

²⁰³Pb - Comments on evaluation of decay data by V. Chisté and M. M. Bé

1 Decay Scheme

²⁰³Pb disintegrates by electron capture to ²⁰³Tl via excited levels. Spin and half-life of the 680-keV level are from the mass-chain evaluation of F. G. Kondev (2005Ko20).

2 Nuclear Data

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

Experimental ²⁰³Pb half-life values (in hours) are given in Table 1:

Table 1: Experimental values of ²⁰³Pb half-life.

Reference	Experimental value (h)	Comments
K. Fajans (1941Fa04)	52,0 (5)	
J. R. Prescott (1954Pr04)	52 (1)	
A. A. Barlett (1958Ba04)	52,1 (2)	
L. Persson (1961Pe12)	52,1 (2)	
G. A. Chackett (1971Ch54)	52,02 (10)	Original uncertainty increased (x 2) for missing details (systematic uncertainty).
H. Houtermans (1979Ho17)	51,88 (2)	
D. D. Hoppes (1982HoZJ)	51,92 (4)	Superseded by 2002Un02.
K. Lindenberg (2001Li17)	51,94 (1)	
M. P. Unterweger (2002Un02)	51,923 (37)	
Recommended value	51,929 (10)	$\chi^2 = 1,37$

The evaluators have chosen to take into account the eight values with associated uncertainty for the calculation. The original uncertainty given by Chackett (1971Ch54) has been multiplied by 2, in order to take into account the systematic uncertainties not considered by 1971Ch54. Then a weighted average of the eight values above has been calculated using LWEIGHT computer program (version 3). The largest contribution comes from the value of Lindenberg (2001Li17), amounting to 75 %.

The recommended value is the weighted average of 51,929 h, with an external uncertainty of 0,010 h and a reduced χ^2 of 1,37.

Experimental 279-keV level half-life values (in ps) are given in Table 2.

Table 2: Experimental 279-keV level half-life.

Reference	Experimental value (ps)
R.E. Azuma (1955Az33)	300 (100)
E. E. Berlovich (1957Be57)	290 (30)
E. Bashandy (1960Ba16)	290 (20)
S. Gorodetzky (1960Go15)	283 (17)
B. Johansson (1960Jo15)	220 (30)
E.C. Pederson (1960Pe16)	282 (8)
A. Schwarzschild (1961Sc04)	281 (6)
J. de Boer (1962De14)	340 (3)
R. Rougny (1964Ro19)	283 (7)
J.C. Palathingal (1967Pa09)	280 (40)
Recommended value	282,3 (37)

The half-life weighted average has been calculated by the LWEIGHT program (version 3).

The evaluators have chosen to take into account for the calculation the ten experimental values shown in Table 2. The Azuma (1955Az33), Johansson (1960Jo15) and de Boer (1962De14) values were rejected by the LWEIGHT program, based on the Chauvenet's criterion, thus they were not used for averaging.

The recommended value is the weighted average of 282,3 ps, with an internal uncertainty of 3,7 ps and a reduced χ^2 of 0,05.

2.1 Electron Capture Transitions

The electron capture probabilities have been deduced from gamma-ray transition intensity imbalance for each level of the decay scheme.

P_K , P_L , P_M values have been calculated for 1st forbidden and 1st forbidden unique electron-capture transitions in the decay of ²⁰³Pb to the excited states in ²⁰³Tl using the LOGFT computer program.

2.2 γ Transitions

Probabilities

The absolute transition probabilities have been deduced from the relative γ -ray emission intensities (see **5.2 Gamma ray emission**), the internal conversion coefficients and the normalization of the decay scheme to an absolute radiation intensity scale.

Multipolarity and internal conversion coefficients

Multipolarities of γ -ray transitions in decay of ²⁰³Tl are from 2005Ko20:

279-keV γ -ray : M1 + E2, with $\delta = +1,17$ (6)

401-keV γ -ray : M1 + E2, with $\delta = 0,030$ (3) (1965Ka02)

680-keV γ -ray : E2

The internal conversion coefficients (ICC's) for these γ -ray transitions have been calculated using the BrIcc computer program, which interpolates the new values in 2006Ra03.

For the 279-keV γ -ray, the evaluators have chosen to follow the recommendations of H. H. Hansen (1985HaZA). The 279-keV γ -ray transition is M1(ℓ -forbidden) + E2. It takes place between the $d_{3/2}$ and $s_{1/2}$ shell model proton configurations. Thus nuclear penetration is significant (see 1979Ha21). The forbidness applies only to the M1 component. Therefore, the evaluators have chosen to use experimental values for α . The experimental data set given by 1985HaZA to determine α_T and α_K are included in Tables 3 and 4, respectively.

Table 3: Experimental values of α_T used by 1985HaZA.

Reference	Original value	Revised by Hansen (1985HaZA) and used value.	Comments
1960Pe22	0,227 (8)		Not used.
1962Ta06	0,2262 (19)	0,2273 (24)	The authors revised their values.
1965Ra12	0,210 (30)		Not used.
1965Wa13	0,222 (15)		Not used.
1971WaYL	0,2267 (7) 0,2240 (9)	0,2267 (16)	The author gives 2 results without explaining the reason of the discrepancy. Hansen has chosen the higher one, with the sum of their uncertainties quoted for both results.
1974Ha29	0,2279 (24)	0,2279 (24)	
2000Sc05	0,2250 (12)	0,2250 (12)	

Reference	Original value	Revised by Hansen (1985HaZA) and used value.	Comments
Recommended value		0,2261 (8)	$\chi^2 = 0,60$.

Hansen's study provides, together with three experimental values, an α_T average of 0,2271 (12). The evaluators have included the most recent measurement of 2000Sc05 (0,2250 (12)) in their evaluation and, with four experimental values (1962Ta06, 1972WaYL, 1974Ha29, 2000Sc05), a weighted average has been calculated using the LWEIGHT computer program (version 3). The recommended value is the weighted average of 0,2261, with an internal uncertainty of 0,0008 and a reduced χ^2 of 0,60.

Table 4: Experimental values of α_K and α_L .

Reference	Original value of α_K	Revised by Hansen (1985HaZA) and used value.	Original value of α_L (10^{-2})	Comments
1952He18	0,23 (10)			Not used.
1954Th17	0,154 (15)			Not used.
1954Wa12	0,15 (1) 0,141 (15)			Not used.
1955Do12	0,147 (2)			Not used.
1955Ma40	0,205 (20)			Not used.
1956No26	0,159 (4)			Not used.
1956Of03	0,150 (10)		4,8 (3)	Not used.
1956Wa30	0,164 (5)	0,164 (5)	4,90 (17)	
1956Wo09	0,130 (10)			Not used.
1958Ni28	0,163 (3)	0,163 (3)	4,87 (12)	
1960Pe22	0,163 (6)	0,163 (6)		
1960Ra04	0,195 (14)			Not used.
1960St21	0,160 (15)			Not used.
1961Hu15	0,1750 (36)			Not used.
1961Su10	0,164 (4)	0,164 (4)	4,49 (34)	
1962Ta06	0,1633 (17)	0,1642 (21)		The authors revised their values.
1963Bu09	0,168 (8)	0,165 (9)		Result had to be corrected for α_K .
1963Cr14	0,162 (3)	0,162 (3)		
1964He19	0,163 (3)	0,163 (3)	4,84 (6)	
1965Ra12	0,158 (24)			Not used.
1967Bo47	0,14 (3)			Not used.
1968Ra26	0,179 (13)			Not used.
1968Sa22	0,156 (7)			Not used.
1974Ha29	0,1653 (17)	0,1653 (17)	4,75 (13)	
Recommended values		0,1640 (10)	4,837 (48)	$\chi^2 = 0,16$; $\chi^2 = 0,22$

For the α_K recommended value, the evaluators, following the recommendations of H. H. Hansen (1985HaZA), used only nine experimental values with their associated uncertainties in the weighted average calculation, using the LWEIGHT computer program (version 3). A recommended value of 0,1640 for α_K (279-keV γ -ray) is a weighted average, with an internal uncertainty of 0,0010 and a reduced χ^2 of 0,16.

Evaluators' recommended α_L is 4,837 (48) 10^{-2} (reduced $\chi^2 = 0,22$), weighted average of values from: A. H. Wapstra (1956Wa30), G. J. Nijgh (1958Ni28), Z. Sujkowski (1961Su10), C. J. Herrlander (1964He19) and H. H. Hansen (1974Ha29).

3 Atomic Data

Atomic values, ω_K , ω_L and n_{KL} , are from Schönfeld and Janssen (1996Sc06).

3.1 X rays and Auger electrons

The X-ray and Auger electrons relative probabilities have been calculated from γ -ray data by using the EMISSION computer program.

4 Electron Emissions

The Auger electrons emission probabilities have been calculated from γ -ray data using the EMISSION computer program.

5 Photon emissions

5.1 K x-rays

X-ray emissions probabilities have been calculated from γ -ray data using the EMISSION computer program.

5.2 Gamma-ray emissions

The measured energies of γ -ray emissions are given in Table 6.

Table 6 : The measured energies of γ -ray emissions, in keV.

γ -ray	1954Pr04	1954Wa12	1958Ni28	1964He19	1969C111	1978He21	2000He14 (evaluated)	Recommended value (keV)
$\gamma_{1.0}$	280 (5)	279 (1)	279,12 (5)	279,16 (2)	279,16 (2)	279,1967 (12)	279,1952 (10)	279,1952 (10)
$\gamma_{2.1}$	400 (7)	400 (2)	403,8 (3)	401,27 (5)	401,28 (40)	401,325 (10)	401,320 (3)	401,320 (3)
$\gamma_{2.0}$	685 (10)	678 (3)			680,7 (6)	680,514 (10)	680,515 (3)	680,515 (3)

The evaluators have adopted the recommended values of R. G. Helmer (2000He14).

The measured relative emission intensities listed in Table 7 are given in values relative to 100 for the 279-keV γ ray.

Table 7: Measured relative γ emission intensity in %.

Energy (keV)	1954Pr04	1954Wa12	1989Ne05	Recommended value (%)
279	100	100	100	100
401	4,7 (3)	4,30 (8)	4,14 (8)	4,24 (8)
680	0,87 (10)	0,80 (1)	0,932 (22)	0,932 (22)

For the 401-keV γ -ray, the recommended value is a weighted average (with an external uncertainty) calculated using the LWEIGHT computer program with these three experimental values. For the 680-keV γ -ray, the calculation using the LWEIGHT computer program showed that the data are discrepant, so the evaluators have chosen to use the most recent and precise result of Zs. Németh (1989Ne05).

The normalization factor to convert the relative emission intensities to absolute emission intensities is calculated using the formula:

$$N = \left(\frac{100}{(\sum(1 + \alpha_T)P_{rel})} \right) \times 100$$

where the sum is over all the γ transitions to the ground state and α_T is the relevant coefficient. In this case, the contributions are from the 279- and 680-keV γ transitions. The uncertainty was calculated through the

propagation on the formula given above.

From the recommended α_T (Table 5) and the evaluated relative emission intensities (Table 7), the deduced normalization factor is **80,94 (5)**.

The evaluated relative and absolute γ -ray emission intensities are given in Table 8.

Table 8 : Evaluated relative and absolute γ -ray emission intensities, in %.

Energy (keV)	Relative emission intensity	Absolute emission intensity
279	100	80,94 (5)
401	4,24 (8)	3,43 (6)
680	0,932 (22)	0,754 (18)

6 References

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