^{227}Ac – Comments on evaluation of decay data by V. P. Chechev and N.K. Kuzmenko

This evaluation was completed in June 2008 with a literature cut off by the same date. The SAISINUC software and associated supporting computer programs were used in assembling the data following the established protocol within DDEP (2002Be).

1. Decay Scheme

The ^{227}Ac decay scheme is based on the evaluation of Browne (2001Br31). ^{227}Ac disintegrates (1,380 (4) %) by alpha transitions to the ground state and excited states of ^{223}Fr and (98,620 (4) %) by beta transitions to the ground state and excited states of ^{227}Th. The decay scheme cannot be considered well established since only approximate values are available for beta and gamma transition probabilities in the ß$^{-}$-decay of ^{227}Ac and the measurements of weak alpha transitions probabilities in the α-decay of ^{227}Ac are not sufficiently accurate.

2. Nuclear Data

Q(α) value is from 2003Au03.

The evaluated half-life of ^{227}Ac is based on the experimental results given in Table 1.

Table 1. Experimental values of the ^{227}Ac half-life (in years)

Reference	Author(s)	Value
1950Ho79	Hollander and Leininger	22,0 (3)
1955To07	Tobailem	21,6 (4)
1956Sh43	Shimanskaya and Yashugina	21,2 (8)
1959Ro51	Robert	21,6 (3)
1963Ei10	Eichelberger et al.	21,7714 (+56 −33)
1967JoZX	Jordan and Blanke	21,7728 (+29 −32)

The weighted mean of the 6 values is 21,772. The internal uncertainty is 0,0022, if we use the smallest uncertainties from 1963Ei10 and 1967JoZX, and 0,0028, if we use the largest uncertainties from these measurements. χ^2/ν = 0,34 and 0,33, respectively.

Our recommended value for the ^{227}Ac half-life is 21,772 (3) years.

2.1 Alpha Transitions

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

The comparison of the adopted energies of alpha particles for most intense transitions with the measured values is shown in Table 3 (columns 3 and 4). The measured energies of the alpha particles (Table 3) have been adjusted for changes in the calibration standards (1986Ry04, 1991Ry01): +3,5 keV correction for values from 1966Ba19, +5 keV correction for values from 1959No41.

Table 2. ^{223}Fr levels populated in the ^{227}Ac α-decay

Level	Level energy, keV	Spin and parity	Half-life	a-transition energy, keV	Probability of alpha transitions (×100)
0	0	3/2(⁻)	22,00 (7) min	5042,19 (14)	0,658 (14)
1	12,89 (5)	(5/2⁻)		5029,30 (15)	0,546 (17)
2	54,97 (7)	½(⁻)		4987,22 (16)	0,0015
3	82,13 (6)	(7/2⁻)		4960,06 (15)	0,087 (7)
4	99,63 (6)	(3/2⁻)		4942,56 (15)	} 0,08 (1)
5	101,00 (6)	(5/2⁻)		4941,19 (15)	
6	134,51 (6)	(3/2⁺)		4907,68 (15)	0,001
7	149,3 (3)	(1/2⁺)			
8	160,48 (7)	(3/2⁺)		4881,71 (16)	0,014 (7)
9	172,08 (6)	(5/2⁺)		4870,11 (15)	0,0011
10	187,18 (10)	(5/2⁻)		4855,01 (17)	} 0,025 (7)
11	189,10 (7)	(7/2⁻)		4853,09 (16)	
12	219,61 (9)	(7/2⁺)		4822,58 (17)	} 0,0012
13	222,75 (10)	(7/2⁺)		4819,44 (17)	
14	242,63 (7)	(5/2)		4799,56 (16)	} 0,006 (3)
15	243,85 (13)	(5/2)		4798,34 (19)	
16	244,66 (15)	(7/2⁻)		4797,53 (21)	
17	298,7 (3)	(9/2⁻)			
18	365,47 (10)			4676,72 (17)	≈ 3·10^{-4}
19	379 (7)			4663 (7)	≈ 4·10^{-5}
20	449 (5)			4593 (5)	≈ 4·10^{-5}
21	503 (7)			4539 (7)	≈ 7·10^{-5}
22	515,20 (22)	3/2⁻		4526,99 (26)	≈ 7·10^{-4}
23	540,74 (25)	(5/2⁺)		4501,45 (29)	≈ 8·10^{-5}
24	601 (7)	(5/2⁻)		4441,19 (16)	≈ 4·10^{-5}

The recommended probabilities of the $\alpha_{0,i}$-transitions with i = 0, 1, 3, 4, 8, 11, 14 are from 1959No41. The remaining ones are from 1966Ba19. A comparison of the α-transition probabilities, taken directly from measurements of 1959No41, 1966Ba19 with those deduced from P(γ+ce) intensity balance, is given in Table 3. The total probability of α-transitions is from 1970Ki12 (1,3800 (36) %), see also 1974Mo05 (1,359 (14) %). The α-decay hindrance factors have been calculated using the ALPHAD computer program from the ENSDF evaluation package with r_0 = 1,538 fm, average of r_0(^{222}Rn) = 1,5397 (4) fm, r_0(^{222}Ra) = 1,5383 (8) fm and r_0(^{224}Ra) = 1,5332 (8) fm, see 2001Br31.

Table 3. Energies and probabilities (×100) of most intense α-transitions in the ^{227}Ac decay

Level	Level energy, keV	Energies of a-particles, obtained from Q(α), keV	Measured energies of a-particles, keV	Probabilities (×100), adopted from 1959No41, 1966Ba19	Probabilities (×100), deduced from intensity balance
0	0	4953,23 (14)	4953,26 (14)	0,658 (14)	0,48 (24)
1	12,89 (5)	4940,57 (15)	4940,7 (8)	0,546 (16)	0,63 (15)
3	82,13 (6)	4872,55 (15)	4872,7 (2)	0,087 (7)	0,09 (3)
4	99,63 (6)	4855,36 (15)	4855 (2)	} 0,08 (1)	} 0,10 (6)
5	101,00 (6)	4854,01 (15)			
6	134,51 (6)	4821,09 (15)	4822 (4)	0,014 (7)	0,0090 (26)
10	187,18 (10)			} 0,025 (7)	} 0,028 (10)
11	189,10 (7)	4767,47 (15)	4768 (3)		

2.2 Beta Transitions

The energies of β^- transitions have been obtained from Q^-(^{227}Ac) and ^{227}Th level energies given in Table 4. The β^--emission probabilities per 100 β^- particles in ^{227}Ac β^--decay have been taken from 1995Li04. The value of $\Sigma P_{\beta-}$ (i) has been obtained as (100 % - ΣPa (i)) = 98,620 (4) %. This is the total probability of beta transitions to the ground state and excited states of ^{227}Th.

Table 4. ^{227}Th levels populated in the ^{227}Ac β^--decay

Level	Level Energy, keV	Spin and Parity	Half-life	β^--emission probability per 100 β^- particles
0	0,0	1/2 +	18,68 (9) d	≈ 54
1	9,3	(5/2+)		≈ 35
2	24,5	3/2+		≈ 10
3	37,9	3/2-		0,3

2.3 Gamma Transitions and Internal Conversion Coefficients

The evaluated energies of the gamma-ray transitions are virtually the same as the gamma-ray energies because nuclear recoil is negligible.

The gamma-ray transition probabilities in ^{223}Fr have been deduced from their gamma-ray emission probabilities and the calculated total ICCs. The gamma-ray transition probabilities in ^{227}Th have been adopted from 1995Li04. ICCs have been calculated by a program supplied with the SAISINUC software (2002Be). This code uses interpolated values of Band et al. (2002Ba85). The multipolarities and mixing ratios δ of the gamma-ray transitions in ^{223}Fr and ^{227}Th have been taken from 2001Br31. The uncertainties in the ICCs for pure multipolarities have been taken as 2 %.

3. Atomic Data

The atomic data (fluorescence yields, X-ray energies and relative probabilities, Auger electrons energies and relative probabilities) were obtained using the SAISINUC software (2002Be).

4.1 Alpha Emissions

Details are given in Section 2.1.

4.2 Beta Emissions

Details are given in Section 2.2.

5. Photon Emissions

5.1 X-Ray Emissions

The absolute emission probabilities of Fr KX and LX-rays and Th LX-rays have been calculated using the EMISSION code (2000Schönfeld). An experimental Fr KX-rays intensity value of 0,0136 (16) % (from 1995Sh03) agrees well with 0,0145 (24) %, deduced by the evaluators.

5.2 Gamma-Ray Emissions

Gamma-Ray Energies

The energies of gamma-rays in ^{223}Fr have been adopted from 1995Sh03. The energies of gamma-rays $\gamma_{1,0}$ and $\gamma_{2,1}$ in ^{227}Th have been adopted from 1959No41. The energies of gamma-rays $\gamma_{2,0}$ and $\gamma_{3,1}$ in ^{227}Th have been adopted from 1997Mu08.

Gamma-Ray Emission Probabilities

The absolute emission probabilities of gamma-rays in ^{223}Fr are from 1995Sh03. The absolute emission probabilities of gamma-rays in ^{227}Th have been deduced from the absolute β^--emission probabilities in the ^{227}Ac β^--decay and α_T using the ratio of P(γ37,9-keV) / P(γ28,6-keV) = 9,0 (12) / 7,7 (10) = 1,17 (22) from ^{227}Pa EC decay (1995Li04), and the value of P(γ24,3-keV) / P(γ15,2-keV) = 20 / 0,44 = 45,5 from alpha decay of ^{231}U (2001Br31).

6. Electron Emissions

The energies of conversion electrons have been obtained from the gamma transition energies and atomic electron binding energies. The emission probabilities of conversion electrons have been deduced from the evaluated P(γ) and ICC values.

The number of K- and L- Auger electrons per 100 disintegrations has been calculated using the EMISSION code (2000Schönfeld).

Average β^- energies have been calculated using the LOGFT computer program.

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