Adopted Levels, Gammas

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	Balraj Singh, M. S. Basunia, Jun Chen et al. ,	NDS 192,315 (2023)	25-Sep-2023

Q(β^-)=−6 *8*; S(n)=6171 *6*; S(p)=7700 *14*; Q(α)=5590.4 *3* 2021Wa16
S(2n)=10382.7 *19*, S(2p)=13469 *18* (2021Wa16).

Dataset by Balraj Singh, S. Basunia, and IAEA-ICTP workshop participants: B.M.S. Amro, S. Basu, S. Das, A. Karmakar, and S.S. Nayak.

^{222}Rn is a naturally occuring radioactive isotope, emitted from the α decay of ^{226}Ra, a long-lived activity produced in the decay chain of ^{238}U, first identified by 1899Cu01, just three years after the discovery of radioactivity, followed by the first measurement of half-life of ^{222}Rn decay by 1902Cu01.

Mass measurement: 2010Li02: Schottky mass spectrometry.

Theoretical nuclear structure calculations:

2021Va08: calculated levels, J^π, yrast positive- and negative-parity states, B(E1), B(E2), B(E3), B(M1), magnetic dipole and electric quadrupole moments using the *spdf*-IBM-2 interacting boson model.

2020Ca18: calculated deformation parameters β_2, β_3, octupole deformation energies, proton quadrupole Q_{20} and octupole Q_{30} moments for octupole-deformed nuclei using Skyrme energy density functional, and covariant energy density functional models.

2019Zh50: calculated empirical proton-neutron interaction, B(E2), B(E3), binding energy, total energy in (β_2,β_3) plane, neutron and proton single-particle levels using the covariant density functional theory and the quadrupole-octupole collective Hamiltonian.

2018Yo12: calculated E(first 4^+)/E(first 2^+) ratio, energy of the first 3^- state using shell model with one-octupole-phonon representing collective octupole vibration across the magic core.

2017Xi15: calculated levels, J^π, B(E1), B(E2), B(E3), electric dipole moment, deformation energy surface in (β_2,β_3) plane, reflection-asymmetric states using microscopic quadrupole-octupole collective Hamiltonian (QOCH), based on based on relativistic energy density functional.

2014De43, 2013De12: calculated energy levels, J^π, deformation parameters, B(E2), $T_{1/2}$ using coherent state model (CSM).

2013Ro30: calculated level energies of 1^- states, B(E1), B(E3) using two-dimensional generator coordinate method (GCM) for quadrupole-octupole coupling with Gogny forces.

2005Za02, 2001Za04: calculated levels, J^π, transition rates, octupole excitations using interacting boson model.

1998Ra05: calculated high-spin levels, J^π, K^π=0^- band using phenomenological model.

1994Li05: calculated total energy surface vs α_{20}, α_{32} deformations, fourfold degenerate levels using the results of realistic total nuclear energy calculations.

1987Ro08: calculated single-particle states, pairing energies, octupole deformation, dipole vs octupole moments, B(E1)/B(E2) using constrained HF plus BCS method.

1983Ro14: calculated potential equilibrium deformation, deformation energies, static quadrupole and hexadecapole moments using density-dependent shell correction method.

1982Le19: calculated potential energy minima, octupole separation energy, and intrinsic reflection symmetry breaking using deformed shell-model.

1981Gy03: calculated potential energy, quadrupole and octupole equilibrium deformations using macroscopic-microscopic method.

1981Pe09: analyzed levels, J^π, strong Coriolis coupling effects for rotational bands based on one-phonon octupole vibrational states.

1980Sh07: analyzed levels, J^π, inverse moments of inertia; deduced structural relation of K^π=0^+ and K^π=0^- bands.

Other theoretical calculations: 14 primary references for structure, and 76 primary references for decay characteristics are in the NSR database, and listed in this dataset as ‘document’ records.

Additional information 1.

^{222}Rn Levels

The K^π=0^+ g.s. band and the K^π=0^- band at 600.66 keV have been interpreted as octupole parity-doublet bands. However, 2022Sp01 and 2020Bu20 in their Coulomb excitation study do not support stable octupole deformation in the ground state of ^{222}Rn.

Cross Reference (XREF) Flags

A ^{226}Ra α decay (1603 y)
B ^{232}Th(^{136}Xe,Xγ)
C Coulomb excitation

E(level)[†]	J^{π}[‡]	$T_{1/2}$[#]	XREF	Comments
0.0[@]	0^+	3.8222 d *9*	ABC	%α=100 With Q(β^-)=−6 *8* (2021Wa16), no β^- decay is expected. Evaluated rms charge radius $<r^2>^{1/2}$=5.692 fm *20* (2013An02). Evaluated $\delta<r^2>(^{222}Rn-^{212}Rn)$=+1.1236 fm^2 *4* (2013An02). Additional information 2. $T_{1/2}$: weighted average of 3.82146 d *85* (2015Be07, from decay curve for integral γ-ray spectrum from 6 keV onwards, weighted average of four measurements: 3.82157 d *32* for 1301 h, 3.82134 d *30* for 1462 h, 3.82169 d *32* for 1185 h, and 3.82124 d *35* for 1357 h; statistical uncertainty of 0.00016 d and systematic uncertainty of 0.00004 d in 2015Be07 combined in quadrature, and total uncertainty increased to 0.00085, to have a maximum relative weight of 50%); 3.8195 d *30* (2004Sc04, ionization chamber, reanalysis of 2004Sc04 data by 2018Po01 gave 3.825 d *5*); 3.8224 d *18* (1995Co34, 4π $\alpha\beta$ liquid scintillation counter, average of six measurements); 3.82351 d *170* (1972Bu33, decay curve for integral γ-ray spectrum measured over 40 half-lives, average of two measurements, quoted uncertainty of 0.00034 increased to 0.00170 as in 1990Ho28 evaluation); 3.83 d *3* (1958Sh69, calorimetry); 3.82290 d *170* (1956Ma64, ionization chamber, average of three measurements, quoted uncertainty of 0.00027 increased to 0.00170 as in 1990Ho28); 3.825 d *5* (1956Ro31, calorimetry, quoted uncertainty of 0.004 increased to 0.005 as in 1990Ho28); 3.825 d *6* (1955To07,1951To25, ionization chamber, average of two measurements, quoted uncertainty of 0.005 increased to 0.006 as in 1990Ho28); 3.823 d *3* (1924Cu01, ionization chamber, average of four measurements, quoted uncertainty of 0.002 increased to 0.003 as in 1990Ho28); 3.825 d *4* (1923Bo01, ionization chamber, average of four measurements). Other: 3.81474 d *14* from 1994Se21 (indirect $T_{1/2}$ deduced in the measurement of efficiency of Lucas scintillation cell by depositing a known quantity of ^{222}Rn and following the decay and ingrowth of Rn and its daughters for a total of 7014 data points, and fitting these data points using several parameters; $T_{1/2}$ value is quoted very precisely, but disagrees by many standard deviations from the other precise and direct measurements). Other nominal recent value=3.81 d *12* (2018Ap01). Measurements prior to 1923, cited from compilations in 1995Co34 and 1995Co35: 3.811 d (1921Bo01); 3.847 d (1913RuZZ); 3.85 d (1910Cu02); 3.747 d (1907Ru04); 3.863 d (1905Sa01); 3.896 d (1904Bu01); 3.71 d (1903Ru05); 3.987 d (1902Cu01). 2005Tr01: measured lower limits for half-lives for double β decay modes of ^{222}Rn: $T_{1/2}$>2.8 y for $0\nu\beta\beta$ and >0.11 y for $2\nu\beta\beta$.
186.211[@] *13*	2^+	0.32 ns *2*	ABC	μ=+0.92 *14* (1970Or02,2020StZV) Q=−1.4 *+5−6* μ: measurement of g=0.45 *7* by $\alpha\gamma(\theta$,H) (1970Or02), integral perturbed angular correlation method. Q: deduced by evaluators from diagonal E2 matrix element (186,2^+ → 186,2^+)=−1.8 *+6−9* in Coulomb excitation (2022Sp01). J^{π}: E2 γ to 0^+. $T_{1/2}$: $\alpha\gamma$(t) (1960Be25). Other measurement: 0.31 ns (1961Fo08).
448.48[@] *6*	4^+	52.5 ps *+44−23*	ABC	(α)(262γ)(θ) data of 1989Po03 rule out J of 0, 1, 2 and 3; population of natural-parity state in α decay from 0^+ parent.
600.74[&] *4*	1^-	0.7 ps *+11−5*	ABC	J^{π}: γ to g.s.; the (α)(601γ)(θ) and (α)(415γ)(θ) data rule out 2; population of natural-parity state in α decay from 0^+ parent.
635.57[&] *9*	3^-	≈0.4 ns	ABC	(α)(449γ)(θ) data of 1989Po03 rules out 0, 1, 2 and 4; population of natural-parity state in α decay from 0^+ parent.
768.08[@] *21*	(6^+)	15.9 ps *+18−11*	BC	J^{π}: γ to 4^+; level is Coulomb excited as g.s. band member.
797.4[&] *5*	(5^-)		BC	J^{π}: gamma to 4^+; possible γ to 3^-; band member.
867.0 *7*	(0^+)		C	J^{π}: gammas to 2^+ and 1^-; possible bandhead of β band (2022Sp01).
867.1[a] *7*	(2^+)		C	J^{π}: γ to 0^+; possible bandhead of γ band.

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued)

^{222}Rn Levels (continued)

E(level)[†]	J^π[‡]	$T_{1/2}$[#]	XREF	Comments
959.2[a] *10*	(3+)		C	J^π: gamma to 2+; possible band member.
1048.7[&] *5*	(7−)		BC	J^π: gamma to (6+); possible γ to (5−); band member.
1111.5[a] *10*	(4+)		C	J^π: γ to 4+; possible band member.
1127.7[@] *3*	(8+)	7.3 ps *+11−16*	BC	J^π: γ to (6+); band member.
1356.5[&] *5*	(9−)	7 ps *+9−5*	BC	J^π: gammas to (7−) and (8+); band member. $T_{1/2}$: 67 ps *+126−57* deduced from B(E2) value in Coulomb excitation. D_0/Q_0=0.00191 $b_{1/2}$ *35* (1999Co02). Average D_0=0.010 $eb^{1/2}$ *2* (1999Co02) for J=9 and 11 states.
1512.5[@] *4*	(10+)	7.8 ps *+51−12*	BC	J^π: γ to (8+); band member.
1707.8[&] *5*	(11−)		B	J^π: gammas to (9−) and (10+); band member. D_0/Q_0=0.00273 $b_{1/2}$ *63* (1999Co02). Average D_0=0.010 $eb^{1/2}$ *2* (1999Co02) for J=9 and 11 states.
1912.9?[@] *6*	(12+)		B	J^π: possible γ to (10+); band member.
2088.7[&] *7*	(13−)		B	J^π: gammas to (11−) and (12+); band member.
2316.7?[@] *8*	(14+)		B	J^π: possible γ to (12+); band member.
2485.0?[&] *9*	(15−)		B	J^π: possible γ to (13−); band member.
2727.2?[@] *10*	(16+)		B	J^π: possible γ to (14+); band member.
2881.6?[&] *10*	(17−)		B	J^π: possible γ to (15−); band member.
3285.6?[&] *12*	(19−)		B	J^π: possible γ to (17−); band member.
3695.8?[&] *13*	(21−)		B	J^π: possible γ to (19−); band member.

[†] From least-squares fit to Eγ data.
[‡] From band assignments in ^{232}Th(^{136}Xe,Xγ) for levels above 635 keV.
[#] For levels above 186 keV, half-lives deduced by evaluators from E2 matrix elements measured (2022Sp01) in Coulomb excitation.
[@] Band(A): $K^\pi=0^+$ g.s. band.
[&] Band(B): $K^\pi=0^-$ octupole vibrational band.
[a] Band(C): Possible γ band.

$\gamma(^{222}Rn)$

B(E2)(W.u.) and B(E1)(W.u.) values are from Coulomb excitation, deduced by evaluators from measured transition matrix elements, with exceptions noted.

E_i(level)	J^π_i	E_γ[†]	I_γ[†]	E_f	J^π_f	Mult.	α[‡]	$I_{(\gamma+ce)}$	Comments
186.211	2^+	186.211 *13*	100	0.0	0^+	E2	0.677 *9*		B(E2)(W.u.)=58 *4*
448.48	4^+	262.27 *5*	100	186.211	2^+	[E2]	0.2087 *30*		B(E2)(W.u.)=90 *+4−7*
600.74	1^-	414.60 *5*	60	186.211	2^+	[E1]	0.01628 *23*		B(E1)(W.u.)=0.0014 *+23−9* B(E1)(W.u.) from $T_{1/2}$ and γ branching, 20% uncertainty assumed in the γ branching ratio.
		600.66 *5*	100	0.0	0^+	[E1]	0.00762 *11*		B(E1)(W.u.)=7×10^{-4} *+21−4*
635.57	3^-	(34.81 *16*)	≈0.032	600.74	1^-	[E2]	1.30×10^3 *4*	≈42	B(E2)(W.u.)=80 *+32−27*
		187.10[@] *20*		448.48	4^+	[E1]	0.1011 *14*		
		449.37 *10*	≈100	186.211	2^+	[E1]	0.0137 *2*	≈100	B(E1)(W.u.)≈4×10^{-6} B(E1)(W.u.) from $T_{1/2}$.
768.08	(6^+)	319.6 *2*	100	448.48	4^+	[E2]	0.1144 *16*		B(E2)(W.u.)=120 *+9−12*
797.4	(5^-)	163.0[@] *5*		635.57	3^-	[E2]	1.116 *21*		B(E2)(W.u.)=4.6 *+12−17*
		348.9 *5*		448.48	4^+				
867.0	(0^+)	266 *2*		600.74	1^-	[E1]	0.0438 *10*		B(E1)(W.u.)=1.4×10^{-3} *+11−8*
		681[#]		186.211	2^+	[E2]	0.0176 *3*		B(E2)(W.u.)=13 *4* Iγ(681γ)/Iγ(266γ)=1.9 *+38−12*, deduced by evaluators from B(E2)(W.u.)/B(E1)(W.u.) ratio.
867.1	(2^+)	681[#]		186.211	2^+	[E2+M1]	0.042 *25*		B(E2)(W.u.)=6.8 *42*
		867		0.0	0^+	[E2]	0.0107 *2*		B(E2)(W.u.)=1.5 *+4−5* Iγ(867γ)/Iγ(681γ)=0.7 *+6−4*, deduced by evaluators from B(E2)(W.u.) ratio, assuming pure E2 for 681.
959.2	(3^+)	773		186.211	2^+	[E2+M1]	0.031 *17*		B(E2)(W.u.)=26 *+14−17*
1048.7	(7^-)	251.4[@] *5*		797.4	(5^-)	[E2]	0.240 *4*		B(E2)(W.u.)=26×10^1 *+12−10*
		280.6 *5*	100 *28*	768.08	(6^+)	[E1]	0.0387 *6*		
1111.5	(4^+)	663		448.48	4^+	[E2+M1]	0.04 *3*		B(E2)(W.u.)=11.5 *+39−45*
1127.7	(8^+)	359.6 *2*	100	768.08	(6^+)	[E2]	0.0819 *12*		B(E2)(W.u.)=149 *+42−19*
1356.5	(9^-)	228.8 *5*	74 *42*	1127.7	(8^+)	[E1]	0.0624 *9*		
		307.7 *5*	100 *42*	1048.7	(7^-)	[E2]	0.1279 *19*		B(E2)(W.u.)=20×10^1 *+19−8*
1512.5	(10^+)	384.9 *2*	100	1127.7	(8^+)	[E2]	0.0680 *10*		B(E2)(W.u.)=100 *+26−39*
1707.8	(11^-)	195.4 *5*	48 *31*	1512.5	(10^+)	[E1]	0.0910 *14*		
		351.2 *5*	100 *31*	1356.5	(9^-)	[E2]	0.0874 *13*		
1912.9?	(12^+)	400.4[@] *5*		1512.5	(10^+)				
2088.7	(13^-)	175.6[@] *5*		1912.9?	(12^+)				
		380.9 *5*	100 *53*	1707.8	(11^-)	[E2]	0.0700 *10*		

$^{222}_{86}Rn_{136}$-4

Adopted Levels, Gammas (continued)

$\gamma(^{222}Rn)$ (continued)

E_i(level)	J^π_i	E_γ †	E_f	J^π_f
2316.7?	(14^+)	403.8@ *5*	1912.9?	(12^+)
2485.0?	(15^-)	396.3@ *5*	2088.7	(13^-)
2727.2?	(16^+)	410.5@ *5*	2316.7?	(14^+)
2881.6?	(17^-)	396.6@ *5*	2485.0?	(15^-)
3285.6?	(19^-)	404.0@ *5*	2881.6?	(17^-)
3695.8?	(21^-)	410.2@ *5*	3285.6?	(19^-)

† From ^{226}Ra α decay for levels up to 636 keV. For higher levels, values are from ^{232}Th(^{136}Xe,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.

Multiply placed.

@ Placement of transition in the level scheme is uncertain.

From ENSDF

$^{222}_{86}Rn_{136}$-5

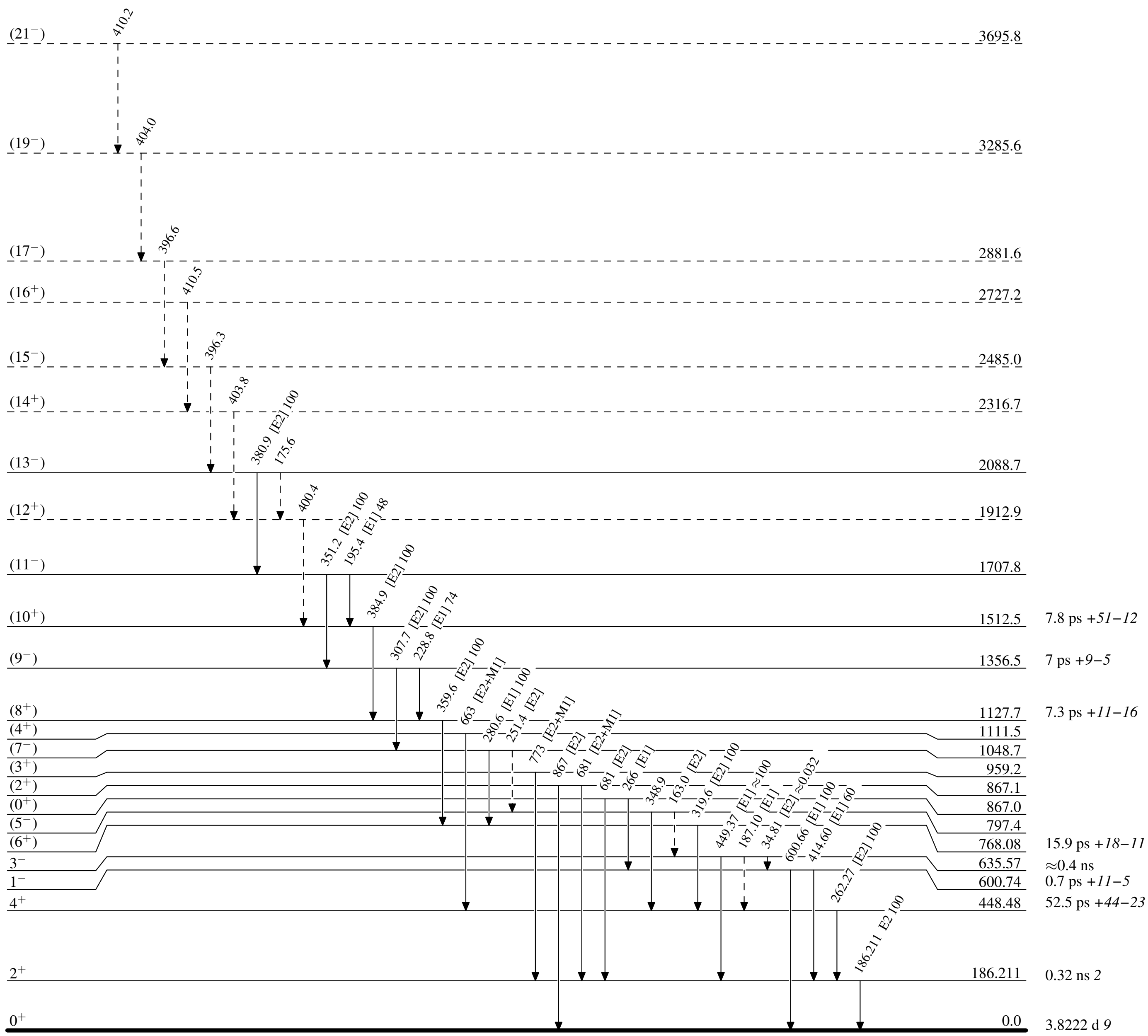
Adopted Levels, Gammas

Legend

Level Scheme

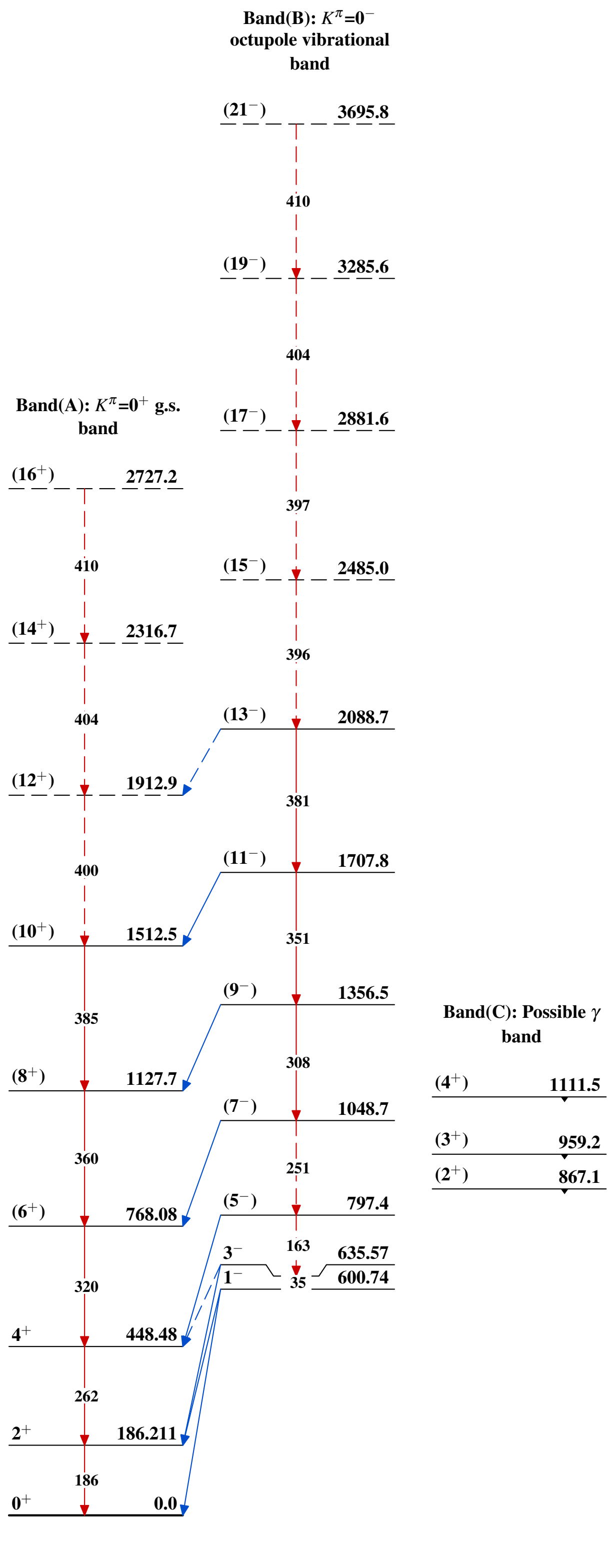
Intensities: Relative photon branching from each level

γ Decay (Uncertain)



$^{222}_{86}Rn_{136}$

Adopted Levels, Gammas



$^{222}_{86}Rn_{136}$