^{211}Po – Comments on Evaluation of Decay Data
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This evaluation was completed in August 2009. The literature available by December 31st, 2008 was included.

1. Evaluation Procedures

The Limitation of Relative Statistical Weight (LWM) 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). 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

^{211}Po decays 100 % by alpha particle emissions, mainly to the ground state of ^{207}Pb. The most recent evaluations of the ^{211}Po nuclear structure and decay data, published in Nuclear Data Sheets, were done by E. Browne (2004) and M.J. Martin (1993). In the present evaluation, the spin, parity and energy of the levels, together with the multipolarities and mixing ratios of the γ-ray transitions, have been adopted from the A=207 ENSDF mass-chain evaluation 1993Ma73.This data evaluation refers only to the decay of the ^{211}Po ground state, and not to the decay of the ^{211}Po metastable state at 1462 keV (with a half-life of 25.2 s).

3. Nuclear Data

The adopted alpha decay energy value Q(α)=7594.48 (51) keV, is from 2003Au03. This value is in very good agreement with the effective Q(α) value of 7594.2 (20) keV, deduced from average radiation energies from the decay scheme data, by using the SAISINUC software, version 2008 April.

3.1. Half-life

In the literature, five measured ^{211}Po half-life ($T_{1/2}$) values are reported. The value from 1931Cu01 is unrealistically low (in strong disagreement with all the other values), and was excluded from the data set, according to the Chauvenet's criterion implemented by the LWEIGHT computer code. The half-life values and their uncertainties are presented in Table 1. The value recommended by Curie et al. (1931), with an estimated uncertainty added by the evaluator, has been also included. The set of data, excluding the value given in 1931Cu01 is consistent and the recommended half-life value, 0.516 (3) s, is the weighted average (LWM, χ^2_ν=3.7) of the four input values. The reference *Nuclear Science References* (NSR) keynumbers are:

Table 1 : ^{211}Po Half-life values

$T_{1/2}$ (seconds)	Uncertainty of $T_{1/2}$ (seconds)	Reference
0.005	0.005	1931Cu01
0.52	0.02	1954Sp32
0.5	0.1	1954Wi26
0.56	0.04	1958To25
0.516	0.003	1974Ba29

3.2. Alpha transitions and emissions

The most important reference in the literature that studies measurements of alpha-particle energies and emission intensities for ^{211}Po alpha transitions is 1991Ry01.

For this evaluation, three adopted alpha-particle energies were deduced as weighted means of the experimental values presented in Table 2; the complete data set of the main alpha-particle group (7450.2 keV) is consistent, while from the other two data sets, the values from 1953AsZZ were rejected from the weighted mean computations, according to Chauvenet's criterion. The hindrance factors were determined by using the ALPHAD version 2.0a (2006) computer program (developed at BNL/NNDC, USA).

Table 2: Energy of the alpha-particles emitted in the ^{211}Po decay

Alpha-particle group	Energy of the alpha particles (experimental), keV	Reference
$\alpha_{0,2}$	6570 (10)	Leininger et al. (1951)
	6570 (40)	1951Ne02
	6560 (10)	1953AsZZ
	6569 (20)	1953Ho49
	6571 (4)	1968GuZX
	6570.0 (25)	1969Go23
	6568 (1)	1978Ya04
	Recommended energy value: 6568.4 (10) keV	
$\alpha_{0,1}$	6900 (10)	Leininger et al. (1951)
	6900 (40)	1951Ne02
	6880 (10)	1953AsZZ
	6895 (20)	1953Ho49
	6890.7 (25)	1962Wa18
	6891 (4)	1968GuZX
	6892.5 (25)	1969Go23
	6891 (1)	1978Ya04
	Recommended energy value: 6891.2 (10) keV	
$\alpha_{0,0}$	7430 (40)	1951Ne02
	7430 (20)	1953Ho49
	7442 (15)	1954Br07
	7450.3 (2)	1962Wa18, updated in 1991Ry01
	7440 (30)	1963Jo09
	7448 (4)	1968GuZX
	7449.8 (30)	1969Go23, updated in 1991Ry01
	7460 (20)	1969Ha32
	7448 (10)	1970Va13
	7443.3 (20)	1982Bo04, updated in 1991Ry01
	7456.2 (30)	1985La17, updated in 1991Ry01
	Recommended energy value: 7450.2 (3) keV	

The reference 1951Ne02 is the only one that reports the detection of another group of alpha particles emitted in the decay of ^{211}Po, with an energy of 6340 (60) keV and an emission probability of $7 \cdot 10^{-4}$. In the report UCRL-2325 (1953), R.W. Hoff doesn't confirm the detection of this alpha-particle decay branch, but establishes that there are no alpha-particle groups with emission probabilities higher than $2 \cdot 10^{-4}$, in the energy range from 6.26 MeV to 6.57 MeV. In a similar study presented in 1969Go23, a maximum limit of $2 \cdot 10^{-5}$ is given for the emission probability of any alpha-particle group in the energy range (5.88 to 6.43) MeV. As there is no other experimental data to confirm the existence of this branch, the evaluator adopted a decay scheme with only the three alpha particle groups given in Table 2.

The recommended emission probabilities of the alpha-particle emissions of 6568.4 keV and 6891.2 keV are the weighted means of the published experimental values, presented in

Table 3. From the first data set in this table, the values of 1978Ya04 (0.58 (1) %) and 1951Ne02 (0.48 (5) %) were rejected by the Chauvenet's criterion. A similar procedure, applied to the second data set from Table 3, lead to the rejection of the value published in the reference 1962Wa18 (0.70 (14) %).

The adopted emission probability of the main alpha-particle emission, 7450.2 keV, was computed from the normalization condition (the sum of the three alpha-particle emission probabilities is 100 %): 98.936 (19) %.

Table 3: Emission probabilities of the alpha-particles emitted in the ^{211}Po decay

Alpha-particles energy (keV)	Experimental emission probability (%)	Reference
6568.4	0.5 (1)	Leininger et al. (1951)
	0.48 (5)	1951Ne02
	0.53 (1)	1953AsZZ
	0.53 (5)	1953Ho49
	0.53 (3)	1968GuZX
	0.537 (19)	1975Ja04
	0.58 (1)	1978Ya04
	0.513 (9)	1985La17
	Recommended emission probability: 0.523 (9) %; HF=17.9	
6891.2	0.6 (1)	Leininger et al. (1951)
	0.57 (5)	1951Ne02
	0.50 (1)	1953AsZZ
	0.50 (5)	1953Ho49
	0.70 (14)	1962Wa18
	0.57 (3)	1968GuZX
	0.546 (19)	1975Ja04
	0.60 (1)	1978Ya04
	0.524 (9)	1985La17
	Recommended emission probability: 0.541 (17) %; HF=272	
7450.2	**Recommended emission probability: 98.936 (19) %; HF=112**	

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

There are only few papers that report measurements of the γ-ray energies and emission probabilities following the ^{211}Po decay: 1954Mi70 and 1975Ja04 (energy values), 1968Br17 and 1985La17 (absolute emission probabilities), respectively. 1975Ja04 and 1972As11 report relative emission probabilities.

The adopted gamma-ray energy values are the weighted means of the experimental values published in 1954Mi70 and 1975Ja04, as presented below in Table 4 (for the 328 keV photons just one measurement was made, and published in 1975Ja04):

Table 4: Gamma-rays energy values in the decay of ^{211}Po

Experimental energy values (keV)	Reference
562 (5)	1954Mi70
569.65 (10)	1975Ja04
Recommended energy value: 569.65 (15) keV	
880 (8)	1954Mi70
897.8 (1)	1975Ja04
Recommended energy value: 897.8 (2) keV	
328.2 (2)	1975Ja04
Recommended energy value: 328.2 (2) keV	

Using the measured 328.2 keV gamma-ray relative photon intensity of 0.6 (2) (the intensity of the 569.65 keV photons is considered as 100, see reference 1975Ja04), the internal conversion coefficients and the intensity balance for each of the two excited states of ^{207}Pb, the corresponding absolute gamma-ray emission probabilities and their uncertainties were computed for all the three γ rays; these data are given below in Table 5. A comparison between the evaluated data and the experimental values (included in the same table, with the corresponding references) shows a good agreement, with the exception of the relative emission probability of 897.8 keV reported by 1985La17.

The internal conversion coefficients were computed with the program BrIcc, version 2.2b/20-Jan-2009, using the "Frozen Orbitals" approximation. In the article of L.J. Jardine (1975), an experimental value of 0.016 (3) was determined for the K-conversion coefficient associated to both gamma-ray transitions of 569.65 keV and 897.8 keV; this value is in good agreement with the theoretical ICC's, computed with BrIcc: 0.01583 (23), respectively 0.0192 (3).

Table 5: γ-rays absolute and relative emission probabilities in the decay of ^{211}Po

E_γ (keV)	Recommended Absolute Emission Probability (%)	Experimental Absolute Emission Probability (%)	Evaluated relative emission probabilities	Experimental relative emission probabilities	Total ICC (α_T)
328.2	0.0032 (11)		0.6 (2)*	0.6 (2)[c]	0.334 (5)
569.65	0.534 (17)	0.534 (19)[a] 0.512 (36)[b]	100	100.0 (14)[b] 100[c,d]	0.0216 (3) E2
897.8	0.507 (9)	0.535 (40)[b]	94.9 (35)	104.4 (20)[b] 97 (5)[c] 83 (11)[d]	0.0233 (4) M1

Note: a – reference 1968Br17; b – reference 1985La17; c – reference 1975Ja04;
d – reference 1972As11 (renormalized); * - value adopted from reference 1975Ja04.

4. Atomic data

The K-shell fluorescence yield (ω_K), the mean L-shell fluorescence yield (ϖ_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 v.3.10, 28-Jan-2003: 0.963 (4), 0.379 (15) and 0.811 (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 EMISSION computer program. The total numbers of K and L Auger electrons emitted per 100 disintegrations were also calculated as 0.00071 (8) and 0.01216 (17), respectively. The energy ranges for K and L Auger electrons were filled-in by the SAISINUC program, version 2008 April.

The relative probability (normalized to $K_{\alpha 1}$ X-rays emission) and the absolute emission probability values of the different groups of K and L X-rays were deduced using the EMISSION program. The adopted values of the total absolute emission probability of the KX-rays and LX-rays were 0.0184 (5) % and 0.00740 (16) %, respectively. The energy range values of the K and L X-rays are from the tables linked to SAISINUC.

Neither measurement of ^{207}Pb KX-rays and LX-rays energies nor of emission probabilities was found in the literature in order to compare it with the results of this evaluation.

5. Main production mode

The main production mode of ^{211}Po is by β^- decay of the ^{211}Bi nuclei (in the Actinium-Uranium natural radioactive series).

6. References

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