^{210}Bi - Comments on evaluation of decay data by V. Chisté and M.-M. Bé Updated by M.A. Kellett

The original evaluation was completed in 2008. An update has been made in November 2014 with a literature cut-off date of October 2014.

1 Decay Scheme

^{210}Bi disintegrates by beta minus emission to the ground state level of ^{210}Po. Weak alpha transitions to excited levels of ^{206}Tl have been observed (1.40 (15) 10^{-4} %). Spins and parities are from the ENSDF mass-chain evaluation of Browne for A = 210 (2003Br13). For ^{206}Tl, spins and parities are from the mass chain evaluation of Kondev (2008Ko21).

2 Nuclear Data

The Q value is from the atomic mass evaluation of Wang *et al.* (2012Wa38).

Experimental ^{210}Bi half-life values (in days) are given in Table 1:

Table 1: Experimental values of the ^{210}Bi half-life.

Reference	Experimental value (d)	Comments
G.N. Antonoff (1910An**)	5.0	
L. Meitner (1911Me**)	5.0	
R. Thaller (1912Th**)	4.85	
L. Bastings (1924Ba**)	4.98	
G. Fournier (1925Fo**)	4.85	Ionization chamber – no uncertainty given.
J.P. McHutchison (1926Mc**)	4.89 (2)	Electroscope. Simple mean of 3 values, with uncertainty of 1/300 as given in paper.
L.F. Curtiss (1926Cu**)	5.07 (5)	Beta-ray electroscope. Superseded by 1927Cu**
L.F. Curtiss (1927Cu**)	4.98 (2)	Beta-ray electroscope. Simple mean of 3 values, uncertainty quoted as ~1/300.
M. Curie (1931Cu01)	5.0 (1)	Recommended value, hence not used.
A. Pompéi (1935Po01)	5.02 (1)	Ionization chamber.
N. Hole (1944Ho**)	5.15 (10)	GM counter.
F. Begemann (1952Be22)	5.02 (2)	GM counter.
E.E. Lockett (1953Lo09)	4.989 (13)	Ionization chamber.
J. Robert (1956Ro18)	5.013 (5)	Ionization chamber. Superseded by 1959Ro51
J. Robert (1959Ro51)	5.013 (5)	Ionization chamber.
Recommended value	**5.011 (5)**	χ^2 = 1.61, χ^2_{crit} = 3.32

The weighted average has been calculated using the LWEIGHT computer program (version 3).

The evaluators have chosen to use the seven experimental values with uncertainties given in Table 1. The values of McHutchison (1926Mc**) and Hole (1944Ho**) have been rejected by the LWEIGHT program based on Chauvenet's criterion. With the remaining data set of five values, the largest contribution to the weighted mean comes from the value of Robert (1959Ro51) amounting to 66 % of the total statistical weight.

The recommended value of the ^{210}Bi half-life is thus the weighted mean of **5.011 d** with an external uncertainty of **0.005 d**. The reduced-χ^2 value is 1.61, compared to χ^2_{crit} = 3.32.

Half-life of ^{210}Po
The half-life of ^{210}Po, 138.3763 (17) d, has been taken from the DDEP evaluation of Chisté and Bé (in Bé *et al.* 2008).

Half-life of ^{206}Tl
The half-life of ^{206}Tl, 4.202 (11) min, has been taken from the latest DDEP evaluation of Kondev (in Bé *et al.* 2008).

2.1 α Transitions and Emissions

The recommended values of the emission energies of the α-particles (Table 2) are taken from the recommendations of Rytz (1991Ry01), which are based on an adjusted mean value from the measured values of 1960Wa14 and 1969La18.

Table 2: Experimental values of emission energies of the α-particles.

Reference	$\alpha_{0,1}$ (keV)	$\alpha_{0,2}$ (keV)	Comments
R.J. Walen (1960Wa14)	4686 (2)	4649 (2)	Uncertainty as given by Rytz.
P. Kauranen (1962Ka27)	4700	4660	Not used: no uncertainty.
R.C. Lange (1969La18)	4697 (5)	4660 (5)	Uncertainty as given by Rytz.
Recommended value (1991Ry01)	**4687 (4)**	**4650 (4)**	χ^2 = 4.2, χ^2_{crit} =6.6

Several experimental values of the α branching to ^{206}Tl are given in Table 3.

Table 3: Experimental and recommended values of total α branching for ^{210}Bi → ^{206}Tl.

Reference	Experimental value (10^{-4} %)	Comments
E. Broda (1947Br36)	0.5	Not used: no uncertainty.
R.J. Walen(1959Wa05)	1.25	Not used: no uncertainty.
R.W. Fink (1956Fi09)	1.7 (2)	
M. Nurmia (1961Nu01)	1.9 (4)	Superseded by 1962Ka27
P. Kauranen (1962Ka27)	1.32 (10)	
Recommended value	**1.40 (15)**	χ^2 = 2.9, χ^2_{crit} =6.6

The weighted average has been calculated using the LWEIGHT computer program (version 3).

The value given by Nurmia (1961Nu01) is from the same laboratory as Kauranen (1962Ka27), thus, it was not included in the averaging procedure. Then, the recommended alpha transition branching is the average of the values given by Fink (1956Fi09) and Kauranen (1962Ka27).

The recommended value of α transitions to the excited levels of ^{206}Tl is thus **1.40 × 10^{-4} %** with an external uncertainty of **0.15 × 10^{-4} %**. The reduced-χ^2 value is 2.9.

The individual α particle probabilities to the 265-keV and 304-keV levels are the renormalized values of Walen and Bastin-Scoffier (1959Wa05, 1960Wa14) to the recommended total transition probability of 1.40 × 10^{-4} % to give **0.56 (6) × 10^{-4} %** (40 (4) %) to the 2^- 266 keV level and **0.84 (9) × 10^{-4} %** (60 (4) %) to the 1^- 305 keV level, respectively.

2.2 β⁻ Transitions and Emissions

The end-point energy of the β^- transition in the decay of ^{210}Bi → ^{210}Po is from the $Q_{\beta-}$ (2012Wa38), which is an adjusted mean of the two values from Daniel (1962Da03) and Hsue (1967Hs01). The recommended and experimental values are shown in Table 4.

For the $\beta_{0,0}$ transition probability and associated uncertainty, the following relation was applied:

$P_{\beta0,0}$ = 100 % - P_{α},

where P_{α} = 1.40 (15) 10^{-4} % (see 2.1 α Transitions and Emissions). Hence, $P_{\beta0,0}$ = 99.99986 (2) %.

The lg ft value was calculated with the program LOGFT (assuming an allowed transition) whereas the average β^{-} energy was calculated for a 1st forbidden transition using the experimentally determined shape factors of Grau Carles (2005Gr41) using the BETASHAPE code of Mougeot (2010MoZU).

Table 4: Experimental and recommended values of the end-point energy of the β^{-} transition.

Reference	$E_{\beta-}$ (keV)
A. Flammersfeld (1939Fl02)	1170
G.J. Neary (1940Ne04)	1170
E.A. Plassmann (1954Pl30)	1155 (5)
H. Daniel (1962Da03)	1160.5 (15)
S.T. Hsue(1967Hs01)	1161.5 (15)
D. Flothmann (1969Fl02)	1153
Recommended value (2012Wa38)	**1161.2 (8)**

2.3 γ Transitions and Emissions

The multipolarity of the γ-ray transitions are from L.I. Rusinov (1961Ru02):

265-keV γ-ray: E2
304-keV γ-ray: M1

The γ-ray transition probabilities following the α-decay of ^{210}Bi → ^{206}Tl were deduced from the decay-scheme balance using the recommended α-particle intensity values given in section 2.1 α Transitions and Emissions, shown in Table 5.

Table 5: Adopted values of α transition and γ-ray emission probabilities.

γ-ray energy (keV)*	α probability (%)	γ-ray absolute transition probability (%)	γ-ray absolute emission probability (%)
265.832 (5)	0.000 056 (6)	0.000 056 (6)	0.000 048 (5)
304.896 (6)	0.000 084 (9)	0.000 084 (9)	0.000 061 (7)

*From 2008Ko21

The γ-ray emission intensities were obtained using the γ-ray transition probabilities (given in Table 6) and the relevant internal conversion coefficients, calculated using the frozen orbital approximation with the BRICC computer code (2008Ki07), which are interpolated from the theoretical values of Band *et al.* (2002Ba85).

3 Atomic Data

Atomic values, ω_K, ϖ_L and n_{KL} are from Schönfeld and Janβen (1996Sc06) as included in the SAISINUC software.

4 References

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