^{236}U – Comments on Evaluation of Decay Data
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This evaluation was completed in April 2008. The literature available by February 2008 was included.

1. Evaluation Procedures

The Limitation of Relative Statistical Weight (LWM) (1988WoZO) method was applied for averaging numbers throughout this evaluation; this method was implemented by using the computer code LWEIGHT, ver. 4 (designed for Excel, MS Office), [1] [2]. The uncertainty assigned to an average value in this evaluation is never lower than the lowest uncertainty of any of the experimental input values.

2. Decay Scheme

^{236}U decays 100 % by alpha-particle emissions, mainly to the ground state and to the 49 keV excited level of ^{232}Th. ^{236}U decays also by spontaneous nuclear fission, with a weak branch (about 9 10^{-8} %). According to Tretyakova et al. (1994Tr12), a very weak cluster decay of ^{236}U (~10^{-13} probability relative to the alpha emission), consisting of Ne and Mg emission, was observed. The spin, parity, energy and half-life of the ^{232}Th excited levels, and the multipolarities of the γ-ray transitions have been adopted from the A=232 ENSDF mass-chain evaluation of E. Browne (2006Br19).

3. Nuclear Data

The adopted alpha-decay energy value Q(α) = 4573.1 (9) keV, is from 2003Au03. This value is in agreement with the effective Q(α) value of 4570 keV (with an uncertainty of 260 keV), calculated from the decay scheme data, by using the SAISINUC software. This agreement proves the consistency and correctness of the decay scheme.

3.1. Half-life

The measured half-life ($T_{1/2}$) values, with the reviewed uncertainties (1989Ho24), are shown below in Table 1. After a new critical review (based on the most precise modern activity measurements by using the defined solid angle α-particle counting method, according to the Bureau International des Poids et Mesures (BIPM), Key Comparison Database, section "Calibration and Measurement Capabilities" (CMCs) - Ionizing Radiation, http://kcdb.bipm.org/AppendixC/), the uncertainty of the most recent half-life value (1972Fl03) was increased from about 0.06 % to 0.25 %; accordingly, the half-life was rounded from 2.3415 10^7 to 2.342 10^7 years. The set of data is consistent and the recommended value, 2.343 10^7 years, with the uncertainty of 0.006 10^7 years, is the weighted average (LWM, χ^2_ν=0.72) of the three input values. The references are expressed as NSR (Nuclear Science References) type keynumbers:

Table 1

$T_{1/2}$ (10^7 years)	Uncertainty of $T_{1/2}$ (10^7 years)	Reference
2.46	0.14	1951Ja09
2.391	0.057	1952Fl20
2.3415	0.0039	1972Fl03

The measured half-life ($T_{1/2}$) values for the ^{236}U spontaneous fission are presented below in Table2:

Table 2

$T_{1/2\ sf}$ (10^{16} years)	Uncertainty of $T_{1/2\ sf}$ (10^{16} years)	Reference
2.0	1.6	Jaffey and Hirsch, 1949 [3]
2.7	0.3	1971Co35
2.43	0.13	1981Vo02
2.7	0.4	1983Be66

The value mentioned in ref. [3] was unpublished, but it is cited in E.K. Hyde, 1964 [4]. This data set is consistent, and the recommended value, 2.49 10^{16} years, with the uncertainty of 0.13 10^{16} years, is the weighted average (LWM, χ^2_ν = 0.36) of the four input values from the first column.

3.2. Alpha transitions and emissions

In the literature, only one reference about measurements of energy and emission probability for ^{236}U alpha transitions was found: 1960Ko04. In another reference (1992It01), the measured energy of the main alpha-particle emission (4.49 MeV) was reported.
For this evaluation, the energies and the intensities of α_0 and α_{49} are from 1960Ko04. The energy of α_{162} is also from 1960Ko04, but its intensity is from γ-ray transition intensity balance. The energy of α_{333} is from Q(α) = 4573.1 (9) keV and E(level) = 333.40 keV; its intensity is from γ-ray transition intensity balance (2006Br19). These values, as well as their α hindrance factors (HF) are shown in Table 3.

Table 3

E_α (keV)	Uncertainty E_α (keV)	Emission intensity (%)	α Hindrance Factor (HF)
4494	3	73.8 (40)	1.0
4445	5	26.1 (40)	1.2
4332	8	0.149 (22)	27.3
4168	-	0.000 14 (5)	1160

3.3. g- transitions: g rays and internal conversion electrons

Measurements of the two main γ-ray transition energies are presented in a paper by Schmorak *et al.*, 1972Sc01. Their uncertainties may have been somewhat underestimated for the detection system that they used. Measurements of the energies and relative intensities for the γ rays following the decay of ^{236}U were published only by Gehrke et al. (2002Ge02), as shown in Table 4.
The decay-scheme normalization condition applied for the ^{232}Th ground state, allowed the determination of the absolute emission probability for the 49.46 keV γ ray ($I_{\gamma 49}$, expressed in %):
$(\alpha^T_{49}+1) \cdot I_\gamma(49) + I_\alpha(4494) = 100$ %, where α^T_{49} = 324.4 is the theoretical internal conversion coefficient (program BrIcc v2.0a, [5]) for the 49-keV γ ray and $I_\alpha(4494)$ = 73.8 (40) %. The resulting value for the absolute emission probability of the main γ ray following the ^{236}U alpha decay, is $I_\gamma(49)$ = 0.081 (12) %. Using this value and the relative intensity values of the 112 keV and 171 keV γ-ray emissions measured by Gehrke *et al.*, the corresponding absolute emission probabilities and their uncertainties were computed and are given below in Table 4.

Table 4:

E_γ (keV)	Uncertainty E_γ (keV)	Relative Emission probability (%)	Absolute Emission probability (%)	Total ICC (α_T)
49.46	0.10	100	0.081 (12)	324
112.79	0.10	24.1 (1)	0.019 5 (31)	6.67
171.15	0.20	0.080 (24)	0.000 065 (22)	1.186

4. Atomic data

The K-shell fluorescence yield (ω_K), the mean L-shell fluorescence yield (ν_L) and the mean number of vacancies in the L-shell produced by one vacancy in the K-shell (η_{KL}) were determined using the computer program EMISSION v3.10, 28-Jan-2003 [6]: 0.969 (4), 0.476 (18) and 0.797 (5) respectively.

4.1. Auger electrons and X-rays

The relative probability values of the K Auger electron emissions (KLL, KLX, KXY) normalized to the KLL value, were computed using the same EMISSION computer program. The total K Auger electron emission probability (absolute) and the emission probability of the L Auger electrons were also calculated. The energy ranges for K and L Auger electrons were filled-in by the SAISINUC program [7].
The relative probability (normalized to $K_{\alpha1}$ X-rays emission) and the absolute emission probability values of the different groups of K and L X-rays were determined using the same EMISSION program. The energy range values of the K and L X-rays are from the tables linked to SAISINUC. The results for absolute emission probabilities of LX rays (I(LX) = 9.4 (10) %) agrees with I(LX) = 9.4 (13) % given in the Table of Radioactive Isotopes [8]. The KX ray emission probabilities are so weak that are not given in reference [8].
Neither measurements of X-ray energies nor of emission probabilities were found in the literature.

5. Main production mode

The main production mode of ^{236}U is by irradiating ^{235}U nuclei with thermal neutrons in nuclear reactors; the ^{236}U is produced by thermal neutron captures: $^{235}U(n,\gamma)^{236}U$. The neutron-capture cross section is 98.3 (8) barn [9].

6. References

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