

**²⁴¹Am -Comments on evaluation of decay data
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This evaluation was completed in October 2002 and revised in January 2004. The literature available by October 2002 was included.

1. Decay scheme

The scheme of ²⁴¹Am decay is rather complex. It contains more than forty excited levels in ²³⁷Np populated by alpha- and gamma-transitions (1995Ak01). For high levels the decay scheme is not completed as great number of observed gamma transitions are not placed in the level scheme and some expected gamma transitions have not been seen.

However the intensive population takes place only for lower levels with the energy less than 230 keV (8 excited levels and ground state in ²³⁷Np) and in this part of the decay scheme is mainly defined. Nevertheless here also there are gamma-transitions scarcely studied and expected but not certainly observed such as 27,02; 54,1; 96,7 keV. This leads to the not very good intensity balance for some levels.

The population of all higher levels does not exceed 0,1% in total.

2. Nuclear Data

Q value is from Audi and Wapstra (1995Au04).

The evaluated value of the ²⁴¹Am half-life has been obtained by averaging the experimental values, in years, given below:

432,7(7)	1967Oe01	Calorimetry
433(7)	1968Br22	Specific Activity Determination
436,6(30)	1968St02	Specific Activity Determination
426,3(21)	1972Jo07	Calorimetry
432,5(7)	1974StYG	Calorimetry
435,0(7)	1974StYZ	Specific Activity Determination
432,8(16)	1974Po16	Specific Activity Determination
432,0(2)	1975Ra35	Calorimetry

The values before 1967 have been omitted due to their large systematic uncertainties (those values lead to the ²⁴¹Am half-life of 458 years).

The eight values were used for statistical processing. The uncertainty of 1975Ra35 was increased to 0,38 y to adjust weights according to the LRSW method.

Statistical processing of the final data set with the reduced χ^2 of 3,58 gives the unweighted mean (UWM) of 432,6(11) and weighted mean (WM) of 432,6 with an internal uncertainty of 0,27 and an external uncertainty of 0,51.

The EV1NEW computer program has chosen WM and the tS (or MBAYS) uncertainty of 0,55. The LWEIGHT program has also chosen WM and expanded the uncertainty so range includes the most precise value of 432,0 (1975Ra35) giving the value of 432,6(6) as result coinciding with the EV1NEW final value.

The adopted value of the ²⁴¹Am half-life is 432,6(6) years.

2.1. Alpha Transitions

The energies of the alpha transitions have been calculated from the Q value and the level energies given in Table 1 from 1995Ak01, with corrections for the 8 lower levels to take into account the adopted energies of gamma transitions from section 2.2.

Table 1. ²³⁷Np levels displayed in the ²⁴¹Am α -decay

Level number	Energy, keV	Spin and parity	Half-life	Probability of α -transition (x100)
0	0,0	5/2 ⁺	2,14 10 ⁶ yr	0,38(1)
1	33,1963(3)	7/2 ⁺	54(24) ps	0,23(1)
2	59,5409(1)	5/2 ⁻	67(2) ns	84,45(10)
3	75,900(3)	9/2 ⁺	~56 ps	<0,04
4	102,961(3)	7/2 ⁻	80(40) ps	13,23(10)
5	130,00(3)	11/2 ⁺		~0,01
6	158,49(2)	9/2 ⁻		1,66(3)
7	191,44(10)	13/2 ⁺		
8	225,96(2)	11/2 ⁻		0,015(5)
9	267,54(2)	3/2 ⁻	5,2(2) ns	5·10 ⁻⁴
10	281,35(2)	1/2 ⁻		
11	305,06(4)	13/2 ⁻		0,0022(3)
12	316,8(2) ?			
13	324,42(5)	7/2 ⁻		0,0013
14	332,36(3)	1/2 ⁺	≤1 ns	
15	359,7(1)	(5/2 ⁻)		6·10 ⁻⁴
16	368,59(3)	5/2 ⁺		9·10 ⁻⁴
17	370,93(3)	3/2 ⁺		3·10 ⁻⁴
18	395,52(5)	15/2 ⁻		7·10 ⁻⁴
19	418(4) ?			
20	434,12(16)	(11/2 ⁻)		4·10 ⁻⁴
21	444,78(10) ?			
22	452,53(5)	9/2 ⁺		~4·10 ⁻⁴
23	459,69(4)	7/2 ⁺		~4·10 ⁻⁴
24	485,96(12)	(9/2 ⁻)		1,1·10 ⁻⁴
25	497,02(6)	17/2 ⁻		
26	514,19(6)	(3/2 ⁻)		
27	545,59(16)	(5/2 ⁻)		1·10 ⁻⁴
28	590,28(15)	(7/2 ⁻)		
29	592,3(10)	13/2 ⁺		
30	598,0(2)	11/2 ⁺		
31	646,1(2)	(9/2 ⁻)		
32	666,2(2)	(5/2 ⁺ , 7/2)		
33	721,95(5)	5/2 ⁻		7·10 ⁻⁴
34	756,00(10)	7/2 ⁻		8,6·10 ⁻⁵
35	770,57(5)			
36	800,00(10)	9/2 ⁻		4(3)·10 ⁻⁵

37	805,8(2)	(7/2 ⁺ , 9/2)		
38	853,36(20)	11/2 ⁻		
39	861,7(5)	(5/2 ⁺ , 7/2)		
40	920,9(5)			
41	946(2)			
42	962(3) ?			
43	1014(3) ?			

The probabilities of the alpha transitions $\alpha_{0,0}$, $\alpha_{0,1}$, $\alpha_{0,2}$, $\alpha_{0,4}$ and $\alpha_{0,6}$ have been obtained by averaging measured values from spectrometric measurements (Table 2).

Table 2. Measured and adopted probabilities (x100) of the five most intensive alpha transitions

	1984Ah06 1993Ahmad	1987Bo25	1994B112	1996 Bueno	1996 Sanchez	1998Ya17	Adopted (WM)
$\alpha_{0,0}$	0,36(1)	0,34(5)	0,36(5)	0,5(2)	0,36(3)	0,394(9)	0,38(1)
$\alpha_{0,1}$	0,23(1)	0,22(3)	0,22(6)	-	0,28(3)	0,224(7)	0,23(1)
$\alpha_{0,2}$	84,6(2)	84,7(9)	84,69(28)	84,5(8)	84,5(3)	84,30(7)	84,45(10)
$\alpha_{0,4}$	13,1(1)	13,0(3)	13,08(24)	12,5(3)	13,2(3)	13,40(8)	13,23(10)
$\alpha_{0,6}$	1,65(8)	1,6(1)	1,66(6)	1,6(2)	1,65(7)	1,67(2)	1,66(3)

The $\alpha_{0,2}$ and $\alpha_{0,4}$ probability values of 1984Ah06 have been revised by the same author in 1993Ahmad cited in 1994B112. In Table 2 the revised values are given.

The probabilities of the alpha transitions $\alpha_{0,3}$, $\alpha_{0,5}$, $\alpha_{0,9}$, $\alpha_{0,13}$, $\alpha_{0,15}$ ÷ $\alpha_{0,33}$ have been adopted from magnetic spectrometer measurements of 1964Ba26. The probabilities of the $\alpha_{0,8}$ and $\alpha_{0,11}$ transitions have been obtained from measurements of 1955Go57, 1964Ba26 and 1965Mi06. The probabilities of the $\alpha_{0,34}$ and $\alpha_{0,36}$ transitions have been computed from the intensity balance of gamma transitions.

2.2. Gamma Transitions and Internal Conversion Coefficients

The energies of gamma transitions are the energies of gamma rays.

The probabilities of the intensive anomalously converted gamma transitions $\gamma_{2,1}$ and $\gamma_{2,0}$ as well as that of $\gamma_{1,0}$ have been adopted from the analysis of Peter N. Johnston (1996Jo28) made in search of optimized values of parameters for low energy photons in the decay of ²⁴¹Am including LX-rays. The decay scheme balance for lower levels of ²³⁷Np is better in 1996Jo28 than previous attempts.

ICC for $\gamma_{2,1}$ and $\gamma_{2,0}$ transitions have been obtained from the evaluation of the gamma ray and L-conversion electron probabilities in 1996Jo28. ICC for $\gamma_{1,0}$ transition have been taken from 1966Le13.

Multipolarities for all other gamma transitions have been adopted from measurements of 1959Sa10, 1964Wo03, 1966Ko06 and 1966Ya05. For these transitions the ICC have been evaluated using the above experimental information on the multipolarity admixture coefficients and the theoretical values from 1978Ro22.

The multipolarity admixture coefficient for $\gamma_{4,2}$ has been obtained by averaging four measurement results from 1963Wo03, 1966Ko06, 1966Ya05 and 1998Ko61.

The probabilities of the gamma transitions, $P_{\gamma+ce}$, have been computed using the evaluated absolute gamma -ray emission probabilities and the total internal conversion coefficients.

3. Atomic Data

3.1. Fluorescence yields

The ω_K and ω_L fluorescence yields are taken from 1996Sc06 (Schönfeld and Janßen).

ω_M is from 1989Hubbell.

3.1.1. X Radiations

The XL -ray energies are taken from 2001Sc08

The XK -ray energies are taken from 1999Schönfeld. Below these calculated (adopted) values are compared with the measurement results of 1982Ba56 and 1983Ah02:

	Calculated (1999 Schönfeld)	Measured in 1982Ba56	Measured in 1983Ah02
$K\alpha_2$	97,069	97,069(3)	97,08(2)
$K\alpha_1$	101,059	101,057(3)	101,07(2)
$K\beta_3$	113,303	113,308(4)	113,30(2)
$K\beta_1$	114,234	114,244(3)	114,24(2)
$K\beta_5$	114,912	-	114,95(2)
$K\beta_2$	117,463		}
$K\beta_4$	117,876		} 117,51(3)
$KO_{2,3}$	118,429	-	118,45(5)

The relative emission probabilities of XK -rays are taken from 1999Schönfeld.

3.1.2. Auger electrons

The energies of Auger electrons are from 1977Larkins.

The ratios $P(KLX)/P(KLL)$ and $P(KXY)/P(KLL)$ are taken from 1996Sc06.

4. Alpha Emissions

The energies of alpha particles, E_α , have been calculated from the energies of alpha transitions taking into account the recoil energies (see also 1995Ak01). The recommended energies of alpha-particles and emission probabilities of the most intensive alpha transitions are given also in 1991Ry01.

The experimental values E_α from spectrometric measurements are given in 1971GR17, 1968Ba25, 1968Ka09, 1965Mi06, 1964Ba26, 1962Le11, 1957Ro20, 1955Go57. They have the lesser accuracy in comparison with the calculated values.

5. Electron emissions

The energies of the conversion electrons have been calculated from the gamma-transition energies given in 2.2 and the electron binding energies.

The emission probabilities of the conversion electrons have been calculated using the conversion coefficients given in 2.2. The values of the emission probabilities of K-Auger electrons have been calculated using the transition probabilities given in 2.1 and 2.2, the atomic data given in 3. and the conversion coefficients given in 2.2. The total emission probability of L-Auger electrons has been calculated from the evaluated $P(XL)$ and ω_L .

6. Photon emissions

6.1 X - Ray emissions

The total absolute emission probability of MX - rays is the measurement result of 1971Ka48.

The absolute emission probabilities of LX - rays have been obtained by averaging of measurement results (per 100 disintegrations) shown in Table 3.

Table 3. Measured and evaluated absolute emission probabilities of LX rays in the decay of ²⁴¹Am

	1971 Ge11	1971 Wa28	1974 Ca16	1974 Ga40	1976 GuZN	1980 Cohen	1988 Co07	1992 BI07	1994 Le37	Adopted (WM)
Ll	0,81(7)	0,87(6)	0,86(2)	-	0,806(40)	0,87(3)	0,83(3)	0,837(10)	0,864(12)	0,848(10) ^a
L α	12,6(9)	13,5(12)	13,20(25)	-	13,2(7)	13,2(3)	12,7(4)	13,01(10)	13,03(13)	13,03(10) ^a
L β	19,1(14)	19,1(14)	19,25(40)	19,46(16)	19,2(10)	19,78(36)	18,3(6)	18,61(15)	18,39(19)	18,86(15) ^b
L γ	4,75(35)	4,75(35)	4,85(15)	-	4,94(25)	4,96(20)	4,8(2)	4,815(38)	4,74(8)	4,81(4) ^c

^a The smallest uncertainty of the measurement results.

^b tS – external uncertainty (or MBAYS).

^c Internal uncertainty of WM.

In 2001Sc08 also the measurement results of 1993Lepy (per 100 disintegrations) are given which are not included in averaging: Ll-0,875(18), L α -13,10(21), L β -18,5(4), L γ -4,84(8).

The total absolute emission probability of LX - rays is obtained by summing of the adopted data in the last column of Table 3: $P(XL) = 37,6(3)$ per 100 disintegrations. This value can be compared with that calculated using total absolute sums Pce_L , Pce_K , and atomic data of sect.3 (ω_K , ω_L , n_{KL}). The latter is 38,6(16) per 100 disintegrations.

The absolute emission probabilities of XK -rays have been computed from the total XK - ray absolute emission probability $P(XK) = 0,00389(8)$ per 100 disintegrations and the relative emission probabilities of XK - rays given in 1999Schönfeld. The above value $P(XK)$ has been calculated using the adopted value of ω_K and the evaluated absolute emission probabilities of K conversion electrons from

section 5. It agrees with measurements of ¹⁹⁷⁶GuZN which give P(XK)=0,0040(1) per 100 disintegrations.

Below the experimental data of ¹⁹⁷⁶GuZN are compared with the calculated (adopted) values of absolute emission probability of KX – ray components:

	1976GuZN (measured)	Calculated (adopted)
K α_2	0,00118(3)	0,00116(3)
K α_1	0,00189(5)	0,00185(4)
K β_3	$2,4(1) \cdot 10^{-4}$	$2,14(5) \cdot 10^{-4}$
K β_1	$4,7(2) \cdot 10^{-4}$	$4,19(9) \cdot 10^{-4}$
K β_5	}	
K $\beta_{2,4}$	} $2,29 \cdot 10^{-4}$	$2,24(6) \cdot 10^{-4}$
KO _{2,3}	}	

6.2. Gamma emissions

The energies of gamma rays $\gamma_{2,0}$ and $\gamma_{2,1}$ have been adopted from 2000He14.

The energy of gamma ray $\gamma_{1,0}$ has been computed as the difference $E\gamma_{2,0} - E\gamma_{2,1}$.

The energies of gamma rays $\gamma_{4,3}$, $\gamma_{3,1}$, $\gamma_{4,2}$ have been taken from 1998Ko61.

The energies of gamma rays $\gamma_{6,4}$, $\gamma_{8,6}$, $\gamma_{4,1}$, $\gamma_{3,0}$, $\gamma_{6,2}$, $\gamma_{4,0}$, $\gamma_{6,1}$, $\gamma_{29,22}$, $\gamma_{11,6}$, $\gamma_{8,3}$, $\gamma_{29,20}$, $\gamma_{9,4}$, $\gamma_{13,6}$, $\gamma_{18,8}$, $\gamma_{11,5}$, $\gamma_{25,11}$, $\gamma_{9,2}$, $\gamma_{13,4}$, $\gamma_{26,10}$, $\gamma_{26,9}$, $\gamma_{21,7}$, $\gamma_{13,2}$, $\gamma_{9,0}$, $\gamma_{20,6}$, $\gamma_{13,1}$, $\gamma_{16,3}$, $\gamma_{20,5}$, $\gamma_{21,5}$, $\gamma_{14,0}$, $\gamma_{16,1}$, $\gamma_{17,1}$, $\gamma_{20,3}$, $\gamma_{16,0}$, $\gamma_{17,0}$, $\gamma_{21,3}$, $\gamma_{22,3}$, $\gamma_{32,9}$, $\gamma_{30,7}$, $\gamma_{21,1}$, $\gamma_{22,1}$, $\gamma_{30,5}$, $\gamma_{27,1}$, $\gamma_{26,0}$, $\gamma_{36,8}$, $\gamma_{31,2}$, $\gamma_{28,0}$, $\gamma_{34,6}$, $\gamma_{33,4}$, $\gamma_{32,1}$, $\gamma_{36,6}$, $\gamma_{34,4}$, $\gamma_{33,2}$, $\gamma_{34,3}$, $\gamma_{33,1}$, $\gamma_{709,42}$ keV, $\gamma_{33,0}$, $\gamma_{35,1}$, $\gamma_{34,0}$, $\gamma_{36,1}$, $\gamma_{35,0}$, $\gamma_{39,2}$ have been adopted from the evaluations of 1988ChZL. Those values were obtained as weighted averages based on the measurements of 1955Da02, 1964Wo03, 1966Ko06, 1976GuZN, 1978Ge06, 1959Sa10, 1968Je01, 1978Ge17, 1978Ov01, 1984Ov02, 1970Ne11, 1966Ya05, 1979Ar11.

The energy of gamma ray $\gamma_{8,4}$ has been obtained as the weighted average of measurement results of 1974HeYW, 1976GuZN, 1978Ge06 and 1998Ko61.

The gamma rays with energies of 128,05 keV, 129,2 keV, 135,3 keV, 136,7keV and 138,5 keV were not observed by others and have been taken from 1979Ar11.

The remaining gamma ray energies have been taken from measurements 1978Ge06, 1978Ge17, and 1976GuZN and 1998Ab43.

The absolute emission probabilities of gamma rays $\gamma_{2,1}$, $\gamma_{1,0}$ and $\gamma_{2,0}$ have been adopted from the detailed Johnston's analysis (1996Jo28) that is based on experimental works of 1983De11, 1957Ma17, 1971Ge11, 1974Ca16, 1976GuZN, 1978Ge06, 1983Ah02, 1984Ov02, 1955Da02, 1975Le09, 1976PI05, 1983Hu04, 1965Mc12.

The remaining gamma ray absolute emission probabilities have been taken from 1978Ge06, 1978Ge17, 1976GuZN and 1998Ab43.

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