^{99}Zr β^- decay 1998Lh03,1979Se01

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	E. Browne, J. K. Tuli	NDS 145, 25 (2017)	1-Jul-2017

Parent: ^{99}Zr: E=0.0; J^π=(1/2$^+$); $T_{1/2}$=2.1 s *1*; Q(β^-)=4715 *16*; %β^- decay=100.0

^{99}Zr source produced by fission of natural uranium induced by 25-MeV protons. On-line mass separation. Measured γ-ray singles and $\gamma\gamma$ coin with a 10-germanium detector array (1998Lh03).

Measured: γ, $\gamma\gamma$, $\gamma\gamma$(t), $\gamma\gamma(\theta)$ (1979Se01); $\gamma\beta$(t) (1990OhZY); γ (1970Ei02).

^{99}Nb Levels

E(level)	J^π[†]	$T_{1/2}$[‡]	Comments
0.0	9/2$^+$	15.0 s *2*	$T_{1/2}$: from Adopted Levels.
365.27 *8*	1/2$^-$	2.5 min *2*	$T_{1/2}$: from Adopted Levels.
387.38 *7*	(7/2$^+$)	17 ps *4*	
469.139 *13*	(5/2)$^+$	0.173 ns *4*	$T_{1/2}$: from $\beta\gamma$(t) (1990OhZY).
544.23 *8*	3/2$^-$	56 ps *10*	
630.70 *22*	5/2$^-$		
765.05 *18*	3/2$^+$		
816.73 *14*	5/2$^+$		
930.91 *9*	(3/2)$^+$	<10 ps	
959.31 *8*	(1/2$^+$,3/2$^+$)	<10 ps	
1015.27 *4*	(3/2)$^+$	<5 ps	
1044.33 *20*			
1974.5 *4*	(1/2$^+$,3/2$^+$)	<5 ns	
2336.3 *3*			

[†] From Adopted Levels.

[‡] From $\gamma\gamma$(t) and $\beta\gamma$(t) (1990OhZY), except as noted.

β^- radiations

E(decay)	E(level)	Iβ^-[†]	Log *ft*	Comments
(2379 *16*)	2336.3	0.13 *4*	5.99 *14*	av Eβ=971.1 *75*
(2741 *16*)	1974.5	0.4 *1*	5.76 *12*	av Eβ=1140.5 *76*
(3671 *16*)	1044.33	1.0 *2*	5.90 *9*	av Eβ=1581.4 *77*
(3700 *16*)	1015.27	57 *4*	4.16 *4*	av Eβ=1595.3 *77*
(3756 *16*)	959.31	30 *2*	4.47 *4*	av Eβ=1622.0 *77*
(3784 *16*)	930.91	10 *1*	4.96 *5*	av Eβ=1635.6 *77*
(3950 *16*)	765.05	0.02 *1*	7.74 *22*	av Eβ=1714.8 *77*
(4171 *16*)	544.23	0.9 *11*	6.2 *6*	av Eβ=1820.4 *77*
(4246 *16*)	469.139	<9	>5.2	av Eβ=1856.3 *77*
(4328 *16*)	387.38	<2	>5.9	av Eβ=1895.5 *77*
(4350 *16*)	365.27	<1.9	>5.9	av Eβ=1906.0 *77*
				Iβ^-: if log *ft*>5.9.

[†] Absolute intensity per 100 decays.

^{99}Zr β^- decay 1998Lh03,1979Se01 (continued)

$\gamma(^{99}Nb)$

Iγ normalization: Normalization from decay scheme using Σ(I(γ+ce) to g.s.)+Σ(I(γ+ce) to 365.3)=99.1 *9* since Iβ(365.3)<1.9 if log *ft*>5.9, and Iβ(g.s.) is highly forbidden. Direct measurements: Iγ normalization=0.56 *8* (JOSEF), Iγ normalization=0.38 *4* (LOHENGRIN), both from comparison with fission product lines of known absolute intensity (1979Se01). Iγ normalization=0.552 (1993De47).

E_γ[†]	I_γ[†b]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[‡]	α[&]	Comments
28.4 *1*	0.39 *11*	959.31	(1/2$^+$,3/2$^+$)	930.91	(3/2)$^+$	(M1)	8.50 *15*	α(K)=7.43 *13*; α(L)=0.892 *16*; α(M)=0.158 *3* α(N)=0.0229 *4*; α(O)=0.001276 *23* %Iγ=0.22 *6*. Mult.: from intensity balance at 930.88 level α(28.4γ)≤5.9, and a comparison with α(E2)=1084 and α(M1)=8.63.
x46.1[@] *3*	0.12[@] *6*							%Iγ=0.07 *4*.
55.9 *1*	3.9 *7*	1015.27	(3/2)$^+$	959.31	(1/2$^+$,3/2$^+$)	[M1]	1.177	α(K)=1.029 *16*; α(L)=0.1224 *19*; α(M)=0.0216 *4* α(N)=0.00315 *5*; α(O)=0.000177 *3* %Iγ=2.2 *4*.
74.3[@] *4*	0.02[@] *1*	544.23	3/2$^-$	469.139	(5/2)$^+$			%Iγ=0.011 *6*.
81.8 *1*	5.5 *8*	469.139	(5/2)$^+$	387.38	(7/2$^+$)	[M1+E2]	1.4 *10*	α(K)=1.13 *78*; α(L)=0.22 *19*; α(M)=0.040 *33* α(N)=0.0054 *44*; α(O)=1.58×10^{-4} *99* %Iγ=3.0 *5*.
84.4[@] *2*	0.16[@] *3*	1015.27	(3/2)$^+$	930.91	(3/2)$^+$			%Iγ=0.088 *17*.
86.7[@] *3*	0.07[@] *2*	630.70	5/2$^-$	544.23	3/2$^-$	[M1+E2]	1.14 *81*	α(K)=0.93 *64*; α(L)=0.18 *15*; α(M)=0.032 *26* α(N)=0.0043 *34*; α(O)=1.31×10^{-4} *81* %Iγ=0.039 *12*.
x88.8[@] *2*	0.09[@] *2*							%Iγ=0.050 *12*.
113.4[@] *4*	0.06[@] *2*	1044.33		930.91	(3/2)$^+$			%Iγ=0.033 *12*.
114.2[@] *2*	0.31[@] *7*	930.91	(3/2)$^+$	816.73	5/2$^+$			%Iγ=0.17 *4*.
165.6[@c] *3*	0.01[@] *1*	930.91	(3/2)$^+$	765.05	3/2$^+$			%Iγ=0.006 *6*.
x175.2[@] *5*	0.09[@] *3*							%Iγ=0.050 *17*.
178.984[#] *12*	9.8 *15*	544.23	3/2$^-$	365.27	1/2$^-$	[M1+E2]	0.093 *48*	α(K)=0.080 *40*; α(L)=0.0109 *62*; α(M)=0.0019 *11* α(N)=2.7×10^{-4} *15*; α(O)=1.25×10^{-5} *55* %Iγ=5.4 *9*.
198.0[@] *5*	0.06[@] *2*	1015.27	(3/2)$^+$	816.73	5/2$^+$			%Iγ=0.033 *12*.
220.9[@] *2*	0.08[@] *2*	765.05	3/2$^+$	544.23	3/2$^-$	[E1]	0.01210	α(K)=0.01066 *16*; α(L)=0.001196 *17*; α(M)=0.000210 *3* α(N)=3.04×10^{-5} *5*; α(O)=1.682×10^{-6} *24* %Iγ=0.044 *12*.
250.4[@] *3*	0.04[@] *1*	1015.27	(3/2)$^+$	765.05	3/2$^+$			%Iγ=0.022 *6*.
347.5[@] *3*	0.08[@] *1*	816.73	5/2$^+$	469.139	(5/2)$^+$	[M1+E2]	0.011 *3*	α(K)=0.0098 *24*; α(L)=0.00118 *33*; α(M)=2.07×10^{-4} *59* α(N)=3.00×10^{-5} *82*; α(O)=1.6×10^{-6} *4* %Iγ=0.044 *6*.

$^{99}_{41}Nb_{58}$-2

^{99}Zr β^- decay 1998Lh03,1979Se01 (continued)

$\gamma(^{99}Nb)$ (continued)

E_γ[†]	I_γ[†][b]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[‡]	δ[‡][a]	α[&]	Comments
[x]363.0[@] 5	0.06[@] 3								%Iγ=0.033 17.
365.1		365.27	1/2$^-$	0.0	9/2$^+$	[M4]		0.372	α(K)=0.311 5; α(L)=0.0505 7; α(M)=0.00916 13 α(N)=0.001307 19; α(O)=6.26×10^{-5} 9 I_γ: a very weak transition observed at LOHENGRIN (1979Se01).
[x]379.2[@] 5	0.10[@] 3								%Iγ=0.055 17.
384.8[@] 3	0.06[@] 2	1015.27	(3/2)$^+$	630.70	5/2$^-$				%Iγ=0.033 12.
386.5[@] 3	0.11[@] 3	930.91	(3/2)$^+$	544.23	3/2$^-$				%Iγ=0.061 17.
387.42[#] 10	14.5 10	387.38	(7/2$^+$)	0.0	9/2$^+$	[M1]		0.00649	α(K)=0.00571 8; α(L)=0.000646 9; α(M)=0.0001138 16 α(N)=1.667×10^{-5} 24; α(O)=9.68×10^{-7} 14 %Iγ=8.0 7.
415.093[#] 13	8.5 7	959.31	(1/2$^+$,3/2$^+$)	544.23	3/2$^-$				%Iγ=4.7 5.
429.3[@] 3	0.38[@] 8	816.73	5/2$^+$	387.38	(7/2$^+$)	[M1+E2]		0.0061 11	α(K)=0.0053 9; α(L)=0.00062 13; α(M)=0.000110 22 α(N)=1.6×10^{-5} 3; α(O)=8.8×10^{-7} 13 %Iγ=0.21 5.
[x]444.5[@] 4	0.06[@] 2								%Iγ=0.033 12.
461.8 2	19.9 10	930.91	(3/2)$^+$	469.139	(5/2)$^+$	M1+E2	>1	0.0053 4	α(K)=0.0047 4; α(L)=0.00055 5; α(M)=9.7×10^{-5} 8 α(N)=1.40×10^{-5} 11; α(O)=7.6×10^{-7} 5 %Iγ=11.0 8. Mult.,δ: δ large from γγ(θ) and hence E1+M2 excluded.
469.137[#] 13	100 8	469.139	(5/2)$^+$	0.0	9/2$^+$	E2		0.00540	%Iγ=55.2 22 α(K)=0.00473 7; α(L)=0.000563 8; α(M)=9.92×10^{-5} 14 α(N)=1.433×10^{-5} 20; α(O)=7.65×10^{-7} 11 ΔIγ=8 estimated by evaluators. Mult.: E2+M1, δ=−2.5.
471.1[@] 3	0.12[@] 4	1015.27	(3/2)$^+$	544.23	3/2$^-$				%Iγ=0.066 23.
490.2 3	1.0 2	959.31	(1/2$^+$,3/2$^+$)	469.139	(5/2)$^+$				%Iγ=0.55 12.
499.9[@] 3	0.06[@] 2	1044.33		544.23	3/2$^-$				%Iγ=0.033 12.
[x]536.7[@] 3	1.5[@] 4								%Iγ=0.83 23.
543.6[@] 4	1.26[@] 18	930.91	(3/2)$^+$	387.38	(7/2$^+$)				%Iγ=0.70 11.
546.13[#] 3	87.8 20	1015.27	(3/2)$^+$	469.139	(5/2)$^+$	M1+(E2)	<−0.4	0.00290 6	α(K)=0.00255 5; α(L)=0.000287 7; α(M)=5.06×10^{-5} 12 α(N)=7.41×10^{-6} 16; α(O)=4.30×10^{-7} 8 %Iγ=48 3.
[x]561.4[@] 3	0.19[@] 6								%Iγ=0.10 4.
575.4[@] 3	1.6[@] 4	1044.33		469.139	(5/2)$^+$				%Iγ=0.88 23.
[x]581.0 4	≈1								%Iγ=0.6 3. E_γ,I_γ: From 1979Se01 (LOHENGRIN separator).
593.994[#] 18	49.5 15	959.31	(1/2$^+$,3/2$^+$)	365.27	1/2$^-$				%Iγ=27.3 19.
[x]600.4[@] 4	0.06[@] 2								%Iγ=0.033 12.

$^{99}_{41}Nb_{58}$-3

^{99}Zr β^- decay 1998Lh03,1979Se01 (continued)

$\gamma(^{99}Nb)$ (continued)

E_γ[†]	I_γ[†][b]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[‡]	α[&]	Comments
627.9 *9*	3.7 *5*	1015.27	$(3/2)^+$	387.38	$(7/2^+)$			%Iγ=2.0 *3*.
650.0 *2*	4.1 *8*	1015.27	$(3/2)^+$	365.27	$1/2^-$			%Iγ=2.3 *5*. E_γ: placed by the evaluators.
816.7[@] *3*	0.12[@] *4*	816.73	$5/2^+$	0.0	$9/2^+$	[E2]	1.17×10^{-3}	α(K)=0.001028 *15*; α(L)=0.0001168 *17*; α(M)=2.06×10^{-5} *3* α(N)=3.00×10^{-6} *5*; α(O)=1.695×10^{-7} *24* %Iγ=0.066 *23*.
960.0 *8*	0.61 *12*	1974.5	$(1/2^+,3/2^+)$	1015.27	$(3/2)^+$			%Iγ=0.34 *7*. E_γ: from measurement at JOSEF (1979Se01).
1043.4[@] *4*	0.18[@] *4*	1974.5	$(1/2^+,3/2^+)$	930.91	$(3/2)^+$			%Iγ=0.099 *23*.
1321.0[@] *3*	0.24[@] *6*	2336.3		1015.27	$(3/2)^+$			%Iγ=0.13 *4*.

[†] Weighted averages from 1998Lh03 and 1979Se01 (LOHENGRIN and JOSEF fission product separators), unless otherwise specified.
[‡] From $\gamma\gamma(\theta)$. Quadrupole γ's are E2 since $T_{1/2}$<5 ns.
[#] Curved-crystal spectrometer measurement (1979Bo26).
[@] From 1998Lh03.
[&] Additional information 1.
[a] If No value given it was assumed δ=1.00 for E2/M1, δ=1.00 for E3/M2 and δ=0.10 for the other multipolarities.
[b] For absolute intensity per 100 decays, multiply by 0.55 *3*.
[c] Placement of transition in the level scheme is uncertain.
[x] γ ray not placed in level scheme.

$^{99}_{41}Nb_{58}$-4

^{99}Zr β^- decay 1998Lh03,1979Se01

Decay Scheme

Intensities: $I_{(\gamma+ce)}$ per 100 parent decays