^{209}Po - Comments on evaluation of decay data by V. Chisté and M. M. Bé

This evaluation was completed in December 2009. The literature available by September 2009 was included.

1 Decay Scheme

^{209}Po disintegrates by alpha emission to excited levels and to the ground state level of ^{205}Pb and by electron capture to the 896-keV excited level of ^{209}Bi.

A good agreement was found between the adopted Q_α and Q_{EC} values from Audi (2003Au03) and the effective Q values, Q_α (4957 (2) keV) and Q_{EC} (1891 (20) keV), calculated from the decay scheme data (and branching ratio).

2 Nuclear Data

The Q values are from the atomic mass evaluation of Audi *et al.* (2003Au03).

Experimental ^{209}Po half-life values (in years) are given in Table 1.

Table 1: Experimental values of ^{209}Po half-life.

Reference	Experimental value (a)	Comments
C. G. Andre (1956An05)	102 (5)	From ^{209}Po/^{208}Po mass and activity ratios and $T_{1/2}(^{208}Po)$ = 2.898 (2) a (see 1991Ma16).
R. Collé (2007Co07)	128 (7)	Decay data from two separate primary standardizations of a ^{209}Po solution standard, carried out ~ 12 years apart.
Recommended value	115 (13)	χ^2 = 6.9

The value from 2007Co07 is not a direct measurement of the ^{209}Po half-life. R. Collé said in a private communication: "My paper which stated the value **128 a** was not a new determination…The whole point was to show that there was evidence to suggest and support that the extant **102 a** value is very wrong, perhaps by 25 %".
However, to take into account all scarce information available, the evaluators have chosen to adopt the simple mean of the two existing values (1956An05 and 2007Co07) with an uncertainty covering them. Then, the recommended value is 115 (13) a.

2.1 α Transitions and Emissions

The energies of the α-particle transitions given in Section 2.1 have been obtained from the Q_α (2003Au03) and the ^{205}Pb level energies from F. G. Kondev (2004Ko28), given in Table 2.

Table 2: ^{205}Pb levels populated in the ^{209}Po α-decay.

Level number	Energy (keV)	Spin and parity	Half-life	Probability of α transition (%)
0	0.0	$5/2^-$	17.3 (7) 10^6 a	19.8 (32)
1	2.329 (7)	$1/2^-$	24.2 (4) µs	79.2 (32)
2	262.833 (25)	$3/2^-$		0.548 (7)

The energies of the $\alpha_{0,0}$, $\alpha_{0,1}$ and $\alpha_{0,2}$ emissions given in Section 4 are from A. M. Mandal (1989Ma05). In 1989Ma05, two weak alpha transitions of 4310 and 4110 keV respectively, were reported. These alpha transitions were not reported here by the evaluators, because other authors have doubts about their existence (1996Sc24, 2004Ko28).

The transition intensity of the $\alpha_{0,2}$ transition has been deduced from the P(γ + ce) decay scheme balance. For the ($\alpha_{0,0}$ + $\alpha_{0,1}$), an unresolved doublet, the evaluators decided to follow the explanation given by V. Chechev (private communication and based on the Schmorak article (1980Sc26)):
"Schmorak found, for odd-A nuclides, that all known cases of hindrance factors (HF) for $p_{1/2}$ to $p_{1/2}$ favoured alpha transitions are grouped around HF = 1.3. For the Po-209 alpha transition to the 2.3 keV excited level (1/2-) in Pb-205, this allows us to adopt HF=1.3. From HF=1.3, alpha intensity is derived being approximately 80 %.
Then, for $p_{1/2}$ to $f_{5/2}$ alpha transitions, which interest us, i.e. the Po-209 alpha transition to the 5/2- ground state of Pb-205, the HF (= 6) is deduced from known (measured) HF for such alpha transitions (Rn-211 to Po-207: 6.75; Ra-213 to Rn-209: 6.39; Th-215 to Ra-211: 6.5) and then, an alpha intensity of approximately 20 % is derived.
Therefore, a ratio of 80/20 (1980Sc26) can be derived from HF systematic and analysis of level characteristics."

Then the total alpha transition intensity was deduced from the P($\alpha_{0,2}$) (= 0.548 (7) %) and P_{EC} (= 0.454 (7) %):

$P(\alpha_{0,0} + \alpha_{0,1}) = 100 - P_{EC} - P(\alpha_{0,2}) = 98.998\ (10)$ %.

With this value of P($\alpha_{0,0}$ + $\alpha_{0,1}$), using the estimation P($\alpha_{0,1}$)/ P($\alpha_{0,0}$) = 80/20 and accepting a relative uncertainty equal to approximately 20 %, the evaluators have obtained the individual values:

P($\alpha_{0,1}$) = 79.2 (32) %
P($\alpha_{0,0}$) = 19.8 (32) %

2.2 Electron Capture Transition

The energy of the electron capture transition has been obtained from the Q(EC) value (2003Au03) and the ^{209}Bi level energy of 896.29 (5) keV given by M. J. Martin (1991Ma16).

The electron capture probability (P_{EC} = 0.454 (7) %) has been deduced from gamma-ray transition intensity imbalance at the 896-keV level.

P_K, P_L, P_M values have been calculated for 2nd forbidden unique electron-capture transition in the decay of ^{209}Po to the excited state in ^{209}Bi using the LOGFT computer program.

2.3 γ Transitions

The gamma-ray transition with energy of 2.328 (7) keV has not been observed directly in the ^{209}Po decay but it was studied in the decay of ^{209}Bi to ^{205}Pb (1971Jo06). The transition probability for this gamma-ray has been obtained from the intensity balance at the ^{205}Pb 2.3-keV level.

The transitions probabilities values for the remaining gamma-rays have been deduced using the γ-ray emission probabilities and the relevant internal conversion coefficients (see **4.2 Gamma Emissions**).

For the three (M1 + E2) γ transitions (^{205}Pb: 260- and 262-keV; ^{209}Bi: 896-keV), the mixing ratios (δ) were deduced by comparison between experimental values of K internal conversion coefficients and the theoretical K ICC calculated using the BrIcc computer code (2008Ki07).

Table 3 shows the experimental and evaluated values of α_K, as well as the deduced mixing ratios.

Table 3: Experimental and evaluated internal conversion coefficients and mixing ratios.

Energy (keV) Reference	260	262	896
G. R. Hagee (1966Ha29)	0.495 (10)	0.495 (10)	0.0170 (5)
A. M. Mandal (1989Ma05)	0.49 (5)	0.49 (5)	
F. Schima (1996Sc24)	0.538 (20)	0.524 (20)	
Evaluated α_K	0.503 (12)	0.500 (9)	0.0170 (5)
χ^2	1.9	0.9	-
δ (mixing ratio)	0.16 (6)	0.05 (7)	-0.62 (4)
α_K theoretical (BRICC)	0.503 (12)	0.500 (9)	0.0170 (5)
α_T theoretical (BRICC)	0.617 (13)	0.612 (10)	0.0208 (6)

The theoretical internal conversion coefficients (ICCs) and the associated uncertainties given in Table 3 have been obtained using the BrIcc computer code with “the frozen orbital approximation” (2008Ki07).

3 Atomic Data

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

4 Emissions

4.1 K x-rays

The X-ray absolute emission probabilities have been calculated from the decay scheme data using the EMISSION computer program and compared in Table 4 with the measured values. These values are in a slight agreement; it is difficult to draw a definite conclusion because there is an unresolved doublet, the Bi $K_{\alpha 2}$ – Pb $K_{\alpha 1}$ at 74.89 keV, which is difficult to separate in the spectrum analysis.

Table 4: Experimental and recommended (calculated) values of K_α X-ray absolute emission probabilities.

	F. Schima (1996Sc24)	Recommended values
Bi K_α X-ray (74.82 – 77.11 keV)	0.202 (5)	0.248 (3)
Pb K_α X-ray (72.80 – 74.97 keV)	0.136 (5)	0.128 (2)

4.2 Gamma emissions

The energies of the γ-rays given in section 6.2 are from F. G. Kondev (2004Ko28).
The experimental and recommended values of γ-ray emission probabilities are given in Table 5.

Table 5: Experimental and recommended values of γ-ray emission probabilities.

E_γ (keV)	G. R. Hagee (1966Ha29)[a]	A. M. Mandal (1989Ma05)[b]	F. Schima (1996Sc24)	Recommended values.
260.5 (1)	0.391	100	0.254 (3)	0.254 (3)
262.8 (1)	0.391	33.3 (16)	0.085 (2)	0.085 (2)
896.6 (1)	0.263	108.1 (75)	0.445 (7)	0.445 (7)

[a] G. R. Hagee was unable to resolve the 260.5- and 262.8-keV γ-ray doublet and the values are given without uncertainties. Not used.
[b] A. M. Mandal quoted relative intensities normalized to the 260.5-keV γ-ray.

The Mandal values (1989Ma05) were omitted from analysis because of a lack of information in the article

about the experimental measurements carried out and, therefore on the results. Then, the adopted values of the absolute emission intensities are the most recent values of F. J. Schima (1996Sc24).

5 Electron emissions

The conversion electron emission probabilities have been deduced from ICC values and γ-ray emission probabilities.

6 References

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