$^{242}Am^{m}$ - Comments on evaluation of decay data

by A. L. Nichols

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Evaluation Procedure

Limitation of Relative Statistical Weight Method (LWM) was applied to average the decay data when appropriate.

Decay Scheme

A simple IT-decay mode dominates the decay scheme of $^{242}Am^{m}$. The small α branch is complex, and many features of this decay mode remain unresolved despite the extensive study of Hoff *et al.* (1990Ho02).

Some confusion arose during the course of the 1950s as to the correct identity of the ground and metastable states of ^{242}Am. This problem was resolved in 1960 by Asaro *et al.* (1960As05) when the 16-hour half-life activity was shown to be the ground state and the longer-lived 140-year isomer was defined as the metastable state. The α branch has been determined by Barnes *et al.* (1959Ba22) and Zelenkov *et al.* (1979Ze05) to be 0.46 (1) %. Hoff *et al.* have studied the emissions from the α-decay mode in considerable detail (1990Ho02), and the more modest measurements of Baranov *et al.* (1979Ba67) and Vylov *et al.* (1980VyZZ) show reasonable agreement with this extensive data set. A small spontaneous fission branch of 1.5 (6) × 10^{-8} % has been quantified by Caldwell *et al.* (1967Ca04), while an upper limit of 4.8 × 10^{-9} % has been specified by Zelenko *et al*. (1986Ze06).

Nuclear Data

The decay characteristics of $^{242}Am^{m}$ need to be better defined for improved quantification of the production and decay heat contributions of ^{242}Cm and ^{244}Cm.

Half-life

A recommended half-life of 143 (2) years has been adopted from the two known measurements (1959Ba22, 1979Ze05). This limited data set is unsatisfactory, and further studies are required to determine the half-life with much greater confidence.

Half-life measurements

Reference	Half-life (years)
1959Ba22	152 ± 7
1979Ze05	141.9 ± 1.7
Recommended value	143 ± 2

Branching Fractions

Barnes *et al.* and Zelenkov *et al.* have determined the α branching fraction for $^{242}Am^{m}$ (1959Ba22, 1979Ze05), and these data were used to derive an α branch of 0.46 (1) % and IT branch of 99.54 (1) %.

Reference	BF_{α}
1959Ba22	0.004 76 ± 0.000 14
1979Ze05	0.004 5 ± 0.000 1
Recommended value	0.004 6 ± 0.000 1
α branch	(0.46 ± 0.01) %

A spontaneous fission branch of 1.5 (6) × 10^{-8} % can be determined from the recommended total half-life of 143 (2) years and measured spontaneous fission half-life of 9.5 (35) × 10^{11} years (1967Ca04). Similarly, an upper limit of 4.8 × 10^{-9} % for the spontaneous fission branch can be derived from equivalent studies of the spontaneous fission half-life of > 3 × 10^{12} years (1986Ze06). Under these uncertain circumstances, a recommended value of < 4.8 × 10^{-9} % has been adopted for the spontaneous fission branch of $^{242}Am^{m}$.

Q values

Q_{IT} of 48.60 (5) keV and Q_{α} of 5637.10 (25) keV were adopted from the evaluated tabulations of Audi *et al.* (2003Au03).

Alpha Particles

Alpha-particle measurements reveal a relatively complex α-decay mode (1979Ba67, 1980VyZZ, 1990Ho02). The Q_{α} of 5637.10 (25) keV (2003Au03) and nuclear level energies as defined by Chukreev *et al.* (2002Ch52) were used to calculated the alpha-particle energies, while the alpha-particle emission probabilities were primarily adopted from the measurements of Hoff *et al.* (1990Ho02) and fortified by the introduction of a number of minor transitions observed by Baranov *et al.* (1979Ba67), all expressed in terms of decay per 100 alphas. Small adjustments were made to some of the low-intensity alpha-particle emission probabilities after consideration of the observed differences between the two sets of measurements (i.e., 5091.9-, 5248.15/5248.21- and 5272.96-keV alpha-particle emission probabilities). Some of the proposed daughter nuclear levels of comparable energy were also judged to be populated by alpha-particle transitions that were not experimentally resolved (i.e., alpha-particle transitions to nuclear levels with energies of 297.03/299.23, 300.68/300.743 and 374.7/376.7 keV). Under these circumstances, the observed alpha-particle emission was arbitrarily shared between the two nuclear levels of relevance. An unweighted mean value of 1.508 (5) was adopted for the radius parameter $r_0(^{238}Np)$ as derived from the equivalent data for neighboring doubly-even nuclei (1998Ak04), and used in the calculation of α-hindrance factors (HF):

$$r_0(^{238}Np) = [r_0(^{240}Pu) + r_0(^{242}Pu) + r_0(^{242}Cm) + r_0(^{244}Cm)] / 4$$

$$= [1.5168\ (3) + 1.5143\ (9) + 1.5013\ (10) + 1.4979\ (7)] / 4 = 1.508\ (5)$$

All of the available alpha-particle decay data were assessed in conjunction with the gamma-ray measurements of Hoff *et al.* These extremely significant gamma-ray studies do not furnish gamma-ray energy and emission probability data that can be adopted to depopulate the major alpha-populating nuclear levels of ^{238}Np in a consistent and satisfactory manner (i.e., nuclear levels at 407.59 keV and 342.439 keV populated by alpha particles with emission probabilities of 5.6 (2) % and 89.0 (7) % per 100 alphas, respectively). These two seriously incomplete features within the decay scheme are also observed to impact in various ways throughout the gamma-ray decay to the ground state of ^{238}Np. While the recommended alpha-particle emissions are believed to be reasonably sound, the related gamma-ray data remain significantly incomplete.

Alpha-particle emissions: energies, emission probabilities and hindrance factors.

1979Ba67		1980VyZZ		1990Ho02		Recommended		
E_{α} *(keV)*	P_{α} *(x100α)*	E_{α} *(keV)*	P_{α} *(x100α)*	E_{α} *(keV)*	P_{α} *(x100α)*	E_{α} *(keV)*	P_{α} *(x100α)*	*HF*
4974.9	~ 0.002	-	-	-	-	4975 (3)	0.002 (1)	2400
5027.1	0.02	-	-	5031 (5)	0.02 (1)	5027.3 (15)	0.02 (1)	540
5064.2	0.22	5065 (5)	0.23	5072 (3)	0.25 (7)	5068 (3)	0.25 (7)	81
5082	0.03	5082 (5)	) 0.34	-	-	5082.6 (12)	0.03 (1)	840
5088.4	0.19		)	5093 (4)	0.21 (7)	5091.9 (7)	0.20 (7)	146
5141.6 (5)	5.82	5142.35 (104)	6.601 (163)	5144.4 (9)	5.6 (2)	5143.07 (26)	5.6 (2)	11.2

1979Ba67		1980VyZZ		1990Ho02		Recommended		
E_α (keV)	P_α (x100α)	E_α (keV)	P_α (x100α)	E_α (keV)	P_α (x100α)	E_α (keV)	P_α (x100α)	HF
5153.3	0.02	-	-	-	-	5153.2 (15)	0.02 (1)	3600
~ 5173	) 0.04	-	-	-	-	5173.45 (26)	0.02 (1)	4900
5173.7	)	-	-	-	-	5175.4 (10)	0.02 (1)	5000
5206.8 (5)	89.84	5205.92 (72)	100.00 (167)	5208.4 (8)	89.0 (7)	5207.15 (25)	89.0 (7)	1.80
5214.7 ?	0.03	-	-	-	-	5215.4 (7)	0.03 (1)	6000
5248.2	~ 0.11	5248 (5)	0.67	5248.4 (22)	1.0 (1)	) 5248.15 (25)	0.4 (1)	730
						) 5248.21 (26)	0.4 (1)	730
5250.0	0.04	-	-	-	-	) 5249.64 (26)	0.02 (1)	14800
						) 5251.80 (25)	0.02 (1)	15300
~ 5273	0.86	5284	~ 0.34	5271 (3)	1.1 (1)	5272.96 (25)	1.0 (1)	414
5313.5	0.69	5312 (5)	0.90	5316 (3)	0.6 (1)	5314.95 (25)	0.6 (1)	1250
-	-	-	-	5331 (5)	0.15 (10)	5331.97 (25)	0.15 (10)	6400
5367.2	1.17	5364 (5)	1.67	5369.1 (18)	1.1 (2)	5367.73 (25)	1.1 (2)	1430
5409.3	1.04	5408 (5)	1.35	5412.4 (21)	1.0 (2)	5410.13 (25)	1.0 (2)	2820
5458.2	0.14	-	-	-	-	5458.68 (25)	0.14 (4)	39000
5517.3	0.006	-	-	-	-	5517.93 (25)	0.003 (3)	4000000
							Σ 100.025	

Gamma Rays

Energies

All gamma-ray transition energies were calculated from the structural details of the proposed decay scheme. The nuclear level energies of Akovali and Chukreev *et al.* were adopted (2002Ak06, 2002Ch52), and used to determine the energies and associated uncertainties of the gamma-ray transitions that populate and depopulate the excited nuclear levels of ^{238}Np and ^{242}Am^{m}.

Emission Probabilities

Dedicated measurements of the gamma-ray emission probabilities of ^{242}Am^{m} are limited to the significant studies of Hoff *et al*. (1990Ho02). Under these rather unsatisfactory circumstances, these gamma-ray decay data were adopted wholesale, although some comparison could be made with the limited data set of Vylov *et al*. (1980VyZZ). Hoff *et al.* have directly identified over 60 gamma-rays with the α-decay mode which has a branch of only 0.46 (1) %, while the major IT decay mode involves only one highly-converted gamma transition (48.60 keV).

Hoff *et al*. report the emission probabilities of a number of unresolved gamma rays in terms of what is believed to be the upper limit for each: 4.0 (3) per 100 α for both 109.61 (1) and 109.618 (3) keV; 0.024 (7) per 100 α for both 139.05 (3) and 139.11 (2) keV; 0.150 (8) per 100 α for both 152.70 (2) and 152.73 (1) keV; 3.50 (10) per 100 α for both 163.1 (5) and 163.29 (1) keV; and 0.122 (10) per 100 α for both 250.33 (3) and 250.37 (2) keV. These data have been adopted and both entries carried forward as values less or equal (≤) to the specified emission probability, as well as being incorporated into the database of recommended emission probabilities and transition probabilities.

The 26.427-keV gamma transition is particularly problematic, with a measured emission probability of 1.36 (1) per 100 α (1990Ho02). Combining this value with the internal conversion coefficients for an E2 transition generates an unrealistic absolute transition probability for this single gamma from the

26.427-keV nuclear level to the ground state of 2.12 %. There is a good possibility that this particular γ line arises partially from the alpha decay of ^{241}Am (isotopic content of 0.79 %, and γ-ray emission energy of 26.345 keV), and/or consists of a number of unresolved transitions that could not be identified nor located elsewhere within the incomplete decay scheme of ^{242}Am^{m}. Therefore, the emission probability per 100 α of the 26.427-keV gamma transition has been significantly reduced to < 0.154, and is primarily based on α and γ transition probabilities per 100 α that are known to populate the 26.427-keV nuclear level.

Np K X-rays complicate the interpretation of the gamma-ray emission probability data over the energy ranges from 97 to 101 keV (Kα) and 113.3 to 118.5 keV (Kβ). Hoff *et al.* observed gamma rays with energies in the vicinity of 97 keV and between 113.7 and 118 keV. While many of these particular emissions can be incorporated into the proposed decay scheme, their emission probabilities and existence in this form are doubtful.

A limited number of the gamma rays observed by Hoff *et al.* could not be placed in the proposed and incomplete alpha-decay scheme: 89.60 (5) keV with P_γ per 100 α of 0.29 (7), 160.61 (2) keV with P_γ per 100 α of 0.09 (4), 165.97 (15) keV with P_γ per 100 α of 0.010 (5), and 233.69 (10) keV with P_γ per 100 α of 0.028 (7).

Gamma-ray emissions: measured and recommended energies and emission probabilities.

1980VyZZ			1990Ho02				**Adopted**	
E_γ (keV)	P_γ^{rel}	P_γ per 100α	E_γ (keV) α decay	P_γ per 100α	E_γ (keV) (n,γ)	P_γ per 100n	**E_γ (keV)**	**P_γ per 100α**
-	-	-	-	-	24.37 (2)	0.0064 (10)	24.34 (1)	-
-	-	-	26.32 (3)	1.36 (10)	26.43 (2)	0.104 (15)	26.427 (2)	< 0.154*
-	-	-	-	-	32.67 (3)	0.026 (4)	32.64 (1)	-
-	-	-	-	-	34.97 (3)	0.082 (11)	34.97 (1)	-
-	-	-	-	-	35.90 (2)	0.0109 (15)	35.90 (1)	-
-	-	-	-	-	43.11 (3)	0.044 (7)	43.11 (1)	-
-	-	-	-	-	43.32 (3)	0.0046 (7)	43.33 (1)	-
-	-	-	-	-	43.84 (3)	0.075 (11)	43.83 (2)	-
-	-	-	-	-	43.98 (4)	0.058 (8)	43.89 (2)	-
-	-	-	-	-	46.84 (3)	0.111 (17)	46.833 (3)	-
-	-	-	-	-	-	-	48.60 (5)	IT decay
49.367 (4)	100	[29.1]	49.35 (2)	29.1 (9)	49.372 (2)	8.57 (14)	49.371 (3)	29.1 (9)
-	-	-	-	-	52.98 (7)	0.029 (4)	53.2 (6)	-
-	-	-	53.69 (3)	0.45 (6)	53.70 (7)	0.038 (6)	53.67 (1)	0.45 (6)
-	-	-	-	-	53.88 (4)	0.017 (3)	53.85 (2)	-
-	-	-	57.54 (6)	0.21 (5)	-	-	57.51 (1)	0.21 (5)
-	-	-	-	-	59.31 (4)	0.0082 (13)	59.32 (1)	-
-	-	-	60.13 (6)	1.19 (11)	60.243 (4)	0.68 (5)	60.247 (3)	1.19 (11)
-	-	-	-	-	62.33 (3)	0.0100 (15)	62.330 (4)	-
66.808 (20)	11.2	3.26	66.89 (2)	3.25 (10)	66.919 (5)	0.23 (3)	66.92 (1)	3.25 (10)
67.9	3.9	1.1	67.93 (3)	0.87 (7)	-	-	67.92 (2)	0.87 (7)
73.3	3.2	0.93	73.66 (2)	1.71 (12)	73.715 (4)	0.49 (15)	73.72 (1)	1.71 (12)
-	-	-	-	-	75.97 (7)	0.0051 (8)	75.98 (1)	-
-	-	-	-	-	79.483 (17)	0.17 (3)	79.48 (1)	-
-	-	-	-	-	79.74 (3)	0.019 (3)	79.73 (2)	-
-	-	-	84.9 (2)	0.21 (7)	-	-	85.16 (7)	0.21 (7)
86.680 (36)	19.5	5.67	86.65 (2)	4.97 (15)	86.676 (2)	2.3 (4)	86.674 (2)	4.97 (15)
-	-	-	89.60 (5)	0.29 (7)	-	-	89.60 (5)	0.29 (7)#
92.5	2.2	0.64	92.52 (3)	0.61 (7)	92.486 (7)	0.19 (4)	92.48 (1)	0.61 (7)
-	-	-	93.82 (3)	0.79 (9)	93.67 (5)	0.19 (4)	93.88 (1)	0.79 (9)
-	-	-	-	-	95.22 (2)	0.046 (6)	95.22 (1)	-
-	-	-	95.7 (6)	-	-	-	96.204 (3)	-
-	-	-		-	96.82 (5)	0.025 (4)	96.78 (1)	-
97.077	$K_{\alpha2}$ (Np)	-	-	-	-	-	-	-
-	-	-	98.0 (6)	-	97.22 (5)	0.046 (6)	97.18 (2)	-
101.068	$K_{\alpha1}$ (Np)	-	-	-	-	-	-	-

1980VyZZ			1990Ho02				**Adopted**	
E_γ (keV)	P_γ^{rel}	*P_γ per 100α*	*E_γ (keV) α decay*	*P_γ per 100α*	*E_γ (keV) (n,γ)*	*P_γ per 100n*	***E_γ (keV)***	***P_γ per 100α***
109.6	12.9	3.75	109.61 (2)	4.0 (3)	109.614 (4)	1.09 (24)	109.61 (1)	≤ 4.0 (3)
			109.62 (2)	4.0 (3)	109.614 (4)	1.09 (24)	109.618 (3)	≤ 4.0 (3)
111.1	1.5	0.44	111.16 (5)	0.55 (9)	111.197 (15)	0.19 (4)	111.18 (1)	0.55 (9)
113.3-114.9	K_β (Np)	-	-	-	-	-	-	-
-	-	-	113.7 (6)	-	-	-	113.9 (5)	-
			114.3 (6)	-	-	-	-	-
117.5-118.4	K_β (Np)	-	-	-	-	-	-	-
-	-	-	117.2 (6)	-	-	-	117.2 (6)	-
-	-	-	117.8 (6)	-	-	-	117.80 (7)	-
-	-	-	117.85 (60)	-	-	-	117.85 (7)	-
-	-	-	121.3 (6)	-	-	-	121.59 (2)	-
-	-	-	-	-	121.69 (4)	0.076 (11)	121.645 (9)	-
-	-	-	122.5 (6)	-	122.76 (7)	0.019 (8)	122.81 (1)	-
-	-	-	126.83 (5)	0.028 (14)	-	-	126.92 (1)	0.028 (14)
-	-	-	131.49 (8)	0.059 (14)	-	-	131.50 (5)	0.059 (14)
-	-	-	132.6 (6)	-	-	-	132.07 (6)	-
135.17 (6)	5.6	1.63	135.19 (2)	1.47 (8)	-	-	135.21 (2)	1.47 (8)
137.02 (6)	5.1	1.48	136.03 (2)	2.05 (6)	136.045 (10)	0.68 (11)	136.045 (2)	2.05 (6)
-	-	-	139.05 (2)	0.024 (7)	-	-	139.05 (3)	≤ 0.024 (7)
-	-	-	139.05 (2)	0.024 (7)	-	-	139.11 (2)	≤ 0.024 (7)
-	-	-	151.07 (5)	0.018 (4)	-	-	151.01 (3)	0.018 (4)
152.75 (6)	0.7	0.2	152.70 (2)	0.150 (8)	152.69 (3)	0.29 (4)	152.70 (2)	≤ 0.150 (8)
-	-	-	152.73 (2)	0.150 (8)	152.69 (3)	0.29 (4)	152.73 (1)	≤ 0.150 (8)
			-	-	153.192 (12)	0.43 (5)	153.19 (1)	-
153.84 (6)	2.4	0.70	153.85 (2)	0.721 (22)	153.870 (9)	0.45 (10)	153.87 (1)	0.721 (22)
-	-	-	156.46 (2)	0.059 (10)	156.452 (2)	4.23 (22)	156.451 (3)	0.059 (10)
-	-	-	160.61 (2)	0.09 (4)	-	-	160.61 (2)	0.09 (4)#
163.24 (4)	12.7	3.70	163.25 (2)	3.50 (10)	163.29 (5)	0.28 (4)	163.1 (5)	≤ 3.50 (10)
-	-	-	163.25 (2)	3.50 (10)	-	-	163.29 (1)	≤ 3.50 (10)
-	-	-	164.67 (7)	-	-	-	164.64 (7)	-
-	-	-	165.97 (15)	0.010 (5)	-	-	165.97 (15)	0.010 (5)#
-	-	-	170.50 (1)	0.136 (10)	-	-	170.7 (8)	0.136 (10)
-	-	-	174.76 (6)	0.038 (10)	-	-	174.76 (6)	0.038 (10)
-	-	-	176.68 (15)	0.006 (3)	176.62 (5)	0.17 (3)	176.66 (2)	0.006 (3)
-	-	-	182.86 (2)	0.199 (7)	182.876 (2)	13.9 (16)	182.878 (2)	0.199 (7)
-	-	-	189.01 (3)	0.059 (10)	189.099 (6)	0.44 (4)	189.10 (1)	0.059 (10)
-	-	-	190.88 (5)	0.023 (5)	-	-	190.88 (5)	0.023 (5)
194.63 (5)	-	-	194.61 (2)	0.308 (10)	-	-	194.59 (2)	0.308 (10)
-	-	-	196.46 (10)	0.021 (10)	-	-	196.52 (1)	0.021 (10)
206.34 (5)	2.0	0.58	206.37 (2)	0.34 (4)	-	-	206.39 (1)	0.34 (4)
-	-	-	213.20 (14)	0.012 (4)	-	-	213.19 (1)	0.012 (4)
-	-	-	215.52 (2)	0129 (21)	215.517 (5)	0.81 (4)	215.522 (4)	0.129 (21)
-	-	-	232.40 (3)	0.122 (7)	232.433 (8)	0.29 (5)	232.43 (1)	0.122 (7)
-	-	-	233.69 (10)	0.028 (7)	233.650 (6)	0.243 (22)	233.69 (10)	0.028 (7)#
-	-	-	237.02 (10)	0.010 (5)	-	-	236.90 (6)	0.010 (5)
-	-	-	238.53 (5)	0.0035 (18)	-	-	238.35 (7)	0.0035 (18)
-	-	-	250.33 (3)	0.122 (10)	-	-	250.33 (3)	≤ 0.122 (10)
-	-	-	250.33 (3)	0.122 (10)	250.40 (4)	0.35 (6)	250.37 (2)	≤ 0.122 (10)
-	-	-	270.55 (6)	0.0063 (18)	-	-	270.55 (7)	0.0063 (18)
-	-	-	272.75 (7)	0.0081 (18)	-	-	272.80 (6)	0.0081 (18)
-	-	-	280.04 (5)	0.0130 (14)	-	-	280.11 (1)	0.0130 (14)
-	-	-	299.20 (14)	0.006 (3)	-	-	299.23 (6)	0.006 (3)

* emission probability per 100 α has been significantly reduced to < 0.154, based on the α branching fraction and γ transition probabilities per 100 α of the γ transitions populating the 26.427-keV nuclear level.

\# not placed in the proposed partial decay scheme.

Placements of gamma-ray transitions.

Adopted E_γ (keV)	Proposed location in decay scheme (^{238}Np nuclear levels)	Adopted E_γ (keV)	Proposed location in decay scheme (^{238}Np nuclear levels)
24.34 (1)	86.674 (2) – 62.330 (4)	121.645 (9)	121.645 (9) – 0
26.427 (2)	26.427 (2) – 0	122.81 (1)	258.853 (8) – 136.045 (2)
32.64 (1)	215.522 (4) – 182.878 (2)	126.92 (1)	342.439 (8) – 215.522 (4)
34.97 (1)	121.645 (9) – 86.674 (2)	131.50 (5)	297.03 (5) – 165.532 (15)
35.90 (1)	62.330 (4) – 26.427 (2)	132.07 (6)	407.59 (6) – 275.519 (9)
43.11 (1)	179.154 (7) – 136.045 (2)	135.21 (2)	300.743 (16) – 165.532 (15)
43.33 (1)	258.853 (8) – 215.522 (4)	136.045 (2)	136.045 (2) – 0
43.83 (2)	106.155 (15) – 62.330 (4)	139.05 (3)	300.743 (16) – 161.69 (2)?
43.89 (2)	165.532 (15) – 121.645 (9)	139.11 (2)	165.532 (15) – 26.427 (2)
46.833 (3)	182.878 (2) – 136.045 (2)	151.01 (3)	312.70 (2) – 161.69 (2)?
49.371 (3)	136.045 (2) – 86.674 (2)	152.70 (2)	258.853 (8) – 106.155 (15)
53.2 (6)	218.7 (6) – 165.532 (15)	152.73 (1)	179.154 (7) – 26.427 (2)
53.67 (1)	232.828 (8) – 179.154 (7)	153.19 (1)	215.522 (4) – 62.330 (4)
53.85 (2)	312.70 (2) – 258.853 (8)	153.87 (1)	275.519 (9) – 121.645 (9)
57.51 (1)	179.154 (7) – 121.645 (9)	156.451 (3)	182.878 (2) – 26.427 (2)
59.32 (1)	121.645 (9) – 62.330 (4)	160.61 (2)	not placed in decay scheme
60.247 (3)	86.674 (2) – 26.427 (2)	163.1 (5)	328.6 (5) – 165.532 (15)
62.330 (4)	62.330 (4) – 0	163.29 (1)	342.439 (8) – 179.154 (7)
66.92 (1)	342.439 (8) – 275.519 (9)	164.64 (7)	300.68 (7) – 136.045 (2)
67.92 (2)	300.743 (16) – 232.828 (8)	165.97 (15)	not placed in decay scheme
73.72 (1)	136.045 (2) – 62.330 (4)	170.7 (8)	389.4 (5) – 218.7 (6)
75.98 (1)	258.853 (8) – 182.878 (2)	174.76 (6)	407.59 (6)– 232.828 (8)
79.48 (1)	215.522 (4) – 136.045 (2)	176.66 (2)	312.70 (2) – 136.045 (2)
79.73 (2)	106.155 (15) – 26.427 (2)	182.878 (2)	182.878 (2) – 0
85.16 (7)	300.68 (7) – 215.522 (4)	189.10 (1)	215.522 (4) – 26.427 (2)
86.674 (2)	86.674 (2) – 0	190.88 (5)	297.03 (5) – 106.155 (15)
89.60 (5)	not placed in decay scheme	194.59 (2)	300.743 (16) – 106.155 (15)
92.48 (1)	179.154 (7) – 86.674 (2)	196.52 (1)	258.853 (8) – 62.330 (4)
93.88 (1)	215.522 (4) – 121.645 (9)	206.39 (1)	342.439 (8) – 136.045 (2)
95.22 (1)	121.645 (9) – 26.427 (2)	213.19 (1)	275.519 (9) – 62.330 (4)
96.204 (3)	182.878 (2) – 86.674 (2)	215.522 (4)	215.522 (4) – 0
96.78 (1)	232.828 (8) – 136.045 (2)	232.43 (1)	258.853 (8) – 26.427 (2)
97.18 (2)	312.70 (2) – 215.522 (4)? X-ray?	233.69 (10)	not placed in decay scheme
109.61 (1)	342.439 (8) – 232.828 (8)	236.90 (6)	299.23 (6) – 62.330 (4)
109.618 (3)	136.045 (2) – 26.427 (2)	238.35 (7)	300.68 (7) – 62.330 (4)
111.18 (1)	232.828 (8) – 121.645 (9)	250.33 (3)	250.33 (3) – 0
113.9 (5)	389.4 (5) – 275.519 (9); X-ray?	250.37 (2)	312.70 (2) – 62.330 (4)
114.3 (6)	not placed in decay scheme; X-ray?	270.55 (7)	376.70 (7) – 106.155 (15)
117.2 (6)	459.6 (6) – 342.439 (8); X-ray?	272.80 (6)	299.23 (6) – 26.427 (2)
117.80 (7)	300.68 (7) – 182.878 (2)? X-ray?	280.11 (1)	342.439 (8) – 62.330 (4)
117.85 (7)	376.70 (7) – 258.853 (8)? X-ray?	299.23 (6)	299.23 (6) – 0
121.59 (2)	300.743 (16) – 179.154 (7)		

Measurements have also been carried out by Hoff *et al*. on the gamma-ray emissions following thermal-neutron capture on ^{237}Np – when judged appropriate, some of these (n,γ) data have been used to develop the proposed decay scheme of $^{242}Am^{m}$. The (n,γ) data were inspected in detail, and the opportunity taken to utilize these gamma-ray emission probabilities in a relative sense if their equivalent gamma-ray data had also been detected and quantified in the $^{242}Am^{m}$ studies. For example, consider the depopulation of the 258.853-keV nuclear level:

Proposed depopulating γ-ray transition (keV)	P_γ per 100n (1990Ho02)	P_γ per 100α (1990Ho02)	P_γ per 100α calculated	P_γ per 100α adopted
43.33	0.0046 (7)	–	0.0019 (3)	0.0019 (3)
75.98	0.0051 (8)	–	0.0021 (3)	0.0021 (3)
122.81	0.019 (8)	–	0.008 (4)	0.008 (4)
152.70	≤ 0.29	≤ 0.150	–	≤ 0.150
196.52	–	0.021 (10)	–	0.021 (10)
232.43	0.29 (5)	0.122 (7)	–	0.122 (7)

Unobserved P_γ per 100 α data can be calculated on the reasonable assumption that the relative emission probabilities of these six depopulating gamma rays would be the same irrespective of the mode of feeding to that nuclear level. The emission probability of the 232.43-keV gamma ray has been measured for both the $^{237}Np(n,\gamma)$ reaction and the α decay of $^{242}Am^{m}$, and this ratio can be used to determine the equivalent relative emission probabilities of the 43.33-, 75.98- and 122.81-keV gamma-ray transitions in the α-decay mode. Thus, P_γ per 100 α for the 75.98-keV gamma ray can be calculated:

$$(0.122/0.29) \times 0.0051\ (8) = 0.0021\ (3)$$

This approach was adopted for a number of specific gamma transitions, as noted in the relevant footnote of the table below.

Despite the introduction of gamma-ray data as outlined above, additional gamma transitions are required to create a more comprehensive and consistent decay scheme for the $^{242}Am^{m}$ alpha-decay mode. While some of these possibilities can be gleaned from the $^{237}Np(n,\gamma)$ reaction data, they cannot be quantified in terms of P_γ per 100 α because of commensurate limitations in the (n,γ) measurements – these particular gamma rays are denoted by a dash (–) within the column entitled "Adopted P_γ per 100 α" in the table below.

Gamma-ray emissions: multipolarities and theoretical internal conversion coefficients (frozen orbital approximation).

Adopted E_γ (keV)	Adopted P_γ per 100 α*	Multipolarity	α_K	α_L	α_{M+}	α_{total}	
24.34 (1)	0.014 (2)#	M1+0.01%E2 δ = 0.01	–	242 (4)	80	322 (5)	α
26.427 (2)	< 0.154‡	M1+1%E2 δ = 0.10	–	252 (4)	86	338 (5)	α
32.64 (1)	0.0041 (6)#	M1+0.02%E2 δ = 0.014	–	102.6 (15)	33.8	136.4 (20)	α
34.97 (1)	–	M1+1%E2 δ = 0.10	–	98.7 (14)	33.2	131.9 (19)	α
35.90 (1)	–	M1+1.8%E2 δ = 0.135	–	101.5 (15)	34.5	136.0 (19)	α
43.11 (1)	0.014 (3)#	M1+0.2%E2 δ = 0.045	–	46.1 (7)	15.2	61.3 (9)	α
43.33 (1)	0.0019 (3)#	M1+9.1%E2 δ = 0.32	–	93.5 (14)	33.2	126.7 (18)	α
43.83 (2)	–	M1+0.9%E2 δ = 0.095	–	47.3 (7)	15.8	63.1 (9)	α
43.89 (2)	–	M1+1.3%E2 δ = 0.115	–	49.2 (7)	16.5	65.7 (10)	α
46.833 (3)	0.0016 (3)#	M1+0.4%E2 δ = 0.063	–	36.7 (6)	12.1	48.8 (7)	α
48.60 (5)	IT decay	E4	–	3.33 (5) x 10^5	3.71 (6) x 10^5	7.04 (8) x 10^5	IT
49.371 (3)	29.1 (9)	E1	–	0.615 (9)	0.206	0.821 (12)	α
53.2 (6)	–	(M1+E2)	–	–	–	–	α

Adopted E_γ (keV)	Adopted P_γ per 100 α*	Multipolarity	α_K	α_L	α_{M+}	α_{total}	
53.67 (1)	0.45 (6)	M1+5.9%E2 δ = 0.25	–	34.2 (5)	11.8	46.0 (7)	α
53.85 (2)	0.0006 (3)#	M1+2.4%E2 δ = 0.16	–	27.8 (4)	9.4	37.2 (6)	α
57.51 (1)	0.21 (5)	E1	–	0.412 (6)	0.137	0.549 (8)	α
59.32 (1)	–	M1+E2	–	–	–	–	α
60.247 (3)	1.19 (11)	M1+0.5%E2 δ = 0.07	–	17.34 (25)	5.76	23.1 (4)	α
62.330 (4)	–	E2	–	98.9 (14)	37.1	136.0 (19)	α
66.92 (1)	3.25 (10)	E1	–	0.277 (4)	0.091	0.368 (6)	α
67.92 (2)	0.87 (7)	M1+11%E2 δ = 0.35 (6)	–	18 (2)	6	24 (3)	α
73.72 (1)	1.71 (12)	E1	–	0.214 (3)	0.071	0.285 (4)	α
75.98 (1)	0.0021 (3)#	E2	–	38.4 (6)	14.4	52.8 (8)	α
79.48 (1)	0.027 (5)#	M1+50%E2 δ = 1.0 (2)	–	19 (3)	7	26 (4)	α
79.73 (2)	–	E2	–	30.6 (5)	11.5	42.1 (6)	α
85.16 (7)	0.21 (7)	M1+50%E2 δ = 1.0 (2)	–	14 (2)	5	19 (3)	α
86.674 (2)	4.97 (15)	M1+1%E2 δ = 0.10	–	5.98 (9)	1.97	7.95 (12)	α
89.60 (5)	0.29 (7)	–	–	–	–	–	α
92.48 (1)	0.61 (7)	E1	–	0.1184 (17)	0.0390	0.1574 (22)	α
93.88 (1)	0.79 (9)	E1	–	0.1138 (16)	0.0375	0.1513 (22)	α
95.22 (1)	–	M1+E2	–	–	–	–	α
96.204 (3)	–	E1	–	0.1068 (15)	0.0352	0.1420 (20)	α
96.78 (1)	0.072 (12)#	E2	–	12.28 (18)	4.62	16.90 (24)	α
97.18 (2)	0.0016 (8)#	E2	–	12.05 (17)	4.53	16.58 (24)	α
109.61 (1)	≤ 4.0 (3)	M1+50%E2 δ = 1.0 (2)	–	4.9 (5)	1.8	6.7 (7)	α
109.618 (3)	≤ 4.0 (3)	E1	–	0.0760 (11)	0.0250	0.1010 (15)	α
111.18 (1)	0.55 (9)	E1	–	0.0733 (11)	0.0241	0.0974 (14)	α
113.9 (5)	–	E2	–	5.77 (15)	2.17	7.94 (20)	α
114.3 (6)	–	–	–	–	–	–	α
117.2 (6)	–	E1	–	0.0639 (13)	0.0211	0.0850 (17)	α
117.80 (7)	–	(M1+E2)	–	–	–	–	α
117.85 (7)	–	E2	–	4.93 (7)	1.85	6.78 (10)	α
121.59 (2)	–	E2	0.178 (3)	4.27 (6)	1.612	6.06 (9)	α
121.645 (9)	–	E2	0.179 (3)	4.27 (6)	1.601	6.05 (9)	α
122.81 (1)	0.008 (4)#	M1+50%E2 δ = 1.0 (2)	5.4 (12)	3.11 (22)	1.09	9.6 (9)	α
126.92 (1)	0.028 (14)	E2	0.196 (3)	3.51 (5)	1.324	5.03 (7)	α
131.50 (5)	0.059 (14)	E1	0.205 (3)	0.0475 (7)	0.0155	0.268 (4)	α
132.07 (6)	–	E1	0.203 (3)	0.0470 (7)	0.0150	0.265 (4)	α
135.21 (2)	1.47 (8)	E1	0.192 (3)	0.0443 (7)	0.0147	0.251 (4)	α
136.045 (2)	2.05 (6)	E1	0.190 (3)	0.0436 (6)	0.0137	0.247 (4)	α
139.05 (3)	≤ 0.024 (7)	E1	0.180 (3)	0.0412 (6)	0.0135	0.235 (4)	α
139.11 (2)	≤ 0.024 (7)	E2	0.211 (3)	2.32 (4)	0.869	3.40 (5)	α
151.01 (3)	0.018 (4)	E1	0.1495 (21)	0.0334 (5)	0.0111	0.194 (3)	α
152.70 (2)	≤ 0.150 (8)	E1	0.1458 (21)	0.0325 (5)	0.0107	0.189 (3)	α
152.73 (1)	≤ 0.150 (8)	E1	0.1457 (21)	0.0324 (5)	0.0107	0.189 (3)	α
153.19 (1)	0.068 (8)#	E1	0.1447 (21)	0.0322 (5)	0.0101	0.187 (3)	α
153.87 (1)	0.721 (22)	M1+1.9%E2 δ = 0.14	5.53 (8)	1.123 (16)	0.367	7.02 (10)	α
156.451 (3)	0.059 (10)	E1	0.1379 (20)	0.0305 (5)	0.0100	0.1784 (25)	α
160.61 (2)	0.09 (4)	–	–	–	–	–	α
163.1 (5)	≤ 3.50 (10)	M1+50%E2 δ = 1.0 (2)	2.5 (5)	1.04 (3)	0.36	3.9 (5)	α

Adopted E_γ (keV)	Adopted P_γ per 100 α*	Multipolarity	α_K	α_L	α_{M+}	α_{total}	
163.29 (1)	≤ 3.50 (10)	M1+50%E2 δ = 1.0 (2)	2.5 (5)	1.04 (3)	0.36	3.9 (5)	α
164.64 (7)	–	(M1 + E2)	–	–	–	–	α
165.97 (15)	0.010 (5)	–	–	–	–	–	α
170.7 (8)	0.136 (10)	(M1+50%E2) δ = 1.0 (2)	2.2 (5)	0.882 (23)	0.318	3.4 (5)	α
174.76 (6)	0.038 (10)	M1+50%E2 δ = 1.0 (2)	2.1 (5)	0.809 (17)	0.191	3.1 (4)	α
176.66 (2)	0.006 (3)	E2	0.181 (3)	0.804 (12)	0.300	1.285 (18)	α
182.878 (2)	0.199 (7)	E1	0.0965 (14)	0.0206 (3)	0.0067	0.1238 (18)	α
189.10 (1)	0.059 (10)	E1	0.0894 (13)	0.0190 (3)	0.0062	0.1146 (16)	α
190.88 (5)	0.023 (5)	E1	0.0875 (13)	0.0185 (3)	0.0061	0.1121 (16)	α
194.59 (2)	0.308 (10)	E1	0.0837 (12)	0.01768 (25)	0.00582	0.1072 (15)	α
196.52 (1)	0.021 (10)	E1	0.0819 (12)	0.01725 (25)	0.00565	0.1048 (15)	α
206.39 (1)	0.34 (4)	E2	0.1454 (21)	0.412 (6)	0.1536	0.711 (10)	α
213.19 (1)	0.012 (4)	M1+50%E2 δ = 1.0 (2)	1.19 (24)	0.401 (11)	0.139	1.73 (25)	α
215.522 (4)	0.129 (21)	E1	0.0664 (10)	0.01376 (20)	0.00454	0.0847 (12)	α
232.43 (1)	0.122 (7)	E1	0.0560 (8)	0.01145 (16)	0.00375	0.0712 (10)	α
233.69 (10)	0.028 (7)	–	–	–	–	–	α
236.90 (6)	0.010 (5)	M1+50%E2 δ = 1.0 (2)	0.89 (18)	0.280 (12)	0.100	1.27 (19)	α
238.35 (7)	0.0035 (18)	E1	0.0530 (8)	0.01078 (16)	0.00352	0.0673 (10)	α
250.33 (3)	≤ 0.122 (10)	(M1+50% E2) δ = 1.0 (2)	0.77 (15)	0.233 (12)	0.077	1.08 (16)	α
250.37 (2)	≤ 0.122 (10)	E1	0.0475 (7)	0.00958 (14)	0.00312	0.0602 (9)	α
270.55 (7)	0.0063 (18)	E1	0.0400 (6)	0.00798 (12)	0.00262	0.0506 (7)	α
272.80 (6)	0.0081 (18)	M1+50%E2 δ = 1.0 (2)	0.61 (12)	0.176 (11)	0.064	0.85 (13)	α
280.11 (1)	0.0130 (14)	E1	0.0371 (6)	0.00735 (11)	0.00235	0.0468 (7)	α
299.23 (6)	0.006 (3)	M1+50%E2 δ = 1.0 (2)	0.48 (9)	0.131 (9)	0.039	0.65 (10)	α

* gamma rays with emission probabilities denoted by a dash (–) are believed to be relevant to the α-decay scheme, but could not be quantified in terms of P_γ per 100 α, and are omitted from the final recommendations.

\# not observed in γ-ray measurements of the α-decay mode of ^{242}Am^{m} – derived from equivalent (n,γ) studies (1990Ho02).

‡ reported emission probability of 1.36 (10) per 100 α decays exceeds expectations considerably from the point of view of the proposed decay scheme and the internal conversion coefficients of this (M1 + 1 % E2) transition – value was reduced to < 0.154 to maintain a satisfactory balance for depopulation of the 26.427(2)-keV nuclear level and population to the ground state of ^{238}Np.

Multipolarities and Internal Conversion Coefficients

The nuclear level schemes specified by Akovali and Chukreev *et al*. have been used to define the multipolarities of the gamma transitions on the basis of known spins and parities (2002Ak06, 2002Ch52). Mixing ratios for many of the (M1 + E2) transitions up to gamma-ray energies of 153.87-keV are the assignments proposed by Hoff *et al.* (1990Ho02), while others were arbitrarily assigned mixing ratios of 1.0 with an uncertainty of 20 %. Others were derived from consideration of population-depopulation of the relevant nuclear levels. Recommended internal conversion coefficients have been determined from the frozen orbital approximation of Kibédi *et al*. (2008Ki07), based on the theoretical model of Band *et al*. (2002Ba85, 2002Ra45).

Significant conflict and inconsistencies remain in the proposed decay scheme for the rather small α branch, despite the impressive work of Hoff *et al*. (1990Ho02). Emphasis has been placed on the validity and comprehensive nature of the α-spectroscopy studies of Baranov *et al*. and Hoff *et al*. (1979Ba67, 1990Ho02) that may be of questionable merit. There are also very strong indications that the known gamma-ray data are unable to support the significant γ depopulation of the 407.59- and 342.439-keV nuclear levels of ^{238}Np. Arguably, further accurate high-resolution gamma-ray spectroscopy studies are required to develop and complete the rather complex α-decay mode with much greater confidence.

Atomic Data

The x-ray and Auger-electron data have been calculated using the evaluated gamma-ray data, and atomic data from 1996Sc06, 1998ScZM and 1999ScZX. Both the x-ray and Auger-electron emission probabilities were determined by means of the EMISSION computer program (version 4.01, 28 January 2003, with the emission.101 database extended to Z = 96 to calculate component L x-ray data for IT decay to ^{242}Am). This program incorporates atomic data from 1996Sc06 and the evaluated gamma-ray data. A number of the gamma-ray emission probabilities can only be quantified in terms of recommended upper limits (≤ and <) – EMISSION calculations have been undertaken with these values reduced by a factor of approximately two and assigned uncertainties of the same magnitude.

K and L X-ray emission probabilities per 100 disintegrations of ^{242}Am^{m}.

			Energy (keV)	Photons per 100 disint.
XL		(Np)	11.871 – 21.491	0.37 (4)
	XL_l	(Np)	11.871	0.0090 (9)
	XL_α	(Np)	13.761 – 13.946	0.143 (13)
	XL_η	(Np)	15.861	0.0022 (4)
	XL_β	(Np)	16.109 – 17.992	0.164 (13)
	XL_γ	(Np)	20.784 – 21.491	0.040 (3)
XK_α	$XK_{\alpha 2}$	(Np)	97.069	0.019 (9)
	$XK_{\alpha 1}$	(Np)	101.059	0.030 (14)
$XK'_{\beta 1}$	$XK_{\beta 3}$	(Np)	113.303	)
	$XK_{\beta 1}$	(Np)	114.234	) 0.011 (5)
	$XK''_{\beta 5}$	(Np)	114.912	)
$XK'_{\beta 2}$	$XK_{\beta 2}$	(Np)	117.463	)
	$XK_{\beta 4}$	(Np)	117.876	) 0.0037 (17)
	$XKO_{2,3}$	(Np)	118.429	)
XL		(Am)	12.377 – 22.836	25.0 (11)
	XL_l	(Am)	12.377	0.608 (18)
	XL_α	(Am)	14.414 – 14.620	9.33 (24)
	XL_η	(Am)	16.819	0.274 (9)
	XL_β	(Am)	16.890 – 19.110	12.2 (3)
	XL_γ	(Am)	22.072 – 22.836	2.90 (8)

Electron energies were determined from electron binding energies tabulated by Larkins (1977La19) and the evaluated gamma-ray energies. Absolute electron emission probabilities were calculated from the evaluated absolute gamma-ray emission probabilities and associated internal conversion coefficients.

Data Consistency

An effective Q-value of 74.31 (5) keV has been adopted from the atomic mass evaluation of Audi *et al*. (2003Au03) while in the course of formulating the decay scheme of ^{242}Am^{m}. This value has subsequently been compared with the Q-value calculated by summing the contributions of the individual emissions to the ^{242}Am^{m} alpha- and IT-decay processes (i.e. α, conversion electrons, γ, etc.):

calculated Q-value = $\sum (E_i \times P_i)$ = 72.9 (12) keV

Percentage deviation from the effective Q-value of Audi *et al*. is (1.9 ± 1.6) %, which supports the derivation of a reasonably consistent decay scheme with a large variant. Much of this deviation can be attributed to the incompleteness of the recommended alpha- and gamma-transition data within the small alpha-decay mode.

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