^{234}U - Comments on evaluation of decay data by V. Chisté and M.M. Bé

This evaluation was completed in 2005. Literature available by September 2005 was included.

1 Decay Scheme

^{234}U disintegrates by alpha emission to excited and ground state levels of ^{230}Th. Spin and half-lives of excited states are from the mass-chain evaluation of Y.A. Akovali (1993Ak02 to A = 230, and 1994Ak05 to A = 234).

2 Nuclear Data

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

The experimental ^{234}U half-life values (in years) are given in Table 1:

Table 1: Experimental values of ^{234}U half-life.

Reference	Original value (10^5 a)	Revised Value by Holden (1981HoZI and 1989Ho24)	Comments
Nier (1939Ni03)	2.70 (27)		**Not used**.
Chamberlain (1946Ch02)	2.29 (14)		**Not used**. Measurements of relative abundance of ^{234}U and ^{238}U.
Chamberlain (1946Ch02)	2.35 (14)		**Not used**. Measurements of α-activity of ^{234}U.
Baldinger (1949Ba41)	2.33 (10)		**Not used**.
Goldin (1949Go18)	2.67 (4)		**Not used**.
Kienberger (1949Ki26)	2.552 (8)		**Not used**. Superseded 1952Ki19
Fleming (1952Fl20)	2.475 (16)	2.475 (24)	**Not used**. Uncertainty increased for missing details.
Kienberger (1952Ki19)	2.520 (8)		**Not used**.
White (1965Wh05)	2.47 (3)		**Not used**.
Meadows (1970MeZN)	2.439 (14)	2.439 (18)	**Not used**. Uncertainty increased for missing details.
de Bievre (1972DeYN)	2.446 (7)	2.450 (9) *	Revised by author (see 1989Ho24)
Lounsbury (1972LoZL)	2.444 (6)	2.458 (13) *	Revised by author (see 1989Ho24)
Geidel'man (1980Ge13)	2.4604 (45)	2.459 (9) *	4πα - x coincidence. Revised uncertainty for missing details.
	2.4570 (45)		Liquid scintillator. Revised uncertainty for missing details.
Poenitz (1983 and 1985 Poenitz)	2.457 (5)		**Not used**.
Davideenam (1984Davideenam)	2.457 (5)		**Not used**. Evaluated value.
Recommended value		**2.455 (6)**	reduced $\chi^2 = 0.28$

The first six and less precise values (1940's) were omitted from analysis. For remaining values, the evaluators have chosen to take into account the recommendations given by N.E. Holden (1989Ho24), thus the only three experimental values (*) with associated uncertainties used to the weighted average are 1972DeYN, 1972LoZL and 1980Ge13. For the data in 1980Ge13, the evaluators have chosen to use the average value of 2.459 (9) 10^5 a, calculated from two experimental values given in the paper to produce a single DDEP value from each laboratory. A weighted average has been calculated using LWEIGHT computer program (version 3). However, the treatment of uncertainties in 1989Ho24 ("… when detailed information on the uncertainties was available in each of these experiments, the standard deviation for the experiment was combined with one third of the systematic error to provide the uncertainty quoted in the table: $\sigma_{tot} = \sigma_{statistical} + 1/3\ \sigma_{systematic}$") seemed more realistic, so the evaluators recommend a half-life of *2.455 10^5 a* with a final uncertainty of

0.006 10^5 a. The reduced χ^2 value is 0.28.

The experimental ^{230}Th half-life values (in years) are given in Table 2:

Table 2: Experimental values of ^{230}Th half-life.

Reference	Value (a)	Uncertainty (a)
M. Curie (1930Cu02)	82 300	2 469
E.K. Hyde (1949Hy03)	80 000	3 000
R.W. Attree (1961Attree)	75 200	1 600
J.W. Meadows (1980Me10)	75 381	295
Recommend value	**75 500**	**500**

The recommended value is the weighted average (calculated with LWEIGHT computer program) of *75.5 10^3 a* with an external uncertainty of *0.5 10^3 a*. The reduced χ^2 value is 3.3.

The evaluated spontaneous fission partial half-life of ^{234}U is based on the experimental results given in Table 3.

Table 3: Experimental values of ^{234}U spontaneous fission half-life (in 10^{16} years).

Reference	Value	Uncertainty	Comments
A. Ghiorso (1952Gh27)	2	1	**Not used**.
H.R. von Gunten (1981Vo02)	1.42	0.08	
S. Wang (1987Sh27)	1.90	0.15	
Recommend value	1.5	0.2	reduced χ^2 = 5.12

The evaluators have not use the value given in 1952Gh27, as recommended in 1989Ho24. Evaluators' recommended value is the weighted average of the two remaining values: *1.5 10^{16} a* with an external uncertainty of *0.2 10^{16} a*. The reduced χ^2 value is 5.12.
This value produces a spontaneous fission branching of 1.6 (2) 10^{-9} %.

2.1 α Transitions

The energies of the α-particle transitions given in Section 2.1 have been calculated from the Q_α (2003Au03) and level energies deduced by the evaluators from a least-squares fit to γ-ray energies.

2.2 γ Transitions

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

For the 634-keV γ-ray (E0 transition), $P_{(\gamma+ce)}$ = 1.4 (7) 10^{-5} % has been deduced from decay scheme balance.

Multipolarities of γ-ray transitions in decay of ^{230}Th are from 1993Ak02:

53-keV γ-ray:	E2	581-keV γ-ray:	E2
120-keV γ-ray:	E2	624-keV γ-ray:	E0 + E2 + M1
454-keV γ-ray:	E1	634-keV γ-ray:	E0
503-keV γ-ray:	[E2]	677-keV γ-ray:	[E2]
508-keV γ-ray:	E1		

The internal conversion coefficients (ICC's) have been calculated using the Icc99v3a computer program (GETICC dialog), which uses interpolated values from new tables of Band et al (2002Ba85). The evaluators have used a fractional uncertainty of 3 % for all conversion coefficients.

3 Atomic Data

Atomic values, ω_K, ϖ_L and n_{KL}, X-ray and Auger electrons relative probabilities are from Schönfeld and Janβen (1996Sc06).

4 α Emissions

α-particle energies are from Q_α (2003Au03) and level energies (see section 2.1). For the $\alpha_{0,0}$ and $\alpha_{0,1}$ emissions, the energies are from A. Rytz (1991Ri01).

The measured α-emission intensities are given in Table 4.

Table 4: Measured α-emission intensities, in %.

Energy (keV)	1955Go57	1960Ba44	1961Ko11	1963Bj03	1984Va41	1987Bo25	Recommended Value
4774.6 ($\alpha_{0,0}$)	72	72.5 (30)	73		71.38 (5)	71.37 (2)	71.37 (2)
4722.4 ($\alpha_{0,1}$)		27.15 (15)	27		28.42 (5)	28.42 (2)	28.42 (2)
4603.5 ($\alpha_{0,2}$)		≤ 0.37 (11)	0.3		0.206 (4)	0.199 (2)	0.210 (2)
4275.2 ($\alpha_{0,3}$)				$4 (1) 10^{-5}$			$4 (1) 10^{-5}$
4150.6 ($\alpha_{0,4}$)				$1.2 (5) 10^{-5}$			$2.6 10^{-5}$
4108.6 ($\alpha_{0,5}$)				$0.3 10^{-5}$			$7.0 10^{-6}$

The U-234 spectrum was recorded by 1984Va41, a second analysis of the same data was done by 1987Bo25, these latest values are the adopted results for the 4774- and 4722-keV α-emissions intensity. The 4603-keV intensity is deduced from the decay scheme, the tree others being negligible.
The 4275-, 4150-, 4108- keV emission intensities are deduced from 1963Bj03 and decay scheme transition probability balance (§6.2).

6 Photon Emissions

6.1 X-rays

The X-ray and Auger electrons absolute intensities have been calculated from γ-ray data and ICC by using the EMISSION computer program.

In the Table 5 the recommended values of ^{230}Th X-ray emission probabilities are compared with the experimental results. Good agreement was found between the experimental results given by 1977Bemis, 1984Va41 and 1995Jo23 and the recommended values calculated from the decay scheme data set. This agreement confirms the completeness and consistency of the decay scheme.

Table 5: Experimental and recommended (calculated) values of ^{230}Th X-ray emission intensities.

Reference	1977Bemis	1984Va41	1995Jo23	Recommended value
11.118 – 19.504 (L X-ray)	9.81 (13)	10.35 (14)	10.02 (7)	10.2 (4)
Lℓ - 11.118			0.206 (3)	0.209 (12)
Lα - 12.808 – 12.967			3.42 (2)	3.48 (17)
Lη - 14.509				0.118 (7)
Lβ - 14.972 – 16.425			5.17 (4)	5.16 (26)
Lγ - 18.363 – 19.504			1.22 (1)	1.21 (6)
89.95 (X $K_{\alpha 2}$)		$2.53 (7) 10^{-3}$		$2.69 (25) 10^{-3}$
93.35 (X $K_{\alpha 1}$)		$4.15 (10) 10^{-3}$		$4.4 (4) 10^{-3}$

6.2 Gamma emissions

The energies of the γ-ray emissions given in Section 6 are from Y.A. Akovali (1993Ak02).
The experimental intensity of the 120-keV γ emission given in Table 6 is relative to the 53-keV γ-ray.

Table 6: Experimental relative γ emission intensity (P_{rel}) in %.

γ Energy (keV)	1966Ah02	1974HeYW	1984Va41	Recommended value
53.20	100	100 (5)	100	100.0 (25)
120.90	34 (4)	34.2 (18)	27.5 (5)	30.8 (24)

The recommended values are the weighted averages of the three values given with uncertainties. The normalization factor to convert the relative emission intensities to absolute emission intensities is calculated with the formula:

$$\text{Normalization factor} = \frac{(100\,\% - 71.371\,(19)\,\%)}{\sum\,[(1\ +\ \alpha_T)P_{rel}\,]} = 0.001\ 253\ (40),$$

where the sum is over all the γ transitions to the ground state and α_T is the relevant conversion coefficient. In this case, the contribution of 508- (see next), 634- and 677-keV γ transitions are considered negligible. The uncertainty was calculated through the propagation on the formula given above.

For the 454- and 508-keV absolute emission probabilities, the evaluators have following relations:
P_γ (454) + P_γ (508) = 4 (1) 10^{-5} (from 1963Bj03) and
P_γ (508) = 0.60 (4) × P_γ (454) (from average value of measured ratios in ^{230}Pa and ^{230}Ac decays. See 1993Ak02).Then the evaluator obtains P_γ (454) = 0.000 025 (6) % and P_γ (508) = 0.000 015 0 (39) %. For the others γ rays, the evaluators present the experimental absolute emission values given in 1993Ak02. The evaluated relative and absolute γ-rays emission intensities are given in Table 7.

Table 7: Evaluated relative and absolute γ-ray emission intensities.

Energy (keV)	Relative emission intensity (%)	Absolute emission intensity (%)
53.20 (2)	100.0 (25)	0.125 3 (40)
120.90 (4)	30.8 (24)	0.038 6 (32)
454.96 (5)		0.000 025 (6)
503.5 (1)		0.000 000 95
508.16 (5)		0.000 015 0 (39)
581.7 (1)		0.000 012 (5)
624.4 (1)		0.000 000 82
677.6 (1)		0.000 001

7 References

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