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Nuclear Data Sheets for A=213*

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Abstract: Evaluated spectroscopic data and level schemes from radioactive decay and nuclear reaction studies are presented for ^{213}Hg, ^{213}Tl, ^{213}Pb, ^{213}Bi, ^{213}Po, ^{213}At, ^{213}Rn, ^{213}Fr, ^{213}Ra, ^{213}Ac, ^{213}Th, and ^{213}Pa. This evaluation for A=213 supersedes the earlier one by the same evaluator, M. S. Basunia (2007Ba19), published in Nuclear Data Sheets 108, 633 (2007).

One highlight of this evaluation is the following:

In ^{213}Po, from ^{208}Pb(^{18}O,Xγ) study 2011As05 proposed revision of spin-parity assignments for 293 level: $7/2^+$ instead of $(11/2^+)$; 440 level: $11/2^+$ instead of $(7/2^+)$; 868 level: $9/2^+$ instead of $(13/2^+)$. New experiments are needed.

Cutoff Date: All data received prior to Jan 1, 2022, have been considered. During this evaluation, the NSR database (2014Pr09) was used extensively.

General Policies and Organization of Material: See the January issue of the *Nuclear Data Sheets* or http://www.nndc.bnl.gov/nds/NDSPolicies.pdf.

Acknowledgements: This evaluation benefits from earlier evaluations by Y. A. Akovali (1992Ak01), Y. A. Ellis (1979El08), C. Maples (1973Ma63), and the ENSDF evaluation of ^{213}Hg by B. Singh and M. Birch (Dated 15-May-2011) and ^{213}Tl by B. Singh (Dated 25-Sep-2012). The evaluator is thankful to the compilers of XUNDL datasets. Also the support of Dr. B. Pritychenko and Mrs. J. Totans (NNDC, BNL) during the evaluation process is deeply acknowledged. The evaluator is grateful to Dr. F.G. Kondev (ANL) for a critical review of the manuscript and useful comments/suggestions and to Dr. E. McCutchan (NNDC, BNL) for the editorial comments and preparation of this manuscript for publication.

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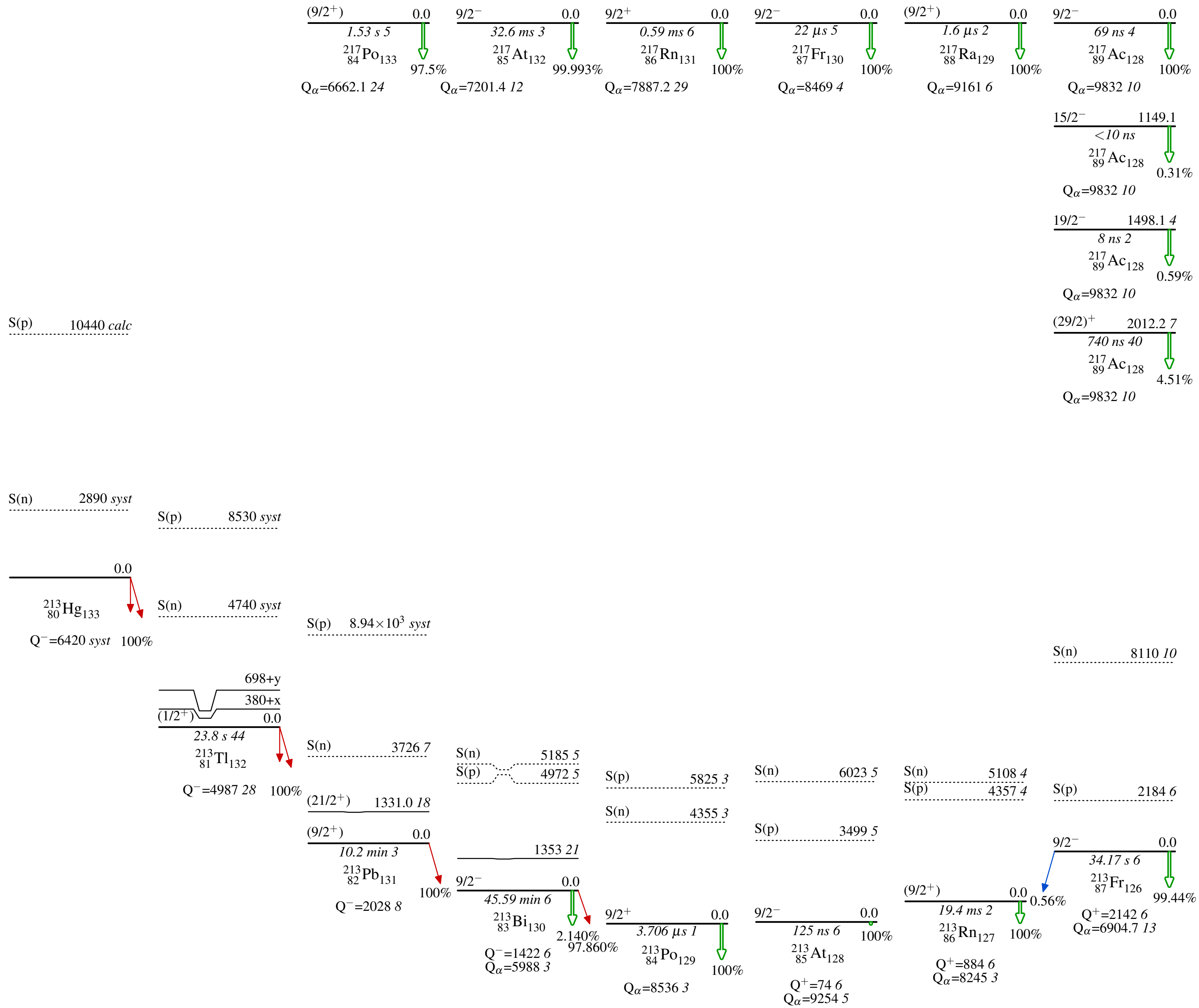
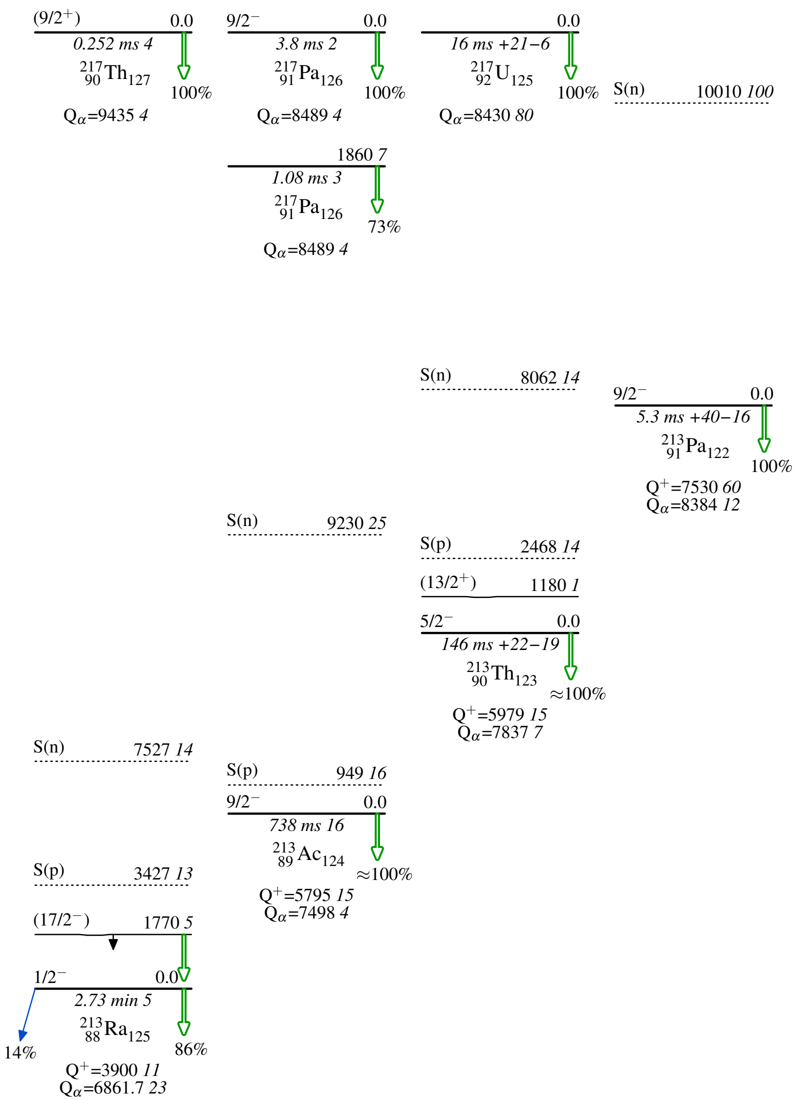
Index for A=213

Skeleton Scheme for A=213



Skeleton Scheme for A=213 (continued)



Ground-State and Isomeric-Level Properties

Nuclide	Level	Jπ	$T_{1/2}$	Decay Mode
^{213}Hg	0.0			%β^-=100; %β^-n=?
^{213}Tl	0.0	(1/2$^+$)	23.8 s *44*	%β^-=100; %β^-n=7.6 *34*
^{213}Tl	380+x		4.1 μs *5*	
^{213}Tl	698+y		0.6 μs *3*	
^{213}Pb	0.0	(9/2$^+$)	10.2 min *3*	%β^-=100
^{213}Pb	1331.0	(21/2$^+$)	0.26 ms *2*	
^{213}Bi	0.0	9/2$^-$	45.59 min *6*	%α=2.140 *10*; %β^-=97.860 *10*
^{213}Bi	1353			
^{213}Po	0.0	9/2$^+$	3.706 μs *1*	%α=100
^{213}At	0.0	9/2$^-$	125 ns *6*	%α=100
^{213}Rn	0.0	(9/2$^+$)	19.4 ms *2*	%α=100
^{213}Fr	0.0	9/2$^-$	34.17 s *6*	%α=99.44 *5*; %ε+%β^+=0.56 *5*
^{213}Ra	0.0	1/2$^-$	2.73 min *5*	%α=86 *2*; %ε+%β^+=14 *2*
^{213}Ra	1770	(17/2$^-$)	2.18 ms *5*	%α=0.6 *4*; %IT=99.4 *4*
^{213}Ac	0.0	9/2$^-$	738 ms *16*	%α≈100
^{213}Th	0.0	5/2$^-$	146 ms *+22−19*	%α≈100
^{213}Th	1180	(13/2$^+$)	8.3 μs *8*	
^{213}Pa	0.0	9/2$^-$	5.3 ms *+40−16*	%α=100
^{217}Po	0.0	(9/2$^+$)	1.53 s *5*	%α=97.5 *25*
^{217}At	0.0	9/2$^-$	32.6 ms *3*	%α=99.993 *3*
^{217}Rn	0.0	9/2$^+$	0.59 ms *6*	%α=100
^{217}Fr	0.0	9/2$^-$	22 μs *5*	%α=100
^{217}Ra	0.0	(9/2$^+$)	1.6 μs *2*	%α=100
^{217}Ac	0.0	9/2$^-$	69 ns *4*	%α=100
^{217}Ac	1149.1	15/2$^-$	<10 ns	%α<0.31
^{217}Ac	1498.1	19/2$^-$	8 ns *2*	%α<0.59
^{217}Ac	2012.2	(29/2)$^+$	740 ns *40*	%α=4.51 *18*
^{217}Th	0.0	(9/2$^+$)	0.252 ms *4*	%α=100
^{217}Pa	0.0	9/2$^-$	3.8 ms *2*	%α=100
^{217}Pa	1860		1.08 ms *3*	%α=73 *4*
^{217}U	0.0		16 ms *+21−6*	%α=100

Adopted Levels

Q(β^-)=6420 *syst*; S(n)=2890 *syst*; S(p)=10440 *calc*; Q(α)=1470 *calc* 2021Wa16,2019Mo01
ΔQ(β^-)=300 (syst), ΔS(n)=420 (syst) (2021Wa16).
S(p) and Q(α) from 2019Mo01.
Q(β^-n)=1680 *360*, S(2n)=7550 *360* (syst, 2021Wa16), S(2p)=19970 (2019Mo01, calculated).
2010Al24: ^{213}Hg nuclide identified in ^{9}Be(^{238}U,X) reaction with a beam energy of 1 GeV/nucleon produced by the SIS synchrotron at GSI facility. Target=2500 mg/cm^2. The fragment residues were analyzed with the high resolving power magnetic spectrometer Fragment separator (FRS). The identification of nuclei was made on the basis of magnetic rigidity, velocity, time-of-flight, energy loss and atomic number of the fragments using two plastic scintillators and two multisampling ionization chambers. The FRS magnet was tuned to center on ^{210}Au, ^{216}Pb, ^{219}Pb, ^{227}At and ^{229}At nuclei along the central trajectory of FRS.
Unambiguous identification of nuclides required the separation of different charge states of the nuclei passing through the FRS. Through the measurement of difference in magnetic rigidity in the two sections of the FRS and the difference in energy loss in the two ionization chambers, the charge state of the transmitted nuclei was determined, especially, that of the singly charged (hydrogen-like) nuclei which preserved their charge in the current experimental setup. Measured production cross sections with 10% statistical and 20% systematic uncertainties.
Criterion established in 2010Al24 for acceptance of identification of a new nuclide: 1. number of events should be compatible with the corresponding mass and atomic number located in the expected range of positions at both image planes of the FRS spectrometer; 2. number of events should be compatible with >95% probability that at least one of the counts does not correspond to a charge-state contaminant. Comparisons of measured σ with model predictions using the computer codes COFRA and EPAX.

^{213}Hg Levels

E(level)	Comments
0	%β^-=100; %β^-n=? The β^- and delayed neutron decay are the only decay modes expected. Calculated %β^-n=4 (2019Mo01). E(level): it is assumed that the observed fragments correspond to nuclei in their ground state. From A/Z plot (figure 1 in 2010Al24), ≈ 35 events are assigned to ^{213}Hg. J$^\pi$: 9/2$^+$ from systematics (2021Ko07), and 5/2$^+$ predicted in 2019Mo01 calculations. $T_{1/2}$: Calculated value 10 s for β decay (2019Mo01), and systematic value of 15 s for β decay (2021Ko07). Production σ=0.546 nb (from e-mail reply of H. Alvarez-Pol to B. Singh (Dated: Oct 29, 2010), which also stated that further analysis was in progress). Production cross section measured in 2010Al24, values are given in figure 2, plot of σ versus mass number for Hg isotopes. Statistical uncertainty=10%, systematic uncertainty=20%.

Adopted Levels, Gammas

Q(β^-)=4987 *28*; S(n)=4740 *syst*; S(p)=8530 *syst*; Q(α)=1590 *syst* 2021Wa16
ΔS(n)=200 (syst), ΔS(p)=300 (syst), ΔQ(α)=400 (syst) (2021Wa16).
S(p) and Q(α) from 2019Mo01.
Q(β^-n)=1261 *27*, S(2n)=8280 *50* (2021Wa16), S(2p)=18760 (2019Mo01, calculated).

2010Ch19, 2012Ch19: ^{213}Tl isotope was produced in the fragmentation of ^{238}U beam at 670 MeV/nucleon with a 4 g/cm^2 ^{9}Be target followed by separation by Fragment Recoil Separator facility at GSI. The fragments were then injected into the cooler electron storage ring ESR. Measured mass and half-life by time-resolved Schottky Mass spectrometry technique.

2010Al24: ^{213}Tl nuclide identified in ^{9}Be(^{238}U,X) reaction with a beam energy of 1 GeV/nucleon produced by the SIS synchrotron at GSI facility. Target=2500 mg/cm^2. The fragment residues were analyzed with the high resolving power magnetic spectrometer Fragment separator (FRS). The identification of nuclei was made on the basis of magnetic rigidity, velocity, time-of-flight, energy loss and atomic number of the fragments using two plastic scintillators and two multisampling ionization chambers. The FRS magnet was tuned to center on ^{210}Au, ^{216}Pb, ^{219}Pb, ^{227}At and ^{229}At nuclei along the central trajectory of FRS.

Unambiguous identification of nuclides required the separation of different charge states of the nuclei passing through the FRS. Through the measurement of difference in magnetic rigidity in the two sections of the FRS and the difference in energy loss in the two ionization chambers, the charge state of the transmitted nuclei was determined, especially, that of the singly charged (hydrogen-like) nuclei which preserved their charge in the current experimental setup. Measured production cross sections with 10% statistical and 20% systematic uncertainties.

Criterion established in 2010Al24 for acceptance of identification of a new nuclide: 1. number of events should be compatible with the corresponding mass and atomic number located in the expected range of positions at both image planes of the FRS spectrometer; 2. number of events should be compatible with >95% probability that at least one of the counts does not correspond to a charge-state contaminant. Comparisons of measured σ with model predictions using the computer codes COFRA and EPAX.

2012Be28: Method of production at GSI facility same as in 2010Al24. In this work half-life of the isotope is measured from an implant of 1526 events using FRS-RISING setup at GSI.

^{213}Tl Levels

Measured mass excess=1763 keV *61* (2010Ch19, 2012Ch19).

Cross Reference (XREF) Flags

A ^{9}Be(^{238}U,Xγ)

E(level)	J$^\pi$	T$_{1/2}$	XREF	Comments
0	(1/2$^+$)	23.8 s *44*	A	%β^-=100; %β^-n=7.6 *34* (2017Ca12,2016Ca25) J$^\pi$: from shell-model calculations (2019Go10 – (^{238}U,Xγ)). 1/2$^+$ from systematics (2021Ko07). Configuration: π ($s^{-1}_{1/2}$). T$_{1/2}$: From 2017Ca12: (ion)β correlated decay curve and analyzed by maximum-likelihood method, also 24 s *4* in 2016Ca25 – same research group. Others: 46 s *+55−26* (2012Be28 – (implant)$\beta\gamma$ correlations of 2768 implants) also in 2014Mo15, 101 s *+484−46* (2010Ch19). %β^-n: beta-delayed neutron branching ratio deduced from implant-β and implant-β-neutron correlations detected in forward and backward directions (2017Ca12,2016Ca25). Production cross section measured in 2010Al24, values are given in figure 2, plot of σ versus mass number for Tl isotopes. Statistical uncertainty=10%, systematic uncertainty=20%. Production σ=9.74 nb (from e-mail reply of H. Alvarez-Pol to B. Singh (Dated: Oct 29, 2010), which also stated that further analysis was in progress. From A/Z plot (figure 1 in 2010Al24), a large number of events is assigned to ^{213}Tl.
0+x?			A	
0+y?			A	

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued)

^{213}Tl Levels (continued)

E(level)	$T_{1/2}$	XREF	Comments
380+x?	4.1 μs *5*	A	$T_{1/2}$: from 380γ(t) (2019Go10). Uncertainty includes statistical and systematic.
698+y?	0.6 μs *3*	A	$T_{1/2}$: from 698γ(t) (2019Go10). Uncertainty includes statistical and systematic.

γ(^{213}Tl)

E_i(level)	E_γ	I_γ	E_f
380+x?	380 *1*	100	0+x?
698+y?	698 *1*	100	0+y?

^{9}Be(^{238}U,Xγ) 2019Go10

Adapted/Edited the XUNDL dataset compiled by B. Singh (McMaster), Feb 01, 2020.

2019Go10: projectile fragmentation of 1 GeV ^{238}U beam from the UNILAC-SIS18 accelerator facilities at GSI with an intensity of 1.5×10^9 ions/spill. Target was 2.5 mg/cm^2 thick ^{9}Be, followed by a 223 mg/cm^2 Nb stripper foil. The reaction products were separated and identified in the magnetic spectrometer Fragment Separator (FRS), based on Bρ-ΔE-Bρ scheme. Implanted in a composite DSSSD detector system consists of three layers. The DSSSD detectors were surrounded by the RISING γ-ray spectrometer consists of 105 HPGe crystals arranged in clusters of seven elements. Measured Eγ, Iγ, delayed γ in coincidence with implanted recoils, $\gamma\gamma$-coin. Deduced isomeric activity and measured half-life. Shell-model calculations.

Experimental level structure of ^{213}Tl seems different from that of ^{209}Tl and ^{211}Tl, as described by 2019Go10, making it difficult to assign the two observed γ rays of 380 and 698 keV, although, shell-model calculations by 2019Go10 for all the three nuclei give similar level pattern.

^{213}Tl Levels

2019Go10 observed two transitions, which are not in coincidence with each other and have half-lives which are incompatible within errors. This suggests two isomeric levels, however their placement in the level scheme could not be determined.

E(level)	J$^\pi$	T$_{1/2}$	Comments
0	(1/2$^+$)		J$^\pi$: From shell-model calculations (2019Go10). Configuration: π (s$^{-1}_{1/2}$).
0+x?			
0+y?			
380+x?		4.1 μs *5*	T$_{1/2}$: from 380γ(t) (2019Go10). Uncertainty includes statistical and systematic.
698+y?		0.6 μs *3*	T$_{1/2}$: from 698γ(t) (2019Go10). Uncertainty includes statistical and systematic.

γ(^{213}Tl)

E$_\gamma$	E$_i$(level)	E$_f$	I$_{(\gamma+ce)}$	Comments
380† *1*	380+x?	0+x?	91‡ *11*	2019Go10 reported I(γ+ce)=26 *5* per 100 ions of ^{213}Tl.
698† *1*	698+y?	0+y?	17‡ *5*	2019Go10 reported I(γ+ce)=7 *3* per 100 ions of ^{213}Tl.

† 698γ and 380γ were not in coincidence.

‡ Corrected measured peak area for efficiency and electron conversion (assuming E2).

Adopted Levels, Gammas

Q(β^-)=2028 *8*; S(n)=3726 *7*; S(p)=8.94×10^3 *syst*; Q(α)=2.98×10^3 *syst* 2021Wa16
ΔS(p)=200 (syst), ΔQ(α)=150 (syst) 2021Wa16.
Assignment: descendant of ^{221}Rn, parent of ^{213}Bi (1964Bu05).
2020De36: ^{238}U(^{48}Ca,X), E=233.3 MeV; measured multi-nucleon transfer reaction cross section $\sigma_{cumulative}$=139 nb/sr *4* for ^{213}Pb.
Calculation of isotope shifts and nuclear change radii:
1990Du03: Calculated isotope shifts and nuclear charge radii for lead isotopes using an enlarged superfluid model.
1987Sa51: Calculated isotope shifts of lead nuclei by including perturbations due to giant monopole and giant quadrupole resonances.
1987Za02: Calculated nuclear charge radius using the HFB method. The calculations were done including a separable four-body interaction and also a three-body contact force in the procedure. Their calculations, which were carried out also for other lead nuclei as well as for mercury isotopes in the region and for tin isotopes, by using an effective interaction, reproduced the odd-even staggering. These calculations were compared with experiments.
1984He17: Calculated lead radii relative to ^{208}Pb radius.

^{213}Pb Levels

Cross Reference (XREF) Flags

A ^{213}Tl β^- decay (23.8 s)
B ^{217}Po α decay
C ^{9}Be(^{238}U,Xγ)

E(level)†	J$^\pi$	T$_{1/2}$	XREF	Comments
0.0	(9/2$^+$)	10.2 min *3*	ABC	%β^-=100 T$_{1/2}$: From 1964Bu05: measured from growth of ^{213}Bi. J$^\pi$: favored α decay (HF=1.4) suggest a $g_{9/2}$ to $g_{9/2}$ transition between ^{217}Po and ^{213}Pb ground states (2004Li28). Also from analogy to ^{215}Po and ^{217}Rn isotones. Suggested configuration: ν ($g^{+1}_{9/2}$).
675	(5/2$^+$,7/2$^+$)		A	J$^\pi$: From 2014Mo02 (^{213}Tl β- decay (23.8 s)) based on shell-model predictions.
772.0 *10*	(13/2$^+$)‡		C	
1083.2 *14*	(15/2$^+$)#		C	
1141.0 *15*	(17/2$^+$)‡		C	
1259.8 *14*	(17/2$^+$)#		C	
1331.0 *18*	(21/2$^+$)‡	0.26 ms *2*	C	Suggested configuration: ν ($g^{+3}_{9/2}$). T$_{1/2}$: From sum of (176,190,311,369,488 and 772)γ(t) (^{238}U,X).

† From Eγ.
‡ Based on 190-369-772 γ cascade from (21/2$^+$) seniority isomer to (17/2$^+$) → (13/2$^+$) → (9/2$^+$) g.s. in (^{238}U,Xγ), supported by shell model calculations.
# Based on shell model calculations (^{238}U,Xγ).

Adopted Levels, Gammas (continued)

$\gamma(^{213}Pb)$

E_i(level)	J^π_i	E_γ†	I_γ†	E_f	J^π_f	Mult.	α#	Comments
675	$(5/2^+,7/2^+)$	675	100	0.0	$(9/2^+)$			E_γ,I_γ: From ^{213}Tl β- decay (23.8 s).
772.0	$(13/2^+)$	772 *1*	100	0.0	$(9/2^+)$			
1083.2	$(15/2^+)$	311‡ *1*	100	772.0	$(13/2^+)$			
1141.0	$(17/2^+)$	369 *1*	100	772.0	$(13/2^+)$			
1259.8	$(17/2^+)$	176‡ *2*	9 *8*	1083.2	$(15/2^+)$			
		488 *1*	100 *9*	772.0	$(13/2^+)$			
1331.0	$(21/2^+)$	190 *1*	100	1141.0	$(17/2^+)$	[E2]	0.512 *12*	B(E2)(W.u.)=7.7×10^{-5} *+7−6*

† From (^{238}U,Xγ).

‡ The ordering of 176γ and 311γ is supported by the proposed level scheme (^{238}U,Xγ).

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.

^{213}Tl β^- decay (23.8 s) 2014Mo02

Parent: ^{213}Tl: E=0.0; J^π=(1/2$^+$); $T_{1/2}$=23.8 s *44*; Q(β^-)=4987 *28*; %β^- decay=100
Adapted/Edited the XUNDL dataset compiled by B. Singh (McMaster), March 5, 2014.
Proposed decay scheme is tentative.
^{213}Tl was produced by projectile fragmentation using E(^{238}U)=1 GeV/nucleon beam at GSI with an intensity of 1.5×10^9 ions/spill (a repetition of 3 s and an extraction time of 1 s). The reaction products were separated and identified in the magnetic spectrometer Fragment Separator (FRS). Separation of ^{213}Tl nuclei is based on Bρ-ΔE-Bρ scheme. Implanted in a composite DSSSD detector system comprising of 3 layers. The DSSSD detectors were surrounded by the RISING γ-ray spectrometer comprised of 105 HPGe crystals arranged clusters of seven elements. Measured Eγ, Iγ, $\gamma\gamma$-coin, β-γ-t coin in coincidence with implanted recoils.

^{213}Pb Levels

E(level)	J^π†	$T_{1/2}$	Comments
0	9/2$^+$	10.2 min *3*	$T_{1/2}$: From Adopted Levels.
675	(5/2$^+$,7/2$^+$)		

† From 2014Mo02 based on shell-model predictions.

γ(^{213}Pb)

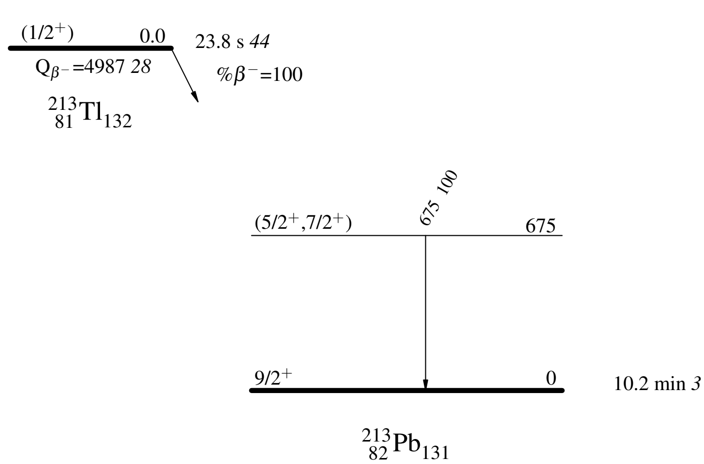
Eγ†	Iγ	E_i(level)	J^π_i	E_f	J^π_f
675	100 *29*	675	(5/2$^+$,7/2$^+$)	0	9/2$^+$

† No numerical datum of the resolution was listed in 2014Mo02.

^{213}Tl β^- decay (23.8 s) 2014Mo02

Decay Scheme

Intensities: Relative I$_\gamma$



^{217}Po α decay 2004Li28,1997Li23,1977Vy02

Parent: ^{217}Po: E=0.0; J^{π}=(9/2^{+}); $T_{1/2}$=1.53 s *5*; Q(α)=6662.1 *24*; %α decay=97.5 *25*
^{217}Po-J^{π},$T_{1/2}$: From 2018Ko01 (A=217 evaluation).
^{217}Po-Q(α): From 2021Wa16.
^{217}Po-%α decay: Based on %α > 95 (2018Ko01 – A=217 evaluation) and using uniform probability distribution.
2004Li28: Parent: ^{221}Rn; studied ^{217}Po level structure and g.s. of ^{213}Pb through α decay; measured $T_{1/2}$ of ^{217}Po, α-γ coin.
1997Li23: Parent: ^{221}Rn; studied ^{217}Po level structure and g.s. of ^{213}Pb through α decay, α-γ coin.
1977Vy02: Parent: ^{221}Rn; studied ^{217}Po, ^{213}Pb, and ^{213}Po level structure, Eα, Eγ, Iγ. ^{213}Pb through α decay.

^{213}Pb Levels

E(level)	J^{π}	$T_{1/2}$	Comments
0.0	(9/2^{+})	10.2 min *3*	J^{π},$T_{1/2}$: From Adopted Levels.

α radiations

Eα	E(level)	Iα‡	HF†	Comments
6539 *4*	0.0	100	1.39 *6*	Eα: Weighted average of 6537 keV *4* (1977Vy02 – Eα=6539 *4*) is decreased by 2 keV, as recommended by 1991Ry01, because of a change in calibration energy), 6543 keV *4* (2003Ku25), and 6540 keV *20* (1956Mo15), 6537 keV *4* (1997Li23). Uncertainty is the lowest input value. Iα: No other α groups were observed; if they exist, Iα≤5% of the Iα(6537α) (1977Vy02).

† Using r_0(^{213}Pb)=1.5395 *4*; average of r_0(^{212}Pb)=1.5412 *3* and r_0(^{214}Pb)=1.5379 *2* (2020Si16).
‡ For absolute intensity per 100 decays, multiply by 0.975 *25*.

$^{9}Be(^{238}U,X\gamma)$ 2021Va03

Produced from ^{238}U fragmentation bombarding ^{9}Be target, E=1 GeV/nucleon; fragments were separated according to their magnetic rigidity (Bρ) with the double-stage magnetic spectrometer, implanted in a double-sided silicon-strip detector (DSSSD). The RISING γ spectrometer consisted of 105 germanium crystals arranged in 15 clusters surrounded the implantation DSSSD. Measured decay products, Eγ, Iγ; deduced half-life, isomer decays with asymmetric E2 transition probabilities.

^{213}Pb Levels

E(level)†	J$^\pi$‡	$T_{1/2}$	Comments
0.0	(9/2$^+$)	10.2 min *3*	$T_{1/2}$,J$^\pi$: From Adopted Levels.
772.0 *10*	(13/2$^+$)#		
1083.2 *14*	(15/2$^+$)		
1141.0 *15*	(17/2$^+$)#		
1259.8 *14*	(17/2$^+$)		
1331.0 *18*	(21/2$^+$)#	0.26 μs *2*	Suggested configuration: ν $(g^{+3}_{9/2})$. $T_{1/2}$: From sum (176,190,311,369,488 and 772)γ(t) (2021Va03).

† From Eγ.
‡ Tentative spin-parity assignment from 2021Va03, based on the systematics and shell model calculations.
# Based on the γ cascade from the (21/2$^+$) seniority isomer, configuration: ν $(g^{3}_{9/2})$ (2021Va03).

γ(^{213}Pb)

E$_\gamma$†	I$_\gamma$&	E$_i$(level)	J$^\pi_i$	E$_f$	J$^\pi_f$	Mult.	α[a]	I$_{(\gamma+ce)}$@	Comments
(71)		1331.0	(21/2$^+$)	1259.8	(17/2$^+$)				
176# *2*	7 *6*	1259.8	(17/2$^+$)	1083.2	(15/2$^+$)	[M1]	1.87 *7*	19 *16*	
190‡ *1*	15 *10*	1331.0	(21/2$^+$)	1141.0	(17/2$^+$)	[E2]	0.512 *12*	22 *15*	
311# *1*	17 *7*	1083.2	(15/2$^+$)	772.0	(13/2$^+$)	[M1]	0.387 *7*	23 *10*	
369‡ *1*	29 *9*	1141.0	(17/2$^+$)	772.0	(13/2$^+$)	[E2]	0.0640 *11*	30 *9*	
488 *1*	77 *8*	1259.8	(17/2$^+$)	772.0	(13/2$^+$)	[E2]	0.0311	79 *8*	E$_\gamma$: In coincidence with 772γ.
772‡ *1*	100 *10*	772.0	(13/2$^+$)	0.0	(9/2$^+$)	[E2]	0.01119	100 *10*	

† Uncertainty from statements in the text.
‡ In mutual coincidence.
# The ordering of 176γ and 311γ is supported by the proposed level scheme.
@ From 2021Va03.
& Deduced by the evaluator, rounded value, using I(γ+ce) and α for assumed γ multipolarity.
[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.

Adopted Levels, Gammas

$Q(\beta^-)$=1422 *6*; S(n)=5185 *5*; S(p)=4972 *5*; $Q(\alpha)$=5988 *3* 2021Wa16

Other studies:

1984Es01: ^{208}Pb(^{18}O,X), E≈80-180 MeV; measured residuals absolute production σ(E).

2020De36: ^{238}U(^{48}Ca,X), E=233.3 MeV; measured multi-nucleon transfer reaction cross section $\sigma_{cumulative}$=2031 nb/sr *8* for ^{213}Bi production.

^{213}Bi Levels

Cross Reference (XREF) Flags

- A ^{213}Pb β^- decay (10.2 min)
- B ^{217}At α decay
- C ^{9}Be(^{238}U,X)

E(level)†	J$^\pi$	T$_{1/2}$	XREF	Comments
0.0	9/2$^-$	45.59 min *6*	ABC	%α=2.140 *10*; %β$^-$=97.860 *10* μ=+3.699 *7* Q=−0.83 *5* Isotope shift: δ<r^2>(^{213}Bi, ^{209}Bi)=0.422 fm^2 *29* (2018Ba03). Other: 0.416 fm^2 *1* (2013An02). J$^\pi$: Based on favored α decay of ^{217}At(J$^\pi$)=9/2$^-$ → to ^{213}Bi g.s.. J$^\pi$(^{217}At)=9/2$^-$ based on ^{221}Fr(J$^\pi$)=5/2$^-$ α decay → 218 level (J$^\pi$)=5/2$^-$ and → E2 γ to g.s. of ^{217}At (1972Dz14, 1977Vy02). Also supported by the HFS and μ measurements (2019Ba22). T$_{1/2}$: Weighted average of 45.59 min *6* (1973Po16), 47 min *1* (1950Ha52), 46 min *1* (1964Gr11), 45.636 min *220* and 45.598 min *91* from Cherenkov counting and γ(t), respectively (2021Ta01), 45.62 min *6* (2013Su13, 2013Ma13 – from beta decay curve). Others: 46 min (1947En03). %α=2.140 *10* from 2013Ma13 and %β$^-$ = 100 − %α. Others: %α=2.09 *3* (1998Ar03), %α=2.20 *3* (1997Ch53), %α=2.16 *11* (1964Gr11), %α=2.0 (1950Ha52), %α=2 (1947En03), and %α=2.022 *26* (1986He06 based on 465γ of ^{209}Tl). Weighted average of all values, with uncertainty, excluding the 1986He06 value yields %α=2.140 *14*. μ: From 2019StZV (based on +3.716 *7* in 1997Ki15, 2000Pe30, 2000Bi23 (laser spectroscopy)). Others: +3.89 *9* (1992Li25 – from γ(θ,t)), the value 3.672 *7* in 2018Ba03 appears to be quoted from 1992Li25 as of Fig. 7, however the reason of the difference is not clear. Q: From 2016St14, 2001Bi23 (reference value −0.516 *15* ^{209}Bi). Others: −0.60 *5* (1997Ki15, 2000Pe30 – reference value −0.370 *26* (^{209}Bi)). −0.68 *5* (2018Ba03 – not clear if it is their measured value or not). Configuration: π ($h^{+1}_{9/2}$).
257.86 *4*	7/2$^-$		AB	J$^\pi$: 257.9γ M1+E2 to 9/2$^-$ state. Unfavored α decay (HF=394) from ^{217}At g.s. (J$^\pi$=9/2$^-$).
593.13 *3*	(5/2,7/2,9/2)$^-$		AB	J$^\pi$: 593.1γ to 9/2$^-$ state, 335.3γ to 7/2$^-$ state.
758.90 *10*	(5/2$^-$,13/2$^-$)		B	J$^\pi$: 758.9γ to 9/2$^-$ state.
874.3 *5*			A	
977.80 *14*			A	
982.89 *10*			A	
1050			B	E(level): From 6037α feeding from ^{217}At.
1142.42 *9*			A	
1149.34 *10*			A	
1171.01 *10*			A	
1202.14? *12*			A	
1222.34? *12*			A	
1287.24? *12*			A	

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued)

^{213}Bi Levels (continued)

E(level)[†]	XREF	Comments
1295.55 *11*	A	
1343.1? *3*	A	
1353 *21*	C	E(level): Isomer (^{238}U,X) was identified from Schottky frequency spectrum (figure 2 in 2012Ch19).
1445.14 *10*	A	
1495.26 *11*	A	
1543.37 *11*	A	
1592.74 *22*	A	

[†] From least-square fit to Eγ. Uncertainties of 720.3γ and 977.5γ from 977.7 keV level, 1187.0γ and 1335.5γ from 1445 were doubled, 1445.4γ and 1592.1γ from 1592 keV level were tripled for the fit. Critical χ^2=2.0, otherwise the reduced χ^2=7.8:

Adopted Levels, Gammas (continued)

γ(^{213}Bi)

E_i(level)	J_i^π	E_γ†	I_γ†	E_f	J_f^π	Mult.	δ	α#	Comments
257.86	7/2⁻	257.89 *6*	100	0.0	9/2⁻	M1+E2	0.59 *13*	0.57 *5*	Mult.: M1+E2 from α(K)exp=0.45 *4* (^{217}At α decay), α(K)exp=0.56 *4* (^{213}Pb β- decay). M1 in 1969LeZW from (α)(K x ray)/(α)(γ) coincidence. δ: Deduced by the evaluator from α(K)exp=0.45 *4*.
593.13	(5/2,7/2,9/2)⁻	335.26 *5*	54 *3*	257.86	7/2⁻				I_γ: Other: 80 *13* (^{213}Pb β- decay).
		593.13 *3*	100 *4*	0.0	9/2⁻				
758.90	(5/2⁻,13/2⁻)	758.9 *1*	100	0.0	9/2⁻				
874.3		874.3‡ *10*	100	0.0	9/2⁻				
977.80		103.5‡ *5*		874.3					
		720.3‡ *1*	56‡ *7*	257.86	7/2⁻				
		977.5‡ *1*	100‡ *13*	0.0	9/2⁻				
982.89		389.8‡ *5*		593.13	(5/2,7/2,9/2)⁻				
		982.9‡ *1*	100‡ *13*	0.0	9/2⁻				
1142.42		1142.4‡ *1*	100	0.0	9/2⁻				
1149.34		893.1‡ *10*	99‡ *14*	257.86	7/2⁻				
		1149.3‡ *1*	100‡ *14*	0.0	9/2⁻				
1171.01		913.8‡ *10*	5‡ *1*	257.86	7/2⁻				
		1171.0‡ *1*	100‡ *13*	0.0	9/2⁻				
1202.14?		944.5‡@ *1*	100	257.86	7/2⁻				
1222.34?		964.7‡@ *1*	100	257.86	7/2⁻				
1287.24?		1029.6‡@ *1*	100	257.86	7/2⁻				
1295.55		1037.7‡ *1*	100	257.86	7/2⁻				
1343.1?		1085.5‡@ *3*	100	257.86	7/2⁻				
1445.14		274.3‡@ *5*	10‡ *5*	1171.01					
		295.4‡ *5*		1149.34					
		302.7‡ *1*	30‡ *4*	1142.42					
		462.7‡ *5*		982.89					
		467.8‡ *5*		977.80					
		1187.0‡ *1*	100‡ *15*	257.86	7/2⁻				
		1445.4‡ *1*	18‡ *3*	0.0	9/2⁻				
1495.26		324.2‡@ *1*	100‡ *13*	1171.01					
		1237.4‡ *1*	86‡ *12*	257.86	7/2⁻				
1543.37		248.0‡ *5*		1295.55					
		565.5‡ *5*		977.80					
		1285.5‡ *1*	100‡ *15*	257.86	7/2⁻				

$\gamma(^{213}Bi)$ (continued)

E_i(level)	J_i^π	E_γ†	I_γ†	E_f	J_f^π
1592.74		1335.5‡ *1*	49‡ *14*	257.86	$7/2^-$
		1592.1‡ *1*	100‡ *14*	0.0	$9/2^-$

† From ^{217}At α decay, except otherwise noted.
‡ From ^{213}Pb β- decay (10.2 m).
# 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.

$^{213}_{83}Bi_{130}$-4

^{213}Pb β^- decay (10.2 min) 2004DeZV

Parent: ^{213}Pb: E=0.0; J$^\pi$=(9/2$^+$); $T_{1/2}$=10.2 min *3*; Q(β^-)=2028 *8*; %β^- decay=100
^{213}Pb-J$^\pi$,$T_{1/2}$: From Adopted Levels.
Adapted/Edited the XUNDL dataset compiled by M. Birch and B. Singh (McMaster); June 8, 2011.
^{213}Pb produced via the reaction ^{232}Th(p,X) with E(p)=1.0 GeV, ionized by a plasma ion source and separated using the ISOLDE on-line mass separator. Detector system included an Si-detector for α-particles, a LEGe (25 mm thick, with 300 μm beryllium entrance window) and a HPGe set up in close geometry for X-rays and γ-rays, as well as a 0.5 mm thick plastic scintillator ΔE detector for β-particles. Measured Eγ, Iγ, Iβ, $\beta\gamma$ and $\gamma\gamma$ coincidence. Deduced levels.

^{213}Bi Levels

E(level)[†]	J$^\pi$[‡]	$T_{1/2}$	Comments
0.0	9/2$^-$	45.59 min *6*	$T_{1/2}$: From Adopted Levels.
257.63 *7*	7/2$^-$		
592.72 *8*	(5/2,7/2,9/2)$^-$		J$^\pi$: Other: (5/2$^-$,7/2$^-$) in 2004DeZV.
874.2 *5*			
977.71 *8*			J$^\pi$: (9/2$^-$) in 2004DeZV.
982.87 *10*			
1142.39 *9*			
1149.33 *10*			
1171.01 *10*			
1202.14? *12*			
1222.34? *12*			
1287.24? *12*			
1295.33 *12*			
1343.1? *3*			
1445.08 *10*			
1495.04 *12*			
1543.15 *12*			
1592.62 *15*			

[†] From least-squares fit of the Eγ data. Uncertainties of following Eγ were doubled in the fitting procedure to get an an acceptable reduced χ^2=2.8 as compared to critical χ^2=2.0, otherwise the reduced χ^2=7.0: 1187.0, 1335.5, 1445.4, 1592.1 from 1445 and 1592 keV levels.
[‡] From Adopted Levels.

β^- radiations

E(decay)	E(level)	Iβ^-[†‡]	Log *ft*	Comments
(435 *8*)	1592.62	1.7	5.5	
(485 *8*)	1543.15	0.9	6.0	
(533 *8*)	1495.04	2.6	5.7	
(583 *8*)	1445.08	8.8	5.2	
(685 *8*)	1343.1?	0.6	6.6	
(733 *8*)	1295.33	2.3	6.1	
(826 *8*)	1202.14?	1.0	6.7	
(857 *8*)	1171.01	6.8	5.9	
(879 *8*)	1149.33	1.9	6.5	
(886 *8*)	1142.39	3.7	6.2	
(1045 *8*)	982.87	2.3	6.6	
(1050 *8*)	977.71	23.4	5.6	
(1154 *8*)	874.2	3.6	6.6	
(1435 *8*)	592.72	1.0	7.5	
(1770 *8*)	257.63	1.4	7.7	
(2028 *8*)	0.0	34.0	6.5	Iβ^-: Ground state feeding, ≤34%, was estimated by 2004DeZV from the absolute β

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^{213}Pb β^- decay (10.2 min) 2004DeZV (continued)

β^- radiations (continued)

E(decay)	E(level)	Comments
		branching of the 264.6 keV γ-ray in ^{217}Bi β- decay and the intensity ratio of the 257.7 keV to 264.6 keV γ transitions.

† Per 100 decays of the parent (2004DeZV).
‡ Absolute intensity per 100 decays.

γ(^{213}Bi)

Iγ normalization: Estimated by the evaluator based on ΣIγ(1+α)=66, assuming g.s. β feeding=34% (in 2004DeZV ≤34%).

E_γ	I_γ‡	E_i(level)	J^π_i	E_f	J^π_f	Mult.	α#	Comments
103.5 *5*		977.71		874.2				
248.0 *5*		1543.15		1295.33				
257.7 *1*	100	257.63	7/2⁻	0.0	9/2⁻	M1+E2	0.45 *26*	Mult.: From α(K)exp=0.56 *4* (2004DeZV).
274.3@ *5*	4.0 *19*	1445.08		1171.01				
295.4 *5*		1445.08		1149.33				
302.7 *1*	12.3 *16*	1445.08		1142.39				
324.2@ *1*	9.5 *12*	1495.04		1171.01				
334.9 *1*	3.2 *5*	592.72	(5/2,7/2,9/2)⁻	257.63	7/2⁻			
389.8 *5*		982.87		592.72	(5/2,7/2,9/2)⁻			
462.7 *5*		1445.08		982.87				
467.8 *5*		1445.08		977.71				
565.5 *5*		1543.15		977.71				
592.9 *1*	4.0 *7*	592.72	(5/2,7/2,9/2)⁻	0.0	9/2⁻	[M1+E2]		
720.3 *1*	62 *8*	977.71		257.63	7/2⁻			
874.3 *10*	27 *4*	874.2		0.0	9/2⁻			
893.1 *10*	6.8 *10*	1149.33		257.63	7/2⁻			
913.8 *10*	3.2 *8*	1171.01		257.63	7/2⁻			
944.5†@ *1*	7.3 *11*	1202.14?		257.63	7/2⁻			
964.7†@ *1*	26 *4*	1222.34?		257.63	7/2⁻			
977.5 *1*	111 *15*	977.71		0.0	9/2⁻			
982.9 *1*	17.0 *23*	982.87		0.0	9/2⁻			
1029.6†@ *1*	4.8 *7*	1287.24?		257.63	7/2⁻			
1037.7 *1*	16.7 *23*	1295.33		257.63	7/2⁻			
1085.5†@ *3*	4.6 *7*	1343.1?		257.63	7/2⁻			
1142.4 *1*	40 *5*	1142.39		0.0	9/2⁻			
1149.3 *1*	6.9 *10*	1149.33		0.0	9/2⁻			
1171.0 *1*	61 *8*	1171.01		0.0	9/2⁻			
1187.0 *1*	41 *6*	1445.08		257.63	7/2⁻			
1237.4 *1*	8.2 *12*	1495.04		257.63	7/2⁻			
1285.5 *1*	6.8 *10*	1543.15		257.63	7/2⁻			
1335.5 *1*	4.2 *12*	1592.62		257.63	7/2⁻			
1445.4 *1*	7.5 *11*	1445.08		0.0	9/2⁻			
1592.1 *1*	8.6 *12*	1592.62		0.0	9/2⁻			

† Depopulation level listed as questionable in 2004DeZV – so do for Eγ by evaluator.
‡ For absolute intensity per 100 decays, multiply by ≈0.154.

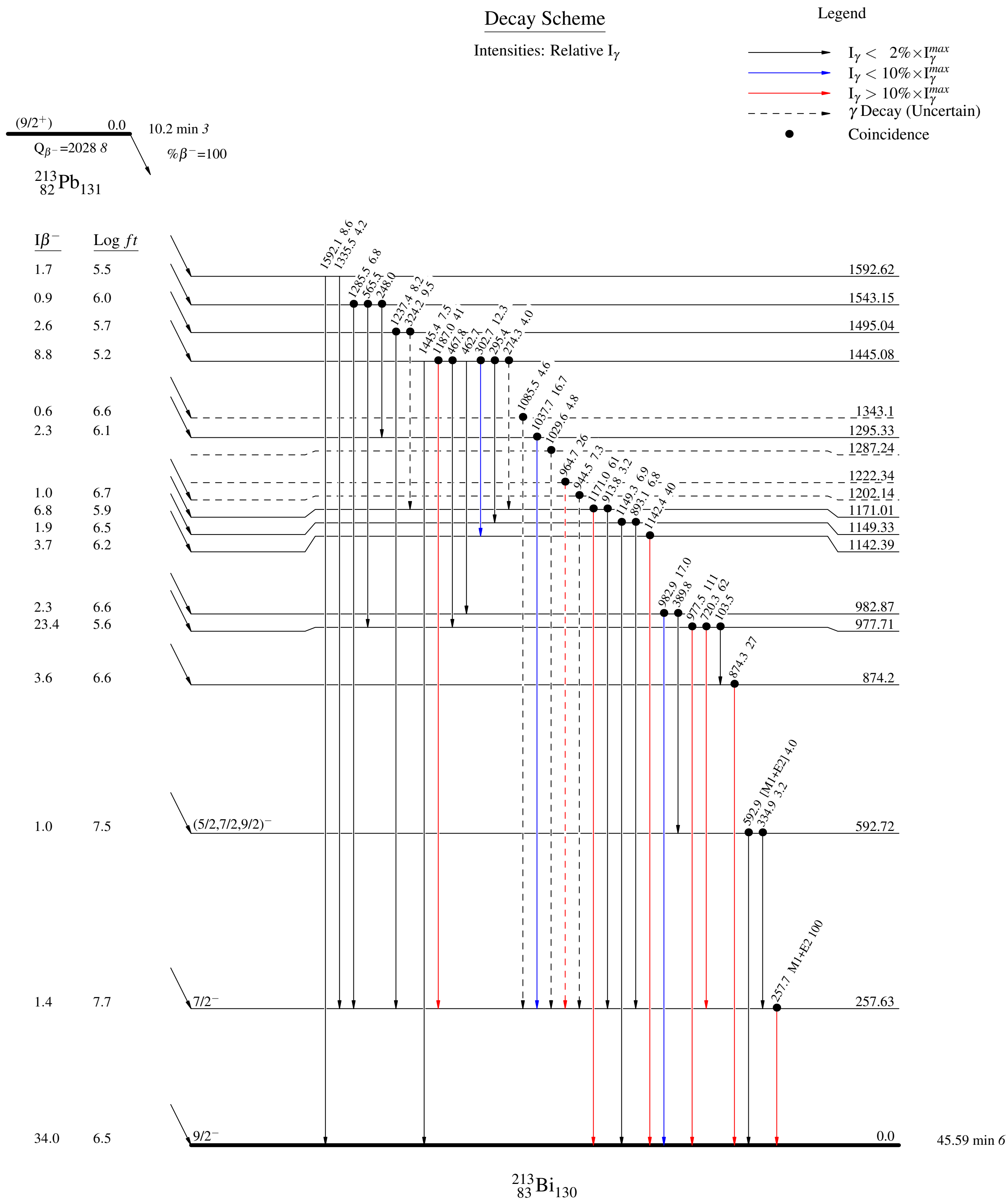
Continued on next page (footnotes at end of table)

^{213}Pb β^- decay (10.2 min) 2004DeZV (continued)

$\gamma(^{213}Bi)$ (continued)

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.

^{213}Pb β^- decay (10.2 min) 2004DeZV



^{217}At α decay 1997Ch19,1997Ch53,1967Dz02

Parent: ^{217}At: E=0.0; J$^{\pi}$=9/2^{-}; $T_{1/2}$=32.6 ms *3*; Q(α)=7201.4 *12*; %α decay=99.993 *3*
^{217}At-J$^{\pi}$,$T_{1/2}$: From 2018Ko01 (A=217 evaluation).
^{217}At-Q(α): From 2021Wa16.
Others: 1969LeZW (αγ,semi), 1964Va20 (αγ,scin), 1962Wa28, 1960Vo05, 1955St04.
1997Ch19: Source: Separated ^{225}Ac from ^{229}Th; Detector: Si(Au) α-detector, HPGe γ-detector; Measured: Eα, Iα, Eγ, Iγ, α-γ coin.
1997Ch53: Source: Separated ^{225}Ac from ^{229}Th; Detector: Si(Au)-α-detector, Measured: Eα.

^{213}Bi Levels

E(level)†	J$^{\pi}$‡	$T_{1/2}$	Comments
0.0	9/2^{-}	45.59 min *6*	$T_{1/2}$: From Adopted Levels.
257.88 *5*	7/2^{-}		
593.13 *3*	(5/2,7/2,9/2)$^{-}$		
758.90 *10*	(5/2^{-},13/2^{-})		
1050			E(level): From 1997Ch53.

† From Eγ, except where otherwise noted. The 465-keV level in ^{213}Bi, reported earlier in 1967Dz02 feeding through 6609-keV α from ^{217}At, was not confirmed by 1997Ch53, instead the 6609α has been assigned to ^{221}Ra (1997Ch53).
‡ From Adopted Levels.

α radiations

Eα†	E(level)	Iα‡@	HF#	Comments
6037	1050	<0.002	>5.4	Eα: From 1997Ch53. In 1968Le07 and 1967Dz02, the 6037α is shown from ^{221}Fr.
6322.0 *16*	758.90	0.005 *1*	37 *8*	
6484.7 *16*	593.13	0.021 *2*	40 *4*	Eα: Others: 6483 *5* (adjusted value in 1991Ry01), 6484.7 *15* (1996GrZT). Iα: Weighted average of 0.02 *1* (1969LeZW), 0.021 *2* (1997Ch19), and 0.020 *3* (1996GrZT). Iγ intensity balance yields 0.018 *1*.
6813.8 *16*	257.88	0.038 *3*	394 *32*	Eα: Others: 6812 *5* (adjusted value in 1991Ry01) and 6813.8 *15* (1996GrZT). Iα: Weighted average of 0.036 *3* (1997Ch19), 0.040 *3* (1996GrZT), and 0.06 *2* (1969LeZW).
7066.9 *16*	0.0	99.9 *1*	1.19 *1*	Eα: Others: 7066.9 *15* (adjusted value in 1991Ry01), 7062 *5* (1977Vy02), 7071 *2* (1982Bo04), 7066.9 *15* (1996GrZT), 7064 *5* (1960Vo05). Iα: From 1969LeZW. Others: Iα=99.9 (1997Ch19), 99.9 (1996GrZT).

† From 1997Ch19. α′s 6849-, 6772-, 6541-, and 6422-keV reported in 1967Dz02 were not confirmed in 1997Ch19,1997Ch53, and 1969LeZW. These α′s are assumed to be due to contaminants and they are not listed here.
‡ From 1997Ch19, except otherwise noted. In 1997Ch19, Iα per 100 ^{217}At decays is reported, assuming the absence of γ-feeding from higher-lying unknown levels.
# r_0(^{213}Bi)=1.5509 *7*, average of r_0(^{212}Pb)=1.5412 *3* and r_0(^{214}Po)=1.5606 *7* (2020Si16).
@ For absolute intensity per 100 decays, multiply by 0.99993 *3*.

γ(^{213}Bi)

Iγ normalization: from 2018Ko01 (A=217 evaluation) based on 1997Ch19.

Continued on next page (footnotes at end of table)

^{217}At α decay 1997Ch19,1997Ch53,1967Dz02 (continued)

γ(^{213}Bi) (continued)

E_γ[†]	I_γ[‡#]	E_i(level)	J_i^π	E_f	J_f^π	Mult.	δ	α[@]	Comments
[x]165.8	<0.0002								E_γ: Reported both in 1997Ch19 and 1964Va20.
257.89 *6*	0.0287 *7*	257.88	7/2⁻	0.0	9/2⁻	M1+E2	0.59 *13*	0.57 *5*	E_γ: Weighted average of 257.88 *4* (1997Ch19), 258.5 *2* (1981Di14), and 257.87 *4* (1996GrZT). I_γ: Others: 0.0297 *20* (1996GrZT), 0.04 *1* (1969ArZV), and also 0.056 *20* by scaling Iγ(258.5)=0.239 *20* (relative) (1981Di14) with Iγ(218)=49 (relative) (1981Di14) and and Iγ(218)=11.38% of ^{221}Fr α decay (11.57% *15* (1986He06) and 11.2% *2* (1997Ch19). Mult.: M1+E2 from α(K)exp=0.45 *4* (1997Ch19). M1 from (α)(K x ray)/(α)(γ) coincidence (1969LeZW). δ: Deduced from α(K)exp=0.45 *4* (1997Ch19) using BriccMixing code.
335.26 *5*	0.0062 *3*	593.13	(5/2,7/2,9/2)⁻	257.88	7/2⁻				E_γ: Weighted average of 335.33 *10* (1997Ch19) and 335.24 *5* (1996GrZT). Others: 334 (1969LeZW). I_γ: Other: 0.0048 *9* (1996GrZT).
[x]501.0	<0.0002								
593.13 *3*	0.0115 *5*	593.13	(5/2,7/2,9/2)⁻	0.0	9/2⁻				E_γ: From 1996GrZT. Others: 593.1 *2* (1997Ch19), 593.1 (1981Di14). I_γ: Other: 0.0128 *9* (1996GrZT), also 0.018 *6* by scaling Iγ(593.1)=0.0507 *25* (relative) (1981Di14) with Iγ(218)=49 (relative) (1981Di14) and and Iγ(218)=11.38% of ^{221}Fr α decay (11.57% *15* (1986He06) and 11.2% *2* (1997Ch19).
758.9 *1*	0.0049 *4*	758.90	(5/2⁻,13/2⁻)	0.0	9/2⁻				

† From 1997Ch19. γ′s 140-, 375-, and 455-keV, reported in 1964Va20, are not placed in the level scheme. These γ rays were not confirmed by 1997Ch19 and 1969LeZW. Also the reported 218γ in 1969LeZW was not confirmed by 1997Ch19 and appears to be associated with ^{217}At. Aforementioned γ could arise due to summing effect or remnant of random coincidence peaks (1997Ch19). These γ are not listed in the dataset.

‡ From 1997Ch19, absolute photon intensity per 100 ^{217}At decays.

\# Absolute intensity per 100 decays.

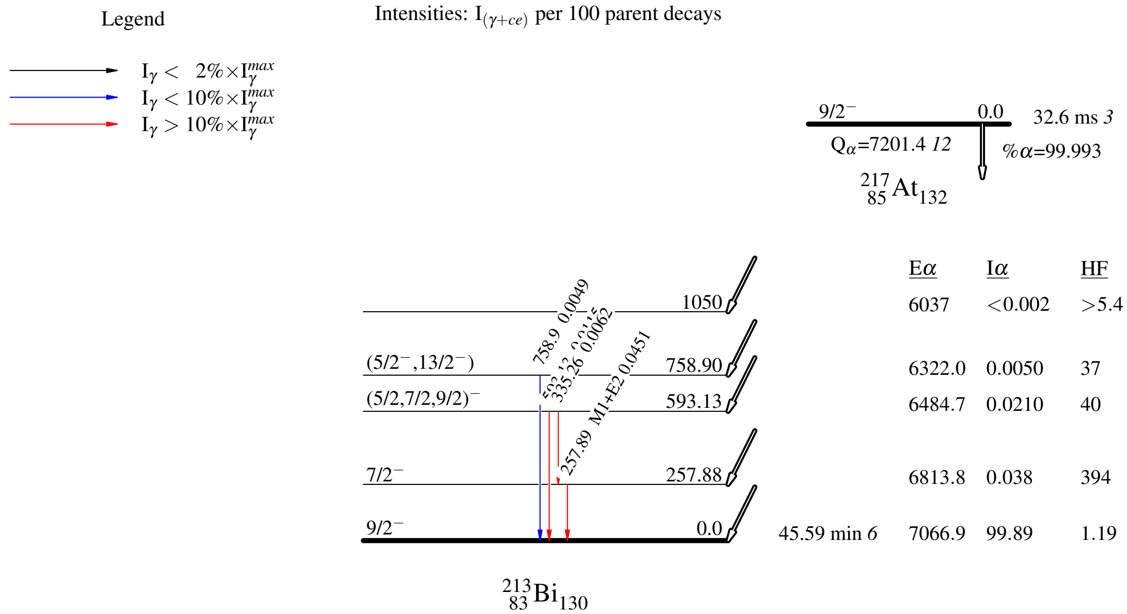
@ Total theoretical internal conversion coefficients, calculated using the BrIcc code (2008Ki07) with Frozen orbital approximation based on γ-ray energies, assigned multipolarities, and mixing ratios, unless otherwise specified.

x γ ray not placed in level scheme.

^{217}At α decay 1997Ch19,1997Ch53,1967Dz02

Decay Scheme

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



^{9}Be(^{238}U,X) 2012Ch19

^{213}Bi nuclide was obtained from fragmentation of ^{238}U beam, E=670 MeV/nucleon, at the GSI heavy-ion synchrotron SIS. Target thickness=4 g/cm^2. Fragments were separated in flight by the Fragment Separator (FRS) and injected into the ESR. Measured masses by Schottky Mass Spectrometry (SMS) technique. The ions produced were mainly fully-stripped (bare) or carried a few electrons. Deduced an isomer in ^{213}Bi.

^{213}Bi Levels

E(level)	J^π	$T_{1/2}$	Comments
0	9/2$^-$	45.59 min *6*	J^π,$T_{1/2}$: from Adopted Levels.
1353 *21*			E(level): Isomer (^{238}U,X) was identified from Schottky frequency spectrum (figure 2 in 2012Ch19). Excitation energy was deduced from Schottky frequency spectrum (figure 2 in 2012Ch19), mass measurement. 2012Ch19 mention γ decay to the ground-state was discovered in the time resolved spectrum shown in Fig. 2. $T_{1/2}$: > 168 s from single-ion tracing evaluation method (2008ChZI).

Adopted Levels, Gammas

$Q(\beta^-)$=−74 *6*; S(n)=4355 *3*; S(p)=5825 *3*; $Q(\alpha)$=8536 *3* 2021Wa16

2020De36: $^{238}U(^{48}Ca,X)$, E=233.3 MeV; measured multi-nucleon transfer reaction cross section $\sigma_{cumulative}$=2350 nb/sr *9* for ^{213}Po.

2015Ba20: ^{136}Xe + ^{208}Pb, E(c.m.)=450 MeV, measured multi-nucleon transfer reaction cross section $\sigma_{cumulative\ yield}$=0.193 mb *39* and $\sigma_{independent\ yield}$=0.190 mb *38* for ^{213}Po.

^{213}Po Levels

Cross Reference (XREF) Flags

A	^{213}Bi β^- decay (45.59 min)
B	^{217}Rn α decay
C	$^{208}Pb(^{18}O,X\gamma)$

E(level)[†]	J$^\pi$[#]	$T_{1/2}$	XREF	Comments
0.0[‡]	9/2$^+$	3.706 μs *1*	ABC	%α=100 J$^\pi$: favored α decay to ^{209}Pb g.s. (J$^\pi$=9/2$^+$). $T_{1/2}$: Weighted average of 3.709 μs *2* (2020Ko06 – 440γ-α(t)), 3.705 μs *1* (2018Al32 – deduced from the 622-day decay curve using parent ^{229}Th), 3.5 μs *3* (2018Sa45 – α_1-α_2-α_3 correlations), 3.65 μs *4* (1998Wa25), 3.75 μs *4* (1997Wa27), 3.70 μs *3* (1997VaZV), and 3.74 μs *2* (1995WaZQ), 4.2 μs *8* (1948Je05), 3.708 μs *8* (2013Su13 – ^{213}Po α decay). Others: 4.2 μs (1949Me54), and 3.65 μs (2002Mo46). Eα (group 1)=8376 *3* (1982Bo04), 8377 *5* (1964Va20), 8368 *10* (1960Vo05); Eα (group 2)=7614 *10* (1964Va20).
292.805 *8*	(11/2$^+$)	78 ps *14*	A	J$^\pi$: 292.78γ (M1+E2) to 9/2$^+$ state. 2011As05 (^{18}O,Xγ) proposed spin parity 7/2$^+$ instead of 11/2$^+$. $T_{1/2}$: From delayed γγ-coin in ^{213}Bi β^- decay (1997Wa27).
440.446 *9*	(7/2$^+$)	93 ps *3*	A	%α<0.001 from 1997Wa27 (see ^{213}Bi β- decay). J$^\pi$: 440γ M1 to 9/2$^+$ state. log *ft*=6.1 in 9/2$^-$ ^{213}Bi β^- decay. HF≥70 estimated in 1997Wa27. 2011As05 (^{18}O,Xγ) proposed spin-parity 11/2$^+$ instead of 7/2$^+$. $T_{1/2}$: From β-γ coincidences in ^{213}Bi β^- decay (1997Wa27).
600.87? *17*	(5/2$^+$)		A	
645.6[‡] *5*	13/2$^+$[@]		C	
867.98 *3*	(13/2$^+$)		A	J$^\pi$: 2011As05 (^{18}O,Xγ) proposed spin-parity to be 9/2$^+$ instead of 13/2$^+$, since it was not populated in their work.
1003.605 *22*	(9/2$^+$)		A	
1045.65 *9*	(9/2$^+$,11/2$^+$)		A	
1068.4[‡] *5*	17/2$^+$[@]		C	
1100.173 *8*	(7/2,9/2,11/2)		A	
1119.38 *4*	(7/2,9/2,11/2)		A	
1328.2 *3*	(7/2,9/2,11/2)		A	
1357.4[‡] *6*	21/2$^+$[@]		C	
1412.9 *8*			C	
1503.6 *8*	(25/2$^+$)[@]		C	Possible configuration: $\pi\ h^{+2}_{9/2}\otimes\nu\ i^{+1}_{11/2}$.
1619.1 *8*	(23/2$^+$)		C	J$^\pi$: 261.7γ to 21/2$^+$.
1779.6 *6*			C	
2017.2 *9*			C	

[†] Deduced by evaluator from a least square fit to the γ-ray energies.

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued)

^{213}Po Levels (continued)

‡ Yrast sequence. Possible configuration: 9/2$^+$: ν ($g^{+1}_{9/2}$), 13/2$^+$: ν ($g^{+1}_{9/2}$)⊗2$^+$, 17/2$^+$: ν ($g^{+1}_{9/2}$)⊗4$^+$, and 21/2$^+$: ν ($g^{+1}_{9/2}$)⊗6$^+$.

From 1998Ar03 (^{213}Bi β^- decay), except where otherwise noted. In 1998Ar03, semiempirical shell-model calculation results were compared as a guide for parity and spin assignments. Additional arguments are given as comments.

@ From (^{18}O,Xγ) based on γ-ray multipole assignments.

Adopted Levels, Gammas (continued)

$\gamma(^{213}Po)$

E_i(level)	J^π_i	E_γ†	I_γ†	E_f	J^π_f	Mult.†	δ†	α@	Comments
292.805	(11/2+)	292.80 *1*	100	0.0	9/2+	M1+E2	1.0 *+5−4*	0.34 *10*	B(M1)(W.u.)=0.0042 *+24−17*; B(E2)(W.u.)=17 *8* Mult.,δ: Mult: from α(K)exp=0.24 *7* (1998MaZO – ^{213}Bi β^- decay).
440.446	(7/2+)	147.66 *5*	0.057 *4*	292.805	(11/2+)	(E2)		1.454 *20*	B(E2)(W.u.)=0.563 *45* Mult.: B(E2)=0.0031 *6* (1997Wa27) is close to the B(E2, 2+ to 0+) values of the neighboring nuclei.
		440.45 *1*	100 *1*	0.0	9/2+	M1+E2	0.39 *+15−19*	0.161 *13*	B(M1)(W.u.)=0.00207 *+21−24*; B(E2)(W.u.)=0.55 *+40−35* Mult.,δ: Mult: from α(K)exp=0.12 *1* (^{213}Bi β^- decay).
600.87?	(5/2+)	600.9 *2*	100	0.0	9/2+				
645.6	13/2+	645.6‡ *5*	100	0.0	9/2+	E2#		0.01796 *25*	
867.98	(13/2+)	574.9 *3*	22 *9*	292.805	(11/2+)				
		867.98 *3*	100 *5*	0.0	9/2+				
1003.605	(9/2+)	402.8 *3*	0.20 *3*	600.87?	(5/2+)				
		710.82 *3*	22.2 *10*	292.805	(11/2+)				
		1003.58 *3*	100 *6*	0.0	9/2+				
1045.65	(9/2+,11/2+)	604.94 *21*	13 *3*	440.446	(7/2+)				
		1045.70 *9*	100 *17*	0.0	9/2+				
1068.4	17/2+	422.8‡ *1*	100	645.6	13/2+	E2#		0.0486 *7*	
1100.173	(7/2,9/2,11/2)	659.75 *2*	12.9 *7*	440.446	(7/2+)				
		807.36 *1*	100.0 *25*	292.805	(11/2+)				
		1100.17 *1*	91 *6*	0.0	9/2+				
1119.38	(7/2,9/2,11/2)	826.55 *5*	13.7 *19*	292.805	(11/2+)				
		1119.40 *6*	100 *4*	0.0	9/2+				
1328.2	(7/2,9/2,11/2)	886.66& *14*	100 *20*	440.446	(7/2+)				
		1328.2 *3*	40 *10*	0.0	9/2+				
1357.4	21/2+	289.0‡ *1*	100	1068.4	17/2+	(E2)#		0.1410 *20*	
1412.9		344.5‡ *5*	100	1068.4	17/2+				
1503.6	(25/2+)	146.2‡ *5*	100	1357.4	21/2+	(E2)		1.512 *29*	α(exp)=0.15 *5* (2011As05) Mult.: From α(exp) (^{18}O,xγ).
1619.1	(23/2+)	261.7‡ *5*	100	1357.4	21/2+				
1779.6		711.2‡ *3*	100	1068.4	17/2+				
2017.2		398.1‡ *5*	100	1619.1	(23/2+)				

† From ^{213}Bi β^- decay, except where otherwise noted.

‡ From (^{18}O,Xγ).

\# From (^{18}O,Xγ) based on the the angular anisotropy ratio R_{ADO} measurements. Evaluator assign as E2 based on the assigned configuration, systematics, and

$^{213}_{84}Po_{129}$-3

$\gamma(^{213}Po)$ (continued)

measurement timescale ($\gamma\gamma$ coin).

@ 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.

^{213}Bi β^- decay (45.59 min) 1998Ar03,1997Wa27,1994Ar23

Parent: ^{213}Bi: E=0.0; J$^\pi$=9/2$^-$; $T_{1/2}$=45.59 min *6*; Q(β^-)=1422 *6*; %β^- decay=97.860 *10*

Others: 2020Go11, 2010Fi10, 2003ChZV, 2002Mo46, 2000Gr35, 1998MaZO, 1989Ko26, 1986He06, 1981Di14, 1977Vy02, 1972Dz14, 1969ArZV, 1969Dz06, 1969DzZZ, 1968Va17, 1967LoZZ, 1955Ma61, 1952Wa24.

1998Ar03,1994Ar23: Source: Chemically separated ^{213}Bi; Detector: p-type coaxial HPGe and planar HPGe; Measured: Eγ, Iγ, γγ coin.

1997Wa27: Source: ^{213}Bi was accumulated on an Al foil from the recoil of ^{217}At decay; Measured: $T_{1/2}$ by the method of delayed coincidences in ^{213}Bi β^- decay.

1989Ko26: Source: Chemically separated ^{213}Bi; Detector: HPGe and LEPS (Low Energy Photon Spectrometer); Eγ, Iγ, γγ coin.

^{213}Po Levels

E(level)†	J$^\pi$‡	$T_{1/2}$	Comments
0.0	9/2$^+$	3.706 μs *1*	J$^\pi$,$T_{1/2}$: From Adopted Levels.
292.805 *8*	(11/2$^+$)	78 ps *14*	J$^\pi$: 292.78γ (M1+E2) to 9/2$^+$ state. $T_{1/2}$: From delayed γγ-coin in ^{213}Bi β^- decay (1997Wa27).
440.446 *9*	(7/2$^+$)	93 ps *3*	%α<0.001 (1997Wa27). $T_{1/2}$: From β-γ coincidences in ^{213}Bi β^- decay (1997Wa27).
600.87? *17*	(5/2$^+$)		
867.98 *3*	(13/2$^+$)		
1003.605 *22*	(9/2$^+$)		
1045.65 *9*	(9/2$^+$,11/2$^+$)		
1100.173 *8*	(7/2,9/2,11/2)		
1119.38 *4*	(7/2,9/2,11/2)		
1328.2 *3*	(7/2,9/2,11/2)		

† Deduced by evaluator from a least square fit to the γ-ray energies.

‡ From 1998Ar03, except otherwise noted. In 1998Ar03, semiempirical shell-model calculation results were compared as a guide for parity and spin assignments.

β^- radiations

E(decay)†	E(level)	Iβ^-‡#	Log *ft*	Comments
(94 *6*)	1328.2	0.00039 *14*	7.67 *18*	
(303 *6*)	1119.38	0.059 *2*	7.08 *4*	
(322 *6*)	1100.173	0.578 *11*	6.17 *3*	
(376 *6*)	1045.65	0.020 *3*	7.85 *7*	
(418 *6*)	1003.605	0.065 *3*	7.49 *3*	
(554 *6*)	867.98	0.0144 *13*	8.64^{1u} *5*	
(821 *6*)	600.87?	0.0042 *8*	10.03^{1u} *9*	
(982 *6*)	440.446	30.1 *4*	6.08 *1*	Iβ^-: 35% *3* of ^{213}Bi β^- decay was measured by 1968Va17, and 32% by 1952Wa24, 1955Ma61.
(1129 *6*)	292.805	0.21 *5*	8.45 *10*	
(1422 *6*)	0.0	66.8 *5*	6.31 *1*	E(decay): 1420 *10* measured value in 1968Va17. Others measurements by 1952Wa24, 1955Ma61. Iβ^-: 65% *3* of ^{213}Bi β^- decay was measured by 1968Va17 and 68% (1955Ma61).

† From excited level energy and Q(β^-). Measured value to g.s is listed in comments.

‡ From intensity balance at each level.

Absolute intensity per 100 decays.

$\gamma(^{213}Po)$

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x-rays (Po): 1972Dz14
I(Kα1    x ray)=1.6%
I(Kα2    x ray)=0.93%
I(Kβ1    x ray)=0.35%
I(Kβ2    x ray)=0.12%
these x-ray intensities were measured by 1972Dz14 in γ
spectrum of 225Ac  and its daughters in equilibrium with it;
intensities were normalized to 225Ac  γ's, given per 100
decays of 225Ac.  The uncertainties were assigned as 10-15%.
The expected total x-ray intensity from level scheme is 4.00% 5.
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E_γ[†]	I_γ[#a]	E_i(level)	J^π_i	E_f	J^π_f	Mult.[&]	δ	α[b]	Comments
147.66 *5*	0.0149 *12*	440.446	(7/2$^+$)	292.805	(11/2$^+$)	(E2)		1.454 *20*	E_γ: Others: 147.1 *1* (2000Gr35), 147.63 *8* (1989Ko26). I_γ: Weighted average of 0.0147 *12* (1998Ar03 – 0.0148 *12*) and 0.022 *8* (2000Gr35). Others: 0.011 *1* (1989Ko26). Mult.: B(E2)=0.0031 *6* (1997Wa27) is close to the B(E2, 2$^+$ to 0$^+$) values of the neighboring nuclei.
292.80 *1*	0.419 *8*	292.805	(11/2$^+$)	0.0	9/2$^+$	M1+E2	1.0 +*5*–*4*	0.34 *10*	E_γ: Weighted average of 292.76 *5* (1998Ar03), 292.81 *1* (2000Gr35), 292.86 *10* (1977Vy02), and 292.80 *1* (1989Ko26). I_γ: Weighted average of 0.413 *23* (1998Ar03 – 0.416 *23*), 0.429 *7* (1986He06), 0.41 *1* (2000Gr35 – 0.40 *1*), 0.31 *4* (2002Mo46), 0.403 *23* (1981Di14 – 0.426 *24*), 0.41 *2* (1989Ko26). Mult.,δ: From α(K)exp=0.24 *7* (1998MaZO), mixing ratio was deduced using the briccMixing code.
402.8 *3*	0.00010[@] *3*	1003.605	(9/2$^+$)	600.87?	(5/2$^+$)	[E2]		0.0552 *8*	E_γ: Weak gamma – not observed by 2000Gr35 and suggested for confirmation.
440.45 *1*	25.9 *2*	440.446	(7/2$^+$)	0.0	9/2$^+$	M1+E2	0.39 +*15*–*19*	0.161 *13*	E_γ: Weighted average of 440.43 *5* (1998Ar03) and 440.44 *1* (2000Gr35), 440.420 *20* (1977Vy02), 440.46 *1* (1989Ko26). Other: 440.4 (2003ChZV). I_γ: Weighted average of 26.2 *3* (2010Fi10), 26.1 *3* (1986He06), 25.4 *3* (2000Gr35), and 25.8 *3* (2020Go11). Others: 21 *1* (1989Ko26 quoted from 1969DZ06), 27.4 (1981Di14), ~25.4 (2003ChZV). Mult.,δ: From α_K=I_e/I_γ=[3.15 *15* (1969DzZZ)/25.9 *2*]=0.12 *1*. Other conversion electron measurements in 1967LoZZ.
574.9 *3*	0.0025 *10*	867.98	(13/2$^+$)	292.805	(11/2$^+$)	[M1+E2]		0.056 *32*	E_γ: Weighted average of 574.8 *3* (1998Ar03), and 575.2 *5* (2000Gr35). I_γ: From 2000Gr35. Other: 0.00063 *17* (1998Ar03).
600.9 *2*	0.0043 *8*	600.87?	(5/2$^+$)	0.0	9/2$^+$				E_γ: Weighted average of 600.7 *3* (1998Ar03) and 601.0 *2* (2000Gr35).

γ(^{213}Po) (continued)

E_γ[†]	I_γ[#a]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[&]	α[b]	Comments
								I_γ: From 2000Gr35 (0.0042 *8*). Other: 0.00069 *22* (1998Ar03 – 0.00070 *22*).
604.94 *21*	0.0023 *6*	1045.65	(9/2$^+$,11/2$^+$)	440.446	(7/2$^+$)			E_γ,I_γ: From 2000Gr35. Other: Eγ=604.9 *3* and Iγ=0.00050 *18* (1998Ar03).
^{x}646.03 *9*	0.00229[@] *22*							E_γ,I_γ: Iγ from 0.00231 *22* (1998Ar03). Other: Eγ 646.0 *1* and Iγ 0.0024 *10* in 2000Gr35.
659.75 *2*	0.0374 *21*	1100.173	(7/2,9/2,11/2)	440.446	(7/2$^+$)			E_γ: Weighted average of 659.77 *2* (1994Ar23) and 659.74 *2* (2000Gr35), 659.81 *10* (1977Vy02). Others: 659.8 *1* (1989Ko26), 659.5 (2003ChZV), 659.77 *5* (1998Ar03) (not listed earlier). I_γ: Weighted average of 0.0358 *20* (1998Ar03 – 0.0361 *20*), 0.035 *11* (2002Mo46), 0.044 *3* (2000Gr35 – 0.044 *3*), and 0.05 *2* (1969ArZV – 0.04 *2*), 0.043 *4* (2003ChZV – 0.042 *4*), 0.031 *3* (1989Ko26).
710.82 *3*	0.0114 *5*	1003.605	(9/2$^+$)	292.805	(11/2$^+$)	[M1+E2]	0.033 *18*	E_γ: From 2000Gr35. Others: 710.81 *21* (1998Ar03), 710.8 *1* (1989Ko26), 710.8 (2003ChZV). I_γ: Weighted average of 0.0101 *11* (1998Ar03 – 0.0102 *11*), 0.0121 *10* (2000Gr35 – 0.0119 *10*), and 0.015 *8* (2002Mo46), 0.0118 *8* (2003ChZV – 0.116 probably is a misprint of 0.0116 *8*), 0.011 *1* (1989Ko26).
807.36[‡] *1*	0.289 *7*	1100.173	(7/2,9/2,11/2)	292.805	(11/2$^+$)			E_γ: Others: 807.37 *1* (2000Gr35), 807.38 *5* (1998Ar03), 807.355 *37* (1977Vy02), 807.4 (2003ChZV). I_γ: Weighted average of 0.290 *12* (1986He06 – 0.292 *12*), 0.289 *18* (2000Gr35 – 0.283 *18*), 0.239 *15* (1998Ar03 – 0.241 *15*), 0.27 *2* (2002Mo46), 0.30 *4* (1969ArZV – 0.24 *3*), 0.303 *10* (2003ChZV – 0.297 *10*), 0.271 *16* (1989Ko26), 0.299 *7* (1981Di14 – 0.316 *7*).
826.55 *5*	0.0067 *5*	1119.38	(7/2,9/2,11/2)	292.805	(11/2$^+$)			E_γ: Weighted average of 826.59 *5* (2000Gr35), 826.8 *2* (1989Ko26), 826.47 *6* (1998Ar03). Other: 826.5 (2003ChZV). I_γ: Weighted average of 0.0077 *13* (2000Gr35 – 0.0077 *13*), 0.0075 *5* (2003ChZV – 0.0074 *5*), 0.0057 *5* (1998Ar03), and 0.0070 *7* (1989Ko26).
867.98 *3*	0.0118 *6*	867.98	(13/2$^+$)	0.0	9/2$^+$			E_γ: Weighted average of 867.98 *3* (1998Ar03) and 867.93 *3* (2000Gr35). Other: 867.9 (2003ChZV). I_γ: Weighted average of 0.0110 *11* (1998Ar03 – 0.0111 *11*) and 0.0125 *11* (2000Gr35 – 0.0123 *11*), 0.0117 *8* (2003ChZV – 0.0115 *8*), and 0.023 *13* (2002Mo46).
^{x}880.91 *1*	0.0041 *5*							E_γ: From 2000Gr35. Other: 880.2 *3* (1998Ar03). I_γ: Weighted average of 0.0029 *10* (1998Ar03) and 0.0043 *4* (2000Gr35 – 0.0042 *4*).
^{x}884.6 *3*	0.00029[@] *10*							E_γ: Weak gamma – not observed by 2000Gr35 and suggested for confirmation.

γ(^{213}Po) (continued)

E_γ[†]	I_γ[#a]	E_i(level)	J^π_i	E_f	J^π_f	Comments
886.66[c] *14*	0.00101 *19*	1328.2	(7/2,9/2,11/2)	440.446	(7/2$^+$)	I_γ: From 0.00102 *19* (1998Ar03).
[x]897.0 *3*	0.00031[@] *9*					E_γ: Weak gamma − not observed by 2000Gr35 and suggested for confirmation.
1003.58 *3*	0.053 *3*	1003.605	(9/2$^+$)	0.0	9/2$^+$	E_γ: Weighted average of 1003.58 *3* (1998Ar03), 1003.59 *3* (2000Gr35), 1003.57 *3* (1989Ko26). Other: 1003.6 (2003ChZV). I_γ: Weighted average of 0.050 *5* (1998Ar03), 0.054 *3* (2000Gr35 − 0.053 *3*), and 0.04 *1* (2002Mo46). Others: 0.0565 *13* (2003ChZV − 0.0554 *13*), 0.043 *4* (1989Ko26).
1045.70 *9*	0.018[@] *3*	1045.65	(9/2$^+$,11/2$^+$)	0.0	9/2$^+$	E_γ: Others: 1045.10 *40* (2000Gr35), 1045.7 (2003ChZV). I_γ: Others: 0.015 *3* (2003ChZV − 0.15 probably is a misprint), 0.035 *19* (2000Gr35 − 0.034 *19*).
1100.17 *1*	0.252 *8*	1100.173	(7/2,9/2,11/2)	0.0	9/2$^+$	E_γ: Weighted average of 1100.18 *2* (2000Gr35), 1100.12 *5* (1998Ar03), 1100.16 *2* (1989Ko26), 1100.14 *6* (1977Vy02). Other: 1100.2 (2003ChZV). I_γ: Weighted average of 0.257 *16* (1998Ar03 − 0.259 *16*), 0.256 *15* (2000Gr35 − 0.251 *17*), 0.259 *7* (1981Di14 − 0.274 *7*), 0.284 *17* (1989Ko26), 0.219 *12* (2003ChZV − 0.215 *12*), and 0.23 *2* (2002Mo46).
1119.40 *6*	0.052 *2*	1119.38	(7/2,9/2,11/2)	0.0	9/2$^+$	E_γ: Unweighted average of 1119.50 *4* (2000Gr35), 1119.29 *5* (1998Ar03), 1119.4 *1* (1989Ko26). Other: 1119.3 (2003ChZV). I_γ: Weighted average of 0.050 *3* (1998Ar03), 0.052 *3* (2000Gr35 − 0.051 *3*), 0.053 *4* (2003ChZV − 0.052 *4*), 0.04 *1* (2002Mo46), and 0.062 *6* (1989Ko26).
1328.2 *3*	0.00039[@] *14*	1328.2	(7/2,9/2,11/2)	0.0	9/2$^+$	E_γ: Weak gamma − not observed by 2000Gr35 and suggested for confirmation.

[†] From 1998Ar03, except otherwise noted.

[‡] From 1989Ko26.

[#] γ-ray intensities were reported with respect to %Iγ(440)=26.1 *3* in 1986He06, 1998Ar03, 2002Mo46; %Iγ(440)=25.4 *3* in 2000Gr35, 2003ChZV; %Iγ(440)=21 *1* in 1989Ko26, 1969ArZV; %Iγ(440)=27.4 in 1981Di14. All values are normalized with respect to %Iγ(440)=25.9 (of this dataset) and listed in the comments, if different.

[@] From 1998Ar03.

[&] From ce measurements of 1955Ma61 and 1969DzZZ, except otherwise noted.

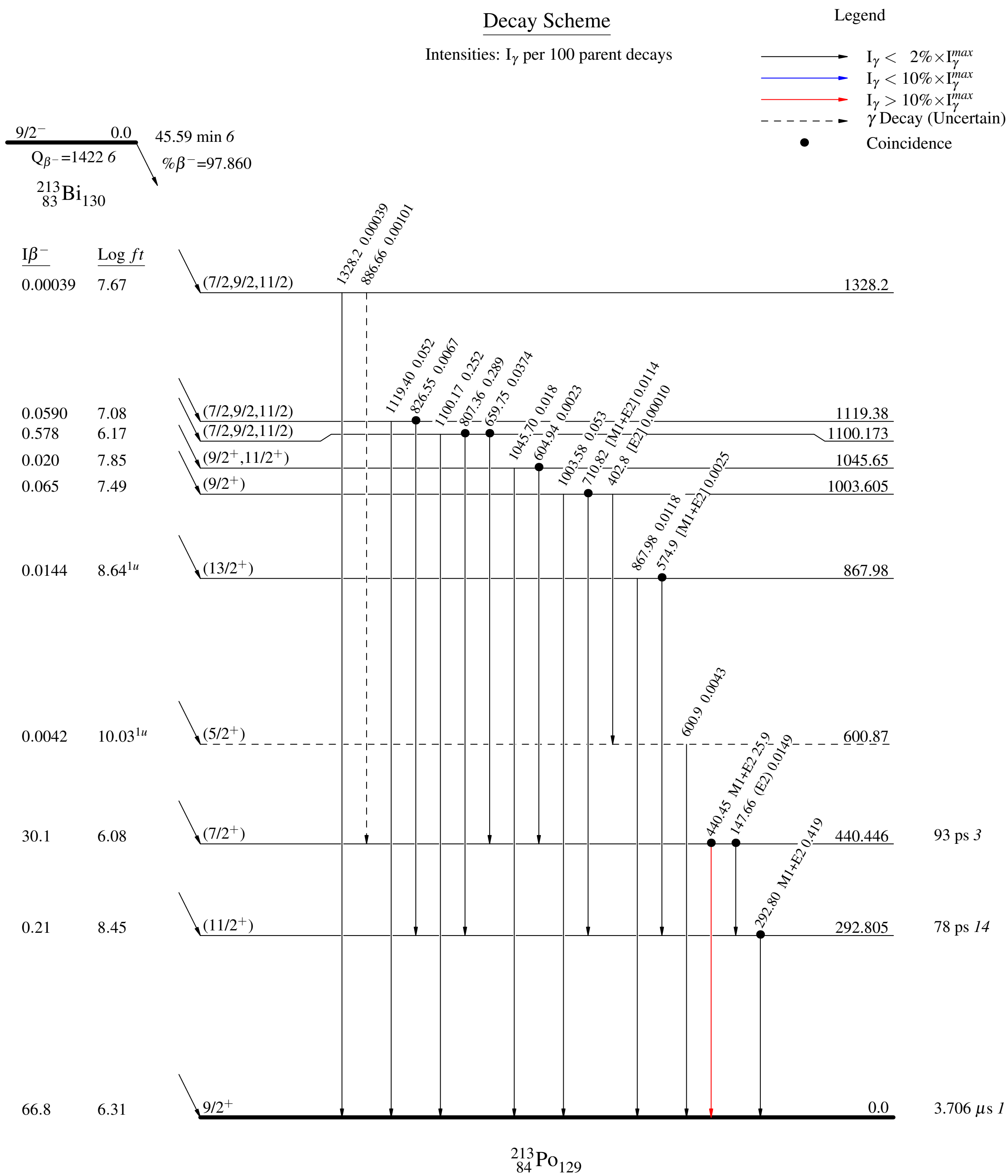
[a] Absolute intensity per 100 decays.

[b] 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.

[c] Placement of transition in the level scheme is uncertain.

[x] γ ray not placed in level scheme.

^{213}Bi β^- decay (45.59 min) 1998Ar03,1997Wa27,1994Ar23



^{217}Rn α decay

Parent: ^{217}Rn: E=0.0; J^π=9/2$^+$; $T_{1/2}$=0.59 ms *6*; Q(α)=7887.2 *29*; %α decay=100
^{217}Rn-J^π: From 2018Ko01 (A=217 evaluation).
^{217}Rn-$T_{1/2}$: Weighted average of 0.54 ms *5* (1961Ru06) and 0.67 ms *6* (2018Sa45). Others: ~1 ms (1949Me54), 1.0 ms *1* (1951Me10), and 0.54 ms *5* in 2018Ko01 (A=217 evaluation).
$\alpha\gamma$: no (7735α)(γ,L x ray) (1961Ru06).
Another α peak at 7.50 MeV with an intensity of 0.1% was observed by 1961Ru06. The energy difference from the 7741-keV α, including the recoil, yields 243 keV for the level energy, if the 7500-keV α is from ^{217}Rn decay. The first excited state in ^{213}Po has been observed at 293 keV in ^{213}Bi decay. The observed α peak at 7.50 MeV may be due to an impurity; no positive identification could be made by 1961Ru06.

^{213}Po Levels

E(level)	J^π	$T_{1/2}$	Comments
0.0	9/2$^+$	3.706 μs *1*	J^π,$T_{1/2}$: From Adopted Levels.

α radiations

Eα	E(level)	Iα‡	HF†	Comments
7738 *3*	0.0	100	1.7 *2*	Eα: Weighted average of 7741 *4* (1982Bo04 – Eα=7739 keV *4* in 1982Bo04 is increased by 2 keV, as recommended by 1991Ry01 for a change in calibration energy) and 7735 *4* (1961Ru06). Other measured values: Eα=7740 *10* (2018Sa45 – 7.74 MeV *1*), 7740 *30* (1951Me10 – 7.74 MeV *3*), 7740 (1949Me54 – 7.74 MeV).

† Using r_0(^{213}Po)=1.5632 *26*, unweighted average of r_0(^{212}Po)=1.5658 *6* (assuming 1.56580 *59* in 2020Si16 – listed as 1.5658 *59*) and r_0(^{214}Po)=1.5606 *7* (2020Si16).
‡ Absolute intensity per 100 decays.

^{208}Pb(^{18}O,Xγ) 2011As05

Adapted/Edited the XUNDL dataset compiled by B. Singh (McMaster); Mar 05, 2011.

E=85 MeV from Vivitron tandem of IReS (Strasbourg). Measured Eγ, Iγ, γγ coin, γ(θ) (ADOs) using Euroball IV array with 71 Compton- suppressed Ge detector systems (15 clusters, 26 clovers and 30 tapered single-Ge detectors; cluster is composed of seven large volume Ge crystals and a clover of four smaller Ge crystals; thus a total 239 individual Ge crystals). Some revisions proposed for J^π assignments of low-spin levels of ^{213}Po populated in the β^- decay of ^{213}Bi.

Measured $\sigma \approx 0.3$ mb for the production of ^{213}Po in the reaction used. From this low cross section, 2011As05 proposed that levels in ^{213}Po were populated by neutron emission of high-lying levels in ^{214}Po for which the production cross section σ=0.5-1 mb.

Proposed revisions of J^π assignments in ^{213}Bi decay: 293 level: 7/2$^+$ instead of (11/2$^+$); 440 level: 11/2$^+$ instead of (7/2$^+$); 868 level: 9/2$^+$ instead of (13/2$^+$), for J^π=13/2$^+$, it was expected to be populated in the 2011As05 work.

^{213}Po Levels

E(level)†	Jπ#	Comments
0.0‡	9/2+	
645.6‡ *5*	13/2+	
1068.4‡ *2*	17/2+	
1357.4‡ *2*	21/2+	
1412.9 *5*		
1503.6 *5*	(25/2+)	Possible configuration: π $(h^{+2}_{9/2})\otimes\nu\ (g^{+1}_{9/2})$, π $h^2_{9/2}\otimes\nu\ i_{11/2}$ (2011As05 – probably a misprint).
1619.1 *5*	(23/2+)	
1779.6 *4*		
2017.2 *7*		

† From Eγ data.

‡ Yrast sequence. Possible configuration: 9/2$^+$: ν $(g^{+1}_{9/2})$, 13/2$^+$: ν $(g^{+1}_{9/2})\otimes 2^+$, 17/2$^+$: ν $(g^{+1}_{9/2})\otimes 4^+$, and 21/2$^+$: ν $(g^{+1}_{9/2})\otimes 6^+$.

Proposed by 2011As05 based on γ-ray multipole assignments.

γ(^{213}Po)

Eγ†	Iγ	Ei(level)	Jπi	Ef	Jπf	Mult.‡	α#	Comments
146.2 *5*	8 *2*	1503.6	(25/2+)	1357.4	21/2+	(E2)	1.512 *29*	α(exp)=1.5 *5* (0.15 *5* in 2011As05 probably a misprint). Mult.: Proposed by 2011As05 based on α(exp), extracted from intensity imbalances measured in spectra in double coincidence with the 146 keV transition and either the 423 or the 646 keV transition.
261.7 *5*	4.8 *14*	1619.1	(23/2+)	1357.4	21/2+			
289.0 *1*	60 *10*	1357.4	21/2+	1068.4	17/2+	Q		R_{ADO}=1.3 *2*.
344.5 *5*	15 *5*	1412.9		1068.4	17/2+			
398.1 *5*	3.5 *12*	2017.2		1619.1	(23/2+)			
422.8 *1*	100	1068.4	17/2+	645.6	13/2+	Q		R_{ADO}=1.18 *10*.
645.6 *5*		645.6	13/2+	0.0	9/2+	Q		R_{ADO}=1.25 *10*.
711.2 *3*	24 *6*	1779.6		1068.4	17/2+			

† 2011As05 state uncertainty as 0.1-0.5 keV. The evaluator assigns as follows: 0.1 keV for intense γ rays (Iγ>40), 0.3 keV for Iγ=20-40, 0.5 keV for Iγ<20.

‡ Assigned by the evaluator, except where otherwise noted, based on the angular anisotropy ratio, R_{ADO}=Iγ(39.3°)/Iγ(76.6°), with respect to the beam axis for the most intense γ rays. It appears that for a quadrupole transition R_{ADO} ~ 1.2 was expect, not

Continued on next page (footnotes at end of table)

^{208}Pb(^{18}O,Xγ) 2011As05 (continued)

γ(^{213}Po) (continued)

mentioned in 2011As05.

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.

Adopted Levels, Gammas

Q(β⁻)=−884 *6*; S(n)=6023 *5*; S(p)=3499 *5*; Q(α)=9254 *5* 2021Wa16
Assignment: daughter of ^{229}Np, ^{225}Pa, ^{221}Ac, and ^{217}Fr (1968Ha14,1970Bo13).
Induced fission data from ^{209}Bi(α,f) reaction were taken, and fission barrier parameters were deduced by 1982Gr21, 1982Gr24, 1983Gr17, 1984Gr06, 1984Gr13, 1984Ig01, 1984It01, 1985It01, 1986Be20, 1986It01, 1987It03, and 1988Gr16.
2020De36: ^{238}U(^{48}Ca,X), E=233.3 MeV; measured multi-nucleon transfer reaction cross section $\sigma_{cumulative}$=54.0 nb/sr *12* for ^{213}At.
2015Ba20: ^{136}Xe + ^{208}Pb, E(c.m.)=450 MeV, measured multi-nucleon transfer reaction cross section $\sigma_{cumulative\ yield}$=0.384 mb *77* and $\sigma_{independent\ yield}$=0.384 mb *77* for ^{213}At.
See 1972Mo10, 1973Ba19, 1974Ba87, 1977Ha41, 1977Pr10, 1979Ad07, 1979Ig04, 1980Ig02, 1983Br06, 1983Br15, 1984Ni09, and 1984Ro23 for calculations of fission barriers and probabilities for decay by fission. Effective moment of inertia was calculated by 1982Ad01.

^{213}At Levels

Cross Reference (XREF) Flags

A ^{217}Fr α decay
B ^{208}Pb(^{7}Li,2nγ),^{209}Bi(^{18}O,^{14}Cγ)
C ^{209}Bi(^{7}Li,p2nγ),^{209}Bi(^{8}He,4nγ)

E(level)†	Jπ‡	$T_{1/2}$	XREF	Comments
0.0	9/2⁻	125 ns *6*	ABC	%α=100 Possible %ε decay to ^{213}Po g.s. is expected to be <2.5×10^{-12} from log *ft*>5.1. Jπ: favored α decay to ^{209}Bi g.s. (Jπ=9/2⁻). Configuration: π ($h^{+1}_{9/2}$). $T_{1/2}$: from 1981Bo29. Other measurements: <2 s (1968Ha14), 110 ns (1975LiZH), 110 ns *20* (1970Bo13, 1976Da18). Probability for decay by ^{8}Be emission relative to α emission was calculated by 1986Pi11. See 1973Ma52 for theoretical calculations of α-decay probabilities. See also 1976De25 for absolute reduced Γ(α) obtained by analyzing ^{209}Bi(α) reaction cross sections. α clustering effects were studied by 1982Ka37. Eα=9080 *5* (1988Hu08), 9080 *12* (1970Bo13), 9060 *20* (1968Ha14).
340.5 *3*	(7/2⁻,9/2⁻)	≤5.5& ns	B	Jπ: 340.5γ (M1,E2) to 9/2⁻ state. Dominant π ($f^{+1}_{7/2}$) with possible π ($h^{+1}_{9/2}$)⊗2⁺ admixture.
724.6 *3*	(13/2⁻)	≤5.5& ns	BC	Jπ: 724.6γ (E2) to 9/2⁻ state. Possible configuration: π ($h^{+1}_{9/2}$)⊗2⁺.
1111.3 *5*	(15/2⁻)	≤5.5& ns	BC	Jπ: 386.7γ (M1+E2) to (13/2⁻) state.
1129.7 *5*	(17/2⁻)	≤5.5& ns	BC	Jπ: 405γ (E2) to (13/2⁻) state. Possible configuration: π ($h^{+1}_{9/2}$)⊗4⁺.
1318.1 *6*	(19/2⁻)	≤5.5& ns	BC	Jπ: 188.4γ D to (17/2⁻) state.
1318.1+x		110 ns *17*	B	E(level),Jπ: 1358 *23* (2021Ko07 – NUBASE) and 25/2⁻ from systematics (2021Ko07 – NUBASE). $T_{1/2}$: from 386.7γ(t) in ^{208}Pb(^{7}Li,2nγ) (1980Sj01 – also 113 ns *10* from 405γ(t) measurements).
1318.1+y	(27/2⁻)#	85@ ns	C	
1681+y	(29/2⁺)#		C	
1838+y	(33/2⁺)#	82@ ns	C	
2194+y	(35/2⁻)#		C	
2570+y	(37/2⁻)#		C	
2620+y	(43/2⁻)#	34.7@ ns	C	possible configuration: π ($[h^{+2}_{9/2},f^{+1}_{7/2}]_{23/2^-}$) ν ($[(g^{+1}_{9/2},i^{+1}_{11/2}]_{10^+}$) (2003LaZZ). $T_{1/2}$: A low-energy (50-keV) unobserved transition was postulated to explain

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Adopted Levels, Gammas (continued)

^{213}At Levels (continued)

E(level)†	J^π‡	$T_{1/2}$	XREF	Comments
				the observed isomer (2003LaZZ – (^{7}Li,p2nγ)).
2926+y	(49/2$^+$)#	45 μs *4*	C	E(level): 2998 *27* (2021Ko07 – NUBASE). possible configuration: π ($[h^{+2}_{9/2},i^{+1}_{13/2}]_{29/2^+}$) ν ($[g^{+1}_{9/2},i^{+1}_{11/2}]_{10^+}$) (2003LaZZ). 306γ [E3] to 43/2$^-$ state. $T_{1/2}$: From 306γ(t) (2003LaZZ – (^{7}Li,p2nγ)).

† From Eγ. Energy levels at 1318.1+y keV and above are from ^{209}Bi(^{7}Li,p2nγ). These level energies are about 235 keV less than the level energy presented in 2003LaZZ. Evaluator labeled these levels with '+y', because placement of some highly converted low energy γ-lines between (27/2$^-$) and 19/2$^-$ states are not clear and the evaluator placed those gammas as unplaced in the ^{209}Bi(^{7}Li,p2nγ),^{209}Bi(^{8}He,4nγ) dataset.

‡ From γ transition multipolarity, deduced from measured γ-ray angular distribution in ^{208}Pb(^{7}Li,2nγ), except otherwise noted.

From 2003LaZZ (^{7}Li,p2nγ), detailed arguments are not available. It appears that the assignment was based on the placement of gamma transitions in the level scheme following the decay of 2626+y isomer (J^π=(49/2$^+$)), shell model calculations, and comparison with a comparable isomer at 4771.4 (J^π=(25$^-$)), $T_{1/2}$=152 μs *5*, in ^{212}At.

@ From time-difference spectra by gating on γ-ray transition above and below the level of interest in ^{209}Bi(^{7}Li,p2nγ) (2003LaZZ).

& From ^{208}Pb(^{7}Li,2nγ),^{209}Bi(^{18}O,^{14}Cγ) (1980Sj01).

γ(^{213}At)

E_i(level)	J^π_i	Eγ†	Iγ	E_f	J^π_f	Mult.#	α@	Comments
340.5	(7/2$^-$,9/2$^-$)	340.5 *3*	100	0.0	9/2$^-$	(M1,E2)	0.24 *15*	
724.6	(13/2$^-$)	724.6 *3*	100	0.0	9/2$^-$	(E2)	0.01473	
1111.3	(15/2$^-$)	386.7 *3*	100	724.6	(13/2$^-$)	(M1+E2)	0.17 *11*	
1129.7	(17/2$^-$)	(18.4)		1111.3	(15/2$^-$)			Transition was not observed. Its existence is inferred from the observed (188.4)(386.7γ) coincidences. Intensity balance at 1111.3 level yields I(γ+ce)(18.4)/Iγ(405.1γ)<1.2 *4*.
		405.1 *3*	100	724.6	(13/2$^-$)	(E2)	0.0568	
1318.1	(19/2$^-$)	188.4 *3*	100	1129.7	(17/2$^-$)	D		
1681+y	(29/2$^+$)	363‡	100	1318.1+y	(27/2$^-$)			
1838+y	(33/2$^+$)	156‡		1681+y	(29/2$^+$)			
		520‡		1318.1+y	(27/2$^-$)			
2194+y	(35/2$^-$)	356‡	100	1838+y	(33/2$^+$)			
2570+y	(37/2$^-$)	376‡	100	2194+y	(35/2$^-$)			
2620+y	(43/2$^-$)	(50)		2570+y	(37/2$^-$)			Eγ: A low-energy (50-keV) unobserved γ transition was postulated to explain the observed isomer (2003LaZZ – (^{7}Li,p2nγ)).
2926+y	(49/2$^+$)	306‡	100	2620+y	(43/2$^-$)	[E3]	0.707	B(E3)(W.u.)=23 *2* The large B(E3)(W.u) value implies ΔJ=ΔL=3 transition, which is consistent with the π ($i^{+1}_{13/2}$) → π ($f^{+1}_{7/2}$) orbitals change.

† From ^{208}Pb(^{7}Li,2nγ), except otherwise noted.

‡ From ^{209}Bi(^{7}Li,p2nγ),^{209}Bi(^{8}He,4nγ).

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued)

$\gamma(^{213}At)$ (continued)

From $^{208}Pb(^{7}Li,2n\gamma)$ (1980Sj01), based on $\gamma(\theta)$ and RUL, except where otherwise noted.

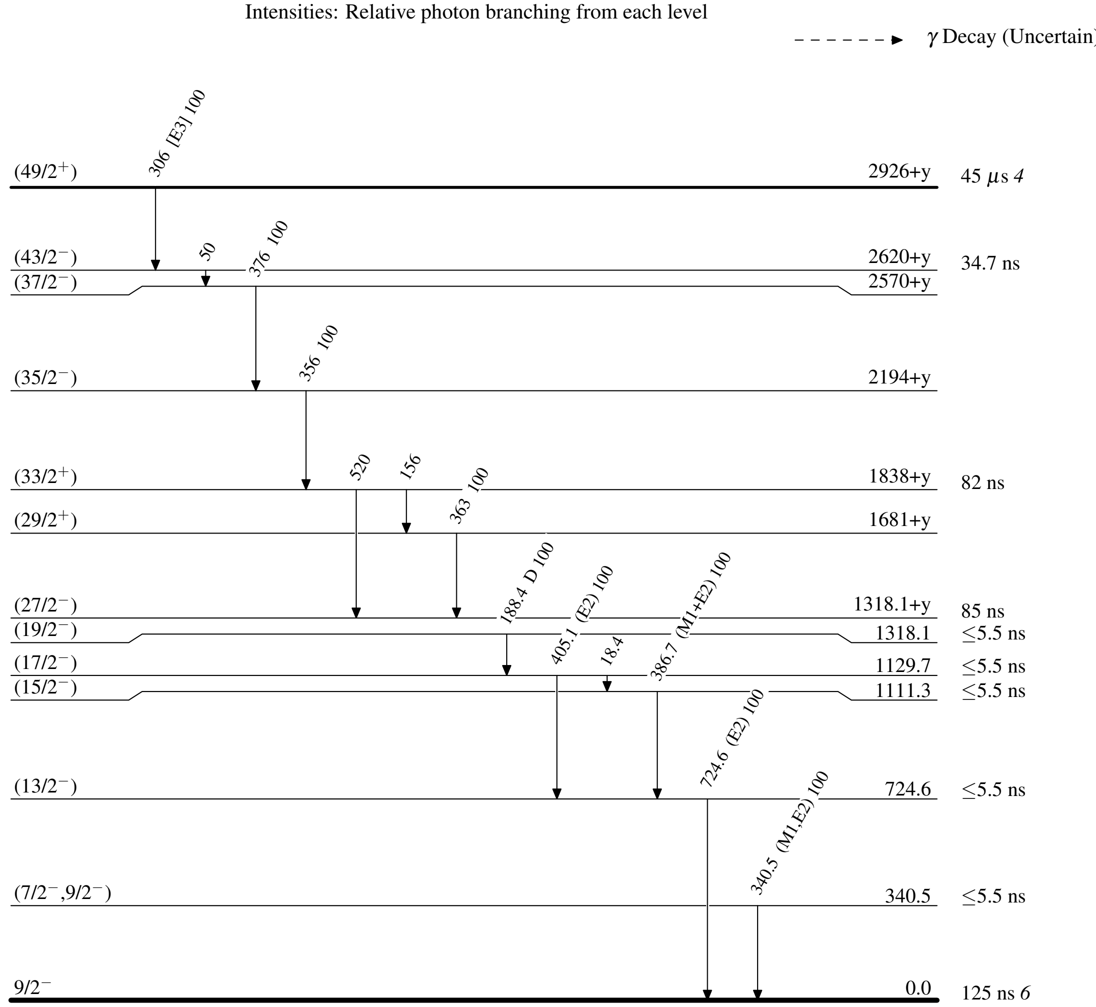
@ Total theoretical internal conversion coefficients, calculated using the BrIcc code (2008Ki07) with Frozen orbital approximation based on γ-ray energies, assigned multipolarities, and mixing ratios, unless otherwise specified.

Adopted Levels, Gammas

Legend

Level Scheme

Intensities: Relative photon branching from each level



$^{213}_{85}At_{128}$

^{217}Fr α decay

Parent: ^{217}Fr: E=0.0; J^π=9/2$^-$; $T_{1/2}$=22 μs *5*; Q(α)=8469 *4*; %α decay=100
^{217}Fr-J^π,$T_{1/2}$: From 2018Ko01 (A=217 evaluation).
^{217}Fr-Q(α): From 2021Wa16.

^{213}At Levels

E(level)	J^π	$T_{1/2}$	Comments
0.0	9/2$^-$	125 ns *6*	J^π,$T_{1/2}$: From Adopted Levels.

α radiations

Eα	E(level)	Iα[‡]	HF[†]	Comments
8313 *5*	0.0	100	1.2 *3*	Eα: Weighted average of 8315 *8* (1970Bo13) and 8312 *5* (1988Hu08), uncertainty is the lower input value. Other measured value: 8310 *20* (1968Ha14).

† Using r_0(^{213}At)=1.5656 *5*, unweighted average of r_0(^{212}Po)=1.5658 *6* (Perhaps 1.5658 *59* in 2020Si16 is a misprint of 1.56580 *59*) and r_0(^{214}Rn)=1.5655 *13* (2020Si16).
‡ Absolute intensity per 100 decays.

^{208}Pb(^{7}Li,2nγ),^{209}Bi(^{18}O,^{14}Cγ) 1980Sj01,1981Bo29

1980Sj01: ^{208}Pb(^{7}Li,2nγ) E=30-34 MeV, (pulsed beam); measured: Eγ, Iγ, Eα, αγ, γγ, γ(θ).
1981Bo29: ^{209}Bi(^{18}O,^{14}Cγ) E=79 MeV (pulsed beam); measured: Eα, Eγ, $T_{1/2}$. Level scheme was not presented.
Others:
2009Vi09 – ^{208}Bi(^{9}Li,4nγ) – measured fusion cross section.
2013Vi01 – ^{208}Bi(^{11}Li,^{6}nγ) – measured fusion cross section.
2015So17 – ^{206}Pb(^{18}O,^{11}B) – measured differential cross section dσ/dΩ=1.2 mb/sr *3*.
1980Me05: ^{208}Pb(^{16}O,^{11}B) E=140-312 MeV; population of continuum states was analyzed.

^{213}At Levels

E(level)†	Jπ‡	$T_{1/2}$	Comments
0.0	9/2⁻	125 ns *6*	Configuration: π ($h^{+1}_{9/2}$. $T_{1/2}$: From Adopted Levels.
340.5 *3*	(7/2⁻,9/2⁻)	≤5.5# ns	
724.6 *3*	13/2⁻	≤5.5# ns	Configuration: π ($h^{+1}_{9/2}$⊗2⁺.
1111.3 *5*	15/2⁻	≤5.5# ns	
1129.7 *5*	(17/2⁻)	≤5.5# ns	Configuration: π ($h^{+1}_{9/2}$⊗4⁺.
1318.1 *6*	(19/2⁻)	≤5.5# ns	
1318.1+x		110 ns *17*	E(level): Other: 1358 *23* (2021Ko07 – NUBASE). All gammas, except the 340.5-keV γ, had delayed components. The 386.7-, 405.1- and 724.6-keV gammas also showed prompt peak in their time spectra; however, existence of any prompt component in 188.4-keV γ could not be excluded (1980Sj01). The 110-ns state, therefore, is at or above 1318.1 keV. $T_{1/2}$: from τ=159 ns *25* (386.7γ)(t) (1980Sj01). The authors also measured (405γ)(t) and obtained τ=163 ns *14* for its ^{213}At component and τ=25 ns *9* for the ^{212}Po component.

† Deduced by evaluator from a least square fit to the γ-ray energies.
‡ Assignments are from 1980Sj01, based on γ-ray multipolarity deduced from γ(θ).
# From 1980Sj01.

γ(^{213}At)

Eγ†	Iγ‡	E_i(level)	$J^π_i$	E_f	$J^π_f$	Mult.#	α@	Comments
(18.4)		1129.7	(17/2⁻)	1111.3	15/2⁻			Transition was not observed. Its existence is inferred from the observed (188.4)(386.7γ) coincidences (1980Sj01).
188.4 *3*	13 *2*	1318.1	(19/2⁻)	1129.7	(17/2⁻)	D		A_2=−0.21 *7* (1980Sj01) It was not possible to exclude the prompt component of 188.4γ due to higher Compton background at this energy region (1980Sj01).
340.5 *3*	40 *4*	340.5	(7/2⁻,9/2⁻)	0.0	9/2⁻	(M1,E2)	0.24 *15*	A_2=+0.14 *4* (1980Sj01) Eγ: Other: 340.6 (1981Bo29).
386.7 *3*	27 *3*	1111.3	15/2⁻	724.6	13/2⁻	(M1+E2)	0.17 *11*	A_2=−0.35 *6* (1980Sj01) Eγ: Other: 388.8 (1981Bo29).
405.1 *3*	33 *9*	1129.7	(17/2⁻)	724.6	13/2⁻	(E2)	0.0568	A_2=+0.21 *5* (1980Sj01 – for doublet) Eγ: Other: 405.1 (1981Bo29). Iγ: γ overlapped with 405-keV transition in ^{212}Po, and Iγ=58 was measured for the total peak. The ^{213}At and ^{212}Po components were deduced by 1980Sj01 from γγ-coincidence measurements.
724.6 *3*	100 *10*	724.6	13/2⁻	0.0	9/2⁻	(E2)	0.01473	A_2=+0.28 *5* (1980Sj01) Eγ: Other: 725.2 (1981Bo29).

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^{208}Pb(^{7}Li,2nγ),^{209}Bi(^{18}O,^{14}Cγ) 1980Sj01,1981Bo29 (continued)

γ(^{213}At) (continued)

† From 1980Sj01. Assignments to ^{213}At were made from the observed (9.08-MeV α from ^{213}At g.s.)(γ) and $\gamma\gamma$-coincidences.
‡ Relative photon intensity, from 1980Sj01, normalized to Iγ=100 for 724.6γ.
# From 1980Sj01 based on γ-ray angular distributions by assuming that the states were aligned and that the dominant γ rays proceed via yrast levels by stretched transitions. Lifetime information was considered to eliminate higher multipolarities. (M1,E2) multipolarities in 1980Sj01 are presented as (M1+E2) here.
@ 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.

^{209}Bi(^{7}Li,p2nγ),^{209}Bi(^{8}He,4nγ) 2003LaZZ,2005Ga46

Other: 2004Da23 – ^{209}Bi(^{7}Li,p2nγ) – measured fusion cross section.
2003LaZZ: ^{209}Bi(^{7}Li,p2nγ) E=48 MeV; Detector: CAESAR array, consisting of six Compton-suppressed HPGe detector and two LEPS detectors, an ADC clock; measured: Eγ, γ-γ coin, $T_{1/2}$.
2005Ga46: ^{209}Bi(^{8}He,4nγ) E=28 MeV; Detector: EXOGAM array, composed of four Compton suppressed Ge Clover detectors; Measured: Eγ. Level scheme not given.

^{213}At Levels

E(level)†	Jπ‡	$T_{1/2}$	Comments
0.0	9/2−	125 ns *6*	$T_{1/2}$: From Adopted Levels.
725	(13/2−)		
1112	(15/2−)		
1130	(17/2−)		
1319	(19/2−)		
1319+y	(27/2−)#	85@ ns	E(level): In 2003LaZZ, this level energy is presented as (1554) keV, can be obtained combining γ-rays, presented as unplaced in this dataset, and 1319 keV level as 1319+92+105+(38)=1554 or 1319+92+55+51=1556. $T_{1/2}$: From τ=122 ns (2003LaZZ).
1682+y	(29/2+)#		E(level): (1917) keV in 2003LaZZ.
1839+y	(33/2+)#	82@ ns	E(level): (2073) keV in 2003LaZZ. $T_{1/2}$: From τ=118 ns (2003LaZZ).
2195+y	(35/2−)#		E(level): (2429) keV in 2003LaZZ.
2571+y	(37/2−)#		E(level): (2805) keV in 2003LaZZ.
2621+y	(43/2−)#	34.7@ ns	E(level): (2855) keV in 2003LaZZ. $T_{1/2}$: From τ=50 ns (2003LaZZ). Possible configuration: π ([$h^{+2}_{9/2}$,$f^{+1}_{7/2}$]$_{23/2^-}$) ν ([$g^{+1}_{9/2}$,$i^{+1}_{11/2}$]$_{10^+}$) (2003LaZZ). $T_{1/2}$: A low-energy (50-keV) unobserved transition was postulated to explain the observed isomer (2003LaZZ).
2927+y	(49/2+)#	45 μs *4*	E(level): Other: 2998 *27* (2021Ko07 – NUBASE). (3161) keV in 2003LaZZ. Possible configuration: π ([$h^{+2}_{9/2}$,$i^{+1}_{13/2}$]$_{29/2^+}$) ν ([$g^{+1}_{9/2}$,$i^{+1}_{11/2}$]$_{10^+}$) (2003LaZZ). $T_{1/2}$: From τ=65 μs *6*, 306γ(t) (2003LaZZ – preliminary result). %Isomeric production ratio=4.7 *5* (2013Bo18) from ^{238}U fragmentation.

† Deduced by evaluator from a least square fit to the γ-ray energies, assuming ΔE=1 keV for all Eγ. Levels above 19/2− state, 1319 keV, are labeled adding '+x' by the evaluator due to premature placements of highly converted low energy γ-lines between (27/2−) and 19/2− states. Those low energy γ-lines are presented as unplaced here in the dataset.
‡ From Adopted Levels, except where otherwise noted.
# From 2003LaZZ, detailed arguments are not available. It appears that the assignment was based on the placement of gamma transitions in the level scheme following the decay of 2626+y isomer (Jπ=(49/2+)), shell model calculations, and comparison with a comparable isomer at 4771.4 (Jπ=(25−)), $T_{1/2}$=152 μs *5*, in ^{212}At.
@ From intermediate time spectra between different parts of γ-ray transitions in 2003LaZZ.

γ(^{213}At)

Eγ†	E_i(level)	J^π_i	E_f	J^π_f	Comments
(17)	1130	(17/2−)	1112	(15/2−)	
(ˣ38‡)					
(50)	2621+y	(43/2−)	2571+y	(37/2−)	Eγ: A low-energy (50-keV) unobserved γ transition was postulated to explain the observed isomer (2003LaZZ).
ˣ51‡					

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^{209}Bi(^{7}Li,p2nγ),^{209}Bi(^{8}He,4nγ) 2003LaZZ,2005Ga46 (continued)

γ(^{213}At) (continued)

E_γ †	E_i(level)	J_i^π	E_f	J_f^π	Mult.	α @	Comments
x55‡							
x88‡							
x92‡							
x105‡							
156	1839+y	(33/2+)	1682+y	(29/2+)			
189#	1319	(19/2−)	1130	(17/2−)			
306	2927+y	(49/2+)	2621+y	(43/2−)	[E3]	0.707	Mult.: Proposed in 2003LaZZ based on predicted E3 strength of 23 W.u. *2* compared to 26 W.u. *1* in ^{212}At (27 W.u. *1* in the ENSDF).
356	2195+y	(35/2−)	1839+y	(33/2+)			
363#	1682+y	(29/2+)	1319+y	(27/2−)			
376#	2571+y	(37/2−)	2195+y	(35/2−)			
387#	1112	(15/2−)	725	(13/2−)			
405#	1130	(17/2−)	725	(13/2−)			
520	1839+y	(33/2+)	1319+y	(27/2−)			
725#	725	(13/2−)	0.0	9/2−			

† From 2003LaZZ, except where otherwise noted.

‡ Placement in 2003LaZZ between the (27/2−) and 19/2− states, in coincidence with 725 keV within a timeframe of 30-850 ns. The evaluator presents these γ-rays as unplaced due to unclear level scheme between (27/2−) and 19/2− states.

This γ-ray is also present in figure of the γ-ray spectrum in 2005Ga46.

@ 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.

x γ ray not placed in level scheme.

Adopted Levels, Gammas

$Q(\beta^-)=-2142$ *6*; S(n)=5108 *4*; S(p)=4357 *4*; $Q(\alpha)=8245$ *3* 2021Wa16

2020De36: $^{238}U(^{48}Ca,X)$, E=233.3 MeV; measured multi-nucleon transfer reaction cross section σ_{direct}=33.0 nb/sr *9* and $\sigma_{cumulative}$=33.0 nb/sr *9* for ^{213}Rn.

2015Ba20: ^{136}Xe + ^{208}Pb, E(c.m.)=450 MeV, measured multi-nucleon transfer reaction cross section $\sigma_{cumulative\ yield}$=0.166 mb *33* and $\sigma_{independent\ yield}$=0.146 mb *29* for ^{213}Po.

^{213}Rn Levels

Cross Reference (XREF) Flags

- A ^{213}Fr ε decay (34.17 s)
- B ^{217}Ra α decay
- C (HI,xnγ)

E(level)†	Jπ‡	$T_{1/2}$#	XREF	Comments
0.0	(9/2+)	19.4 ms *2*	ABC	%α=100 Only α decay observed. Possible ε decay to ^{213}At g.s. is expected to be <5.8×10^{-4}% from log *ft*>5.1. Jπ: Based on analogy with the spin-parity of ^{209}Pb and ^{211}Po isotones. Configuration: ν ($g^{+1}_{9/2}$). $T_{1/2}$: Weighted average of 19.5 ms *1* from 8088α(t), 18.0 ms *4* from 7550α(t) and 19.0 ms *5* from 7552α(t) − all from 2000He17; 20.5 ms *10* (1970TaZS); 21 ms *4* 8064α(t) (2005Li17) − χ^2=3.8 cf. χ^2_{crit}=2.4. Unweighted average: 19.6 ms *5*. Others: 25.0 ms *2* 8088α(t) outlier (1970Va13); 16 ms *1* (2019Mi08 − from time correlations between ^{217}Ra and ^{213}Rn α decays); 31 ms 8024α(t), 15 ms 7976α(t), 8.1 ms 8074α(t), 4.3 ms 8177α(t) − all four values from 2003Ni10, 19 ms (1962Gr20), and 16 ms *+5−3* (2021Hu19 − rounded value of 15.88 ms *+547−324*).
704.90 *19*	(11/2+)		A C	Jπ: 705.0γ M1 to (9/2+). Configuration: Dominant ν ($i^{+1}_{11/2}$).
896.05 *15*	(15/2−)	26.3 ns *7*	C	Jπ: 191.1γ M2 to (11/2+) and 896.1γ E3 to (9/2+). Configuration: Dominant ν ($j^{+1}_{15/2}$).
1259.60 *17*	(13/2+)		C	Jπ: 1259.6γ to (9/2+). Configuration: ν ($g^{+1}_{9/2}$)⊗2+.
1347.1 *4*			A	
1352.7 *5*			A	
1529.00 *18*	(17/2+)		C	Jπ: 269.4γ E2 to (13/2+), 632.9γ E1 to (15/2−). Configuration: ν ($g^{+1}_{9/2}$)⊗4+.
1574.1 *3*			C	
1612.4?			C	
1663.98 *20*	(21/2+)	29.1 ns *14*	C	μ=4.73 *11* Jπ: 135.0γ E2 to (17/2+), 767.9γ (E3) to (15/2−). Configuration: ν ($g^{+1}_{9/2}$)⊗6+. μ: From 2020StZV, 1988St10.
1663.98+x *20*	(25/2+)	1.01 μs *21*	C	μ=7.6 *3* Configuration: Dominant ν ($g^{+1}_{9/2}$) π ([$h^{+1}_{9/2}$,$f^{+1}_{7/2}$]$_{8+}$). μ: From 2020StZV, 1988St10.
1703.5? *4*			C	
1745.89 *24*			C	
1785.2 *4*			A	
1788.70 *24*			C	
1834.1 *5*			A	
1856.59+x *14*	(25/2+)		C	Jπ: 192.6γ (M1) to (25/2+). A_2/A_0 (192.6γ)=0.40 *6* is consistent with ΔJ=0 transition. Configuration: Dominant ν ($g^{+1}_{9/2}$) π ([$h^{+2}_{9/2}$]$_{8+}$).
1879.3 *3*			C	
1936.9 *3*			C	
2007.39 *23*			C	

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued)

^{213}Rn Levels (continued)

E(level)†	Jπ‡	$T_{1/2}$#	XREF	Comments
2072.78 *21*			C	
2121.58+x *20*	(27/2)		C	
2184.3 *3*			C	
2186.69+x *13*	(31/2⁻)	1.36 μs *7*	C	μ=9.86 *8* Jπ: 330.1γ (E3) to (25/2⁺), 522.7γ E3 to (25/2⁺). Configuration: $\nu\ (g^{+1}_{9/2})\ \pi\ [(h^{+1}_{9/2},i^{+1}_{13/2})_{11-}]$. μ: From 2020StZV, 1988St10 (9.90 *8*).
2201.48+x *16*	(27/2⁻)		C	Jπ: 344.9γ (E1) to (25/2⁺), 537.5γ (E1) to (25/2⁺).
2227.5 *3*			C	
2257.5 *3*			C	
2327.1 *4*			C	
2610.7 *4*			C	
2640.79+x *24*			C	
2662.0+x *3*			C	
2676.96+x *14*	(29/2⁺)		C	Jπ: 490.2γ D+Q to (31/2⁻), 1013.0γ Q to (25/2⁺).
2684.5+x *3*			C	
2739.79+x *19*	(31/2⁻)		C	Jπ: 553.1γ M1 to (31/2⁻).
2786.69+x *19*	(29/2⁺)		C	Jπ: 930.1γ to (25/2⁺).
2915.78+x *16*	(33/2)⁺		C	Jπ: 729.1γ E1 to (31/2⁻).
2983.99+x *15*	(33/2⁺)		C	Jπ: 68.2γ M1 to (33/2⁺), 797.3γ E1 to (31/2⁻).
3029.31+x *19*	(37/2⁺)	26.3 ns *7*	C	μ=13.61 *13* Jπ: 45.3γ E2 to (33/2⁺), 113.5γ E2 to (33/2⁺). Configuration: Dominant $\nu\ (g^{+1}_{9/2})\ \pi\ ([h^{+3}_{9/2},f^{+1}_{7/2}]_{14+})$. μ: From 2020StZV, 1988St10 (13.67 *13*).
3181.77+x *19*	(35/2⁻)		C	Jπ: 995.1γ (E2) to (31/2⁻).
3301.32+x *24*			C	
3441.13+x *22*	(39/2⁻)		C	Jπ: 411.8γ E1 to (37/2⁺).
3495.4+x *3*	(43/2⁻)	27.7 ns *7*	C	μ=15.52 *15* Jπ: 54.3γ E2 to (39/2⁻). Configuration: $\nu\ (g^{+1}_{9/2})\ \pi\ ([h^{+3}_{9/2},i^{+1}_{13/2}]_{17-})$. μ: From 2020StZV, 1988St10 (15.59 *15*).
3604.8+x *3*			C	
3623.8+x *4*			C	
3922.9+x *4*	(43/2⁻)		C	Jπ: 427.5γ M1 to (43/2⁻). A_2/A_0 (427.5γ)=0.26 *7* is consistent with ΔJ=0 transition.
3927.3+x *4*			C	
4047.9+x *4*	(45/2⁻)		C	Jπ: 552.5γ M1 to (43/2⁻).
4050.3+x *4*			C	
4343.1+x *4*			C	
4505.5+x *4*	(49/2⁺)	11.8 ns *7*	C	μ=19.8 *3* Jπ: 1010.1γ E3 to (43/2⁻). Configuration: $\nu\ (j^{+1}_{15/2})\ \pi\ ([h^{+3}_{9/2},i^{+1}_{13/2}]_{17-})$. μ: From 2020StZV, 1988St10 (19.87 *29*).
4532.7+x *4*			C	
4581.3+x *11*			C	
4723.0+x *4*			C	
4875.6+x *4*	(49/2⁺)		C	Jπ: 370.1γ M1 to (49/2⁺). A_2/A_0 (370.1γ)=0.33 *5* is consistent with ΔJ=0 transition.
5225.6+x *4*	(51/2⁺)		C	Jπ: 350.0γ M1+E2 to (49/2⁺), 720.1γ (M1) to (49/2⁺).
5763.7+x *4*	(53/2,55/2)		C	Jπ: 1258.1γ to (49/2⁺) and (51/2⁺).
5928.9+x *4*	(53/2,55/2)		C	Jπ: 165.2 M1 to (53/2,55/2).
5928.9+y *4*	(55/2⁺)	164 ns *10*	C	μ=16.54 *14* E(level): y=x+z. Configuration: $\nu\ ([p^{-1}_{1/2},g^{+1}_{9/2}i^{+1}_{11/2}]_{21/2-})\ \pi\ ([h^{+3}_{9/2},i^{+1}_{13/2}]_{17-})$. μ: From 2020StZV, 1988St10 (16.61 *14*).
6743.90+y *20*		59 ns	C	$T_{1/2}$: From 815γ(t) in 1989Lo02 (HI,Xnγ).

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued)

^{213}Rn Levels (continued)

E(level)†	$T_{1/2}$#	XREF	Comments
7926.4+y *3*		C	
8831.8+y *4*	14 ns	C	$T_{1/2}$: From 905γ(t) in 1989Lo02 (HI,Xnγ).

† From least square fit to the γ-ray energies assuming equal weight if no uncertainty for Eγ. In the latter case, no uncertainty for the level is listed.

‡ Proposed in (HI,xnγ) based on γ multipolarity assignments from conversion electron and $\gamma(\theta)$ measurements. Monotonically increasing spins are assumed. See 1988St10, 1989Lo02, and 1990St14 for configuration assignments.

From 1988St10 (HI,xnγ), except where otherwise noted.

$\gamma(^{213}Rn)$

E_i(level)	J^π_i	E_γ[†]	I_γ	E_f	J^π_f	Mult.[†]	α[@]	Comments
704.90	(11/2+)	704.9 *3*	100	0.0	(9/2+)	M1	0.0606 *9*	E_γ: weighted average of 704.3 *5* from ^{213}Fr ε decay and 705.0 *2* from (HI,xnγ). Mult.: from α(K)exp, α(L)exp and α(M)exp measurements (2016Pr08 – ^{213}Fr ε decay (34.17 s)).
896.05	(15/2−)	191.1 *2*	0.44 *8*	704.90	(11/2+)	M2	9.96 *14*	B(M2)(W.u.)=0.53 *10*
		896.1 *2*	100	0.0	(9/2+)	E3	0.02500 *35*	B(E3)(W.u.)=34.4 *10*
1259.60	(13/2+)	1259.6 *2*	100	0.0	(9/2+)			
1347.1		1347.0[‡] *5*	100	0.0	(9/2+)			
1352.7		1352.7[‡] *5*	100	0.0	(9/2+)			
1529.00	(17/2+)	269.4 *2*	1.6 *1*	1259.60	(13/2+)	E2	0.1922 *27*	
		632.9 *2*	100 *10*	896.05	(15/2−)	E1	0.00688 *10*	
1574.1		314.5 *2*	100	1259.60	(13/2+)			
1612.4?		352.8[a] *2*	36 *14*	1259.60	(13/2+)			
		907.4[a] *2*	100 *20*	704.90	(11/2+)			
1663.98	(21/2+)	135.0 *2*	100 *2*	1529.00	(17/2+)	E2	2.351 *33*	B(E2)(W.u.)=1.69 *9*
		767.9 *2*	3.6 *4*	896.05	(15/2−)	(E3)	0.0365 *5*	B(E3)(W.u.)=1.05 *13*
1703.5?		(39.5[#])		1663.98	(21/2+)			
1745.89		(81.9[#])		1663.98	(21/2+)			
		216.9 *2*	100	1529.00	(17/2+)			
1785.2		438.0[‡] *5*	16[‡] *2*	1347.1				
		1080.7[‡] *5*	19[‡] *3*	704.90	(11/2+)			
		1785.0[‡] *5*	100[‡] *9*	0.0	(9/2+)			
1788.70		259.7 *2*	100	1529.00	(17/2+)			
1834.1		1834.1[‡] *5*	100	0.0	(9/2+)			
1856.59+x	(25/2+)	192.6 *2*	100	1663.98+x	(25/2+)	M1	2.045 *29*	A_2/A_0=0.40 *6* (1988St10)
1879.3		1174.4 *2*	100	704.90	(11/2+)			
1936.9		233.4 *2*	100 *12*	1703.5?				
		272.9 *2*	19 *6*	1663.98	(21/2+)			
2007.39		218.7 *2*	≈12	1788.70				
		261.5 *2*	≈12	1745.89				
		343.4 *2*	100 *25*	1663.98	(21/2+)			
2072.78		543.7 *2*	12 *6*	1529.00	(17/2+)			
		1176.8 *2*	100 *19*	896.05	(15/2−)			
2121.58+x	(27/2)	457.6[&] *2*	100	1663.98+x	(25/2+)			
2184.3		520.3 *2*	100	1663.98	(21/2+)			
2186.69+x	(31/2−)	(65.1[#])		2121.58+x	(27/2)			I(γ+ce)(65.1γ)<7 from intensity balance at 2121.6+x level.
		330.1 *2*	1.9 *2*	1856.59+x	(25/2+)	(E3)	0.552 *8*	B(E3)(W.u.)=13.0 *15*
		522.7 *2*	100 *2*	1663.98+x	(25/2+)	E3	0.1073	B(E3)(W.u.)=27.4 *14*
2201.48+x	(27/2−)	344.9 *2*	100 *4*	1856.59+x	(25/2+)	(E1)	0.02429 *34*	
		537.5 *2*	33 *4*	1663.98+x	(25/2+)	(E1)	0.00951 *13*	

Adopted Levels, Gammas (continued)

γ(^{213}Rn) (continued)

E_i(level)	J^{π}_i	E_γ[†]	I_γ	E_f	J^{π}_f	Mult.[†]	δ	α[@]	Comments
2227.5		563.5 2	100	1663.98	(21/2$^+$)				
2257.5		184.7 2	100	2072.78					
2327.1		390.2 2	100	1936.9					
2610.7		383.2 2	100	2227.5					
2640.79+x		454.1 2	100	2186.69+x	(31/2$^-$)				
2662.0+x		460.5 2	100	2201.48+x	(27/2$^-$)				
2676.96+x	(29/2$^+$)	490.2 2	100 8	2186.69+x	(31/2$^-$)	D+Q		0.0115	
		1013.0 2	85 31	1663.98+x	(25/2$^+$)	Q		0.00802	
2684.5+x		483.0 2	100	2201.48+x	(27/2$^-$)				
2739.79+x	(31/2$^-$)	(99.0[#])		2640.79+x					
		553.1 2		2186.69+x	(31/2$^-$)	M1		0.1147 16	
2786.69+x	(29/2$^+$)	930.1 2	100	1856.59+x	(25/2$^+$)				
2915.78+x	(33/2)$^+$	238.8 2	1.3 10	2676.96+x	(29/2$^+$)				
		729.1 2	100 5	2186.69+x	(31/2$^-$)	E1		0.00525	
2983.99+x	(33/2$^+$)	68.2 2	3.0 3	2915.78+x	(33/2)$^+$	M1+E2	0.23 +6−8	9.9 12	
		197.3 2	2.3 3	2786.69+x	(29/2$^+$)				
		244.2 2	7.8 20	2739.79+x	(31/2$^-$)	(E1)		0.0535 7	
		307.0 2	2.0 12	2676.96+x	(29/2$^+$)				
		797.3 2	100 2	2186.69+x	(31/2$^-$)	E1		0.00444 6	
3029.31+x	(37/2$^+$)	45.3 2	≈33	2983.99+x	(33/2$^+$)	E2		359 5	B(E2)(W.u.)=3.9 +5−7
		113.5 2	100 33	2915.78+x	(33/2)$^+$	E2		4.85 7	B(E2)(W.u.)=0.12 +10−5
		842.6[a] 2	167 33	2186.69+x	(31/2$^-$)	[E3]		0.0290 4	B(E3)(W.u.)=0.8 +6−3
3181.77+x	(35/2$^-$)	266.0 2	≈8	2915.78+x	(33/2)$^+$				
		995.1 2	100 12	2186.69+x	(31/2$^-$)	(E2)		0.00821 11	
3301.32+x		272.0 2	100	3029.31+x	(37/2$^+$)				
3441.13+x	(39/2$^-$)	139.8 2	0.88 16	3301.32+x					
		259.4 2	≈0.77	3181.77+x	(35/2$^-$)				
		411.8 2	100.0 19	3029.31+x	(37/2$^+$)	E1		0.01652 23	
3495.4+x	(43/2$^-$)	54.3 2	100	3441.13+x	(39/2$^-$)	E2		148.8 21	B(E2)(W.u.)=3.83 21
3604.8+x		575.5 2	100	3029.31+x	(37/2$^+$)				
3623.8+x		128.4 2	100	3495.4+x	(43/2$^-$)				
3922.9+x	(43/2$^-$)	427.5 2	100	3495.4+x	(43/2$^-$)	M1		0.2282 32	A_2/A_0=0.26 7 (1988St10)
3927.3+x		431.9 2	100	3495.4+x	(43/2$^-$)				
4047.9+x	(45/2$^-$)	(125.0[#])	<2	3922.9+x	(43/2$^-$)				
		552.5 2	100 9	3495.4+x	(43/2$^-$)	M1		0.1150 16	
4050.3+x		445.5 2	100	3604.8+x					
4343.1+x		420.2 2	100	3922.9+x	(43/2$^-$)				
4505.5+x	(49/2$^+$)	457.6[&] 2	<6	4047.9+x	(45/2$^-$)			0.579	
		1010.1 2	100 8	3495.4+x	(43/2$^-$)	E3		0.01891 26	B(E3)(W.u.)=33.4 +21−27
4532.7+x		609.8 2	100	3922.9+x	(43/2$^-$)				
4581.3+x		(48.6[#])		4532.7+x					
		533.4[a] 2		4047.9+x	(45/2$^-$)				

$\gamma(^{213}Rn)$ (continued)

E_i(level)	J^π_i	E_γ[†]	I_γ	E_f	J^π_f	Mult.[†]	δ	α[@]	Comments
4723.0+x		217.5 *2*	100	4505.5+x	$(49/2^+)$				
4875.6+x	$(49/2^+)$	370.1 *2*	100	4505.5+x	$(49/2^+)$	M1		0.337 *5*	A_2/A_0=0.33 *5* (1988St10)
5225.6+x	$(51/2^+)$	350.0 *2*	90 *20*	4875.6+x	$(49/2^+)$	M1+E2	0.70 *+26−23*	0.29 *5*	
		720.1 *2*	100 *30*	4505.5+x	$(49/2^+)$	(M1)		0.0572 *8*	
5763.7+x	(53/2,55/2)	538.1 *2*	62 *6*	5225.6+x	$(51/2^+)$				
		1258.1 *2*	100 *19*	4505.5+x	$(49/2^+)$				
5928.9+x	(53/2,55/2)	165.2 *2*	100 *25*	5763.7+x	(53/2,55/2)	M1		3.15 *4*	
		1053.3 *2*	75 *25*	4875.6+x	$(49/2^+)$				
		1423.3 *2*	75 *25*	4505.5+x	$(49/2^+)$				
6743.90+y		815.0 *2*	100	5928.9+y	$(55/2^+)$				
7926.4+y		1182.5 *2*	100	6743.90+y					
8831.8+y		905.4 *2*	100	7926.4+y					

[†] From (HI,xnγ), except where otherwise noted.
[‡] From ^{213}Fr ε decay (34.17 s).
[#] From level energy difference. Transition was not observed; existence proposed from coincidence data.
[@] 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.
[&] Multiply placed.
[a] Placement of transition in the level scheme is uncertain.

$^{213}_{86}Rn_{127}$-6

^{213}Fr ε decay (34.17 s) 2016Pr08

Parent: ^{213}Fr: E=0.0; J$^{\pi}$=9/2^{-}; $T_{1/2}$=34.17 s *6*; Q(ε)=2142 *6*; %ε+%β^{+} decay=0.56 *5*
^{213}Fr-Q(ε): From 2021Wa16: AME-2020.
Adapted/Edited the XUNDL dataset compiled by B. Singh (McMaster) Jan 6, 2017.
2016Pr08: ^{213}Fr produced in U(p,X), E(p)=1.4 GeV pulsed beam at ISOLDE-CERN facility using UC_x target and general purpose separator (GPS). Measured Eγ, Iγ, (x ray)γ- and γγ-coin using two HPGe detectors, and conversion electrons using a Mini-Orange magnetic spectrometer and a Si(Li) detector. Deduced levels, ε feedings, and log *ft* values. Shell-model calculations.

^{213}Rn Levels

E(level)†	J$^{\pi}$‡	$T_{1/2}$‡
0.0	(9/2^{+})	19.4 ms *2*
704.3 *5*	(11/2^{+})	
1347.0 *5*		
1352.7 *5*		
1785.0 *5*		
1834.1 *5*		

† From Eγ data.
‡ From Adopted Levels.

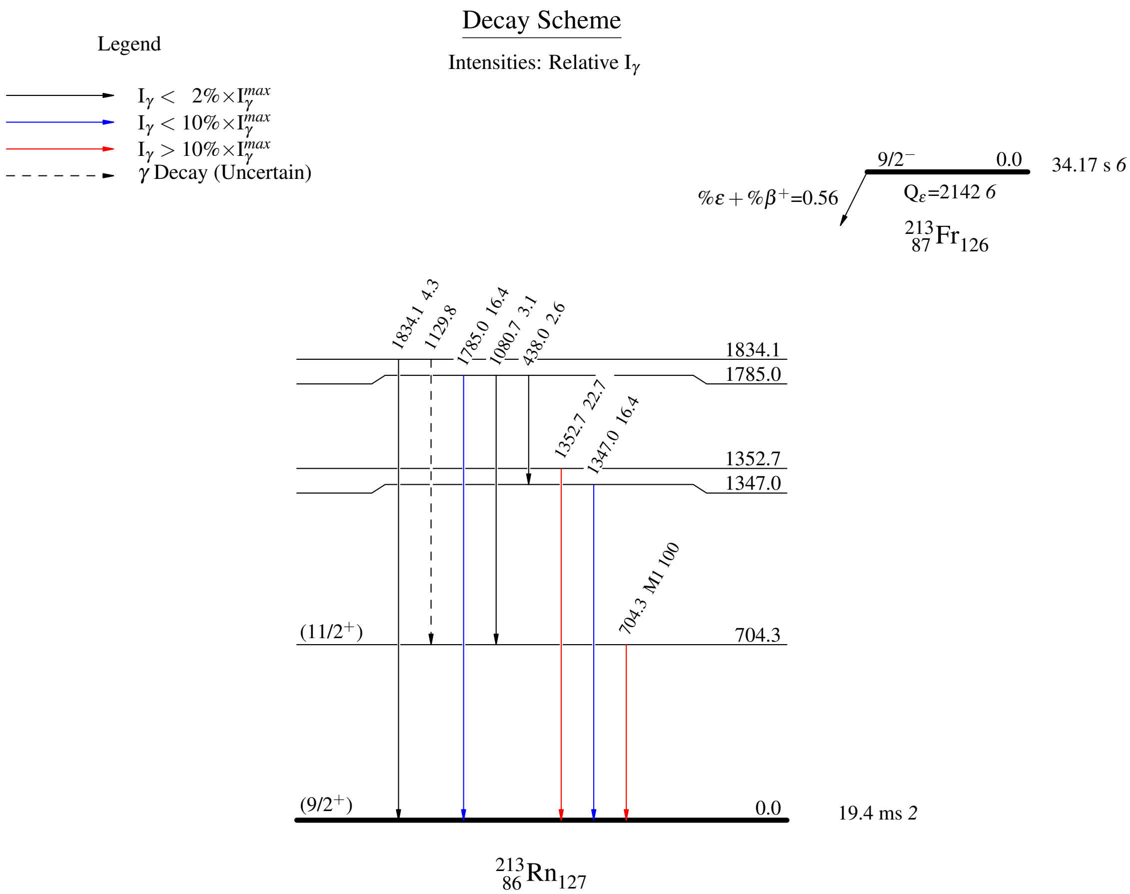
γ(^{213}Rn)

Iγ normalization: Ground state (g.s.) feeding is expected and not known and so not normalized. If no g.s. ε feeding is assumed, normalization factor is 0.603 *11*. 2016Pr08 estimates ε feeding to the g.s. of 5% or 30% corresponding to log *ft* 7.4 or 6.6, respectively, based on the log *ft* value systematics for first forbidden transitions.

Eγ†	Iγ	E_i(level)	J^{π}_i	E_f	J^{π}_f	Mult.	α‡	Comments
438.0 *5*	2.6 *3*	1785.0		1347.0				
704.3 *5*	100	704.3	(11/2^{+})	0.0	(9/2^{+})	M1	0.0606	α(K)exp=0.0502 *59*; α(L)exp=0.0097 *13*; α(M)exp=0.0023 *3* (2016Pr08) Mult.: from α(K)exp, α(L)exp and α(M)exp measurements (2016Pr08). δ: The subshell α(exp) values yield δ=0.00 *12* using the BriccMixing code.
1080.7 *5*	3.1 *5*	1785.0		704.3	(11/2^{+})			
1129.8# *5*		1834.1		704.3	(11/2^{+})			Weak γ ray. Uncertain placement, not adopted.
1347.0 *5*	16.4 *14*	1347.0		0.0	(9/2^{+})			
1352.7 *5*	22.7 *19*	1352.7		0.0	(9/2^{+})			
1785.0 *5*	16.4 *14*	1785.0		0.0	(9/2^{+})			
1834.1 *5*	4.3 *5*	1834.1		0.0	(9/2^{+})			

† Uncertainty in Eγ is stated by 2016Pr08 as within 0.5 keV and 0.5 keV has been assigned for each Eγ by the evaluator.
‡ 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.

^{213}Fr ε decay (34.17 s) 2016Pr08



^{217}Ra α decay 1970To07,1970Va13,2019Mi08

Parent: ^{217}Ra: E=0.0; J^π=(9/2$^+$); $T_{1/2}$=1.6 μs *2*; Q(α)=9161 *6*; %α decay=100

^{217}Ra-J^π: From 2018Ko01 (A=217 evaluation).

^{217}Ra-$T_{1/2}$: from 8995α(t) (1970Va13 – good statistics). Others: 1.7 μs *3* (1990An19 – appears to supersede their earlier value 1.7 us *1* (1990AnZU)), 1.4 μs *+4−3* (2019Ya04), 4 μs *2* (1970To07), and 2.5 μs *2* (2019Mi08 – from time correlations between ^{221}Th and ^{217}Ra α decays). Weighted average of all the data, without 2.5 μs *2* (2019Mi08) yields the same value.

^{217}Ra-Q(α): From 2021Wa16.

Others: 2021Hu19, 1990An19, 1990AnZU.

1970To07: ^{221}Th was produced from ^{208}Pb(^{16}O,3n), E=10.6 MeV/nucleon, 99% enriched ^{208}Pb target, alpha spectra were obtained on-line using the helium-jet recoil transport method for ^{221}Th decay chain, Si(Au) detector. Measured Eα, $T_{1/2}$; deduced Qα. FWHM = 25 keV.

1970Va13: ^{221}Th was produced bombarding different targets with different projectiles, measured Eα of the ^{221}Th decay chain. Deduce t, Q.

2019Mi08: Studied ^{225}U α decay chain, produced by the fusion evaporation reactions of E=212, 217, and 226 MeV (mid-target) ^{48}Ca beams on a ≈530 μg/cm^2 ^{181}Ta target sandwiched between carbon layers of 50 μg/cm^2 upstream and 10 μg/cm^2 downstream. Evaporation residues (ERs) were separated by the SHIP velocity filter and implanted into the COMPAct Spectroscopy Set-up (COMPASS), consisting of a Double sided Silicon Strip Detector (DSSD), surrounded by 4 Single sided Silicon Strip Detectors (SSSDs). Measured energy and time spectra of correlations between ER and α particles from subsequent decays. Deduced halflife.

^{213}Rn Levels

E(level)	J^π	$T_{1/2}$	Comments
0.0	(9/2$^+$)	19.4 ms *2*	J^π,$T_{1/2}$: From Adopted Levels.

α radiations

2019Mi08 reported two Eα of values 8990 keV *40* (8.99 MeV *4*) and 8910 keV *40* (8.91 MeV *4*). 8990α is in good agreement with the literature value for the ^{217}Ra g.s. to ^{213}Rn g.s. decay. The other 8910α, if considered to decay from ^{217}Ra g.s., it would feed an excited level at about 84 keV *41* (deduced from Qα(^{221}Ra) and Eα). 2019Mi08 did not propose any depopulation or feeding level for this Eα, and no known excited levels in ^{217}Ra or ^{213}Rn are matching for the decay of this Eα.

Eα	E(level)	Iα‡	HF†	Comments
8992 *8*	0.0	100	1.69 *22*	Eα: Weighted average of 8990 *8* (1970To07, semi), 8995 *10* (1970Va13, semi), 8990 *40* (2019Mi08 – 8.99 MeV *4*), and 8988 *26* (2019Ya04). Uncertainty is the lowest input value. Other: 8966 *15* (2021Hu19).

† Using r_0(^{213}Rn)=1.5526 *27*, extrapolated value based on r_0(^{212}Rn)=1.5433 *36* and r_0(^{214}Rn)=1.5655 *13* (2020Si16).

‡ Absolute intensity per 100 decays.

(HI,xnγ)

^{204}Hg(^{14}C,5nγ) E=80-94 MeV (1989Lo02).
^{208}Pb(^{9}Be,4nγ) E=45-60 MeV (1988St10);
^{204}Hg(^{13}C,4nγ) E=72-75 MeV (1988St10).
^{208}Pb(^{9}Be,4nγ) E=31-57 MeV (1988Fu10);
^{206}Pb(^{12}C,αnγ) E=63-75 MeV (1988Fu10).
^{208}Pb(^{14}C,α5nγ) E=75-95 MeV (1983Lo16).

1989Lo02 measured: Eγ, Iγ, γ(θ), γγ, γγ(t), ce, pulsed beam-γ(t).
1988St10 measured: Eγ, Iγ, γ(θ), γγ, γγ(t), γ(θ,H,t), ce, pulsed beam-γ(t).
1988Fu10 measured: Eγ, Iγ, γ(θ), γγ, γγ(t), γ(linear polarization), pulsed beam-γ(t).
1983Lo16 measured: Eγ, Iγ, γ(θ), γγ, γγ(t), pulsed beam-γ(t).

Others:
2004Da23: ^{209}Bi(^{7}Li,3nγ) – measured incomplete fusion cross section.
2009Vi09: ^{208}Bi(^{9}Li,4nγ) – measured evaporation residue (ER) cross section.
2010Da04: ^{208}Pb,^{209}Bi(^{9}Be,X), E=44.0, 50.0. 60.0 MeV, – measured incomplete fusion cross section.
2011Ka30: Pt(^{36}S,X), E=5.96 MeV/nucleon and W(^{48}Ca,X), E=5.41 MeV/nucleon – measured differential cross section dσ/dΩ.
The level scheme constructed by 1988St10, except where noted otherwise, is presented here. There are a number of differences between the level schemes of 1988St10 and 1989Lo02, especially at high energy levels and their deexcitation. The γs associated with the three highest energy levels of this dataset, proposed by 1989Lo02, are adopted without the proposed γ multipolarity assignments for consistency. These are listed in comments.

Results from γ(θ,H,t) measurements:

E(level)	J^π	deduced g factor 1988St10	deduced magnetic moment μ
1664.0	21/2$^+$	0.45 *1*	4.73 *11*
1664.0+x	25/2$^+$	0.61 *2*	7.6 *3*
2186.7+x	31/2$^-$	0.639 *5*	9.90 *8*
3029.3+x	37/2$^+$	0.739 *7*	13.67 *13*
3495.4+x	43/2$^-$	0.725 *7*	15.59 *15*
4505.5+x	49/2$^+$	0.811 *12*	19.87 *29*
5928.8+x	(55/2$^+$)	0.604 *5*	16.61 *14*

^{213}Rn Levels

See 1989Lo02 for calculations of level energies by using the deformed Woods-Saxon potential, and for inferred deformations.
See 1988St10 and 1990St14 for shell-model level energies calculated by using empirical interaction energies derived from neighboring nuclei. See 1988St10 and 1990St14 also for calculations of g-factors and comparison with their experiment.

E(level)†	J^π‡	$T_{1/2}$@	Comments
0.0	(9/2$^+$)	19.4 ms *2*	J^π,$T_{1/2}$: From Adopted Levels.
705.00 *16*	11/2$^+$		
896.09 *15*	15/2$^-$	26.3 ns *7*	Configuration: Dominant ν ($j^{+1}_{15/2}$). $T_{1/2}$: From τ=38 ns *1* (1988St10). Others: 25 ns *3* (1988Fu10), 50 ns *1* (1983Lo16), 28 ns (1989Lo02 – same first author of 1983Lo16).
1259.62 *17*	13/2$^+$		
1529.03 *17*	17/2$^+$		
1574.1 *3*			
1612.4?			
1664.02 *20*	21/2$^+$	29.1 ns *14*	Configuration: ν ($g^{+1}_{9/2}$)⊗6$^+$. $T_{1/2}$: From τ=42 ns *2* (1988St10). Others: 16 ns *5* (1983Lo16) and 16 ns (1989Lo02).

Continued on next page (footnotes at end of table)

(HI,xnγ) (continued)

^{213}Rn Levels (continued)

E(level)[†]	Jπ[‡]	$T_{1/2}$[@]	Comments
1664.02+x *20*	25/2+	1.01 μs *21*	Configuration: Dominant ν ($g^{+1}_{9/2}$) π ($[h^{+1}_{9/2},f^{+1}_{7/2}]_{8+}$). %Isomeric production ratio=6 *3* (2013Ba29), E=1 GeV/nucleon, from ^{238}U fragmentation. $T_{1/2}$: From τ=1.45 μs *30* (1988St10). Others: ~1 μs (1983Lo16), 0.680 μs (1989Lo02 – same first author of 1983Lo16).
1703.5? *4*			
1745.93 *23*			
1788.73 *23*			
1856.63+x *14*	25/2+		Jπ: A_2/A_0 value consistent with ΔJ=0 transition. Configuration: Dominant ν ($g^{+1}_{9/2}$) π ($[h^{+2}_{9/2}]_{8+}$).
1879.4 *3*			
1936.9 *3*			
2007.43 *23*			
2072.82 *21*			
2121.62+x *20*	(27/2)		
2184.3 *3*			
2186.73+x *13*	31/2−	1.36 μs *7*	Configuration: ν ($g^{+1}_{9/2}$) π ($[h^{+1}_{9/2},i^{+1}_{13/2}]_{11-}$). $T_{1/2}$: From τ=1.96 μs *10* (1988St10). Others: ~2 μs (1983Lo16), 1.4 μs (1989Lo02 – same first author of 1983Lo16). %Isomeric production ratio=7.2 *31* (2013Bo18) and 17 *2* (2013Ba29 – using only one transition), E=1 GeV/nucleon, from ^{238}U fragmentation.
2201.52+x *16*	(27/2−)		
2227.5 *3*			
2257.5 *3*			
2327.1 *4*			
2610.7 *4*			
2640.83+x *24*			
2662.0+x *3*			
2677.00+x *14*	29/2+		
2684.5+x *3*			
2739.83+x *19*	31/2−		
2786.73+x *19*	29/2+		
2915.82+x *16*	33/2+		
2984.03+x *15*	33/2+		
3029.35+x *19*	37/2+	26.3 ns *7*	Configuration: Dominant ν ($g^{+1}_{9/2}$) π ($[h^{+3}_{9/2},f^{+1}_{7/2}]_{14+}$). $T_{1/2}$: From τ=38 ns *1* (1988St10). Others: 24 ns (1989Lo02), 55 ns *8* (1983Lo16 – for (37/2) with 795.5γ depopulating the state – 795.8γ (797.3γ here) placed from (33/2+) at 2984.0+x in 1989Lo02 – same first author of 1983Lo16).
3181.81+x *19*	(35/2−)		
3301.36+x *24*			
3441.17+x *22*	39/2−		
3495.5+x *3*	43/2−	27.7 ns *7*	Configuration: ν ($g^{+1}_{9/2}$) π ($[h^{+3}_{9/2},i^{+1}_{13/2}]_{17-}$). $T_{1/2}$: From τ=40 ns *1* (1988St10). Others: 26 ns (1989Lo02), 35 ns *2* (1983Lo16). %Isomeric production ratio=9 *5* (2013Ba29 – using only one transition), E=1 GeV/nucleon, from ^{238}U fragmentation.
3604.8+x *3*			
3623.9+x *4*			
3923.0+x *4*	(43/2−)		
3927.4+x *4*			
4048.0+x *4*	(45/2−)		
4050.3+x *4*			
4343.2+x *4*			
4505.6+x *4*	49/2+[#]	11.8 ns *7*	Configuration: ν ($j^{+1}_{15/2}$) π ($[h^{+3}_{9/2},i^{+1}_{13/2}]_{17-}$). $T_{1/2}$: From τ=17 ns *1* (1988St10). Other: 14 ns (1989Lo02).
4532.8+x *4*			

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(HI,xnγ) (continued)

^{213}Rn Levels (continued)

E(level)†	J$^{\pi}$‡	$T_{1/2}$@	Comments
4581.4+x *11*			
4723.1+x *4*			
4875.6+x *4*	(49/2$^+$)		
5225.6+x *4*	(51/2$^+$)#		
5763.7+x *4*	(53/2,55/2)		
5928.9+x *4*	(53/2,55/2)		
5928.9+y *4*	(55/2$^+$)	164 ns *10*	y=x+z, where 5 ≤ z ≤ 50-keV estimated in 1988St10 − see comments for expected (50) keV γ from 5928.9+y level. Configuration: ν ([$p_{1/2}^{-1}$,$g_{9/2}^{+1}i_{11/2}^{+1}$]$_{21/2-}$) π ([$h_{9/2}^{+3}$,$i_{13/2}^{+1}$]$_{17-}$). $T_{1/2}$: From τ=237 ns *15* (1988St10). Other: 157 ns (1989Lo02). %Isomeric production ratio=0.8 *2* (2013Ba29 − using only one transition), E=1 GeV/nucleon, from ^{238}U fragmentation.
6743.90+y *20*		59 ns	Level proposed by 1989Lo02 (6636 + Δ′). J$^{\pi}$: J$^{\pi}$=(61/2$^+$) in 1989Lo02. $T_{1/2}$: From 815γ(t) in 1989Lo02.
7926.4+y *3*			Level proposed by 1989Lo02 (6818 + Δ′). J$^{\pi}$: (65/2,67/2) in 1989Lo02.
8831.8+y *4*		14 ns	Level proposed by 1989Lo02 (8724 + Δ′). J$^{\pi}$: (71/2,73/2) in 1989Lo02. $T_{1/2}$: From 905.4γ(t) (1989Lo02).

† From least square fit to the γ-ray energies assuming equal weight if no uncertainty for Eγ. In the latter case, no uncertainty for the level is listed.

‡ Proposed by 1988St10 from γ multipolarities assigned based on conversion electron and $\gamma(\theta)$ measurements.

Spin in 1989Lo02 is two units less than those given here because of the 54.3-keV transition, not seen by 1989Lo02.

@ From 1988St10, except noted otherwise. Mean lifetime reported in 1988St10, determined from $\gamma\gamma$ coin, γX coin, pulsed beam, and time differential perturbed angular distribution (TDPAD) g-factor measurements. Others values are listed in the comments section.

(HI,xnγ) (continued)

γ(^{213}Rn)

See 1988St10 for B(E3) values calculated using the empirical-shell model, and comparison with experiments. See 1989Dr02 and 1985Be05 for systematics of E3 strengths of 15/2$^-$ to 9/2$^+$ transitions in the region.

E_γ[†@]	I_γ[&]	E_i(level)	J^π_i	E_f	J^π_f	Mult.[b]	δ	α[c]	Comments
(39.5[‡])		1703.5?		1664.02	21/2$^+$				
45.3[#] 2	≈1	3029.35+x	37/2$^+$	2984.03+x	33/2$^+$	E2		359 5	Mult.: α(exp) ~380 (1988St10).
(48.6[‡])		4581.4+x		4532.8+x					
(≤50[‡])		5928.9+y	(55/2$^+$)						Transition not observed, expected a γ transition 5 ≤ Eγ ≤ 50-keV in 1988St10 based on the observation that the 165.2γ deexciting the 5928.8+x-keV level had a prompt component, suggesting that the 164-ns level is above the 5928.9+x level.
54.3[#] 2	≈1[a]	3495.5+x	43/2$^-$	3441.17+x	39/2$^-$	E2		148.8 21	Mult.: α(exp)=160 70 (1988St10).
(65.1[‡])		2186.73+x	31/2$^-$	2121.62+x	(27/2)				
68.2[#] 2	7.6[a] 7	2984.03+x	33/2$^+$	2915.82+x	33/2$^+$	M1+E2	0.23 +6−8	9.9 12	Mult.,δ: From α(exp)=9.8 11 (1988St10).
(81.9[‡])		1745.93		1664.02	21/2$^+$				
(99.0[‡])		2739.83+x	31/2$^-$	2640.83+x					
113.5[#] 2	3 1	3029.35+x	37/2$^+$	2915.82+x	33/2$^+$	E2		4.85 7	A_2/A_0=+0.15 10 (1988St10) Mult.: α(exp)=5.9 16 (1988St10).
(125.0[‡] 2)	<1	4048.0+x	(45/2$^-$)	3923.0+x	(43/2$^-$)				
128.4[#] 2	3.4[a] 4	3623.9+x		3495.5+x	43/2$^-$				
135.0 2	274 5	1664.02	21/2$^+$	1529.03	17/2$^+$	E2		2.351 33	A_2/A_0=0.07 1 (1988St10) A_2=+0.085 12; A_4=−0.008 23 (1988Fu10) A_2/A_0=+0.03 5; A_4/A_0=−0.04 8 (1983Lo16 − for doublet) E_γ: Others: 135.3 2 (1989Lo02), 135.1 (1988Fu10), 131.3 (1983Lo16). Mult.: α(exp)=2.46 4 (1988St10).
139.8[#] 2	2.3[a] 4	3441.17+x	39/2$^-$	3301.36+x					
165.2 2	4 1	5928.9+x	(53/2,55/2)	5763.7+x	(53/2,55/2)	M1		3.15 4	E_γ: Other: 165.7 2 (1989Lo02). Mult.,δ: From α(exp)=3 1 (1988St10). δ=0.3 8 using the BriccMixing code.
184.7[#] 2	2.0 5	2257.5		2072.82					
191.1[#] 2	4.4 8	896.09	15/2$^-$	705.00	11/2$^+$	M2		9.96 14	A_2/A_0=−0.06 28 (1988St10) Mult.: α(exp)=9.9 13 (1988St10).
192.6[#] 2	29 1	1856.63+x	25/2$^+$	1664.02+x	25/2$^+$	M1		2.045 29	A_2/A_0=0.40 6 (1988St10) Mult.: α(exp)=2.5 3 (1988St10).

$\gamma(^{213}Rn)$ (continued)

E_γ [†@]	I_γ [&]	E_i(level)	J_i^π	E_f	J_f^π	Mult. [b]	δ	α [c]	Comments
197.3[#] 2	6.0[a] 7	2984.03+x	33/2+	2786.73+x	29/2+				
216.9[#] 2	8.2[a] 12	1745.93		1529.03	17/2+				
217.5[#] 2	13[a] 2	4723.1+x		4505.6+x	49/2+				
218.7[#] 2	≈1	2007.43		1788.73					
233.4[#] 2	9 1	1936.9		1703.5?					
238.8[#] 2	1.5 12	2915.82+x	33/2+	2677.00+x	29/2+				
244.2[#] 2	20 5	2984.03+x	33/2+	2739.83+x	31/2−	(E1)		0.0535 7	A_2/A_0=−0.15 4 (1988St10) Mult.: α(exp)<0.3, α(exp)=0.0 3 in 1988St10.
259.4[#] 2	≈2[a]	3441.17+x	39/2−	3181.81+x	(35/2−)				
259.7[#] 2	≈1[a]	1788.73		1529.03	17/2+				
261.5[#] 2	≈1[a]	2007.43		1745.93					
266.0[#] 2	≈3[a]	3181.81+x	(35/2−)	2915.82+x	33/2+				
269.4[#] 2	15 1	1529.03	17/2+	1259.62	13/2+	E2		0.1922 27	A_2/A_0=0.01 6 (1988St10) Mult.: α(exp)=0.18 16, deduced from intensity balance (1988St10).
272.0[#] 2	5 1	3301.36+x		3029.35+x	37/2+				A_2/A_0=−0.26 15 (1988St10)
272.9[#] 2	1.7 5	1936.9		1664.02	21/2+				
307.0[#] 2	5 3	2984.03+x	33/2+	2677.00+x	29/2+				
314.5[#] 2	6 1	1574.1		1259.62	13/2+				
330.1[#] 2	9 1	2186.73+x	31/2−	1856.63+x	25/2+	(E3)		0.552 8	Mult.: α(exp)<0.5, α(exp)=0.2 3 in 1988St10.
343.4[#] 2	8 2	2007.43		1664.02	21/2+				A_2/A_0=0.34 13 (1988St10)
344.9[#] 2	54 2	2201.52+x	(27/2−)	1856.63+x	25/2+	(E1)		0.02429 34	A_2/A_0=−0.28 3 (1988St10) Mult.: α(exp)<0.17 (1988St10).
350.0 2	9 2	5225.6+x	(51/2+)	4875.6+x	(49/2+)	M1+E2	0.70 +26−23	0.29 5	A_2/A_0=−0.39 14 (1988St10) Mult.,δ: From α(K)exp=0.23 4, and α(L)exp<0.09 (1988St10). There is disagreement between the multipolarity assignments of 1988St10 and 1989Lo02. α(K)exp=0.23 4 was deduced, and M1 was suggested by 1988St10; from a weak K line, 1989Lo02 deduced E1 multipolarity. However, since the 720.1γ (parallel to the cascading 350.0 and 370.1 gammas) and the 370.1γ are (M1), the 350.0γ probably is not E1.
352.8[e] 2	1.8 7	1612.4?		1259.62	13/2+				
370.1 2	8 2	4875.6+x	(49/2+)	4505.6+x	49/2+	M1		0.337 5	A_2/A_0=0.33 5 (1988St10) E_γ: Other measurement: 369.4 (1989Lo02). Mult.,δ: From α(K)exp=0.22 4, α(L)exp=0.12 1 (1988St10). δ=0.00 12 using the BriccMixing code. Intensities measured by 1989Lo02 suggest that the 350.0γ is stronger, and therefore, should be below

$^{213}_{86}Rn_{127}$-14

(HI,xnγ) (continued)

γ(^{213}Rn) (continued)

E_γ [†@]	I_γ [&]	E_i(level)	J_i^π	E_f	J_f^π	Mult. [b]	α [c]	Comments
								the 370.1γ. However, if the above placement between the above γ switched, then placement of 1053.3γ from 5928.8+x keV level to this level (1988St10) do not fit the level energy difference. So, 1988St10 level structure is followed by the evaluator. 1053.3γ is not reported in 1989Lo02.
383.2[#] 2	<1	2610.7		2227.5				
390.2[#] 2	5 1	2327.1		1936.9				
411.8 2	260 5	3441.17+x	39/2⁻	3029.35+x	37/2⁺	E1	0.01652 23	A_2/A_0=−0.18 1 (1988St10) A_2/A_0=−0.29 3; A_4/A_0=−0.05 5 (1983Lo16) E_γ: Others: 412.2 2 (1989Lo02), 411.8 (1988Fu10). Mult.: α(K)exp=0.035 4, and α(L)exp=0.005 1 (1988St10).
420.2[#] 2	<1	4343.2+x		3923.0+x	(43/2⁻)			
427.5[#] 2	16 3	3923.0+x	(43/2⁻)	3495.5+x	43/2⁻	M1	0.2282 32	A_2/A_0=0.26 7 (1988St10) Mult.: α(K)exp=0.19 3, and α(L)exp=0.08 2 (1988St10).
431.9[#] 2	13 1	3927.4+x		3495.5+x	43/2⁻			
445.5[#] 2	≈1[a]	4050.3+x		3604.8+x				
454.1[#] 2	13 2	2640.83+x		2186.73+x	31/2⁻			A_2/A_0=0.0 1 (1988St10)
457.6[d] 2	30 5	2121.62+x	(27/2)	1664.02+x	25/2⁺			
457.6[d] 2	<3	4505.6+x	49/2⁺	4048.0+x	(45/2⁻)			I_γ: Determined by 1988St10 from coincidence spectra. E_γ: Other: 456.9 2 (1989Lo02). This transition was placed on the level scheme only once by 1989Lo02.
460.5[#] 2	4 1	2662.0+x		2201.52+x	(27/2⁻)			
483.0[#] 2	5 1	2684.5+x		2201.52+x	(27/2⁻)			
490.2[#] 2	13 1	2677.00+x	29/2⁺	2186.73+x	31/2⁻	D+Q		A_2/A_0=−0.15 8 (1988St10) Mult.: from A_2/A_0.
520.3[#] 2	8[a] 2	2184.3		1664.02	21/2⁺			
522.7 2	480 10	2186.73+x	31/2⁻	1664.02+x	25/2⁺	E3	0.1073	A_2/A_0=0.130 6 (1988St10) A_2/A_0=+0.00 2; A_4/A_0=+0.00 4 (1983Lo16) A_2=+0.148 11; A_4=+0.017 18 (1988Fu10) E_γ: Others: 521.7 2 (1989Lo02) and 522.7 (1988Fu10), 521.7 (1983Lo16). Mult.: α(K)exp=0.060 2, α(L)exp=0.036 2, and α(M)exp=0.013 1 (1988St10). Polarization amplitude=−0.01 4 (1988Fu10).
533.4[#e] 2		4581.4+x		4048.0+x	(45/2⁻)			E_γ: From decay scheme of 1988St10; this transition was not listed by the authors.
537.5 2	18 2	2201.52+x	(27/2⁻)	1664.02+x	25/2⁺	(E1)	0.00951 13	E_γ: Other: 536.7 2 (1989Lo02).
538.1 2	10[a] 1	5763.7+x	(53/2,55/2)	5225.6+x	(51/2⁺)			E_γ: Other: 536.7 2 (1989Lo02).
543.7[#] 2	2[a] 1	2072.82		1529.03	17/2⁺			
552.5 2	47 4	4048.0+x	(45/2⁻)	3495.5+x	43/2⁻	M1	0.1150 16	E_γ: Other: 551.8 2 (1989Lo02).

$^{213}_{86}Rn_{127}$-15

(HI,xnγ) (continued)

γ(^{213}Rn) (continued)

E_γ[†@]	I_γ[&]	E_i(level)	J^π_i	E_f	J^π_f	Mult.[b]	α[c]	Comments
								Mult.: α(K)exp=0.12 2 (1988St10). The α(K)exp value is presented for 553γ with a multipolarity M1 in Table 3 (1988St10). Evaluator presents the same α(K)exp value and M1 multipolarity for both the 552.5γ and 553.1γ from (45/2⁻) state at 4048.0+x and 31/2⁻ state at 2737.4+x levels, respectively.
553.1[#] 2	26 4	2739.83+x	31/2⁻	2186.73+x	31/2⁻	M1	0.1147 16	Mult.: α(K)exp=0.12 2 (1988St10). The α(K)exp value is presented for 553γ with a multipolarity M1 in Table 3 (1988St10). Evaluator presents the same α(K)exp value and M1 multipolarity for both the 552.5γ and 553.1γ from (45/2⁻) state at 4048.0+x and 31/2⁻ state at 2737.4+x levels, respectively.
563.5[#] 2	28 1	2227.5		1664.02	21/2⁺			A_2/A_0=−0.11 7 (1988St10)
575.5[#] 2	12 3	3604.8+x		3029.35+x	37/2⁺			A_2/A_0=−0.05 10 (1988St10)
609.8[#] 2	7 3	4532.8+x		3923.0+x	(43/2⁻)			A_2/A_0=−0.19 6 (1988St10)
632.9 2	95×10¹ 10	1529.03	17/2⁺	896.09	15/2⁻	E1	0.00688 10	A_2/A_0=−0.112 24 (1988St10) A_2/A_0=−0.15 5; A_4/A_0=+0.12 10 (1983Lo16) A_2=−0.095 6; A_4=+0.010 11 (1988Fu10) E_γ: Others: 631.7 2 (1989Lo02), 632.7 (1988Fu10), 631.7 (1983Lo16). Mult.: α(K)exp=0.008 1, α(L)exp=0.0014 2, and α(M)exp<0.0009 (1988St10). Polarization amplitude=−0.01 2 (1988Fu10).
705.0[#] 2	770 5	705.00	11/2⁺	0.0	(9/2⁺)	M1	0.0604 8	A_2/A_0=−0.03 2 (1988St10) Mult.: α(K)exp=0.040 3 and α(L)exp=0.013 2 (1988St10).
720.1 2	10 3	5225.6+x	(51/2⁺)	4505.6+x	49/2⁺	(M1)	0.0572 8	E_γ: Other: 718.9 2 (1989Lo02). Mult.: α(K)exp=0.041 4 (1988St10).
729.1 2	115 6	2915.82+x	33/2⁺	2186.73+x	31/2⁻	E1	0.00525	E_γ: Others: 727.8 2 (1989Lo02) and 728.7 (1988Fu10). Mult.: there are disagreements between the experimental Ice′s and the angular distributions measured by 1988St10 and by 1989Lo02: α(K)exp<0.0065, α(L)exp=0.004 1 (1988St10), α(K)exp=0.019 (1989Lo02); angular distribution: A_2/A_0=−0.22 2 (1988St10), −0.02 4 (1989Lo02).
767.9 2	10 1	1664.02	21/2⁺	896.09	15/2⁻	(E3)	0.0365 5	A_2/A_0=0.4 1 (1988St10) E_γ: Other: 767.6 (1988Fu10). Mult.: E3 is expected from the level scheme; angular distribution is consistent with this multipolarity; no conversion electron line was observed.
797.3 2	256 5	2984.03+x	33/2⁺	2186.73+x	31/2⁻	E1	0.00444 6	A_2/A_0=−0.168 8 (1988St10) A_2/A_0=−0.01 2; A_4/A_0=−0.02 2 (1983Lo16) E_γ: Comparable 795.5γ from (37/2) level as (E3) in 1983Lo16. E_γ: Others: 795.8 2 (1989Lo02), 797.2 (1988Fu10), 795.5 (1983Lo16). Mult.: α(K)exp=0.0048 4 and α(L)exp=0.0013 3 (1988St10).

(HI,xnγ) (continued)

γ(^{213}Rn) (continued)

E_γ[†@]	I_γ[&]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[b]	α[c]	Comments
815.0 *2*	≈100[@]	6743.90+y		5928.9+y	(55/2$^+$)			Mult.: E3 from A_2/A_0=0.29 *5*, A_4/A_0=0.28 *4*; α(K)exp=0.027 (1989Lo02).
842.6[#e] *2*	5[a] *1*	3029.35+x	37/2$^+$	2186.73+x	31/2$^-$			Placement of 842.6γ between the 37/2$^+$ state at 3029.3+x and the 31/2$^-$ state at 2186.7+x keV requires the 842.6γ to be an E3 transition, with B(E3)(W.u.)=0.7 *4*.
896.1 *2*	1000	896.09	15/2$^-$	0.0	(9/2$^+$)	E3	0.02500 *35*	A_2=+0.155 *7*; A_4=+0.009 *11* (1988Fu10) A_2/A_0=0.098 *9* (1988St10) E_γ: Others: 894.5 *2* (1989Lo02), 896.0 (1988Fu10), 894.5 (1983Lo16). Mult.: α(K)exp=0.016 *1*, α(L)exp=0.0059 *4*, and α(M)exp=0.0016 *2* (1988St10). Polarization amplitude=−0.04 *2* (1988Fu10).
905.4 *2*	60[@] *18*	8831.8+y		7926.4+y				E_γ: From 1989Lo02. Mult.: (E3) from A_2/A_0=0.34 *7*, A_4/A_0=0.41 *10*; α(K)exp≤0.024 (1989Lo02).
907.4[e] *2*	5 *1*	1612.4?		705.00	11/2$^+$			E_γ: Other: 905.4 (1989Lo02). This transition was placed by 1989Lo02 to deexcite a level at 8724 + Δ′ keV, 8831.8+y in this dataset.
930.1[#] *2*	12 *1*	2786.73+x	29/2$^+$	1856.63+x	25/2$^+$			A_2/A_0=0.0 *1* (1988St10)
995.1[#] *2*	35 *4*	3181.81+x	(35/2$^-$)	2186.73+x	31/2$^-$	(E2)	0.00821 *11*	A_2/A_0=0.13 *5* (1988St10)
1010.1 *2*	51 *4*	4505.6+x	49/2$^+$	3495.5+x	43/2$^-$	E3	0.01891 *26*	A_2/A_0=0.47 *2* (1988St10) E_γ: Other: 1008.1 *2* (1989Lo02). Mult.: α(K)exp=0.0155 *12*, α(L)exp=0.0049 *5*, and α(M)exp=0.0014 *3* (1988St10).
1013.0[#] *2*	11 *4*	2677.00+x	29/2$^+$	1664.02+x	25/2$^+$	Q		A_2/A_0=0.10 *9* (1988St10) Mult.: from A_2/A_0 by the evaluator.
1053.3[#] *2*	3[a] *1*	5928.9+x	(53/2,55/2)	4875.6+x	(49/2$^+$)			
1174.4[#] *2*	17 *3*	1879.4		705.00	11/2$^+$			
1176.8[#] *2*	16 *3*	2072.82		896.09	15/2$^-$			A_2/A_0=0.14 *10* (1988St10)
1182.5 *2*	≈80[@]	7926.4+y		6743.90+y				E_γ: From 1989Lo02. Mult.: (E3) from A_2/A_0=0.36 *2*, A_4/A_0=0.02 *3*; α(K)exp≤0.025 (1989Lo02).
1258.1 *2*	16 *3*	5763.7+x	(53/2,55/2)	4505.6+x	49/2$^+$			E_γ: Other: 1255.9 *2* (1989Lo02).
1259.6[#] *2*	24 *3*	1259.62	13/2$^+$	0.0	(9/2$^+$)			
1423.3[#] *2*	3[a] *1*	5928.9+x	(53/2,55/2)	4505.6+x	49/2$^+$			

[†] From 1988St10, unless noted otherwise. ΔEγ=0.2 keV listed by evaluator based on the e-mail communications (dated: Feb 3, 2022) with the first author, A.E.Stuchbery, of 1988St10. The reported Eγ in 1988St10 and 1988Fu10, and those of 1989Lo02 are discrepant. However, the data reported in 1988St10 and

(HI,xnγ) (continued)

γ(^{213}Rn) (continued)

1988Fu10 are consistent.

‡ From level energy difference. Transition was not observed; existence proposed from coincidence data.

Transition was not seen by others.

@ From 1989Lo02.

& Relative singles intensity measured in ^{208}Pb(57-MeV ^{9}Be,4n) by 1988St10 and normalized to Iγ(896)=1000.

[a] From coincidence data (1988St10).

[b] From conversion electron measurements by 1989Lo02 and 1988St10, angular distribution measurements of 1989Lo02, 1988St10, 1988Fu10, and 1983Lo16.

[c] 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.

[d] Multiply placed.

[e] Placement of transition in the level scheme is uncertain.

Adopted Levels, Gammas

$Q(\beta^-)=-3900$ *11*; S(n)=8110 *10*; S(p)=2184 *6*; $Q(\alpha)=6904.7$ *13* 2021Wa16

2015Ba20: ^{136}Xe + ^{208}Pb, E(c.m.)=450 MeV, measured multi-nucleon transfer reaction cross section $\sigma_{cumulative\ yield}$=0.0402 mb *80* a $\sigma_{independent\ yield}$=0.0402 mb *80* for ^{213}Fr.

1986Hi01,1988Ne03: $^{197}Au(^{16}O,F)$, E=95-124 MeV, measured neutron fission-fragment angular correlations for the compound nuclei. 1988Ne03 measured average number of neutrons preceding fission.

2009Pa49: $^{238}U(p,X)$, E=1 GeV; measured fission and spallation yields from different mass targets.

2014Si03: $^{194}Pt(^{19}F,X)$, E=96.2-137.3 MeV; measured spectra and angular distribution of evaporation residues (ER), σ(ER, E).

1972Le23: $^{205}Tl(^{12}C,4n)$, E=60-90 MeV, measured σ(E).

^{213}Fr Levels

Cross Reference (XREF) Flags

A	^{213}Ra ε decay (2.73 min)	D	^{217}Ac α decay (8 ns)
B	^{217}Ac α decay (69 ns)	E	^{217}Ac α decay (740 ns)
C	^{217}Ac α decay: E=1.15 MeV	F	(HI,xnγ)

E(level)[†]	J^π[‡]	$T_{1/2}$[#]	XREF	Comments
0.0	9/2⁻	34.17 s *6*	BCDEF	%α=99.44 *5*; %ε+%β^+=0.56 *5* μ=+4.02 *8*; Q=−0.14 *2* J^π: Measured by Atomic Beam Magnetic Resonance (ABMR) technique (1978Ek02, 1978Ek05); configuration: π ($h^{+1}_{9/2}$) from μ and shell model. $T_{1/2}$: Weighted average of 34.6 s *3* (1974Ho27), 34.7 s *3* (1967Va20), 33.7 s *15* (1964Gr04), 34.14 s *6* (2013Fi08), 33.2 s *20* (2016Pr08 – 605.9-keV conversion electron (t) (corresponding to the 704.3 keV γ ray). 28.4 s *35* (2016Pr08 – from 577.0γ(t) of ^{209}At following the α decay of ^{213}Fr), 34.1 s *7* and 34 s *6* (2012No08 – the latter value was measured for $^{213}Fr^{+86}$ at rest and both from α(t)), 16 s *+37−13* (2015De22), 20 s *+48−8* (2019Mi08). Others: 35.0 s *2* (1982Bo04 – possibly contribution from ^{213}Ra, ^{211}Po contaminations not discussed), 34 s (1961Gr42 – from 6770α(t)). %α: Weighted average of %α=99.1 *1*, %(ε+β^+)=0.9 *1* (1974Ho27), %α=99.48 *3*, %(ε+β^+)=0.52 *3* (1964Gr04) and %α=99.43 *3*, %(ε+β^+)=0.57 *3* (1967Va20). χ^2=6.7 cf. χ^2_{crit}=3.0. Other: %α=99.75 *15*, %(ε+β^+)=0.25 *15* (2017Lo13 – possible escape of ^{213}Rn). (ε+β^+) branching was deduced from comparison of ^{213}Fr and ^{213}Rn α′s in by 1964Gr04, 1967Va20, 1974Ho27, and 2017Lo13. Weighted average of all values is the same as above with χ^2=5.9 cf. χ^2_{crit}=2.6 and unweighted average: %α=99.44 *13*, %(ε+β^+)=0.56 *13*. μ: From 2019StZV, (1985Co24 and 1986Ek02 – by LASER induced optical pumping). Other: 3.996 *14* (1980Li22 – deduced from g_l value). Q: From 2016St14, 1985Co24. δ<r^2>(^{212}Fr,^{213}Fr)=0.06829 fm^2 *8* (1987Co19) and 0.02780 *3* (1985Co24). Same first author for both. Uncertainty is statistical only, 1987Co19 noted the systematic uncertainty to be a few percent. Isotope shift measurement – 2014Co18.
498.0 *10*	(7/2⁻)		E	J^π: From dominant I_α=11 with respect to I_α(10540)=100 in ^{217}Ac α decay (740 ns).
1105.0 *10*	(13/2)⁺		E	J^π: 1105γ M2 to 9/2⁻ g.s. and I_α(10540)=90 *6* branching in ^{217}Ac α decay (740 ns).
1188.80 *10*	13/2⁻	<2.1 ns	F	J^π: 1188.8γ E2 to 9/2⁻ state. Configuration: π ($h^{+1}_{9/2}$)⊗2⁺.
1411.00 *15*	17/2⁻	18 ns *1*	F	μ=7.5 *14* (1986By01,2020StZV) J^π: 222.2γ E2 to 13/2⁻ state. g=0.88 *16* by γ(H,θ,t) in (HI,xnγ) (1986By01). Configuration: π ($h^{+1}_{9/2}$)⊗4⁺.
1590.40 *18*	21/2⁻	505 ns *14*	F	μ=9.28 *3* (2020StZV) J^π: 179.4γ E2 to 17/2⁻ state. Measurements: g=0.888 *3* (1977Be56, 1976Ha37);

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Adopted Levels, Gammas (continued)

^{213}Fr Levels (continued)

E(level)†	J$^{\pi}$‡	$T_{1/2}$#	XREF	Comments
				0.888 *4* (1979Ho06); 0.89 *2* (1986By01) by γ(H,θ,t) in (HI,xnγ); 0.888 *3* (1978Ha50). Configuration: π $(h^{+1}_{9/2})\otimes 6^+$.
1856.30 *20*	23/2$^-$	<1.4 ns	F	J$^{\pi}$: 265.9γ M1+E2 to 21/2$^-$ state. Configuration: π $(h^{+2}_{9/2},f^{+1}_{7/2})$.
2537.61 *23*	29/2$^+$	238 ns *6*	F	μ=15.15 *5*; Q=−0.70 *7* J$^{\pi}$: 681.3γ E3 to 23/2$^-$ state. Main configuration: π $(h^{+2}_{9/2},i^{+1}_{13/2})$. $T_{1/2}$: Other: 243 ns *21* (1986By01). μ: From 2020StZV, 1977Be56. g factor measurements by γ(H,θ,t), corrected for Knight shift: g=1.055 *5* (1989By01), 1.049 *2* (1979Ho06), 1.0494 *18* (1977Be56,1976Ha37,1978Ha50), 1.04 *2* (1974Re09), and 1.05 *3* (1973ReZP). Q: From 1990By03, 2016St14. Deduced value using B(E2) for the 8$^+$ to 6$^+$ transition in ^{212}Rn and an effective charge of 1.5e. See also 1991Ha02 for calculations. Q=0.81 *4* in 1990Ha30 from level mixing spectroscopy.
2740.2 *3*	27/2$^-$	<7 ns	F	J$^{\pi}$: 884γ E2 to 23/2$^-$ state. Configuration: π $(h^{+2}_{9/2},f^{+1}_{7/2})\otimes 2^+$.
2950.5 *3*	31/2$^-$	<2.1 ns	F	J$^{\pi}$: 413.0γ E1 to 29/2$^+$ state, 210.4γ (E2) to 27/2$^-$ state. Configuration: π $(h^{+2}_{9/2},f^{+1}_{7/2})\otimes 4^+$.
3427.34 *24*	33/2$^+$	<2.1 ns	F	J$^{\pi}$: 476.9γ E1 to 31/2$^-$ state, 889.7γ E2 to 29/2$^+$ state. Configuration: π $(h^{+2}_{9/2},i^{+1}_{13/2})\otimes 2^+$.
3489.2 *4*	(33/2)		F	J$^{\pi}$: 538.7γ (D) to 31/2$^-$ state.
3655.4 *4*	37/2$^+$	2.4 ns *7*	F	J$^{\pi}$: 228.1γ E2 to 33/2$^+$ state. Configuration: π $(h^{+2}_{9/2},i^{+1}_{13/2})\otimes 4^+$.
4029.2 *5*			F	
4082.9 *4*	39/2$^+$	<1.4 ns	F	J$^{\pi}$: 427.5γ M1+E2 to 37/2$^+$ state.
4653.6? *11*			F	
4675.4 *4*		<2.1 ns	F	Two cascading gammas combining the level with 47/2$^-$, three cascading gammas from 49/2$^+$ state, and probable M1 character of the 592.5γ to 39/2$^+$ suggest (41/2$^+$).
4695.9 *4*	39/2$^-$	<2.1 ns	F	J$^{\pi}$: 1040.3γ E1 to 37/2$^+$ state.
4898.5 *4*	41/2$^-$	<2.8 ns	F	J$^{\pi}$: 815.6γ E1 to 39/2$^+$ state.
4982.0 *6*			F	If 306.5γ to 4675.4-keV level is E1, as implied by intensity balance at 4675.4-keV level, and if J^{π}(4675.4-keV level) is (41/2$^+$), J^{π}(4982.0-keV level)=(43/2$^-$) is consistent with being populated from 49/2$^+$ state through three cascading γ transitions.
4992.7 *4*	45/2$^-$	13 ns *2*	F	μ=23.2 *7* J$^{\pi}$: 909.8γ E3 to 39/2$^+$ state, 94.4γ E2 to 41/2$^-$ state. Measurements: g=0.990 *25* (1979Ho06); 1.03 *3* (1986By01) by γ(H,θ,t) in (HI,xnγ). Configuration: π $(h^{+3}_{9/2},i^{+2}_{13/2})$. μ: From 2020StZV, 1986By01 from time-differential perturbed angular distribution (TDPAD) measurements.
5001.9 *5*			F	784.0γ from 47/2$^-$ state and two cascading γ transitions to 39/2$^+$ state (326.3γ (D) and 592.5γ (D)) suggest J^{π}=(43/2$^-$).
5220.2 *5*			F	
5506.3 *4*	43/2$^-$	<2.1 ns	F	J$^{\pi}$: 810.2γ E2 to 39/2$^-$ state.
5785.9 *4*	47/2$^-$	<1.4 ns	F	J$^{\pi}$: 793.2γ M1 to 45/2$^-$ state. 279.6γ E2 to 43/2$^-$ state.
5814.8 *5*	(45/2$^+$)		F	J$^{\pi}$: 308.3γ (E1) to 43/2$^-$ state.
5951.5 *5*			F	
6102.7 *6*	(49/2$^-$)		F	J$^{\pi}$: 316.8γ (M1+E2) to 47/2$^-$ state.
6334.1 *5*			F	
6572.9 *4*	49/2$^+$	<2.1 ns	F	J$^{\pi}$: 786.9γ E1 to 47/2$^-$ state.
6715.3 *5*	53/2$^+$	6.2 ns *14*	F	J$^{\pi}$: 142.3γ E2 to 49/2$^+$ state, 929.5γ E3 to 47/2$^-$ state. Configuration: π $([h^{+4}_{9/2},i^{+1}_{13/2}]_{37/2^+})$ ν $([p^{-1}_{1/2},j^{+1}_{15/2}]_{8^+})$.
6724.5 *7*	(55/2$^+$)		F	J$^{\pi}$: 621.8γ to (49/2$^-$) state presumably an E3, since of the cascading 621.8γ and 316.8γ (from 49/2$^-$ state) later one is (M1+E2).
6803.0 *8*	(55/2)		F	J$^{\pi}$: Assuming the 738.8γ from the 7541 level is dipole; no γ from (59/2$^+$).
6812.8 *6*			F	
7135.0 *8*			F	
7247.5 *8*			F	

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued)

^{213}Fr Levels (continued)

E(level)†	Jπ‡	T1/2#	XREF	Comments
7288.0 *7*	(57/2$^+$)	<2.1 ns	F	Jπ: 563.3γ M1 to (55/2$^+$) state.
7374.4 *8*	(57/2,59/2)		F	Jπ: 349.5γ from (59/2$^+$) state at 7723 keV is probably dipole; possible γ to (57/2$^+$); level decays through six cascading gammas to 45/2$^-$ level. If 349.5γ is E1, then π=(−).
7541.8 *7*	(57/2)		F	Jπ: 182.0γ from (59/2$^+$) state at 7723 keV is dipole; 817.7γ to (55/2$^+$) state. If 182.0γ is M1, as suggested by the intensity balance at the 7723.3 level, then Jπ=(57/2$^+$).
7723.7 *7*	(59/2$^+$)		F	Jπ: 182γ D to (57/2), 349.5γ D to (57/2,59/2). Configuration: π ($[h^{+3}_{9/2},i^{+1}_{13/2},f_{7/2}]_{39/2^+}$) ν ($[p^{-2}_{1/2},g_{9/2},i_{11/2}]_{10^+}$).
7983.6 *7*	(61/2$^-$)	<3.5 ns	F	Jπ: 1259γ E3 to (55/2$^+$), Possible configuration: π($[h^{+3}_{9/2},i^{+2}_{13/2}]_{45/2^-}$) ν ($[p^{-1}_{1/2},j^{+1}_{15/2}]_{8^+}$).
8094.9 *7*	(65/2$^-$)	3.1 μs *2*	F	μ=22.5 *2*; Q=−2.19 *53* Jπ: 371.2γ (E3) to (59/2$^+$) state. Configuration: π ($[h^{+3}_{9/2},i^{+2}_{13/2}]_{45/2^-}$) ν ($[p^{-2}_{1/2},g_{9/2},i_{11/2}]_{10^+}$). μ: From 2020StZV, 1989By01 from time-differential perturbed angular distribution (TDPAD) measurements. Q: From 1991Ha02 (not given in 2016St14), if Q(29/2$^+$ state) =−0.70 *7*. In 1990Ha30, Q=2.51 *51* was obtained by level mixing spectroscopy, a g-factor of 0.695 *7* was used.

† Deduced by the evaluator from a least squares fit to the γ-ray energies. Eγ related to uncertain placement and expected ones were ignored.

‡ Spins and parities for levels above 1188 keV are from (HI,xnγ) data. These assignments are based on γ angular distribution, linear polarization, conversion electron measurements, and transition strengths.

All excited states′ half-lives are from (HI,xnγ) data.

Adopted Levels, Gammas (continued)

$\gamma(^{213}Fr)$

All γ properties are from (HI,xnγ) data.

E_i(level)	J_i^π	E_γ	I_γ	E_f	J_f^π	Mult.	δ	α[‡]	Comments
498.0	(7/2⁻)	498	100	0.0	9/2⁻				
1105.0	(13/2)⁺	1105	100	0.0	9/2⁻	M2		0.0479 *7*	Mult.: from ce in ^{217}Ac α decay (740 ns) (1985De14).
1188.80	13/2⁻	1188.8 *1*	100	0.0	9/2⁻	E2		0.00616 *9*	
1411.00	17/2⁻	222.2 *1*	100	1188.80	13/2⁻	E2		0.382 *5*	B(E2)(W.u.)=0.556 *+33−30*
1590.40	21/2⁻	179.4 *1*	100	1411.00	17/2⁻	E2		0.823 *12*	B(E2)(W.u.)=0.0438 *13*
1856.30	23/2⁻	265.9 *1*	100	1590.40	21/2⁻	M1+E2	0.9 *+11−9*	0.60 *31*	
2537.61	29/2⁺	681.3 *1*	100	1856.30	23/2⁻	E3		0.0529 *7*	B(E3)(W.u.)=26.4 *7*
2740.2	27/2⁻	202.8[#] *4*		2537.61	29/2⁺				
		884.0 *3*	100 *16*	1856.30	23/2⁻	E2		0.01087 *15*	
2950.5	31/2⁻	210.4 *3*	<33	2740.2	27/2⁻	(E2)		0.462 *7*	
		413.0 *2*	100 *2*	2537.61	29/2⁺	E1		0.01695 *24*	
3427.34	33/2⁺	476.9 *2*	45.7 *20*	2950.5	31/2⁻	E1		0.01255 *18*	
		889.7 *1*	100 *4*	2537.61	29/2⁺	E2		0.01073 *15*	
3489.2	(33/2)	538.7 *3*	100	2950.5	31/2⁻	(D)			
3655.4	37/2⁺	228.1 *2*	100	3427.34	33/2⁺	E2		0.349 *5*	B(E2)(W.u.)=3.8 *+16−8*
4029.2		540.0 *3*	100	3489.2	(33/2)				
4082.9	39/2⁺	427.5 *1*	100	3655.4	37/2⁺	M1+E2	0.10 *3*	0.246 *4*	
4653.6?		624.2[#] *5*	100	4029.2					
4675.4		592.5 *3*	100 *7*	4082.9	39/2⁺				
4695.9	39/2⁻	(42.3[†])		4653.6?					
		665[#]		4029.2					
		1040.3 *3*	100 *10*	3655.4	37/2⁺	E1		0.00286 *4*	Other probable gammas from the level are ignored.
4898.5	41/2⁻	815.6 *2*	100	4082.9	39/2⁺	E1		0.00443 *6*	
4982.0		306.5 *4*	100	4675.4					
4992.7	45/2⁻	94.4 *3*	3.4 *9*	4898.5	41/2⁻	E2		11.49 *24*	B(E2)(W.u.)=1.80 *+48−43*
		909.8 *2*	100 *8*	4082.9	39/2⁺	E3		0.0255 *4*	B(E3)(W.u.)=46 *+10−7*
5001.9		326.3 *4*	100	4675.4		(D)			
5220.2		(227.5[†])		4992.7	45/2⁻				
		238		4982.0					
		545.1 *5*	100	4675.4					
5506.3	43/2⁻	810.2 *3*	100	4695.9	39/2⁻	E2		0.01293 *18*	
5785.9	47/2⁻	279.6 *2*	46 *4*	5506.3	43/2⁻	E2		0.1797 *25*	
		784.0 *4*	2.3 *8*	5001.9					
		793.2 *3*	100 *16*	4992.7	45/2⁻	M1		0.0481	
5814.8	(45/2⁺)	308.3 *3*	60 *20*	5506.3	43/2⁻	(E1)		0.0322 *5*	
		594.7 *4*	100 *20*	5220.2					
5951.5		949.4 *3*	91 *36*	5001.9					
		959.0 *3*	100 *27*	4992.7	45/2⁻				

γ(^{213}Fr) (continued)

E_i(level)	J^π_i	E_γ	I_γ	E_f	J^π_f	Mult.	α[‡]	Comments
6102.7	(49/2⁻)	316.8 *4*	100	5785.9	47/2⁻	(M1+E2)	0.34 *22*	
6334.1		382.7 *3*	100	5951.5				
6572.9	49/2⁺	239.0 *4*	9 *5*	6334.1				
		469.7[#] *4*		6102.7	(49/2⁻)			
		758.0 *4*	16 *3*	5814.8	(45/2⁺)			
		786.9 *1*	100 *9*	5785.9	47/2⁻	E1	0.00473 *7*	
6715.3	53/2⁺	142.3 *3*	71 *9*	6572.9	49/2⁺	E2	2.027 *33*	B(E2)(W.u.)=4.6 *+15−9*
		929.5 *3*	100 *20*	5785.9	47/2⁻	E3	0.02428 *34*	B(E3)(W.u.)=38 *+13−9*
6724.5	(55/2⁺)	(9.2[†])		6715.3	53/2⁺			
		621.8 *3*	100 *33*	6102.7	(49/2⁻)	[E3]	0.0681 *10*	
6803.0	(55/2)	(78.4[†])	100	6724.5	(55/2⁺)			
6812.8		478.7 *3*	100	6334.1				
7135.0		322.2 *5*	100	6812.8				
7247.5		(112.2[†])	100	7135.0				
7288.0	(57/2⁺)	563.3 *3*	100	6724.5	(55/2⁺)	M1	0.1187 *17*	
7374.4	(57/2,59/2)	(86.3[†])		7288.0	(57/2⁺)			
		127.2 *4*	100 *19*	7247.5				
7541.8	(57/2)	253.6 *4*	100 *7*	7288.0	(57/2⁺)			
		294.1 *3*	13 *3*	7247.5				
		738.8 *3*	12.8 *15*	6803.0	(55/2)	D		
		817.7 *3*	15 *5*	6724.5	(55/2⁺)			
7723.7	(59/2⁺)	182.0 *3*	56 *11*	7541.8	(57/2)	D		
		349.5 *3*	100 *6*	7374.4	(57/2,59/2)	D		
		435.6 *4*	11 *3*	7288.0	(57/2⁺)			
		998.9 *3*	16 *5*	6724.5	(55/2⁺)			
7983.6	(61/2⁻)	695		7288.0	(57/2⁺)			
		1259.1 *3*	100 *5*	6724.5	(55/2⁺)	E3	0.01229 *17*	
8094.9	(65/2⁻)	111.3 *2*	64.0 *19*	7983.6	(61/2⁻)	(E2)	5.66 *9*	B(E2)(W.u.)=0.0162 *11*
		371.2 *2*	100 *8*	7723.7	(59/2⁺)	(E3)	0.372 *5*	B(E3)(W.u.)=26.6 *24*

[†] Transition expected, but not observed.

[‡] 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.

^{213}Ra ε decay (2.73 min) 1984Gu29

Parent: ^{213}Ra: E=0.0; $J^{\pi}=1/2^{-}$; $T_{1/2}$=2.73 min *5*; Q(ε)=3900 *11*; %ε+%β^{+} decay=14 *2*

^{213}Ra was produced from ^{204}Pb(^{12}C,4n) reaction, reaction products recoiled out of the thin target and were stopped in 500 μg/cm^{2} carbon foils. The foils were transported by a belt into the spectrometer for the measurements. A Si(Li) detector for electrons on the long side and a gamma-x-ray counter for γ-rays about 3 cm from the foils on the short side were used. The e^{-}-x-ray coincidences occur predominanantly with the x-ray emitted as a consequence of a K-converted transition. Measured K-conversion lines. No Eγ, Iγ, I_e are reported.

γ(^{213}Fr)

Eγ[†]
[x]175
[x]195
[x]208
[x]218
[x]227[‡]
[x]317[‡]
[x]339
[x]400
[x]475
[x]498

† From Fig. 11 in 1984Gu29. Eγ are labeled for corresponing K-conversion electrons lines.
‡ Comparable Eγ is only available in the adopted gammas from (HI,Xnγ) studies.
x γ ray not placed in level scheme.

^{217}Ac α decay (69 ns)

Parent: ^{217}Ac: E=0.0; J^π=9/2$^-$; $T_{1/2}$=69 ns *4*; Q(α)=9832 *10*; %α decay=100

^{217}Ac-J^π: From 2018Ko01 (A=217 evaluation).

^{217}Ac-$T_{1/2}$: from 1985De14 α(t) (earlier value 72 ns *5* in 1981MaYW). Others: 75 ns *3* (1982GoZU); 111 ns *7* (1973No09, from α(t), previous value was 0.10 μs *1* in 1972No06 − due to pulsed beam of ~100 ns, possibly missed the long-lived component of g.s. decay − noted in 1985De14), 150 ns *+370−60* (2019Mi08). Adopted $T_{1/2}$ in 2018Ko01 (A=217 evaluation) is also 69 ns *4*.

^{217}Ac-Q(α): From 2021Wa16.

^{213}Fr Levels

E(level)	J^π	$T_{1/2}$	Comments
0.0	9/2$^-$	34.17 s *6*	J^π,$T_{1/2}$: From Adopted Levels.

α radiations

No strong γ transitions belonging to ^{213}Fr were observed by 1973No09. The observed 9650-keV α has been assigned as the transition to the ^{213}Fr g.s. by considering the Q(α) systematics and the known levels in ^{213}Fr.

α angular distribution was measured by 1973No09 following production of ^{217}Ac in the ^{207}Pb(^{14}N,4n) reaction where nuclear alignment is expected to be preserved during its short (69 ns) half-life. The angular distribution was found to be isotropic within 2%, indicating that the 9650α has mainly L=0 component.

Eα	E(level)	Iα‡	HF†	Comments
9650 *10*	0.0	100	1.0 *1*	Eα: from 1973No09 (semi). Others: 9870 keV (1982SaZO), 9300 keV *200* (2019Mi08 − 9.3 MeV *2*).

† Using r_0(^{213}Fr)=1.5460 *27*, unweighted average of r_0(^{212}Rn)=1.5433 *36* and r_0(^{214}Ra)=1.5487 *30* (2020Si16).

‡ Absolute intensity per 100 decays.

^{217}Ac α decay: E=1.15 MeV

Parent: ^{217}Ac: E=1149.1; J^π=15/2$^-$; $T_{1/2}$<10 ns; Q(α)=9832 *10*; %α decay<0.31
^{217}Ac-E: 1985De14 show a doublet parent of 1147 (17/2$^-$) and 1150 (15/2$^-$), which are 1146.6 and 1149.1, respectively, in 2018Ko01 (A=217 evaluation).
^{217}Ac-J^π: From 2018Ko01 (A=217 evaluation).
^{217}Ac-$T_{1/2}$: From 1985De14.
^{217}Ac-Q(α): From 2021Wa16.
^{217}Ac-%α decay: From ≤0.27 *4* in (1985De14).

^{213}Fr Levels

E(level)	J^π	$T_{1/2}$	Comments
0.0	9/2$^-$	34.17 s *6*	J^π,$T_{1/2}$: From Adopted Levels.

α radiations

Eα	E(level)	Iα‡	HF†	Comments
10780 *15*	0.0	100	>8000	Eα: measured by 1985De14. The 9.65 and 10.54 MeV α's from the g.s. and 740-ns isomer of ^{217}Ac were used as calibration energies. Other: 10820 keV (1982SaZO). Iα: α intensity per 100 α decays from the level.

† Using r_0(^{213}Fr)=1.5460 *27*, unweighted average of r_0(^{212}Rn)=1.5433 *36* and r_0(^{214}Ra)=1.5487 *30* (2020Si16).
‡ For absolute intensity per 100 decays, multiply by <0.0031.

^{217}Ac α decay (8 ns)

Parent: ^{217}Ac: E=1498.1 *4*; J^π=19/2$^-$; $T_{1/2}$=8 ns *2*; Q(α)=9832 *10*; %α decay<0.59

^{217}Ac-E: 1985De14 show a doublet parent of 1498 (19/2$^-$) and 1529 (21/2$^-$), which are 1498.1 and 1528.4, respectively, in 2018Ko01 (A=217 evaluation).

^{217}Ac-$T_{1/2}$: From 1973No02. Also quoted in 1985De14.

^{217}Ac-Q(α): From 2021Wa16.

^{217}Ac-%α decay: From ≤0.46 *13* (1985De14).

^{213}Fr Levels

E(level)	J^π	$T_{1/2}$	Comments
0.0	9/2$^-$	34.17 s *6*	J^π,$T_{1/2}$: From Adopted Levels.

α radiations

Eα	E(level)	Iα[‡]	HF[†]	Comments
11137 *15*	0.0	100	<2.7×10^4	Eα: From 1985De14 (peaks at 9.65 and 10.54 MeV, measured by 1973No09 were used as calibration points). Other: 11130 (1973No09). Iα: α intensity per 100 α decays from the level.

† Using r_0(^{213}Fr)=1.5460 *27*, unweighted average of r_0(^{212}Rn)=1.5433 *36* and r_0(^{214}Ra)=1.5487 *30* (2020Si16). Assuming %α branching=0.30 *30* of ^{217}Ac.

‡ For absolute intensity per 100 decays, multiply by <0.0059.

^{217}Ac α decay (740 ns)

Parent: ^{217}Ac: E=2012.2 *7*; J$^{\pi}$=(29/2)$^{+}$; $T_{1/2}$=740 ns *40*; Q(α)=9832 *10*; %α decay=4.51 *18*
^{217}Ac-E,J$^{\pi}$,$T_{1/2}$: From 2018Ko01 (A=217 evaluation).
^{217}Ac-Q(α): From 2021Wa16.
^{217}Ac-%α decay: From 2018Ko01 (A=217 evaluation).

^{213}Fr Levels

E(level)	J$^{\pi}$	$T_{1/2}$	Comments
0.0	9/2^{-}	34.17 s *6*	J$^{\pi}$,$T_{1/2}$: From Adopted Levels.
498	(7/2^{-})		J$^{\pi}$: From dominant I_{α}=11 with respect to I_{α}(10540)=100.
1105	(13/2)$^{+}$		J$^{\pi}$: 1105γ M2 to 9/2^{-} g.s. and I_{α}(10540)=90 *6*.

α radiations

$\alpha(\theta)$: 1985De14, 1973No09.
$(\alpha)(\gamma)$: 1985De14.

Eα	E(level)	Iα[#&]	HF[@]	Comments
10540[†]	1105	90 *6*	1.67×10^{4} *16*	
11137[‡] *15*	498	7.1 *21*	2.50×10^{6} *76*	
11625[‡] *17*	0.0	2.7 *5*	4.21×10^{7} *84*	Eα: Other: 11570 keV (1982SaZO).

[†] Measurement of 1973No09.
[‡] Measurement of 1985De14. Eα=9.650 MeV and Eα=10.54 MeV lines were used as calibration energies.
[#] From 1985De14.
[@] Using r_0(^{213}Fr)=1.5460 *27*, unweighted average of r_0(^{212}Rn)=1.5433 *36* and r_0(^{214}Ra)=1.5487 *30* (2020Si16).
[&] For absolute intensity per 100 decays, multiply by 0.0451 *18*.

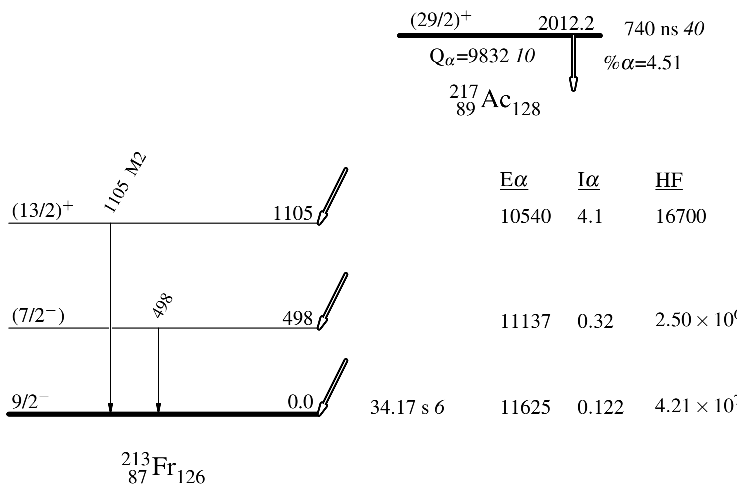
γ(^{213}Fr)

E$_{\gamma}$	E$_i$(level)	J$^{\pi}_i$	E$_f$	J$^{\pi}_f$	Mult.	α[†]	Comments
498	498	(7/2^{-})	0.0	9/2^{-}			
1105	1105	(13/2)$^{+}$	0.0	9/2^{-}	M2	0.0479	Mult.: from ce (1985De14 – quoted from their Ref. 8).

[†] 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.

^{217}Ac α decay (740 ns)

Decay Scheme



(HI,xnγ)

2010Da04: ^{209}Bi(^{9}Be,X), E=44.0, 50.0. 60.0 MeV, − measured fusion cross section.

The decay scheme of levels below E≤2538 keV was constructed by 1971MaXH from their γγ coincidence data, and it was confirmed by 1976Ha37. The main cascade of strongly populated levels above 2538 keV and up to 6573 keV was added by 1979Ho06 from their coincidence data; the levels above 6573-keV and the weakly populated side cascades were built by 1986By01 and 1989By01. Delayed and out-of-beam coincidences were also taken by 1989By01, designed to study the high energy isomeric state. The placements of 1259.1 and 563.3 gammas to feed the 6725-keV level were based on the coincidences observed with the 621.8-keV γ (1991ByZZ). The level scheme shown in 1989By01 is presented here.

2011Ka30: Pt(^{36}S,X), E=5.96 MeV/nucleon and W(^{48}Ca,X), E=5.41 MeV/nucleon − measured differential cross section dσ/dΩ.

^{204}Hg(^{14}N,5nγ)	E=94 MeV, pulsed beam	1974Re09
^{205}Tl(^{12}C,4nγ)	E=71^{-} to 80-MeV pulsed beams	1976Ha37
^{205}Tl(^{13}C,5nγ)	E=72^{-} to 86-MeV pulsed beams	1979Ho06
^{205}Tl(^{12}C,4nγ),	^{205}Tl(^{13}C,5nγ) E=77-96 MeV; and	
^{198}Pt(^{19}F,5nγ)	E=102 MeV, pulsed beam	1986By01
^{205}Tl(^{13}C,5nγ)	E=90 MeV, pulsed beam	1989By01
^{238}U fragmentation at E/A=900 MeV		2006Po01

Other: 1971MaXH.

^{213}Fr Levels

E(level)†	Jπ‡	$T_{1/2}$#	Comments
0.0	9/2−	34.17 s *6*	Configuration: π ($h_{9/2}^{+1}$). $T_{1/2}$: From Adopted Levels.
1188.80 *10*	13/2−	<2.1 ns	Jπ: Configuration: π ($h_{9/2}^{+1}$)⊗2+.
1411.00 *15*	17/2−	18 ns *1*	Configuration: π ($h_{9/2}^{+1}$)⊗4+. $T_{1/2}$: Other: $T_{1/2}$≤60 ns − measured by delayed coincidence method (1976Ha37). g(1411 level)=0.88 *16* (1986By01).
1590.40 *18*	21/2−	505 ns *20*	Configuration: π ($h_{9/2}^{+1}$)⊗6+. %Isomeric production ratio=22 *2* (2013Ba29), E=1 GeV/nucleon, from ^{238}U fragmentation. $T_{1/2}$: Weighted average of 499 ns *21* (1986By01) and 510 ns *20* (1976Ha37). Uncertainty is the lower input value. Other: ≈1 μs (1971MaXH). g(1590 level)=0.888 *3* (1977Be56,1976Ha37); 0.888 *4* (1979Ho06); 0.89 *2* (1986By01).
1856.30 *20*	23/2−	<1.4 ns	Configuration: π ($h_{9/2}^{+2}$,$f_{7/2}^{+1}$).
2537.61 *23*	29/2+	238 ns *6*	Q=−0.70 *7* Q: From 1990By03, deduced using the B(E2) value for the 8+ to 6+ transition in ^{212}Rn and an effective charge of 1.5e. Other: Q=0.81 *4* was obtained by 1990Ha30 by level mixing spectroscopy. Configuration: π ($h_{9/2}^{+2}$,$i_{13/2}^{+1}$). %Isomeric production ratio=23 *2* (2013Ba29), E=1 GeV/nucleon, from ^{238}U fragmentation; and Isomeric population ratio %R_{exp}=12 *8* (2006Po01), E=900 MeV/nucleon. $T_{1/2}$: From 1976Ha37. Others: 243 ns *21* (1986By01) and ≈0.5 μs (1971MaXH). g(2537 level)=1.0494 *18* (1977Be56,1976Ha37), 1.04 *2* (1974Re09), 1.055 *5* (1989By01) by γ(H,θ,t).
2740.2 *3*	27/2−	<7 ns	Configuration: π ($h_{9/2}^{+2}$,$f_{7/2}^{+1}$)⊗2+.
2950.5 *3*	31/2−	<2.1 ns	Configuration: π ($h_{9/2}^{+2}$,$f_{7/2}^{+1}$)⊗4+.
3427.34 *24*	33/2+	<2.1 ns	Configuration: π ($h_{9/2}^{+2}$,$i_{13/2}^{+1}$)⊗2+.
3489.2 *4*	33/2		
3655.4 *4*	37/2+	2.4 ns *7*	Configuration: π ($h_{9/2}^{+2}$,$i_{13/2}^{+1}$)⊗4+. $T_{1/2}$: Other: 4.1 ns (1979Ho06).
4029.2 *5*			
4082.9 *4*	39/2+	<1.4 ns	
4653.6? *11*			
4675.4 *4*		<2.1 ns	
4695.9 *4*	39/2−	<2.1 ns	
4898.5 *4*	41/2−	<2.8 ns	

Continued on next page (footnotes at end of table)

(HI,xnγ) (continued)

^{213}Fr Levels (continued)

E(level)†	Jπ‡	$T_{1/2}$#	Comments
4982.0 *6*			
4992.7 *4*	45/2−	13 ns *2*	μ=23.2 *7* Jπ: 909.8γ E3 to 39/2+ state, 94.4γ E2 to 41/2− state. g(4993 level)=0.990 *25* (1979Ho06), 1.03 *3* (1986By01) by γ(H,θ,t). Configuration: π $(h^{+3}_{9/2},i^{+2}_{13/2})$. $T_{1/2}$: Other: 13.5 ns (1979Ho06). μ: From 1986By01 (time-differential perturbed angular distribution (TDPAD) measurements).
5001.9 *5*			
5220.2 *5*			
5506.3 *4*	43/2−	<2.1 ns	
5785.9 *4*	47/2−	<1.4 ns	
5814.8 *5*	(45/2+)		
5951.5 *5*			
6102.7 *6*	49/2−		
6334.1 *5*			
6572.9 *4*	49/2+	<2.1 ns	$T_{1/2}$: Other: 7 ns (1979Ho06).
6715.3 *5*	53/2+	6.2 ns *14*	Configuration: π $([h^{+4}_{9/2},i^{+1}_{13/2}]_{37/2^+})$ ν $([p^{-1}_{1/2},j^{+1}_{15/2}]_{8^+})$.
6724.5 *7*	55/2+		Jπ: Assignment based on 9.2γ M1 to 53/2+ state (1989By01). $T_{1/2}$: The half-life 6.2 ns *14* was determined by 1989By01 from the 142- and 929-keV γ's deexciting the 6715-keV level. Since the 621.8γ was observed in coincidence with the 1259.1γ (from 7983.6) and 563.3γ (from 7288.0), $T_{1/2}$(6724-keV level) is short. The same half-life of 6.2 ns *14* was assigned to both 6715- and 6724-keV levels.
6803.0 *8*	(55/2)		Jπ: From Adopted Levels.
6812.8 *6*			
7135.0 *8*			
7247.5 *8*			
7288.0 *7*	57/2+	<2.1 ns	
7374.4 *8*	(57/2,59/2)		E(level): From Adopted Levels.
7541.8 *7*	(57/2)		E(level): From Adopted Levels.
7723.7 *7*	59/2+		Configuration: π $([h^{+3}_{9/2},i^{+1}_{13/2},f_{7/2}]_{39/2^+})$ ν $([p^{-2}_{1/2},g_{9/2},i_{11/2}]_{10^+})$.
7983.6 *7*	61/2−	<3.5 ns	Jπ: 1259γ E3 to 55/2+ state. Possible configuration: π$([h^{+3}_{9/2},i^{+2}_{13/2}]_{45/2^-})$ ν $([p^{-1}_{1/2},j^{+1}_{15/2}]_{8^+})$. $T_{1/2}$: From 1989By01.
8094.9 *7*	65/2−	3.1 μs *2*	μ=22.5 *2*; Q=−2.19 *53* Configuration: π $([h^{+3}_{9/2},i^{+2}_{13/2}]_{45/2^-})$ ν $([p^{-2}_{1/2},g_{9/2},i_{11/2}]_{10^+})$. μ: From 1989By01 (time-differential perturbed angular distribution (TDPAD) measurements). Q: From 1991Ha02, relative to Q(29/2+ state)=−0.70 *7*. In 1990Ha30, Q=2.51 *51* was obtained by level mixing spectroscopy, a g-factor of 0.695 *7* was used.

† Deduced by the evaluator from a least squares fit to the γ-ray energies. Eγ related to uncertain placement and expected ones were ignored.

‡ From 1989By01. The assignments were based on the γ-ray transition multipolarities, determined by the γ-ray angular distributions and conversion electron, linear polarization measurements of 1979Ho06, transition strengths, and shell states in neighboring nuclei.

Obtained by 1986By01 from pulsed-beam, chopped-beam, γγ(t) and n,γ(t) measurements, unless otherwise noted.

γ(^{213}Fr)

E_γ [†]	I_γ [a]	E_i(level)	J_i^π	E_f	J_f^π	Mult. [b]	α [c]	Comments
(9.2[#])		6724.5	55/2+	6715.3	53/2+	M1	778 *11*	Mult.: α(exp)(M1)=828.1. Other multipolarities were ruled out by 1989By01 by considering the transition strength limits deduced from the measured $T_{1/2}$=6.2 ns which was assigned also to the 6724-keV level. 0.21 *4*<Iγ<0.51 *6* from intensity balance at the 6724-keV and 6715-keV levels, assuming that the 9.2-keV transition is M1 and the 621.8γ is an E3 transition. An assumption of E1 multipolarity and the intensity balance would yield 10<Iγ<24 and 0.002<B(E1)(W.u.)<0.005.
(42.3[#])		4695.9	39/2−	4653.6?				
[x]60.3[@] *3*								
(78.4[#])		6803.0	(55/2)	6724.5	55/2+			
(86.3[#])		7374.4	(57/2,59/2)	7288.0	57/2+			
94.4 *3*	4 *1*	4992.7	45/2−	4898.5	41/2−	E2	11.49 *24*	A_2=+0.09 *26* (1986By01) I_γ: from Iγ(94.4γ)/Iγ(909.7γ)=4 *1*/117 *2*, measured by 1986By01. Iγ(94.4γ) was not listed by 1991ByZZ.
111.3 *2*	80.0 *24*	8094.9	65/2−	7983.6	61/2−	E2	5.66 *9*	A_2=+0.17 *13* or +0.35 *15* (1986By01 – contaminant peaks were comparable > 1/3). Mult.: From α(exp)=6.2 *3*, determined from the delayed intensity data (1989By01).
(112.2[#])		7247.5		7135.0				
127.2 *4*	11.6 *22*	7374.4	(57/2,59/2)	7247.5				
142.3 *3*	93 *12*	6715.3	53/2+	6572.9	49/2+	E2	2.027 *33*	A_2=+0.04 *10* or +0.22 *7* and A_4=−0.16 *14* or −0.20 *10* (1986By01 – contaminant peaks were comparable > 1/3). Mult.: From total α<40, from intensity balance in 1986By01.
179.4 *1*	538 *24*	1590.40	21/2−	1411.00	17/2−	E2	0.823 *12*	A_2=+0.73 *8* or +0.16 *1* and A_4=−0.01 *1* or +0.00 *3* (1986By01 – contaminant peaks were comparable > 1/3). Mult.: From total α=0.83 *18*, deduced from delayed intensity measurement (1986By01).
182.0 *3*	42 *8*	7723.7	59/2+	7541.8	(57/2)	D		A_2=−0.007 *272* or −0.23 *20* (1986By01 – contaminant peaks were comparable > 1/3). The angular distribution suggests a dipole character for the 182.5γ. α(E1)=0.1106, α(M1)=2.616.
202.8[d] *4*		2740.2	27/2−	2537.61	29/2+			
210.4 *3*	<43	2950.5	31/2−	2740.2	27/2−	(E2)	0.462 *7*	A_2=+0.29 *79*; A_4=−0.05 *11* (1986By01) Iγ<38 *5* (1991ByZZ).
222.2 *1*	694 *30*	1411.00	17/2−	1188.80	13/2−	E2	0.382 *5*	A_2=+0.08 *1* or +0.17 *2* and A_4=+0.00 *2* or −0.01 *2* (1986By01). Mult.: From α(L)exp=0.16 *6*, α(M)exp=0.048 *20* (1986By01).
(227.5[#])		5220.2		4992.7	45/2−			
228.1 *2*	425 *26*	3655.4	37/2+	3427.34	33/2+	E2	0.349 *5*	A_2=+0.293 *14*; A_4=−0.091 *19* (1979Ho06) Mult.: From α(L)exp=0.12 *5*, α(M)exp=0.067 *23* (1986By01), pol=0.81 *45* (1979Ho06). A_2=+0.22 *3* or +0.26 *6* and A_4=−0.02 *4* or −0.09 *8* (1986By01).

$^{213}_{87}$Fr$_{126}$-14

$\gamma(^{213}$Fr) (continued)

E_γ[†]	I_γ[a]	E_i(level)	J^π_i	E_f	J^π_f	Mult.[b]	δ	α[c]	Comments
238[&]		5220.2		4982.0					
239.0 *4*	19 *9*	6572.9	49/2+	6334.1					
253.6 *4*	131 *9*	7541.8	(57/2)	7288.0	57/2+				
265.9 *1*	283 *13*	1856.30	23/2−	1590.40	21/2−	M1+E2	0.9 +*11*−*9*	0.60 *31*	A_2=−0.11 *1* or −0.09 *2* and A_4=+0.03 *1* or +0.01 *3*. Mult.: From total α=0.76 *18* (1986By01).
279.6 *2*	117 *11*	5785.9	47/2−	5506.3	43/2−	E2		0.1797 *25*	A_2=+0.19 *2* or +0.23 *4* and A_4=−0.03 *3* or +0.01 *7* (1986By01 − contaminant peaks were comparable > 1/3). Mult.: From α(K)exp=0.06 *4* (1986By01).
294.1 *3*	17 *4*	7541.8	(57/2)	7247.5					
306.5 *4*	15.4 *24*	4982.0		4675.4					α(E1)=0.0326, α(M1)=0.614, α(E2)=0.136.
308.3[‡] *3*	18 *6*	5814.8	(45/2+)	5506.3	43/2−	(E1)		0.0322 *5*	A_2=−0.24 *17*; A_4=−0.08 *23* (1986By01)
316.8 *4*	24 *4*	6102.7	49/2−	5785.9	47/2−	(M1+E2)		0.34 *22*	A_2=−0.78 *3*, A_4=+0.06 *4* or A_2=−0.81 *11* (1986By01). Mult.: the measured large A_2 value indicated some quadrupole admixture. Authors′ earlier assignment of E1 (1986By01) from conversion electron measurement has been withdrawn (1991ByZZ). Since the ce(K 317γ) line was contaminated by the ce(M 222γ), the angular distribution measurements were more reliable for determination of its multipolarity. E1+M2 with any significant amount of M2 admixture is ruled out because of short half-life of the 6102-keV level.
322.2 *5*	13 *4*	7135.0		6812.8					
326.3 *4*	16 *5*	5001.9		4675.4		(D)		0.0283	A_2=−0.11 *4*, A_4=−0.02 *6* or A_2=−0.09 *10* (1986By01 − contaminant peaks were comparable > 1/3). α: for E1, as implied by the intensity balance at the 4675-keV level. α(M1)=0.517. The angular distribution is consistent with a dipole transition.
349.5[‡] *3*	75 *4*	7723.7	59/2+	7374.4	(57/2,59/2)	D			A_2=−0.41 *3*; A_4=−0.05 *5* (1986By01) Mult.: No ce line was listed for this transition. It is assumed that ce lines were weak, suggesting E1 or E2 multipolarity. The angular distribution coefficient listed is in agreement with a dipole character. α(E1)=0.0243.
371.2[‡] *2*	125 *10*	8094.9	65/2−	7723.7	59/2+	E3		0.372 *5*	A_2=+0.03 *6*; A_4=+0.04 *8* (1986By01) Mult.: α(exp)=0.35 *7*, deduced by 1989By01 (method was not discussed), and E3 multipolarity was assigned. Although α(exp) is also consistent with an M1 transition [α(M1)=0.3638], if its placement is correct, $T_{1/2}$(8094 level) suggests E3 multipolarity.
382.7[‡] *3*	27 *3*	6334.1		5951.5					A_2=+0.13 *6*; A_4=+0.05 *8* (1986By01) Mult.: α(K)exp=0.20 *7* and M1/E2 in 1986By01 but different placement in 1986By01 compared to that in 1989By01.

$^{213}_{87}Fr_{126}$-15

(HI,xnγ) (continued)

γ(^{213}Fr) (continued)

E_γ[†]	I_γ[a]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[b]	δ	α[c]	Comments
413.0 *2*	129 *3*	2950.5	31/2⁻	2537.61	29/2⁺	E1		0.01695 *24*	A_2=−0.222 *24*; A_4=+0.034 *34* (1979Ho06) A_2=−0.16 *3*; A_4=+0.08 *5* (1986By01) Mult.: From α(K)exp=0.047 *24* (1986By01), pol=0.36 *12* (1979Ho06).
427.5 *1*	255 *11*	4082.9	39/2⁺	3655.4	37/2⁺	M1+E2	0.10 *3*	0.246 *4*	A_2=−0.424 *13*; A_4=+0.023 *19* (1979Ho06) A_2=−0.32 *2*; A_4=+0.01 *2* (1986By01) Mult.: From α(K)exp=0.28 *7*, α(L)exp=0.051 *15*, α(M)exp=0.018 (5) (1986By01), pol=−0.32 *8* (1979Ho06).
435.6 *4*	8.4 *20*	7723.7	59/2⁺	7288.0	57/2⁺				
469.7[d] *4*		6572.9	49/2⁺	6102.7	49/2⁻				E_γ: from 1986By01; transition was not listed by 1991ByZZ.
476.9 *2*	137 *6*	3427.34	33/2⁺	2950.5	31/2⁻	E1		0.01255 *18*	A_2=−0.257 *20*; A_4=+0.059 *29* (1979Ho06) A_2=−0.21 *2*; A_4=+0.05 *2* (1986By01) Mult.: α(K)exp<0.047 (1986By01), pol=0.25 *12* (1979Ho06).
478.7 *3*	25 *4*	6812.8		6334.1					
538.7 *3*	27.8 *10*	3489.2	33/2	2950.5	31/2⁻	(D)			A_2=−0.47 *6* (1986By01) α(E1)=0.00981, α(M1)=0.1337, α(E2)=0.0310.
540.0 *3*	17.2 *10*	4029.2		3489.2	33/2				
545.1 *5*	<76	5220.2		4675.4					
563.3 *3*	136 *6*	7288.0	57/2⁺	6724.5	55/2⁺	M1		0.1187 *17*	A_2=−0.47 *6*; A_4=+0.23 *10* (1986By01)
592.5 *3*	33 *7*	4675.4		4082.9	39/2⁺				A_2=−0.53 *4* (1986By01) The angular distribution is consistent with a dipole transition; the intensity balance at the 4675-keV level is worse if it is an E1 transition. α(E1)=0.00812, α(M1)=0.1038.
594.7 *4*	30 *6*	5814.8	(45/2⁺)	5220.2					
621.8 *3*	18 *6*	6724.5	55/2⁺	6102.7	49/2⁻	[E3]		0.0681 *10*	A_2=+0.19 *14* (1986By01)
624.2[@d] *5*		4653.6?		4029.2					
665[&d]		4695.9	39/2⁻	4029.2					
681.3 *1*	439 *15*	2537.61	29/2⁺	1856.30	23/2⁻	E3		0.0529 *7*	A_2=+0.20 *1*; A_4=+0.02 *1* (1986By01) Mult.: α(K)exp=0.046 *5*, α(L)exp=0.018 *2*, and α(M)exp=0.007 *1* (1986By01).
695[&]		7983.6	61/2⁻	7288.0	57/2⁺				
738.8[‡] *3*	16.8 *20*	7541.8	(57/2)	6803.0	(55/2)	D			A_2=−0.33 *10* (1986By01) Mult.: The angular distribution is consistent with dipole character for this transition. α(E1)=0.00532, α(M1)=0.0580.
758.0[‡] *4*	34 *7*	6572.9	49/2⁺	5814.8	(45/2⁺)				A_2=+0.26 *15*; A_4=−0.15 *21* (1986By01)
784.0 *4*	6 *2*	5785.9	47/2⁻	5001.9					
786.9 *1*	214 *20*	6572.9	49/2⁺	5785.9	47/2⁻	E1		0.00473 *7*	A_2=−0.292 *53*; A_4=+0.020 *82* (1979Ho06) A_2=−0.21 *2*; A_4=+0.02 *3* (1986By01) Mult.: From α(K)exp=0.007 *2* (1986By01).
793.2 *3*	254 *40*	5785.9	47/2⁻	4992.7	45/2⁻	M1		0.0481	A_2=−0.212 *78*; A_4=+0.048 *120* (1979Ho06) A_2=−0.067 *15*; A_4=+0.04 *2* (1986By01) Mult.,δ: α(K)exp=0.041 *7*, α(L)exp=0.0097 *10* (1986By01),

(HI,xnγ) (continued)

γ(^{213}Fr) (continued)

E_γ[†]	I_γ[a]	E_i(level)	J^π_i	E_f	J^π_f	Mult.[b]	α[c]	Comments
								pol=−0.52 *36* (1979Ho06). δ=0.00 *19* using the α(K)exp and α(L)exp data.
810.2 *3*	144 *8*	5506.3	43/2⁻	4695.9	39/2⁻	E2	0.01293 *18*	A_2=+0.23 *2*; A_4=+0.03 *4* (1986By01) Mult.: α(K)exp=0.0065 *35* (1986By01).
815.6 *2*	157 *9*	4898.5	41/2⁻	4082.9	39/2⁺	E1	0.00443 *6*	A_2=−0.229 *18*; A_4=+0.002 *26* (1979Ho06) A_2=−0.24 *2*; A_4=+0.09 *3* (1986By01) Mult.: From α(K)exp=0.006 *3* (1986By01), pol=0.35 *15* (1979Ho06).
817.7 *3*	20 *6*	7541.8	(57/2)	6724.5	55/2⁺			
884.0 *3*	31 *5*	2740.2	27/2⁻	1856.30	23/2⁻	E2	0.01087 *15*	A_2=+0.22 *6* (1986By01) Mult.: From α(K)exp=0.015 *6* (1986By01).
889.7 *1*	300 *12*	3427.34	33/2⁺	2537.61	29/2⁺	E2	0.01073 *15*	A_2=0.311 *18*; A_4=−0.085 *29* (1979Ho06) A_2=+0.24 *1*; A_4=−0.02 *2* (1986By01) Mult.: From α(K)exp=0.011 *2*, α(L)exp=0.002 *1* (1986By01), pol=0.53 *14* (1979Ho06).
909.8 *2*	116 *9*	4992.7	45/2⁻	4082.9	39/2⁺	E3	0.0255 *4*	A_2=0.538 *37*; A_4=+0.038 *51* (1979Ho06) A_2=+0.43 *3*; A_4=+0.06 *4* (1986By01) Mult.: From α(K)exp=0.023 *3*, α(L)exp=0.006 *1* (1986By01), pol=0.88 *22* (1979Ho06).
929.5 *3*	132 *26*	6715.3	53/2⁺	5785.9	47/2⁻	E3	0.02428 *34*	A_2=+0.46 *3*; A_4=+0.03 *5* (1986By01) Mult.: From α(K)exp=0.014 *8*, α(L)exp=0.0045 *15* (1986By01).
949.4[‡] *3*	10 *4*	5951.5		5001.9				A_2=−0.03 *13* (1986By01)
959.0[‡] *3*	11 *3*	5951.5		4992.7	45/2⁻			A_2=+0.23 *14* (1986By01)
[x]963.4[@] *5*								
998.9 *3*	12 *4*	7723.7	59/2⁺	6724.5	55/2⁺			
1040.3 *3*	111 *11*	4695.9	39/2⁻	3655.4	37/2⁺	E1	0.00286 *4*	A_2=−0.27 *3*; A_4=+0.04 *4* (1986By01) Mult.: From α(K)exp=0.0017 *6* (1986By01).
1188.8 *1*	1000 *40*	1188.80	13/2⁻	0.0	9/2⁻	E2	0.00616 *9*	A_2=+0.041 *6*; A_4=−0.01 *1* (1986By01) Mult.: From α(K)exp=0.0053 *6*, α(L)exp=0.00097 *10* (1986By01).
1259.1 *3*	254 *12*	7983.6	61/2⁻	6724.5	55/2⁺	E3	0.01229 *17*	A_2=+0.15 *4*; A_4=+0.00 *6* (1986By01) Mult.: From α(K)exp=0.010 *2* (1986By01).

[†] From 1991ByZZ, except where otherwise noted. See also 1989By01, 1986By01, 1976Ha37, 1977Be56. Other measurements: 1971MaXH, 1974Re09.

[‡] Eγ placement from 1989By01.

[#] Transition was not observed; energy from decay scheme.

[@] From 1986By01, not listed by 1991ByZZ.

[&] From level scheme shown in 1989By01; transition was not listed by 1991ByZZ and 1986By01.

[a] Relative photon intensities, measured by 1991ByZZ in a time window 2-9 microseconds after the beam burst. Therefore, these Iγ's represent relative feedings through the 4.5−μs isomer at 8095 keV. See also 1986By01.

[b] From conversion electron measurements and angular distribution of the γ-ray (1986By01), except otherwise noted.

$^{213}_{87}Fr_{126}$-17

(HI,xnγ) (continued)

γ(^{213}Fr) (continued)

[c] 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.
[d] Placement of transition in the level scheme is uncertain.
[x] γ ray not placed in level scheme.

$^{213}_{87}Fr_{126}$-18

Adopted Levels, Gammas

Q(β^-)=−5795 *15*; S(n)=7527 *14*; S(p)=3427 *13*; Q(α)=6861.7 *23* 2021Wa16

2011Ka30: Pt(^{36}S,X), E=5.96 MeV/nucleon and W(^{48}Ca,X), E=5.41 MeV/nucleon − measured differential cross section dσ/dΩ.

2002Mi20: Measured evaporation residue production cross section of ^{213}Ra, bombarding ^{154}Sm target with ^{64}Ni beam, E=4-5 MeV/nucleon.

2009Ga07: Measured production cross section of ^{213}Ra in the ^{209}Bi(^{10}B,X) reaction, E(cm)=52-72 MeV.

^{213}Ra Levels

Cross Reference (XREF) Flags

- A ^{217}Th α decay
- B ^{213}Ra IT decay (2.18 ms)
- C ^{204}Pb(^{13}C,4nγ)

E(level)†	J$^\pi$‡	T$_{1/2}$	XREF	Comments
0.0	1/2$^-$	2.73 min *5*	ABC	%α=86 *2*; %ε+%β^+=14 *2* μ=+0.610 *2* T$_{1/2}$: Weighted average of 2.74 min *6* (1968Lo15), 2.75 min *15* (1967Va22), 2.7 min *3* (1955Mo68), and 2.54 min *+21−18* (9247α(t)) (2000Ni02 − also reported 2.7 min *+21−8* (8713α(t)) and 2.5 min *+12−6* (8429α(t)). Other: 2.72 min (1961Gr42). All from ^{213}Ra α decay measurements. J$^\pi$: spin measured (hyperfine structure by LASER spectroscopy, 1983Ah03). Configuration: ν (p$^{-1}_{1/2}$) from measured μ. μ: From 2019StZV, 1987Ar20 − Larmor precession, optical pumping by LASER. Others: 0.62 *3* (1983Ah03), 0.592 *11* (1987We03). %α: Weighted average of 87 *2* (2017Lo13) and 80 *5* (1967Va22); %ε+%β = 100 − %α.
546.35 *5*	(5/2$^-$)	21.5 ps *28*	ABC	J$^\pi$: 546.35γ (E2) to 1/2$^-$ g.s.; probable configuration: ν (f$^{-1}_{5/2}$). T$_{1/2}$: From τ=31 ps *4* (2021Ge07 − (^{13}C,4nγ)), from γ gated time difference measurements by Generalised Centroid Difference method.
820 *6*	(3/2$^-$)		A	E(level): Level energy calculated by the evaluator using Q(α) (^{217}Th) and Eα feeding this level. J$^\pi$: From systematics of ^{211}Rn isotone.
1608.85 *21*	(9/2$^-$)		BC	J$^\pi$: 1062.5γ (E2) to 5/2$^-$ state. Systematics of 9/2$^-$ levels in nuclei with 125 neutrons (see 1976Ra37).
1769.72 *22*	(13/2$^-$)		BC	J$^\pi$: 160.87γ to (9/2$^-$) state is predominantly E2; no γ to the (5/2$^-$) state. Please see ^{213}Ra IT decay (2.18 ms) dataset.
1770 *5*	(17/2$^-$)	2.18 ms *5*	BC	%α=0.6 *4*; %IT=99.4 *4* μ=7.4 *4* E(level): From ^{213}Ra IT decay (2.18 ms). J$^\pi$: Measured g=0.87 *5* (1994Ne01) value supports the configuration: π ([h$^{+2}_{9/2}$]$_{8+}$)$\otimes\nu$ (p$^{-1}_{1/2}$) for which the calculated magnetic moment, 7.672 *33*, is in good agreement with the measured g value (1994Ne01). T$_{1/2}$: From IT decay. μ: From 2019StZV, 1994Ne01 − Level Mixing Spectroscopy (LEMS). %α: From 2006Ku26. Other: 0.6 in 1976Ra37 (also ≈1) − both in the ^{213}Ra IT decay (2.18 ms) dataset. %IT = 100 − %α.
2287.50 *10*	(21/2$^-$)		C	Configuration: π(h$^6_{9/2}$)$_{8+}\otimes\nu$f$^{-1}_{5/2}$.
2609.90 *15*	(23/2$^+$)	18.7 ns *21*	C	Configuration: π[(h$^5_{9/2}$)$_{9/2}$i$_{13/2}$]$_{11-}\otimes\nu$p$^{-1}_{1/2}$. T$_{1/2}$: From (455γ+731γ)(322γ)(Δt) measurements (^{13}C,4nγ) − 2018Pa04).
3065.3 *4*	(25/2$^+$)		C	Configuration: π[(h$^5_{9/2}$)$_{9/2}$i$_{13/2}$]$_{10-}\otimes\nu$f$^{-1}_{5/2}$.
3136.6 *3*	(25/2$^-$)		C	Configuration: π(h$^6_{9/2}$)$_{12+}\otimes\nu$p$^{-1}_{1/2}$.
3281.1 *5*	(25/2$^-$)		C	Configuration: π[(h$^5_{9/2}$)$_{17/2}$f$_{7/2}$]$_{12+}\otimes\nu$p$^{-1}_{1/2}$.
3340.4 *4*	(27/2$^+$)		C	Configuration: π[(h$^5_{9/2}$)$_{9/2}$i$_{13/2}$]$_{11-}\otimes\nu$f$^{-1}_{5/2}$.

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued)

^{213}Ra Levels (continued)

E(level)[†]	J^{π}[‡]	$T_{1/2}$	XREF	Comments
3345.60 *22*	(25/2⁻)		C	Configuration: $\pi(h^6_{9/2})_{10+}\otimes\nu f^{-1}_{5/2}$.
3433.2 *3*	(27/2⁻)		C	Configuration: $\pi[(h^5_{9/2})_{21/2}f_{7/2}]_{13+}\otimes\nu p^{-1}_{1/2}$.
3441.4 *5*	(29/2⁻)		C	Configuration: $\pi[(h^5_{9/2})_{21/2}f_{7/2}]_{14+}\otimes\nu p^{-1}_{1/2}$.
3863.8 *11*	(27/2⁺)		C	Configuration: $\pi[(h^5_{9/2})_{13/2}i_{13/2}]_{13-}\otimes\nu p^{-1}_{1/2}$.
3878.0 *7*	(29/2⁺)		C	Configuration: $\pi[(h^5_{9/2})_{17/2}i_{13/2}]_{14-}\otimes\nu p^{-1}_{1/2}$.
4006.9 *5*	(31/2⁺)		C	Configuration: $\pi[(h^5_{9/2})_{17/2}i_{13/2}]_{15-}\otimes\nu p^{-1}_{1/2}$.
4047.7 *7*	(33/2⁺)	34.7 ns *21*	C	Configuration: $\pi[(h^5_{9/2})_{21/2}i_{13/2}]_{16-}\otimes\nu p^{-1}_{1/2}$. $T_{1/2}$: From (455γ+731γ)(322γ)(Δt) measurements ((^{13}C,4nγ) − 2018Pa04). Lifetime measured by (beam pulse)(566γ and 667γ)(t) showed no difference.
4047.7+x?	(35/2⁺)		C	
4506.2+x?	(37/2⁺)		C	

† Deduced by the evaluator from a least square fit to the γ-ray energies, except where otherwise noted.
‡ Above 1770 level, spin-parity assignments are from (^{13}C,4nγ) − 2018Pa04, based on proposed γ multipolarity from measured γ(θ) data and deduced total conversion coefficients.

γ(^{213}Ra)

E_i(level)	J^{π}_i	E_γ[†]	I_γ[†]	E_f	J^{π}_f	Mult.[†]	δ[†]	α[@]	Comments
546.35	(5/2⁻)	546.35[‡] *5*	100[‡]	0.0	1/2⁻	(E2)[‡]		0.0315 *4*	B(E2)(W.u.)=6.9 +*11*−*8*
1608.85	(9/2⁻)	1062.5[‡] *2*	100[‡]	546.35	(5/2⁻)	(E2)[‡]		0.00802 *11*	
1769.72	(13/2⁻)	160.87[‡] *5*	100[‡]	1608.85	(9/2⁻)	E2[‡]		1.328 *19*	
2287.50	(21/2⁻)	517.5 *1*	100	1770	(17/2⁻)	Q[#]			
2609.90	(23/2⁺)	322.4 *1*	100	2287.50	(21/2⁻)	(E1)		0.0299 *4*	α(exp)=0.11 *5* (2018Pa04) B(E1)(W.u.)=2.94×10⁻⁷ +*36*−*31*
3065.3	(25/2⁺)	455.4 *4*	100	2609.90	(23/2⁺)	D+Q[#]			
3136.6	(25/2⁻)	849.1 *3*	100	2287.50	(21/2⁻)	Q[#]			
3281.1	(25/2⁻)	993.6 *7*	100	2287.50	(21/2⁻)	Q[#]			
3340.4	(27/2⁺)	275.0 *4*	72 *3*	3065.3	(25/2⁺)	M1+E2	0.64 *2*	0.697 *14*	α(exp)=0.99 *8* (2018Pa04); A_2=−0.41 *16*
		730.5 *5*	100 *5*	2609.90	(23/2⁺)	Q[#]			
3345.60	(25/2⁻)	1058.1 *2*	100	2287.50	(21/2⁻)	Q[#]			
3433.2	(27/2⁻)	87.6 *4*		3345.60	(25/2⁻)				
		152.1 *5*	18.7 *16*	3281.1	(25/2⁻)	M1+E2	0.7 *3*	3.7 *6*	α(exp)=3.7 *5* (2018Pa04)
		296.6 *2*	100.0 *24*	3136.6	(25/2⁻)	M1		0.732 *10*	α(exp)=0.96 *9* (2018Pa04)
3441.4	(29/2⁻)	304.8 *8*	100	3136.6	(25/2⁻)				
3863.8	(27/2⁺)	798.5 *10*	100	3065.3	(25/2⁺)				
3878.0	(29/2⁺)	436.7 *8*	100 *8*	3441.4	(29/2⁻)				
		537.8 *11*	83 *8*	3340.4	(27/2⁺)	D[#]			
4006.9	(31/2⁺)	565.5 *2*	100.0 *17*	3441.4	(29/2⁻)	D[#]			
		666.5 *4*	24.4 *10*	3340.4	(27/2⁺)	Q[#]			
4047.7	(33/2⁺)	169.7 *3*	82 *4*	3878.0	(29/2⁺)	E2		1.079 *17*	α(exp)=1.3 *2* (2018Pa04) B(E2)(W.u.)=0.422 +*31*−*28*
		606.3 *5*	100 *6*	3441.4	(29/2⁻)	[M2]		0.277 *4*	B(M2)(W.u.)=0.103 *8*
4047.7+x?	(35/2⁺)	y[&]		4047.7	(33/2⁺)				
4506.2+x?	(37/2⁺)	458.7[&] *6*		4047.7+x?	(35/2⁺)				

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued)

$\gamma(^{213}Ra)$ (continued)

† From (^{13}C,4nγ), except where otherwise noted.

‡ From ^{213}Ra IT decay (2.18 ms).

In 2018Pa04 (^{13}C,4nγ) based on $\gamma(\theta)$ data M1, E1, E2, and M1+E2 were assigned, evaluator list those as D, Q, D+Q.

@ 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.

^{213}Ra IT decay (2.18 ms) 1976Ra37,1994Ne01,2006Ku26

Parent: ^{213}Ra: E=1770 *5*; J$^{\pi}$=(17/2^{-}); $T_{1/2}$=2.18 ms *5*; %IT decay=99.4 *4*

Others: 2004He25, 1993Ne04.

1976Ra37: The decay scheme is given as constructed by 1976Ra37. Measured $\gamma\gamma$ coin.

1994Ne01: Measured g factor for the 17/2^{-} isomeric state using an indirect method that is the ratio of Korringa constant for two isomers is proportional to the inverse ratio of the respective g factors.

2006Ku26: ^{213}Ra isotope produced by ^{48}Ca(^{170}Er,5n), E=4.25, 4.30 MeV/nucleon, and ^{50}Ti(^{170}Er,X), 4.35 MeV/nucleon, reactions. Evaporation residues were separated in-flight with the velocity filter SHIP. Measured Eγ, Iγ, $\gamma\gamma$, ce, lifetimes using a 16-strip PIPS detector and a Ge-Clover detector placed behind the pips.

2004He25: ^{208}Pb(^{12}C,7n), E=68-136 MeV; measured prompt and delayed Eγ, Iγ, $\gamma\gamma$-coin, (recoil)γ-coin; Deduced levels, spin, parity, half-life.

1993Ne04: Determined the static-quadrupole-interaction frequency of the 17/2^{-} isomeric state using level-mixing-spectroscopy (LEMS).

2004He25: Measured half-life of the (17/2^{-}) isomeric state.

x-rays: 1976Ra37

E(x ray)	Iγ(relative)		
85.4	4.2 *3*	Kα_2	x ray
88.5	6.2 *4*	Kα_1	x ray
100.0	2.1 *3*	Kβ_1′	x ray
103.0	0.7 *2*	Kβ_2′	x ray

^{213}Ra Levels

E(level)†	J$^{\pi}$	$T_{1/2}$	Comments
0.0	1/2^{-}	2.73 min *5*	J$^{\pi}$,$T_{1/2}$: From Adopted Levels.
546.35 *5*	(5/2^{-})	21.5 ps *28*	$T_{1/2}$: From Adopted Levels. J$^{\pi}$: 546.35γ E2 to 1/2^{-} state.
1608.85 *21*	(9/2^{-})		J$^{\pi}$: 1062.5γ (E2) to (5/2^{-}) state.
1769.72 *22*	(13/2^{-})		J$^{\pi}$: 160.8γ E2 to (9/2^{-}) state requires (13/2^{-}), in 1976Ra37 *J*$^{\pi}$ is given as (13/2^{-},11/2^{-}).
1770 *5*	(17/2^{-})	2.18 ms *5*	%α=0.6 *4* E(level): From 1770 +*5*−*1* (2006Ku26). Others: ≈1770 (1976Ra37), 1769 *7* can be deduced considering Eα=8467 *5* and Eα=6731 *5* (1976Ra37) from the isomeric level and g.s. ^{213}Ra α decay, respectively, to the g.s. of ^{209}Rn. J$^{\pi}$: Measured g=0.87 *5* (1994Ne01) value supports the configuration $[(\pi 1h^2_{9/2})_{8+}\otimes(\nu 3p^{-1}_{1/2})]_{17/2-}$ for which the calculated magnetic moment, 7.672 *33*, is in good agreement with the measured g value (1994Ne01). $T_{1/2}$: Weighted average of 2.1 ms *1* (1976Ra37), 2.20 ms *5* (2006Ku26), and 2.2 ms *1* (545.4γ) (2004He25) – uncertainty is the lowest input value. 2004He25 also reported two more values of 2.1 ms *1* (1061.2γ) and 2.1 ms *1* (160.4γ). All three values determined by 2004He25 from the decrease of γ-ray intensities within the 14.6 ms pause between two consecutive beam bursts. %α: 0.6 *4* (2006Ku26) and 0.6 (1976Ra37 – also ≈1).

† From Eγ, except where otherwise noted.

^{213}Ra IT decay (2.18 ms) 1976Ra37,1994Ne01,2006Ku26 (continued)

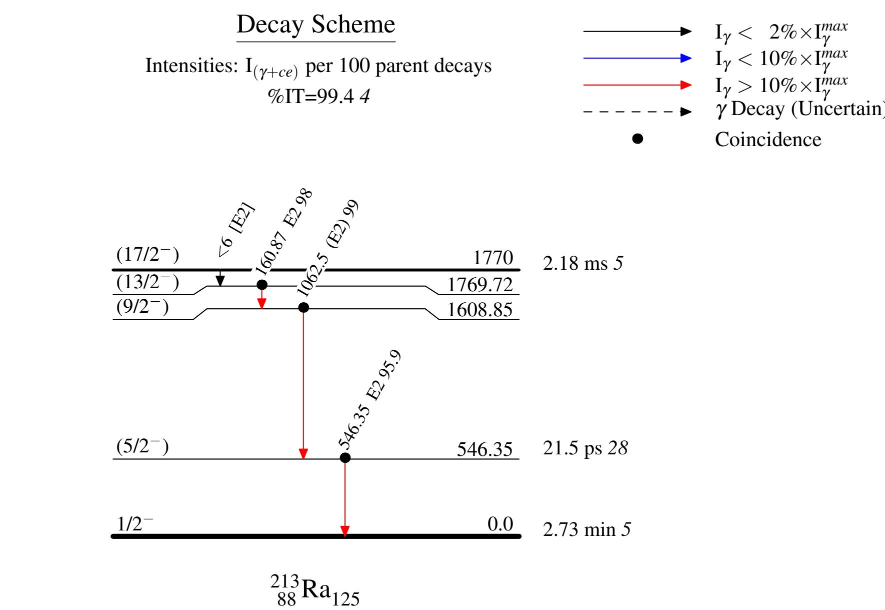
$\gamma(^{213}Ra)$

Iγ normalization: Absolute Iγ deduced by the evaluator equating the total transition intensity for each of the 546.35, 1062.5, and 160.87 cascading γ's to the 99.4 *4* IT decay branching. Measured Iγ used to deduced the absolute intensities is listed in the comments.

E_γ[†]	I_γ[‡@]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[#]	α[&]	Comments
(<6)		1770	(17/2⁻)	1769.72	(13/2⁻)	[E2]		E_γ: From level scheme.
160.87 *5*	42.2 *24*	1769.72	(13/2⁻)	1608.85	(9/2⁻)	E2	1.328	α(K)exp=0.25 *2* (1976Ra37) α(K)exp=0.26 *6* (2006Ku26) E_γ: Others: 160.4 *5* (2004He25), 161.2 *1* (2006Ku26). In 1976Ra37, a transition ≈161γ was shown in Fig. 7 to feed the level at 1608.85 (9/2⁻), but argued it would not depopulate the isomeric state (J^π=(17/2⁻)) as an E2 transition. Iγ(rel)=43.5 *25*: Weighted average of 46 *2* (1976Ra37) and 41 *2* (2006Ku26).
546.35 *5*	93.0 *11*	546.35	(5/2⁻)	0.0	1/2⁻	E2	0.0315	α(K)exp=0.02 *1* (1976Ra37) α(K)exp=0.024 *9* (2006Ku26) E_γ: Others: 545.4 *5* (2004He25), 546.2 *1* (2006Ku26). Iγ(rel)=100.4 *12*: Weighted average of 104 *3* (1976Ra37) and 100 *1* (2006Ku26).
1062.5 *2*	98.4 *27*	1608.85	(9/2⁻)	546.35	(5/2⁻)	(E2)	0.00802	α(K)exp=0.005 *10* (1976Ra37) α(K)exp=0.014 *9* (2006Ku26) E_γ: Others: 1061.2 *5* (2004He25), 1062.1 *1* (2006Ku26). Iγ(rel)=99.4 *27*: Weighted average of 100 *3* (1976Ra37) and 97 *6* (2006Ku26).

† Measurements of 1976Ra37 (semi).
‡ Deduced by evaluator (see normalization comments) using the Iγ(rel) listed in comments.
# Proposed in 1976Ra37 based on α(K)exp data.
@ Absolute intensity per 100 decays.
& 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.

^{213}Ra IT decay (2.18 ms) 1976Ra37,1994Ne01,2006Ku26



^{217}Th α decay 2005Ku31,2002He29,2000Ni02

Parent: ^{217}Th: E=0.0; J$^{\pi}$=(9/2^{+}); T$_{1/2}$=0.252 ms *4*; Q(α)=9435 *4*; %α decay=100

^{217}Th-J$^{\pi}$,T$_{1/2}$: From 2018Ko01 (A=217 evaluation). Other T$_{1/2}$=0.249 ms *11* (2019Zh54). Consideration of 2019Zh54 value with the ones in 2018Ko01 yields same T$_{1/2}$=0.252 ms *4*.

^{217}Th-Q(α): From 2021Wa16.

Others: 2005Li17, 2000He17, 1968Va18, 2005YeZZ, and 2008DoZZ.

2005Ku31: ^{217}Th produced through ^{170}Er(^{50}Ti,3n)^{217}Th; E=4.35 A-MeV; Detector: 16-strip PIPS-detector, Ge-Clover detector of 4 crystals; Measured: Eα, Iα, investigated by Evaporation Residues (ER)-γ-α- coincidences.

2002He29: ^{217}Th produced through ^{181}Ta(^{40}Ar,p3n)^{217}Th, Target: 99.988% natural tantalum; E=182 MeV; Detector: 16-strip PIPS-detector, Ge-Clover detector of 4 crystals; Measured: Eα, Iα, α-γ coincidences.

2000Ni02: ^{217}Th produced through ^{198}Pt(^{28}Si,α5n)^{217}Th; E=140-180 MeV; Detector: Double sided strip detector, TOF signal; Measured: Eα, Iα, t, deduced J^{π} of 818 state.

2000He17: ^{217}Th produced through ^{170}Er(^{50}Ti,3n)^{217}Th; E=215-235 MeV; Detector: 16-strip PIPS-detector, a HPGe detector; Measured: Eα, Iα.

2005Li17: Isotope produced by fragment separator of 1 GeV/u ^{238}U beam; Measured: Eα.

1968Va18: ^{217}Th produced through ^{206}Pb(^{16}O,5n)^{217}Th; E=166 MeV; 97.22% ^{206}Pb isotopes in the target; Detector: Semi; Measured: Eα, T$_{1/2}$.

2005YeZZ: ^{217}Th from ^{181}Ta(^{40}Ar,p3n)^{217}Th; Detector: array of silicon strip, 7 HPGe, time-of-flight detectors; Measured Eα; no γ event was attributed to the decay of ^{217}Pa isomer.

^{213}Ra Levels

E(level)†	J$^{\pi}$‡	T$_{1/2}$‡	Comments
0.0	1/2^{-}	2.73 min *5*	T$_{1/2}$: From Adopted Levels.
545 *6*	(5/2^{-})	21.5 ps *28*	T$_{1/2}$: From Adopted Levels.
820 *6*	(3/2^{-})		J$^{\pi}$: From systematics of ^{211}Rn isotone.

† Deduced by the evaluator using Q(α)(^{217}Th) and Eα.

‡ From Adopted Levels, except noted otherwise.

α radiations

Eα	E(level)	Iα‡	HF†	Comments
8456 *4*	820	3.69 *14*	24 *1*	Eα: Weighted average of 8460 *7* (2005Ku31), 8455 *5* (2002He29), 8459 *15* (2000He17), and 8429 *32* (2000Ni02). Iα: Normalization value of 1.67 *14*: Weighted average of 3.0 *2* (2005Ku31), 3.7 *1* (2002He29), 3.8 *1* (2000He17), and 5.1 *+20−16* (2000Ni02).
8726 *4*	545	1.65 *8*	283 *16*	Eα: Weighted average of 8727 *8* (2005Ku31), 8725 *5* (2002He29), 8731 *15* (2000He17), and 8713 *32* (2000Ni02). Iα: Normalization value of 1.64 *8*: Weighted average of 1.5 *1* (2005Ku31), 1.8 *1* (2002He29), 1.6 *1* (2000He17), and 2.6 *+16−11* (2000Ni02).
9260 *4*	0.0	94.7 *7*	108 *2*	Eα: Weighted average of 9250 *10* (1968Va18), 9269 *9* (2005Ku31), 9250 *47* (2005Li17), 9261 *5* (2002He29), 9268 *15* (2000He17), 9247 *15* (2000Ni02), and 9257 *15* (2019Zh54). Iα: Normalized value of 94.2 *7*: Unweighted average of 95.5 *3* (2005Ku31), 94.5 *5* (2002He29), 94.6 *6* (2000He17), and 92.3 *6* (2000Ni02). Weighted average 94.8 *6* with χ^2=7.8 cf. χ^2_{crit}=2.6.

† Using r$_0$(^{213}Ra)=1.5091 *22* obtained from interpolation (or unweighted average) of radius parameters r$_0$(^{212}Ra)=1.4695 *14* and r$_0$(^{214}Ra)=1.5487 *30* (2020Si16).

‡ Absolute intensity per 100 decays.

^{204}Pb(^{13}C,4nγ) 2018Pa04,2021Ge07

Combined 2021Ge07 data with the XUNDL dataset of 2018Pa04, compiled by B. Singh (McMaster), Feb 8, 2018.

2018Pa04: E(^{13}C)=80 MeV pulsed beam. Target=5.4 mg/cm^2 thick, 99.6% enriched ^{204}Pb. Prompt and delayed (out-of-beam) γ rays were detected using CAESAR array of nine Compton-suppressed HPGe detectors, and two LEPS Ge detectors for low-energy γ radiation. Measured Eγ, Iγ, $\gamma\gamma$-coin, $\gamma(\theta)$. Deduced high-spin levels, J^π, lifetime of a new isomer, total conversion coefficients of low-energy γ rays, multipolarities, configurations.

2021Ge07 (same lab and research group of 2018Pa04): E(^{13}C)=80 MeV pulsed beam. Target=5.4 mg/cm^2 thick, 99.6% enriched ^{204}Pb. Emitted γ rays were measured using the CAESAR array of six Compton-suppressed $LaBr_3$ detectors, three suppressed HPGe and one unsuppressed LEPS Ge detector. Measured Eγ, $\gamma\gamma$-coin, $\gamma\gamma$ time difference spectra. Deduced lifetime for the 5/2$^-$ state at 546 keV.

^{213}Ra Levels

Nominal configurations are as given in 2018Pa04 in their Table V.

E(level)†	$J^{\pi\ddagger}$	$T_{1/2}$	Comments
0.0	1/2$^-$		Configuration: $\pi(h^6_{9/2})_{0+}\otimes\nu p^{-1}_{1/2}$.
546.35 *5*	(5/2$^-$)	21.5 ps *28*	Configuration: $\pi(h^6_{9/2})_{0+}\otimes\nu f^{-1}_{5/2}$. $T_{1/2}$: From τ=31 ps *4* (2021Ge07), from γ gated time difference measurements by Generalised Centroid Difference method.
1608.85 *21*	(9/2$^-$)		Configuration: $\pi(h^6_{9/2})_{4+}\otimes\nu p^{-1}_{1/2}$.
1769.72 *22*	(13/2$^-$)		Configuration: $\pi(h^6_{9/2})_{6+}\otimes\nu p^{-1}_{1/2}$.
1770 *5*	(17/2$^-$)	2.18 ms *5*	E(level),$T_{1/2}$: From Adopted Levels. Configuration: $\pi(h^6_{9/2})_{8+}\otimes\nu p^{-1}_{1/2}$.
2287.50 *10*	21/2$^-$		Configuration: $\pi(h^6_{9/2})_{8+}\otimes\nu f^{-1}_{5/2}$.
2609.90 *14*	23/2$^+$	18.7 ns *21*	Configuration: $\pi[(h^5_{9/2})_{9/2}i_{13/2}]_{11-}\otimes\nu p^{-1}_{1/2}$. $T_{1/2}$: from τ=27 ns *3* (^{13}C,4nγ) – 2018Pa04) – based on (455γ+731γ)(322γ)(Δt) measurements.
3065.3 *4*	25/2$^+$		Configuration: $\pi[(h^5_{9/2})_{9/2}i_{13/2}]_{10-}\otimes\nu f^{-1}_{5/2}$.
3136.6 *3*	25/2$^-$		Configuration: $\pi(h^6_{9/2})_{12+}\otimes\nu p^{-1}_{1/2}$.
3281.1 *5*	25/2$^-$		Configuration: $\pi[(h^5_{9/2})_{17/2}f_{7/2}]_{12+}\otimes\nu p^{-1}_{1/2}$.
3340.4 *4*	27/2$^+$		Configuration: $\pi[(h^5_{9/2})_{9/2}i_{13/2}]_{11-}\otimes\nu f^{-1}_{5/2}$.
3345.60 *22*	25/2$^-$		Configuration: $\pi(h^6_{9/2})_{10+}\otimes\nu f^{-1}_{5/2}$.
3433.2 *3*	27/2$^-$		Configuration: $\pi[(h^5_{9/2})_{21/2}f_{7/2}]_{13+}\otimes\nu p^{-1}_{1/2}$.
3441.4 *5*	29/2$^-$		Configuration: $\pi[(h^5_{9/2})_{21/2}f_{7/2}]_{14+}\otimes\nu p^{-1}_{1/2}$.
3863.8 *8*	27/2$^+$		Configuration: $\pi[(h^5_{9/2})_{13/2}i_{13/2}]_{13-}\otimes\nu p^{-1}_{1/2}$.
3878.0 *6*	29/2$^+$		Configuration: $\pi[(h^5_{9/2})_{17/2}i_{13/2}]_{14-}\otimes\nu p^{-1}_{1/2}$.
4006.9 *5*	31/2$^+$		Configuration: $\pi[(h^5_{9/2})_{17/2}i_{13/2}]_{15-}\otimes\nu p^{-1}_{1/2}$.
4047.7 *6*	33/2$^+$	34.7 ns *21*	Configuration: $\pi[(h^5_{9/2})_{21/2}i_{13/2}]_{16-}\otimes\nu p^{-1}_{1/2}$. $T_{1/2}$: from τ=50 ns *3* ((^{13}C,4nγ) – 2018Pa04) – based on (455γ+731γ)(322γ)(Δt) measurements. Lifetime measured by (beam pulse)(566γ and 667γ)(t) showed no difference.
4047.7+x?	(35/2$^+$)		
4506.2+x?	(37/2$^+$)		

† From least-squares fit to Eγ data.

‡ Up to 1770 from Adopted Levels, above assignments are from 2018Pa04, based on proposed γ multipolarity from measured $\gamma(\theta)$ data and deduced total conversion coefficients.

γ(^{213}Ra)

A_2 values are from 2018Pa04, with A_4 set to zero. These data were obtained in γγ-coin mode, with coincident gates placed on known ΔJ=2, E2 transitions. Typical A_2 values, based on alignment σ/J=0.3, were expected as −0.2 for ΔJ=1, dipole, +0.28 for ΔJ=2, quadrupole (E2), and +0.46 for ΔJ=3, octupole (E3) transitions.

The α(total)expt values are from 2018Pa04, based on intensity balance arguments in γγ-coin mode.

E_γ	I_γ[#]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[@]	δ[@]	α[&]	Comments
y[a]		4047.7+x?	(35/2$^+$)	4047.7	33/2$^+$				
(8.2[†])		3441.4	29/2$^-$	3433.2	27/2$^-$	[M1]		1213 *17*	
(14.2[†])		3878.0	29/2$^+$	3863.8	27/2$^+$	[M1]		236.8 *33*	E_γ: 14.4 in 2018Pa04.
(40.8[†])		4047.7	33/2$^+$	4006.9	31/2$^+$	[M1]		42.8 *6*	E_γ: 40.9 in 2018Pa04.
87.6 *4*		3433.2	27/2$^-$	3345.60	25/2$^-$	[M1]		4.56 *9*	
152.1 *5*	2.3 *2*	3433.2	27/2$^-$	3281.1	25/2$^-$	M1+E2	0.7 *3*	3.7 *6*	α(exp)=3.7 *5* (2018Pa04) α for δ(E2/M1)=0.7 (deduced by 2018Pa04 from α(total)exp).
160.87[‡] *5*		1769.72	(13/2$^-$)	1608.85	(9/2$^-$)				
169.7 *3*	4.4 *2*	4047.7	33/2$^+$	3878.0	29/2$^+$	E2		1.079 *17*	α(exp)=1.3 *2* (2018Pa04)
[x]204									γ in coin with 297, 314, 377, 397/398, 416, 447, 518, 849, 994 and 1058 γ rays.
275.0 *4*	4.2 *2*	3340.4	27/2$^+$	3065.3	25/2$^+$	M1+E2	0.64 *2*	0.697 *14*	α(exp)=0.99 *8* (2018Pa04); A_2=−0.41 *16* δ: Deduced using the α(exp) datum and BriccMixing code.
296.6 *2*	12.3 *3*	3433.2	27/2$^-$	3136.6	25/2$^-$	M1		0.732 *10*	α(exp)=0.96 *9* (2018Pa04); A_2=−0.73 *4* δ: 0.00 *16* from the α(exp) datum and BriccMixing code.
304.8 *8*	1.8 *2*	3441.4	29/2$^-$	3136.6	25/2$^-$	[E2]		0.1450 *23*	
[x]314									γ in coin with 204, 297, 377, 397/398, 416, 447, 518, 849, 994 and 1058 γ rays.
322.4 *1*	44.6 *6*	2609.90	23/2$^+$	2287.50	21/2$^-$	E1		0.0299 *4*	α(exp)=0.11 *5* (2018Pa04); A_2=−0.31 *5*
[x]377									γ in coin with 204, 297, 314, 397/398, 416, 447, 518, 849, 994 and 1058 γ rays.
[x]397									γ in coin with 204, 297, 314, 377, 398, 416, 447, 518, 849, 994 and 1058 γ rays.
[x]398									γ in coin with 204, 297, 314, 377, 397, 416, 447, 518, 849, 994 and 1058 γ rays.
[x]416									γ in coin with 204, 297, 377, 397/398, 518, 849, 994 and 1058 γ rays.
436.7 *8*	2.4 *2*	3878.0	29/2$^+$	3441.4	29/2$^-$	[E1]		0.01557 *23*	
[x]447									γ in coin with 204, 297, 377, 397/398, 518, 849, 994 and 1058 γ rays.
455.4 *4*	7.1 *3*	3065.3	25/2$^+$	2609.90	23/2$^+$	M1+E2			A_2=−1.06 *6*
458.7[a] *6*		4506.2+x?	(37/2$^+$)	4047.7+x?	(35/2$^+$)				
[x]459									γ in coin with 297, 397/398, 518, 565, 667, 849, 994 and 1058 γ rays.

γ(^{213}Ra) (continued)

E_γ	I_γ[#]	E_i(level)	J^π_i	E_f	J^π_f	Mult.[@]	α[&]	Comments
517.5 *1*	100	2287.50	21/2⁻	1770	(17/2⁻)	E2		A_2=+0.26 *1*
537.8 *11*	2.0 *2*	3878.0	29/2⁺	3340.4	27/2⁺	M1		A_2=−0.46 *7*
546.35[‡] *5*		546.35	(5/2⁻)	0.0	1/2⁻			
565.5 *2*	41.0 *7*	4006.9	31/2⁺	3441.4	29/2⁻	E1		A_2=−0.46 *6*
606.3 *5*	5.4 *3*	4047.7	33/2⁺	3441.4	29/2⁻	[M2+E3]	0.18 *10*	
666.5 *4*	10.0 *4*	4006.9	31/2⁺	3340.4	27/2⁺	E2		A_2=+0.38 *13*
730.5 *5*	5.8 *3*	3340.4	27/2⁺	2609.90	23/2⁺	E2		A_2=+0.38 *17*
798.5 *10*	0.7 *2*	3863.8	27/2⁺	3065.3	25/2⁺	[M1+E2]	0.033 *19*	
849.1 *3*	24.4 *6*	3136.6	25/2⁻	2287.50	21/2⁻	E2		A_2=+0.38 *4*
993.6 *7*	3.7 *3*	3281.1	25/2⁻	2287.50	21/2⁻	E2		A_2=+0.33 *14*
1058.1 *2*	28.3 *7*	3345.60	25/2⁻	2287.50	21/2⁻	E2		A_2=+0.30 *5*
1062.5[‡] *2*		1608.85	(9/2⁻)	546.35	(5/2⁻)			

[†] This γ not seen but required from the analysis of γγ-coin data. Energy deduced from level-energy difference.

[‡] From Adopted Gammas.

[#] Delayed γ-intensities relative to Iγ(517.5)=100 for 'out-of-beam' data.

[@] From 2018Pa04, based on γ(θ) data and α(tot)exp. Multipolarities listed in square brackets are from ΔJ^π assigned in their work (see footnote 'a' in Table I of 2018Pa04).

[&] 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.

[a] Placement of transition in the level scheme is uncertain.

[x] γ ray not placed in level scheme.

Adopted Levels, Gammas

Q(β^-)=−5979 *15*; S(n)=9230 *25*; S(p)=949 *16*; Q(α)=7498 *4* 2021Wa16

Assignment: ^{209}Bi(^{12}C,8n) excit (1961Gr42,1968Va04); ^{197}Au(^{20}Ne,4n) excit (1968Va04); ^{203}Tl(^{16}O,6n) excit (1968Va04); ^{205}Tl(^{16}O,8n) excit (1968Va04); parent of ^{209}Fr (1968Va04).

2002Sa22, 2003Ik01: ^{138}Ba(^{82}Se,p6n), E(cm)=193-251 MeV and ^{134}Ba(^{82}Se,p2n); measured evaporation residue cross section σ.

2002Mi20: ^{154}Sm(^{64}Ni,p4n), E=4-5 MeV/nucleon, measured evaporation residue cross section σ.

2015Ma63: ^{162}Dy(^{54}Cr,p2n), E=5.1 MeV/nucleon, measured evaporation residue cross section σ.

^{213}Ac Levels

Cross Reference (XREF) Flags

A ^{217}Pa α decay (3.8 ms)
B ^{217}Pa α decay (1.08 ms)

E(level)†	J$^\pi$	T$_{1/2}$	XREF	Comments
0.0	9/2$^-$	738 ms *16*	AB	%α≈100 μ=+4.2 *4* Only α decay was observed. Eα=7360 keV *30* (1997Mi03). Possible ε decays to 1608.85 (9/2$^-$) and 546.35 (5/2$^-$) levels are expected to be <25% and <0.05%, if log *ft*>3.6 and log $f^{1}t$>8.5, respectively. β gross theory calculations by 1973Ta30 give T$_{1/2}$(β^+)≈50 s, which suggests %(ε+β^+)≈1.6. J$^\pi$: Favored α decay to ^{209}Fr g.s. (J$^\pi$=9/2$^-$). Also J=(9/2) has been proposed in 2017Fe10, based on direct HFS measurements. Configuration: π ($h^{+1}_{9/2}$). T$_{1/2}$: Weighted average of 731 ms *17* (2000He17) and 800 ms *50* (1968Va04). Other: ≈1 s (1961Gr42). μ: From 2019StZV, 2017Gr18 − in-gas laser ionization and spectroscopy (IGLIS). Also see 2017Fe10.
466.50 *20*			AB	
612.80 *10*			AB	
634.30 *10*			AB	J$^\pi$: Tentative J^π=(13/2$^-$) in 2002He29.
1063.20 *15*			B	
1884.00 *25*			B	J$^\pi$: Tentative J^π=(21/2$^-$) in 2002He29.

† From Eγ.

γ(^{213}Ac)

E$_i$(level)	E$_\gamma$†	E$_f$	J$^\pi_f$
466.50	466.5 *2*	0.0	9/2$^-$
612.80	612.8 *1*	0.0	9/2$^-$
634.30	634.3 *1*	0.0	9/2$^-$
1063.20	450.4 *1*	612.80	
1884.00	820.8 *2*	1063.20	

† From ^{217}Pa α decay (1.08 ms).

^{217}Pa α decay (3.8 ms) 2002He29,2000He17,1968Va18

Parent: ^{217}Pa: E=0.0; J^π=9/2$^-$; $T_{1/2}$=3.8 ms *2*; Q(α)=8489 *4*; %α decay=100

^{217}Pa-J^π: Based on favored α-decay chain from ^{217}Pa g.s. to g.s. of ^{213}Ac, J^π=9/2$^-$, to g.s. of ^{209}Fr, J^π=9/2$^-$ (firm J^π=9/2−(^{209}Fr) in 2015Ch30).

^{217}Pa-$T_{1/2}$: From 2018Ko01 (A=217 evaluation).

^{217}Pa-Q(α): From 2021Wa16.

Others: 1998Ik01, 1996An21, 1979Sc09, and 2005YeZZ.

2002He29: ^{217}Pa produced through ^{181}Ta(^{40}Ar,4n)^{217}Pa, Target: 99.988% natural tantalum; E=182 MeV; Detector: 16-strip PIPS-detector, Ge-Clover detector of 4 crystals; Measured: Eα, Iα, α-α coincidences.

2000He17: ^{217}Pa produced through ^{170}Er(^{51}V,4n)^{217}Pa; E=214-286 MeV; Detector: 16-strip PIPS-detector, a HPGe detector; Measured: Eα, Iα.

1968Va18: ^{217}Pa produced through ^{206}Pb(^{20}Ne,p8n)^{217}Pa and ^{208}Tl(^{20}Ne,11n)^{217}Pa; Detector: Semi; Measured: Eα.

1998Ik01: ^{217}Pa produced through ^{194}Pt(^{28}Si,p4n)^{217}Pa; E=163−MeV and 175-MeV; Detector: double sided position sensitive strip detector; Measured: Eα, $T_{1/2}$.

1996An21: ^{217}Pa from ^{170}Er(^{51}V,4n)^{217}Pa; E=28-87 MeV; Detector: ER are separated in flight, 16-strip PIPS detector, a HPGe detector; Measured: Eα, $T_{1/2}$.

1979Sc09: ^{181}Ta(^{40}Ar,4n)^{217}Pa; E=165-202 MeV; Measured: Eα, $T_{1/2}$.

2005YeZZ: ^{217}Pa from ^{181}Ta(^{40}Ar,4n)^{217}Pa; Detector: array of silicon strip, 7 HPGe, time-of-flight detectors; Measured Eα.

^{213}Ac Levels

E(level)†	J^π	$T_{1/2}$	Comments
0	9/2$^-$	738 ms *16*	J^π,$T_{1/2}$: From Adopted Levels.
466.1 *20*			E(level): Other: 468 *6* from Eα and Qα.
612.5 *8*			E(level): Other: 616 *6* from Eα and Qα.
634.3 *11*			E(level): Other: 634 *6* from Eα and Qα. J^π: In 2002He29, J^π=(13/2$^-$) is presented for this level in the tentative partial decay scheme of ^{213}Ac.

† From Eγ. Values from the Eα and Q(α) are listed in comments.

α radiations

Eα	E(level)	Iα‡#	HF†	Comments
7710 *5*	634.3	0.3 *2*	7 *5*	Eα: From 2002He29.
7728 *5*	612.5	0.3 *2*	8 *6*	Eα: From 2002He29.
7873 *5*	466.1	0.4 *2*	18 *9*	Eα: From 2002He29.
8336 *4*	0	99 *1*	1.72 *15*	Eα: Weighted average of 8337 *5* (2002He29), 8334 *15* (2000He17), 8330 *50* (1998Ik01), 8330 *10* (1996An21), 8334 *15* (1979Sc09), and 8340 *10* (1968Va18).

† Using r_0(^{213}Ac)=1.491 *21*, unweighted average of r_0(^{212}Ra)=1.4695 *14* and r_0(^{214}Th)=1.512 *14* (2020Si16).

‡ From 2002He29.

Absolute intensity per 100 decays.

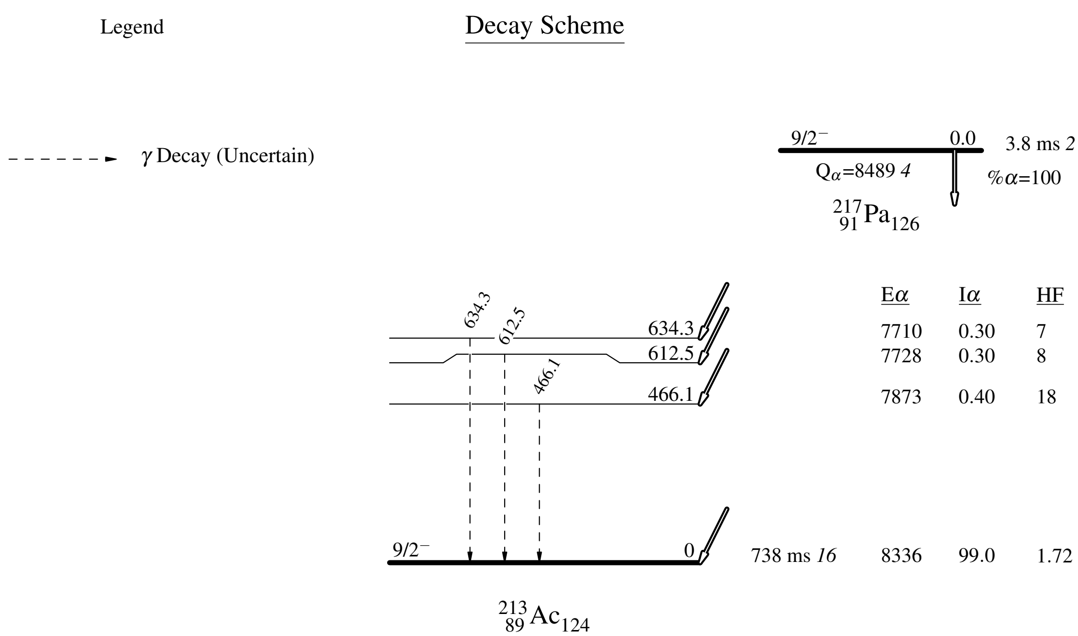
^{217}Pa α decay (3.8 ms) 2002He29,2000He17,1968Va18 (continued)

γ(^{213}Ac)

E_γ †	E_i(level)	E_f	J^π_f
466.1‡ *20*	466.1	0	9/2⁻
612.5‡ *8*	612.5	0	9/2⁻
634.3‡ *11*	634.3	0	9/2⁻

† From 2002He29.
‡ Placement of transition in the level scheme is uncertain.

^{217}Pa α decay (3.8 ms) 2002He29,2000He17,1968Va18



^{217}Pa α decay (1.08 ms) 2002He29,2000He17,1998Ik01

Parent: ^{217}Pa: E=1860 *7*; $T_{1/2}$=1.08 ms *3*; Q(α)=8489 *4*; %α decay=73 *4*

^{217}Pa-E: From 2021Ko07 – NUBASE. Other: 1855 *6* can be deduced from the energy difference of the 10157 keV *5* and 8336 keV *4* (Eα – see ^{217}Pa α decay (3.8 ms)) Eα, emitted in the decay of ^{217}Pa isomer (1.08-ms) and g.s. (3.8-ms), respectively, by assuming these α particles feeding the g.s. of ^{213}Ac. In 2002He29 and 2018Ko01 – 1854 keV *7*, considering using Eα=8337 keV *5* for the ^{217}Pa g.s. α decay.

^{217}Pa-J^π: Tentative J^π=(29/2$^-$) in 2002He29. In 2018Ko01 (A=217 evaluation) recommended spin-parity is (23/2$^-$).

^{217}Pa-$T_{1/2}$: From 2018Ko01 (A=217 evaluation).

^{217}Pa-Q(α): From 2021Wa16.

^{217}Pa-%α decay: From 2002He29.

Others: 1996An21, 1979Sc09, and 2008DoZZ.

2002He29: ^{217}Pa produced through ^{181}Ta(^{40}Ar,4n)^{217}Pa, Target: 99.988% natural tantalum; E=182 MeV; Detector: 16-strip PIPS-detector, Ge-Clover detector of 4 crystals; Measured: Eα, Iα, α-α coincidences.

2000He17: ^{217}Pa produced through ^{170}Er(^{51}V,4n)^{217}Pa; E=214-286 MeV; Detector: 16-strip PIPS-detector, a HPGe detector; Measured: Eα, Iα.

1998Ik01: ^{217}Pa produced through ^{194}Pt(^{28}Si,p4n)^{217}Pa; E=163−MeV and 175-MeV; Detector: double sided position sensitive strip detector; Measured: Eα, $T_{1/2}$.

1996An21: ^{217}Pa from ^{170}Er(^{51}V,4n)^{217}Pa; E=28-87 MeV; evaporation residue were separated in flight, 16-strip PIPS detector, a HPGe detector; Measured: Eα, $T_{1/2}$.

1979Sc09: ^{181}Ta(^{40}Ar,4n)^{217}Pa; E=165-202 MeV; Measured: Eα, $T_{1/2}$.

^{213}Ac Levels

E(level)†	J^π	$T_{1/2}$	Comments
0.0	9/2$^-$	738 ms *16*	J^π: From Adopted Levels.
466.5 *2*			
612.8 *1*			
634.30 *10*			J^π: Tentative J^π=(13/2$^-$) in 2002He29.
1063.2? *2*			E(level): Proposed in 2002He29 (Fig. 4) for connecting the excited level at 188 (assumed J^π=(21/2$^-$)) with the 634 level (assumed J^π=(13/2$^-$)) through 820.8γ-450γ-cascade.
1884.0 *3*			E(level): Others: 1887 *9* or 1882 *9* – using the Eα, Q(α), and the isomeric state of ^{217}Pa at 1860 keV *7* or 1855 keV *6*. J^π: Tentative J^π=(21/2$^-$) in 2002He29.

† From Eγ.

α radiations

Eα‡	E(level)	Iα‡#	HF†	Comments
8306 *5*	1884.0	11 *2*	5.0 *11*	
9533 *5*	634.30	6 *1*	1.35×10^4 *26*	Eα: Other: 9540 *50* (1998Ik01).
9552 *5*	612.8	9 *1*	9.9×10^3 *15*	Eα: Other: 9648 *15* (2000He17).
9697 *5*	466.5	2 *1*	9.5×10^4 *49*	Eα: Other: 9694 *20* (2000He17).
10157 *5*	0.0	72 *4*	2.61×10^4 *28*	Eα: Others: 10155 *15* (2000He17), 10140 *50* (1998Ik01), 10155 *15* (1996An21), and 10160 *20* (1979Sc09).

† Using r_0(^{213}Ac)=1.491 *21*, unweighted average of r_0(^{212}Ra)=1.4695 *14* and r_0(^{214}Th)=1.512 *14* (2020Si16).
‡ From 2002He29.
# For absolute intensity per 100 decays, multiply by 0.73 *4*.

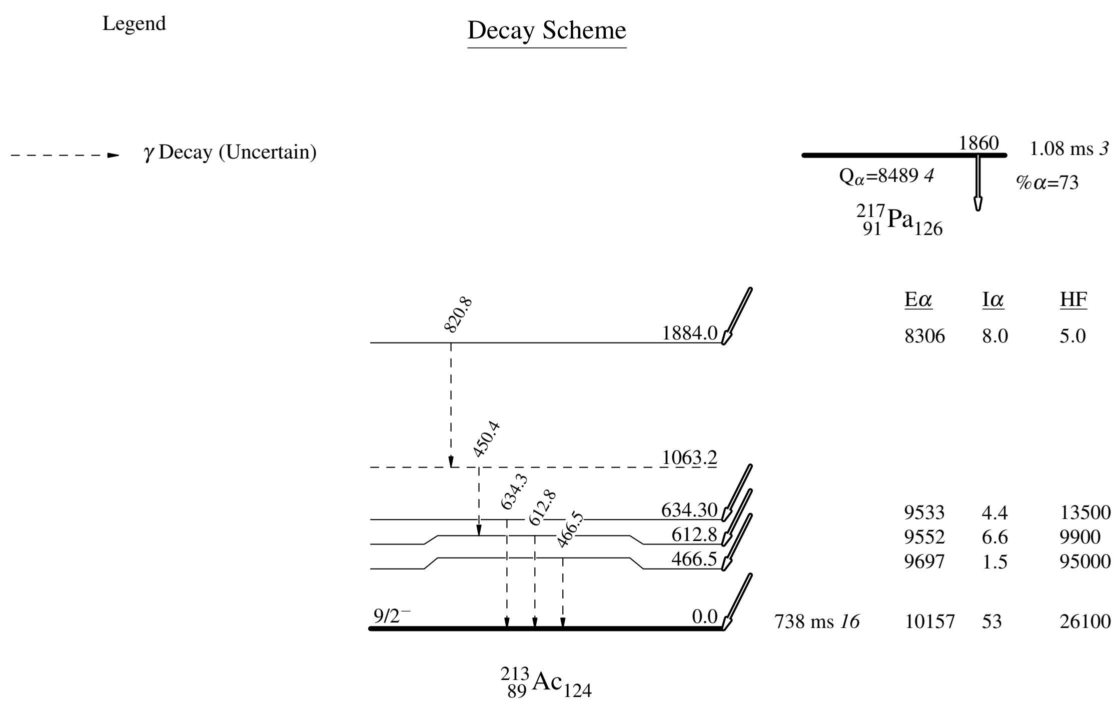
^{217}Pa α decay (1.08 ms) 2002He29,2000He17,1998Ik01 (continued)

$\gamma(^{213}Ac)$

E_γ[†]	E_i(level)	E_f	J^π_f	Comments
450.4[‡] *1*	1063.2?	612.8		
466.5[‡] *2*	466.5	0.0	9/2⁻	
612.8[‡] *1*	612.8	0.0	9/2⁻	E_γ: Weighted average of 613.0 *2* and 612.7 *1*.
634.3[‡] *1*	634.30	0.0	9/2⁻	
820.8[‡] *2*	1884.0	1063.2?		

† From 2002He29.
‡ Placement of transition in the level scheme is uncertain.

^{217}Pa α decay (1.08 ms) 2002He29,2000He17,1998Ik01



Adopted Levels, Gammas

$Q(\beta^-)=-7530$ *60*; S(n)=8062 *14*; S(p)=2468 *14*; $Q(\alpha)=7837$ *7* 2021Wa16
Assignment: ^{206}Pb(^{16}O,9n) excit (1968Va18), ^{177}Hf(^{40}Ar,4n) excit (1980Ve01).
2002Mi20: ^{154}Sm(^{64}Ni,5n), E=4-5 MeV/nucleon, measured evaporation residue cross section σ.
2002Sa22, 2003Ik01: ^{138}Ba(^{82}Se,7n), E(cm)=193-251 MeV and ^{134}Ba(^{82}Se,3n); measured evaporation residue cross section σ.
2007Ma57 and 2008La14: 2007Ma57 reported long-lived isomer (half-life $\geq 1 \times 10^8$ year) for ^{213}Th from mass measurement and abundances relative to ^{232}Th in a study of naturally-occurring thorium using inductively coupled plasma-sector field mass spectrometry. Not confirmed by accelerator mass spectrometry (AMS) measurements (2008La14). An upperlimit of 1.2×10^{12} was determined for the detection of ^{213}Th/^{232}Th.

^{213}Th Levels

Cross Reference (XREF) Flags

A ^{217}U α decay
B ^{164}Dy(^{54}Cr,5nγ)
C ^{176}Hf(^{40}Ar,3nγ)

E(level)	J^π	$T_{1/2}$	XREF	Comments
0	5/2$^-$	146 ms *+22−19*	ABC	%$\alpha\approx$100 J^π: favored α decay to 5/2$^-$ g.s. of ^{209}Ra. Configuration: ν ($f^{-1}_{5/2}$). Only α decay is reported. Branching for a possible ($\varepsilon+\beta^+$) decay to ^{213}Ac is estimated by the evaluator as $\approx$1.4% from $T_{1/2}(\varepsilon+\beta^+)\approx$10 second, calculated by 1973Ta30 using β gross theory. Eα=7700 keV *30* (1997Mi03). $T_{1/2}$: Weighted average of 150 ms *25* (1968Va18 – 7690α(t)) and 130 ms *+50−30* (1980Ve01 – 7689α(t)).
799 *1*	(9/2$^-$)		BC	J^π: 381γ M2 from (13/2)$^+$.
1180 *1*	(13/2$^+$)	8.3 μs *8*	BC	J^π: Proposed by 2007Kh22 in analogy of 13/2$^+$ isomeric states in ^{205}Po, ^{207}Po, ^{209}Rn, and ^{211}Ra. Configuration: ν ($i^{-1}_{13/2}$). $T_{1/2}$: From (^{40}Ar,3nγ) – 2021Zh24. Other value 1.3 μs *3* ((^{54}Cr,5nγ) – reported as 1.4 μs *4* in 2007Kh22) is discrepant. The 2021Zh24 value is chosen based on the transition strenghs B(M2)(W.u.) of the 13/2$^+$ isomers for N=123 isotones: 0.0056 *+6−5* (^{213}Th), 0.0046 *3* (^{211}Ra) (2013Si17), 0.0043 *5* (^{209}Rn) (2015Ch30), and 0.0026 *2* (^{207}Po) (2011Ko04).

γ(^{213}Th)

E_i(level)	J^π_i	E_γ†	I_γ†	E_f	J^π_f	Mult.	α‡	Comments
799	(9/2$^-$)	799 *1*	100	0	5/2$^-$			
1180	(13/2$^+$)	381 *1*	100	799	(9/2$^-$)	(M2)	1.331 *22*	B(M2)(W.u.)=0.0056 *+6−5* Mult.: from α(exp)=0.77 *29*, deduced from intensity balance at 799 level (^{54}Cr,5nγ) (2007Kh22).

† From (^{54}Cr,5nγ).
‡ 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.

^{217}U α decay **2000Ma65,2005Le42**

Parent: ^{217}U: E=0; $T_{1/2}$=16 ms *+21−6*; Q(α)=8430 *80*; %α decay=100
^{217}U-$T_{1/2}$: From 2018Ko01 (A=217 evaluation).
^{217}U-J^{π}: In 2005Le42, J^{π}=(1/2$^-$) was proposed.
^{217}U-Q(α): From systematics in 2021Wa16.
2000Ma65: ^{217}U was produced through $^{182}W(^{40}Ar,5n)^{217}U$; Target 92% enriched; E=193 MeV; multi-strip silicon detector; Eα, $T_{1/2}$ measured.
2005Le42: ^{217}U was produced through $^{182}W(^{40}Ar,5n)^{217}U$; E=186 MeV, double-sided silicon detector; Eα, $T_{1/2}$ measured.

^{213}Th Levels

E(level)	J^{π} †	$T_{1/2}$ †
0	5/2$^-$	146 ms *+22−19*

† From Adopted Levels.

α radiations

Eα	E(level)	Iα ‡	HF †	Comments
8018 *14*	0	100	<6	Eα: Weighted average of 8005 *20* (2000Ma65), 8024 *14* (2005Le42). Uncertainty is the lower input value. HF: Limit based on the calculated value of 2 *4*, where HF≠0.

† Using $r_0(^{213}Th)$=1.499 *24* is deduced from interpolation (or unweighted average) of $r_0(^{214}Th)$=1.512 *14* and $r_0(^{212}Th)$=1.486 *33* (2020Si16).
‡ Absolute intensity per 100 decays.

^{164}Dy(^{54}Cr,5nγ) 2007Kh22

Enriched (96.8%) $^{164}DyF_3$ target (thickness=393 μg/cm^2). ^{54}Cr beam, E=258 MeV, from the UNILAC accelerator at GSI. Evaporation residues were separated with SHIP velocity filter and implanted in 16 strip Si detector. HPGe detector of four crystals and particle detectors. Measured Eγ, Iγ, (evaporation residues)$\gamma\alpha$ correlations.

^{213}Th Levels

E(level)†	J$^\pi$	$T_{1/2}$	Comments
0	5/2$^-$		J$^\pi$: From Adopted Levels. Production σ=0.5 μb at 55-MeV excitation energy (2007Kh22).
799 *1*	(9/2)$^-$		J$^\pi$: 381γ M2 from (13/2)$^+$.
1180.0 *14*	(13/2)$^+$	1.3 μs *3*	$T_{1/2}$: Weighted average of measured values: 1.0 μs *4* – X-ray(t), 1.7 μs *6* – 381γ(t), 2.4 μs *16* – 799γ(t) in 2007Kh22. 2007Kh22 report the weighted average value of 1.4 μs *4*. J$^\pi$: Proposed by 2007Kh22 in analogy of 13/2$^+$ isomeric states in ^{205}Po, ^{207}Po, ^{209}Rn, and ^{211}Ra. Production σ=0.16 μb *11* and 0.5 μb *3* at 47- and 55-MeV excitation energy, respectively (2007Kh22).

† From Eγ.

γ(^{213}Th)

I(K x ray)=121 *24* (2007Kh22).

E$_\gamma$	I$_\gamma$	E$_i$(level)	J$_i^\pi$	E$_f$	J$_f^\pi$	Mult.	Comments
381 *1*	100	1180.0	(13/2)$^+$	799	(9/2)$^-$	M2	Mult.: from α(exp)=0.77 *29* (2007Kh22) deduced from intensity balance at 799 level.
799 *1*	177 *29*	799	(9/2)$^-$	0	5/2$^-$		

^{176}Hf(^{40}Ar,3nγ) 2021Zh24

^{40}Ar beam, E=183, 190 MeV, from Sector-Focusing Cyclotron (SFC) of HIRFL-Lanzhou facility. Enriched target (84.6%) in ^{176}Hf. Evaporation residues (ERs) were separated using the SHANS gas-filled recoil separator, and implanted into three position-sensitive silicon strip detectors (PSSDs). Two multi-wire proportional counters (MWPCs) and two HPGe detectors. Measured half-life of the $13/2^+$ isomer. Shell model calculations.

^{213}Th Levels

E(level)†	J^{π}‡	$T_{1/2}$	Comments
0	$5/2^-$		
799 *1*	$(9/2^-)$		
1180 *1*	$(13/2^+)$	8.30 μs *82*	%IT=100 $T_{1/2}$: from (381γ+799γ)(t) (2021Zh24). For individual γ(t): 9.56 μs *174* – γ(381)(t) and 8.80 μs *140* – γ(799)(t) (2021Zh24).

† From Eγ.

‡ From Adopted Levels. Same assignments are listed in 2021Zh24 without parentheses. References or arguments were not listed/mentioned.

γ(^{213}Th)

E_{γ}	E_i(level)	J^{π}_i	E_f	J^{π}_f
381 *1*	1180	$(13/2^+)$	799	$(9/2^-)$
799 *1*	799	$(9/2^-)$	0	$5/2^-$

Adopted Levels

S(n)=1.001×10^4 *10*; S(p)=−250 *60*; Q(α)=8384 *12* 2021Wa16

^{150}Er(^{51}V,X), E=5.2-5.6 MeV/nucleon; measured Eα, Iα, αα correlation (1995Ni05). The production cross sections for ^{213}Pa were measured to be 100 pb *50* and 200 pb *100* at the beam energies of 5.4 A-MeV and 5.6 A-MeV, respectively.

^{213}Pa Levels

E(level)	J^π	$T_{1/2}$	Comments
0	9/2−	5.3 ms *+40−16*	%α=100 J^π: Based on favored α-decay chain from ^{213}Pa g.s. to g.s. of ^{209}Ac, J^π=9/2−, to g.s. of ^{205}At, J^π=9/2− (firm J^π=9/2−(^{205}At) in 2020Ko17). Configuration: π ($h^{+1}_{9/2}$). $T_{1/2}$: Weighted average of 5.3 ms *+40−16* (1995Ni05 − from measured time intervals between implantation of evaporation residue (ER) and the first α-decay − also in 2000He17 and 1996An21 − same research group of 1995Ni05) and 4.9 ms *+59−18* (2020Au04 − extracted with the exact maximum likelihood method of three correlated α decay chains). Uncertainty is the lower input value. Eα: 8236 keV *20*, 8236 keV *15*, and 8236 keV *15* reported in 1995Ni05, 1996An21, and 2000He17, respectively, all from the same group. 8210 keV *20* in 2020Au04. Proton decay is allowed for S(p)=−250 *60*, However, 2020Au04 noted − proton emission was found unlikely.

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