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

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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 relatively simple decay scheme was constructed from the β^-/EC ratio and branching fraction measurements of Hoff *et al.* (1955Ho67, 1959Ho02), Baranov and Shlyagin (1955Ba31), Asaro *et al.* (1960As05), Gasteiger *et al.* (1969Ga17), Aleksandrov *et al.* (1969Al20) and Gabeskiriya (1972Ga35). There are no known well-defined gamma-ray spectroscopic studies.

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. The possible existence of an alpha branch has been extensively considered by Barnes *et al.* (1959Ba22) and Aleksandrov *et al.* (1969Al20). While Barnes *et al.* found such a branch (BF_α = 0.004 76 (14)), subsequent studies have shown no evidence for this particular decay mode, and Aleksandrov *et al.* were only able to set a limit of less than 10^{-7} of the total ^{242}Am decay.

Nuclear Data

^{242}Am needs to be better characterised for improved quantification of the production and decay heat contributions of ^{242}Cm and ^{244}Cm.

Half-life

The recommended half-life of 16.01 (2) hours has been adopted from three known sets of measurements (1953Ke38, 1969Al20, 1982Wi05). Five independent half-life measurements were individually reported by Aleksandrov *et al.* (1969Al20) from which a value of 16.07 (14) hours was calculated (LWM). A limited data set of effectively three studies is rather unsatisfactory, and further measurements are required to determine the half-life with much greater confidence.

Half-life measurements

Reference	Half-life (hours)
1953Ke38	16.01 ± 0.02
1969Al20	16.07 ± 0.14
1982Wi05	16.1 ± 0.1
Recommended value	16.01 ± 0.02

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 were adopted (2002Ak06), and used to determine the energies and associated uncertainties of the gamma-ray transitions that depopulate the first excited states of ^{242}Pu and ^{242}Cm.

Emission Probabilities

There are no known dedicated measurements of the gamma-ray emission probabilities. Under these unsatisfactory circumstances, the proposed gamma-ray decay data were derived from the tabulated P_{ce}/P_{β} data of Baranov and Shlyagin (1955Ba31) and the BF_{β} measurements (1959Ba22, 1959Ho02, 1969Al20, 1969Ga17, 1972Ga35). A BF_{β} of 0.831 (3) was derived in terms of LWM, with the uncertainty extended to the minimum value measured (± 0.003); this parameter was adopted in preference to the equivalent LWM calculation for the β^-/EC ratio (i.e. 4.88 (8) compared with a value of 4.92 (9) calculated from the weighted mean BF_{β}).

β^-/EC ratio and BF_{β}.

Reference	BF_{β}	β^-/EC
1955Ba31	0.82	4.6
1955Ho67	0.81	4.2
1959Ba22	0.836 ± 0.008*	5.1 ± 0.2
1959Ho02	0.836 ± 0.003	5.1 ± 0.1*
1960As05	0.836*	5.1
1969Al20	0.82 ± 0.01*	4.6 ± 0.3
1969Ga17	0.828 ± 0.004	4.8 ± 0.1*
1972Ga35	0.827 ± 0.003*	4.78 ± 0.08
Recommended value	0.831 ± 0.003	[4.88 ± 0.08]

* Emphasis of the publication, and assumed to be the primary measurement.

Baranov and Shlyagin determined the conversion-electron emission intensities separately for both the electron-capture and beta decay processes, along with the β^- decay in equivalent units (1955Ba31) to furnish the following ratios:

P_{ce}(EC component)/$P_{\beta-}$ = 153.5/1200, and

P_{ce}(β^- component)/$P_{\beta-}$ = 661/1200.

One problem involves the assignment of uncertainties to the $P_{ce}/P_{\beta-}$ values as determined by Baranov and Shlyagin. Both parameters are the ratios of two equivalent measurements, and the resulting uncertainty for each of these ratios was assumed to be approximately 5 %:

P_{ce}(EC component)/$P_{\beta-}$ = 153.5/1200 = 0.128 (6)

P_{ce}(β^- component)/$P_{\beta-}$ = 661/1200 = 0.551 (28).

Using these data and BF_{β} of 0.831 (3):

$P_{ce}(\beta^-)$ = 0.551 (28) × 0.831 (3) = 0.458 (23) for the 42.13-keV gamma-ray,
and P_{ce}(EC) = 0.128 (6) × 0.831 (3) = 0.106 (5) for the 44.54-keV gamma-ray.

These values were then used in conjunction with the theoretical internal conversion coefficients to calculate the absolute gamma-ray emission probabilities.

Quite remarkably, the resulting gamma-ray emission probabilities are in good agreement with the tabulated spectroscopic data of Vylov *et al.* (1980VyZZ) which are listed as 42.129 (7) keV and 0.039 (5) %, and 44.542 (25) keV and 0.015 (3) %. Accurate, high-resolution gamma-ray measurements are required to confirm the validity of the proposed decay scheme.

Gamma-ray emissions: recommended energies, emission probabilities, multipolarities and theoretical internal conversion coefficients (frozen orbital approximation).

	E_γ (keV)	P_γ^{abs}	Multi	α_K	α_L	α_{M+}	α_{tot}	
$\gamma_{1,0}$ (Cm)	42.13 (5)	0.040 ± 0.002	E2	-	836 (12)	319 (5)	1155 (17)	β^-
$\gamma_{1,0}$ (Pu)	44.54 (2)	0.014 ± 0.001	E2	-	544 (8)	204 (3)	748 (11)	EC

Multipolarities and Internal Conversion Coefficients

The nuclear level scheme specified by Akovali has been used to define the multipolarities of the gamma transitions on the basis of known spins and parities (2002Ak06). 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).

Beta Particles

Energies and emission probabilities

Beta-particle energies were calculated from the nuclear level energies of Akovali (2002Ak06) and a Q_{β^-} value of (664.5 ± 0.4) keV taken from Audi *et al.* (2003Au03).

Assuming virtually full internal conversion of the 42.13-keV gamma transition, the beta-particle emission probabilities were calculated from BF_β of 0.831 (3) and $P_{ce}(\beta^-)$ of 0.458 (23):

Beta-particle Emission Probabilities per 100 Disintegrations of ^{242}Am.

	E_β (keV)	av. E_β (keV)	P_β	Transition type	log *ft*
$\beta^-_{0,1}$	622.4 ± 0.4	185.92 ± 0.14	45.8 ± 2.3	1st forbidden non-unique	6.84
$\beta^-_{0,0}$	664.5 ± 0.4	200.17 ± 0.14	37.3 ± 2.3	1st forbidden non-unique	7.03

EC Transitions

Energies and transition probabilities

EC transition energies were calculated from the nuclear level energies of Akovali (2002Ak06) and a Q_{EC} value of (751.3 ± 0.7) keV from Audi *et al.* (2003Au03).

Assuming virtually full internal conversion of the 44.54-keV gamma transition, the EC transition probabilities were calculated from BF_{EC} of 0.169 (3) and $P_{ce}(EC)$ of 0.106 (5):

EC Transition Probabilities per 100 Disintegrations of ^{242}Am.

	E_{EC} (keV)	P_{EC}	Transition type	log *ft*	P_K	P_L	P_M
$EC_{0,1}$	706.8 ± 0.7	10.6 ± 0.5	1st forbidden non-unique	7.26	0.7261 (23)	0.2016 (15)	0.0532 (10)
$EC_{0,0}$	751.3 ± 0.7	6.3 ± 0.6	1st forbidden non-unique	7.55	0.7303 (22)	0.1987 (15)	0.0522 (10)

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 of daughter Cm). This program incorporates atomic data from 1996Sc06 and the evaluated gamma-ray data.

K and L X-ray Emission Probabilities per 100 Disintegrations of ^{242}Am.

			Energy keV	Photons per 100 disint.
XL		(Pu)	12.124 – 22.153	10.8 (5)
	XL_l	(Pu)	12.124	0.293 (11)
	XL_α	(Pu)	14.087 – 14.282	4.56 (16)
	XL_η	(Pu)	16.333	0.084 (4)
	XL_β	(Pu)	16.498 – 18.541	4.64 (15)
	XL_γ	(Pu)	21.420 – 22.153	1.03 (4)
XK_α	$XK_{\alpha2}$	(Pu)	99.525	3.55 (17)
	$XK_{\alpha1}$	(Pu)	103.734	5.6 (3)
$XK'_{\beta1}$	$XK_{\beta3}$	(Pu)	116.244	)
	$XK_{\beta1}$	(Pu)	117.228	) 2.06 (11)
	$XK''_{\beta5}$	(Pu)	117.918	)
$XK'_{\beta2}$	$XK_{\beta2}$	(Pu)	120.540	)
	$XK_{\beta4}$	(Pu)	120.969	) 0.72 (4)
	$XKO_{2,3}$	(Pu)	121.543	)
XL		(Cm)	12.633 – 23.527	18.0 (11)
	XL_l	(Cm)	12.633	0.451 (22)
	XL_α	(Cm)	14.746 – 14.961	6.8 (3)
	XL_η	(Cm)	17.314	0.194 (11)
	XL_β	(Cm)	17.286 – 19.688	8.7 (4)
	XL_γ	(Cm)	22.735 – 23.527	2.09 (10)

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 679.2 (4) 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. This value has subsequently been compared with the Q-value calculated by summing the contributions of the individual emissions to the ^{242}Am beta- and EC-decay processes (i.e. β^-, conversion electrons, γ, etc.):

$$\text{calculated Q-value} = \sum (E_i \times P_i) = 679\ (22)\ \text{keV}$$

Percentage deviation from the effective Q-value of Audi *et al*. is (0 ± 3) %, which supports the derivation of a highly consistent decay scheme with a large variant.

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