

¹⁴⁷Pm - Comments on evaluation of decay data by V. Chisté and M. M. Bé

This evaluation was completed in May 2011, including all publications by this date.

1 Decay Scheme

¹⁴⁷Pm disintegrates 100 % by beta minus emissions to the ¹⁴⁷Sm ground state mainly.

A good agreement was found between the effective Q value (224.5 (4) keV) calculated from the decay scheme data and the adopted and recommended value from the mass adjustment of Audi (2003Au03).

2 Nuclear Data

The Q value is from the atomic mass evaluation of Audi *et al.* (2003Au03).

Experimental ¹⁴⁷Pm half-life values (in years) are given in Table 1:

Table 1: Experimental values of ¹⁴⁷Pm half-life.

Reference	Experimental value (a)	Comments
E. A. Melaika (1955Me52)	2.52 (8)	Outlier.
R. P. Schuman (1956Sc87)	2.66 (2)	Outlier.
W. F. Merritt (1957Me47)	2.64 (2)	
J. P. Cali (1959Ca**)	2.7 (1)	Outlier.
E. I. Wyatt (1961Wy01)	2.50 (3)	Superseded by 1968Re04.
F. P. Roberts (1963Ro20)	2.67 (6)	Superseded by 1965Wh04.
S. C. Anspach (1965An07)	2.618 (7)	
J. F. Eichelberger (1965Ei04)	2.6226 (20)	Superseded by 1967Jo07.
K. F. Flynn (1965Fl02)	2.60 (2)	
E. J. Wheelwright (1965Wh04)	2.620 (5)	
K. C. Jordan (1967Jo07)	2.6234 (4)	
S. A. Reynolds (1968Re04)	2.62 (1)	
Recommended value	2.6234 (4)	$\chi^2 = 0.64$

A weighted average has been calculated using LWEIGHT computer program (version 3). The Melaika (1955Me52), Schuman (1956Sc87) and Cali (1959Ca**) values have been shown to be outlier, based on the Chauvenet's criterion and thus were omitted in the final calculation. The largest contribution to the weighted average comes from the value of K. C. Jordan (1967Jo07), with a statistical weight of 98 %.

The adopted value is the weighted average of 2.6234 a with an internal uncertainty of 0.0004 a. The reduced- χ^2 value is 0.64.

For ¹⁴⁷Sm, the experimental half-life values (in years) are given in Table 2:

Table 2: Experimental values of ¹⁴⁷Sm half-life.

Reference	Experimental value (10 ¹¹ a)	Comments
W. F. Libby (1934Li03)	0.92 (6)	Corrected for (Sm nat./Sm-147) = 0.1498 by R. D. MacFarlane (1961Ma05).
R. Hosemann (1936Ho**))	1.5 (1)	Corrected for (Sm nat./Sm-147) = 0.1498 by R. D. MacFarlane (1961Ma05).
P. Cuer (1946Cu**))	1.3 (1)	
E. Picciotto (1949Pi**))	1.00 (5)	Corrected for (Sm nat./Sm-147) = 0.1498 by R. D. MacFarlane (1961Ma05).
G. Beard (1954Be69)	1.25 (6)	Superseded by 1958Be78.
G. E. Leslie (1956Le55)	1.15 (6)	
G. Beard (1958Be78)	1.06 (4)	Corrected for wrong Sm content by P. M. Wright (1961Wr02). Original value: 1.28 (4). Superseded by 1987Al28.
M. Karras (1960Ka**))	1.14 (5)	Superseded by 1960Ka23.
M. Karras (1960Ka23)	1.17 (5)	
R. D. MacFarlane (1961Ma05)	1.15 (5)	Superseded by 1970Gu14.
P. M. Wright (1961Wr02)	1.05 (2)	
D. Donhoffer (1964Do01)	1.04 (3)	
K. Valli (1965Va16)	1.08 (2)	
M. C. Gupta (1970Gu14)	1.06 (2)	
B. Al-Bataina (1987Al28)	1.05 (4)	
J. B. Martins (1992Ma56)	1.06 (4)	Corrected for wrong Sm content by F. Begemann (2001Be81). Original value: 1.23 (4).
N. Kinoshita (2003Ki26)	1.17 (2)	Questioned by 2009Ko15.
K. Kossert (2009Ko15)	1.070 (9)	
Recommended value	1.079 (12)	$\chi^2 = 3.9$

The first 3 values (1934Li03, 1936Ho** and 1946Cu**) have been shown outliers, based on the Chauvenet's criterion and thus were omitted in the final calculation. With the eleven remaining values (1949Pi**, 1956Le55, 1960Ka23, 1961Wr02, 1964Do01, 1965Va16, 1970Gu14, 1987Al28, 1992Ma56, 2003Ki26 and 2009Ko15), a weighted average has been calculated using LWEIGHT computer program (version 3). The largest contribution to the weighted average comes from the value of K. Kossert (2009Ko15), with a statistical weight of 46 %.

The adopted value is the weighted average of $1.079 \cdot 10^{11}$ a with an external uncertainty of $0.012 \cdot 10^{11}$ a. The reduced- χ^2 value is 3.9.

2.1 β^- Transitions

The maximum energies of the β^- transitions in the decay of ¹⁴⁷Pm → ¹⁴⁷Sm have been obtained from the Q⁻ value (2003Au03) and the level energies from N. Nica (2009Ni02) (Table 3).

Table 3: ¹⁴⁷Sm levels populated in the decay of ¹⁴⁷Pm and adopted β^- transition probabilities.

Level Number	Level energy, (keV) ^a	Spin and parity	Half-life [*]	Adopted P_{β^-} (%)
0	0	7/2 ⁻	1.060 (11)·10 ⁻¹¹ s	99.994 56 (13)
1	121.223 (12)	5/2 ⁻	0.798 (17) ns	0.005 42 (13)
2	197.298 (11)	3/2 ⁻	1.25 (3) ns	0.000 000 40 (7)

* Given by N. Nica (2009Ni02),

^a from least-squares fit to E_{γ} 's.

The adopted β^- transition probabilities and the associated uncertainties (Table 3) were deduced from the γ transition probability balance at each level of the decay scheme.

The values of log ft and average β^- energies have been calculated with the program LOGFT for the unique 1st and 1st forbidden β^- transitions.

2.2 γ Transitions

The γ -ray transition probabilities were calculated using the γ -ray emission intensities and the relevant internal conversion coefficients (see **4.2 γ Emissions**).

For all γ transitions, the internal conversion coefficients (ICC) and the associated uncertainties were interpolated from theoretical values of I. M. Band et al. (2002Ba85) using the BrIcc computer program (2008Ki07) for the “frozen orbital” approximation.

For multipolarity and mixing ratio of the γ -ray transitions, the evaluators used:

1) The multipolarities of the 76- and 197-keV γ -ray transitions are from N. Nica (2009Ni02):

76-keV γ -ray: M1 + E2, $\delta = 0.655$ (34);

197-keV γ -ray: E2.

2) For the 121-keV γ -ray transition, the adopted mixing ratio (δ) is the weighted mean of the δ values found in the literature and shown in the Table 4.

Table 4: Experimental and recommended mixing ratio and ICC.

E_{γ} (keV)	δ experimental (mixing ratio)	Comments
121.220 (7)	0.25 (21) (1958An36) -0.06 (2) (1962Al19) ^a -0.33 (4) (1962Sc09) 0.34 (3) (1966Av02) -0.35 (4) (1966Go26) [‡] -0.38 (3) (1970Va38) -0.40 (+26,-15) (1971Be53) -0.278 (20) (1989Ad10)	Calculated [*] from K/L = 6.2 (6). Calculated by 1977Kr13 ($\gamma\gamma(\theta)$). Calculated [*] from $L_1:L_2:L_3 = 1.0$ (2): 0.24 (4): 0.16 (2). Calculated [*] from K: $L_{1+2}:L_3 = 450$ (40): 73 (7): 10 (1). Calculated by 1977Kr13 ($\gamma\gamma(\theta)$). Superseded by 1970Va38. Calculated by 1977Kr13 ($\gamma\gamma(\theta)$). Calculated by 1977Kr13 ($\gamma\gamma(\theta)$).
Recommended value	- 0.317 (19), $\chi^2 = 1.7$	$\alpha_K(\text{BRICC} - 121\text{-keV } \gamma\text{-ray}) = 0.815$ (12).

^a Outlier value, based on the Chauvenet's criterion and thus was omitted in the final calculation.

[‡] Superseded by 1970Va38.

^{*} Using BrIccMixing program, version 2.2a (same package of BrIcc computer program).

3 Atomic Data

Atomic values, ω_K , ω_L , n_{KL} and the X-ray relative probabilities are from Schönfeld and Janßen (1996Sc06).

4 Photon Emissions

4.1 X-ray Emissions

The X-ray absolute intensities were deduced from the decay data using the EMISSION computer code.

4.2 Gamma emissions

The energies of the γ -rays given in Table 5 were derived from the ¹⁴⁷Sm adopted levels (Table 2).

The experimental absolute values of the 121-keV γ -ray emission intensities in the decay of ¹⁴⁷Pm are given in the table 5.

Table 5: Absolute experimental γ -ray emission intensities for the 121-keV transition.

Reference	Absolute γ -ray intensity (10^{-3} %)	Comments
H. Langevin-Joliot (1956La17)	3.0 (5)	
N. Starfelt (1957St05)	3.4 (5)	
R. S. Mowatt (1970Mo02)	2.73 (18)	
D. McConnon (1971Mc09)	2.93 (14)	
H. H. Hansen (1973HaHY)	3.0 (3)	
U. Schötzgig (1990Sc08)	2.65 (6)	
Recommended value	2.72 (6)	$\chi^2 = 1.33$

The adopted value is the weighted average of $2.72 \cdot 10^{-3}$ % with an external uncertainty of $0.06 \cdot 10^{-3}$ %. The reduced- χ^2 value is 1.33.

For the 197-keV γ -ray emission, the adopted value of the γ -ray relative intensity ($1.2 (2) \cdot 10^{-4}$) comes from the unique measurement found in the literature given by P. H. Barrett (1969Ba33).

Our recommended γ -ray emission probabilities are given in Table 6.

Table 6: Recommended relative and absolute γ -ray intensities (%).

E_γ (keV)	Relative γ -ray intensity (%)	Absolute γ -ray intensity (%)
(76.073 (10))^a	$4.1 (7) \cdot 10^{-6}$	$1.1 (2) \cdot 10^{-8}$
121.220 (17)	100	$2.72 (6) \cdot 10^{-3}$
197.299 (12)	$1.2 (2) \cdot 10^{-4}$	$3.3 (5) \cdot 10^{-7}$

^a not observed in this decay scheme.

The 76-keV γ -ray transition has been observed in the ¹⁴⁷Eu electron capture decay, but not in the ¹⁴⁷Pm β^- decay. From the ¹⁴⁷Eu electron capture decay (1989Ad10):

$I_\gamma(76 \text{ keV})/I_\gamma(197 \text{ keV}) = 0.0344 (11)$ and

$I_\gamma(197 \text{ keV}) = 1.2 (2) \cdot 10^{-4}$. Then $I_\gamma(76 \text{ keV}) = 4.1 (7) \cdot 10^{-6}$.

This very weak transition was included in the decay scheme.

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