^{237}U - Comments on evaluation of decay data by V.P. Chechev and N.K. Kuzmenko

This evaluation was done originally in September 2005 and then revised in April 2009 with a literature cut-off by the same date.

1 Decay Scheme

The decay scheme is based on 2006Ba41.

2 Nuclear Data

Q^- value is from 2003Au03.

The recommended half-life of ^{237}U is based on the experimental results given in Table 1.

Table 1. Experimental values of the ^{237}U half-life (in days)

Reference	Author(s)	Value
1949Me43	Melander and Slatis	6,63 (5)
1953Wa05	Huizenga and Flynn	6,75 (1)
1958Ca16	Cabell et al.	6,752 (2)

The weighted mean of the 3 values from the Table 1 of 6,752 (2) is dominated by the very accurate value of 1958Ca16. The EV1NEW computer program, which uses the limitation of relative statistical weights by 0,5 (LRSW method), increased the 1958Ca16 uncertainty from 0,002 to 0,0098 and gave 6,749 (16).

Therefore, the recommended value of ^{237}U half-life is 6,749 (16) days.

2.1 Beta Transitions

The energies of β^- transitions have been obtained from the Q^- value and the level energies given in Table 2 from 2006Ba41.

Table 2. ^{237}Np levels populated in ^{237}U β^- decay

Level	Energy, keV	Spin and Parity	Half-life	Probability of β^- transitions (×100)
0	0,0	$5/2^+$	$2,144 (7) \times 10^6$ a	-
1	33,19629 (22)	$7/2^+$	54 (24) ps	-
2	59,54092 (10)	$5/2^-$	67 (2) ns	6,7 (42)
3	75,899 (5)	$9/2^+$	≈ 28 ps	-
4	102,959 (3)	$7/2^-$	80 (40) ps	-
5	267,556 (12)	$3/2^-$	5,2 (2) ns	40,9 (31)
6	281,356 (18)	$1/2^-$	-	48,2 (25)
7	332,376 (16)	$1/2^+$	≤ 1,0 ns	2,9 (9)
8	368,602 (20)	$5/2^+$	-	-
9	370,928 (23)	$3/2^+$	-	1,3 (9)

The probabilities of β^- transitions have been deduced from the P(γ+ ce) balance at each level of ^{237}Np.

The 459,1 keV $\beta^-_{0,2}$ transition probability of 7 (4) % has been obtained using the relation of 100-Σ $P_i(\beta^-)$. The value deduced from the P(γ+ ce) balance is 7 (6) %.

Some experimental estimations of the β^- transition energies and probabilities are given in 1949Me43, 1953Wa05 and 1957Ra04. More precise measurements would prove beneficial.

2.2 Gamma-ray Transitions and Internal Conversion Coefficients

The recommended energies of the gamma-ray transitions are mainly the same as the gamma-ray energies because nuclear recoil is negligible for ^{237}Np.

The gamma-ray transition probabilities have been obtained from the gamma-ray emission probabilities and the total internal conversion coefficients (ICCs). Multipolarities of gamma-ray transitions have been taken from 2006Ba41. The ICCs have been interpolated using the BRICC package with the so called "*Frozen Orbital*" approximation (2008Ki07). The relative uncertainties of the ICC for pure multipolarities have been taken as 2 %.

The ICC for the intense E1 anomalously converted gamma-ray-transitions $\gamma_{2,1}$ (26,3- keV) and $\gamma_{2,0}$ (59,5- keV) have been obtained from a joint analysis of the gamma-ray and L-, M- conversion electron probabilities measured in ^{241}Am α decay and ^{237}U β^- decay (1996Jo28, 2006Ba41). The experimental conversion electron data are given in 1959Sa10, 1964Wo03, 1966Ko06, 1966Le13, 1966Ya05, and 1998Ko61. For discussion of E1 anomalously converted gamma transitions see 1960As02, 1966Ya05, 1967Pa23, 1970Gr36, and 1996Jo28.

The E2/M1 mixing ratio of 16,6 (25) % for $\gamma_{4,2}$(43,4-keV) has been obtained by averaging the four measurement results from 1964Wo03 (17,6 (19) %), 1966Ko06 (13 (2) %), 1966Ya05 (11 (4) %), and 1998Ko61 (21,2 (22) %).

The E2/M1 mixing ratio of 15 (8) % for $\gamma_{9,7}$ (38,5- keV) has been deduced using the ratio P_{ce} (L_2; $\gamma_{9,7}$) / P_{ce} (M_3; $\gamma_{9,7}$) = 10 (5) from 1966Ya05 and the theoretical values from the BRICC package. $P_{\gamma+ce}$ ($\gamma_{9,8}$ 2,3-keV) has been deduced assuming that there is no β^- feeding to the 368,59-keV level.

$P_{\gamma+ce}$ ($\gamma_{3,1}$ 42,7-keV) and $P_{\gamma+ce}$ ($\gamma_{3,0}$ 75,8-keV) have been deduced from $P\gamma_{3,0}/P\gamma_{3,1}$ = 3/28 (see 2006Ba41) assuming that there is no β^- feeding to the 75,92-keV level.

The gamma-ray transitions with energies 114,09 keV and 340,45 keV have not been placed in the level scheme.

3 Atomic Data

The atomic data are from Schönfeld and Janβen (1996Sc06).

4 Electron Emissions

The energies of the conversion electrons have been obtained from the gamma-ray transition energies and the electron binding energies.

The absolute emission probabilities of the conversion electrons have been calculated using recommended P_γ and ICC values.
The total absolute emission probabilities of K and L Auger electrons have been calculated using the EMISSION computer program.

β^- average energies have been calculated using the LOGFT computer program.

5. Photon Emissions

5.1 X-ray Emissions

The absolute emission probabilities of U KX and LX-rays have been calculated using the EMISSION computer program.

In Table 3 the calculated values are compared to the experimental data. The uncertainty in the detector efficiency (2 %) was added to the uncertainties listed in 1976GuZN.

Table 3. Experimental and recommended Np KX - ray emission probabilities in decay of ^{237}U

	Energy (keV)	1966Ya05	1976GuZN	Recommended (calculated)
$K\alpha_2$	97,069	16,2 (17)	15,8 (7)	14,8 (4)
$K\alpha_1$	101,059	22,6 (24)	25,2 (9)	23,5 (6)
$K'\beta_1$	113,944	9,8 (10)	9,22 (32)	8,57 (27)
$K'\beta_2$	117,463	3,1 (4)	2,3 (5)	2,95 (10)

5.2 Gamma-rays emissions

The energies of gamma rays $\gamma_{2,1}$ (26,3-keV) and $\gamma_{2,0}$ (59,5-keV) are from 2000He14. $E\gamma_{1,0}$ (33,2 keV) has been calculated as the difference $E\gamma_{2,0}$ - $E\gamma_{2,1}$. The energies of gamma rays $\gamma_{4,3}$, $\gamma_{3,1}$, $\gamma_{4,2}$ have been taken from 1998Ko61. The rest gamma-ray energies have been adopted from 2006Ba41 based on experimental data of 1996Ya05, and 1976GuZN. Other measurements: 1957Ra04, 1963Ak04, 1968Da24, 1971Cl03. The uncertainty in the detector efficiency (2 %) was added to the uncertainties listed in 1976GuZN.

In Table 4 the experimental and evaluated absolute gamma ray emission probabilities ($P\gamma$) are presented.

Table 4. Experimental and evaluated absolute gamma-ray emission probabilities (%) in decay of ^{237}U.

$E\gamma$, keV	1966Ya05	1971Cl03	1976GuZN	1982BuZF	1984BaYS	1985He02	1985Wi04	Evaluated
51,01	0,21 (10)		0,340 (14)		0,44 (6)			0,340 (14)
59,54	32,9 (40)	32,8 (25)	34,5 (8)		33,8 (9)			34,1 (9)
64,83	1,15 (16)	1,19 (9)	1,30 (3)		1,31 (5)		1,282 (17)	1,286 (17)
164,61	1,80 (9)	1,82 (14)	1,84 (5)		1,85 (5)	1,865 (23)	1,853 (23)	1,855 (23)
208,00			21,7 (5)	21,5 (14)		21,2 (3)	21,2 (3)	21,28 (30)
221,80	0,0199 (18)	0,0182 (14)	0,0212 (8)		0,0199 (25)			0,0204 (8)
234,40	0,0190 (18)	0,0273 (20)	0,0205 (8)		0,0224 (40)			0,0205 (8)
267,54	0,698 (30)	0,755 (20)	0,740 (18)		0,723 (25)	0,714 (22)	0,711 (10)	0,721 (10)
332,36	1,18 (8)	1,19 (9)	1,21 (3)		1,18 (4)		1,200 (16)	1,199 (16)
335,38	0,094 (9)	0,109 (9)	0,097 (3)		0,092 (5)		0,0951 (22)	0,0958 (22)
368,59	0,045 (4)	0,044 (3)	0,043 (2)		0,042 (3)		0,0392 (17)	0,0416 (17)
370,94	0,109 (9)	0,125 (10)	0,110 (4)		0,109 (6)		0,1073 (17)	0,109 (2)

The measurement results for gamma ray emission probabilities given in 1976GuZN, 1982BuZF, 1985He02, 1985Wi04 are absolute. The measurements results given in 1966Ya05, 1971Cl03, 1984BaYS are relative. The latter ones have been renormalized by evaluators at $P\gamma$(208 keV) = 21,3 (3) %.

$P\gamma_{6,5}$ has been deduced from Pce(M1) = 29,9 (3) %, as measured by 1966Ya05, and ICC α_{M1} = 281 (9).

$P\gamma_{4,1}$ has been deduced from $P\gamma_{4,1}$/ $P\gamma_{4,2}$ = 2,9 (4) / 73 (8), as measured in ^{241}Am α-decay (see 2006Ba41).

$P\gamma_{4,0}$ has been deduced from $P\gamma_{4,0}$/ $P\gamma_{4,2}$ = 19,5 (1) / 73 (8), as measured in ^{241}Am α-decay (see 2006Ba41).

$P\gamma_{8,2}$ has been deduced from $P\gamma_{8,2}$/ $P\gamma_{8,1}$ = 10,14 / 49,6 as measured in ^{241}Am α-decay (see 2006Ba41).

$P\gamma_{8,3}$ has been deduced from $P\gamma_{8,3}$/ $P\gamma_{5,2}$ = 0,000 12 (3), as measured by 1966Ya05.

$P\gamma_{9,7}$ has been deduced by evaluators from the ratio P_{ce} (L_2; $\gamma_{9,7}$) / P_{ce} (K; $\gamma_{5,2}$) = 0,0056 (20) from 1966Ya05 and total ICC's.

Pγ (340,4-keV) has been adopted from 1976GuZN.

6. Consistency of Recommended Data

The most accurate Q value, Q(M), is taken from the atomic mass adjustment table of Audi et al. (2003Au03). Comparison of Q(eff)(deduced as the sum of average energies per disintegration ($\sum E_i \times P_i$) for all emissions accompanying ^{237}U β^- decay) with the tabulated decay energy Q(M) allows to check a consistency of the recommended decay-scheme parameters obtained in this evaluation.

Here E_i and P_i are the evaluated energies and emission probabilities of the i-th alpha particle, beta particle, gamma ray, X-ray, etc. Consistency (percentage deviation) is determined by $\{[Q(M)-Q(eff))]/Q(M)\} \times 100$. "Percentage deviations above 5 % would be regarded as high and imply a poorly defined decay scheme; a value of less than 5 % indicates the construction of a reasonably consistent decay scheme" (quoted from the article by A.L. Nichols in Appl. Rad. Isotopes 55 (2001) 23-70).

For the above ^{237}U decay data evaluation we have Q(M) = 518,6(6) keV and Q(eff) = 519(23) keV, i.e. consistency is not worse than 4,4 %.

7. References

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