Adopted Levels, Gammas

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. K. Tuli, E. Browne	NDS 157, 260 (2019)	1-Mar-2019

Q(β^-)=−95.2 *11*; S(n)=9276.21 *97*; S(p)=12349.6 *27*; Q(α)=−8156.8 *36* 2017Wa10

Reference 2018Az05 compiled in XUNDL by B. Singh (McMaster), June 17, 2018.

Other reactions:

^{82}Se(pol d,d): 19887Nu03 E=12 MeV; measured dσ/dΩ and vector-analyzing power.

Se(n,n),(n,n′): 1976La12, E=6 MeV to 10 MeV. Natural and enriched targets. Measured $\sigma(\theta)$ for elastic and inelastic scattering. No individual levels were observed for inelastic scattering. 2000Za09 (1999Za09,1999Za07 same authors): Calculated s and p wave n-strength functions, s-wave scattering length 1976La12,1981Br23: Coupled-channels calculations 1990Go13: Coupled-channel analysis of $\sigma(\theta)$ for (n,n) and (n,n′) with excitation of the 2^+ state at E=1.5, 2.0, 2.5, 3.0, 5.0, 6.0 MeV. Others: 1984Ko09 (E=1 MeV), 1980Ko17 (slow n′s).

Theoretical calculations: 1982Ah06 (transition strengths); 1988Pe04 (Boson expansion theory).

Some (beyond 1994) Calculations for 0ν, 2ν 2β- decay $T_{1/2}$, Matrix elements, theory, study of various models: 2001St24, 2001St13, 2001Si33, 2001Ka15, 2001Fa10, 2000Ve05, 2000Su06, 2000Ra13, 2000Pa47, 2000Pa25, 2000Ki24, 2000Fa14, 2000Cl02, 2000Bo05, 2000Ba68, 2000Ba54, 1999Si18, 1999Ca62, 1999Ba38, 1998Ba05, 1998Su22, 1998Su19, 1998Sc11, 1998Ru08, 1998Kl25, 1998Kl18, 1998Kl10, 1998Fa19, 1998Fa17, 1998Be49, 1998Ba76, 1998Ba55, 1998Au04, 1997To05, 1997Ra09, 1997Kr01, 1997Ej01, 1997Ba19, 1996Si29, 1996Sc09, 1996Ru21, 1996Ru04, 1996Pa02, 1996Mo23, 1996Hi06, 1996Hi04, 1996Ej02, 1996Ca35, 1996Ca35, 1996Au07, 1995Ru18, 1995Ba17.

See 1981MuZQ for neutron resonances.

^{82}Se Levels

Q value for 2β^- decay=2997.9 keV *5* (2017Wa10).

Cross Reference (XREF) Flags

A	^{82}As β^- decay (13.6 s)	E	^{82}Se(p,p′γ)	I	^{82}Se IT decay (6.6 ns)
B	^{82}As β^- decay (19.1 s)	F	Coulomb excitation	J	(HI,xnγ)
C	^{80}Se(t,p)	G	^{82}Se(d,d′)		
D	^{82}Se(p,p′),(pol p,p′)	H	^{82}Se(n,n′γ)		

E(level)[†]	J^π	$T_{1/2}$[‡]	XREF	Comments
0[#]	0^+	9.6×10^{19} y *10*	ABCDEFGHIJ	%2β^-=100 $T_{1/2}$: From 2012Si23 for $T_{1/2}$(2ν2β-)(^{82}Se 0^+ to 0^+) other values: 0.83×10^{20} y *+9−7* (1999Pi08,1999Sa02), 10.8×10^{20} y *+26−6* from 1992El07 (see also 1987El11, 1987El10, 1986El01), 1.2×10^{20} y *1* from geochemical measurements (1988Li11); 1.0×10^{20} y *4* (1985Ma57), 2.8×10^{20} y *9* (1973Sr05), 1.4×10^{20} y *3* (1970Ki21), all from isotopic anomaly of ^{82}Kr in geological samples, 0.9×10^{20} y *1* (2002Ba52). $T_{1/2}$: $T_{1/2}$(0ν2β-)(^{82}Se 0^+ to 0^+)>3.2×10^{23} y (90% confidence level); (2012Si23);>2.4×10^{21} y (1999Sa02,2000Ar16, 2001Va34) other:>2.7×10^{22} y (1993Mo36). Calculated $T_{1/2}$ (2002Su13,2002Si12). $T_{1/2}$: >2.4E24 y lower limit for 0$\nu\beta\beta$ decay mode (2018Az05); measured at 90% credible interval, from a maximum likelihood analysis of events in the 2800-3200 keV region. This half-life can be compared with $T_{1/2}$>3.6×10^{23} y, obtained using NEMO detector with a larger ^{82}Se exposure of ≈3.5 kg y (2011Ba55). From the half-life limit, deduced effective Majorana neutrino mass of <(376-770) meV, depending on the nuclear matrix element calculations (2018Az05).

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Adopted Levels, Gammas (continued)

^{82}Se Levels (continued)

E(level)[†]	J^π	$T_{1/2}$[‡]	XREF	Comments
654.71[#] *16*	2^+	12.8 ps *7*	ABCDEFGHIJ	μ=+0.99 *6*(1978Br38,2014StZZ); Q=−0.22 *7* (1977Le11,2016St14) J^π: from angular distribution and vector-analyzing power in (pol p,p′) (1984De01). $T_{1/2}$: from 2016Pr01,deduced from B(E2).
1410.22 *17*	0^+	30 ps	BCDEF H	J^π: L(t,p)=0. $T_{1/2}$: from B(E2) deduced from Coulomb excitation.
1731.51 *10*	2^+	0.94 ps *11*	AB DEFgH J	J^π: L(t,p)=2+4, L(p,p′)=2+4 for the unresolved 1731+1735 doublet. log *ft*=7.0 from (1^+) and γ to 0^+ indicate that this is the 2^+ member of 1731+1735 doublet. $T_{1/2}$: from B(E2) deduced from Coulomb excitation.
1735.10[#] *24*	4^+	0.96 ps *15*	ABCDEFgHIJ	μ=2.3 *15* (1998Sp03,2014StZZ) J^π: see 1731.51 level. $T_{1/2}$: from B(E2) in Coul ex, other: 0.95 ps *25* in (n,n′γ).
2550.28 *16*	(4^+)	1.7[@] ps *3*	A CDEF H J	J^π: γ to 2^+; γ from (4^-,5^-). J^π suggested in (HI,xnγ), Coul. Ex.
2624.1 *4*	(0^+)	0.04 ps *1*	B E H	J^π: from level feeding calculations in (n,n′γ) (1998Ko52).
2893.66 *18*	5^-	>131.7[@] ps	A CD H J	J^π: L(p,p′)=5.
3009.14 *19*	3^-	0.020 ps *5*	BCDE H	J^π: from angular distribution and vector-analyzing power in (pol p,p′).
3103.3 *4*	(4^+)		CD H	J^π: L(p,p′)=4; in conflict to this L(t,p)=(5). (n,n′γ) supports adopted J^π.
3144.8[#] *5*	6^+	0.39[@] ps *+13−9*	IJ	J^π: assumed stretched E2 cascade.
3238.78 *21*	(4^+)	0.30 ps *+12−8*	D H	XREF: D(3293). J^π: L(p,p′)=4. E(level): 1998Ko52 did not find a level at 3293, but saw a level at 3238 with similar J^π.
3378.44 *24*	(3^-)	0.12 ps *4*	D H	XREF: D(3384). J^π: L(p,p′)=3.
3445.9 *4*	0^+		C H	XREF: C(3449). J^π: L(t,p)=0+(5). See also 3454 level.
3454.15 *20*	(5^-)		A H	J^π: log *ft*=5.5 from (5^-). γ to (3,4^+). L(t,p)=0+(5) at 3449 keV. Note, however, that the angular momentum of the L=5 admixture is more speculated than established.
3517.8[#] *5*	8^+	6.6 ns *4*	IJ	%IT=100 J^π: From (HI,xnγ) assumed stretched E2 cascade. Expected Configuration=$(\nu\ g_{9/2})^{-2}$. Systematics of 8^+ isomers In N=48 nuclides (1999Ma21,2002Is03). $T_{1/2}$: from IT decay (1999Ma21).
3591.67 *20*	2^+	0.28 ps *+12−8*	CD H	XREF: C(3586). J^π: L(t,p)=2.
3631.26 *21*	(0^+)		D H	XREF: D(3624). J^π: from level feeding calculations In (n,n′γ) (1998Ko52).
3664.0 *4*	2^+		C H	J^π: L(t,p)=2.
3667.5 *3*	(1,2^+)		B	J^π: log *ft*=6.2 from (2^-) and γ to 0^+.
3688.9 *6*	(4^+)		D H	XREF: D(3677). J^π: L(p,p′)=4.
3757.0 *5*	2^+		CD H	XREF: D(3750). J^π: L(t,p)=2.
3794.9 *5*	(7^-)		J	
3798? *4*	(4^+)		D	J^π: L(p,p′)=4. E(level): level not seen in (n,n′γ) and other studies.
3831.0 *6*	0^+		C H	J^π: L(t,p)=0.
3865.06 *25*	(3^-)		D H	J^π: L(p,p′)=3.
3917.9 *6*	2^+		CD H	J^π: L(t,p)=2.
4034.5 *4*	2^+	0.17 ps *+10−5*	CD H	XREF: D(4026).

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Adopted Levels, Gammas (continued)

^{82}Se Levels (continued)

E(level)[†]	J^π	$T_{1/2}$[‡]	XREF	Comments
				J^π: L(t,p)=2.
4088.0 *4*	(4⁻,5⁻)		A	J^π: log *ft*=5.5 from (5⁻). γ to (3,4⁺).
4094.3 *3*	(5⁻)		H	J^π: J=5 from (n,n′γ) calculations (1998Ko52).
4134 *6*	2⁺		C	J^π: L(t,p)=2.
4231.8 *9*			J	
4244.98 *20*	(1⁻)		B	J^π: log *ft*=5.4 from (2⁻), γ to 0⁺, 2⁺.
4391.3 *4*	2⁺	0.13 ps *3*	C H	J^π: L(t,p)=2.
4466 *4*	(4⁺)		C	J^π: L(t,p)=(4).
4535 *7*	(4⁺)		CD	XREF: C(4518). J^π: L(t,p)=(4).
4584 *4*	(4⁺)		CD	J^π: L(t,p)=(4).
4809 *13*	(1⁻)		C	J^π: L(t,p)=(1).
4881 *13*	(4⁺)		C	J^π: L(t,p)=(4).
4969 *11*			C	
4983.3 *8*	(9⁺)		J	J^π: from (HI,xnγ).
5029 *12*	(1⁻)		C	J^π: L(t,p)=(1).
5046.3 *12*			J	
5192.0 *10*			J	
5457.0[#] *8*	(10⁺)	<1.04[@] ps	J	J^π: from (HI,xnγ).
5687.0 *9*	(11)		J	J^π: from (HI,xnγ).
6128.9 *10*	(12)		J	J^π: from (HI,xnγ).

[†] Levels connected by γ′s to the g.s. are calculated from the adopted gammas using least-squares fit. Others are from (p,p′), (t,p), or weighted averages of both.
[‡] From DSA in (n,n′γ), unless indicated otherwise.
[#] Band(A): Yrast sequence (2009Po04).
[@] From 2018Li20, recoil-distance DSA.

γ(^{82}Se)

E_i(level)	J^π_i	E_γ[†]	I_γ[†]	E_f	J^π_f	Mult.	α[@]	Comments
654.71	2⁺	654.7 *5*	100	0	0⁺	[E2]	1.25×10^{-3}	α(K)=0.001111 *16*; α(L)=0.0001181 *17*; α(M)=1.84×10^{-5} *3* α(N)=1.553×10^{-6} *22* B(E2)(W.u.)=17.3 *10*
1410.22	0⁺	755.6 *1*	100	654.71	2⁺	[E2]	8.46×10^{-4}	α(K)=0.000753 *11*; α(L)=7.96×10^{-5} *12*; α(M)=1.238×10^{-5} *18* α(N)=1.050×10^{-6} *15* B(E2)(W.u.)=3.62
1731.51	2⁺	1076.4 *4*	26 *5*	654.71	2⁺	[E2]	3.55×10^{-4}	α(K)=0.000316 *5*; α(L)=3.30×10^{-5} *5*; α(M)=5.14×10^{-6} *8* α(N)=4.38×10^{-7} *7* B(E2)(W.u.)=4.1 *10* E_γ: from β⁻ decay.
		1731.5 *1*	100 *5*	0	0⁺	[E2]	3.15×10^{-4}	α(K)=0.0001172 *17*; α(L)=1.211×10^{-5} *17*; α(M)=1.88×10^{-6} *3* α(N)=1.613×10^{-7} *23*; α(IPF)=0.000184 *3* B(E2)(W.u.)=1.45 *21*
1735.10	4⁺	1079.8 *5*	100	654.71	2⁺	[E2]	3.52×10^{-4}	B(E2)(W.u.)=19 *3* α(K)=0.000314 *5*; α(L)=3.28×10^{-5} *5*; α(M)=5.10×10^{-6} *8* α(N)=4.35×10^{-7} *7*

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Adopted Levels, Gammas (continued)

$\gamma(^{82}Se)$ (continued)

E_i(level)	J_i^π	E_γ†	I_γ†	E_f	J_f^π	Mult.	α@	Comments
2550.28	(4+)	815.1 *2*	52 *13*	1735.10	4+			
		818.6 *2*	91 *13*	1731.51	2+	[E2]	6.87×10^{-4}	α(K)=0.000612 *9*; α(L)=6.45×10^{-5} *9*; α(M)=1.003×10^{-5} *14* α(N)=8.52×10^{-7} *12* B(E2)(W.u.)=16 *4*
		1895.5 *1*	100 *9*	654.71	2+	[E2]	3.70×10^{-4}	α(K)=9.88×10^{-5} *14*; α(L)=1.019×10^{-5} *15*; α(M)=1.586×10^{-6} *23* α(N)=1.358×10^{-7} *19*; α(IPF)=0.000259 *4* B(E2)(W.u.)=0.26 *6*
2624.1	(0+)	1969.4 *3*	100	654.71	2+	[E2]	3.98×10^{-4}	α(K)=9.21×10^{-5} *13*; α(L)=9.49×10^{-6} *14*; α(M)=1.476×10^{-6} *21* α(N)=1.265×10^{-7} *18*; α(IPF)=0.000295 *5* B(E2)(W.u.)=23 *6*
2893.66	5−	343.3‡ *1*	100‡ *17*	2550.28	(4+)			
		1158.3‡ *8*	10‡ *3*	1735.10	4+			
3009.14	3−	2354.4 *1*	100	654.71	2+	[E1]	9.10×10^{-4}	α(K)=3.94×10^{-5} *6*; α(L)=4.03×10^{-6} *6*; α(M)=6.27×10^{-7} *9* α(N)=5.38×10^{-8} *8*; α(IPF)=0.000865 *13* B(E1)(W.u.)=0.0014 *4*
3103.3	(4+)	1368.2 *2*	100	1735.10	4+			
3144.8	6+	1409.7‡ *4*	‡	1735.10	4+	[E2]	2.53×10^{-4}	α(K)=0.0001763 *25*; α(L)=1.83×10^{-5} *3*; α(M)=2.85×10^{-6} *4* α(N)=2.43×10^{-7} *4*; α(IPF)=5.55×10^{-5} *8* B(E2)(W.u.)=12 *+3−5*
3238.78	(4+)	1507.3 *3*	75 *19*	1731.51	2+	[E2]	2.61×10^{-4}	α(K)=0.0001539 *22*; α(L)=1.594×10^{-5} *23*; α(M)=2.48×10^{-6} *4* α(N)=2.12×10^{-7} *3*; α(IPF)=8.82×10^{-5} *13* B(E2)(W.u.)=4.9 *+19−24*
		2584.0 *2*	100 *10*	654.71	2+	[E2]	6.55×10^{-4}	α(K)=5.69×10^{-5} *8*; α(L)=5.85×10^{-6} *9*; α(M)=9.10×10^{-7} *13* α(N)=7.80×10^{-8} *11*; α(IPF)=0.000591 *9* B(E2)(W.u.)=0.44 *+14−19*
3378.44	(3−)	1646.9 *3*	96 *20*	1731.51	2+	[E1]	4.44×10^{-4}	α(K)=6.77×10^{-5} *10*; α(L)=6.94×10^{-6} *10*; α(M)=1.079×10^{-6} *16* α(N)=9.25×10^{-8} *13*; α(IPF)=0.000368 *6* B(E1)(W.u.)=0.00033 *14*
		2723.7 *3*	100 *10*	654.71	2+	[E1]	1.12×10^{-3}	α(K)=3.21×10^{-5} *5*; α(L)=3.28×10^{-6} *5*; α(M)=5.10×10^{-7} *8* α(N)=4.38×10^{-8} *7*; α(IPF)=0.001086 *16* B(E1)(W.u.)=8.E−5 *3*
3445.9	0+	1714.4 *3*	100	1731.51	2+			
3454.15	(5−)	560.5 *1*	100 *20*	2893.66	5−			
		903.7 *3*	20 *4*	2550.28	(4+)			
3517.8	8+	373.0 *2*	100	3144.8	6+	[E2]	0.00706	α(K)=0.00626 *9*; α(L)=0.000687 *10*; α(M)=0.0001067 *15* α(N)=8.88×10^{-6} *13* B(E2)(W.u.)=0.56 *4*
3591.67	2+	1859.9 *2*	100 *17*	1731.51	2+	[E2]	3.57×10^{-4}	α(K)=0.0001024 *15*; α(L)=1.056×10^{-5} *15*; α(M)=1.643×10^{-6} *23* α(N)=1.407×10^{-7} *20*; α(IPF)=0.000242 *4* B(E2)(W.u.)=3.3 *+12−16*
		2182.0 *3*	16.7 *17*	1410.22	0+	[E2]	4.84×10^{-4}	α(K)=7.65×10^{-5} *11*; α(L)=7.87×10^{-6} *11*; α(M)=1.224×10^{-6} *18*

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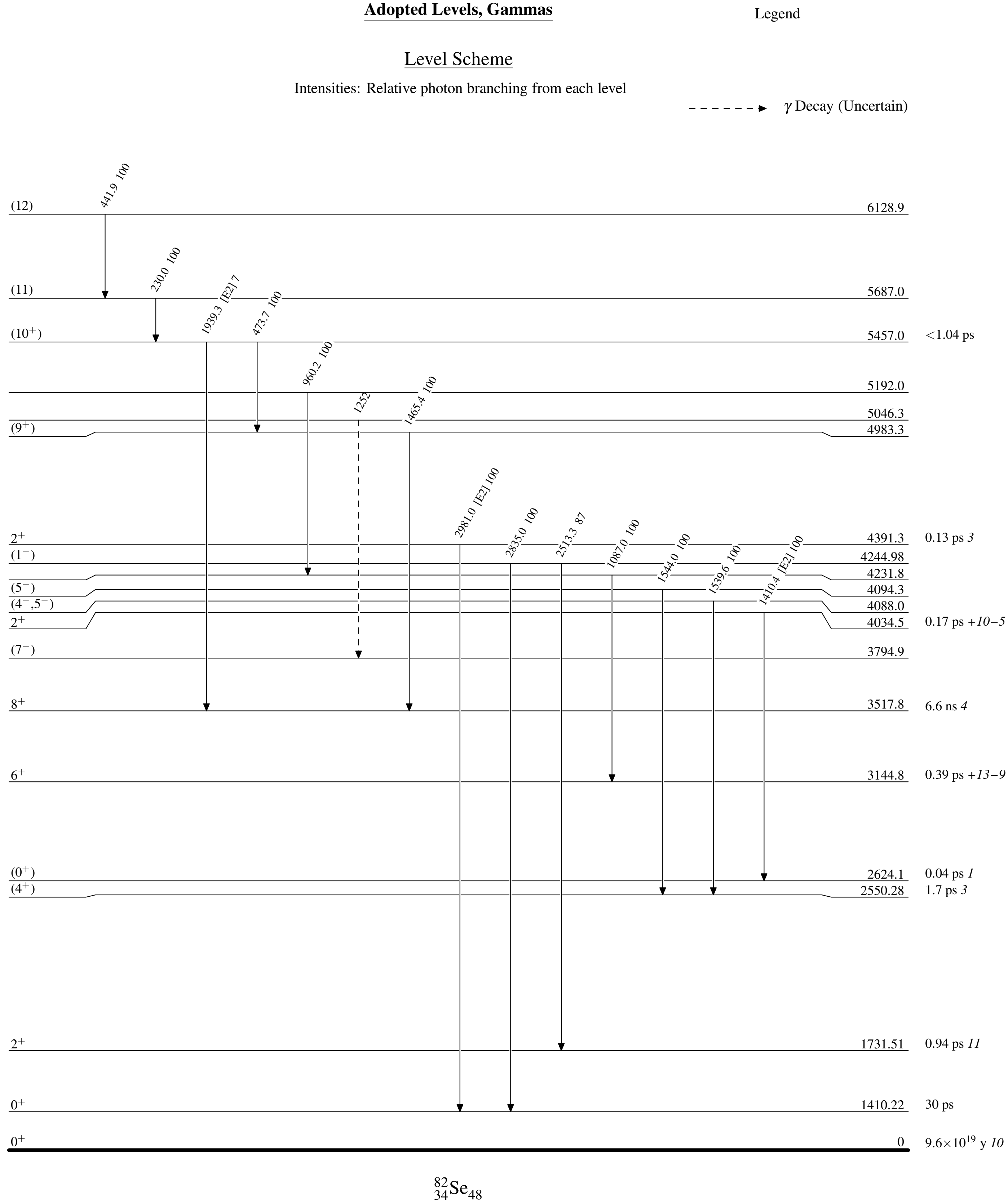
Adopted Levels, Gammas (continued)

$\gamma(^{82}Se)$ (continued)

E_i(level)	J_i^π	E_γ†	I_γ†	E_f	J_f^π	Mult.	α@	Comments
								$\alpha(N)=1.049\times10^{-7}$ *15*; $\alpha(IPF)=0.000398$ *6* B(E2)(W.u.)=0.25 *+9−12*
3591.67	2^+	3591 *1*	12 *5*	0	0^+	[E2]	1.05×10^{-3}	$\alpha(K)=3.33\times10^{-5}$ *5*; $\alpha(L)=3.41\times10^{-6}$ *5*; $\alpha(M)=5.30\times10^{-7}$ *8* $\alpha(N)=4.55\times10^{-8}$ *7*; $\alpha(IPF)=0.001017$ *15* B(E2)(W.u.)=0.015 *+8−10*
3631.26	(0^+)	1899.7 *3*	67 *14*	1731.51	2^+			
		2976.5 *2*	100 *20*	654.71	2^+			
3664.0	2^+	1113.7 *3*	100 *17*	2550.28	(4^+)			
		3009 *1*	33 *9*	654.71	2^+			
3667.5	$(1,2^+)$	3667.4# *3*	100#	0	0^+			
3688.9	(4^+)	3034.1 *5*	100	654.71	2^+			
3757.0	2^+	2346 *1*	32 *11*	1410.22	0^+			
		3102.4 *5*	100 *11*	654.71	2^+			
3794.9	(7^-)	901.2‡ *4*	100‡	2893.66	5^-			
3831.0	0^+	3176.2 *5*	100	654.71	2^+			
3865.06	(3^-)	970.4 *3*	100 *17*	2893.66	5^-			
		2134.5 *3*	83 *9*	1731.51	2^+			
3917.9	2^+	3263.1 *5*	100	654.71	2^+			
4034.5	2^+	1410.4 *2*	100	2624.1	(0^+)	[E2]	2.53×10^{-4}	$\alpha(K)=0.0001761$ *25*; $\alpha(L)=1.83\times10^{-5}$ *3*; $\alpha(M)=2.84\times10^{-6}$ *4* $\alpha(N)=2.43\times10^{-7}$ *4*; $\alpha(IPF)=5.57\times10^{-5}$ *8* B(E2)(W.u.)=28 *+9−17*
4088.0	$(4^-,5^-)$	1539.6 *3*	100	2550.28	(4^+)			
4094.3	(5^-)	1544.0 *2*	100	2550.28	(4^+)			
4231.8		1087.0‡ *7*	100‡	3144.8	6^+			
4244.98	(1^-)	2513.3‡ *2*	87‡ *5*	1731.51	2^+			
		2835.0‡ *3*	100‡ *6*	1410.22	0^+			
4391.3	2^+	2981.0 *3*	100	1410.22	0^+	[E2]	8.21×10^{-4}	$\alpha(K)=4.48\times10^{-5}$ *7*; $\alpha(L)=4.60\times10^{-6}$ *7*; $\alpha(M)=7.15\times10^{-7}$ *10* $\alpha(N)=6.14\times10^{-8}$ *9*; $\alpha(IPF)=0.000771$ *11* B(E2)(W.u.)=0.87 *21*
4983.3	(9^+)	1465.4‡ *8*	100‡	3517.8	8^+			
5046.3		1252‡& *1*	‡	3794.9	(7^-)			
5192.0		960.2‡ *5*	100‡	4231.8				
5457.0	(10^+)	473.7‡ *5*	100‡	4983.3	(9^+)			
		1939.3‡ *8*	7‡ *3*	3517.8	8^+	[E2]	3.86×10^{-4}	$\alpha(K)=9.47\times10^{-5}$ *14*; $\alpha(L)=9.77\times10^{-6}$ *14*; $\alpha(M)=1.519\times10^{-6}$ *22* $\alpha(N)=1.301\times10^{-7}$ *19*; $\alpha(IPF)=0.000280$ *4* B(E2)(W.u.)>0.061
5687.0	(11)	230.0‡ *3*	100‡	5457.0	(10^+)			
6128.9	(12)	441.9‡ *5*	100‡	5687.0	(11)			

† From (n,n′γ), unless given otherwise.
‡ From (HI,xnγ).
# From ^{82}As β^- Decay (19.1 s).
@ Additional information 1.
& Placement of transition in the level scheme is uncertain.

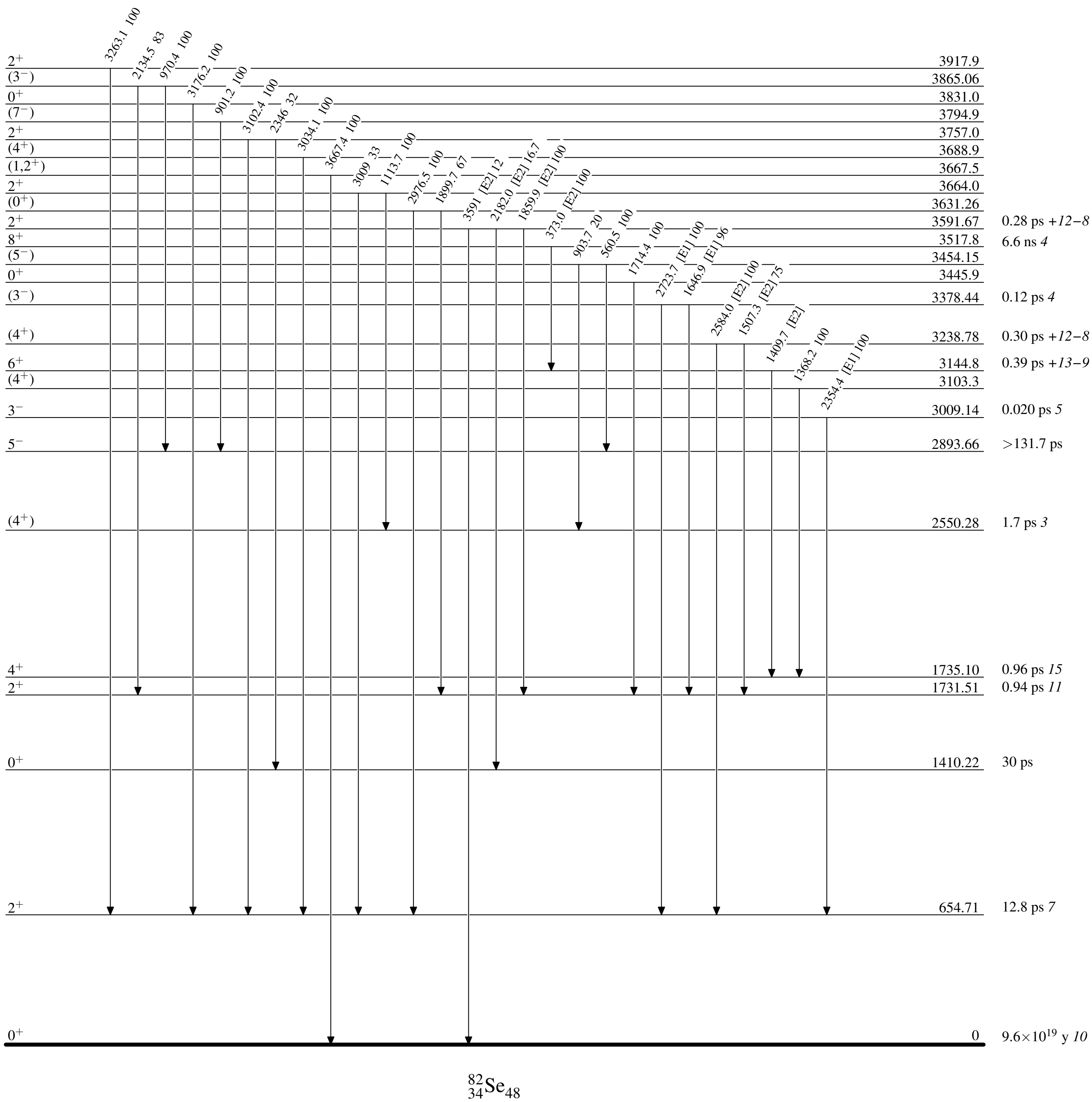
Adopted Levels, Gammas



Adopted Levels, Gammas

Level Scheme (continued)

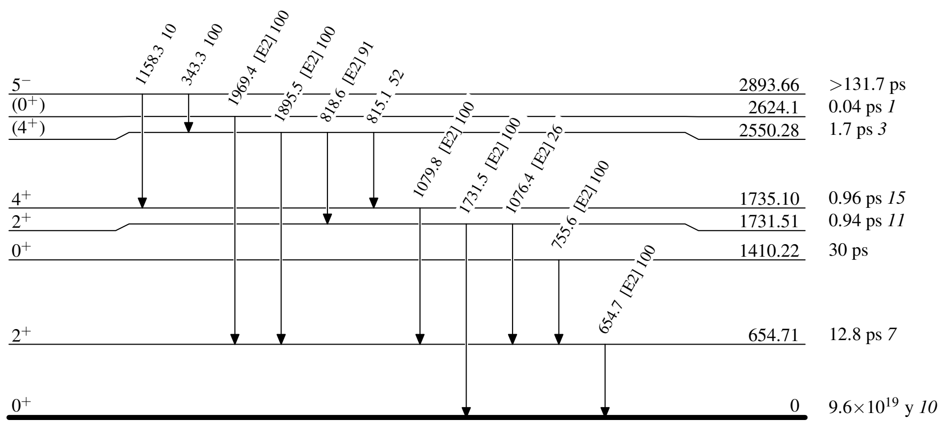
Intensities: Relative photon branching from each level



Adopted Levels, Gammas

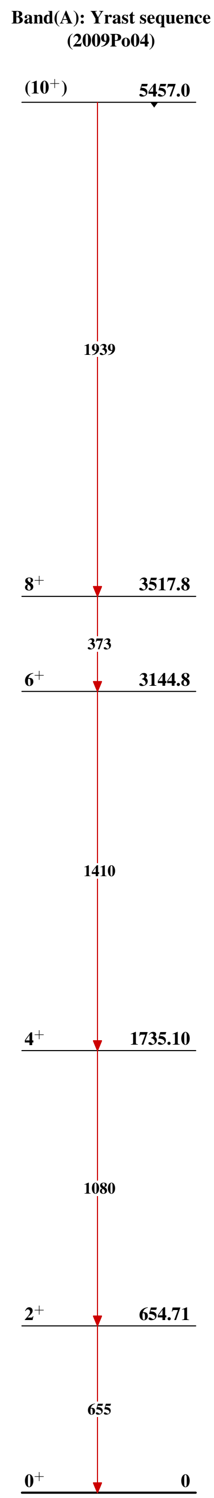
Level Scheme (continued)

Intensities: Relative photon branching from each level



$^{82}_{34}Se_{48}$

Adopted Levels, Gammas



$^{82}_{34}Se_{48}$