^{65}Cu(α,nγ),^{66}Zn(α,pnγ) 1993Ti04,1976Mo22

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	E. A. Mccutchan	NDS 113, 1735 (2012)	1-Mar-2012

1993Ti04: ^{65}Cu(α,nγ), E(α)=14.5 MeV. Measured Eγ, Iγ, $\gamma\gamma$, and internal conversion electrons with two HPGe detectors (FWHM = 2 keV at 1.3 MeV) and a magnetic plus Si(Li) electron spectrometer (FWHM=2.7 keV at 0.9 MeV).

1976Mo22: ^{65}Cu(α,nγ), E(α)=12-21 MeV and ^{66}Zn(α,pnγ), E(α)=25-40 MeV. Measured relative yield functions, Eγ, Iγ, $\gamma\gamma$, $\gamma(\theta)$, $\gamma(\theta)$(DCO), and $T_{1/2}$ using Ge(Li) detectors (FWHM=3.6 keV at 1 MeV).

1973BaYF: ^{65}Cu(α,nγ), E(α)=13 MeV. Measured $T_{1/2}$ and g-factor for the 1230-keV level by differential perturbed angular distribution (DPAD) of γ-rays.

Others: 1995Fe15, 1975EbZZ, 1973HaWI.

^{68}Ga Levels

E(level)†	J$^\pi$‡	$T_{1/2}$#	Comments
0	1^+		
175.017 *8*	2^+	≤5 ns	
320.971 *12*	1^+		
374.564 *15*	2^+		
375.582 *11*	3^+	≤5 ns	
496.091 *16*	4^+	≤5 ns	
514.300 *19*	1^+		
555.467 *16*	0^+		
564.523 *13*	2^+		
583.791 *16*	2^-	≤5 ns	
676.052 *21*	3^+		
806.159 *18*	4^+	≤5 ns	
825.335 *2*	$1^+,2^+$		
838.709 *21*	$1^+,2^+$		
841.177 *20*	3^+		
876.750 *18*	4^-	≤5 ns	
946.846 *25*	$1^+,2^+$		
1055.95 *3*	3^-	≤5 ns	
1064.113 *22*	(1,2,3)		
1101.194 *22*	(1,2,3)		
1103.51 *3*	5^-	≤5 ns	
1123.174 *23*	$1^+,2,3^+$		
1210.59 *5*	$2^+,3^+$		
1216.19 *8*	$2^+,3,4^+$		
1223.45 *8*	$(5)^+$	≤5 ns	
1229.86 *4*	7^-	60 ns *2*	g=+0.102 *3* $T_{1/2}$: from delayed pulse timing (1973BaYF); Other: 54 ns *8* from delayed pulse timing (1976Mo22). g: from differential perturbed angular distribution of γ rays (1973BaYF).
1231.71 *4*	(3,4)		
1247.56 *4*	5^-	≤5 ns	
1287.00 *5*	$2^+,3,4^+$		
1296.40 *4*	(2,3,4)		
1323.23 *4*	6^-	≤5 ns	
1350.48? *14*			
1442.48 *11*	(3,4,5)		
1489.17 *9*	(2,3,4)		
1493.82 *4*	$(3,4)^-$	≤5 ns	J$^\pi$: assigned as $(5,6)^+$ in 1976Mo22.
1523.20 *7*			
1539.44? *11*			
1548.25 *11*			
1570.48 *10*			

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^{65}Cu(α,nγ),^{66}Zn(α,pnγ) 1993Ti04,1976Mo22 (continued)

^{68}Ga Levels (continued)

E(level)†	Jπ‡	E(level)†	Jπ‡	$T_{1/2}$#	E(level)†	Jπ‡	$T_{1/2}$#
1656.61 *8*	(2,3,4)	1973.18 *24*			2896.07 *15*	9^+	≤5 ns
1687.73 *4*	$(5,6)^-$	2088.06 *13*	(6)	≤5 ns	2952.9 *10*	(8,9)	≤5 ns
1742.38 *7*	(3,4,5)	2102.97 *6*	8	≤5 ns	3817.59 *15*	(9)	≤5 ns
1798.21 *10*	(2,3,4,5)	2284.67 *11*	(7,8)	≤5 ns	3964.98 *18*	11^+	≤5 ns
1857.28 *6*	$(5,6,7)^-$	2396.77 *11*	$9^{(-)}$	≤5 ns			
1945.99 *7*	(5,6,7)	2611.84 *11*	8	≤5 ns			

† From a least-squares fit to Eγ data of 1993Ti04 up to the 1973 level; data from 1976Mo22 used for levels above this.
‡ From 1993Ti04 for levels below 2 MeV, based on measured α(K) values, decay properties of levels and results from ^{68}Zn(p,nγ) study by same authors (1993Ti03). Above 2 MeV, from 1976Mo22 based on excitation function and $\gamma(\theta)$ measurements.
# From delayed electronic timing (1976Mo22), except where noted otherwise.

$\gamma(^{68}Ga)$

α(K)exp: From 1993Ti04 normalized to α(K)=0.0142 (2008Ki07) for 175γ assumed to be M1. Note that 1993Ti04 and 1993Ti03 in (p,nγ) quote the same set of values for transitions seen in the two reactions, which are a weighted average of their (α,nγ) and (p,nγ) measurements.

E_γ†	I_γ‡	E_i(level)	J_i^π	E_f	J_f^π	Mult.#	δ@	Comments
75.6 *5*	≤20	1323.23	6^-	1247.56	5^-			
120.52 *2*	709 *38*	496.091	4^+	375.582	3^+	M1(+E2)	+0.12	α(K)exp=0.043 *6* δ: Others: <0.21 from α(K)exp and −0.07 *4* from $\gamma(\theta)$ (1973HaWI).
126.35 *3*	134 *7*	1229.86	7^-	1103.51	5^-	E2		α(K)exp=0.28 *8* δ: δ(M3/E2)=+0.0 *2* (1976Mo22). Other: <0.11 from α(K)exp.
139.74 *3*	0.8 *3*	514.300	1^+	374.564	2^+			
145.94 *2*	1.9 *3*	320.971	1^+	175.017	2^+			
175.01 *1*	1000 *52*	175.017	2^+	0	1^+	M1		Mult.: data normalized to α(K)(exp)=0.0142, assuming pure M1 for 175γ. δ: +0.0 *2* from $\gamma(\theta)$ (1976Mo22) and −0.10 *4* from $\gamma(\theta)$ (1973HaWi).
189.93 *7*	2.2 *3*	564.523	2^+	374.564	2^+			
200.56 *1*	669 *45*	375.582	3^+	175.017	2^+	M1+E2	−0.54 *12*	α(K)exp=0.018 *3* δ: 0.54 *12* from α(K)exp, sign from $\gamma(\theta)$ in 1976Mo22. Others:−0.3 *2* from $\gamma(\theta)$ (1976Mo22) and +1.0 *1* from $\gamma(\theta)$ (1973HaWI).
219.72 *3*	116 *6*	1323.23	6^-	1103.51	5^-	M1(+E2)	−0.02	α(K)exp=0.0085 *24* δ: Other: <0.37 from α(K)exp.
226.84 *18*	6.5 *4*	1103.51	5^-	876.750	4^-			
234.49 *2*	0.9 *3*	555.467	0^+	320.971	1^+			
243.53 *3*	2.6 *3*	564.523	2^+	320.971	1^+			
246.97[c] *13*	7.0 *9*	1350.48?		1103.51	5^-			
262.91 *9*	1.3 *3*	583.791	2^-	320.971	1^+			
274.08 *9*	2.2 *5*	1570.48		1296.40	(2,3,4)			
276.67 *4*	4.8 *7*	841.177	3^+	564.523	2^+			
292.98 *2*	100 *6*	876.750	4^-	583.791	2^-	E2		α(K)exp=0.0109 *17* δ: −0.1 *2* from $\gamma(\theta)$ (1976Mo22).

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^{65}Cu(α,nγ),^{66}Zn(α,pnγ) 1993Ti04,1976Mo22 (continued)

$\gamma(^{68}Ga)$ (continued)

E_γ[†]	I_γ[‡]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[#]	δ[@]	Comments
297.41 *15*	46.1 *23*	1103.51	5^-	806.159	4^+			
310.07 *2*	57 *3*	806.159	4^+	496.091	4^+	M1(+E2)	−0.16	α(K)exp=0.0042 *10* δ: Other: <0.38 from α(K)exp.
320.98 *2*	27.2 *24*	320.971	1^+	0	1^+			
321.05 *7*	33 *3*	496.091	4^+	175.017	2^+	(E2)[a]		δ: −0.2 *2* from $\gamma(\theta)$ (1976Mo22).
332.05 *10*	2.5 *4*	1548.25		1216.19	2^+,3,4^+			
339.28 *2*	16.3 *14*	514.300	1^+	175.017	2^+			
339.38 *18*	6.8 *11*	1442.48	(3,4,5)	1103.51	5^-			
345.11 *4*	3.5 *4*	841.177	3^+	496.091	4^+			
354.97 *5*	9.2 *6*	1231.71	(3,4)	876.750	4^-			
364.79 *18*	2.2 *5*	1687.73	$(5,6)^-$	1323.23	6^-			
370.77 *3*	103 *6*	1247.56	5^-	876.750	4^-	M1+E2	−0.4	α(K)exp=0.0025 *8* δ: Other: <0.77 from α(K)exp.
374.57 *2*	106 *6*	374.564	2^+	0	1^+	M1(+E2)	<0.66[b]	α(K)exp=0.0026 *4*
375.60 *3*	328 *18*	375.582	3^+	0	1^+	(E2)[a]		δ: −0.2 *2* from $\gamma(\theta)$ (1976Mo22).
380.65 *3*	33.8 *19*	876.750	4^-	496.091	4^+			
389.51 *2*	4.8 *4*	564.523	2^+	175.017	2^+			
408.78 *4*	2.5 *3*	583.791	2^-	175.017	2^+			
417.42 *10*	16.6 *9*	1223.45	$(5)^+$	806.159	4^+			
419.69 *6*	0.8 *7*	1523.20		1103.51	5^-			
419.72 *5*	11.9 *13*	1296.40	(2,3,4)	876.750	4^-			
425.07 *16*	3.9 *3*	1489.17	(2,3,4)	1064.113	(1,2,3)			
430.59 *2*	60 *3*	806.159	4^+	375.582	3^+	M1(+E2)	−0.1	α(K)exp=0.0018 *5* δ: Other: <0.95 from α(K)exp.
440.06 *5*	11.4 *7*	1687.73	$(5,6)^-$	1247.56	5^-			
446.52 *5*	9.7 *6*	1323.23	6^-	876.750	4^-			
457.82 *5*	10.5 *6*	1687.73	$(5,6)^-$	1229.86	7^-			
466.60 *2*	30.4 *18*	841.177	3^+	374.564	2^+	M1(+E2)	<0.38[b]	α(K)exp=0.0014 *3*
472.16 *2*	63 *4*	1055.95	3^-	583.791	2^-	M1(+E2)	+0.18	α(K)exp=0.0014 *3* δ: <0.84 from α(K)exp.
499.3[&] *1*		2896.07	9^+	2396.77	$9^{(-)}$			
501.04 *2*	65 *7*	676.052	3^+	175.017	2^+			
501.15 *3*	60 *6*	876.750	4^-	375.582	3^+	E1(+M2)	<0.35[b]	α(K)exp=0.0006 *3*
517.74 *2*	6.6 *12*	838.709	1^+,2^+	320.971	1^+			
534.05 *5*	15.2 *12*	1857.28	$(5,6,7)^-$	1323.23	6^-	M1(+E2)	<0.45[b]	α(K)exp=0.0011 *4*
555.47 *2*	7.5 *7*	555.467	0^+	0	1^+			
564.53 *2*	38 *4*	564.523	2^+	0	1^+	M1(+E2)	<0.28[b]	α(K)exp=0.00088 *14*
572.28 *2*	10.6 *10*	946.846	1^+,2^+	374.564	2^+			
583.80 *2*	247 *23*	583.791	2^-	0	1^+	E1(+M2)[a]	−0.03 *4*	δ: from $\gamma(\theta)$ in 1973HaWi; Other: 0.0 *2* from $\gamma(\theta)$ (1976Mo22).
584.27 *4*	29 *3*	1687.73	$(5,6)^-$	1103.51	5^-	M1+E2	<1.15[b]	α(K)exp=0.0010 *3*
607.42 *3*	464 *38*	1103.51	5^-	496.091	4^+	E1(+M2)	+0.03	α(K)exp=0.00034 *10* δ: Others: −0.07 *4* from $\gamma(\theta)$ (1973HaWI) and <0.22 from α(K)(exp).
631.09 *4*	10.4 *9*	806.159	4^+	175.017	2^+			
638.73 *23*	1.1 *4*	1742.38	(3,4,5)	1103.51	5^-			
647.92 *5*	8.7 *12*	1231.71	(3,4)	583.791	2^-			
649.94 *23*	1.3 *4*	1973.18		1323.23	6^-			
662.69[c] *10*	8.1 *12*	1539.44?		876.750	4^-			
663.67 *4*	1.3 *10*	838.709	1^+,2^+	175.017	2^+			
675.97 *7*	0.9 *4*	676.052	3^+	0	1^+			
686.44 *7*	7.3 *7*	1742.38	(3,4,5)	1055.95	3^-			
712.57 *7*	6.1 *8*	1296.40	(2,3,4)	583.791	2^-			

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^{65}Cu(α,nγ),^{66}Zn(α,pnγ) 1993Ti04,1976Mo22 (continued)

$\gamma(^{68}Ga)$ (continued)

E_γ[†]	I_γ[‡]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[#]	δ[@]	Comments
716.17 *6*	12.0 *12*	1945.99	(5,6,7)	1229.86	7^-			
720.17 *13*	10.3 *11*	1216.19	2^+,3,4^+	496.091	4^+			
727.15 *12*	68 *7*	1223.45	$(5)^+$	496.091	4^+	M1+E2	−1.4	α(K)exp=0.00045 *15* δ: Others: +0.9 *3* from $\gamma(\theta)$ (1973HaWI) and <1.5 from α(K)(exp) (1993Ti04).
727.99 *12*	14.3 *24*	1103.51	5^-	375.582	3^+			
733.76 *34*	2.2 *7*	1229.86	7^-	496.091	4^+			
735.60 *7*	7.6 *8*	1231.71	(3,4)	496.091	4^+			
[x]743.66 *5*	12.2 *8*							
748.65 *3*	1.9 *4*	1123.174	1^+,2,3^+	374.564	2^+			
779.73 *5*	21.8 *4*	2102.97	8	1323.23	6^-			E_γ: Observed by 1993Ti04 however authors give no specific placements for γ's originating from states above 2 MeV; the evaluator has followed the placement of 1976Mo22 and 1973HaWI who assigned a 780γ to this level. δ: 0.0 *2* for J=8 or +0.4 *2* for J=7 from $\gamma(\theta)$ (1976Mo22).
790.84 *13*	1.6 *4*	1287.00	2^+,3,4^+	496.091	4^+			
811.11 *8*	5.3 *6*	1687.73	$(5,6)^-$	876.750	4^-			
825.33 *2*	17.1 *14*	825.335	1^+,2^+	0	1^+			
835.00 *4*	11.9 *9*	1210.59	2^+,3^+	375.582	3^+			
840.32 *13*	17 *6*	1216.19	2^+,3,4^+	375.582	3^+			
841.21 *10*	≤4.7	841.177	3^+	0	1^+			
842.21 *14*	11.8 *13*	1945.99	(5,6,7)	1103.51	5^-			
847.93 *18*	4.7 *6*	1223.45	$(5)^+$	375.582	3^+			
856.18 *20*	≤8.7	1231.71	(3,4)	375.582	3^+			E_γ: doublet; the transitions feed the 376 and 1247 levels.
864.6[&] *1*		2088.06	(6)	1223.45	$(5)^+$	(D+Q)[a]	−0.02	
889.09 *2*	20.5 *13*	1064.113	(1,2,3)	175.017	2^+			
920.63 *10*	4.1 *5*	1296.40	(2,3,4)	375.582	3^+			
926.17 *2*	20.3 *22*	1101.194	(1,2,3)	175.017	2^+			
[x]956.79 *9*	13.4 *9*							
993.33 *17*	4.2 *4*	1489.17	(2,3,4)	496.091	4^+			
997.74 *4*	36.0 *22*	1493.82	$(3,4)^-$	496.091	4^+	E1(+M2)	<0.52[b]	α(K)exp=0.00015 *7* δ: other: δ=+0.45 from 1976Mo22 is inconsistent with mult=E1(+M2).
1041.35 *13*	15.0 *11*	1216.19	2^+,3,4^+	175.017	2^+			
1052.19 *18*	3.4 *5*	1548.25		496.091	4^+			
1054.8[&] *1*		2284.67	(7,8)	1229.86	7^-			E_γ: slightly contaminated by the 1054γ from ^{67}Ga. δ: +0.12 *20* for J=7 or +1.4 *2* for J=8 from $\gamma(\theta)$ (1976Mo22).
1066.67 *13*	16.3 *12*	1442.48	(3,4,5)	375.582	3^+			
1068.9[&] *1*		3964.98	11^+	2896.07	9^+	(E2)[a]		δ: δ(M3/E2)=−0.07 *20* (1976Mo22).
1111.98 *5*	12.0 *8*	1287.00	2^+,3,4^+	175.017	2^+			
1113.44 *12*	23.3 *13*	1489.17	(2,3,4)	375.582	3^+			
1118.12 *9*	8.1 *7*	1493.82	$(3,4)^-$	375.582	3^+			
1123.12 *3*	5.1 *6*	1123.174	1^+,2,3^+	0	1^+			
1160.18 *18*	5.5 *5*	1656.61	(2,3,4)	496.091	4^+			
1166.9[&] *1*		2396.77	$9^{(-)}$	1229.86	7^-	(E2)[a]		δ: δ(M3/E2)=+0.05 *20* (1976Mo22).
1280.78 *18*	4.8 *5*	1656.61	(2,3,4)	375.582	3^+			
1288.6[&] *1*		2611.84	8	1323.23	6^-	(E2)[a]		δ: δ(M3/E2)=0.0 *2* (1976Mo22).
1302.15 *10*	7.8 *7*	1798.21	(2,3,4,5)	496.091	4^+			

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^{65}Cu(α,nγ),^{66}Zn(α,pnγ) 1993Ti04,1976Mo22 (continued)

$\gamma(^{68}Ga)$ (continued)

E_γ[†]	I_γ[‡]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[#]	δ[@]
1420.8[&] *1*		3817.59	(9)	2396.77	$9^{(-)}$	(D+Q)[a]	−4.7
1422.3 *3*	2.2 *5*	1798.21	(2,3,4,5)	375.582	3^+		
1481.75 *10*	13.8 *11*	1656.61	(2,3,4)	175.017	2^+		
1723.0[&] *1*		2952.9	(8,9)	1229.86	7^-		

[†] Weighted average of (p,nγ) (1993Ti03) and (α,nγ) (1993Ti04) data. 1993Ti04 and 1993Ti03 in their (α,nγ) and (p,nγ) datasets, respectively, use the same set of energies for transitions seen in both reactions.
[‡] From 1993Ti04. Iγ is relative to Iγ(175γ)=1000.
[#] From α(K)exp (1993Ti04), unless indicated otherwise.
[@] From $\gamma(\theta)$ (1976Mo22), unless indicated otherwise. 1976Mo22 make a general statement that the uncertainties are ≤0.2.
[&] From 1976Mo22; not seen by 1993Ti04.
[a] From $\gamma(\theta)$ and ΔJ^π of initial and final levels.
[b] From α(K)exp (1993Ti04).
[c] Placement of transition in the level scheme is uncertain.
[x] γ ray not placed in level scheme.

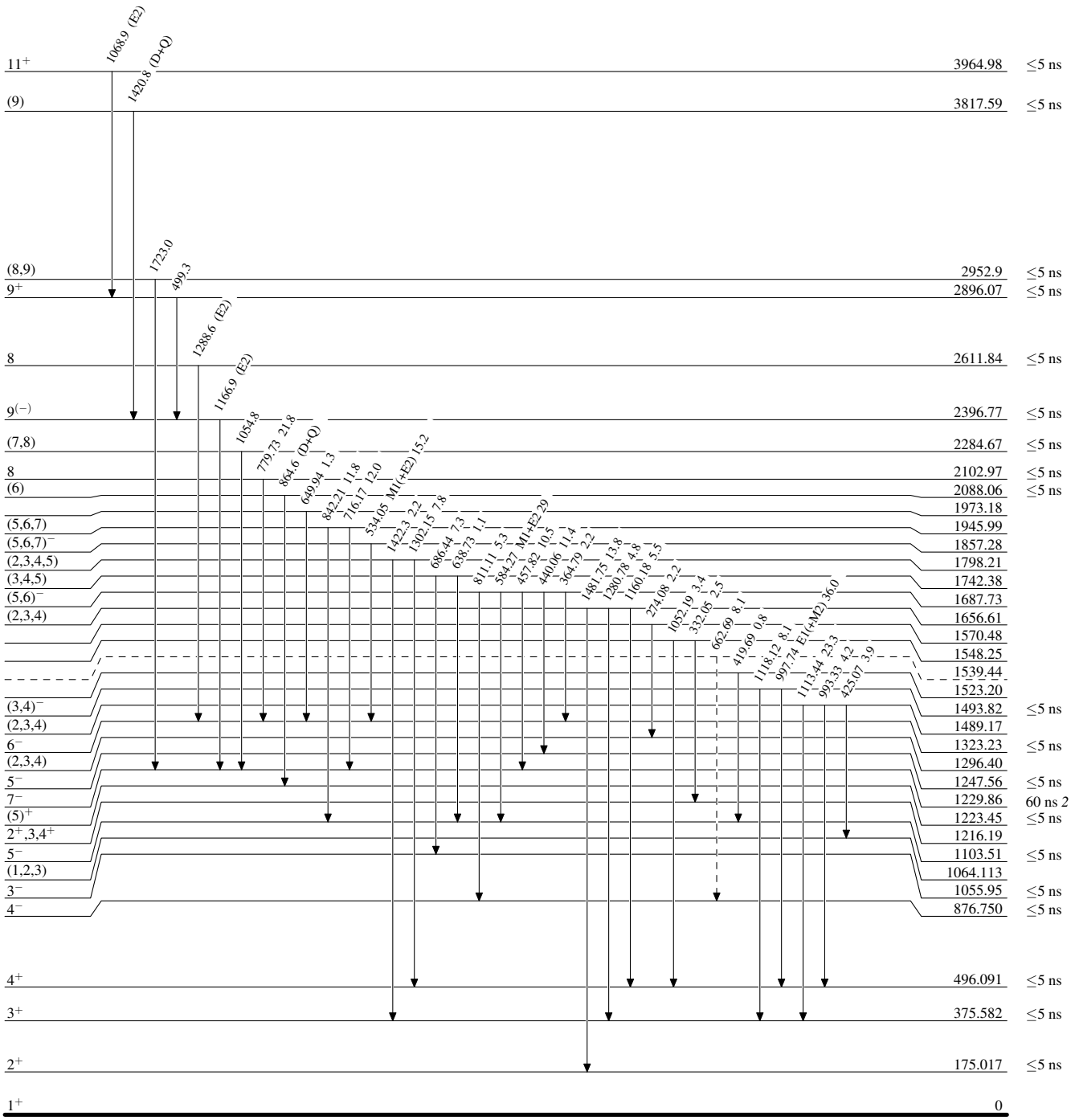
^{65}Cu(α,nγ),^{66}Zn(α,pnγ) 1993Ti04,1976Mo22

Legend

$I_\gamma < 2\% \times I_\gamma^{max}$
$I_\gamma < 10\% \times I_\gamma^{max}$
$I_\gamma > 10\% \times I_\gamma^{max}$
γ Decay (Uncertain)

Level Scheme

Intensities: Relative I_γ



$^{68}_{31}Ga_{37}$

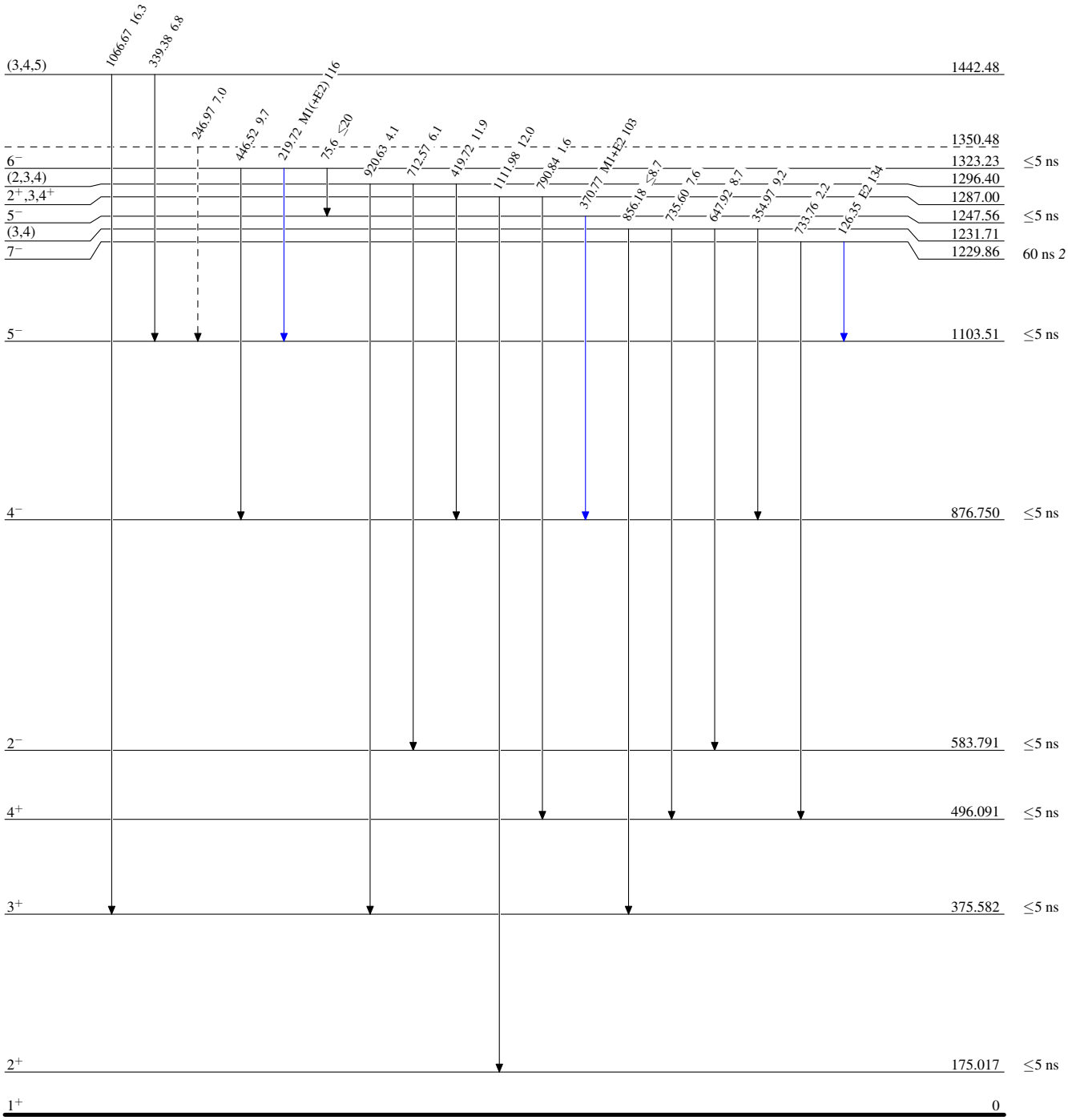
^{65}Cu(α,nγ),^{66}Zn(α,pnγ) 1993Ti04,1976Mo22

Legend

$I_\gamma < 2\% \times I_\gamma^{max}$
$I_\gamma < 10\% \times I_\gamma^{max}$
$I_\gamma > 10\% \times I_\gamma^{max}$
γ Decay (Uncertain)

Level Scheme (continued)

Intensities: Relative I_γ



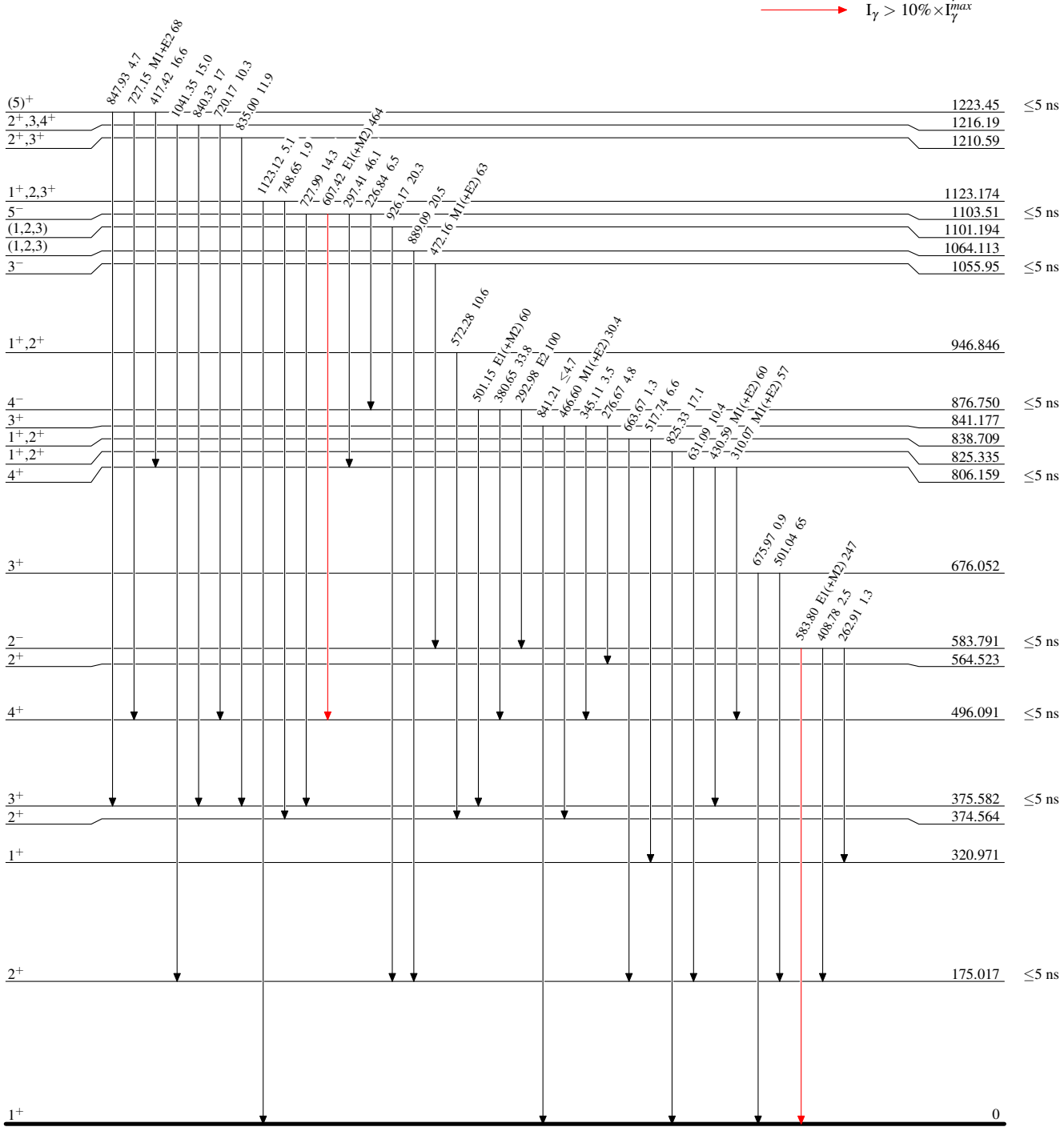
$^{68}_{31}Ga_{37}$

^{65}Cu(α,nγ),^{66}Zn(α,pnγ) 1993Ti04,1976Mo22

Level Scheme (continued)

Intensities: Relative I_γ

Legend
$I_\gamma < 2\% \times I_\gamma^{max}$
$I_\gamma < 10\% \times I_\gamma^{max}$
$I_\gamma > 10\% \times I_\gamma^{max}$

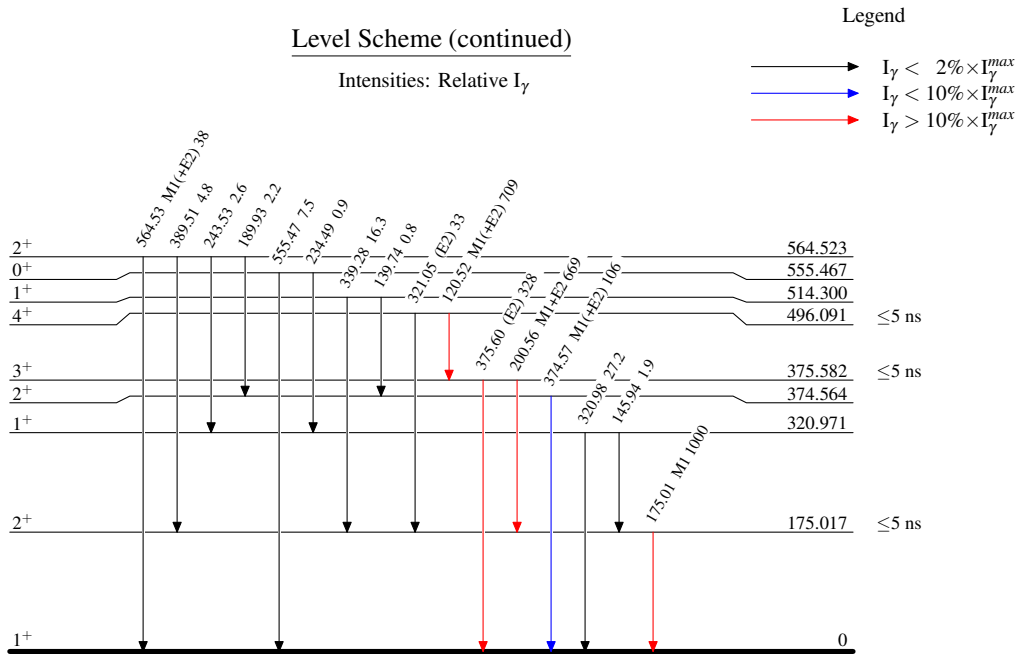


$^{68}_{31}Ga_{37}$

^{65}Cu(α,nγ),^{66}Zn(α,pnγ) 1993Ti04,1976Mo22

Level Scheme (continued)

Intensities: Relative I_γ



$^{68}_{31}Ga_{37}$