Adopted Levels, Gammas

Type	Author	History Citation	Literature Cutoff Date
Full Evaluation	Balraj Singh	NDS 114,1 (2013)	20-Oct-2012

Q(β^-)=−5610 *24*; S(n)=1.252×10^4 *7*; S(p)=4286 *25*; Q(α)=−5.21×10^3 *3* 2012Wa38
Note: Current evaluation has used the following Q record −5635 27 *12546* 58 *4310* 27 −5233 *33* 2011AuZZ.
S(2n)=22918 *28*, S(2p)=12210 *27* (2011AuZZ).
Values in 2003Au03: Q(β^-)=−5650 *30*, S(n)=12650 *100*, S(p)=4316 *29* Q(α)=−5230 *30*, S(2n)=22610 *70*, S(2p)=12210 *27*.
Two activities in ^{89}Nb isotope produced and identified by 1954Di16 in bombardment of Nb and Zr with protons, followed by half-life measurement. Later studies of ^{89}Nb decay: 1955Ma13, 1964Bu11, 1966Hy02, 1966Ha45, 1969HaZP, 1971Ar16, 1974Vo08, 1997Hi06.
Structure calculations: 2011Ro08, 1997He24, 1996Ru02, 1992Si15, 1985Am02.
Additional information 1.

^{89}Nb Levels

1993Bo33 give detailed shell-model calculations for high-spin (J>13/2) levels.

Cross Reference (XREF) Flags

A	^{89}Mo ε decay (2.11 min)	D	^{89}Y(α,4nγ)
B	^{58}Ni(^{36}Ar,5pγ)	E	^{90}Zr(^{3}He,p3nγ)
C	^{89}Y(^{3}He,3nγ)	F	^{92}Mo(p,α)

E(level)†	J$^\pi$‡	T$_{1/2}$#	XREF	Comments
0.0	(9/2$^+$)	2.03 h *7*	ABCDEF	%ε+%β^+=100 μ=6.216 *5* (1997Hi06,2011StZZ) %ε+%β^+: if (9/2$^+$) lies above the (1/2$^-$) state, %IT<0.004 if E(9/2$^+$ state)=35 keV. μ: from g=1.3813 *12* (NMR on oriented nuclei and $\gamma(\theta$,H,t), 1997Hi06). J$^\pi$: probable allowed ε,β^+ transition from (9/2$^+$) and systematics of niobium isotopes. Configuration=$\pi g_{9/2}$ (1993Bo33). E(level): probable g.s. (1975SeZX). T$_{1/2}$: from 1969HaZP (also 1975HaYQ). Others: 1.9 h *2* (1971Ar16), 1.9 h (1966Hy02), 2.0 h (1964Bu11), 1.9 h (1955Ma13), 1.9 h *3* (1954Di16).
<35	(1/2)$^-$	66 min *2*	A F	%ε+%β^+=100 Configuration=$\pi p_{1/2}$. Population from ^{89}Mo ε decay is uncertain. E(level): from 1975SeZX. Others: E=−30 keV to 30 keV from Eβ+ (1970HaZH), 0 *30* (2011AuZY). J$^\pi$: log *ft*=5.6 to 3/2$^-$ (see also ^{89}Nb β^+ decay), systematics of niobium isotopes. 1/2 in 1997Mo25 calculation probably corresponds to this isomer. T$_{1/2}$: from 1969HaZP (also 1975HaYQ). Others: 78 min *6* (1971Ar16), 66 min *4* (1966Ha45), 42 min (1964Bu11), 48 min (1954Di16). %IT<0.002 if E(isomer)=35 keV and if 66-min state lies above the 2.0-h state.
658.6 *2*	(7/2$^+$)	@	AB E	J$^\pi$: ΔJ=1 γ to (9/2$^+$) and systematics.
760			F	
≈838?			A	
844.0 *10*	(7/2,9/2,11/2)&		A F	
1003.41 *10*	(13/2$^+$)	@	BCDEF	J$^\pi$: ΔJ=2 γ to (9/2$^+$).

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Adopted Levels, Gammas (continued)

^{89}Nb Levels (continued)

E(level)[†]	Jπ[‡]	$T_{1/2}$[#]	XREF	Comments
				Configuration=$\pi g_{9/2}(\nu g_{9/2}^{-2})_{2+}$.
1155.3 *3*	(7/2,9/2,11/2)[&]	@	A EF	
1272.0 *3*	(7/2,9/2,11/2)[&]		A	
1550			F	
1640.2 *10*	(7/2,9/2,11/2)[&]		A	
1694.0? *4*			A F	
1789.6? *11*			A F	
1935.29 *14*	(17/2$^+$)	@	BCDE	Jπ: ΔJ=2 γ to (13/2$^+$).
2050			F	
2136.4 *2*	(15/2)	@	E	Jπ: ΔJ=1 γ to (13/2$^+$).
2151.56 *16*	(17/2$^-$)	0.51 ns *5*	BCDE	Jπ: ΔJ=(0), (D) γ to (17/2$^+$). $T_{1/2}$: recoil-distance Doppler shift (1993Bo33). Other: 6 ns *4* (γ(t),1982Di09).
2191.5 *2*			B	
2192.92 *16*	(21/2$^+$)	13.8 ns *4*	BCDE	μ=+3.40 *7* (1994Kr01,2011StZZ) μ: from g=+0.324 *7* (1994Kr01) in (HI,xnγ). Jπ: ΔJ=2, E2 γ to (17/2$^+$). $T_{1/2}$: from γ(t) (1995Ka06). Others: 14 ns *2* (1994Kr01), 14 ns *4* (1982Di09), 15 ns *5* (1977Sp03).
2221.0 *10*	(7/2,9/2,11/2)[&]		A F	XREF: F(2200).
2420.0 *10*	(7/2,9/2,11/2)[&]		A	
2517.8 *2*	(21/2$^-$)		BCDE	Jπ: ΔJ=(2) γ to (17/2$^-$).
2522.98 *18*	(19/2$^+$)	@	BCDE	Jπ: ΔJ=1 γ to (21/2$^+$).
2728.1 *3*		@	E	Jπ: γ to (17/2$^+$).
2935.0 *3*		@	E	
2955.70 *18*	(23/2$^+$)	<0.35 ps	BCDE	Jπ: ΔJ=1 γ to (21/2$^+$).
3135.2 *2*	(19/2$^-$)	@	E	Jπ: ΔJ=1 γ to (21/2$^-$) and γ to (17/2$^-$).
3141.94 *17*	(21/2$^-$)	<10 ps	B DE	
3402.99 *19*	(25/2$^+$)	3.5 ps *14*	BCDE	Jπ: ΔJ=1 γ to (23/2$^+$).
3805.68 *18*	(25/2$^-$)	34.7 ps *14*	B DE	Jπ: ΔJ=2, E2 γ to (21/2$^-$), γ to (25/2$^+$).
4076.02 *19*	(25/2$^+$)		B	Jπ: ΔJ=1 γ to (23/2$^+$), γ to (21/2$^+$).
4553.6 *2*	(27/2$^-$)	<0.7 ps	B DE	Jπ: ΔJ=1 γ to (25/2$^-$).
4797.2? *3*			B	E(level): ordering of 244-721 cascade is not established.
4808.7 *2*	(29/2$^-$)	2.70 ps *21*	B D	Jπ: ΔJ=1 γ to (27/2$^-$). $T_{1/2}$: effective half-life not corrected for feeding (1995Za11). Other: <1.4 ps (RDDS 1993Si14).
4908.5? *3*			B	E(level): ordering of 498-355 cascade is not established.
5041.3 *2*	(29/2$^+$)	0.76 ps *28*	B	Jπ: ΔJ=(2), (E2) γ to (25/2$^+$).
5324.1 *2*	(31/2$^-$)		B	Jπ: ΔJ=(1) γ to (29/2$^-$).
5407.3 *2*			B	Jπ: γ rays to (25/2$^-$) and (27/2$^-$).
5697.7 *2*	(33/2$^-$)		B	Jπ: γ to (31/2$^-$).
5917.0? *3*			B	Jπ: γ to (29/2$^+$). E(level): ordering of 183-876 cascade is not established.
6100.2 *2*	(33/2$^+$)	1.25 ps *14*	B	Jπ: ΔJ=(2), (E2) γ to (29/2$^+$), γ to (33/2$^-$). $T_{1/2}$: effective half-life not corrected for feeding (1995Za11).
6131.5 *3*			B	Jπ: γ to a level which decays to (29/2$^+$).
6451.8? *3*			B	E(level): ordering of 498-320 cascade is not established.
6547.5 *2*			B	Jπ: γ rays to (29/2$^-$) and (31/2$^-$).
6658.3? *3*			B	Jπ: γ to (33/2$^+$). E(level): ordering of 614-558 cascade is not established.
6949.6 *4*			B	
7272.6 *6*			B	

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued)

^{89}Nb Levels (continued)

† From least-squares fit to Eγ data.
‡ For levels populated in in-beam γ-ray studies, ascending spins are assumed as the excitation energy increases. Further, $\Delta J=2$ transitions are assumed as E2 and $\Delta J=1$ transitions, generally, as M1+E2.
# From recoil-distance Doppler shift (RDDS) and differential decay curve method (DDCM) (1995Za11), unless otherwise stated.
@ <4 ns from γ(t) in (^{3}He,3nγ) (1977Sp03).
& Probable ε,β^+ feeding (allowed or first forbidden) from (9/2$^+$).

Adopted Levels, Gammas (continued)

γ(^{89}Nb)

E_i(level)	J_i^π	E_γ[†]	I_γ[†]	E_f	J_f^π	Mult.[‡]	δ[#]	α[@]	Comments
658.6	(7/2$^+$)	658.6 *2*	100	0.0	(9/2$^+$)	D			E_γ: from (^{3}He,p3nγ) (1982Di09) and ^{89}Mo ε decay (1983OxZZ).
≈838?		803.0 *10*	100	<35	(1/2)$^-$				
844.0	(7/2,9/2,11/2)	844.0 *5*	100	0.0	(9/2$^+$)				
1003.41	(13/2$^+$)	1003.4 *1*	100	0.0	(9/2$^+$)	Q			
1155.3	(7/2,9/2,11/2)	496.4[&] *5*	11.0 *9*	658.6	(7/2$^+$)				
		1155.3 *3*	100 *10*	0.0	(9/2$^+$)				E_γ: from ^{89}Mo ε decay.
1272.0	(7/2,9/2,11/2)	1272.0 *3*	100	0.0	(9/2$^+$)				
1640.2	(7/2,9/2,11/2)	1640.2 *10*	100	0.0	(9/2$^+$)				
1694.0?		1035.4[&] *3*	100	658.6	(7/2$^+$)				
1789.6?		1131[&] *1*	100	658.6	(7/2$^+$)				
1935.29	(17/2$^+$)	931.88 *9*	100	1003.41	(13/2$^+$)	Q			
2136.4	(15/2)	1133.0 *2*	100	1003.41	(13/2$^+$)	D			
2151.56	(17/2$^-$)	216.2 *1*	100	1935.29	(17/2$^+$)	(E1)		0.0129	B(E1)(W.u.)=6.5×10^{-5} *7* Mult.: γ(θ) and ΔJ^π.
2191.5		1188.1 *2*	100	1003.41	(13/2$^+$)				
2192.92	(21/2$^+$)	257.7 *1*	100	1935.29	(17/2$^+$)	E2		0.0386	B(E2)(W.u.)=1.47 *5*
2221.0	(7/2,9/2,11/2)	2221.0 *10*	100	0.0	(9/2$^+$)				
2420.0	(7/2,9/2,11/2)	2420.0 *10*	100	0.0	(9/2$^+$)				
2517.8	(21/2$^-$)	366.7 *2*	100	2151.56	(17/2$^-$)	(Q)			
2522.98	(19/2$^+$)	330.1 *1*	100	2192.92	(21/2$^+$)	D			
2728.1		792.8 *2*	100	1935.29	(17/2$^+$)				
2935.0		206.9 *1*	100	2728.1					
2955.70	(23/2$^+$)	762.8 *1*	100	2192.92	(21/2$^+$)	(M1+E2)	−0.03 *2*		B(M1)(W.u.)>(0.14)
3135.2	(19/2$^-$)	617.9 *2*	100 *11*	2517.8	(21/2$^-$)	D			
		983.2 *2*	<280	2151.56	(17/2$^-$)				
3141.94	(21/2$^-$)	619.0 *1*	17.3 *24*	2522.98	(19/2$^+$)	[E1]			B(E1)(W.u.)>2.1×10^{-5}
		949.0 *2*	1.4 *5*	2192.92	(21/2$^+$)	[E1]			B(E1)(W.u.)>4.7×10^{-7}
		990.3 *1*	100 *11*	2151.56	(17/2$^-$)	(E2)			B(E2)(W.u.)>2.1
3402.99	(25/2$^+$)	447.3 *1*	100	2955.70	(23/2$^+$)	(M1+E2)	−0.10 *5*		B(M1)(W.u.)=(0.07 *3*); B(E2)(W.u.)=(4 *4*)
3805.68	(25/2$^-$)	402.7 *1*	74 *8*	3402.99	(25/2$^+$)	(E1)			B(E1)(W.u.)=6.2×10^{-5} *9* I_γ: 118 *13* in (α,4nγ).
		663.7 *1*	100 *12*	3141.94	(21/2$^-$)	E2			B(E2)(W.u.)=3.0 *5*
		850.1 *2*	5.6 *9*	2955.70	(23/2$^+$)	[E1]			B(E1)(W.u.)=5.0×10^{-7} *10*
4076.02	(25/2$^+$)	1120.3 *1*	52 *8*	2955.70	(23/2$^+$)	D+Q	−0.12 *7*		
		1883.1 *2*	100 *8*	2192.92	(21/2$^+$)				
4553.6	(27/2$^-$)	747.9 *1*	100	3805.68	(25/2$^-$)	(M1+E2)	−0.09 *6*		B(M1)(W.u.)>(0.074) δ: other: −0.20 *7*.
4797.2?		721.2 *2*	100	4076.02	(25/2$^+$)				
4808.7	(29/2$^-$)	255.1 *1*	100 *17*	4553.6	(27/2$^-$)	(M1+E2)	−0.09 *4*	0.0186 *4*	B(M1)(W.u.)=(0.28 *7*); B(E2)(W.u.)=(40 *40*)

$^{89}_{41}Nb_{48}$-4

Adopted Levels, Gammas (continued)

γ(^{89}Nb) (continued)

E_i(level)	J_i^π	E_γ[†]	I_γ[†]	E_f	J_f^π	Mult.[‡]	Comments
4808.7	(29/2$^-$)	1003.0 *1*	75 *17*	3805.68	(25/2$^-$)	[E2]	B(E2)(W.u.)=3.7 *11*
4908.5?		354.8 *2*	100	4553.6	(27/2$^-$)		
5041.3	(29/2$^+$)	244.2 *2*	10.5 *9*	4797.2?			I_γ: in table III (1993Bo33), Iγ values of 244γ and 965γ are reversed: Iγ(244γ)=26 *7*, Iγ(965γ)=10 *3*.
		965.3 *1*	26 *5*	4076.02	(25/2$^+$)	[E2]	B(E2)(W.u.)=7 *3* I_γ: see comment for 244 γ.
		1638.3 *2*	100 *10*	3402.99	(25/2$^+$)	(E2)	B(E2)(W.u.)=2.0 *8*
5324.1	(31/2$^-$)	515.4 *1*	100	4808.7	(29/2$^-$)	D	
5407.3		498.4 *3*	33 *5*	4908.5?			
		853.8 *2*	54 *5*	4553.6	(27/2$^-$)		
		1601.6 *2*	100 *13*	3805.68	(25/2$^-$)		
5697.7	(33/2$^-$)	373.6 *1*	100	5324.1	(31/2$^-$)		
5917.0?		875.7 *3*	100	5041.3	(29/2$^+$)		
6100.2	(33/2$^+$)	183.2 *3*	8.2 *27*	5917.0?			
		402.5 *2*	28 *14*	5697.7	(33/2$^-$)	[E1]	B(E1)(W.u.)=0.0009 *5*
		1058.8 *1*	100 *11*	5041.3	(29/2$^+$)	(E2)	B(E2)(W.u.)=10.6 *22*
6131.5		724.3 *2*	100	5407.3			
6451.8?		320.3 *1*	100	6131.5			
6547.5		416.0 *2*	100 *17*	6131.5			
		1223.2 *2*	43 *7*	5324.1	(31/2$^-$)		
		1738.9 *2*	97 *13*	4808.7	(29/2$^-$)		
6658.3?		558.1 *2*	100	6100.2	(33/2$^+$)		
6949.6		497.8 *2*	100	6451.8?			
7272.6		614.3 *5*	100	6658.3?			

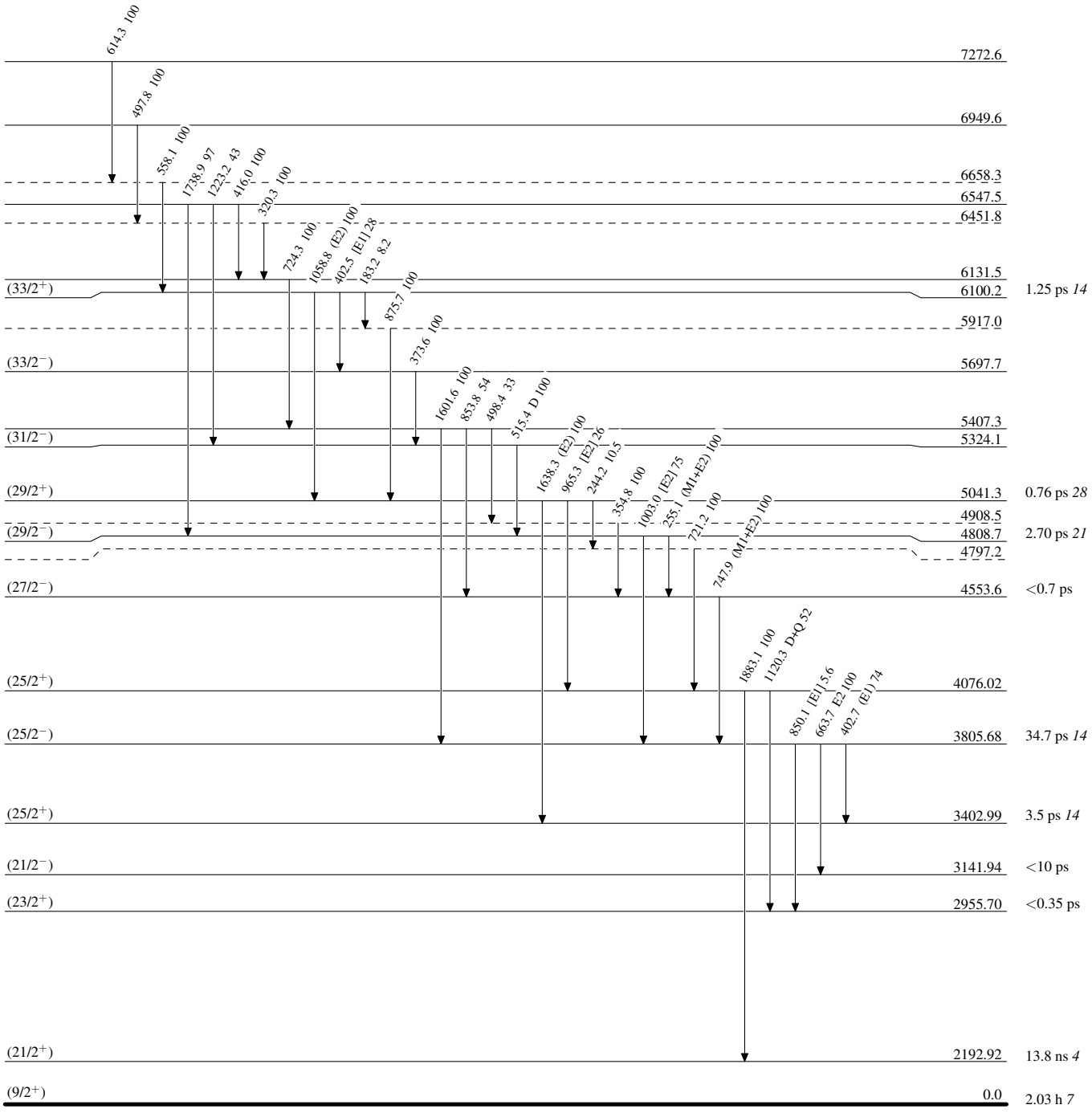
[†] For common levels populated in in-beam γ-ray studies, the values are from (HI,xnγ).
[‡] Mult=Q is from ΔJ=2, further restricted to E2 for known lifetimes. Mult=D or D+Q (restricted to M1+E2 for significant admixture) from ΔJ=1, and mult=D (E1) from ΔJ=0.
[#] From (HI,xnγ).
[@] Total theoretical internal conversion coefficients, calculated using the BrIcc code (2008Ki07) with Frozen orbital approximation based on γ-ray energies, assigned multipolarities, and mixing ratios, unless otherwise specified.
[&] Placement of transition in the level scheme is uncertain.

$^{89}_{41}Nb_{48}$-5

Adopted Levels, Gammas

Level Scheme

Intensities: Relative photon branching from each level



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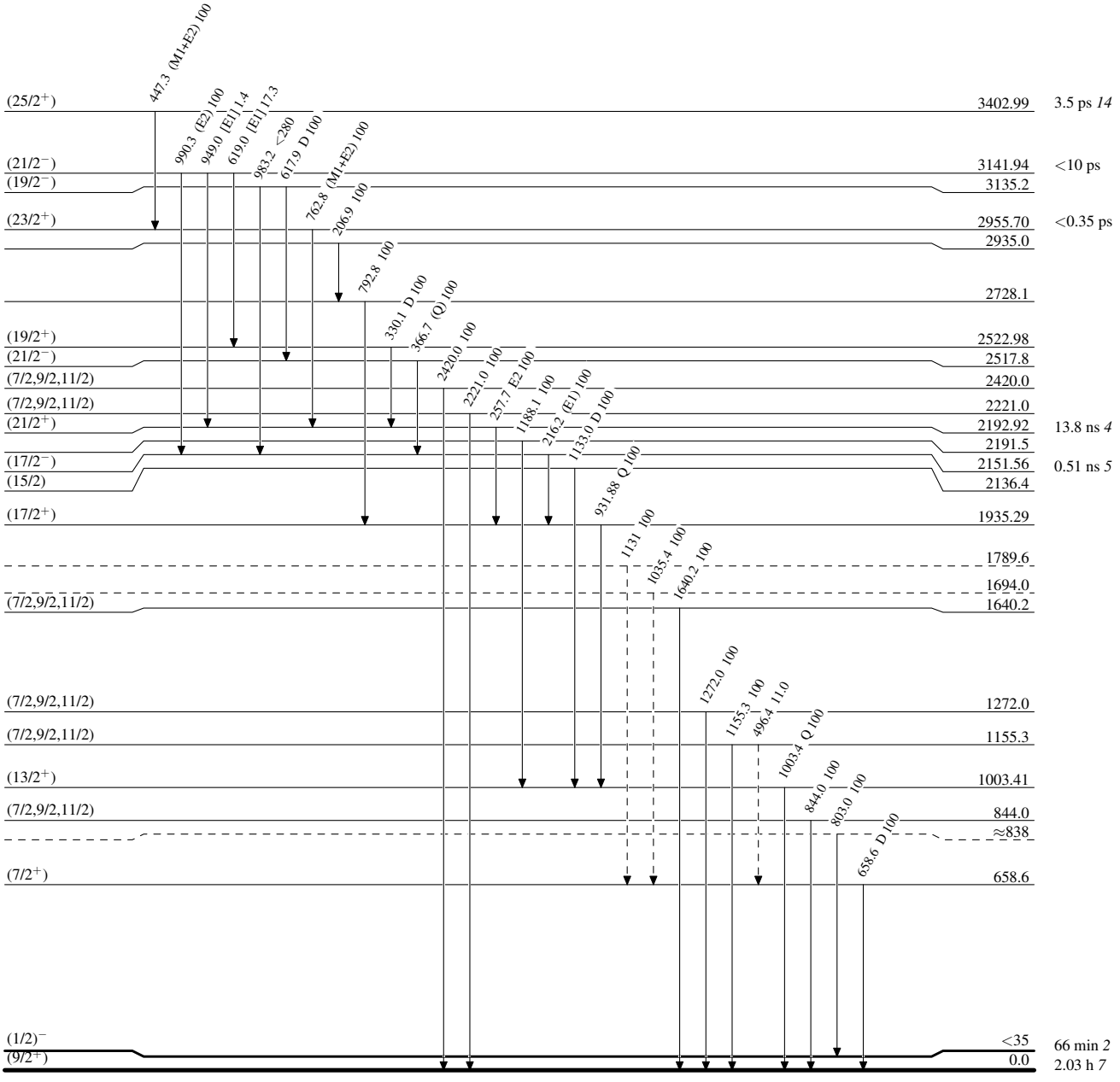
Adopted Levels, Gammas

Legend

Level Scheme (continued)

Intensities: Relative photon branching from each level

γ Decay (Uncertain)



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