^{238}Np - Comments on evaluation of decay data by V. P. Chechev and N.K. Kuzmenko

This evaluation was completed in November 2006 with a literature cut off by the same date.

1. Decay Scheme

The decay scheme is based on the evaluation of Chukreev *et al.* (2002Ch52) and can be basically considered completed.

2. Nuclear Data

Q^- value is from 2003Au03.

The evaluated half-life of ^{238}Np is based on the experimental results given in Table 1.

Table 1. Experimental values of the ^{238}Np half-life (in days)

Reference	Author(s)	Value
1950Fr53	Freedman *et al.*	2,10 (1)
1958Al92	Albridge *et al.*	2,16 (15)
1966Qa01	Qaim	2,117 (2)
1990Ch35	Chang *et al.*	2,0980 (3)*
2006Re09	Rengan *et al.*	2,1024 (5)*

* Only statistical uncertainty

The evaluators increased the relative uncertainties of 1990Ch35 and 2006Re09 to 0,05 % to take into account possible systematic uncertainties. The LWEIGHT computer program has omitted the outlier of 1958Al92 and used a weighted average of 2,1024 with the expanded uncertainty of 0,0044 to give a recommended value.

The adopted value of the ^{238}Np half-life is 2,102 (5) days.

2.1. Beta Transitions

The energies of β^- transitions have been calculated from the Q^- value and the level energies given in Table 2 from 2006Re09. The probabilities of β^--transitions have been deduced from the P(γ+ce) balance for each level of ^{238}Pu.

The β transition probability to the 44-keV level has been deduced from the 44-keV level intensity balance using P($\gamma_{1,0}$ +ce)(44,07-keV) obtained from the intensity balance for the ground state (see 2.2)

Table 2. ^{238}Pu levels populated in the ^{238}Np β^--decay

Level number	Level Energy, keV	Spin and parity	Half-life	Probability of β^--transition (%)
0	0,0	0^+	87,74 (3) a	-
1	44,08 (2)	2^+	177 (5) ps	41,0 (25)
2	145,95 (2)	4^+		-
3	303,38 (6)	6^+		-
4	605,14 (4)	1^-		0,103 (3)
5	661,40 (6)	3^-		0,036 (3)
6	763,24 (11)	5^-		-
7	941,46 (8)	0^+		-
8	962,78 (2)	1^-		1,25 (1)
9	968,2 (4)	(2^-)		0,082 (6)
10	983,09 (7)	2^+		0,27 (3)
11	985,45 (5)	2^-		0,49 (1)
12	1028,54 (2)	2^+		44,75 (19)
13	1069,94 (2)	3^+		11,50 (7)
14	1082,56 (6)	$(4)^-$		-
15	1202,46 (8)	$(3)^-$		0,51 (6)

Table 3. Measured and evaluated β^- energies (keV) and probabilities (%) in the ^{238}Np decay

1955Ra28		1956Ba95	1962Bo03		**Evaluated**	
Eb$^-$	**P**b$^-$	**P**b$^-$	**E**b$^-$	**P**b$^-$	**E**b$^-$	**P**b$^-$
			200	8	221,6 (4)	11,50 (7)
			250 (10)	31		
258	53	55			263,0 (4)	44,75 (19)
			280 (10)	20		
			1133	2,8		
1272	47	45	1236 (5)	38	1247,4 (4)	41,0 (25)

2.2. Gamma Transitions and Internal Conversion Coefficients

The evaluated energies of gamma-ray transitions are essentially the same as the gamma-ray energies because nuclear recoil is negligible.

The P(γ+ce) values have been calculated from the gamma-ray emission probabilities and the total internal conversion coefficients (ICC's).

For E0- gamma transition 941,5-keV ($\gamma_{7,0}$) the value P(ce) = 0,0106 (9) is based on measurements P(ceK) of 1981Le15 and ICC ratios from the BrIcc package.

The experimental values of ICC's (from 1981Le15) have been adopted for the following gamma-ray transitions: 120,11-keV ($\gamma_{15,14}$), 220,9-keV ($\gamma_{-1,6}$), 923,9-keV ($\gamma_{13,2}$), (E0+E2) gamma-ray transition 939-keV ($\gamma_{10,1}$) (see also 1960Al29), 983,0-keV ($\gamma_{10,0}$) and 984,5-keV ($\gamma_{12,1}$). ICC's have been interpolated from the BrIcc package. The relative uncertainties of α_K, α_L, α_M, α_T for pure multipolarities have been taken as 2 %. The multipolarities and E2/M1, M2/E1 mixing ratios have been taken from 2002Ch52. These are based on

conversion electron measurements of 1952Du12, 1956Ba95, 1956Sm18, 1960As10, and 1965Ak02.

P($\gamma_{1,0}$ +ce)(44,08-keV) has been deduced from the intensity balance for the ground state assuming that there is no beta-feeding to the ''0''-level. The second forbidden beta-transition is expected to the ground state with lg *ft* > 15 which implies < 0,01 % (2006Re09).

3. Atomic Data

3.1. Fluorescence yields

Fluorescence yield data are from 1996Sc06 (Schönfeld and Janßen).

3.1.1. X rays

The Pu KX-ray relative emission probabilities have been taken from 1999ScZX

3.1.2. Auger Electrons

The energies of Auger electrons have been calculated from atomic electron binding energies.
The P(KLX)/P(KLL), P(KXY)/P(KLL) ratios have been taken from 1996Sc06.

5. Electron Emissions

The energies of the conversion electrons have been calculated from the gamma transition energies and the electron binding energies.

The emission probabilities of the conversion electrons have been calculated using evaluated P_γ and ICC values.

The 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.

6. Photon emissions

6.1. X-Ray Emissions

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

Table 4. Measured and evaluated probabilities of Pu KX in the decay of ^{238}Np.

	1972Wi22	1981Le15	Evaluated
$K\alpha_2$	0,18(1)		0,210 (8)
$K\alpha_1$	0,272(12)		0,332 (12)
$K\beta'_1$		0,11	0,122 (5)
$K\beta'_2$		0,050	0,042 (2)

6.2. Gamma Emissions

The gamma ray energies have been evaluated from experimental data (Table 3)

Table 5. The measured and recommended gamma ray energies in the ^{238}Np β^--decay (keV).

1970Lederer	1972Wi22	1981Le15	2006Re09	Recommended
44	44,08 (3)		44,06 (2)	44,07 (2)
101,93 (4)	101,88 (2)		101,88 (3)	101,88 (2)
			103,74 (2)	103,74 (2)
			116,27 (8)	116,27 (8)
			117,27 (8)	117,27 (8)
119,9 (1)	120,14 (5)		120,09 (5)	120,11 (5)
			120,5	120,5
			120,70 (8)	120,70 (8)
			121,70 (8)	121,70 (8)
132,49 (11)	132,6 (6)		132, 8 (5)	132,5 (1)
157,4 (3)		157,42 (5)	157,42	157,42 (5)
173,78 (11)	174,06 (8)		174,08 (5)	174,08 (5)
220,87 (11)			220,87	220,87 (11)
301,19 (12)	301,81 (19)		301,37 (7)	301,37 (7)
319,29 (11)			319,96 (20)	319,29 (11)
321,75 (20)			321,75	321,75 (20)
323,98 (9)	324,08 (17)		324,07 (15)	324,02 (9)
357,60 (9)	357,64 (7)		357,68 (9)	357,64 (7)
378,05 (13)			378,0 (10)	378,05 (13)
380,28 (13)	380,33 (22)		380,33 (10)	380,31 (10)
421,15 (11)	421,12 (16)		421,05 (10)	421,10 (10)
459,8 (2)		459,80 (22)	459,8 (2)	459,8 (2)
515,58 (12)	515,47 (17)	515,25 (19)	515,53 (7)	515,51 (7)
561,09 (10)	561,15 (7)	561,02 (10)	561,17 (5)	561,14 (5)
605,24 (13)	605,14 (9)	605,04 (10)	605,18 (5)	605,16 (5)
617,45 (12)	617,39 (11)	617,22 (12)	617,41 (5)	617,39 (5)
837,18 (15)	837,0 (4)	837,01 (15)	836,88 (7)	836,96 (7)
882,65 (7)	882,63 (3)		882,63 (3)	882,63 (3)
897,28 (20)		897,33 (10)	897,55 (30)	897,34 (10)
918,70 (7)	918,69 (4)	918,7 (2)	918,70 (4)	918,70 (4)
923,99 (6)	923,98 (2)		923,99 (2)	923,99 (2)
936,57 (9)	936,61 (6)		936,60 (5)	936,60 (5)
939,00 (10)	938,6 (5)	938,91 (10)	938,85 (30)	938,94 (10)
941,39 (6)	941,38 (5)		941,41 (4)	941,40 (4)
941,5 (3)				941,5 (3)
962,80 (7)	962,77 (3)	962,8 (2)	962,76 (2)	962,76 (2)
984,46 (7)	984,45 (2)	984,5 (1)	984,45	984,45 (2)
1025,87 (6)	1025,87 (2)		1025,87 (2)	1025,87 (2)
1028,54 (6)	1028,54 (2)	1028,5 (2)	1028,53 (2)	1028,54 (2)

The absolute emission probabilities for gamma-rays have been deduced from the evaluated relative intensities (see Table 6) using the weighted mean $P(\gamma_{12,1})$(984,5-keV) = 0,2518 (13) of the two absolute measurement results: 0,2517 (13) from 2006Re09 and 0,2519 (21) from 1990Ch15.

It should be noted that in 1981Le15 the differing absolute value of $P(\gamma_{12,1})$(984,5-keV) = 0,278 (8) was deduced from an intensity balance for the ground state of ^{238}Pu.

Using the value of 0,397 (6) from 2006Re09 for the relative gamma ray intensity of $\gamma_{1,0}$ (44,07-keV) and the evaluated relative intensities for the remaining gamma-rays from Table 4, we obtain from the ground state intensity balance the value of $P(\gamma_{12,1})$(984,5-keV) = 0,257 (6) which supports our above more exact value and disagree with 1981Le15.

The absolute gamma ray intensity for $\gamma_{1,0}$ (44,07-keV) has been deduced from the evaluated $P(\gamma_{1,0}$ + c.e.)(44.07 keV) and the adopted total ICC.

The absolute gamma ray intensities for $\gamma_{5,1}$ (617,36-keV) and $\gamma_{6,2}$ (617,36-keV) have been deduced using the

ratio P($\gamma_{5,1}$)(617,36-keV) /P($\gamma_{6,2}$)(617,36-keV) = 65/9 adopted from 1981Le15.

The relative gamma ray intensity (P'(γ)) and energy for $\gamma_{9,4}$ (924-keV) have been adopted from 1970Be57.

The recommended P'(γ) for $\gamma_{1,0}$ (44,07-keV) has been obtained as a ratio of the evaluated P($\gamma_{1,0}$)(44,07-keV) to P($\gamma_{12,1}$)(984,5-keV) and it has also been compared to measured values.

Table 6. Measured and evaluated relative gamma-ray intensities.

Energy (keV)	1972Wi22	1981Le15*	1990Ch35	2006Re09	Recommended
44,07	≈0,2	0,32 (4) [a]	0,35 (4)	0,397 (6)	0,406 (9)
99,53				0,771 (8)	0,771 (8)
101,9	0,88 (2)	0,97 (4)	1,01 (3)	1,01 (1)	1,00 (3)
103,7				1,24 (1)	1,24 (1)
116,3				0,158	0,158
117,3				0,295	0,295
120,1	0,41 (2)	0,37 (3)		0,453 (9)	0,40 (2)
120,5				0,079	0,079
120,7					
121,7				0,040 (4)	0,040 (4)
132,5	0,013 (7)	0,0101 (7)		0,0056 (3)	0,0056 (3)
157,4		≈0,004			≈0,004
174,0	0,11 (1)	0,094 (4)	0,091 (3)	0,088 (6)	0,091 (3)
220,9		0,0122 (14)		0,007 (6)	0,012 (2)
301,4	0,05 (1)	0,043 (4)	0,040 (4)	0,054 (11)	0,042 (4)
319,3		0,032 (4)		0,038 (12)	0,033 (4)
321,8		0,0047 (22)		0,008 (8)	0,005 (2)
324,0	0,070 (11)	0,058 (4)	0,057 (3)	0,061 (10)	0,058 (3)
336,4					0,0009 (5)
357,6	0,22 (2)	0,191 (11)	0,200 (5)	0,20 (1)	0,200 (5)
378,0		0,012 (2)		0,008 (8)	0,012 (2)
380,3	0,05 (1)	0,043 (2)		0,064 (12)	0,044 (2)
421,1	0,096 (15)	0,083 (4)	0,087 (4)	0,079 (12)	0,085 (4)
459,8		≈0,011		0,009 (6)	0,009 (6)
515,5	0,14 (2)	0,155 (7)	0,148 (5)	0,14 (1)	0,150 (5)
561,1	0,43 (2)	0,41 (2)	0,416 (7)	0,461 (16)	0,423 (7)
605,2	0,31 (3)	0,284 (14)	0,318 (9)	0,29 (2)	0,306 (9)
617,39 (5) } 617,4	0,29 (3)	0,266 (14)	0,270 (9)	0,262 (12)	0,268 (9)
837,0	0,076 (22)	0,101 (7)		0,079 (3)	0,082 (3)
882,6	3,19 (16)	3,13 (11)	3,23 (3)	3,17 (2)	3,19 (2)
885,0				0,16 (2)	0,16 (2)
897,3		0,029 (4)	0,029 (4)	0,032 (8)	0,029 (4)
918,7	2,16 (11)	2,12 (7)	2,11 (2)	2,09 (2)	2,10 (2)
923,99	10,4 (5)	10,3 (3)	10,4 (1)	10,32 (6)	10,34 (6)
924					0,26
936,6	1,39 (7)	1,44 (4)	1,46 (2)	1,41 (11)	1,45 (2)
938,9	0,13 (6)	0,10 (3)	0,13 (1)	0,13 (1)	0,13 (1)
941,4	1,91 (10)	1,98 (7)	2,04 (2)	1,97 (2)	2,00 (2)
941,5					
962,8	2,56 (13)	2,52 (7)	2,56 (3)	2,56 (3)	2,56 (3)
968,5	0,06 (2)	-	-	0,004	0,06 (2)
983,0					0,27 (8)
984,4	100	100	100	100	100
1025,9	34,5 (17)	34,9 (22)	34,59 (50)	34,82 (18)	34,79 (18)
1028,5	72,5 (36)	73,0 (29)	72,61 (70)	72,42 (37)	72,47 (37)

* Absolute gamma-ray emission probabilities cited in 1981Le15 (normalized to 27,8 for the 984,5-keV gamma- ray) have been converted to the relative gamma-ray intensities.
[a] Measured value. In 1981Le15 it is noted that the value deduced from an intensity balance is 0,36 (2).

7. References

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