^{223}Ra -Comments on evaluation of decay data
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Evaluated in December 2010 with a literature cut-off by the same date.

1. DECAY SCHEME

^{223}Ra decays 100 % to levels of ^{219}Rn by emission of α particles, with a very small branch of 6.4 (1) × 10^{-8} % by emission of ^{14}C (1991Ma16). The adopted ^{219}Rn levels populated in the ^{223}Ra α decay are based on the measurement by Sheline *et al.* (1998Sh02) and the *NDS* evaluation by Browne (2001Br31). An intense population takes place only to levels in ^{219}Rn with energy less than 500 keV (11 excited levels and ground state) and, in this part, the decay scheme is well defined, though, at some levels, there is a certain discrepancy in the P(α) values measured and deduced from probability balance.

At the same time, for a number of levels with higher energy there is disagreement between measured probabilities of alpha-transitions and the values deduced from P(γ+ce) balance. Besides, the placement of some γ-rays in the level scheme is uncertain and some observed γ-ray transitions have not been placed. Therefore, in this part the decay scheme cannot be considered as fully completed. Further measurements are needed to determine the γ-ray transitions and ^{223}Ra α decay scheme with greater precision.

The decay scheme overall consistency is verified by the comparison between Q(calc) = 6027 (133) keV, deduced from the evaluated average energies of all emissions, and Q(α) = 5978.99 (21) keV from the atomic mass evaluation of Audi *et al.* (2003Au03). Percentage deviation between Q(calc) and Q(α) is (0.8 ± 2.2) %. The deviation is not big but more than for other α decaying applied radionuclides. This indicates the need in new precise measurements of α-particle and γ-ray transitions in decay of ^{223}Ra.

2. NUCLEAR DATA

Q(α) value is from Audi *et al.* (2003Au03).

The ^{223}Ra half-life is based on the experimental results given in Table 1.

Table 1: Experimental values of ^{223}Ra half-life (in days)

Reference	Author(s)	Original value	Re-estimated	Method
1954Ha60	Hagee *et al.*	11.685 (56)		Proportional α counting
1959Ro51	Robert	11.22 (5)		Microcalorimetry
1965Ki05	Kirby *et al.*	11.4347 (11) [a]	11.4347 (44) [a]	Microcalorimetry
1965Ki05	Kirby *et al.*	11.4267 (62) [b]	11.427 (17) [b]	Proportional α counting
1967JoZX	Jordan and Blanke	11.372 (45)		Calorimetry
1987Mi10	Miller *et al.*	11.444 (46)		From α-activity following ^{227}Th decay

[a] The original value was deduced as a weighted average of the data from observations with two calorimeters: 11.4432 (57) and 11.4344 (11) days. The uncertainties are probable errors of a single observation. To take into account the contribution of possible unrecognized systematic errors associated with the method, the evaluator expanded the uncertainty to a half of the difference of the two experimental results (0.0044 day).

[b] The original value was deduced as a weighted average of the data from observations with a 2π windowless proportional counter for 10 samples. The uncertainties of the 10 measurement results include only statistical errors. To take into account the contribution of possible unrecognized systematic errors associated with the method, for the re-estimated value the evaluator used the smallest uncertainty of 0.017 d stated in the measurements.

From the six values adopted in the data analysis, the LWEIGHT computer program increased the uncertainty in the value of 11.4347 (1965Ki05) to 0.0139 to adjust weights according to the LRSW method and used a weighted average of 11.429 and an external uncertainty of 0.028 ($\chi^2/\nu = 8.05$).

The recommended value for the ^{223}Ra half-life is 11.43 (3) days.

2.1. Alpha Transitions

The energies of the alpha transitions have been obtained from the Q(α) value and ^{219}Rn level energies given in Table 2 from 2001Br31, where they were deduced from a least-squares fit to gamma-ray energies.

Table 2: ^{219}Rn levels populated in ^{223}Ra α-decay

Level	Energy (keV)	Spin and parity	Half-life	Probability of α- transition (%)
0	0.0	$5/2^+$	3.96 (1) s	1.0 (2)
1	4.47 (1)	$(9/2)^+$	15.4 (13) ns	-
2	14.37 (1)	$(7/2)^+$	875 (30) ps	0.32 (4)
3	126.77 (2)	$(11/2)^+$	402 (20) ps	10.0 (3)
4	158.64 (1)	$(7/2)^+$	42.3 (50) ps	49.6 (12)
5	269.48 (1)	$3/2^+$	14.2 (23) ps	25.8 (11)
6	338.27 (1)	$(5/2)^+$	6.1 (28) ps	10.6 (10)
7	342.78 (2)	$(5/2, 7/2)^-$		-
8	376.26 (2)	$(9/2)^+$	6.9 (38) ps	0.74 (25)
9	377.33 (6)	$(7/2, 9/2)^-$		-
10	397.1 (4)			≈ 0.008
11	445.03 (1)	$(5/2)^+$	6.2 (31) ps	1.60 (24)
12	446.82 (3)	$(5/2)^-$		0.50 (8)
13	490.92 (2)	$(5/2, 7/2, 9/2)^-$		-
14	514.5 (1)	$(9/2^+)$		≈ 0.13
15	517.7 ?			-
16	541.99 (2)	$(7/2^+)$		≈ 0.13
17	594.1 (1)	$(7/2)^-$		0.16 (4)

18	598.72 (2)	$(5/2, 7/2, 9/2)^+$		0.093
19	623.68 (4)			0.042
20	646.1 (1)			0.041
21	672.6 (5)			0.0053
22	711.3 (1)			0.026
23	732.8 (1)			0.021
24	748			≈ 0.0017
25	773			$\approx 6\times10^{-4}$
26	800			$\approx 3\times10^{-4}$
27	830			$\approx 2\times10^{-4}$
28	851			$\approx 4\times10^{-4}$
29	861			$\approx 6.3\times10^{-4}$
30	873			$\approx 4.4\times10^{-4}$

The recommended values of α-transition probabilities (P(α)) are based on the measurements of 1957Pi31, 1962Gi04, 1962Wa18, 1970Da08 and also on the P(α) values deduced by the evaluator from P(γ+ce) balance at the corresponding ^{219}Rn levels (Table 3).

As the lower part of the decay scheme (^{219}Rn levels with energy less than 500 keV) is reasonably complete and well defined, the probabilities of the prominent α-transitions reaching them have been deduced from P(γ+ce) balances. The uncertainties of the recommended values were expanded, where necessary, to cover the unweighted mean (UWM) of experimental P(α) values.

The probabilities of weak α-transitions (P(α) < 0.0015) have been taken mainly from the measurements of 1962Wa18 with magnetic spectrometer and also from the measurements of 1970Da08 with semiconductor detector. The P(α) values reported in 1962Wa18 have been renormalized to a sum of 100 % by 1970Da08. The uncertainties reported in 1970Da08 are only statistical (from averaging data of three measurements) and comparable with the supposed uncertainties of 1962Wa18, 1962Gi04 and 1957Pi31.

Table 3: Experimental and recommended probabilities (per 100 decays) of alpha-transitions observed in ^{223}Ra α decay

	α-particle energy	1957Pi31	1962Gi04	1962Wa18 [a]	1970Da08	UWM	Deduced from P(γ+ce) balance	**Recommended**
$\alpha_{0,0}$	5871	0.96	1.5	0.85	0.85 (4)	1.04 (16)		**1.0 (2)** [c]
$\alpha_{0,2}$	5858	0.3		0.31	0.32 (4)			**0.32 (4)** [d]
$\alpha_{0,3}$	5747	10.5	10.2	8.85 (18) [b]	9.50 (58)	9.8 (4)	10.0 (3)	**10.0 (3)** [e]
$\alpha_{0,4}$	5716	50.4	48.0	52.2 (11) [b]	52.5 (8)	50.8 (10)	49.6 (9)	**49.6 (12)** [e]
$\alpha_{0,5}$	5607	23.6	25.7	25.3 (5) [b]	24.2 (4)	24.7 (5)	25.8 (6)	**25.8 (11)** [e]
$\alpha_{0,6}$	5540	10.3	10.2	8.85 (18) [b]	9.16 (30)	9.6 (4)	10.60 (17)	**10.6 (10)** [e]
$\alpha_{0,8}$	5502	0.86	1.3	0.78	1.00 (15)	0.99 (11)	0.74 (3)	**0.74 (25)** [e]
$\alpha_{0,10}$	5481			≈ 0.008			0.0007 (4)	**≈ 0.008**
$\alpha_{0,11}+\alpha_{0,12}$	5434	2.4	2.5	2.24	2.27 (20)	2.35 (6)	2.10 (9)	**2.10 (25)** [e]

	α-particle energy	1957Pi31	1962Gi04	1962Wa18 [a]	1970Da08	UWM	Deduced from P(γ+ce) balance	**Recommended**
$\alpha_{0,14}$	5366	0.20	} Σ 0.25	0.108	≈ 0.13	0.15 (3)	0.014 (7)	**≈ 0.13** [d]
$\alpha_{0,16}$	5339	0.07		0.098	≈ 0.13	0.099 (17)	0.089 (6)	**≈ 0.13** [d]
$\alpha_{0,17}$	5287	} Σ 0.3	} Σ 0.3	0.126	≈ 0.16		0.16 (4)	**0.16 (4)** [e]
$\alpha_{0,18}$	5283			0.093				**0.093**
$\alpha_{0,19}$	5259			0.042			0.079 (8)	**0.042**
$\alpha_{0,20}$	5236			0.041			0.022 (4)	**0.041**
$\alpha_{0,21}$	5212			0.0053			0.0011 (6)	**0.0053**
$\alpha_{0,22}$	5173			0.026			0.013 (4)	**0.026**
$\alpha_{0,23}$	5152			0.021			0.0134 (27)	**0.021**
$\alpha_{0,24}$	5135			≈ 0.0017				**≈ 0.0017**
$\alpha_{0,25}$	5112			≈ 0.0006				**≈ 0.0006**
$\alpha_{0,26}$	5086			≈ 0.0003				**≈ 0.0003**
$\alpha_{0,27}$	5056			≈ 0.0002				**≈ 0.0002**
$\alpha_{0,28}$	5036			≈ 0.0004				**≈ 0.0004**
$\alpha_{0,29}$	5026			≈ 0.00063				**≈ 0.00063**
$\alpha_{0,30}$	5014			≈ 0.00044				**≈ 0.00044**

[a] Authors did not report individual uncertainties for intensity of each α-particle group but stated the relative uncertainty of 2 % for intense α-lines and 10 % for weak α-lines.

[b] Uncertainty given by Rytz (1991Ry01).

[c] Value recommended by Rytz (1991Ry01)

[d] Adopted from 1970Da08.

[e] Deduced from P(γ+ce) balance. Uncertainties were expanded to cover UWM of experimental P_α values.

The α decay hindrance factors have been calculated using the ALPHAD computer program from the ENSDF evaluation package with $r_0(^{219}Rn) = 1.543$ fm (2001Br31).

2.2. Gamma Transitions and Internal Conversion Coefficients

The recommended energies of the gamma-ray transitions are the same as those of the gamma-ray energies corrected by the minor nuclear recoil of ^{219}Rn.

The gamma-ray transition probabilities (P(γ+ce)) have been deduced from their evaluated gamma-ray emission probabilities (P(γ)) and total internal conversion coefficients (ICCs).

ICCs have been interpolated using the BrIcc computer program, version v2.2a, with the "frozen orbital" approximation (2008Ki07). Multipolarities of the gamma-ray transitions and E2/M1 mixing ratios (δ) are those deduced by 2001Br31, on the basis of measurements of conversion electrons (ce) by 1970Da08, 1970Kr01, 1972HeYM, 1974Ri05, and 1998Sh02.

P(γ+ce) values for the gamma-ray transitions $\gamma_{1,0}$ (4.4 keV), $\gamma_{9,7}$ (34.5 keV) and $\gamma_{22,18}$ (112.6 keV) have been deduced from probability balances at the ^{219}Rn ground state (level '0'), level '7' (342.8 keV) and level '18' (598.7 keV), respectively.

3. ATOMIC DATA

The fluorescence yields, X-ray energies and relative probabilities, and Auger energies and relative probabilities are from the SAISINUC software.

4. ALPHA EMISSIONS

The recommended energies of alpha particles have been deduced from the Q(α) value, taking into account the recoil energies for ^{219}Rn.

The recommended α-particle energies are compared in Table 4 with the experimental results from spectrometric measurements by 1957Pi31, 1961Ry02, 1962Wa18, 1964Wa19, 1970Da08, and 1971Gr17.

Table 4: Experimental and recommended α-particle energies (keV) in the decay of ^{223}Ra [a]

	1957Pi31	1961Ry02	1962Wa18 [b]	1964Wa19	1970Da08	1971Gr17	**Recommended**
$\alpha_{0,0}$	5870 (2)		5871.6 (10)	5869.5 (17)	5871 (3)		**5871.63 (21)**
$\alpha_{0,2}$	5856		5857.5 (10)		5857 (3)		**5857.52 (21)**
$\alpha_{0,3}$	5745 (2)	5745.5	5747.4		5747 (3)	5747.0 (4)	**5747.14 (21)**
$\alpha_{0,4}$	5715	5714.3	5716.1		5715 (3)	5716.23 (29)	**5715.84 (21)**
$\alpha_{0,5}$	5605	5605.3	5607.1		5606 (3)	5606.73 (30)	**5606.99 (21)**
$\alpha_{0,6}$	5537	5537.1	5539.6		5537 (3)	5539.8 (9)	**5539.43 (21)**
$\alpha_{0,8}$	5500		5501.6 (10)		5501 (3)		**5502.12 (21)**
$\alpha_{0,11}$	5432		5433.6 (5)		5435 (3)		**5434.59 (21)**
$\alpha_{0,14}$	5363		5365.6 (10)		5367 (3)		**5366.37 (23)**
$\alpha_{0,16}$	5337		5338.7 (10)		5339 (3)		**5339.37 (21)**
$\alpha_{0,17}$	5287		5287.3 (10)		5288 (3)		**5288.19 (23)**

[a] Authors' experimental values have been adjusted for changes in calibration energies following 1977Ma31 and 1991Ry01.

[b] Uncertainties of 1962Wa18 are the values estimated by 1977Ma31.

5. ELECTRON EMISSIONS

The energies of the conversion electrons have been obtained from the gamma-ray transition energies and the atomic electron binding energies from 1977La19. The emission probabilities of the conversion electrons have been deduced using the evaluated P(γ) and ICC values. Measurements of the ^{219}Rn conversion electrons were carried out by 1969Be67, 1970Da08, 1970Kr01, 1972HeYM, 1974Ri05, and 1998Sh02.

The total absolute emission probabilities of K and L Auger electrons have been calculated using the EMISSION computer program (1996Sc06, 2000Sc47).

6. PHOTON EMISSIONS

6.1 X - Ray emissions

The absolute emission probabilities of Rn KX- and LX-rays were calculated using the EMISSION computer program (Table 5). In 1976Bl13 the emission probabilities of Rn KX-rays were measured relatively to Pγ ($\gamma_{5,0}$ 269.5 keV). The experimental absolute P(KX) values are given in Table 5 using the evaluated Pγ ($\gamma_{5,0}$ 269.5 keV) = 14.23 (15) %.

Table 5: Experimental (1976Bl13) and calculated absolute Rn KX-ray emission probabilities (%)

	1976Bl13	Calculated
$K\alpha_2$ (Rn)	11.5 (13)	14.86 (23)
$K\alpha_1$ (Rn)	19.4 (24)	24.5 (4)
$K\beta'_1$ (Rn)	9.4 (7)	8.50 (18)
$K\beta'_2$ (Rn)	1.71 (14)	2.72 (7)

6.2. Gamma emissions

6.2.1. Gamma-ray energies

The gamma-ray energies (E_γ) for $\gamma_{1,0}$ (4.5 keV), $\gamma_{2,1}$ (9.9 keV), $\gamma_{2,0}$ (14.4 keV), $\gamma_{4,3}$ (31.9 keV), $\gamma_{12,7}$ (104.0 keV), $\gamma_{4,2}$ (144.3 keV), $\gamma_{8,3}$ (249.5 keV), $\gamma_{7,0}$ (342.8 keV), $\gamma_{8,2}$ (361.9 keV), $\gamma_{9,1}$ (372.9 keV), $\gamma_{8,0}$ (376.3 keV), $\gamma_{16,4}$ (383.4 keV), $\gamma_{12,2}$ (432.4 keV), $\gamma_{16,0}$ (542.0 keV), and $\gamma_{19,0}$ (623.7 keV) have been deduced directly from the adopted ^{219}Rn level energies.

The remaining gamma-ray energies have been taken mainly from 2001Br31. They are weighted averages of the experimental values from 1998Sh02, 1976Bl13, 1972HeYM, 1970Da08, 1970Kr01, and 1968Br17, except as specified otherwise in footnotes of Table 6. The most precise measurements of E_γ from 1976Bl13 with Ge(Li) detector dominate the weighted averages.

Less accurate measurements of E_γ were reported in 1957Pi31, 1957Pa07, 1966Po02, 1969Be67, they were not used in the evaluation.

It should be noted that in 2001Br31 many questionable unplaced gamma-ray transitions are given from some spectrometric measurement results published in the above references, but they have not been yet confirmed by other authors. Observation of such gamma-ray transitions may be assigned to daughters of ^{223}Ra or other isotope impurities and most of these gamma-rays have not been included in the current evaluation. The criterion for their inclusion was an observation in α-γ high resolution coincidence with planar and high efficiency coaxial Ge detectors in the latest experiment by 1998Sh02.

6.2.2. Gamma-ray emission probabilities

The experimental and evaluated relative emission probabilities (I_γ) of gamma-rays in decay of ^{223}Ra are presented in Table 6. The adopted values are the weighted means of the experimental values except when noted. The statistical processing was done using the LWEIGHT computer program. The uncertainties assigned in this evaluation to the recommended values are always greater than or equal to the smallest uncertainty in any of the experimental values used in the calculation.

The normalization factor (N) was obtained from the probability balance to the ^{219}Rn ground state (level ‘0’) and excited levels ‘1’ (4.5 keV) and ‘2’ (14.4 keV):

$\Sigma(1+\alpha T)I_\gamma\ (\gamma_{i,0}\ ,\ \gamma_{j,1}\ ,\ \gamma_{k,2}) + P(\alpha_{0,0}) + P(\alpha_{0,2}) = 1$

where i = 4, 5, 6, 7, 8, 11, 16, 17, 18, 19, 20, 22, 23;

j = 3, 4, 6, 8, 9, 14, 16, 19, 20, 23;

k=4, 5, 6, 7, 8, 9, 11, 12, 14, 16, 17, 18, 19, 20, 22, 23.

N = P(γ) (269.5 keV) = 0.1423 (15).

This adopted value can be compared with the measured Pγ (269.5 keV) of 0.140 (15) (1968Br17) and the value of 0.136 (10) (1970Da08) deduced from an α-feed of the 269 keV level in ^{219}Rn.

The absolute gamma-ray emission probabilities (P(γ)) have been deduced from the evaluated relative gamma-ray emission probabilities (Table 6) using the derived normalization factor of 0.1423 (15).

P(γ) values for the gamma-ray transitions $\gamma_{2,1}$ (9.9 keV) and $\gamma_{2,0}$ (14.4 keV) have been obtained directly from probability balance at the ^{219}Rn level ‘2’ (14.4 keV) and the ratio of $P(\gamma_{2,1}$ - 9.9 keV)/$P(\gamma_{2,0}$ - 14.4 keV) = 0.86 (9) deduced from measured ratio of intensities of conversion electrons (1974Ri05) and the ratio of theoretical ICCs.

Pγ value for the gamma-ray transition $\gamma_{1,0}$ (4.5 keV) has been estimated from Pγ+ce using the total theoretical ICC α_T.

Table 6: Recommended energies (E_γ) and experimental and evaluated relative emission probabilities (I_γ) of gamma-rays in decay of ^{223}Ra

	Recommended E_γ (keV)	**1968Br17**	**1970Kr01**	**1970Da08**	**1972HeYM**	**1976Bl13**	**1998Sh02**	**Evaluated I_γ**
$\gamma_{1,0}$	**4.47 (1)** [a]							
$\gamma_{2,1}$	**9.90 (2)** [a]							
$\gamma_{2,0}$	**14.37 (1)** [a]							
$\gamma_{4,3}$	**31.87 (2)** [a]		0.000 74 (15)				0.001	**0.000 74 (15)**
$\gamma_{9,7}$	**34.5 (2)** [b]							
$\gamma_{12,9}$	**69.5 (1)** [b]						0.05 (2)	**0.05 (2)**
$\gamma_{15,12}$	**70.9 (2)** [b]						0.025 (8)	**0.025 (8)**
$\gamma_{11,7}$	**102.2 (2)** [b]						0.006 (3)	**0.006 (3)**
$\gamma_{17,13}$	**103.2 (2)** [b]	0.100 (14) [e]			0.12 (7) [e]		0.04 (2)	**0.04 (2)**
$\gamma_{12,7}$	**104.04 (4)** [a]					0.134 (15)	0.14 (2)	**0.136 (15)**
$\gamma_{11,6}$	**106.78 (3)**	0.164 (29)	0.14 (3)	0.16 (4)	0.19 (6)	0.157 (15)	0.17 (1)	**0.164 (10)**
$\gamma_{12,6}$	**108.5 (2)** [b]						0.04 (2)	**0.04 (2)**
$\gamma_{5,4}$	**110.856 (10)**	0.40 (6)	0.331 (29) [f]	0.41 (4)	0.21 (9) [f]	0.40 (4)	0.42 (3)	**0.41 (3)**
$\gamma_{22,18}$	**112.6** [c]							
$\gamma_{13,8}$	**114.7 (2)**				0.07 (4)		0.07 (3)	**0.07 (3)**
$\gamma_{3,1}$	**122.319 (10)**	8.2 (11)	8.75 (15)	9.8 (10)	8.7 (4)	7.5 (8)	8.7 (1)	**8.70 (10)**
$\gamma_{20,14}$	**131.6 (2)**				0.037 (22)		0.04 (2)	**0.04 (2)**
$\gamma_{14,8}$	**138.3 (3)** [b]						0.012 (5)	**0.012 (5)**
$\gamma_{4,2}$	**144.27 (2)** [a]	22.1 (21)	23.8 (5)	23.0 (24)	27.4 (18) [f]	21.6 (22)	23.5 (5)	**23.6 (5)**
$\gamma_{17,12}$	**147.2 (2)** [b]						0.04 (2)	**0.04 (2)**
$\gamma_{4,1}$	**154.208 (10)**	38.6 (29)	41.1 (8)	38 (4)	44.4 (26)	38 (4)	41 (1)	**41.0 (8)**
$\gamma_{4,0}$	**158.635 (10)**	5.0 (5)	5.02 (10)	5.6 (6)	5.3 (4)	4.6 (4)	5.0 (1)	**5.01 (10)**
$\gamma_{16,8}$	**165.8 (2)**				0.037 (22)		0.04 (2)	**0.038 (20)**

	Recommended E_γ (keV)	1968Br17	1970Kr01	1970Da08	1972HeYM	1976Bl13	1998Sh02	Evaluated I_γ
$\gamma_{11,5}$	**175.65 (15)**		0.10 (3)		0.15 (4)		0.14 (3)	**0.12 (3)**
$\gamma_{12,5}$	**177.3 (1)**	0.21 (7)	0.34 (3)		0.35 (6)		0.34 (3)	**0.33 (3)**
$\gamma_{6,4}$	**179.54 (6)**	1.07 (29)	1.07 (29)	1.10 (13)	1.16 (15)	1.01 (10)	1.1 (1)	**1.08 (10)**
$\gamma_{20,12}$	**199.3 (3)**				0.022 (15)		0.02 (1)	**0.021 (10)**
$\gamma_{18,9}$	**221.32 (24)**	0.25 (7)	0.22 (4)		0.25 (4)		0.26 (4)	**0.25 (4)**
$\gamma_{19,8}$	**247.2 (5)**				0.066 (22)		0.07 (2)	**0.068 (20)**
$\gamma_{8,3}$	**249.49 (3)** [a]	0.26 (7)			0.29 (13)		0.28 (7)	**0.27 (7)**
$\gamma_{17,7}$	**251.6 (3)**	0.49 (11)	0.27 (7)	0.42 (15)	0.49 (15)	0.47 (7)	0.3 (1)	**0.39 (7)**
$\gamma_{5,2}$	**255.2 (2)**	0.43 (11)		0.37 (15)	0.24 (7)	0.33 (7)	0.38 (5)	**0.34 (5)**
$\gamma_{17,6}$	**255.7 (3)**				0.037 (22)		0.04 (2)	**0.039 (20)**
$\gamma_{18,6}$	**260.4 (3)**				0.044 (22)		0.05 (2)	**0.047 (20)**
$\gamma_{5,0}$	**269.463 (10)**	100 (11)	100 (2)	100 (7)	100 (4)	100 (4)	100 (2)	**100 (2)**
$\gamma_{10,3}$	**270.3 (4)** [b]						0.005 (3)	**0.005 (3)**
$\gamma_{23,12}$	**286.0 (4)** [b]						0.008 (4)	**0.008 (4)**
$\gamma_{12,4}$	**288.18 (3)**	1.14 (14)	1.16 (5)	1.08 (12)	0.93 (13) [f]	1.07 (5)	1.15 (3)	**1.13 (3)**
$\gamma_{6,2}$	**323.871 (10)**	26.5 (29)	29.4 (6)	26.5 (26)	26.8 (11)	26.8 (13)	28.7 (5)	**28.5 (5)**
$\gamma_{7,2}$	**328.38 (3)** [a]	1.43 (14)	1.52 (7)	1.19 (24)	1.18 (18)	1.40 (8)	1.5 (5)	**1.43 (7)**
$\gamma_{6,1}$	**334.01 (6)**	0.61 (9)	0.76 (6)	0.91 (18)	0.69 (11)	0.54 (7)	0.73 (4)	**0.70 (4)**
$\gamma_{6,0}$	**338.282 (10)**	19.3 (18)	21 (5)	19.0 (20)	19.2 (7)	18.5 (9)	20.4 (4)	**20.0 (4)**
$\gamma_{7,0}$	**342.78 (2)** [a]	1.43 (14)	1.70 (9)	1.5 (4)	0.71 (16) [f]	1.49 (12)	1.6 (1)	**1.59 (9)**
$\gamma_{23,9}$	**355.5 (2)** [b]						0.03 (1)	**0.03 (1)**
$\gamma_{14,4}$	**355.7 (2)** [b]						0.02 (1)	**0.02 (1)**
$\gamma_{8,2}$	**361.89 (2)** [a]	0.29 (7)	0.34 (4)	0.37 (7)	0.24 (6)	0.298 (22)	0.20 (5)	**0.20 (5)** [g]
$\gamma_{9,2}$	**362.9 (2)** [b]						0.11 (5)	**0.11 (5)**
$\gamma_{22,7}$	**368.56 (12)**				0.06 (3)		0.06 (3)	**0.06 (3)**
$\gamma_{8,1}$	**371.676 (15)**	3.9 (4)	3.56 (7)	4.0 (6)	4.2 (4)	3.14 (16)	3.5 (1)	**3.51 (7)**

	Recommended E_γ (keV)	1968Br17	1970Kr01	1970Da08	1972HeYM	1976Bl13	1998Sh02	Evaluated I_γ
$\gamma_{9,1}$	**372.86 (1)** [a,b]	≈ 0.7				0.73 (8)	0.36	**0.36** [i]
$\gamma_{8,0}$	**376.26 (2)** [a]			0.088 (29)			0.09 (3)	**0.09 (3)**
$\gamma_{16,4}$	**383.35 (2)** [a]	≈ 0.04		0.11 (4)	0.029 (22)		-	**0.05 (3)**
$\gamma_{14,3}$	**387.7 (2)**				0.10 (4)		0.11 (4)	**0.11 (4)**
$\gamma_{23,7}$	**390.1 (2)**	≈ 0.05			0.022 (15)		0.05 (2)	**0.032 (15)**
$\gamma_{11,2}$	**430.6 (3)**				0.14 (4)		0.14 (4)	**0.14 (4)**
$\gamma_{12,2}$	**432.45 (3)** [a]	0.24 (3)	0.26 (4)	≈0.22	0.24 (6)	0.186 (30) [f]	0.25 (2)	**0.25 (2)**
$\gamma_{11,0}$	**445.033 (12)**	8.7 (4)	11.0 (8) [f]	9.3 (10)	9.2 (7)	8.5 (4)	9.3 (3)	**9.0 (3)**
$\gamma_{20,4}$	**487.5 (2)**	0.071 (14)	0.10 (4)	≈0.11	0.08 (4)		0.08 (1)	**0.08 (1)**
$\gamma_{-1,1}$	**490.8 (3)** [b]						0.012 (5)	**0.012 (5)**
$\gamma_{14,2}$	**500.0 (4)** [b]						0.010 (4)	**0.010 (4)**
$\gamma_{14,1}$	**510.0 (4)** [b]						0.003 (2)	**0.003 (2)**
$\gamma_{-1,2}$	**523.2 (4)** [b]						0.010 (4)	**0.010 (4)**
$\gamma_{16,2}$	**527.611 (13)**	0.50 (5)	0.54 (5)	0.51 (10)	0.47 (11)	0.410 (22) [f]	0.51 (3)	**0.51 (3)**
$\gamma_{-1,3}$	**532.9 (4)** [b]						0.010 (4)	**0.010 (4)**
$\gamma_{16,1}$	**537.6 (1)** [b]						0.015 (5)	**0.015 (5)**
$\gamma_{16,0}$	**541.99 (2)** [a,b]						0.010 (4)	**0.010 (4)**
$\gamma_{21,3}$	**545.8 (5)** [b]						0.008 (4)	**0.008 (4)**
$\gamma_{23,4}$	**574.1 (7)** [b]						0.008 (4)	**0.008 (4)**
$\gamma_{17,2}$	**579.6 (3)** [b]						0.010 (4)	**0.010 (4)**
$\gamma_{18,2}$	**584.3 (3)** [b]						0.010 (4)	**0.010 (4)**
$\gamma_{17,0}$	**594.0 (3)** [b]						0.010 (4)	**0.010 (4)**
$\gamma_{18,0}$	**598.721 (24)**	0.57 (6)	0.76 (7)	0.68 (11)	0.66 (13)	0.626 (30)	0.68 (3)	**0.65 (3)**
$\gamma_{19,2}$	**609.31 (4)**	0.36 (4)	0.54 (7)	0.46 (7)	0.30 (11)	0.373 (22)	0.41 (2)	**0.40 (2)**
$\gamma_{19,1}$	**619.1 (4)** [b]						0.025 (8)	**0.025 (8)**
$\gamma_{19,0}$	**623.68 (4)** [a]	0.057 (29)					0.06 (3)	**0.06 (3)**

	Recommended E_γ (keV)	1968Br17	1970Kr01	1970Da08	1972HeYM	1976Bl13	1998Sh02	Evaluated I_γ
$\gamma_{20,2}$	**631.7 (7)**			0.22 (7)			0.003 (2)	**0.003 (2)**
$\gamma_{20,1}$	**641.7 (4)** [b]						0.012 (5)	**0.012 (5)**
$\gamma_{20,0}$	**646.1 (5)** [b]						0.003 (3)	**0.003 (3)**
$\gamma_{22,2}$	**696.9 (7)** [b]						0.005 (2)	**0.005 (2)**
$\gamma_{22,0}$	**711.3 (2)** [b]	0.025 (7)					0.026 (7)	**0.026 (7)**
$\gamma_{23,2}$	**718.4 (4)** [b]						0.010 (4)	**0.010 (4)**
$\gamma_{23,1}$	**728.4 (8)** [b]						0.002 (1)	**0.002 (1)**
$\gamma_{23,0}$	**732.8 (6)** [b]						0.004 (2)	**0.004 (2)**
$\gamma_{-1,4}$	**737.2 (8)** [b]						0.002 (1)	**0.002 (1)**

[a] From the adopted ^{219}Rn level energies.

[b] From 1998Sh02; new gamma-ray transition observed.

[c] Reported only by 1998Sh02 without uncertainty in energy and without intensity value.

[d] Not reported by 1998Sh02 but observed in 1968Br37, 1970Da08, 1972HeYM, 1976Bl13.

[e] Reported γ-ray with energy of 103.7 keV that may be a sum of 103.2 keV and 104.0 keV γ-rays.

[f] Omitted on Chauvenet's criterion.

[g] Adopted from 1998Sh02 because of possible contribution of impurity Pb γ-rays in measurements of single γ-spectra.

[h] Adopted from 1998Sh02 because of contribution of unplaced 373.3 keVγ-ray observed in measurements of single γ-spectra and not observed in α-γ coincidences.

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