^{210}Pb - Comments on evaluation of decay data by V. Chisté and M. M. Bé

This evaluation was completed in 2007. Literature available by October 2007 has been included.

1 Decay Scheme

^{210}Pb disintegrates by beta minus emission to an excited level and to the ground state level of ^{210}Bi. A weak alpha transition to the ^{206}Hg ground state has been observed (1.9 (4) 10^{-6} %). Spins and parities are from the ENSDF mass-chain evaluations by E. Browne (2003Br13 for A = 210) and R. G. Helmer (1990He18 for A = 206).

The good agreement found between the adopted Q(β^-) value of Audi and the effective Q(β^-) value of 63.9 (11) keV calculated from decay scheme data indicates the completeness and correctness of the decay scheme.

2 Nuclear Data

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

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

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

Reference	Experimental value (a)	Comments
G. N. Antonoff (1910An**)	16.5	Not used. No uncertainty. ZnS counting.
I. Curie (1929Cu**)	23	Not used. No uncertainty. α counting.
M. Curie (1931Cu01)	19.5	Not used. No uncertainty.
F. Wagner (1950Wa**)	25.4 (15)	Ion Chamber.
R. J. Tobailem (1955To14)	19.40 (35)	Ion Chamber.
W. F. Merritt (1957Me47)	22.4 (4)	4π proportional counter.
G. Harbottle (1959Ha20)	20.4 (3)	Ion Chamber.
B. D. Pate (1959Pa03)	23.3 (5)	4π proportional counter.
W. R. Eckelmann (1960Ec01)	21.4 (5)	Geological.
L. Imre (1963Im02)	22.85 (70)	β counting.
H. Ramthun (1964Ra12)	21.96 (51)	Calorimetry.
H. R. von Gunten (1967Vo04)	22.2 (10)	Proportional counter.
A. Höndorf (1969Ho06)	22.26 (11)	α spectrometry.
G. A. Rech (2002Re18)	21.8 (3)	γ spectrometry.
Adopted value	**22.23 (12)**	χ^2 = 1.53

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

The evaluators have chosen to take into account the eleven experimental values with reported uncertainties found in the literature and given in Table 1. The values of Wagner (1950Wa**), Tobailem (1955To14) and Harbottle (1959Ha20) are rejected by the LWEIGHT program, because they are outliers, based on the Chauvenet's criterion. The largest contribution (71 %) to the weighted average comes from the value of Höndorf (1969Ho06).

The adopted value of ^{210}Pb half-life is a weighted average of **22.23 a** and the external uncertainty of **0.12 a**. The reduced-χ^2 value is 1.53.

2.1 α Transitions and Emissions

The transition energy of the α-particles group to the ground of ^{206}Hg given in Section 2.1 is from Q_α (2003Au03).

For the probability of the α transition to the ground state of ^{206}Hg, the available published data are given in Table 2.

Table 2: Experimental and adopted values of the α transition probability to the ground state of ^{206}Hg.

Reference	Experimental value (10^{-6} %)	Comments
M. Nurmia (1961Nu01)	1.8 (5)	Superseded by 1962Ka27
P. Kauranen (1962Ka27)	1.7 (3)	
G. K. Wolf (1964Wo05)	2.7 (6)	
Adopted value	**1.9 (4)**	$\chi^2 = 2.22$

The adopted value of α transition to the ground state of ^{206}Hg is the weighted average, calculated using LWEIGHT computer program, of **1.9 10^{-6} %** with the external uncertainty of **0.4 10^{-6} %**. The reduced-χ^2 value is 2.22.

2.2 β^- Transitions and Emissions

The end-point energies of the β^- transitions in the decay of ^{210}Pb → ^{210}Bi have been obtained from the Q_{β^-} (2003Au03) value and the level energies of R. G. Helmer (1990He18), given in Table 3.

Table 3: ^{210}Bi level populated in the decay of ^{210}Pb.

Level Number	Level energy, (keV)	Spin and parity.
0	0	1^-
1	46.539 (1)	0^-

For these two levels, the adopted β^- transition probabilities and the associated uncertainties were deduced from the γ transition probability balance at each level of the decay scheme, taking into account, also, the α transition probability to the ground state of ^{206}Hg. In the table 4, our adopted values of β^- transitions probabilities are compared with the experimental results found in the literature: C. S. Wu (1953Wu28), J. Tousset (1957To16 and 1958To10), W. Stanners (1956St99) and I. M. Rogachev (1963Ro31). Except to C. S. Wu (1953Wu28), a fair agreement has been found, within the uncertainty limits, between the experimental results and the recommended values for the 17-keV and 63.5-keV β^- transitions.

Table 4: Adopted and experimental values of β^- transition probabilities.

	17-keV β^- transition	63.5-keV β^- transition
C. S. Wu (1953Wu28)	92 (5) %	8 (5) %
J. Tousset (1957To16)		19 (4) %
J. Tousset (1958To10)	81 (14) %	19 (4) %
W. Stanners (1956St99)	84.5 (35) %	15.5 (35) %
I. M. Rogachev (1963Ro31)		≤ 19 (2) %
Adopted value	80.2 (13) %	19.8 (13) %

The values of log ft and average β^- energies have been calculated with the program LOGFT for the 1st forbidden β^- transitions.

2.3 γ Transitions

The 46.5-keV γ-ray transition probability was calculated using the γ-ray emission intensity (see **5.2 γ Emissions**) and the relevant internal conversion coefficient. Multipolarity of this γ-ray transition is M1 (from E. Browne (2003Br13)).

The internal conversion coefficients (ICC) and their associated uncertainties for 46.5-keV γ-ray transition have been calculated using the BrIcc computer program (calculation for 'hole'), which interpolated from theoretical values of I. M. Band (2002Ba85). The α_T value is then 17.86 (25) compared to the previous value of 19.0 (6) from Rösel tables.

3 Atomic Data

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

4 Electron Emissions

The conversion electrons emission probabilities have been deduced using the γ-ray emission intensities and ICC's. The calculated total conversion electrons intensity of 75.2 (10) % is in fair agreement with the measured value of 81 (4) % from W. Stanners (1956St99).

5 Photon Emissions

5.1 X-ray Emissions

The X-ray absolute intensities have been calculated from γ-ray data and ICC using the EMISSION computer program and compared in Table 5 with the measured values found in the literature. For L_l, L_α and L_η x-rays, a good agreement was found between the experimental results given by 1987Me17 and 1990Sc08 and the recommended values deduced from decay scheme balance.

Table 5: Experimental and recommended (calculated) values of L X-ray absolute intensities.

	R. W. Fink (1957Fi06)	R. J. Gehrke (1971Ge11)	D. Metha (1987Me17)[a]	U. Schötzig (1990Sc08)	Recommended Values
L_l			0.584 (18)	0.55 (3)	0.552 (17)
L_α			10.27 (32)	9.48 (17)	10.3 (3)
L_η			0.074 (4)	0.075 (4)	0.075 (2)
L_β			11.6 (4)	10.9 (4)	9.05 (13)
L_γ			2.64 (8)	2.36 (5)	1.97 (3)
L total	23.8 (20)	22.8 (15)	25.2 (3)	23.4 (4)	22.0 (5)

[a] Normalized with I_γ (46.5-keV) = 4.252 (40) % (see **5.2** γ Emissions.)

5.2 γ Emissions

The energy of the γ-ray emission given in Section 5 is from R. G. Helmer (1981He15 and 2000He14).
For the 46.5-keV γ-ray from ^{210}Bi, the experimental data set of absolute γ-ray emission intensity and adopted value in this evaluation are given in Table 6.

Table 6: The experimental data set of the relative γ-ray emission intensity.

Reference	Experimental values (%)	Comments
D. K. Butt (1951Bu37)	3.5 (4)	Not used by the evaluators.
C. S. Wu (1953Wu28)	2.8 (6)	Not used by the evaluators.
P. E. Damon (1954Da23)	3.8 (6)	Not used by the evaluators.
R. W. Fink (1957Fi06)	4.5 (4)	
I. Y. Krause (1958Kr71)	4.05 (8)	Not used by the evaluators.
K. Ya. Gromov (1969Gr33)	4.8 (6)	
K. Debertin (1983De11)	4.18 (9)	Superseded by 1990Sc08.
Y. Hino (1990Hi03)	4.26 (7)	
U. Schötzig (1990Sc08)	4.24 (5)	
Adopted value	4.252 (40)	χ^2 = 0.42

The sets of values from D. K. Butt (1951Bu37), C. S. Wu (1953Wu28) and P. E. Damon (1954Da23) were omitted from analysis due to discrepancy with the other data and a lack of information in the articles about experimental measurements carried out and, therefore on the results.

The original uncertainty given by I. Y. Krause (1958Kr71) (= 0.08) seems under-estimated for the measurement method (NaI spectrometry) then it was decided to omit this value from the analysis.

The adopted value for 46.5-keV γ-ray emission intensity is the weighted average, calculated using LWEIGHT computer program, of **4.252 %** with the internal uncertainty of **0.040 %**. The reduced-χ^2 value is 0.42.

The evaluated absolute 46.5-keV γ-ray emission and transition probabilities are given in Table 7.

Table 7: Recommended absolute 46.5-keV γ-ray emission and transition probabilities.

Energy (keV)	Absolute γ-ray emission probability (%)	Absolute γ-ray transition probability (%)
46.539 (1)	4.252 (40)	80.2 (13)

6 References

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