^{33}Na β^- decay (8.1 ms) 2001Nu02,1984Gu19

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	Jun Chen and Balraj Singh	NDS 199,1 (2025)	30-Sep-2024

Parent: ^{33}Na: E=0.0; $J^\pi=(3/2^+)$; $T_{1/2}$=8.1 ms *3*; Q(β^-)=18.82×10^3 *45*; %β^- decay=100

^{33}Na-Q(β^-): from 2021Wa16.

^{33}Na-J^π,$T_{1/2}$: From the Adopted Levels of ^{33}Na.

^{33}Na-%β^- decay: %β^-n=47 *6*, %β^-2n=13 *3* (2001Nu02,2002Ra16).

2001Nu02, 2002Ra16 (also 2002Nu02,2004Co29): ^{33}Na source was produced in fragmentation reactions by 1.4 GeV protons from the PS/Booster at CERN impinging on a uranium-carbide target. Fragments were ionized, accelerated and mass separated by the ISOLDE facility, and then transported to the experimental setup. γ rays were detected with two large-volume Ge detectors; β particles were detected with a thin plastic scintillator detector; β-delayed neutrons were detected with eight low-threshold neutron detectors. Measured Eγ, Iγ, Eβ, Iβ, $\gamma\gamma$-coin, $\beta\gamma$-coin, $\beta\gamma\gamma$-coin, βnγ-coin, nγ-coin, β(t), γ(t), βn(t). Deduced levels, J, π, parent $T_{1/2}$, β-decay branching ratios, log *ft*, β-delayed neutron emission probabilities. Comparisons with shell-model calculations.

1984Gu19: Na isotopes were produced in the fragmentation of a 30 g/cm^2 iridium target by 10 GeV protons from CERN synchrotron. γ rays were detected with two Ge(Li) detectors and β particles were detected with a thin 2π plastic scintillator. Measured Eγ, Iγ, Eβ, Iβ, $\gamma\gamma$-coin, $\beta\gamma\gamma$-coin. Four unplaced γ rays reported.

1984La03: similar setup as that in 1984Gu19, plus a 4π liquid-scintillator neutron detector. Measured β-delayed neutrons. Deduced parent $T_{1/2}$, β-delayed neutron emission probabilities.

1998NoZW: ^{33}Na source was produced by fragmentation of a 95 MeV/nucleon ^{40}Ar beam from the RIKEN Ring Cyclotron and separated by the RIPS separator. β particles were detected with silicon detectors. Measured β(t). Deduced parent $T_{1/2}$.

^{33}Na also decays to ^{31}Mg by β^-2n (13% *3*) and to ^{32}Mg by β^-n (47% *6*) (2001Nu02).

All data are from 2001Nu02, unless otherwise stated.

The data on neutron energies are not available in detail to deduce all the level energies in ^{33}Mg populated by ^{33}Na β decay. Several γ rays are unplaced and there still could be unobserved transitions in the large energy gap allowed by the Q(β^-) value, indicating that the level scheme is incomplete.

^{33}Mg Levels

E(level)[†]	J^π[‡]	$T_{1/2}$	Comments
0.0	3/2$^-$	90.3 ms *10*	J^π: 2001Nu02 proposed $(3/2)^+$. $T_{1/2}$: from the Adopted Levels.
158.8? *5*			E(level): 2001Nu02 proposed a level at 158 keV with $J^\pi=(7/2^-)$ from tentative placement of 546γ from 705 level to a 158 level, but no γ decay from this level was reported. The 546.2γ is now placed from a level of this energy, thus the existence of 158 level is suspect and it has been omitted in Adopted Levels.
484.11 *8*	$(5/2^-)$		J^π: 2001Nu02 proposed $(3/2)^-$.
546.21 *10*	$(3/2^-)$		
705.01 *8*	$(3/2,5/2^+)$		J^π: 2001Nu02 proposed $(5/2^+)$.
1242.42 *11*	$(1/2^-,3/2^-)$		J^π: 2001Nu02 proposed $(1/2^+)$.
3780[#]			E(level): from neutron group at 800 *60* keV.
4000[#]			E(level): from neutron group at 1020 *80* keV.
2280+x			E(level): x<16540 *450* from Q(β^-)(^{33}Na)-S(n)(^{33}Mg), where Q(β^-)=18820 *450* and S(n)=2280 *4* from 2021Wa16. This represents a range of unobserved levels that subsequently decay to ^{32}Mg via one-neutron emission, including 3780 and 4000 levels above.
8058+y			E(level): y<10760 *450* from Q(β^-)(^{33}Na)-S(2n)(^{33}Mg), where S(2n)=8058 *4* from 2021Wa16. This represents a range of unobserved levels that subsequently decay to ^{31}Mg via two-neutron emission.

[†] From a least-squares fit to γ-ray energies, unless otherwise noted.

[‡] From the Adopted Levels.

[#] Decays to ^{32}Mg by neutron emission.

^{33}Na β^- decay (8.1 ms) 2001Nu02,1984Gu19 (continued)

β^- radiations

E(decay)	E(level)	Iβ^-[‡]	Log *ft*	Comments
(5×10^3[@] *5*)	8058+y	13 *3*		Iβ^-: from adopted %β^-2n=13 *3* for the decay of ^{33}Na g.s. (2001Nu02,2002Ra16).
(8×10^3[@] *8*)	2280+x	47 *6*		Iβ^-: from adopted %β^-n=47 *6* for the decay of ^{33}Na g.s. (2001Nu02,2002Ra16).
(1.76×10^4 *5*)	1242.42	2.9[†] *12*	5.8[†]	av Eβ=8.45×10^3 *22*
(1.81×10^4 *5*)	705.01	7.0[†] *26*	5.5[†]	av Eβ=8.71×10^3 *22*
(1.83×10^4 *5*)	546.21	8.8[†] *33*	5.4[†]	av Eβ=8.79×10^3 *22*
(1.83×10^4[#] *5*)	484.11	<1.5[†]	>6.2[†]	av Eβ=8.83×10^3 *22*
(1.88×10^4[#] *5*)	0.0	20 *10*	5.0	av Eβ=9.06×10^3 *22*
				Iβ^-,Log *ft*: branching ratio is from 100−%β^-n-%β^-2n-ΣI(γ to g.s.) and considered as upper limit and log *ft* as lower limit, due to possible unobserved γ transitions and levels. Parent J^π=(3/2$^+$) of ^{33}Na indicates a forbidden decay to this 3/2$^-$ g.s. in ^{33}Mg, which would expect a much higher log *ft* value than 5.1 quoted here. This supports that there are unobserved feedings and the deduced g.s. feeding of 20 *10* might be attributed mostly to them. Due to the forbidden nature and possible unobserved feedings, the evaluators consider this decay branch with a large feeding questionable.

[†] β branching ratios are from γ-ray intensity imbalance and considered by the evaluators as upper limits due to possible unobserved transitions and associated log *ft* values as lower limits.
[‡] Absolute intensity per 100 decays.
[#] Existence of this branch is questionable.
[@] Estimated for a range of levels.

γ(^{33}Mg)

Iγ normalization: Deduced by 2001Nu02 from absolute γ-intensity measurements using the activity of well-known ^{26}Na as standard, simultaneous detection of β and γ rays, and efficiencies of β- and γ-detectors.

E$_\gamma$[†]	I$_\gamma$[†#]	E$_i$(level)	J$_i^\pi$	E$_f$	J$_f^\pi$	Comments
221.0 *1*	8.7 *10*	705.01	(3/2,5/2$^+$)	484.11	(5/2$^-$)	%Iγ=1.9 *7* E$_\gamma$,I$_\gamma$: doublet. The second component is assigned to a transition in ^{31}Mg populated by ^{33}Na β^-2n decay.
[x]297.9[‡] *1*	4.0 *4*					%Iγ=0.88 *33*
484.1 *1*	18.7 *19*	484.11	(5/2$^-$)	0.0	3/2$^-$	%Iγ=4.1 *16* Other: Eγ=484.9 *10*, Iγ=14 *11* (1984Gu19).
546.2 *1*	40 *4*	546.21	(3/2$^-$)	0.0	3/2$^-$	%Iγ=8.8 *33* 2001Nu02 considered different scenarios for the placement of 546γ and proposed placement from 705 level to a 159 level as the probable one, which is also adopted by 2021Ba28 in ^{9}Be(^{34}Mg,^{33}Mgγ) without further supporting evidence. However, this γ could also define a level of this energy, a possibility which 2001Nu02 considered less likely based on rather weak arguments. 2006El03 observed a 561 *17* γ in ^{1}H(^{34}Mg,^{33}Mgγ), which they suggested was most likely the same as 546.2γ in decay work, but no 704.9γ was seen in that study, which may imply that 546.2γ and 704.9γ de-excite different levels. Moreover, the non-observation of this 546γ and observations of 220γ and 703γ from 703 level

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^{33}Na β^- decay (8.1 ms) 2001Nu02,1984Gu19 (continued)

$\gamma(^{33}Mg)$ (continued)

E_γ [†]	I_γ [†#]	E_i(level)	J_i^π	E_f	J_f^π	Comments
						by 2017Ri06 in ^{9}Be(^{46}Ar,^{33}Mgγ), and the observations of all those three transitions by 2021Ba28 with 546γ much stronger than 703γ further support that 546γ and 703γ deexcite different levels. Therefore a level at 546.2 keV has been defined in Adopted Levels by the evaluators and is also adopted here and the placement from 705 level is considered as questionable. Other: Eγ=546.5 *10*, Iγ=40 *13* (1984Gu19).
546.2[@]		705.01	(3/2,5/2$^+$)	158.8?		E$_\gamma$: tentative placement (2001Nu02), but the evaluators suggest that the main placement is from 546 level. See comments at 546.2γ from 546 level.
704.9 *1*	23.2 *21*	705.01	(3/2,5/2$^+$)	0.0	3/2$^-$	%Iγ=5.1 *19* Other: Eγ=704.3 *10*, Iγ=23 *11* (1984Gu19).
758.2 *1*	6.1 *7*	1242.42	(1/2$^-$,3/2$^-$)	484.11	(5/2$^-$)	%Iγ=1.3 *5*
[x]845.7[‡] *2*	2.5 *4*					%Iγ=0.55 *22*
[x]1011.3[‡] *2*	1.6 *4*					%Iγ=0.35 *16*
1242.8 *2*	7.1 *19*	1242.42	(1/2$^-$,3/2$^-$)	0.0	3/2$^-$	%Iγ=1.6 *7* Other: Eγ=1242.6 *18*, Iγ=26 *10* (1984Gu19).
[x]1857.7[‡] *4*	4.1 *6*					%Iγ=0.9 *4*
[x]1976.9 *5*	6.7 *19*					%Iγ=1.5 *7*
[x]2236.9 *5*	7.0 *9*					%Iγ=1.5 *6*

[†] From 2001Nu02. Intensities are relative to 100 for 885.3γ in ^{32}Mg populated in β^-n decay of ^{33}Na.

[‡] The evaluators note that 1857.7-1011.3=846.4, which matches the gamma energy of 845.7 *2* within the uncertainty range and may suggest a level at 1011.3+845.7=1856 and another level either at 1011 or 846. Also, 845.7−297.9=547.8 which is close in energy to 546.2γ.

[#] For absolute intensity per 100 decays, multiply by 0.22 *8*.

[@] Placement of transition in the level scheme is uncertain.

[x] γ ray not placed in level scheme.

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