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Nuclear Data Sheets for A = 215,219,223,227*

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Abstract: This publication presents evaluated spectroscopic data and corresponding level schemes from radioactive decay and nuclear reaction studies for all nuclei with mass numbers A=215, 219, 223, and 227.

Nuclei with mass number A=215 have spherical shape, and their nuclear structure has been interpreted in terms of the shell model. Nuclei with mass number A=219 belong to a transitional region, with spherical, quadrupole, and possibly, octupole deformations, and those with mass numbers A=223 and 227, to newly studied regions of deformations (pure quadrupole coexisting with possible octupole). Because deformations are small in these regions, nuclear states are no longer fully characterized by single Nilsson orbitals. This terminology, however, is used throughout this evaluation to label states rather than to accurately describe their nature.

Highlights of this publication include the emission of ^{14}C by ^{223}Ra, discovered by Rose and Jones (84Ro30), and its fine structure, measured by Brillard et al. (89Br34). This constitutes a new mode of decay and provides additional arguments for configuration assignments. They further include the first set of nuclear levels in ^{215}Fr, ^{215}Ra, and ^{215}Ac, determined from in-beam γ-ray spectroscopic measurements.

Two major publications have been extensively used in this evaluation: the theoretical paper "Reflection-asymmetric Rotor Model of Odd-A ≈219-229 Nuclei" by Leander and Chen (88Le13), which presents a calculation of single-particle state properties by the coupling of shell-model states to a reflection-asymmetric rotor core; and the review paper "Intrinsic States of Deformed Odd-A Nuclei in the Mass Regions (151≤A≤193) and (A≥221)" by Jain et al. (90Ja11), which gives the systematics and assignments of single-particle states in such mass regions.

These evaluations for A=215, 219, 223, and 227 supersede the earlier ones by C. Maples: 77Ma29, *Nuclear Data Sheets* **22**, 207 (1977); 77Ma30, *Nuclear Data Sheets* **22**, 223 (1977); 77Ma31, *Nuclear Data Sheets* **22**, 243 (1977); and 77Ma32, *Nuclear Data Sheets* **22**, 275 (1977).

Cutoff Date: All data received by August 1990 have been evaluated.

General Policies and Organization of Material: See the January issue of Nuclear Data Sheets.

Acknowledgments: The evaluator is grateful to Ch. Briancon, G. D. Jones, G. Ardisson, and H. L. Hall, for making available their unpublished data on A=223. He is also indebted to I. Ahmad for enlightening discussions regarding the α decay of ^{227}Pa.

General Comments: The analysis of γ-ray data is described in detail in 86BrZQ. γ-ray energies given by various authors are fit to a level scheme for each data set through a weighted least-squares analysis. The corresponding intensities are assumed to be linearly related, and the scales are adjusted using the methods of Tepel (80TeZW) and Lederer (82LeZJ). A similar procedure is followed for summary data sets of adopted levels and gammas, encompassing γ-ray data from both radioactive decay and reaction measurements. A statistical analysis is performed and data uncertainties are increased when necessary to minimize X^2. These calculations are done with the computer code GAMUT (84FiZU). Uncertainties of absolute γ-ray intensities are calculated using the method of Browne (86Br21); multipole mixing ratios from internal conversion data are deduced using the minimization method and computer code of Rysavy, et al. (80Ry04).

Throughout this evaluation, rotational band parameters are from 90Ja11.

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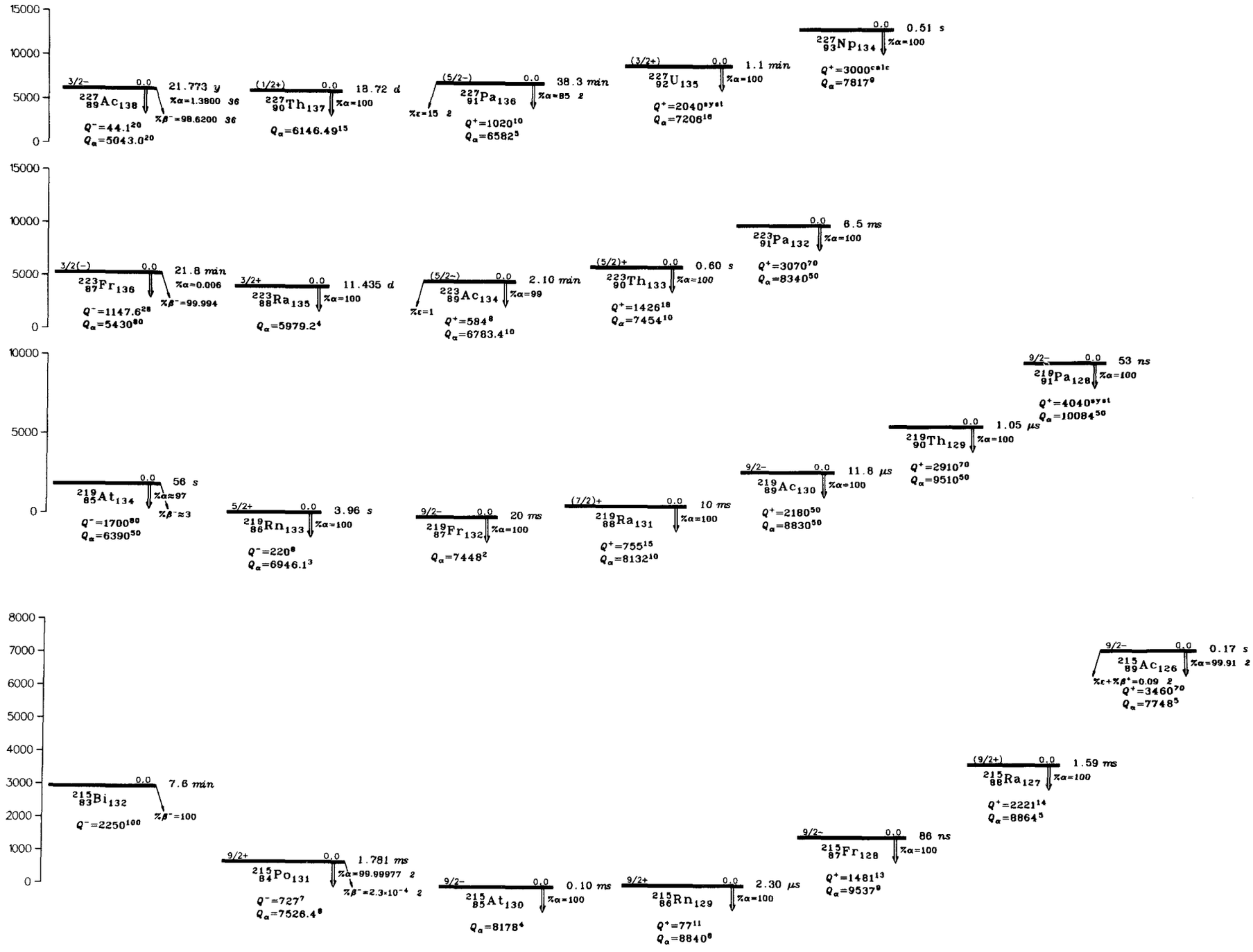
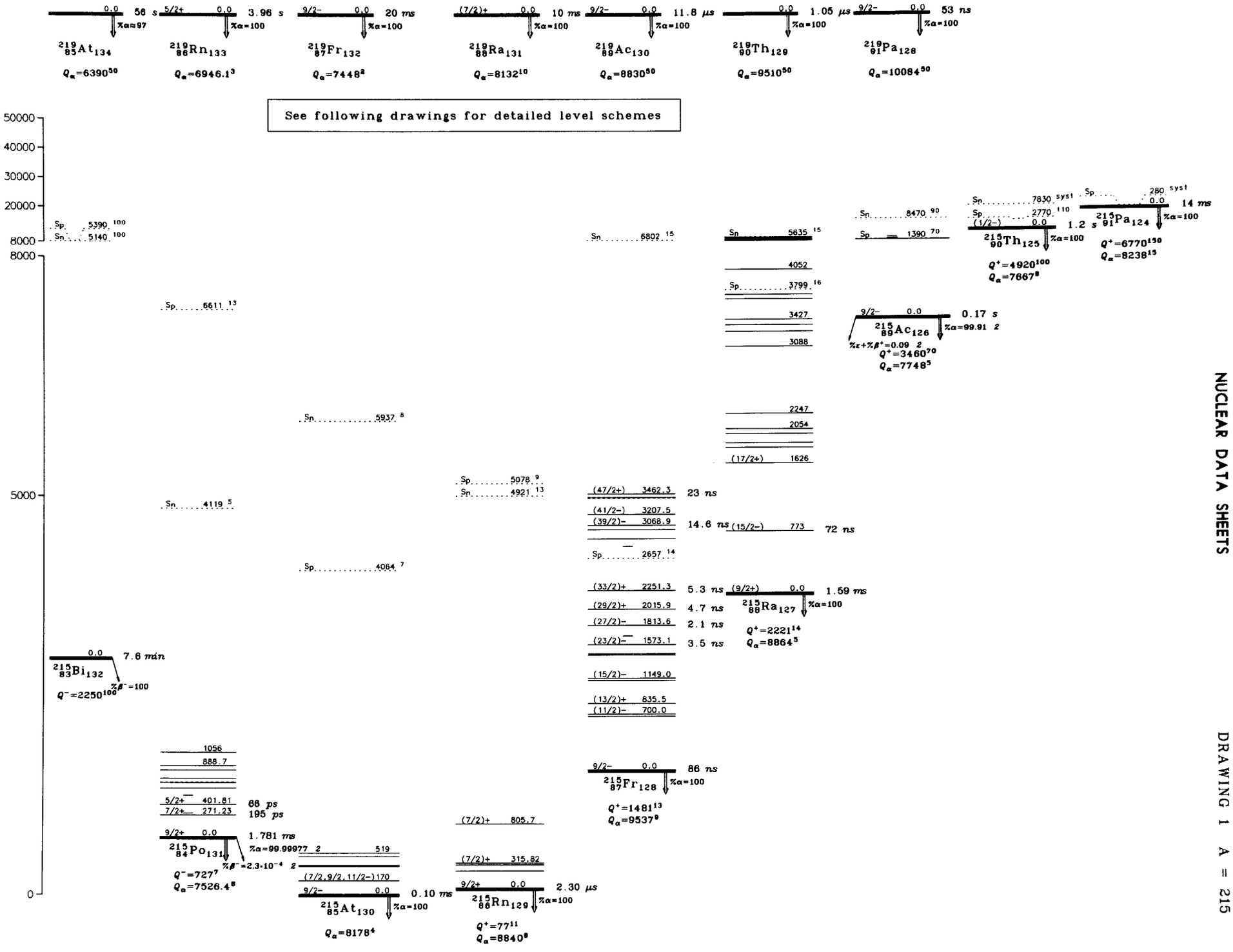
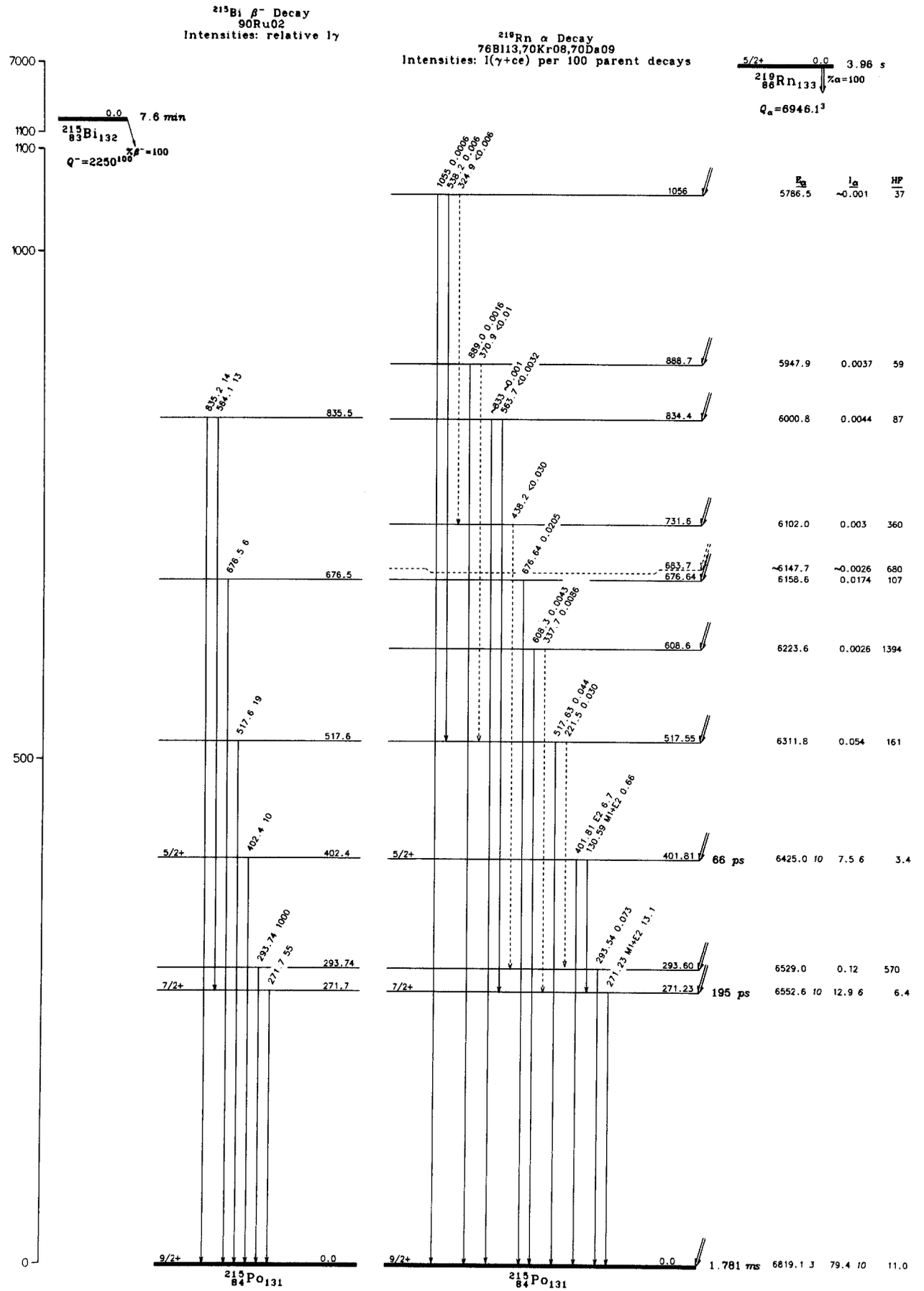
α decay chain from A=227–215



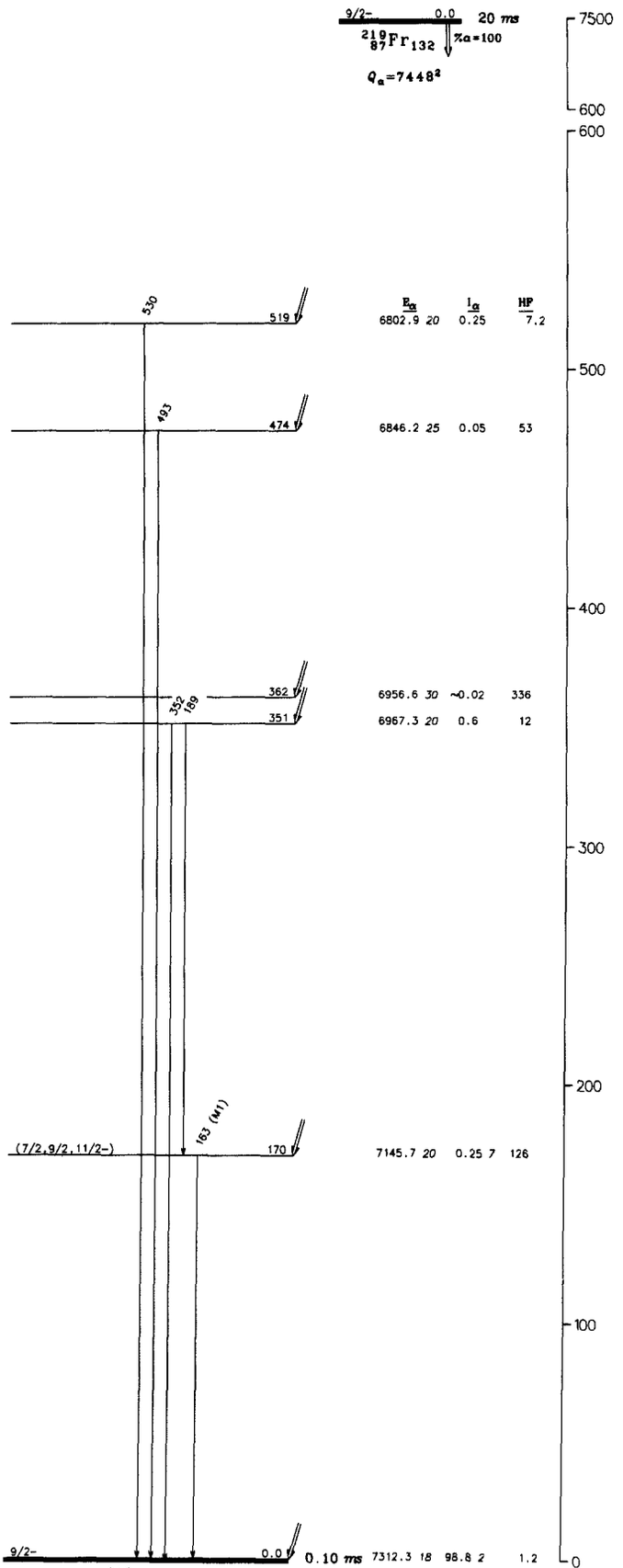
Index for A = 215

Nuclide	Data Type	Drawings: Levels	Drawings: Radiations	Tables: Levels	Tables: Radiations
	Skeleton Scheme for A = 215	673			
^{215}Bi	Adopted Levels	673		680	
	^{219}At α Decay				680
^{215}Po	Adopted Levels, Gammas	673		681	681
	^{215}Po α Decay				682
	^{215}Bi β$^-$ Decay	674	674	682	680
	^{219}Rn α Decay	674	674	682	682
^{215}At	Adopted Levels, Gammas	673		685	685
	^{215}At α Decay				685
	^{219}Fr α Decay	675	675	686	686
^{215}Rn	Adopted Levels, Gammas	673		687	687
	^{215}Rn α Decay				687
	^{219}Ra α Decay	676	676	687	688
^{215}Fr	Adopted Levels, Gammas	673		689	690
	^{215}Fr α Decay				691
	^{208}Pb(^{11}B,4nγ)	677	677	692	692
	^{219}Ac α Decay	677	677	691	691
^{215}Ra	Adopted Levels, Gammas	673		694	695
	^{215}Ra α Decay				695
	^{208}Pb(^{13}C,6nγ)	678	678	696	696
	^{219}Th α Decay	678	678	695	695
^{215}Ac	Adopted Levels, Gammas	673		697	697
	^{215}Ac α Decay				697
	^{204}Pb(^{15}N,4nγ)	679	679	698	698
	^{219}Pa α Decay	679	679	698	698
^{215}Th	Adopted Levels	673		699	
	^{215}Th α Decay				699
^{215}Pa	Adopted Levels	673		699	

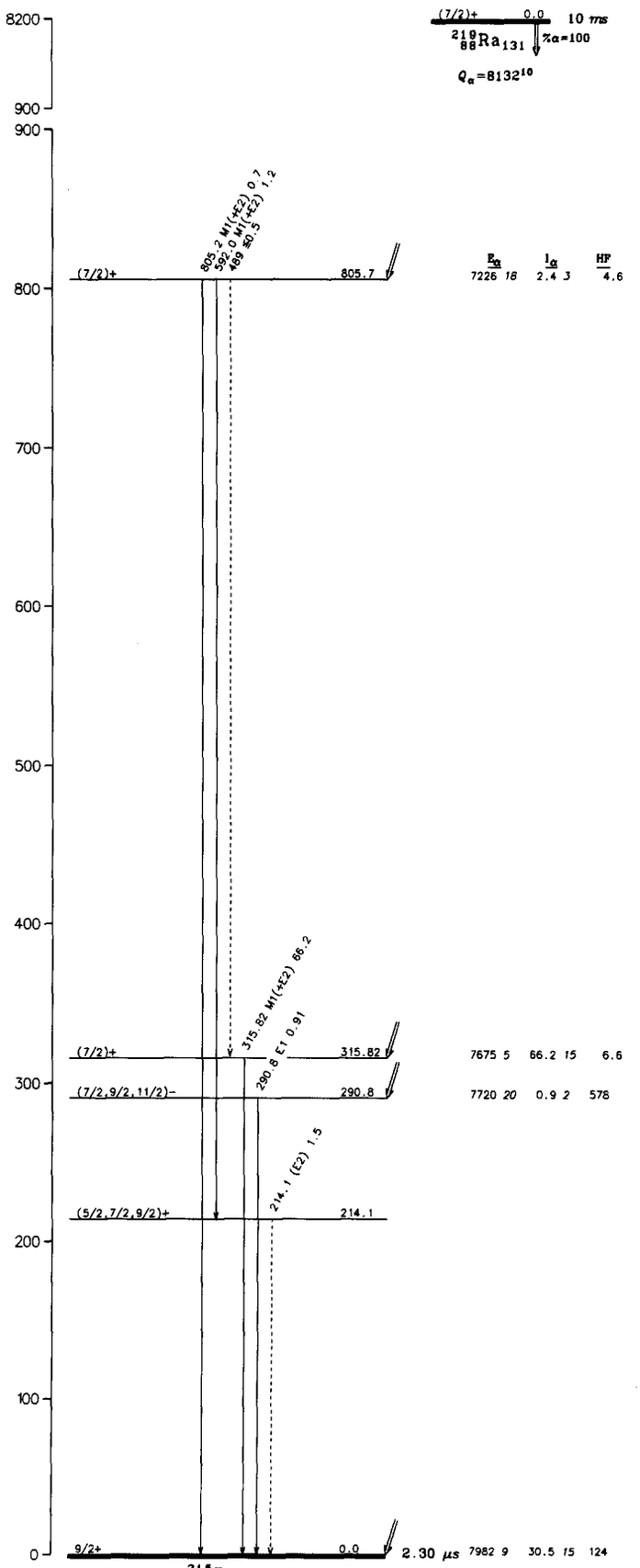

See following drawings for detailed level schemes
$^{219}_{85}At_{134}$ Q_α=6390 50
$^{219}_{86}Rn_{133}$ Q_α=6946.1 3
$^{219}_{87}Fr_{132}$ Q_α=7448 2
$^{219}_{88}Ra_{131}$ Q_α=8132 10
$^{219}_{89}Ac_{130}$ Q_α=8830 50
$^{219}_{90}Th_{129}$ Q_α=9510 50
$^{219}_{91}Pa_{128}$ Q_α=10084 50
$^{215}_{83}Bi_{132}$ 7.6 min
Q^-=2250 100
$^{215}_{84}Po_{131}$ 1.781 ms
Q^-=727 7
Q_α=7526.4 8
$^{215}_{85}At_{130}$ 0.10 ms
Q_α=8178 4
$^{215}_{86}Rn_{129}$ 2.30 μs
Q^+=7711
Q_α=8840 8
$^{215}_{87}Fr_{128}$ 86 ns
Q^+=1481 13
Q_α=9537 9
$^{215}_{88}Ra_{127}$ 1.59 ms
Q^+=2221 14
Q_α=8864 5
$^{215}_{89}Ac_{126}$ 0.17 s
Q^+=3460 70
Q_α=7748 5
$^{215}_{90}Th_{125}$ 1.2 s
Q^+=4920 100
Q_α=7667 8
$^{215}_{91}Pa_{124}$ 14 ms
Q^+=6770 150
Q_α=8238 15


215Bi β- Decay
90Ru02
Intensities: relative Iγ
218Rn α Decay
76Bl13,70Kr08,70Da09
Intensities: I(γ+ce) per 100 parent decays
5/2+ 0.0 3.96 s
219 86Rn133 %α=100
Qα=6946.13
0.0 7.6 min
215 83Bi132 %β-=100
Q-=2250100
7000
1100
1100
1000
500
0
1056
888.7
835.5
834.4
731.6
683.7
676.64
676.5
608.6
517.55
517.6
402.4
401.81
293.60
293.74
271.23
271.7
0.0
9/2+
7/2+
5/2+
66 ps
195 ps
1.781 ms
215 84Po131
215 84Po131
Eα Iα HP
5786.5 ~0.001 37
5947.9 0.0037 59
6000.8 0.0044 87
6102.0 0.003 360
~6147.7 ~0.0026 680
6158.6 0.0174 107
6223.6 0.0026 1394
6311.8 0.054 161
6425.0 10 7.5 6 3.4
6529.0 0.12 570
6552.6 10 12.9 6 6.4
6819.1 3 79.4 10 11.0

^{219}Fr α Decay
68Ba73,66Gr07,82Bo04

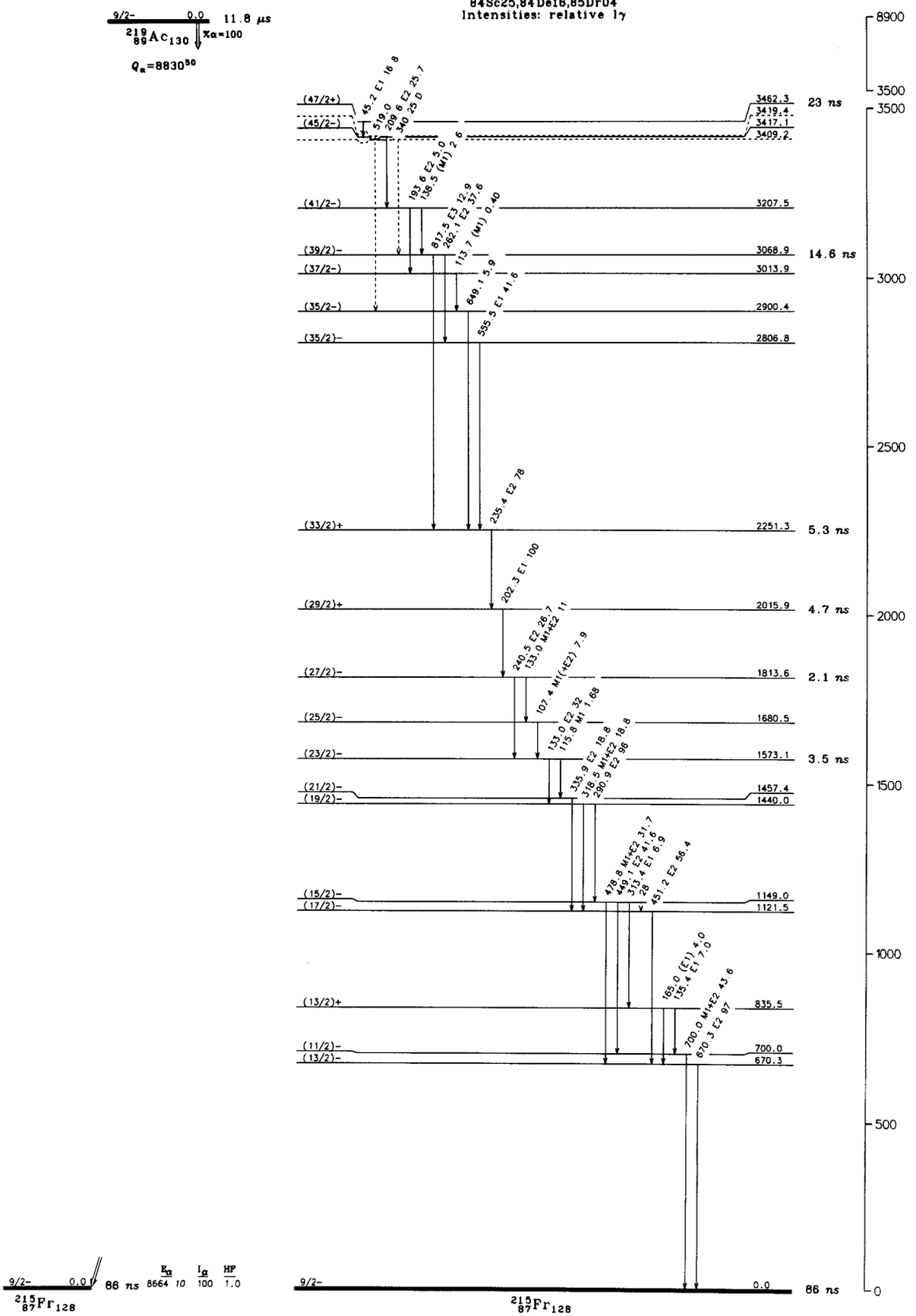


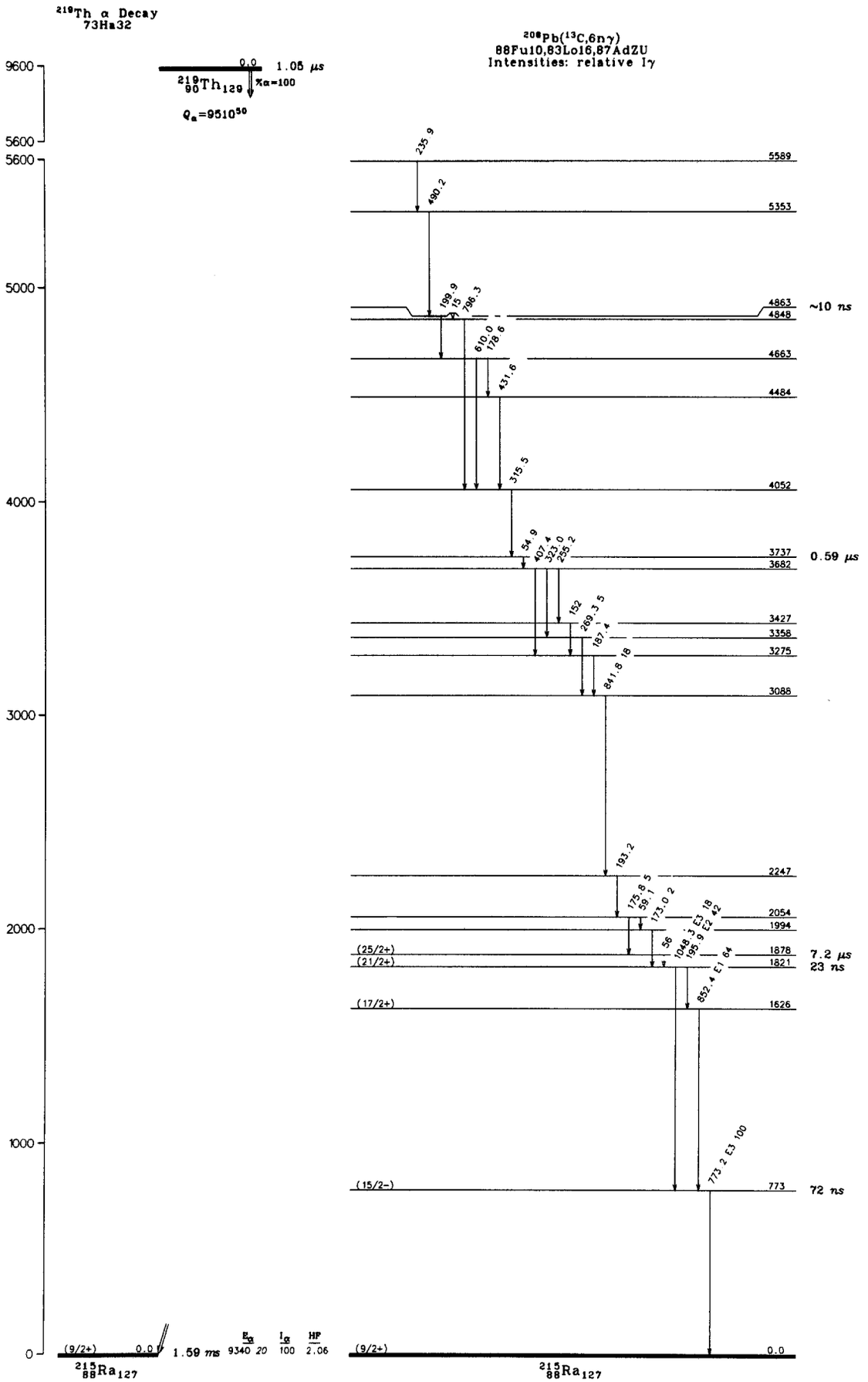
^{219}Ra α Decay
87El02,70Va13,69Ha32
Intensities: I(γ+ce) per 100 parent decays

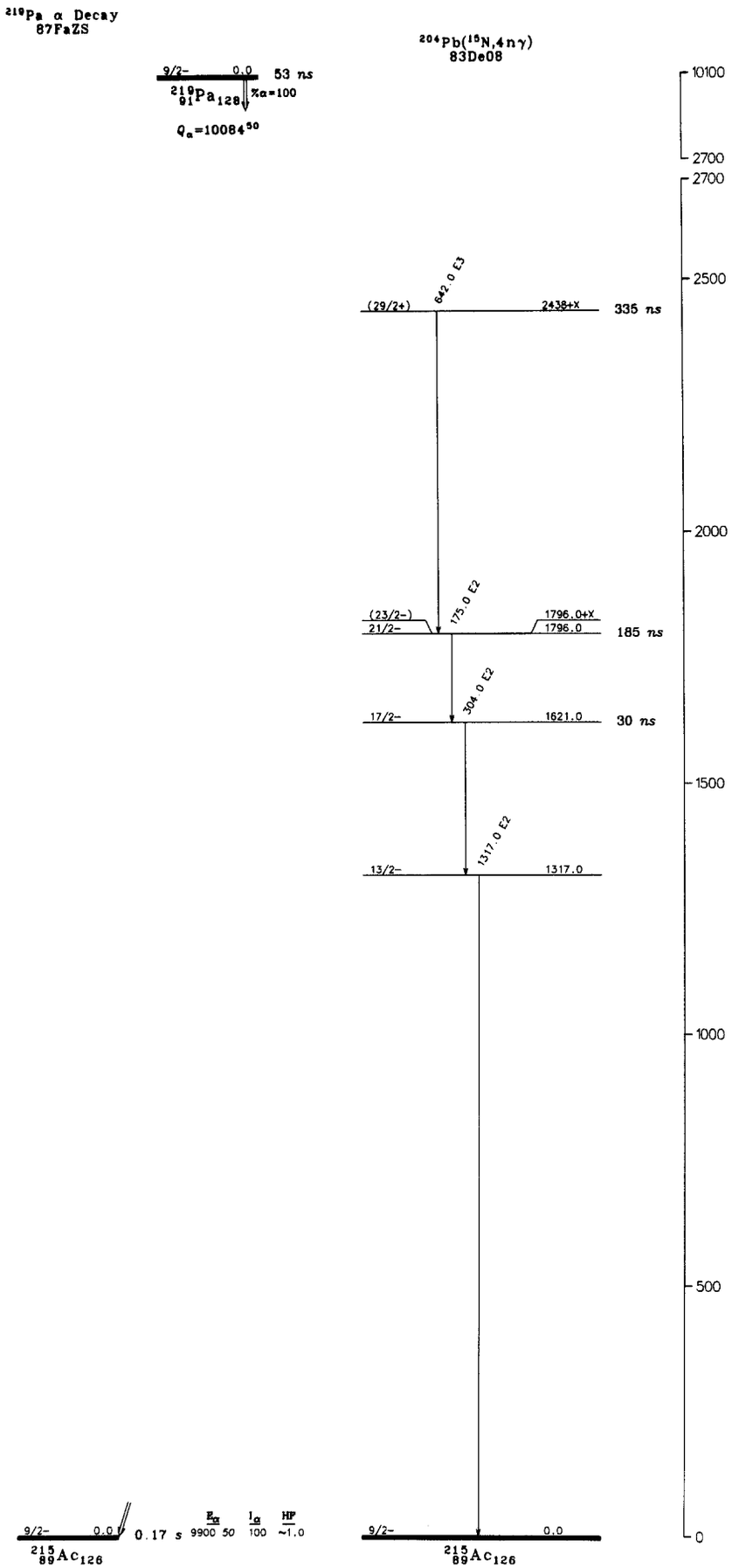


^{219}Ac α Decay
70Bo13,89Mi17

^{208}Pb(^{11}B,4nγ)
84Sc25,84De16,85Dr04
Intensities: relative Iγ




219Th α Decay
73Ha32
0.0 1.05 μs
219 90Th129 %α=100
Qα=9510 50
208Pb(13C,6nγ)
88Fu10,83Lo16,87AdZU
Intensities: relative Iγ
9600
5600
5000
4000
3000
2000
1000
0
235.9
490.2
199.9 15
786.3
610.0
178.6
431.6
315.5
54.9
407.4
323.0
255.2
152
269.3 5
187.4
841.8 18
193.2
175.8 5
59.1
173.0 2
56
1048.3 E3 18
195.9 E2 42
852.4 E1 64
773.2 E3 100
5589
5353
4863
4848
~10 ns
4663
4484
4052
3737
3682
0.59 μs
3427
3358
3275
3088
2247
2054
1994
(25/2+)
(21/2+)
1878
1821
7.2 μs
23 ns
(17/2+)
1626
(15/2-)
773
72 ns
(9/2+) 0.0
1.59 ms
Eα Iα HF
9340 20 100 2.06
215 88Ra127
(9/2+) 0.0
215 88Ra127


219Pa α Decay
87FaZS
9/2- 0.0 53 ns
219 91Pa128 %α=100
Qα=10084 50
204Pb(15N,4nγ)
83De08
10100
2700
2700
642.0 E3
(29/2+) 2438+X 335 ns
2500
2000
175.0 E2
(23/2-) 1796.0+X
21/2- 1796.0 185 ns
304.0 E2
17/2- 1621.0 30 ns
1500
1317.0 E2
13/2- 1317.0
1000
500
0
9/2- 0.0 0.17 s
Eα Iα HP
9900 50 100 ~1.0
215 89Ac126
9/2- 0.0
215 89Ac126

^{215}Bi Adopted Levels

Q(β^-)=2250 *100*; S(n)=5140 *100*; S(p)=5390 *100*; Q(α)≈5200 85Wa02.
Q(α): estimated by evaluator from 85Wa02.
Descendant of ^{227}Ac (53Hy83,65Nu03). Parent of ^{215}Po (53Hy83).
Source produced by spallation of 200-MeV protons on targets of ^{232}Th. ^{215}Bi activity was identified by mass separation and by the observation of known γ rays in the daughter nucleus ^{215}Po (90Ru02).

E(level)	$T_{1/2}$	Comments
0.0	7.6 min *2*	$T_{1/2}$: weighted average of 7.7 min *2* (90Ru02), 7.5 min *4* (89Bu09), and 7.4 min *6* (65Nu03). Other value: 8 min *2* (53Hy83). %β^-=100. β^- particles were detected in a 4π plastic scintillator (90Ru02). β^- decay had been previously inferred by measurements of the α decay of the ^{215}Po daughter nucleus (53Hy83). %α≈8.×10^{-5} from Q(α) systematics.

$\gamma(^{215}Po)$ from ^{215}Bi β^- Decay 90Ru02

^{215}Bi mass-separated source produced by spallation of 200-MeV protons on targets of ^{232}Th. Measured Eγ, Iγ, $\gamma\gamma$ coin, $\beta\gamma$ coin. Detectors: 4π plastic scintillator, Ge(Li).
β^- feeding to ^{215}Po g.s. has not been determined, so the decay scheme normalization was not deduced.

Eγ‡	E(level)	Iγ
271.7† *1*	271.7	55 *5*
293.74† *5*	293.74	1000 *70*
402.4 *3*	402.4	10 *4*
517.6 *2*	517.6	19 *3*
564.1 *3*	835.5	13 *3*
676.5 *3*	676.5	6 *2*
835.2 *3*	835.5	14 *3*

† Assignment of this transition to ^{215}Bi β^- decay is confirmed by its coincidence with Po x rays, and also by its decay rate, which is consistent with a half-life of 7.7 min for ^{215}Bi.
‡ All γ-ray transitions given here have been previously observed in the α decay of ^{219}Rn.

α radiations from ^{219}At α Decay 53Hy83

Measured Eα. Detector: ion chamber.

Eα	Iα†	Comments
6275 *50*	100	Eα: original energy of 53Hy83 has been increased by 5 keV because of a change in the calibration energy of ^{211}Bi α particles from 6618 and 6272 keV to 6622.9 and 6278.2 keV, respectively (91Ry01).

† For α intensity per 100 decays, multiply by ≈0.97.

^{215}Po Adopted Levels

Q(β^-)=727 *7*; S(n)=4119 *5*; S(p)=6611 *13*; Q(α)=7526.4 *8* 85Wa02.

Cross Reference (XREF) Flags

A ^{219}Rn α Decay
B ^{215}Bi β^- Decay

E(level)†	Jπ	XREF	$T_{1/2}$	Comments
0.0	9/2+	AB	1.781 ms *4*	$T_{1/2}$: weighted average of 1.778 ms *5* (61Vo06), and 1.784 ms *6* (71Er02). Other value: 1.83 ms *4* (42Wa04). Jπ: favored α decay (HF=1.4) to ^{211}Pb (Jπ=9/2+). Probable configuration=(ν $1g_{9/2}$). %α=99.99977 *2*; %β^-=2.3×10^{-4} *2*. %β^- from 50Av61. Other values: %$\beta^-\approx$5×10^{-4} (44Ka01,44Ka02); %$\beta^-\approx$4×10^{-4} (55Ad09).
271.23 *1*	7/2+	AB	195 ps *15*	$T_{1/2}$: (α)(ce)(t) coin (74Bo11). Other value: <250 ps (69Be67). Jπ: 271.2γ M1+E2 to 9/2+, 130.6γ M1+E2 from 5/2+.
293.60 *4*		AB		
401.81 *1*	5/2+	AB	66 ps *7*	Jπ: favored α decay (HF=3.4) from ^{219}Rn (Jπ=5/2+). $T_{1/2}$: from $T_{1/2}(402)/T_{1/2}(271)$=0.336 *23* (Doppler shift measurement in ^{219}Rn α decay) and using $T_{1/2}$(271)=195 ps *15* (74Bo11).
517.55 *5*		AB		
608.6 *7*		A		
676.64 *7*		AB		
683.7?		A		
731.6 *6*		A		
834.4 *13*		AB		
888.7 *11*		A		
1056 *1*		A		

† From ^{219}Rn α decay.

^{215}Po Adopted γ radiations

E(level)	Eγ†	Iγ†	Mult.†	δ†	α	Comments
271.23	271.23 *1*	100	M1+E2	3.7 *4*	0.210 *6*	B(M1)(W.u.)=0.00032 *7*; B(E2)(W.u.)=19.9 *16*.
293.60	293.54 *4*	100				
401.81	130.59 *3*	1.9 *2*	M1+E2	0.64 *6*	4.55 *12*	B(M1)(W.u.)=0.0017 *3*; B(E2)(W.u.)=14 *3*.
	401.81 *1*	100 *3*	E2		0.0561	B(E2)(W.u.)=9.2 *11*.
517.55	221.5‡ *3*	68 *10*				
	517.63 *6*	100 *5*				
608.6	337.7‡ *10*	100 *25*				
	608.3 *10*	50 *25*				
676.64	676.64 *7*	100				
731.6	438.2‡ *6*	100				
834.4	563.7 *15*					
	≈833					
888.7	370.9‡ *15*					
	889.0 *15*					
1056	324.9‡ *10*	<100				
	538.2 *15*	100 *50*				
	1055 *2*	10 *5*				

† From ^{219}Rn α decay.
‡ Placement of transition in the level scheme is uncertain.

α radiations from ^{215}Po α Decay 62Wa18

Others: 70Da09, 68Br17, 65Va10, 61Ry02.
Branching: %α=99.99977 *2* (50Av61).

Eα	E(level)	Iα†	HF§	Comments
≈6950.1‡	≈447	≈0.022	≈220	
≈6956.7‡	438.8	≈0.034	≈150	
7386.1 *8*	0.0	100	1.4 *1*	Eα: from 71Gr17 (adjusted for change in calibration standard, 91Ry01).

‡ From 62Wa18, 71Gr17.
§ $r_0(^{211}Pb)$=1.542 *4*.
† For α intensity per 100 decays, multiply by 0.9999977 *2*.

γ(^{211}Pb) from ^{215}Po α Decay 62Wa18

Branching: %α=99.99977 *2* (50Av61).

Eγ	E(level)	Iγ†‡	Comments
438.8 *3*	438.8	≈0.04	Eγ,Iγ: from 77Ma29.

‡ Photons per 100 α decays.
† For absolute intensity per 100 decays, multiply by 0.9999977 *2*.

^{215}Po Levels from ^{215}Bi β$^-$ Decay 90Ru02

E(level): from γ-ray energies.
Jπ: from adopted levels.
See drawings for level data.

^{215}Po Levels from ^{219}Rn α Decay 76Bl13,70Kr08,70Da09

E(level): deduced by evaluator from a least-squares fit to γ rays from 76Bl13, 70Kr08, 70Da09, 68Br17, and 67Da20.
Jπ: from adopted levels.
Only levels with $T_{1/2}$ are given; see drawings for other level data.

E(level)	Jπ	$T_{1/2}$	Comments
0.0	9/2+	1.781 ms *4*	$T_{1/2}$: from adopted levels.
271.23 *1*	7/2+	195 ps *15*	$T_{1/2}$: (α)(ce)(t) coin (74Bo11). Other value: <250 ps (69Be67).
401.81 *1*	5/2+	66 ps *7*	$T_{1/2}$: from $T_{1/2}(402)/T_{1/2}(271)$=0.336 *23* (Doppler shift measurement), and $T_{1/2}(271)$=195 ps *15* (74Bo11).

α radiations from ^{219}Rn α Decay 76Bl13,70Kr08,70Da09

α particle energies of 57Pi31 presented in comments have been increased by 3 keV because of a change in the calibration energy of ^{242}Cm (77Ma30).

Eα	E(level)	Iα@	HF#	Comments
5786.5	1056	≈0.001	37	Eα,Iα: from 65Va10. Iα: Iα=0.014 *3*, deduced by evaluator from transition intensity balance.
5947.9§	888.7	0.0037§	59	Originally assigned by 62Wa18 to ^{211}Bi α decay. Reassigned by 65Va10 (on the basis of αγ coin measurements) to ^{219}Rn α decay. Iα: Iα<0.012, deduced by evaluator from transition intensity balance.
6000.8§	834.4	0.0044§	87	Iα: Iα<0.004, deduced by evaluator from transition intensity balance.

Continued on next page (footnotes at end of table)

α radiations from ^{219}Rn α Decay 76Bl13,70Kr08,70Da09 (continued)

Eα	E(level)	Iα@	HF#	Comments
6102.0§	731.6	0.003§	360	Iα: Iα<0.03, deduced by evaluator from transition intensity balance.
≈6147.7§&	683.7?	≈0.0026§	680	65Va10 suggest this α-particle group may belong to ^{211}Bi.
6158.6§	676.64	0.0174§	107	Iα: Iα=0.020 *2*, deduced by evaluator from transition intensity balance.
6223.6§	608.6	0.0026§	1394	Iα: Iα=0.013 *3*, deduced by evaluator from transition intensity balance.
6311.8§	517.55	0.054§	161	Iα: Iα=0.057 *6*, deduced by evaluator from transition intensity balance.
6425.0† *10*	401.81	7.5‡ *6*	3.4	Other value: Iα=7.5 *5* (62Gi04). Eα=6423.9 (61Ry02). Eα=6422, Iα=5 (57Pi31,77Ma30). Iα: Iα=7.4 *2*, deduced by evaluator from transition intensity balance.
6529.0§	293.60	0.12§	570	
6552.6† *10*	271.23	12.9‡ *6*	6.4	Eα=6552.8 (62Wa18,77Ma30). Iα=12.9 *6* (62Gi04). Eα=6550.9 (61Ry02). Eα=6550, Iα=13 (57Pi31,77Ma30). Iα: Iα=12.4 *4*, deduced by evaluator from transition intensity balance.
6819.1† *3*	0.0	79.4‡ *10*	11.0	Other values: Eα=6819.0 (62Wa18,77Ma30). Iα=79.6 *10* (62Gi04). Eα=6817.6 *10* (61Ry02). Eα=6816 *2*, Iα=82 (57Pi31,77Ma30). Iα: Iα=80.1 *12*, deduced by evaluator from transition intensity balance.

† From 71Gr17, detector: magnetic spectrometer. Adjusted value recommended by 91Ry01.
‡ From 62Wa18, detector: magnetic spectrograph. Adjusted value recommended by 91Ry01.
§ From 62Wa18, detector: magnetic spectrograph. Original Eα values have been increased by evaluator an average of 1.5 keV because of changes in the calibration energies of ^{215}Po and ^{211}Bi (77Ma30).
# Using $r_0(^{215}Po)$=1.556, from adjacent even-even nuclei.
& Existence of this branch is questionable.
@ For α intensity per 100 decays, multiply by 1.0.

γ(^{215}Po) from ^{219}Rn α Decay 76Bl13,70Kr08,70Da09

76Bl13: precise measurement of Eγ, Iγ. Detector: Ge(Li).
70Kr08: measured Eγ, Iγ, αγ(θ), αγ(lin pol, θ), Ice. Detectors: Ge(Li), magnetic spectrometer.
70Da09: measured Eγ, Iγ, γγ coin, Ice. Detectors: Ge(Li), scint, magnetic spectrometer.
68Br17, 67Da20: measured Eγ, Iγ. Detector: Ge(Li).
Others: 72HeYM, 69Be67, 66Po02, 65Va10, 57Pa07, 57Pi31.
For αγ(θ) measurements see: 72HeYM, 70Kr08, 70Da09, 69Be67, 67Le05, 65Cl05, and 61Br32.
For αγ linear polarization correlations and γγ(θ) measurements see 70Kr08.
Iγ normalization: from Iγ(271γ, ^{219}Rn)/Iγ(269γ, ^{223}Ra)=0.786 *42*, measured from a ^{223}Ra source with ^{219}Rn in equilibrium (76Bl13), and using %Iγ(269γ, ^{223}Ra)=13.7 *2* (see ^{223}Ra α decay). The excellent agreement of the α-particle abundances to the g.s., 271, and 402 levels (deduced from transition intensity balances) with values measured directly confirm the quality of the γ-ray data and that of the decay scheme normalization.

Eγ†	E(level)	Iγ†‡	Mult.	δ	α	Comments
130.59 *3*	401.81 *1*	1.1 *1*	M1+E2	0.64 *6*	4.55 *12*	Others: 68Br17, 65Va10. Mult.,δ: from ce(L1)/ce(L2) exp=2.4 *5* and ce(L1)/ce(L3) exp=2.8 *4* (70Da09).
221.5§ *3*	517.55 *5*	0.28 *4*				This γ ray has been assigned by 68Br17 and 70Kr08 to the decay of ^{223}Ra, and by 70Da09 to the decay of ^{219}Rn (77Ma30).

Continued on next page (footnotes at end of table)

γ(^{215}Po) from ^{219}Rn α Decay 76Bl13,70Kr08,70Da09 (continued)

Eγ†	E(level)	Iγ†‡	Mult.	δ	α	Comments
271.23 *1*	271.23 *1*	100 *3*	M1+E2	3.7 *4*	0.210 *6*	Mult.,δ: from ce(L1)/ce(L2) exp=0.516 *47*, ce(L1)/ce(L3) exp=1.035 *92* (70Da09), and ce(K):ce(L1):ce(L2):ce(L3) exp=30.6 *9*:4.5:8.3 *5*:3.6 *9* (72HeYM). Other values: α(K)exp=0.107 *16*, α(L3)exp=0.016 *5*, ce(L3)/ce(L1)+ce(L2) exp=0.40 *6* (70Kr08). Other values: Eγ=271.6, Iγ=87 (57Pi31), Eγ=268, Iγ=11.0 (57Pa07). Other: 66Po02.
293.54 *4*	293.60 *4*	0.68 *4*				
324.9§ *10*	1056 *1*	<0.06				Eγ,Iγ: from 67Da20.
337.7§ *10*	608.6 *7*	0.08 *2*				
370.9§ *15*	888.7 *11*	<0.1				Eγ,Iγ: from 67Da20. Other value: Iγ≈0.02 (65Va10).
x380		≈0.0003				γ ray is uncertain (65Va10).
401.81 *1*	401.81 *1*	59 *2*	E2		0.0561	Other values: Eγ=401, Iγ=77 (66Po02); Eγ=400.6, Iγ=48 (57Pi31). Others: 65Va10, 57Pa07. Mult.: from α(K)exp=0.027 *12* and ce(K)/ce(L3) exp=7 *2* (70Kr08).
438.2§ *6*	731.6 *6*	<0.28				Eγ,Iγ: from 67Da20. Other value: Eγ=438.7 *3*, Iγ=0.48 *5* (68Br17). 68Br17 assigned this transition to the decay of ^{215}Po. 67Da20 suggested (on the basis of αγ-coin results of 65Va10) that the contribution from ^{215}Po decay is 0.26≤Iγ≤0.44, which establishes an upper limit of Iγ≈0.28 from ^{219}Rn decay (77Ma30).
517.63 *6*	517.55 *5*	0.41 *2*				Eγ,Iγ: Eγ=516.5 *5*, Iγ=0.22 *5* (70Da09) were not included in the input for averaging. Other: 65Va10.
538.2 *15*	1056 *1*	0.06 *3*				Eγ,Iγ: from 67Da20. Other value: Iγ≈0.003 (65Va10).
563.7 *15*	834.4 *13*	<0.030				Eγ,Iγ: from (67Da20). Other value: Iγ≈0.02 (65Va10).
608.3 *10*	608.6 *7*	0.04 *2*				Other value: Iγ≈0.026 (65Va10).
676.64 *7*	676.64 *7*	0.19 *2*				Other value: Iγ≈0.1 (65Va10).
≈833	834.4 *13*	≈0.01				Eγ,Iγ: from 65Va10.
889.0 *15*	888.7 *11*	0.015 *7*				Eγ,Iγ: from 67Da20. Other value: Iγ≈0.01 (65Va10).
1055 *2*	1056 *1*	0.006 *3*				Eγ,Iγ: from 67Da20. Other value: Iγ≈0.003 (65Va10).

† Weighted average from 76Bl13, 70Kr08, 70Da09, 68Br17, and 67Da20. The most precise γ-ray energies are from 76Bl13, which dominate the weighted average.
§ Placement of transition in the level scheme is uncertain.
‡ For absolute intensity per 100 decays, multiply by 0.108 *6*.
x γ ray not placed in level scheme.

^{215}At Adopted Levels

Q(β^-)=-77 *11*; S(n)=5937 *8*; S(p)=4064 *7*; Q(α)=8178 *4* 85Wa02.

Cross Reference (XREF) Flags

A ^{219}Fr α Decay

E(level)†	Jπ	XREF	$T_{1/2}$	Comments
0.0	9/2-	A	0.10 ms *2*	%α=100. $T_{1/2}$: from 51Me10. Jπ: favored α decay (HF=2.7) to ^{211}Bi g.s. (Jπ=9/2-).
170 *2*	(7/2,9/2,11/2-)	A		Jπ: 163γ (M1) to 9/2-.
351 *2*		A		
362 *3*		A		
474 *3*		A		
519 *2*		A		

† Level energies deduced from α-particle energies (68Ba73) disagree with those deduced from γ-ray energies (66Gr07) by ≈10 keV. The reason for this inconsistency is unknown. A possible explanation would be that the 7312α populates a level at ≈10 keV rather than the g.s. (77Ma30). Level energies in ^{215}At then would be: 0, 11, 363, 493, and 530.

^{215}At Adopted γ radiations

E(level)	Eγ†	Mult.
170	163	(M1)
351	189	
	352	
474	493	
519	530	

† From 66Gr07.

α radiations from ^{215}At α Decay 82Bo04,66Gr07

Other: 51Me10.
All data are from 66Gr07, unless otherwise noted.

Eα	E(level)	Iα†	HF‡	Comments
7610 *10*	408	0.05 *2*	440 *220*	Iα: from $\alpha\gamma$.
8026 *4*	0.0	99.95 *2*	3.3 *9*	Eα: from 82Bo04, value recommended by 91Ry01. Iα: value recommended by 91Ry01.

‡ $r_0(^{211}Bi)$=1.552 *9*.
† For α intensity per 100 decays, multiply by 1.0.

$\gamma(^{211}$Bi) from ^{215}At α Decay 82Bo04,66Gr07

Eγ	E(level)	Comments
≈404	408	Eγ: from $\alpha\gamma$.

^{215}At Levels from ^{219}Fr α Decay 68Ba73,66Gr07,82Bo04

^{219}Fr source: descendant of ^{227}Pa. See adopted levels for a comment regarding the disagreement between level energies and γ-ray energies.
68Ba73: measured Eα, Iα. Detector: magnetic spectrograph.
66Gr07: measured Eα, Iα, Eγ, αγ coin. Detectors: semi, scint.
82Bo04: ^{219}Fr source produced by spallation of 5-GeV protons on targets of U and Th. Measured Eα, Iα. Detectors: semi.
Jπ: from adopted levels.
E(level): from Eα.
See drawings for level data.

α radiations from ^{219}Fr α Decay 68Ba73,66Gr07,82Bo04

66Gr07 did not report standard sources used for energy calibration.

Eα‡	E(level)	Iα‡§	HF†	Comments
6802.9 *20*	519	0.25	7.2	Other value: Eα=6780 *10*, value deduced by 77Ma30 from an α spectrum presented in 66Gr07. Original Eα=6680 is probably a typographical error. Iα=0.3 *1* (66Gr07).
6846.2 *25*	474	0.05	53	Other value: Eα=6820 *10*; value deduced by 77Ma30 from an α spectrum presented in 66Gr07. Original Eα=6720 is probably a typographical error. Iα=0.2 *1* (66Gr07).
6956.6 *30*	362	≈0.02	336	
6967.3 *20*	351	0.6	12	Other values: Eα=6950 *10*, Iα(6967α + 6957α)=0.8 *1* (66Gr07).
7145.7 *20*	170	0.25 *7*	126	Iα: weighted average of 0.3 *1* (66Gr07) and 0.2 *1* (68Ba73,77Ma30). Eα: other value: 7140 *10* (66Gr07).
7312.3 *18*	0.0	98.8 *2*	1.2	Eα: value adjusted from Eα=7312.2 *20* (68Ba73) and Eα=7317 *4* (82Bo04), and recommended by 91Ry01. Other values: Eα=7300 *10*, Iα=98.4 (66Gr07); Eα=7307 *20*, energy has been increased by 7 keV to account for changes in calibration energies (51Me10,77Ma30). Iα: from 91Ry01.

† Using $r_0(^{215}At)$=1.568, from adjacent even-even nuclei.
‡ From 68Ba73, unless otherwise specified.
§ For α intensity per 100 decays, multiply by 1.0.

γ(^{215}At) from ^{219}Fr α Decay 68Ba73,66Gr07,82Bo04

Eγ†	E(level)	Mult.	Comments
163	170 *2*	(M1)	Mult.: from α(K)exp≈2, deduced from K x ray measurement (66Gr07).
189	351 *2*		
352	351 *2*		
493	474 *3*		
530	519 *2*		

† From 66Gr07.

^{215}Rn Adopted Levels

Q(β^-)=-1481 *13*; S(n)=4921 *13*; S(p)=5078 *9*; Q(α)=8840 *8* 85Wa02.

Cross Reference (XREF) Flags

A ^{219}Ra α Decay

E(level)†	Jπ	XREF	$T_{1/2}$	Comments
0.0	9/2+	A	2.30 μs *10*	$T_{1/2}$: from 70Va13. Jπ: favored α decay (HF=1.5) to ^{211}Po (Jπ=9/2+). configuration: odd-neutron configuration=(ν $1g_{9/2}$). %α=100. %ε<1.0×10^{-11} for log *ft*>5.9. %ε+%β^+<3×10^{-7}, theory (73Ta30).
214.1 *2*	(5/2,7/2,9/2)+	A		Jπ: 592γ M1 from (7/2)+.
290.8 *3*	(7/2,9/2,11/2)-	A		Jπ: 291γ E1 to 9/2+.
315.82 *4*	(7/2)+	A		Jπ: Jπ=(7/2,11/2)+ from αγ(θ) (89Ha26). 316γ M1 to 9/2+. Low α hindrance factor (HF=6.6) from ^{219}Ra (Jπ=(7/2)+) suggests Jπ=(7/2)+ for this level.
805.7 *4*	(7/2)+	A		Jπ: 805γ M1 to 9/2+. Low α hindrance factor (HF=4.6) from ^{219}Ra (Jπ=(7/2)+) suggests Jπ=(7/2)+ for this level.

† From ^{219}Ra α decay.

^{215}Rn Adopted γ radiations

E(level)	Eγ†	Mult.†	α	I(γ+ce)†
214.1	214.1‡ *2*	(E2)	0.419	100
290.8	290.8 *3*	E1	0.0360	100
315.82	315.82 *4*	M1(+E2)		100
805.7	489‡ *1*			≤42
	592.0 *3*	M1(+E2)		100 *17*
	805.2 *4*	M1(+E2)		58 *17*

† From ^{219}Ra α decay.
‡ Placement of transition in the level scheme is uncertain.

α radiations from ^{215}Rn α Decay 70Va13

Branching: 100% (77Ma29).
Others: 69Ha32, 52Me13.

Eα	E(level)	Iα†	HF‡	Comments
8674 *8*	0.0	100	1.6 *4*	Eα: Eα adjusted by -1 keV because of change in calibration standard (77Ma29).

‡ $r_0(^{211}Po)$=1.548 *10*.
† For α intensity per 100 decays, multiply by ≈1.00.

^{215}Rn Levels from ^{219}Ra α Decay 87El02,70Va13,69Ha32

87El02: ^{219}Ra activity was produced as descendant of ^{223}Th. Measured Eα, Eγ, Iγ, Ice, αγ coin, α-ce coin. Detectors: semi, Ge(Li), Si(Li). Assignment of α-particle groups to ^{219}Ra has been based on the agreement with Eα from 70Va13, and on the observation of Rn K x ray in coincidence with α particles.
Because of the decay scheme normalization, evaluator interpreted absolute γ-ray transition intensities reported by authors as absolute I(γ+ce) (photons plus conversion electrons) intensities.
70Va13: ^{219}Ra activity was produced by ^{208}Pb(^{16}O,αn), and identified by excitation functions, cross bombardment, and genetic relationship to its α-decay daughter nucleus ^{215}Rn. Measured Eα, Iα. Detector: semi.
69Ha32: ^{219}Ra activity was produced as descendant of ^{227}U, ^{223}Th, and identified by its genetic relationship to its α-decay daughter nucleus ^{215}Rn. Measured Eα, Iα. Detector: semi.
Jπ: from adopted levels.
E(level): from γ-ray energies.
See drawings for level data.

α radiations from ^{219}Ra α Decay 87El02,70Va13,69Ha32

Eα	E(level)	Iα‡	HF†	Comments
7226 *18*	805.7	2.4 *3*	4.6	Eα: from 87El02, weighted average of 7220 *20* (in coin with 592γ) and 7250 *40* (in coin with 805γ). Iα: deduced by evaluator from transition intensity balance.
7675 *5*	315.82	66.2 *15*	6.6	Eα,Iα: from 87El02, measured in coincidence with 316γ. Other values: Eα=7675 *10*, Iα=65 *5* (70Va13); Eα=7700 *20*, Iα=70 *10* (69Ha32). Iα: Iα=65.7 *15* deduced by evaluator from transition intensity balance.
7720 *20*	290.8	0.9 *2*	578	Eα: from 87El02, measured in coincidence with 291γ. Iα: deduced by evaluator from transition intensity balance.
7982 *9*	0.0	30.5 *15*	124	Iα: deduced by evaluator using ΣIα=100%. Other values: Iα=30 *10* (69Ha32), Iα=35 *2* (70Va13). Other: 52Me13. Iα: Iα=30.7 *16* deduced by evaluator from transition intensity balance. Eα: weighted average of 7980 *10* (70Va13) and 7990 *20* (69Ha32).

† Using $r_0(^{215}Rn)$=1.578, from adjacent even-even nuclei. α hindrance factors presented by 87El02 do not agree with values given here. Authors do not specified the value of r_0 used in their calculation.
‡ For α intensity per 100 decays, multiply by 1.0.

γ(^{215}Rn) from ^{219}Ra α Decay 87El02,70Va13,69Ha32

See 89Ha26 for αγ(θ).

Eγ†	E(level)	Mult.	α	I(γ+ce)†‡§	Comments
214.1# *2*	214.1 *2*	(E2)	0.419	1.5 *3*	Mult.: from α(L)exp=0.14 *3*. Assignment to ^{219}Ra α decay is not definite. Transition may be E1+M2 and may belong to ^{223}Th α decay (87El02).
290.8 *3*	290.8 *3*	E1	0.0360	0.91 *18*	Mult.: from α(K)exp<0.05 (87El02).
315.82 *4*	315.82 *4*	M1(+E2)		66.2 *15*	I(γ+ce): from a precise measurement of 7675α abundance (87El02). Mult.: from α(K)exp=0.55 *8*, α(L)exp=0.10 *2*, and α(M)exp=0.020 *3* (87El02).
489# *1*	805.7 *4*			≤0.5	
592.0 *3*	805.7 *4*	M1(+E2)		1.2 *2*	Mult.: from α(K)exp=0.07 *2* and α(L)exp=0.03 *1* (87El02).
805.2 *4*	805.7 *4*	M1(+E2)		0.7 *2*	Mult.: from α(K)exp=0.03 *2* (87El02).

† From 87El02.
‡ Absolute transition intensity measured relative to % I(γ+ce)=66.2 *15* for 316γ. This value results from a precise measurement of the α-particle abundance that populates the 316 level (87El02).
# Placement of transition in the level scheme is uncertain.
§ For absolute intensity per 100 decays, multiply by 1.0.

^{215}Fr Adopted Levels

Q(β^-)=−2221 *14*; S(n)=6802 *15*; S(p)=2657 *14*; Q(α)=9537 *9* 85Wa02.

The low-lying states of ^{215}Fr result from the coupling of an h9/2 proton to the 0+, 2+, 4+, 6+, and 8+ states of the even core (^{214}Rn). The energies of these even-spin states are similar to those of the 9/2, and (11/2,13/2), (15/2,17/2), (21/2,19/2) doublets in ^{215}Fr. The long-range α particle groups emitted from these states in ^{215}Fr are analogous to those emitted from the g.s., 4+, 6+, and 8+ states in ^{216}Ra. Their branchings from each level have not been measured, only their intensities relative to the total number of α particles in the spectrum in coincidence with γ rays are given (84Sc25).

Cross Reference (XREF) Flags

A ^{208}Pb(^{11}B,4nγ)
B ^{219}Ac α Decay

E(level)#	Jπ‡	XREF	$T_{1/2}$#	Comments
0.0	9/2−	AB	86 ns *5*	$T_{1/2}$: slope of α-decay time spectrum fitted to two components: 86 and 30 ns (84De16). Other values: 87 ns *6* (73HaZO); 104 ns *16*, slope of time spectrum measurement (84Sc25); 118 ns *21*, measured for about 130 ns only (74No02). Jπ: favored α decay (HF≈1) to ^{211}At (Jπ=9/2−). configuration: configuration=(π $1h_{9/2}$) coupled to 0+. %α=100. No ε decay, from systematics of log *ft* values. %ε+%β^+<1.0×10^{-8}, theory (73Ta30).
670.3 *1*	(13/2)−	A		Jπ: 670γ E2 to 9/2−. configuration: configuration=(π $1h_{9/2}$) coupled to 2+.
700.0 *1*	(11/2)−	A		Jπ: 700γ M1+E2 to 9/2−. configuration: configuration=(π $1h_{9/2}$) coupled to 2+.
835.5† *1*	(13/2)+	A		Eα=10160 *30*, Iα=0.038 *15* (84Sc25). Jπ: 135γ E1 to (11/2)−.
1121.5† *1*	(17/2)−	A		Eα=10460 *30*, Iα(1121+1149)=0.008 *1* (84Sc25). Other values: Eα=10493 *20*, Iα(1121+1149)=0.005 (84De16). Jπ: 451γ E2 to (13/2)−. configuration: configuration=(π $1h_{9/2}$) coupled to 4+.
1149.0† *1*	(15/2)−	A		Jπ: 479γ M1+E2 to (13/2)−. configuration: configuration=(π $1h_{9/2}$) coupled to 4+.
1440.0†§ *1*	(19/2)−	A		Eα=10740 *30*, Iα=0.041 *3* (84Sc25). Other values: Eα=10789 *15*, Iα=0.015 (84De16). Jπ: 318γ M1+E2 to (17/2)−. configuration: configuration=(π $1h_{9/2}$) coupled to 6+.
1457.4§ *2*	(21/2)−	A		Jπ: 336γ E2 to (17/2)−. configuration: configuration=(π $1h_{9/2}$) coupled to 6+.
1573.1†§ *2*	(23/2)−	A	3.5 ns *14*	Eα=10890 *30*, Iα=0.036 *3* (84Sc25). Eα=10919 *15*, Iα=0.030 (84De16). Jπ: 115.8γ M1 to (21/2)−. Theoretical g-factor=0.12 (84Sc25) for the assigned shell-model configuration compares with experimental g-factor=0.33 *10* (84De16). configuration: configuration=(π $1h_{9/2}{}^{+5}$+ν $2g_{9/2}{}^{+1}$ ν $1i_{11/2}{}^{+1}$).
1680.5 *2*	(25/2)−	A		Jπ: 107.4γ M1(+E2) to (23/2)−. configuration: configuration=((π $1h_{9/2}$)$^{+5}$+(ν $2g_{9/2}$)$^{+1}$+(ν $1i_{11/2}$)$^{+1}$).
1813.6 *2*	(27/2)−	A	2.1 ns *14*	$T_{1/2}$: from 84Sc25. Jπ: 133γ M1+E2 to (25/2)−, 240.5γ E2 to (23/2)−. configuration: configuration=(π $1h_{9/2}{}^{+4}$,$2f_{7/2}{}^{+1}$)+(ν $2g_{9/2}{}^{+1}$,$1i_{11/2}{}^{+1}$).
2015.9 *2*	(29/2)+	A	4.7 ns *12*	$T_{1/2}$: weighted average of 5.5 ns *14* (84Sc25) and 3 ns *2* (84De16). Jπ: 202γ E1 to (27/2)−. Theoretical g-factor=0.43 (84Sc25) for the assigned shell-model configuration agrees with experimental g-factor=0.47 *20* (84De16). configuration: configuration=(π $1h_{9/2}{}^{+4}$,$1i_{13/2}{}^{+1}$)+(ν $2g_{9/2}{}^{+2}$). μ=6.8 *29*. μ: DPAD (84De16,89Ra17).

Continued on next page (footnotes at end of table)

^{215}Fr Adopted Levels (continued)

E(level)#	Jπ‡	XREF	$T_{1/2}$#	Comments
2251.3 *3*	(33/2)+	A	5.3 ns *11*	$T_{1/2}$: weighted average of 5.5 ns *14* (84Sc25) and 5 ns *2* (84De16). Jπ: 235.4γ E2 to (29/2)+. Theoretical g-factor=0.49 (84Sc25) for the assigned shell-model configuration agrees with experimental g-factor=0.47 *10* (84De16). configuration: configuration= ($\pi\ 1h_{9/2}^{+4},1i_{13/2}^{+1}$)+($\nu\ 2g_{9/2}^{+1},1i_{11/2}^{+1}$). μ=7.8 *17*. μ: DPAD (84De16,89Ra17).
2806.8 *3*	(35/2)-	A		Jπ: 555.5γ E1 to (33/2)+. configuration: configuration=($\pi\ 1h_{9/2}^{+5}$)+($\nu\ 2g_{9/2}^{+1},1i_{11/2}^{+1}$).
2900.4 *3*	(35/2-)	A		Jπ: predicted by shell model (84Sc25). configuration: configuration=($\pi\ 1h_{9/2}^{+4},2f_{7/2}^{+1}$)+($\nu\ 2g_{9/2}^{+1},1i_{11/2}^{+1}$).
3013.9 *4*	(37/2-)	A		Jπ: 113.7γ (M1) to (35/2-). configuration: configuration=($\pi\ 1h_{9/2}^{+5}$)+($\nu\ 2g_{9/2}^{+1},1i_{11/2}^{+1}$).
3068.9 *3*	(39/2)-	A	14.6 ns *14*	$T_{1/2}$: γγ(t) (262γ-555γ time curves fitted to a two-level decay formula) (84Sc25). Jπ: 818γ E3 to (33/2)+. Theoretical g-factor=0.41 (84Sc25) for the assigned shell model configuration agrees with experimental g-factor=0.47 *2* (84De16). configuration: configuration=(($\pi\ 1h_{9/2}^{+4},1i_{13/2}^{+1}$)+($\nu\ 1i_{11/2}^{+1},1j_{15/2}^{+1}$). μ=9.17 *20*. μ: DPAD (84De16,89Ra17).
3207.5 *4*	(41/2-)	A		Jπ: 138.5γ (M1) to (39/2)-. configuration: configuration=($\pi\ 1h_{9/2}^{+5}$)+($\nu\ 2g_{9/2}^{+1}\ 1i_{11/2}^{+1}$).
3409.2? *3*		A		
3417.1 *4*	(45/2-)	A		Jπ: 210γ (E2) to (41/2-).
3419.4? *3*		A		
3462.3 *5*	(47/2+)	A	23 ns *2*	$T_{1/2}$: γγ(t) (262γ-555γ time curves fitted to a two-level decay formula), and from 210γ time spectrum (84Sc25). Other values: $T_{1/2}$=33 ns *5*, γγ(t) for all γ rays; $T_{1/2}$=30 ns *5*, time spectrum of g.s. α transition fitted to a two-component decay (84De16). Jπ: 45γ E1 to (45/2-). Jπ: configuration=($\pi\ 1h_{9/2}^{+4},1i_{13/2}^{+1}$)+($\nu\ 2g_{9/2}^{+1},1i_{11/2}^{+1}$).

† Emission of long-range α particles from this level has been observed (84Sc25).
‡ Multiple quasi-particle shell model configurations presented here are from 84Sc25.
§ Measured $T_{1/2}$ (84Sc25) and g-factor=0.33 *10* (84De16) correspond to 1440, 1457, or 1573 level.
# From ^{208}Pb(^{11}B,4nγ).

^{215}Fr Adopted γ radiations

E(level)	Eγ†	Iγ†	Mult.†	δ†	α	Comments
670.3	670.3 *1*	100	E2		0.0193	
700.0	700.0 *1*	100	M1+E2	-3.75 *+55-40*	0.0212 *6*	
835.5	135.4 *1*	100 *4*	E1		0.229	
	165.0 *1*	57 *3*	(E1)		0.142	
1121.5	451.2 *1*	100	E2		0.0479	
1149.0	(28)					
	313.4 *1*	17 *1*	E1		0.0312	
	449.1 *1*	100 *3*	E2		0.0485	
	478.8 *1*	76 *5*	M1+E2	-3.75 *+50-40*	0.0515 *18*	
1440.0	290.9 *1*	100 *3*	E2		0.162	
	318.5 *1*	20 *1*	M1+E2	10 *+6-2*	0.128	
1457.4	335.9 *1*	100	E2		0.106	
1573.1	115.8 *2*	5.3 *6*	M1		9.96	B(M1)(W.u.)=5.0×10^{-5} *22*.
	133.0 *1*	100 *9*	E2		2.72	B(E2)(W.u.)=12 *5*.
1680.5	107.4 *3*	100	M1(+E2)		10 *3*	
1813.6	133.0 *1*	41 *11*	M1+E2	0.50 *15*	5.9 *4*	B(M1)(W.u.)=0.0004 *3*; B(E2)(W.u.)=1.7 *15*.
	240.5 *1*	100 *4*	E2		0.297	B(E2)(W.u.)=1.1 *8*.

Continued on next page (footnotes at end of table)

^{215}Fr Adopted γ radiations (continued)

E(level)	Eγ†	Iγ†	Mult.†	α	Comments
2015.9	202.3 *1*	100	E1	0.0865	B(E1)(W.u.)=4.5×10^{-6} *12*.
2251.3	235.4 *1*	100	E2	0.319	B(E2)(W.u.)=1.5 *3*.
2806.8	555.5 *1*	100	E1	0.00929	
2900.4	649.1 *1*	100			
3013.9	113.7 *3*	100	(M1)	10.5	
3068.9	262.1 *1*	100 *3*	E2	0.224	B(E2)(W.u.)=0.26 *3*.
	817.5 *1*	34 *3*	E3	0.0336	B(E3)(W.u.)=27 *4*.
3207.5	138.5 *3*	52 *10*	(M1)	5.98	
	193.6 *2*	100 *20*	E2	0.634	
3409.2?	340.25‡ *15*	100	D		
3417.1	209.6 *2*	100	E2	0.476	
3419.4?	519.0‡ *3*	100			
3462.3	45.2 *3*	100	E1	0.910	B(E1)(W.u.)=4.6×10^{-5} *5*.

† From ^{208}Pb(^{11}B,4nγ).
‡ Placement of transition in the level scheme is uncertain.

α radiations from ^{215}Fr α Decay 74No02,70Bo13,84Sc25

Branching: from log *ft* systematics.

Eα	E(level)	Iα‡	HF§	Comments
9360 *8*	0.0	≈100	≈0.93	Eα: weighted average of measurements by 74No02, 73HaZO, 70Bo13.
10160† *30*				Iα=0.038 *15* (84Sc25).
10460† *30*				Iα=0.008 *1* (84Sc25).
				Eα=10493 *20*, Iα=0.005 (84De16).
10740† *30*				Iα=0.041 *3* (84Sc25).
				Eα=10789 *15*, Iα=0.015 (84De16).
10890† *30*				Iα=0.036 *3* (84Sc25).
				Eα=10919 *15*, Iα=0.030 (84De16).

† Long-range α particle group from an excited state in ^{215}Fr. Intensity is from αγ coin and relative to the total number of α particles in the spectrum (84Sc25).
§ $r_0(^{211}At)$=1.536 *7*.
‡ For α intensity per 100 decays, multiply by 1.0.

^{215}Fr Levels from ^{219}Ac α Decay 70Bo13,89Mi17

70Bo13: ^{219}Ac activity was produced as descendant of ^{223}Pa by the following reactions: ^{205}Tl(^{22}Ne,4n),(^{208}Pb(^{19}F,4n), ^{209}Bi(^{20}Ne,α2n), and ^{209}Bi(^{22}Ne,α4n), E=90–135 MeV. the activity was identified by excitation functions, cross bombardments, and by genetic relationships between parent and daughter nuclei. Measured Eα. Detector: semi.
89Mi17: ^{219}Ac activity was produced by ^{209}Bi(^{16}O,α2n) and ^{205}Tl(^{16}O,2n), E=87.4–101.9 MeV, and identified by mass separation and excitation functions. Measured Eα. Detector: semi. Deduced ^{219}Ac half-life.

E(level)	Jπ	$T_{1/2}$
0.0	9/2-	86 ns *5*

α radiations from ^{219}Ac α Decay 70Bo13,89Mi17

Eα	E(level)	Iα†	HF	Comments
8664 *10*	0.0	100	1.0	Eα: from 70Bo13. Original energy has been decreased by 1 keV because of a change in the calibration energy of ^{212}Po (77Ma30).

† For α intensity per 100 decays, multiply by 1.0.

^{215}Fr Levels from ^{208}Pb(^{11}B,4nγ) 84Sc25,84De16,85Dr04

^{204}Hg(^{15}N,4nγ), ^{207}Pb(^{11}B,3n) (84De16).

84Sc25: target: >99% enriched ^{208}Pb, E(^{11}B)=66 MeV. Measured Eγ, Iγ, $\gamma\gamma$ coin, $\alpha\gamma$ coin, $\gamma\gamma$(t), $\alpha\gamma$(t), $\gamma(\theta)$ for θ=90°, 115°, 127°, 138°, and 149°. Measured level half-lives, α decay from g.s. and excited levels. Deduced γ-ray multipolarities. Detectors: Ge(Li), high-purity germanium, Si surface barrier.

84De16: ^{208}Pb(^{11}B,4n), target: 98% enriched ^{208}Pb, E(^{11}B)=58, 62 MeV. Measured Eγ, Iγ, $\gamma\gamma$ coin, $\alpha\gamma$ coin, ce ce coin, $\gamma\gamma$(t), $\alpha\gamma$(t), differential perturbed angular distribution (DPAD) of α particles, α decay from g.s. and excited levels, level half-lives. The ^{207}Pb(^{11}B,3n) reaction was used to confirm the assignment of measured α particles to ^{215}Fr.

84De16: ^{204}Hg(^{15}N,4nγ), target: 98% enriched ^{204}Hg cooled to -30° C, E(^{15}N)≈78 MeV. Measured differential perturbed angular distribution (DPAD) for γ rays. Deduced γ-ray multipolarities, g-factors, half-lives.

85Dr04: target: enriched ^{208}Pb, E(^{11}B)=45-66 MeV. Measured Eγ, Iγ, $\gamma\gamma$ coin, $\gamma(\theta)$ for θ=0° to 90° in 15° increments, γ-ray excitation functions and linear polarizations. Deduced γ-ray multipolarities. Detectors: Ge(Li).

E(level): deduced by evaluator from a least-squares fit to γ-ray energies of 84Sc25 and 85Dr04.

E(level)(1440.0,1457.4,1573.1 levels): measured $T_{1/2}$ (84Sc25) and g-factor=0.33 *10* (84De16) correspond to 1440, 1457, or 1573 level.

Only levels with $T_{1/2}$ are given; see drawings for other level data.

E(level)	Jπ	$T_{1/2}$	Comments
0.0	9/2-	86 ns *5*	$T_{1/2}$: slope of α-decay time spectrum fitted to two components: 86 and 30 ns (84De16). Other values: 87 ns *6* (73HaZO); 104 ns *16*, slope of time spectrum measurement (84Sc25); 118 ns *21*, measured for about 130 ns only (74No02).
1573.1 *2*	(23/2)-	3.5 ns *14*	$T_{1/2}$: $\gamma\gamma$(t) centroid shift method (84Sc25). Other value: 4 ns *2*, $\gamma\gamma$(t) centroid shift method (84De16).
1813.6 *2*	(27/2)-	2.1 ns *14*	$T_{1/2}$: $\gamma\gamma$(t), $\alpha\gamma$(t) centroid shift method (84Sc25).
2015.9 *2*	(29/2)+	4.7 ns *12*	$T_{1/2}$: weighted average of 5.5 ns *14*, $\gamma\gamma$(t), $\alpha\gamma$(t) centroid shift method (84Sc25), and 3 ns *2*, $\gamma\gamma$(t) centroid shift method (84De16). g-factor=0.47 *20*, DPAD of γ rays (84De16).
2251.3 *3*	(33/2)+	5.3 ns *11*	$T_{1/2}$: weighted average of 5.5 ns *14*, $\gamma\gamma$(t), $\alpha\gamma$(t) centroid shift method (84Sc25), and 5 ns *2*, $\gamma\gamma$(t) centroid shift method (84De16). g-factor=0.47 *10*, DPAD of γ rays (84De16).
3068.9 *3*	(39/2)-	14.6 ns *14*	$T_{1/2}$: $\gamma\gamma$(t) (262γ-555γ time curves fitted to a two-level decay formula) (84Sc25). g-factor=0.47 *2* (corrected for diamagnetism and Knight shift), DPAD of γ rays (84De16). g-factor=0.48 *2*, DPAD of α particles (84De16).
3462.3 *5*	(47/2+)	23 ns *2*	$T_{1/2}$: $\gamma\gamma$(t) (262γ-555γ time curves fitted to a two-level decay formula), and from 210γ time spectrum (84Sc25). Other values: $T_{1/2}$=33 ns *5*, $\gamma\gamma$(t) for all γ rays; $T_{1/2}$=30 ns *5*, time spectrum of g.s. α transition fitted to a two-component decay (84De16).

γ(^{215}Fr) from ^{208}Pb(^{11}B,4nγ) 84Sc25,84De16,85Dr04

Eγ[†]	E(level)	Iγ[‡]	Mult.[§]	δ	α	Comments
(28)	1149.0 *1*					
45.2 *3*	3462.3 *5*	16.8 *20*	E1		0.910	
107.4 *3*	1680.5 *2*	7.9 *10*	M1(+E2)			
113.7 *3*	3013.9 *4*	0.40 *10*	(M1)		10.5	
115.8 *2*	1573.1 *2*	1.68 *20*	M1		9.96	
133.0 *1*	1573.1 *2*	32 *3*	E2		2.72	
	1813.6 *2*	11 *3*	M1+E2	0.50 *15*	5.9 *4*	δ: from γ-ray time differential perturbed angular distribution (84De16).
135.4 *1*	835.5 *1*	7.0 *3*	E1		0.229	
138.5 *3*	3207.5 *4*	2.6 *5*	(M1)		5.98	
165.0 *1*	835.5 *1*	4.0 *2*	(E1)		0.142	Iγ: from Iγ(165)/Iγ(135)=0.567 (85Dr04).
193.6 *2*	3207.5 *4*	5.0 *10*	E2		0.634	
202.3 *1*	2015.9 *2*	100 *3*	E1		0.0865	
209.6 *2*	3417.1 *4*	25.7 *10*	E2		0.476	
235.4 *1*	2251.3 *3*	78 *3*	E2		0.319	
240.5 *1*	1813.6 *2*	26.7 *10*	E2		0.297	
262.1 *1*	3068.9 *3*	37.6 *10*	E2		0.224	

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$\gamma(^{215}Fr)$ from $^{208}Pb(^{11}B,4n\gamma)$ 84Sc25,84De16,85Dr04 (continued)

Eγ†	E(level)	Iγ‡	Mult.§	δ	α	Comments
290.9 *1*	1440.0 *1*	96 *3*	E2		0.162	
313.4 *1*	1149.0 *1*	6.9 *3*	E1		0.0312	
318.5 *1*	1440.0 *1*	18.8 *10*	M1+E2	10 *+6-2*	0.128	δ: from γ(θ) (85Dr04).
335.9 *1*	1457.4 *2*	18.8 *10*	E2		0.106	
340.25# *15*	3409.2? *3*		D			Eγ: from 85Dr04. γ ray was also observed, but not placed in the decay scheme, by 84Sc25.
449.1 *1*	1149.0 *1*	41.6 *10*	E2		0.0485	
451.2 *1*	1121.5 *1*	56.4 *20*	E2		0.0479	
478.8 *1*	1149.0 *1*	31.7 *20*	M1+E2	-3.8 *+5-4*	0.0515 *18*	δ: from γ(θ) (85Dr04). Other value: −6 *+3-4*, γ-ray time differential perturbed angular distribution (84De16).
519.0# *3*	3419.4? *3*					Eγ: observed by 85Dr04 only.
555.5 *1*	2806.8 *3*	41.6 *20*	E1		0.00929	
649.1 *1*	2900.4 *3*	5.9 *10*				(E1) from (84Sc25); E2+M1 (δ=−1.2 *+18-12*), (85Dr04).
670.3 *1*	670.3 *1*	97 *4*	E2		0.0193	
700.0 *1*	700.0 *1*	43.6 *20*	M1+E2	-3.8 *+6-4*	0.0212 *6*	δ: from γ(θ) (85Dr04). Other value: −7 *+3-13*, γ-ray time differential perturbed angular distribution (84De16).
817.5 *1*	3068.9 *3*	12.9 *10*	E3		0.0336	

† Weighted average from 84Sc25 and 85Dr04.
‡ From 84Sc25, unless otherwise specified.
§ From: differential perturbed angular distribution of γ rays, and conversion electron data (84De16); γ(θ) and transition intensity balances (84Sc25); and γ(θ) and asymmetry values from γ-ray linear polarization measurements (85Dr04).
# Placement of transition in the level scheme is uncertain.

^{215}Ra Adopted Levels

Q(β^-)=-3460 *70*; S(n)=5635 *15*; S(p)=3799 *16*; Q(α)=8864 *5* 85Wa02.

The low-lying yrast levels in ^{215}Ra have been interpreted in terms of the shell model by coupling the odd neutron to experimentally determined energies in ^{214}Ra (83Lo16). The enhancement of the 773-keV E3 transition in ^{215}Ra is due mostly to the coupling of the particle orbital to the octupole phonon in the ^{208}Pb core. Its B(E3)(W.u.)=26 *1* agrees with the systematics for E3 transitions in the ^{208}Pb region (83Lo16). See also 89Dr02, 85Be05, and 88Fu10 for further discussions on B(E3) values for this nucleus.

Cross Reference (XREF) Flags

A ^{208}Pb(^{13}C,6nγ)
B ^{219}Th α Decay

E(level)†	Jπ	XREF	$T_{1/2}$†	Comments
0.0	(9/2+)	AB	1.59 ms *9*	$T_{1/2}$: weighted average of 1.56 ms *10* (70To08) and 1.7 ms *2* (68Va18). Other value: 1.6 ms (61Gr43,62Gr20). Jπ: α decay systematics of N=127 isotones (*i.e.* ^{211}Po and ^{213}Rn) suggest Jπ=(9/2+). Shell model configuration for the odd neutron is expected to be g9/2. configuration: configuration=(ν $1g_{9/2}$) coupled to 0+. %α=100. No ε decay, from systematics of log *ft* values. %ε+%β^+<2×10^{-4}, theory (73Ta30).
773 *1*	(15/2-)	A	72 ns *3*	$T_{1/2}$: weighted average of 68.6 ns *21*, $\gamma\gamma$(t) (89Dr02); 77 ns *2*, $\gamma\gamma$(t) (88Fu10); and 67 ns *3* (87AdZU). Other values: 110 ns *8*, pulsed beam method (89Dr02); 120 ns *10*, pulsed beam method (83Lo16). The $\gamma\gamma$(t) method provides a more accurate half-life than the pulsed beam method, the reason being that most of the 773γ intensity decays with 7.2 μs, the half-life of the 1877 level, making it more difficult to measure a shorter half-life (in the ns range) with the pulsed beam method. Jπ: 773γ E3 to (9/2+). Analogy with 896-keV state (Jπ=(15/2-)) in ^{213}Rn. configuration: configuration=(ν $1j_{15/2}$) coupled to 0+.
1626 *1*	(17/2+)	A		Jπ: 852γ E1 to (15/2-). Analogy with 1529-keV state (Jπ=(17/2+)) in ^{213}Rn. configuration: configuration=(ν $1g_{9/2}$) coupled to 4+.
1821 *1*	(21/2+)	A	23 ns *5*	Jπ: 196γ E2 to (17/2+), 1048γ E3 to (15/2-). Analogy with 1664-keV state (Jπ=(21/2+)) in ^{213}Rn (88Fu10). configuration: configuration=(ν $1g_{9/2}$) coupled to 6+. $T_{1/2}$: from 83Lo16.
1878 *2*	(25/2+)	A	7.2 μs *2*	$T_{1/2}$: pulsed beam method (88Fu10). Other value: ≥2 μs, pulsed beam method (83Lo16). Jπ: configuration=g9/2 for the odd neutron coupled to 8+ in the ^{214}Ra core is predicted by the shell model. Analogous state at >1664 keV with $T_{1/2}$≈1 μs has been observed in ^{213}Rn (88Fu10). configuration: configuration=(ν $1g_{9/2}$) coupled to 8+.
1994 *2*		A		
2054 *2*		A		
2247 *2*		A		
3088 *2*		A		
3275 *2*				
3358 *2*		A		
3427 *2*		A		
3682 *2*		A		
3737 *3*		A	0.59 μs *18*	$T_{1/2}$: pulsed beam method (87AdZU). g-factor=0.734 *7*, stroboscopic observation of perturbed γ-ray angular distributions (87AdZU).
4052 *3*		A		
4484 *3*		A		
4663 *3*		A		
4848 *3*		A		
4863 *3*		A	≈10 ns	$T_{1/2}$: from 87AdZU.
5353 *3*		A		
5589 *3*		A		

† From ^{208}Pb(^{13}C,6nγ).

^{215}Ra Adopted γ radiations

E(level)	Eγ†	Iγ†	Mult.†	α	Comments
773	773.2 *10*	100	E3	0.0409	B(E3)(W.u.)=35.8 *14.*
1626	852.4 *10*	100	E1	0.00427	
1821	195.9 *10*	100 *29*	E2	0.643	B(E2)(W.u.)=0.54 *23.*
	1048.3 *10*	43 *5*	E3	0.0198	B(E3)(W.u.)=2.9 *10.*
1878	(56)	100	[E2]	154	B(E2)(W.u.)=0.0120 *12.*
1994	173.0 *10*	100			
2054	59.1 *10*				
	175.8 *10*				
2247	193.2 *10*	100			
3088	841.8 *10*	100			
3275	187.4 *10*	100			
3358	269.3 *10*	100			
3427	152 *1*	100			
3682	255.2 *10*				
	323.0 *10*				
	407.4 *10*				
3737	54.9 *10*	100			
4052	315.5 *10*	100			
4484	431.6 *10*	100			
4663	178.6 *10*				
	610.0 *10*				
4848	796.3 *10*	100			
4863	(15)				
	199.9 *10*				
5353	490.2 *10*	100			
5589	235.9 *10*	100			

† From ^{208}Pb(^{13}C,6nγ).

α radiations from ^{215}Ra α Decay 70To18,68Va18

Branching: 100%, from log *ft* systematics.

Eα‡	E(level)	Iα†‡	HF§	Comments
7882 *6*	833	2.8 *4*	17	
8171 *6*	538	1.4 *4*	243	
8699 *4*	0.0	95.8 *7*	96	Iα,Eα: values recommended by 91Ry01.

‡ Average of measurements by 70To18, 68Va18. See also 91Ry01.
§ $r_0(^{211}Rn)$=1.498 *5.*
† For α intensity per 100 decays, multiply by 1.0.

^{215}Ra Levels from ^{219}Th α Decay 73Ha32

^{219}Th activity was produced by ^{206}Pb(^{16}O,3n), E=80-90 MeV. Isotopic assignment is based on its genetic relationship to ^{215}Ra, and on measured excitation functions. Measured Eα. Detector: semi.

E(level)	Jπ	$T_{1/2}$	Comments
0.0	(9/2+)	1.59 ms *9*	Jπ,$T_{1/2}$: from adopted levels.

α radiations from ^{219}Th α Decay 73Ha32

Eα	E(level)	Iα†	HF	Comments
9340 *20*	0.0	100	2.06	HF: using $r_0(^{215}Ra)$=1.561, from adjacent even-even nuclei.

† For α intensity per 100 decays, multiply by 1.0.

^{215}Ra Levels from ^{208}Pb(^{13}C,6nγ) 88Fu10,83Lo16,87AdZU

89Dr02.
^{206}Pb(^{12}C,3nγ), ^{206}Pb(^{13}C,4nγ), ^{208}Pb(^{12}C,5nγ).
88Fu10: ^{206}Pb(^{12}C,3nγ), E=67 MeV, ≥90% enriched ^{206}Pb target. Measured Eγ, Iγ, $\gamma\gamma$ coin, $\gamma(\theta)$ for 9 angles between θ=80° and 160°, γ-ray linear polarization, $\gamma\gamma$(t). Detectors: Ge(Li). Deduced transition multipolarities. Measured level half-lives using a pulsed beam method, and also $\gamma\gamma$(t).
83Lo16: ^{208}Pb(^{13}C,6nγ), E=95 MeV, 99% enriched ^{208}Pb target. Measured Eγ, Iγ, $\gamma(\theta)$ for 8 angles between 6° and 158°, $\gamma\gamma$ coin, $\gamma\gamma$(t). Detector: Ge(Li). Deduced transition multipolarities. Measured level half-lives using a pulsed beam method.
89Dr02: ^{208}Pb(^{12}C,5nγ), E=80 MeV, 99% enriched ^{208}Pb target. Measured Eγ, Iγ. Detector: Ge(Li).
89Dr02: ^{206}Pb(^{13}C,4nγ), E=78 MeV, 92% enriched ^{206}Pb target. Measured Eγ, Iγ, Ice, $\gamma\gamma$(t). Detectors: Ge(Li) Compton suppression system, Si(Li). Deduced transition conversion coefficients and multipolarities. Measured level half-lives using a pulsed beam method, and $\gamma\gamma$(t).
87AdZU: ^{206}Pb(^{13}C,4nγ), E=80 MeV. Measured Eγ, $\gamma\gamma$ coin, $\gamma\gamma$(t). Detector: Ge(Li), high-purity germanium. Measured level half-lives. Measured g-factor by stroboscopic observation of γ-ray perturbed angular distributions.
E(level): deduced by evaluator from a least-squares fit to γ-ray energies, using 1 keV uncertainty for γ-ray energies from 87AdZU. Levels above 1877 keV have been reported by 87AdZU only.
Jπ: from adopted levels.
Only levels with $T_{1/2}$ are given; see drawings for other level data.

E(level)	Jπ	$T_{1/2}$	Comments
773 *1*	(15/2-)	72 ns *3*	$T_{1/2}$: from adopted levels.
1821 *1*	(21/2+)	23 ns *5*	$T_{1/2}$: from 83Lo16.
1878 *2*	(25/2+)	7.2 μs *2*	$T_{1/2}$: pulsed beam method (88Fu10). Other value: ≥2 μs, pulsed beam method (83Lo16).
3737 *3*		0.59 μs *18*	$T_{1/2}$: pulsed beam method (87AdZU). g-factor=0.734 *7*, stroboscopic observation of γ-ray perturbed angular distributions (87AdZU).
4863 *3*		≈10 ns	$T_{1/2}$: from 87AdZU.

γ(^{215}Ra) from ^{208}Pb(^{13}C,6nγ) 88Fu10,83Lo16,87AdZU

Eγ†	E(level)	Iγ†	Mult.§	α	Comments
(15)	4863 *3*				
54.9‡ *10*	3737 *3*				
(56)	1878 *2*				
59.1‡ *10*	2054 *2*				
152‡ *1*	3427 *2*				
173.0 *10*	1994 *2*	2 *1*			Eγ=173.4 (87AdZU).
175.8 *10*	2054 *2*	5 *2*			Eγ=175.9 (87AdZU).
178.6‡ *10*	4663 *3*				
187.4‡ *10*	3275 *2*				
193.2‡ *10*	2247 *2*				
195.9 *10*	1821 *1*	42 *12*	E2	0.643	Eγ: Eγ=195.1 (83Lo16); Eγ=196.0 (87AdZU).
199.9‡ *10*	4863 *3*				
235.9‡ *10*	5589 *3*				
255.2‡ *10*	3682 *2*				
269.3 *10*	3358 *2*	5 *2*			Eγ=271.6 (87AdZU).
315.5‡ *10*	4052 *3*				
323.0‡ *10*	3682 *2*				
407.4‡ *10*	3682 *2*				
431.6‡ *10*	4484 *3*				
490.2‡ *10*	5353 *3*				
610.0‡ *10*	4663 *3*				
773.2 *10*	773 *1*	100	E3	0.0409	Mult.: α(K)exp=0.0257 *11*, α(L)exp=0.0096 *6*, and α(M)exp=0.00027 *5* confirm the E3 multipolarity of this transition (89Dr02). Eγ: Eγ=771.5 (83Lo16).
796.3‡ *10*	4848 *3*				
841.8 *10*	3088 *2*	18 *2*			
852.4 *10*	1626 *1*	64 *3*	E1	0.00427	Eγ: Eγ=850.1 (83Lo16).
1048.3 *10*	1821 *1*	18 *2*	E3	0.0198	

† From 88Fu10 at E(^{12}C)=67 MeV, unless otherwise specified.
‡ From 87AdZU.
§ From $\gamma(\theta)$ and γ-ray linear polarization measurements (83Lo16, 88Fu10).

^{215}Ac Adopted Levels

Q(β^-)=-4920 *100*; S(n)=8470 *90*; S(p)=1390 *70*; Q(α)=7748 *5* 85Wa02.
Q(α): from Eα=7604 *5* to ^{211}Fr g.s. (68Va04).
States in ^{215}Ac have been interpreted in terms of the shell model configurations h9/2, f7/2, and i13/2 available for the seven protons beyond closed shell (Z=82) (83De08).

Cross Reference (XREF) Flags

A ^{204}Pb(^{15}N,4nγ)
B ^{219}Pa α Decay

E(level)§	Jπ†	XREF	$T_{1/2}$‡	Comments
0.0	9/2-	AB	0.17 s *1*	$T_{1/2}$: from 68Va04. Jπ: favored α decay (HF=1.3) to ^{211}Fr (Jπ=9/2-). %α=99.91 *2*; %ε+%β^+=0.09 *2*. %α: from 68Va04.
1317.0 *5*	13/2-	A		Jπ: 1317γ stretched E2 to 9/2-. configuration: configuration=(π $1h_{9/2}$)$^{+7}$.
1621.0 *7*	17/2-	A	30 ns *10*	Jπ: 304γ stretched E2 to 13/2-. configuration: configuration=(π $1h_{9/2}$)$^{+7}$. μ=7.82 *16*. μ: DPAD (83De08,89Ra17).
1796.0 *9*	21/2-	A	185 ns *30*	Jπ: 175γ stretched E2 to 17/2-. configuration: configuration=(π $1h_{9/2}$)$^{+7}$. μ=9.66 *20*. μ: DPAD (83De08,89Ra17).
1796.0+x	(23/2-)	A		configuration: configuration=(π $1h_{9/2}{}^{+6}$, $2f_{7/2}{}^{+1}$).
2438+x	(29/2+)	A	335 ns *10*	Jπ: 642γ stretched E3 to (23/2-). B(E3)(W.u.)=24.7 *9* is similar to that of the corresponding E3 transition in ^{213}Fr, and typical of fast E3 transitions in this region. configuration: configuration=(π $1h_{9/2}{}^{+6}$, $1i_{13/2}{}^{+1}$). μ=15.13 *30*. μ: DPAD (83De08,89Ra17).

† Spin and parity and proton configuration assignments are based on the analogy with the corresponding levels in the isotones ^{211}At and ^{213}Fr, and also on the agreement of experimental g-factors with shell-model predictions (*i.e.* constant values for h9/2 states). Additional arguments are given with individual levels.
‡ From ^{204}Pb(^{15}N,4nγ), measured with the DPAD method.
§ X=50 keV *50*, extrapolated from Eγ=511 keV in ^{211}At, and Eγ=265 keV in ^{213}Fr.

^{215}Ac Adopted γ radiations

E(level)	Eγ†	Iγ	Mult.†	α	Comments
1317.0	1317.0 *5*	100	E2	0.00572	
1621.0	304.0 *5*	100	E2	0.156	B(E2)(W.u.)=0.08 *3*.
1796.0	175.0 *5*	100	E2	1.04	B(E2)(W.u.)=0.119 *20*.
2438+x	642.0 *5*	100	E3	0.0711	B(E3)(W.u.)=27.4 *9*. B(E3)(W.u.)=27.4 *9* is similar to that of the corresponding E3 transition in ^{213}Fr, and typical of fast E3 transitions in this region. The strength enhancement of such transitions is due to the coupling with octupole vibrations of the even core nucleus.

† From ^{204}Pb(^{15}N,4nγ).

α radiations from ^{215}Ac α Decay 68Va04

Branching: 99.91% (68Va04).

Eα	E(level)	Iα†	HF‡	Comments
7604 *5*	0.0	100	1.25 *22*	Eα: adjusted for change in calibration standard (91Ry01).

‡ $r_0(^{211}Fr)$=1.461 *7*.
† For α intensity per 100 decays, multiply by 0.9991 *2*.

^{215}Ac Levels from ^{219}Pa α Decay 87FaZS

^{219}Pa was produced by ^{204}Pb(^{19}F,4n), E=100 MeV. Assignment of this activity to ^{219}Pa is based on excitation functions, and on the systematics of α-particle energies and half-lives for other protactinium isotopes. Measured Eα. Detector: annular system of gas detectors.

E(level)	Jπ	$T_{1/2}$
0.0	9/2-	0.17 s *1*

α radiations from ^{219}Pa α Decay 87FaZS

Eα	E(level)	Iα†	HF	Comments
9900 *50*	0.0	100	≈1.0	HF: using $r_0(^{215}Ac)$=1.566, from adjacent even-even nuclei.

† For α intensity per 100 decays, multiply by ≈1.00.

^{215}Ac Levels from ^{204}Pb(^{15}N,4nγ) 83De08

Target: 99.7% enriched ^{204}Pb, E(^{15}N)=84 MeV. Measured Eγ, Iγ, γγ coin. Measured γ-ray differential perturbed angular distributions (DPAD), level half-lives, and g-factors. Measured γ rays in coincidence with delayed α particles. Deduced transition multipolarities. Detectors: Ge(Li), high-purity germanium, semi.
E(level): from γ-ray energies. X=50 keV *50*, extrapolated from Eγ=511 keV in ^{211}At, and Eγ=265 keV in ^{213}Fr.
Jπ: from adopted levels.
$T_{1/2}$: from DPAD measurements.
Only levels with $T_{1/2}$ are given; see drawings for other level data.

E(level)	Jπ	$T_{1/2}$	Comments
1621.0 *7*	17/2-	30 ns *10*	g-factor=0.91 *1*, uncorrected for diagmagnetism and Knight shift.
1796.0 *9*	21/2-	185 ns *30*	g-factor=0.91 *1*, uncorrected for diagmagnetism and Knight shift.
2438+x	(29/2+)	335 ns *10*	g-factor=1.033 *10*, uncorrected for diagmagnetism and Knight shift.

γ(^{215}Ac) from ^{204}Pb(^{15}N,4nγ) 83De08

The assignment of γ rays to ^{215}Ac was based on the measurement of coincident Ac x rays, of delayed α particles (from ^{215}Ac and ^{216}Ac, with a ratio of 2:1), and on the level systematics of analogous levels in the lighter isotones ^{211}At and ^{213}Fr.

Eγ	E(level)	Mult.†	α
175.0 *5*	1796.0 *9*	E2	1.04
304.0 *5*	1621.0 *7*	E2	0.156
642.0 *5*	2438+x	E3	0.0711
1317.0 *5*	1317.0 *5*	E2	0.00572

† From measured A_2 angular distribution coefficients, and comparison with the corresponding transitions in ^{211}At and ^{213}Fr. All multipolarities are stretched.

^{215}Th Adopted Levels

Q(β^-)=-6770 *150*; S(n)=7830 *SY*; S(p)=2770 *110*; Q(α)=7667 *8* 85Wa02.
Q(α): from Eα=7524 *8* to g.s. of ^{211}Ra (68Va18).
Activity was produced by ^{208}Pb(^{16}O,7n), E=90-160 MeV, and identified by excitation functions, genetic relationship to daughter nuclei, and by the agreement with α-particle energy decay systematics (68Va18).

E(level)	Jπ	$T_{1/2}$	Comments
0.0	(1/2-)	1.2 s *2*	$T_{1/2}$: from 68Va18. Jπ: from α-decay systematics of N=125, Jπ=1/2- isotones ^{209}Po, ^{211}Rn, and ^{213}Ra. These nuclei strongly populate a 5/2- g.s., and, 1/2- and 3/2- excited states. The hindrance factors for ^{215}Th α decay are: 5.5 (5/2-), 1.6 (1/2-), and 6.2 (3/2-), using r_0=1.459 from adjacent even-even nuclei. configuration: expected shell-model configuration for the odd proton is p1/2. %α=100. No ϵ decay observed (lim 1.5%) (68Va18).

α radiations from ^{215}Th α Decay 68Va18

Eα‡	E(level)	Iα†	HF§
7333 *10*	195?	8 *3*	8 *4*
7395 *8*	131?	52 *3*	2.0 *8*
7524 *8*	0.0	40 *3*	7 *3*

‡ Corrected for change in calibration standard (77Ma29).
§ r_0(^{211}Ra)=1.480 *13*.
† For α intensity per 100 decays, multiply by >0.985.

^{215}Pa Adopted Levels

S(p)=280 *SY*; Q(α)=8238 *15* 85Wa02.
Q(α): from Eα=8085 *15* to ^{211}Ac g.s. (79Sc09).
^{215}Pa activity was produced by ^{181}Ta(^{40}Ar,6n), E=165-202 MeV, and separated from the beam with a velocity filter. The activity was identified by excitation functions, and by its genetic relationship to daughter nuclei. Measured Eα. Detector: semi (79Sc09).

E(level)	$T_{1/2}$	Comments
0.0	14 ms *+20-3*	$T_{1/2}$: from 79Sc09. %α=100.

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