^{60}Ga $\varepsilon+\beta^+$ decay (69.4 ms) 2001Ma96,2021Or01

Parent: ^{60}Ga: E=0; $J^\pi=2^+$; $T_{1/2}$=69.4 ms *2*; Q(ε)=14160 *15*; $\%\varepsilon+\%\beta^+$ decay=100.0

^{60}Ga-J^π: from the Adopted Levels of ^{60}Ga.

^{60}Ga-$T_{1/2}$: weighted average of 70 ms *15* (2001Ma96), 70 ms *13* (2002Lo13), 76 ms *3* (2017Ku12), 70.8 ms *20* (2017GoZT,2020Gi02), and 69.4 ms *2* (2021Or01).

^{60}Ga-Q($\varepsilon+\beta^+$): deduced by evaluators using ^{60}Zn mass excess (2021Wa16) and ^{60}Ga mass excess of −40015 *15*; weighted average of −40016 *15* (2021Or01), −40005 *30* (2021Pa44), and −40034 *46* (2023Wa10).

^{60}Ga-$\%\varepsilon+\%\beta^+$ decay: $\%(\varepsilon+\beta^+)$p=1.6 *7*, $\%(\varepsilon+\beta^+)\alpha$<0.023 *20* (2001Ma96).

2001Ma96: ^{60}Ga was produced via the ^{28}Si(^{36}Ar,p3n) fusion evaporation reaction using a 4.71 MeV/u ^{36}Ar primary beam at the GSI On-Line Mass Separator. A 55-keV $^{60}Ga^{1+}$ beam was extracted and implanted into a tape for $\beta\gamma$ measurements and carbon foils for βp and $\beta\alpha$ measurements in a beam-on/beam-off mode. Positrons were detected using a plastic scintillator and γ rays were detected using Ge detectors. Particles were detected using Si ΔE-E telescopes at another beam line. Measured Eγ, Iγ, $\gamma\gamma$-coin, $\beta\gamma$-coin, E_p(>0.6 MeV), I_p, E_α, and I_α. Deduced levels, J, π, ^{60}Ga $T_{1/2}$, and ^{60}Ga mass using the known ^{60}Zn mass, the Eγ from the T=1 IAS in ^{60}Zn, and the Coulomb displacement energy systematics (1997An07). Identified a total of 802 proton events and deduced $\%(\varepsilon+\beta^+)$p=1.6 *7*. Identified 9 α candidate events and deduced $\%(\varepsilon+\beta^+)\alpha$<0.023 *20*.

2021Or01: ^{60}Ga was produced via the projectile fragmentation of a 345-MeV/u ^{78}Kr primary beam impinging on a 5-mm thick ^{9}Be target, identified in the RIKEN BigRIPS separator by Bρ-ΔE-ToF, transported to the exit of the ZeroDegree spectrometer, and implanted into the Wide-range Active Silicon Strip Stopper Array for Beta and ion detection (WAS3ABi) consisting of three 1-mm-thick DSSDs. γ rays were detected using the EUroball-RIKEN Cluster Array of 12 cluster-type Ge detectors. Measured E_p(>1.5 MeV), Eγ, Iγ, pγ-coin, $\beta\gamma$-coin, $\gamma\gamma$-coin, and implant-decay time correlations. Deduced levels, ^{60}Ga $T_{1/2}$, and ^{60}Ga mass using the known ^{59}Zn mass, the E_p and Eγ from the T=2 IAS in ^{60}Ga populated by ^{60}Ge decay in the same experiment.

The decay scheme is considered incomplete due to a large gap of 9 MeV between the highest observed level at E=4852 and Q(ε)=14160 *15*. There may be missing transitions from unobserved levels in the gap.

^{60}Zn Levels

E(level)	J^π	Comments
0	0^+	
1003.53 *10*	2^+	
2558.54 *23*	(2^+)	
4851.97 *32*	2^+	Isobaric analog state (T=1) of ^{60}Ga g.s.

ε,β^+ radiations

E(decay)	E(level)	Iβ^+ ‡	Iε‡	Log *ft*†	I($\varepsilon+\beta^+$)†‡
(9308 *15*)	4851.97	44.0 *32*	0.058 *5*	3.66 *4*	44.1 *32*
(11602 *15*)	2558.54	9.2 *10*	0.0061 *7*	4.85 *5*	9.2 *10*
(13157 *15*)	1003.53	17 *5*	0.008 *2*	4.9 *+2−1*	17 *5*

† $\varepsilon+\beta^+$-feeding from γ+ce intensity balance at each level. Quoted I($\varepsilon+\beta^+$) values are considered upper limits due to the incomplete decay scheme, and the associated log *ft* values are considered lower limits.

‡ Absolute intensity per 100 decays.

$\gamma(^{60}Zn)$

Iγ normalization: absolute γ-ray intensities per 100 decays of ^{60}Ga were measured by 2021Or01 based on the total number of implanted ^{60}Ga (7.6×10^5) and $\beta\gamma$ detection efficiencies, correcting for DAQ dead time.

Eγ	Iγ†	E$_i$(level)	Comments
x669.3 *3*	0.58 *15*		$\%I\gamma$=0.36 *9*
x850.8 *1*	1.21 *16*		$\%I\gamma$=0.75 *10*

Continued on next page (footnotes at end of table)

^{60}Ga $\varepsilon+\beta^+$ decay (69.4 ms) 2001Ma96,2021Or01 (continued)

$\gamma(^{60}Zn)$ (continued)

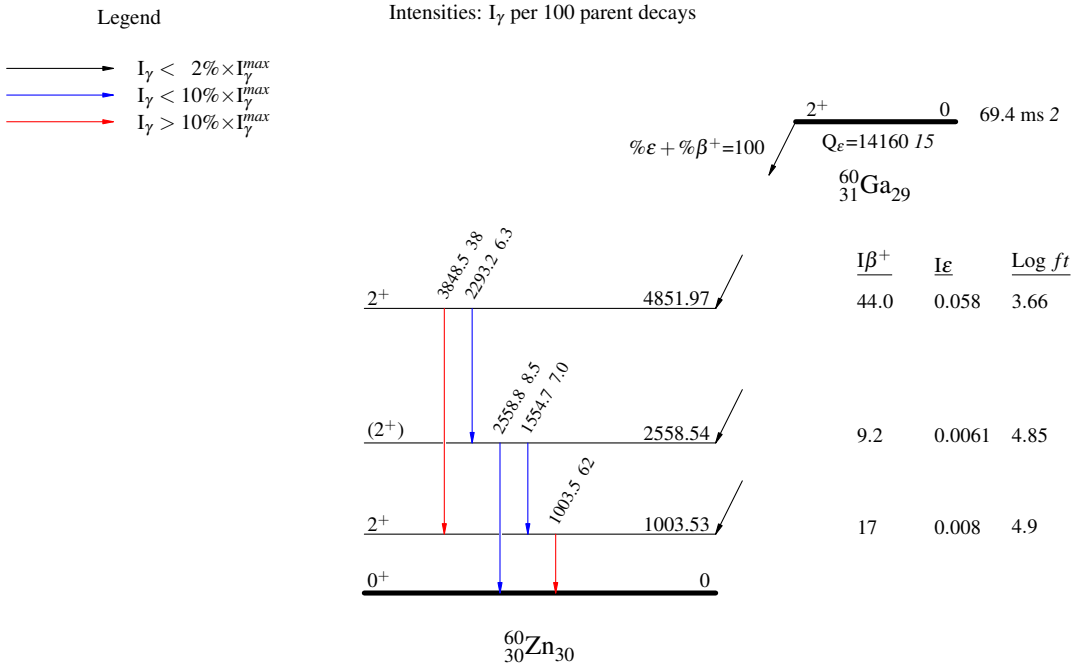
E_γ	I_γ †	E_i(level)	J_i^π	E_f	J_f^π	Comments
x913.9 *3*	0.48 *16*					%Iγ=0.30 *10*
1003.5 *1*	100 *5*	1003.53	2^+	0	0^+	%Iγ=62.0 *31* E_γ: from 2021Or01. Other: 1003.7 *2* (2001Ma96). I_γ: from 2021Or01. Other: 100 *17* (2001Ma96).
x1028.6 *2*	0.61 *13*					%Iγ=0.38 *8*
x1188.4 *1*	2.58 *16*					%Iγ=1.60 *10*
x1201.8 *2*	0.47 *11*					%Iγ=0.29 *7*
x1413.7 *2*	0.57 *11*					%Iγ=0.35 *7*
x1442.1 *1*	0.65 *13*					%Iγ=0.40 *8*
x1481.4 *1*	2.10 *16*					%Iγ=1.30 *10*
1554.7 *3*	11.3 *8*	2558.54	(2^+)	1003.53	2^+	%Iγ=7.0 *5* E_γ: from 2021Or01. Other: 1554.9 *6* (2001Ma96). I_γ: from 2021Or01. Other: 12 *5* (2001Ma96).
x1780.8 *6*	0.32 *16*					%Iγ=0.20 *10*
x2047.2 *4*	1.13 *32*					%Iγ=0.70 *20*
2293.2 *4*	10.2 *8*	4851.97	2^+	2558.54	(2^+)	%Iγ=6.3 *5* E_γ: from 2021Or01. Other: 2293.0 *10* (2001Ma96). I_γ: from 2021Or01. Other: 10 *5* (2001Ma96).
x2334.2 *3*	1.29 *32*					%Iγ=0.80 *20*
x2434.2 *2*	2.90 *32*					%Iγ=1.80 *20*
2558.8 *4*	13.7 *10*	2558.54	(2^+)	0	0^+	%Iγ=8.5 *6* E_γ: weighted average of 2559.0 *8* (2001Ma96) and 2558.7 *4* (2021Or01). I_γ: from 2021Or01. Other: 13 *5* (2001Ma96).
x2624.3 *5*	0.48 *16*					%Iγ=0.30 *10*
x2826.0 *2*	2.10 *32*					%Iγ=1.30 *20*
x2884.0 *4*	1.29 *32*					%Iγ=0.80 *20*
x2996.8 *2*	3.2 *5*					%Iγ=1.98 *31*
x3337.4 *1*	11.5 *10*					%Iγ=7.1 *6*
x3394.8 *1*	11.3 *10*					%Iγ=7.0 *6*
3848.5 *4*	61 *5*	4851.97	2^+	1003.53	2^+	%Iγ=37.8 *31* E_γ: from 2021Or01. Other: 3848.3 *7* (2001Ma96). I_γ: from 2021Or01. Other: 57 *13* (2001Ma96).
x3889.1 *3*	4.5 *13*					%Iγ=2.8 *8*
x4000.9 *2*	4.5 *7*					%Iγ=2.8 *4*
x4805.0 *4*	0.65 *16*					%Iγ=0.40 *10*
x4850.2 *5*	0.32 *16*					%Iγ=0.20 *10*
x4891.9 *3*	0.65 *16*					%Iγ=0.40 *10*

† For absolute intensity per 100 decays, multiply by 0.62.
x γ ray not placed in level scheme.

^{60}Ga ε+β$^+$ decay (69.4 ms) 2001Ma96,2021Or01

Decay Scheme

Intensities: I_γ per 100 parent decays



	Iβ$^+$	Iε	Log *ft*
4851.97	44.0	0.058	3.66
2558.54	9.2	0.0061	4.85
1003.53	17	0.008	4.9