(HI,xnγ) 1983Ar09,1983Ch44,1987Be20

Type	Author	History Citation	Literature Cutoff Date
Full Evaluation	Coral M. Baglin	NDS 111, 1807 (2010)	15-Jun-2010

Dataset includes ^{124}Sn(^{48}Ti,4nγ), ^{156}Gd(^{16}O,4nγ), ^{159}Tb(^{14}N,5nγ) and ^{172}Yb(α,8nγ). for ^{96}Zr(^{76}Ge,4nγ), please see separate dataset.

Others: 1964St12, 1965St03, 1967Ne02, 1972Da33, 1972Li14, 1975Sk01, 1981De36, 1986De01, 2009Co03.

2009Co03: ^{124}Sn(^{48}Ti,4nγ); E(^{48}Ti)=190 MeV; self-supporting ^{124}Sn target, ^{197}Au stopper; SPEEDY detector array (9 Compton-suppressed segmented Clover detectors grouped At 0°, 41.5° and 138.5°); measured Eγ, $\gamma\gamma$ coin, level lifetime from recoil-distance Doppler shift (coincidence mode). see also 2009PiZX.

1987Be20: ^{124}Sn(^{48}Ti,4nγ); E(^{48}Ti)=210, 215 MeV; HERA array (21 Compton-suppressed Ge detectors); measured Eγ, Iγ, angular correlations.

1983Ch44: ^{156}Gd(^{16}O,4nγ), E(^{16}O)=85 MeV; ^{124}Sn(^{48}Ti,4nγ), E(^{48}Ti)=216 MeV; 5 or 6 Compton-suppressed Ge detectors; measured Eγ, Iγ, $\gamma\gamma$ coin, $\gamma(\theta)$, γ-ray multiplicities (using 50 bismuth-germanate crystal array), ce spectra.

1983Ar09: ^{159}Tb(^{14}N,5nγ); E(^{14}N)=92-95 MeV; large-solid-angle Compton-suppression spectrometer with average suppression≈10, Ge(Li) and NaI detectors; measured Eγ, Iγ, $\gamma\gamma$ coin, $\gamma(\theta)$ (5 angles between 90° and 150°).

1981Ja11: ^{159}Tb(^{14}N,5nγ); E(^{14}N)=95 MeV; two Compton-suppression spectrometers, Ge(Li) detector; measured Eγ, Iγ, $\gamma(\theta)$ At 5 angles (90° to 156°).

1977Bo14: ^{124}Sn(^{48}Ti,4nγ); E(^{48}Ti)=195 MeV. ^{122}Sn(^{50}Ti,4nγ); E(^{50}Ti)=198 MeV.

1972Li34: ^{172}Yb(α,8nγ); E(α)=100 MeV.

The level scheme is from 1987Be20. Data are from 1983Ar09, 1983Ch44, and 1987Be20 (reactions listed above).

See 1981De36, 1983Ar09, and 1986De01 for measurements of continuum γ-ray spectra at high spins.

See 1978Be24 for γ-ray yields for population of states up through 16$^+$ in ^{181}Ta(π^-,13nγ).

Others: 1973Ne08 (decay timing in ^{152}Sm(^{20}Ne,4nγ)), 1981Hj01 (γ-ray multiplicities in ^{164}Dy(^{12}C,^{8}Nγ)), 1982Pe10 and 1983Pe21 (γ-ray multiplicities in ^{160}Gd(^{16}O,^{8}Nγ)), 1988St11 (γ-ray energy correlations at very high spins in ^{124}Sn(^{48}Ti,4nγ)).

^{168}Hf Levels

The orbitals associated with the quasiparticle labels used here are the following:
α: ν 5/2[642], α=+1/2;
B: ν 5/2[642], α=−1/2;
E: ν 5/2[523], α=+1/2;
F: ν 5/2[523], α=−1/2.

E(level)[†]	J^{π}[‡]	$T_{1/2}$[#]	Comments
0.0[&]	0$^+$		
124.0[&] *2*	2$^+$	0.89 ns *4*	
385.6[&] *3*	4$^+$	30.6[@] ps *15*	other $T_{1/2}$: 36 ps *4* (1977Bo14).
756.9[&] *4*	6$^+$	4.9[@] ps *3*	other $T_{1/2}$: 5.9 ps *6* (1977Bo14).
1213.6[&] *4*	8$^+$	1.46[@] ps *18*	other $T_{1/2}$: 1.98 ps *19* (1977Bo14).
1735.6[&] *5*	10$^+$	0.71[@] ps *10*	$T_{1/2}$: 10%−15% correction applied by 2009Co03 to account for contribution from unshifted component to shifted peak. other $T_{1/2}$: 1.00 ps *15* (1977Bo14).
1813.2[c] *4*	6$^-$		
1992.3[a] *5*	6$^-$		
2066.7[b] *5*	9$^-$		
2081.9[e] *8*			
2155.5[c] *5*	8$^-$		
2193.2[a] *4*	8$^-$		
2305.6[&] *5*	12$^+$	0.52 ps *18*	
2322.0[e] *5*	(9$^-$)		

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(HI,xnγ) 1983Ar09,1983Ch44,1987Be20 (continued)

^{168}Hf Levels (continued)

E(level)[†]	Jπ[‡]	$T_{1/2}$[#]	E(level)[†]	Jπ[‡]	E(level)[†]	Jπ[‡]
2466.6[a] 5	10⁻		4439.5[d] 8	20⁺	7562.8[d] 11	28⁺
2473.8[b] 5	11⁻		4578.2[b] 8	19⁻	7663 2	
2553.1[c] 6	10⁻		4579.4[c] 8	18⁻	7860.6[a] 10	28⁻
2646.6[e] 6	(11⁻)		4933.8[a] 8	20⁻	8199.5[b] 11	29⁻
2828.0[a] 5	12⁻		5049.1[&] 7	20⁺	8501.9[d] 12	30⁺
2857.0[d] 6	14⁺	0.84 ps 18	5123.9[d] 8	22⁺	8762.7[a] 10	30⁻
2937.6[b] 5	13⁻		5199.0[b] 9	21⁻	9116.4[b] 11	31⁻
2976.9[c] 6	12⁻		5214.7[c] 9	20⁻	9501.3[d] 12	32⁺
2989.8[&] 6	14⁺		5574.1[a] 9	22⁻	9730.6[a] 11	32⁻
3269.0[a] 6	14⁻		5763.1[&] 12	(22⁺)	10093.3[b] 11	33⁻
3309.9[d] 7	16⁺	1.82 ps 20	5855.1[b] 9	23⁻	10552.0[d] 13	34⁺
3442.0[b] 7	15⁻		5874.9[d] 9	24⁺	10756.6[a] 11	34⁻
3452.7[c] 7	14⁻		5895.3[c] 9	22⁻	11119.8[b] 12	35⁻
3623.8[&] 6	16⁺		6268.7[a] 9	24⁻	11639.0[d] 13	36⁺
3777.2[a] 7	16⁻		6567.7[b] 10	25⁻	11828.5[a] 12	36⁻
3831.9[d] 7	18⁺		6629.4[c] 10	24⁻	12182.3[b] 12	37⁻
3989.4[c] 8	16⁻		6687.5[d] 10	26⁺	12743.5[d] 14	(38⁺)
3989.7[b] 8	17⁻		7029.2[a] 10	26⁻	12932[a] 2	(38⁻)
4322.4[&] 7	18⁺		7348.6[b] 10	27⁻	13258[b] 2	(39⁻)
4335.8[a] 8	18⁻		7424.9[c] 10	(26⁻)	14346[b] 2	(41⁻)

[†] From least-squares fit to Eγ.

[‡] From angular correlation data for γ rays in projected coincidence spectra, and fits of γ-ray cascades into interconnected bands (1987Be20). Cranking-model calculations explain the band-crossing at 14⁺ as resulting from alignment of the $i_{13/2}$ neutrons. See Adopted Levels for evaluator's assignments.

[#] From recoil-distance Doppler-shift In singles mode (1977Bo14), except As noted.

[@] From RDDS using differential decay curve method (2009Co03). Authors' average of values obtained for deexciting γ gated by direct or indirect feeding γ with four different detector angle combinations.

[&] Band(A): $K^{\pi}=0^+$ g.s. band.

[a] Band(B): $K^{\pi}=5^-$, α=0 AF band.

[b] Band(C): $K^{\pi}=5^-$, α=1 AE band.

[c] Band(D): π=−, α=0 BE? band.

[d] Band(E): yrast band. Band built on 14⁺ 2857 level; crosses g.s. band at $J^{\pi}=14^+$.

[e] Band(F): π=(−), α=1 band fragment.

γ(^{168}Hf)

E_γ[†]	I_γ[‡]	E_i(level)	J_i^π	E_f	J_f^π	Mult.	α[a]	Comments
124.0 2		124.0	2⁺	0.0	0⁺	E2	1.553	Mult.: A_2=+0.20 2, A_4=−0.07 3 (1983Ar09); A_2=+0.27 2, A_4=−0.01 2 (1972Li34). not M2 from RUL.
144.6 3	1.5	2466.6	10⁻	2322.0	(9⁻)	(M1)[#]	1.399	Mult.: ΔJ=1 transition (1987Be20).
181.4 3	1	2828.0	12⁻	2646.6	(11⁻)	(M1)[#]	0.739	Mult.: ΔJ=1 transition (1987Be20).
201.0 3	1.4	2193.2	8⁻	1992.3	6⁻			
240 1	<1	2322.0	(9⁻)	2081.9				
261.6 2	100	385.6	4⁺	124.0	2⁺	E2	0.1205	Mult.: A_2=+0.22 2, A_4=−0.04 3 (1983Ar09); A_2=+0.31 1, A_4=0.00 2 (1972Li34). not M2 from RUL.

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(HI,xnγ) 1983Ar09,1983Ch44,1987Be20 (continued)

γ(^{168}Hf) (continued)

E_γ[†]	I_γ[‡]	E_i(level)	J_i^π	E_f	J_f^π	Mult.	α[a]	Comments
273.3 3	7.9	2466.6	10^-	2193.2	8^-	(E2)[#]	0.1052	
311.1 3	2	2466.6	10^-	2155.5	8^-	(E2)[#]	0.0711	
320 1	2.0	3309.9	16^+	2989.8	14^+	E2[&]	0.0654 11	Mult.: Q from γ(θ) (1981Ja11); not M2 from RUL.
325 1	<1	2646.6	(11^-)	2322.0	(9^-)	(E2)[#]	0.0625 11	
331[b] 1	1	2066.7	9^-	1735.6	10^+	(E1)[#]	0.0169 3	Mult.: adopted value is (E2) and γ feeds a 7^- 1734 level.
342.3 3	4	2155.5	8^-	1813.2	6^-	(E2)[#]	0.0537	
361.4 3	10.8	2828.0	12^-	2466.6	10^-	(E2)[#]	0.0460	
371.3 2	100	756.9	6^+	385.6	4^+	E2	0.0427	Mult.: A_2=+0.21 2, A_4=−0.06 3 (1983Ar09); A_2=+0.29 2, A_4=−0.02 2 (1972Li34). not M2 from RUL.
380.0 3	2.3	2193.2	8^-	1813.2	6^-	(E2)[#]	0.0400	
397.6 3	3.6	2553.1	10^-	2155.5	8^-	(E2)[#]	0.0353	
399.8 3	1.3	2466.6	10^-	2066.7	9^-	(M1)[#]	0.0863	
407.1 3	5.0	2473.8	11^-	2066.7	9^-	(E2)[#]	0.0331	
423.8 3	4.0	2976.9	12^-	2553.1	10^-	(E2)[#]	0.0297	
441.0 3	13.9	3269.0	14^-	2828.0	12^-	(E2)[#]	0.0267	
452 1	1	3442.0	15^-	2989.8	14^+	(E1)[#]		
452.9 3	44	3309.9	16^+	2857.0	14^+	(E2)	0.0249	
456.6 3	96	1213.6	8^+	756.9	6^+	E2	0.0244	Mult.: A_2=+0.31 3, A_4=−0.09 3 (1983Ar09); A_2=+0.34 2, A_4=+0.05 3 (1972Li34). not M2 from RUL.
463.7 3	13.7	2937.6	13^-	2473.8	11^-	(E2)[#]	0.0234	
475.8 3	4.0	3452.7	14^-	2976.9	12^-	(E2)[#]	0.0219	
504.4 5	15	3442.0	15^-	2937.6	13^-	(E2)[#]	0.0189	
508.2 3	12.9	3777.2	16^-	3269.0	14^-	(E2)[#]	0.0186	
[x]522 1								
522.0 3	80	1735.6	10^+	1213.6	8^+	E2[&]	0.01738	Mult.: A_2=+0.20 2, A_4=−0.05 3 (1983Ar09) for 522.0 doublet; A_2=+0.34 3, A_4=+0.02 4 (1972Li34). Q from 1981Ja11; not M2 from RUL.
522.0 3	36	3831.9	18^+	3309.9	16^+	Q[&]		Mult.: A_2=+0.20 2, A_4=−0.05 3 (1983Ar09) for doublet.
536.7 3	3.3	3989.4	16^-	3452.7	14^-	(E2)[#]	0.01623	
547.7 3	14.5	3989.7	17^-	3442.0	15^-	(E2)[#]	0.01544	
551.5 3	49	2857.0	14^+	2305.6	12^+	E2	0.01518	Mult.: A_2=+0.20 3, A_4=−0.05 4 (1983Ar09). not M2 from RUL. other: A_2=+0.33 5, A_4=+0.04 7 (1972Li34) for line contaminated by 12^+ to 10^+ transition In ^{170}Hf.
558.6 3	12.5	4335.8	18^-	3777.2	16^-	(E2)[#]	0.01472	
570.1 3	70	2305.6	12^+	1735.6	10^+	E2	0.01402	Mult.: A_2=+0.20 2, A_4=−0.05 3 (1983Ar09). not M2 from RUL. Additional information 1.
588.5 3	13.8	4578.2	19^-	3989.7	17^-	(E2)[#]	0.01299	
590.0 3	2.5	4579.4	18^-	3989.4	16^-	(E2)[#]	0.01291	
598.0 3	11.4	4933.8	20^-	4335.8	18^-	(E2)[#]	0.01251	
[x]600[@]								
607.6 3	29	4439.5	20^+	3831.9	18^+	Q		Mult.: A_2=+0.15 8, A_4=−0.04 12 (1983Ar09).
619.6 3	11.1	5199.0	21^-	4578.2	19^-	(E2)[#]	0.01151	
[x]627 1								

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(HI,xnγ) 1983Ar09,1983Ch44,1987Be20 (continued)

γ(^{168}Hf) (continued)

E_γ[†]	I_γ[‡]	E_i(level)	J^π_i	E_f	J^π_f	Mult.	α[a]	Comments
632.1 3	15	2937.6	13⁻	2305.6	12⁺	(E1)[#]		I_γ: combined value for 632.1γ and 633.9γ.
633.9 3	15	3623.8	16⁺	2989.8	14⁺	(E2)[#]	0.01092	I_γ: combined value for 632.1γ and 633.9γ.
635.3 3	1.6	5214.7	20⁻	4579.4	18⁻	(E2)[#]	0.01086	
640.3 3	8.6	5574.1	22⁻	4933.8	20⁻	(E2)[#]	0.01067	
[x]649[@]								
656.1 3	8.9	5855.1	23⁻	5199.0	21⁻	(E2)[#]	0.01009	
680.6 3	1.3	5895.3	22⁻	5214.7	20⁻	(E2)[#]		
684.0 3	12	2989.8	14⁺	2305.6	12⁺	Q[&]		
684.4 3	24	5123.9	22⁺	4439.5	20⁺	Q		Mult.: A_2=+0.19 11, A_4=−0.07 17 (1983Ar09).
694.6 3	7.2	6268.7	24⁻	5574.1	22⁻	(E2)[#]		
698.6 3	6.2	4322.4	18⁺	3623.8	16⁺	(E2)[#]		
[x]703 1								
712.6 3	7.0	6567.7	25⁻	5855.1	23⁻	(E2)[#]		
714[b] 1	2.2	5763.1	(22⁺)	5049.1	20⁺	(E2)[#]		
726.7 3	5.1	5049.1	20⁺	4322.4	18⁺	(E2)[#]		
734.1 3	1	6629.4	24⁻	5895.3	22⁻	(E2)[#]		
738.2 3	9	2473.8	11⁻	1735.6	10⁺	(E1)[#]		
751.0 4	18	5874.9	24⁺	5123.9	22⁺	Q		Mult.: A_2=+0.12 18, A_4=−0.2 3 (1983Ar09).
760.5 3	6.4	7029.2	26⁻	6268.7	24⁻	(E2)[#]		
[x]763 1								
767.0 3	3.4	3623.8	16⁺	2857.0	14⁺	(E2)[#]		
780.9 3	5.1	7348.6	27⁻	6567.7	25⁻	(E2)[#]		
795.5[b] 3	<1	7424.9	(26⁻)	6629.4	24⁻	(E2)[#]		
[x]812 1								
812.6 3	13	6687.5	26⁺	5874.9	24⁺	Q		Mult.: A_2=+0.22 21, A_4=−0.12 30 (1983Ar09).
831.4 3	4.3	7860.6	28⁻	7029.2	26⁻	(E2)[#]		
850.9 3	11.5	8199.5	29⁻	7348.6	27⁻	(E2)[#]		I_γ: combined value for 850.9γ and 853.0γ.
853.0 3	11.5	2066.7	9⁻	1213.6	8⁺	(E1)[#]		I_γ: combined value for 850.9γ and 853.0γ.
875.3 4	7.3	7562.8	28⁺	6687.5	26⁺	(E2)[#]		
902.1 3	2.9	8762.7	30⁻	7860.6	28⁻	(E2)[#]		
916.9 3	2.4	9116.4	31⁻	8199.5	29⁻	(E2)[#]		
939.1 5	3.9	8501.9	30⁺	7562.8	28⁺	(E2)[#]		
942 1	<1	2155.5	8⁻	1213.6	8⁺	(E1)[#]		
967.9 3	1.8	9730.6	32⁻	8762.7	30⁻	(E2)[#]		
975[b] 1	<1	7663		6687.5	26⁺			
976.9 3	1.7	10093.3	33⁻	9116.4	31⁻	(E2)[#]		
979.4 3	4	2193.2	8⁻	1213.6	8⁺	(E1)[#]		
999.4 3	2.5	9501.3	32⁺	8501.9	30⁺	(E2)[#]		
1026.0 3	1.3	10756.6	34⁻	9730.6	32⁻	(E2)[#]		
1026.5 3	1.4	11119.8	35⁻	10093.3	33⁻	(E2)[#]		
1050.7 5	1.6	10552.0	34⁺	9501.3	32⁺	(E2)[#]		
1056.4 3	5	1813.2	6⁻	756.9	6⁺	(E1)[#]		
1062.5 3	0.8	12182.3	37⁻	11119.8	35⁻	(E2)[#]		
1071.9 3	0.7	11828.5	36⁻	10756.6	34⁻	(E2)[#]		
1076[b] 1	<0.5	13258	(39⁻)	12182.3	37⁻	(E2)[#]		
1087.0 3	1	11639.0	36⁺	10552.0	34⁺	(E2)[#]		

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(HI,xnγ) 1983Ar09,1983Ch44,1987Be20 (continued)

γ(^{168}Hf) (continued)

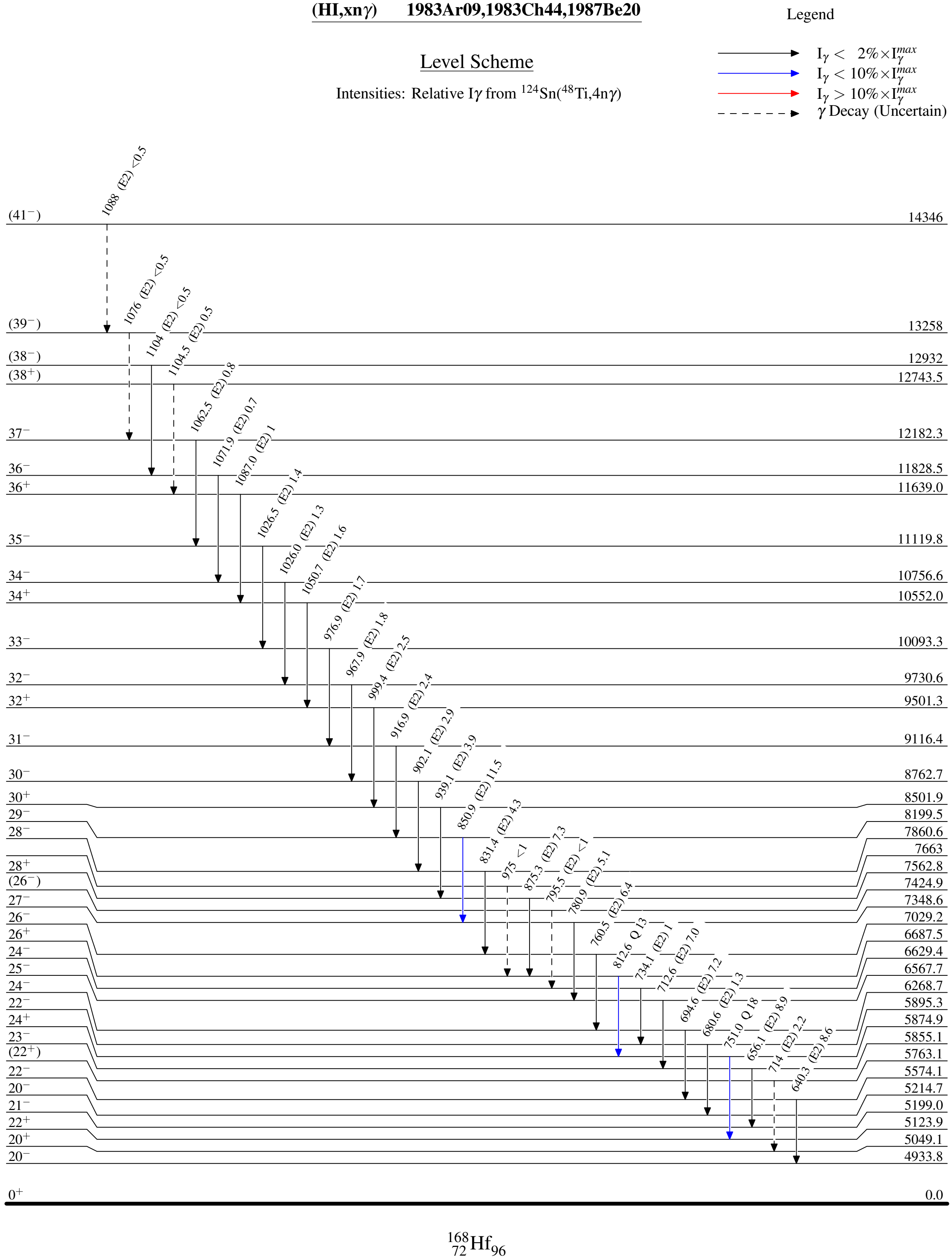
E_γ[†]	I_γ[‡]	E_i(level)	J^π_i	E_f	J^π_f	Mult.
1088[b] *1*	<0.5	14346	(41^-)	13258	(39^-)	(E2)[#]
1104 *1*	<0.5	12932	(38^-)	11828.5	36^-	(E2)[#]
1104.5[b] *3*	0.5	12743.5	(38^+)	11639.0	36^+	(E2)[#]
1109 *1*	2	2322.0	(9^-)	1213.6	8^+	(E1)[#]
1236[b] *1*	1	1992.3	6^-	756.9	6^+	
1325 *1*	1	2081.9		756.9	6^+	

[†] Weighted average from 1983Ar09 and 1987Be20.
[‡] Arbitrary units relative to Iγ(261.6γ)=100 (1987Be20); ΔIγ≈10% except for weak transitions (ΔIγ up to 50%).
[#] Inferred from level scheme In 1983Ch44; authors report that J^π values were established from ce and γ(θ) data, but those data are not enumerated.
[@] Appears to belong to ^{168}Hf, but could not Be placed In level scheme (1987Be20).
[&] Stretched Q based on A_2 between +0.20 and +0.34, A_4 between −0.01 and −0.09 (1981Ja11). A_2 and A_4 for specific transitions not listed by authors.
[a] 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.
[b] Placement of transition in the level scheme is uncertain.
[x] γ ray not placed in level scheme.

(HI,xnγ) 1983Ar09,1983Ch44,1987Be20

Level Scheme

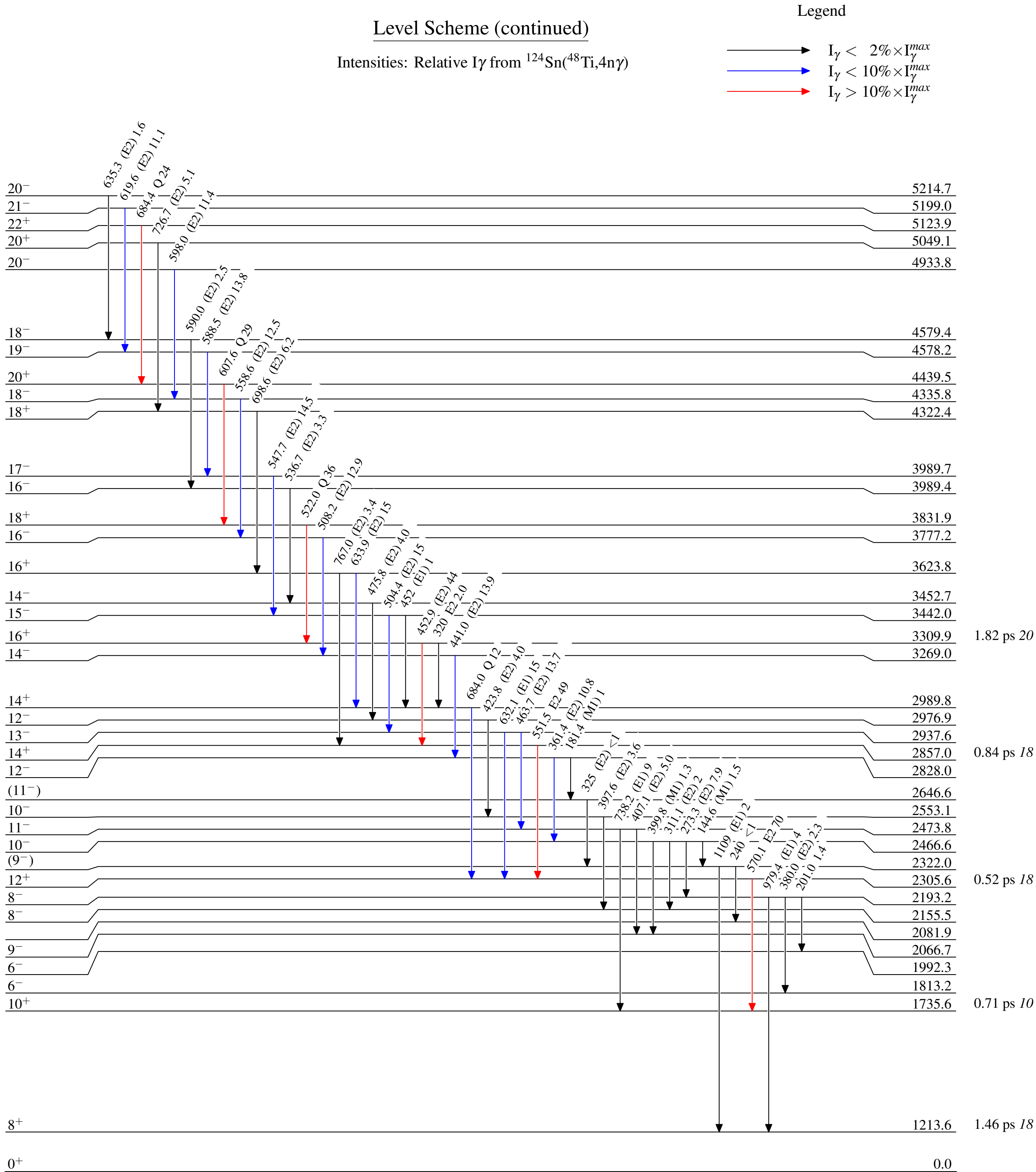
Intensities: Relative Iγ from $^{124}Sn(^{48}Ti,4n\gamma)$



(HI,xnγ) 1983Ar09,1983Ch44,1987Be20

Level Scheme (continued)

Intensities: Relative Iγ from $^{124}Sn(^{48}Ti,4n\gamma)$

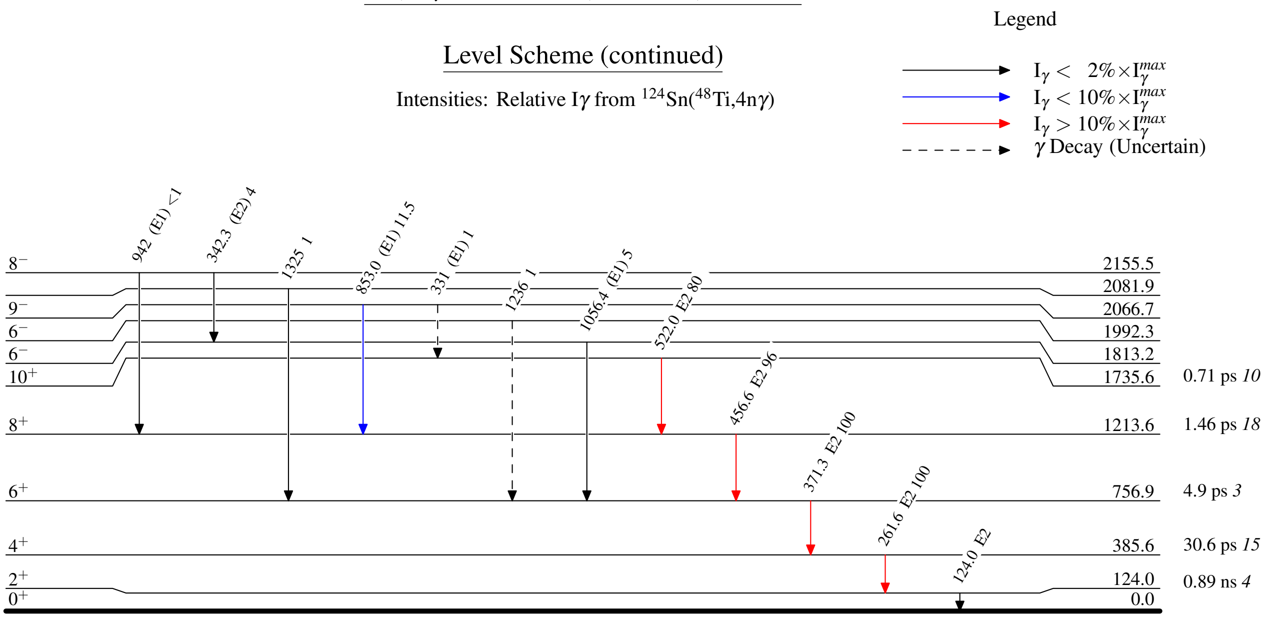


$^{168}_{72}Hf_{96}$

(HI,xnγ) 1983Ar09,1983Ch44,1987Be20

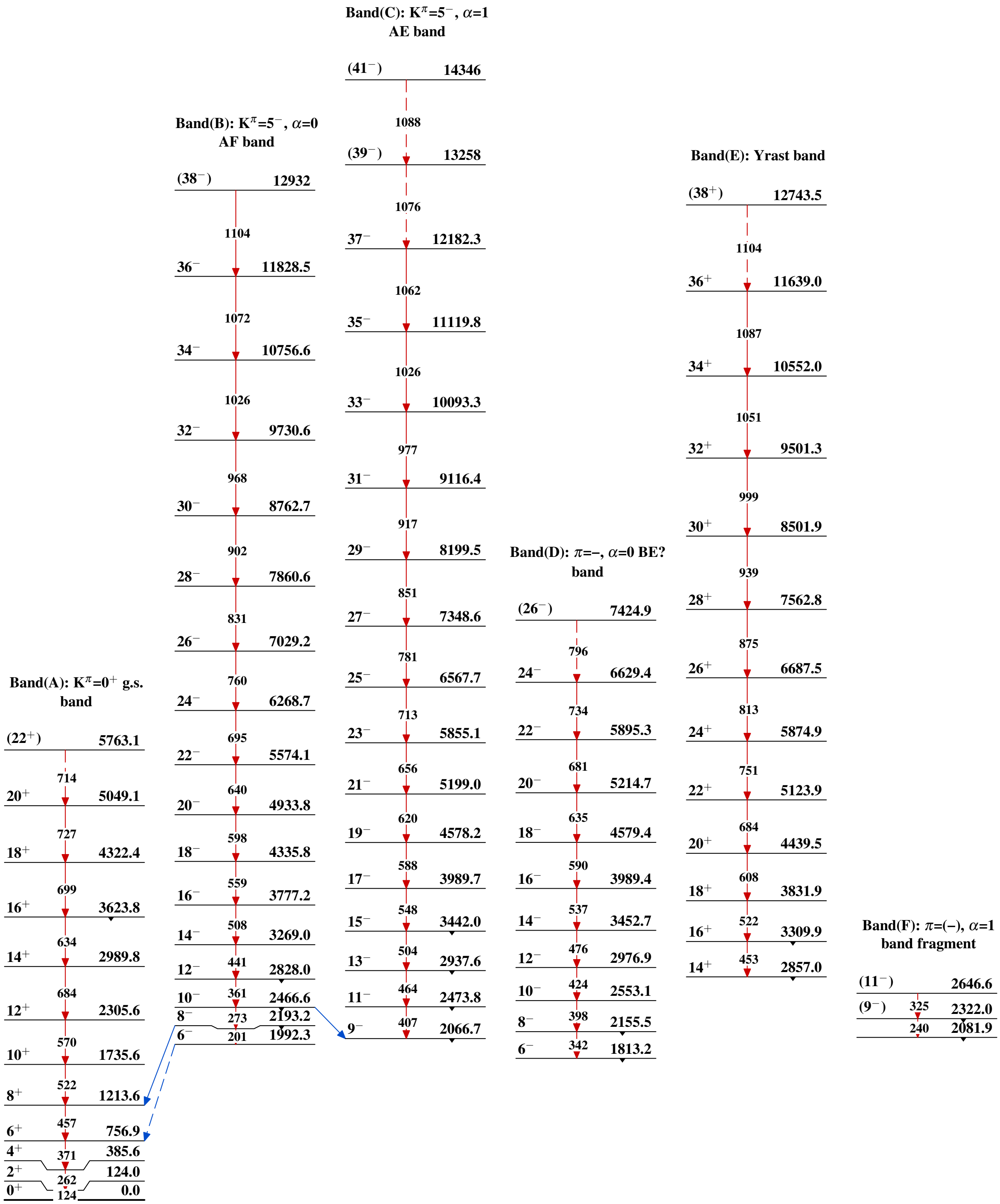
Level Scheme (continued)

Intensities: Relative Iγ from $^{124}Sn(^{48}Ti,4n\gamma)$



$^{168}_{72}Hf_{96}$

(HI,xnγ) 1983Ar09,1983Ch44,1987Be20



$^{168}_{72}Hf_{96}$