energies of related ^{8}Be, ^{9}B, and ^{12}C were obtained from an invariant mass analysis.

The authors found evidence for population of ^{13}N* states at 11.3, 11.8, 12.4, 13.1, and 13.7 MeV; only the 11.8 MeV state was previously reported. These states show significant clustering. The evaluator notes that for 1.9×10^5 decays, 17 events should have proceeded through the ^{13}N*(15.1 MeV) IAS state and resulted in 3αp events.

In Table I, (2024Bi01) clarifies the deduced decay modes. Some interpretation of the (2005Kn02) ^{13}O β-p_0 results are included in the present analysis. A state at 11.3 MeV mainly decays to ^{9}B$_{g.s.}$; the authors suggest this new state may have been overlooked by

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(2005Kn02) where a narrow peak is visible at E_p=8.64 MeV that was attributed to the peak corresponding to p_2 decay from $^{13}N^*$(15.1 MeV) at E_p=8.68 MeV; this new state also has a component to ^{12}C(7.65 MeV). Authors suggest the E_x=11.8 MeV group corresponds to the known J^π=3/2$^-$ E_x=11.74 state; it is mainly seen in the p_2 channel and the present analysis associates the (2005Kn02) $E_p\approx$9.78 MeV counts with this state. A new state at E_x=12.4 MeV is found to decay mainly to ^9B via α_0 and α_1 with a small component to ^{12}C(7.65 MeV). Authors suggest a strong $^9B(1/2^+)\otimes\alpha$ configuration. A state at E_x=13.1 MeV appears to decay mainly via α_3 emission; in such a case a $^9B(5/2^+)\otimes\alpha$ configuration would be likely; however involvement of ^9B(2.78 MeV: 1/2$^-$) cannot be ruled out which would suggest J=1/2$^-$. Authors suggest possible evidence of a peak at E_p=6.20 MeV in (2005Kn02) that could correspond to p_0 decay to this level. This state is associated with a state previously reported at 13.26 MeV. Lastly, a state at E_x=13.7 is reported to decay via p_2, and α0,1,3; J^π=3/2$^-$ or 5/2$^-$ are permitted, but L=3 would be required for p_2 decay so 3/2$^-$ is preferred.

Theory:
1993Ch06: Shell model analysis of β-decay.
2003Sm02: Analysis of B(GT) rates.
2012Sa50: Global analysis of isospin-breaking corrections in superallowed decays.

Studies relevant to ^{13}O properties include: (1996Ma37, 1996Ma38, 1999Ma46).

^{13}N Levels

E(level)†	J$^{\pi\dagger}$	$\Gamma^{\dagger\ddagger}$	Comments
0	1/2$^-$	9.9584 min *36*	
3500.4 *8*	3/2$^-$	55.0 keV *6*	Γ: See 63 keV *4* in (2005Kn02). %Iβ-p0=9.8 *20*; this implies %p_0=100.
7377 *6*	5/2$^-$	66 keV *9*	Γ: See 104 keV *20* in (2005Kn02). %Iβ-p0=0.009 *4* and %Iβ-p1=0.235 *29*; this implies %p_0=3.6 and %p_1=96.4.
8918 *11*	1/2$^-$	278 keV *16*	Γ: From (2005Kn02). %Iβ-p0=0.519 *40* and %Iβ-p1=0.441 *29*; this implies %p_0=54.1 and %p_1=45.9.
9476 *8*	3/2$^-$	30 keV	Γ: See 143 keV *18* in (2005Kn02). %Iβ-p0=0.137 *12* and %Iβ-p1=0.104 *11*; this implies %p_0=56.9 and %p_1=43.1.
11.3×10$^{3\#}$ *1*	[3/2$^-$]$^\#$	<200 keV	Γ: Deduced in (2024Bi01); if this state is observed in (2005Kn02) (2024Bi01) suggest Γ<40 keV. Suggested to decay via α_0+$^9B_{g.s.}$, p+$^{12}C_{g.s.}$ and p+^{12}C(7654.7 MeV).
11700 *30*	5/2$^-$	115 keV *30*	Γ: See 315 keV *112* (2005Kn02). J$^\pi$: In (2024Bi01), decay to p+^{12}C(7654.7 MeV) is reported for a state in this energy region; they suggest the J^π=3/2$^-$ state near E_x=11.8 MeV was involved. Iβ-p0=0.015 *4* and %$p_1\leq$0.002; this implies %p_0=100. A small branch via p_2 decay is reported in (2024Bi01).
12.4×10$^{3\#}$ *1*	[3/2$^-$]$^\#$		Suggested to decay via α_0+$^9B_{g.s.}$, α_1+^{9}B(1.8 MeV) and p+^{12}C(7.6547 MeV).
12937 *24*		>400 keV	E(level): See 13.26 MeV *10* deduced from E_p in (2005Kn02). Γ: See 521 keV *210* (2005Kn02). J$^\pi$: See (−) in (2005Kn02). %Iβ-p0=0.011 *3*; this implies %p_0=100.
13.1×10$^{3\#}$ *1*	[1/2$^-$,5/2$^-$]$^\#$		J$^\pi$: 1/2$^-$ for α_4 decay through ^{9}B(2.78:1/2$^-$) is preferred. Suggested to decay via α_1+^{9}B(1.8 MeV), α_0+^{9}B(2.75 MeV) or α_0+^{9}B(2.78 MeV) and p+$^{12}C_{g.s.}$.
13.7×10$^{3\#}$ *1*	[3/2$^-$]$^\#$		Suggested to decay via α_0+$^9B_{g.s.}$, α_1+^{9}B(1.8 MeV), α_0+^{9}B(2.75 MeV) and p+^{12}C(7654.7 MeV).
15064.56 *40*	3/2$^-$	0.932 keV *28*	%Iβ-p0=0.0048 *7*, %Iβ-p1=0.0029 *5* and %Iβ-p2=0.0011 *2*; when γ and α

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^{13}N Levels (continued)

E(level)†	Jπ†	Γ†‡	Comments
			decay are considered, this implies %γ=4.9%, %α=53.4, %p_0=22.8, %p_1=14.0 and %p_2=4.9.
15.30×10^3 *20*	(3/2$^+$)	0.35 MeV *14*	E(level): deduced from E_p. J^π: If populated in this (2005Kn02), the transition is allowed and π=−; however the evaluator expresses reservations upon consideration of the background near where perhaps three or four counts attributed to this broad state are identified. The evaluator discounts the merit of any J^π constraints based on the suggestion this is an allowed transition. %Iβ-p0=0.004 *3* and %p_1≤0.0004; this implies %p_0=100.

† From Adopted Levels, except where noted.
‡ From fit to β-p spectrum from ^{13}O β^+ decay (2005Kn02).
# Four new states are suggested at ^{13}N*(11.3, 12.4, 13.1 and 13.7 MeV) (2023Bi03, 2024Bi01). The authors indicate an independent branching-ratio measurement from the number of implants is not reliable due to sizeable noise in some detectors; using their reported count rates the evaluator could suggest %Iβ on the order of 0.01-0.02% for each state. No intensity is assigned in the present evaluation. Assuming these are allowed decays, J^π arguments are given based on the various decay modes.

ε,β^+ radiations

εK, εL, εM, εN: Additional information 1.
av Eβ: Additional information 2.

E(decay)	E(level)	Iβ^+ †‡	Iε‡	Log *ft*	I($\varepsilon+\beta^+$)‡	Comments
(2.47×10^3 *20*)	15300	0.004 *3*	7×10^{-6} *7*	3.56 *45*	0.004 *3*	av Eβ=6.0×10^2 *9*; εK=0.0016 *9*; εL=1.2×10^{-4} *7* The deduced Iβ differs slightly from (2005Kn02) Iβ=0.004 *2*.
(2705 *10*)	15064.56	0.019 *4*	2.07×10^{-5} *44*	3.16 *9*	0.019 *4*	av Eβ=710.9 *46*; εK=0.001011 *35*; εL=7.79×10^{-5} *27*
(4833 *26*)	12937	0.011 *3*	1.06×10^{-6} *29*	4.96 *12*	0.011 *3*	av Eβ=1718 *13*; εK=8.95×10^{-5} *33*; εL=6.90×10^{-6} *26* The $I_{p\_rel}(p_0)$=0.11 *9* and $I_{p\_rel}(p_1)$≤0.09 given in (2005Kn02) are incompatible with %Iβ=0.011 *3* given in their table II; after considering Fig. 2, the evaluator takes $I_{p\_rel}(p_0)$=0.11 *3* rather than $I_{p\_rel}(p_0)$=0.11 *9*, and uncertainty from p_1 is neglected.
(6070 *32*)	11700	0.015 *4*	6.4×10^{-7} *17*	5.38 *12*	0.015 *4*	av Eβ=2319 *16*; εK=3.93×10^{-5} *14*; εL=3.03×10^{-6} *11* The deduced Iβ differs slightly from (2005Kn02) Iβ=0.015 *8*.
(8294 *13*)	9476	0.24 *2*	3.53×10^{-6} *30*	4.919 *36*	0.24 *2*	av Eβ=3407 *6*; εK=1.366×10^{-5} *29*; εL=1.053×10^{-6} *23*
(8852 *15*)	8918	0.96 *5*	1.14×10^{-5} *6*	4.469 *23*	0.96 *5*	av Eβ=3681 *7*; εK=1.105×10^{-5} *24*; εL=8.52×10^{-7} *19* The deduced Iβ differs slightly from (2005Kn02) Iβ=0.96 *4*.
(10393 *12*)	7377	0.24 *3*	1.71×10^{-6} *22*	5.44 *5*	0.24 *3*	av Eβ=4440 *6*; εK=6.62×10^{-6} *13*; εL=5.11×10^{-7} *11* The deduced Iβ differs slightly from (2005Kn02) Iβ=0.24 *2*.

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ϵ,β^{+} radiations (continued)

E(decay)	E(level)	Iβ^{+} [†‡]	Iε [‡]	Log *ft*	I($\varepsilon+\beta^{+}$) [‡]	Comments
(14270 *10*)	3500.4	9.8 *20*	2.7×10^{-5} *5*	4.55 *9*	9.8 *20*	av Eβ=6353.1 *49*; εK=2.524×10^{-6} *47*; εL=1.946×10^{-7} *38*
(17770 *10*)	0	88.7 *20*	1.287×10^{-4} *37*	4.088 *10*	88.7 *20*	av Eβ=8083.0 *49*; εK=1.347×10^{-6} *24*; εL=1.038×10^{-7} *20* Iβ^{+}: From 100%-Σ(decay to excited states).

† Normalized to absolute I_p(3.51)=Iβ(3.51)=9.8% *20* from (1990As01).

‡ Absolute intensity per 100 decays.