^{212}Bi – Comments on evaluation of decay data
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Evaluated: July/August 2001
Re-evaluated: January 2004 and May 2010

Evaluation Procedures

Limitation of Relative Statistical Weight Method (LWM) was applied to average numbers throughout the evaluation. The uncertainty assigned to the average value was always greater than or equal to the smallest uncertainty of the values used to calculate the average.

Decay Scheme

^{212}Bi undergoes beta decay to ^{212}Po (beta branch of 64.07 (7) %), and alpha decay to ^{208}Tl (alpha branch of 35.93 (7) %). The alpha branch was calculated as the weighted mean of the measurements of 1960Sc07, 1962Be09, 1962Fl03 and 1965Wa09, with the uncertainty increased to include the most precise value of 36.00 (3) %.

Reference	α-decay branch (%)
1960Sc07	35.96 (6)
1962Be09	35.81 (4)
1962Fl03	36 (1)
1965Wa09	36.00 (3)*
Recommended value	35.93 (7)

* Uncertainty increased to ± 0.033 so that weighting does not exceed 50 %.

A reasonably consistent decay scheme has been constructed from a combination of alpha-particle studies by 1951Ry17 (two main emissions modified), 1960Wa14, and 1962Be09, and the gamma-ray measurements of 1960Sc07, 1962Be09, 1962Fl03, 1966KlZZ, 1967Be19, 1968Yt02, 1972DaZA (1973Da38), 1978Av01, 1982Be09, 1982Sa36, 1983Sc13, 1983Va22, 1984Ge07 and 1992Li05.

Nuclear Data

^{228}Th decay chain is important in quantifying the environmental impact of the decay of naturally-occurring ^{232}Th. Specific radionuclides in this decay chain are noteworthy because of their decay characteristics (^{224}Ra alpha decay to ^{220}Rn; ^{212}Bi and ^{208}Tl gamma-ray emissions).

Half-life

The recommended half-life is the unweighted mean of two somewhat elderly measurements (1914Le01 and 1961Ap03). Further studies are merited to determine this value with greater confidence.

Reference	Half-life (min)
1914Le01	60.480 (52)
1961Ap03	60.600 (43)*
Recommended value	60.54 (6)

* Uncertainty increased to ± 0.052 so that weighting does not exceed 50 %.

There is no evidence of any change in the half-life of ^{212}Bi on extreme cooling of alpha-active ^{224}Ra samples and decay products within a metallic environment (2007St23). Sources were held at temperatures at and below 1 kelvin for periods of several days, and exhibited an upper limit of change in the alpha-decay half-lives of the order of 1 %.

Alpha Particles

Energies

All alpha-particle energies were calculated from the structural details of the proposed decay scheme. The nuclear level energies specified by 2007Ma45 and Q-values of 2003Au03 were used to determine the energies and uncertainties of the alpha-particle transitions to the various levels, while allowing for the significant recoil components.

Emission Probabilities

The main alpha-particle emission probabilities emitted directly by ^{212}Bi were calculated from the evaluated gamma-ray emission probabilities (see below) and theoretical internal conversion coefficients, combined with an alpha branch of 35.93 (7) %. These data are in excellent agreement with the measured emission probabilities of the two main alpha transitions (1951Ry17, 1960Wa14 and 1962Be09), but deviate considerable for the low-intensity transitions that are poorly resolved. Under such circumstances, the low-intensity alpha-particle data of 60Wa14 were adopted when appropriate, while others were derived from the gamma-ray studies. A value of 1.50 (2) was adopted for the radius parameter r_0(^{208}Tl) as specified by Martin to calculate the hindrance factors (2007Ma45).

Alpha-particle energies, measured relative and recommended absolute emission probabilities, and hindrance factors.

E_α(keV)	P_α^{rel}				P_α^{abs}	HF
	1951Ry17	1960Wa14	1962Be09		Recommended value*	
5302 (2)	0.016	0.000 11 (1)	-	-	0.000 040 (4)‡	20 300
5344 (2)	0.147	0.001	-	-	0.000 36 (3)‡	3 770
5481.4 (3)	-	0.014	~ 0.04	~ 0.02	0.005 0 (4)‡	1 380
5606.60 (5)	1.08	1.19	)	)	0.43 (3)‡	67
			) 1.35 (6)	) 1.22 (2)		
5625.7 (4)	-	0.162 5	)	)	0.060 (3)	595
5768.29 (6)	1.67	1.78	1.63 (11)	1.67 (2)	0.61 (3)	279
6051.04 (3)	69.86#	69.7	70.2 (3)	70.2 (2)	25.1 (1)	126
6090.14 (3)	27.16#	27.1	27.0 (5)	26.8 (2)	9.7 (1)	481
9498.78 (11)†	-	-	-	-	0.002 4 (2)	-
10432.94 (11)†	-	-	-	-	0.001 0 (1)	-
10552.1 (2)†	-	-	-	-	0.010 6 (7)	-

* Recommended emission probabilities derived from evaluated gamma-ray emission probabilities, theoretical internal conversion coefficients and alpha branch of 35.93 (7) %, unless stated otherwise (expressed per 100 disintegrations of ^{212}Bi).
‡ Data reported by 1960Wa14 adopted and adjusted for alpha branch; uncertainties were estimated when not quoted.
† Arises from $\beta^-\alpha$ decay (long-range alpha particles).
# Data reported incorrectly; re-assigned by evaluator.

Long-range alpha-particle emissions from the $\beta^-\alpha$ decay mode have been observed at energies greater than 9 MeV by 1951Ry17, 1962Be09 and 1965Le08. Some of the excited states of ^{212}Po populated by the beta of ^{212}Bi undergo subsequent alpha decay (in competition with the gamma-ray decay). These nuclear levels at 1800.9, 1679.45 and 727.330 keV emit high-energy, long-range alpha particles (energies of 10552.1, 10432.94 and 9498.78 keV, respectively). All measurements were expressed relative to 10^6 emission probability for the 8785.17-keV alpha particle of ^{212}Po, but with no quoted uncertainties. These long-range alpha particles constitute part of the ^{212}Bi decay, and their emission probabilities were determined from the measurements of 1951Ry17, 1962Be09 and 1965Le08:

Alpha-particle emissions ($\beta^-\alpha$ decay).

E_α (keV)	P_α^{rel}			
	1951Ry17	1962Be09	1965Le08	Mean value
[8 785.17 (11)]*	10^6	10^6	10^6	10^6
9 498.78 (11)	35	45	34	38
10 432.94 (11)	20	17	10	16
10 552.1 (2)	170	167	160	166
total α (of $\beta^-\alpha$)	225	229	204	219 (15)

* ^{212}Po alpha decay directly to the ground state of ^{208}Pb as $\alpha_{0,0}$.

Total α emissions from $\beta^-\alpha$ decay have an estimated mean value of 219 relative to 10^6 for the emission probability of the 8785.17-keV alpha particle of ^{212}Po, with an uncertainty of ± 15 to cover the range of measured data. Therefore, a mean value of 0.014 % was estimated for the $\beta^-\alpha$ branch, combined with an uncertainty of approximately 7 % (($\beta^-\alpha$) branch of 0.014 (1) %):

$$\beta^-\alpha \text{ branch} = [219 (15) \times 64.07 (7)] / 10^6 = 0.014 (1) \%$$

Absolute alpha-particle emission probabilities for this small branch were calculated from the mean values and ($\beta^-\alpha$) branch.

Beta Particles

Energies
All beta-particle energies were calculated from the structural details of the proposed decay scheme. The nuclear level energies of 2005Br03 and Q-value of 2252.1 (17) keV from 2003Au03 were used to determine the energies and uncertainties of the beta-particle transitions to the various levels.

Emission Probabilities
The beta-particle emission probabilities were calculated from gamma-ray transition intensity balances, using the recommended gamma-ray emission probabilities and the theoretical internal conversion coefficients determined from the frozen orbital approximation of Kibédi *et al.* (2008Ki07) and based on the theoretical model of Band *et al.* (2002Ba85, 2002Ra45).

Beta-particle energies, emission probabilities, transition types and log *ft* values.

E_β(keV)	P_β		transition type	log *ft*
	1957Bu34	Recommended value*		
446.1 (17)	8.5	0.68 (4)	(1st forbidden non-unique)	6.67
451.2 (17)	-	0.032 (4)	(1st forbidden non-unique)	8.03
572.7 (17)	-	0.21 (4)	(1st forbidden non-unique)	7.55
631.4 (17)	6	1.90 (3)	(1st forbidden non-unique)	6.740
739.4 (17)	-	1.44 (1)	(1st forbidden non-unique)	7.094
1524.8 (17)	10	4.50 (6)	(1st forbidden non-unique)	7.718
2252.1 (17)	63	55.31 (9)	(1st forbidden non-unique)	7.267

* Recommended emission probabilities derived from evaluated gamma-ray emission probabilities, theoretical internal conversion coefficients, beta branch of 64.06 (7) % and beta-alpha branch of 0.014 (1) % (expressed per 100 disintegrations of ^{212}Bi).

Gamma Rays

Energies
All gamma-ray transition energies were calculated from the structural details of the proposed decay scheme. The nuclear level energies of 2005Br03 and 2007Ma45 were adopted, and used to determine the energies and associated uncertainties of the gamma-ray transitions between the various populated-depopulated levels.

Emission Probabilities
The gamma-ray measurements of 1960Sc07, 1962Be09, 1962Fl03, 1967Be19, 1968Yt02, 1972DaZA/1973Da38, 1978Av01, 1982Sa36, 1983Sc13, 1983Va22, 1984Ge07 and 1992Li05 were used to determine the emission probabilities of the major gamma rays. These data have been measured relative to widely differing decay parameters: beta-decay mode, alpha-decay mode, per decay of ^{212}Bi (i.e., absolute emission probabilities), and relative to the 583.19- and 2614.51-keV gamma rays of ^{208}Tl. All of these measured data were adjusted to absolute emission probabilities when appropriate, and weighted mean values determined.

Absolute transition probabilities were estimated for the 180.2- and 1800.9-keV gamma rays in the beta-decay mode, and the 164.80-, 433.5-, 492.84-, 580.5- and 620.4-keV gamma rays in the alpha-decay mode. The latter values were derived from measurements of the low-intensity alpha-particle emission probabilities by 1960Wa14, and involved the introduction of uncertainty estimates that varied between 10 % and 50 % (depending on the number of significant figures quoted in the measurement of the relevant alpha-particle emission probability).

Published gamma-ray emission probabilities.

E_γ (keV)		P_γ						
		1960Sc07*	**1962Be09**	**1962Fl03‡**	**1967Be19#**	**1968Yt02$**	**1972DaZA$**	**1978Av01Δ**
39.858 (4)	(Tl)	-	-	-	-	-	-	-
43 (3)	(Tl)	-	-	-	-	-	-	-
143 (3)	(Tl)	-	-	-	-	-	-	-
144 (2)	(Tl)	-	-	-	-	-	-	-
164.80 (6)	(Tl)	-	-	-	-	-	-	-
180.2 (2)	(Po)	-	-	-	-	-	-	-
267 (2)	(Tl)	-	-	-	-	-	-	-
287 (2)	(Tl)	-	-	-	-	-	-	-
288.18 (5)	(Tl)	-	0.775 (40)#	-	0.82 (2)	-	0.9 (2)	0.97 (5)
289 (2)	(Tl)	-	-	-	-	-	-	-
310 (2)	(Tl)	-	-	-	-	-	-	-
328.04 (5)	(Tl)	-	0.299 (23)#	-	0.33 (1)	-	0.36 (7)	-
433.5 (4)	(Tl)	-		-	0.04 (1)	-	~ 0.025	-
452.98 (4)	(Tl)	-	) 1.18 (5)#	-	0.84 (2)	-	0.88 (17)	1.10 (6)
473.4 (4)	(Tl)	-	)	-	0.122 (8)	-	0.10 (3)	-
492.84 (4)	(Tl)	-	-	-	< 0.008	-	-	-
580.5 (3)	(Tl)	-	-	-	-	-	-	-
620.4 (3)	(Tl)	-	-	-	-	-	-	-
727.330 (9)	(Po)	11.1 (7)	) 100†	11.8 (24)	-	-	17.6 (17)	21.0 (8)
785.37 (9)	(Po)	1.70 (26)	)	-	-	-	2.8 (6)	3.26 (16)
893.408 (14)	(Po)	0.66 (7)	4.9 (3)†	0.5 (1)	-	-	0.94 (19)	-
952.12 (2)	(Po)	0.16 (4)	-	-	-	-	0.46 (9)	-
1073.6 (2)	(Po)	) 0.99 (8)	) 10.1 (4)†	-	-	-	~ 0.03	-
1078.63 (10)	(Po)	)	)	0.7 (1)	-	-	1.4 (2)	-
1512.70 (8)	(Po)	0.49 (5)	3.4 (3)†	-	-	0.99 (15)	0.8 (1)	-
1620.738 (10)	(Po)	2.81 (20)	20.0 (6)†	3.0 (6)	-	4.85 (50)	3.9 (4)	-
1679.450 (14)	(Po)	-	-	-	-	0.230 (7)	0.16 (3)	-
1800.9 (2)	(Po)	-	-	-	-	-	-	-
1805.96 (10)	(Po)	0.17 (3)	1.4 (2)†	0.5 (1)	-	0.41 (10)	0.25 (5)	-

Published gamma-ray emission probabilities (cont.).

E_γ (keV)		P_γ (cont.)				
		1982Sa36¶	**1983Sc13**Ψ	**1983Va22**Ψ	**1984Ge07**Δ	**1992Li05**Ψ
39.858 (4)	(Tl)	0.9 (1)	-	-	3.49 (28)	-
43 (3)	(Tl)	-	-	-	-	-
143 (3)	(Tl)	-	-	-	-	-
144 (2)	(Tl)	-	-	-	-	-
164.80 (6)	(Tl)	-	-	-	-	-
180.2 (2)	(Po)	-	-	-	-	-
267 (2)	(Tl)	-	-	-	-	-
287 (2)	(Tl)	-	-	-	-	-
288.18 (5)	(Tl)	0.32 (3)	0.274 (23)	-	1.106 (10)	0.389 (57)
289 (2)	(Tl)	-	-	-	-	-
310 (2)	(Tl)	-	-	-	-	-
328.04 (5)	(Tl)	-	0.120 (4)	-	0.423 (20)	3.23 (12)
433.5 (4)	(Tl)	-	-	-	-	-
452.98 (4)	(Tl)	0.42 (5)	0.256 (23)	-	1.191 (11)	0.370 (49)
473.4 (4)	(Tl)	-	-	-	-	-
492.84 (4)	(Tl)	-	-	-	-	-
580.5 (3)	(Tl)	-	-	-	-	-
620.4 (3)	(Tl)	-	-	-	-	-
727.330 (9)	(Po)	6.9 (4)	6.56 (15)	7.00 (18)	21.63 (13)	6.93 (18)
785.37 (9)	(Po)	1.01 (7)	1.07 (5)	-	3.62 (4)	1.05 (5)
893.408 (14)	(Po)	0.49 (8)	0.352 (36)	-	1.25 (6)	-
952.12 (2)	(Po)	-	-	-	-	-
1073.6 (2)	(Po)	-	-	-	-	-
1078.63 (10)	(Po)	-	0.58 (4)	-	1.85 (6)	0.555 (41)
1512.70 (8)	(Po)	-	0.276 (42)	-	-	-
1620.738 (10)	(Po)	-	1.38 (8)	-	4.88 (10)	1.44 (9)
1679.450 (14)	(Po)	-	-	-	-	-
1800.9 (2)	(Po)	-	-	-	-	-
1805.96(10)	(Po)	-	-	-	-	-

* Emission probabilities expressed in terms of ^{212}Bi β^- decay mode only.
† Emission probabilities expressed in terms of (727 + 785)-keV gamma rays of ^{212}Bi.
‡ Emission probabilities relative to ^{212}Po α decay.
# Emission probabilities expressed in terms of ^{212}Bi α decay mode only.
$ Emission probabilities relative to P_γ(2614.51 keV) of ^{208}Tl.
Δ Emission probabilities relative to P_γ(583.19 keV) of ^{208}Tl.
¶ Emission probabilities relative to P_γ(238.63 keV) of ^{212}Pb specified as 0.430 (20), compared with recommended value of 0.436 (4).
Ψ Absolute emission probabilities.

Absolute gamma-ray emission probabilities per 100 disintegrations of ^{212}Bi.

E_γ (keV)		P_γ^{abs}						
		1960Sc07	**1962Be09**	**1962Fl03**	**1967Be19**	**1968Yt02**	**1972DaZA**	**1978Av01**
39.858 (4)	(Tl)	-	-	-	-	-	-	-
43 (3)	(Tl)	-	-	-	-	-	-	-
143 (3)	(Tl)	-	-	-	-	-	-	-
144 (2)	(Tl)	-	-	-	-	-	-	-
164.80 (6)	(Tl)	-	-	-	-	-	-	-
180.2 (2)	(Po)	-	-	-	-	-	-	-
267 (2)	(Tl)	-	-	-	-	-	-	-
287 (2)	(Tl)	-	-	-	-	-	-	-
288.18 (5)	(Tl)	-	0.278 (14)	-	0.29 (1)	-	0.3 (1)	0.35 (2)
289 (2)	(Tl)	-	-	-	-	-	-	-
310 (2)	(Tl)	-	-	-	-	-	-	-
328.04 (5)	(Tl)	-	0.107 (8)	-	0.12 (1)	-	0.13 (3)	-
433.5 (4)	(Tl)	-		-	0.014 (4)	-	~ 0.009	-
452.98 (4)	(Tl)	-	) 0.424 (18)	-	0.30 (1)	-	0.32 (6)	0.40 (2)
473.4 (4)	(Tl)	-	)	-	0.044 (3)	-	0.04 (1)	-
492.84 (4)	(Tl)	-	-	-	< 0.003	-	-	-
580.5 (3)	(Tl)	-	-	-	-	-	-	-
620.4 (3)	(Tl)	-	-	-	-	-	-	-
727.330 (9)	(Po)	7.11 (45)	) [7.85]	7.6 (15)	-	-	6.3 (6)	7.6 (3)
785.37 (9)	(Po)	1.09 (17)	)	-	-	-	1.0 (2)	1.17 (6)
893.408 (14)	(Po)	0.42 (4)	0.38 (2)	0.32 (6)	-	-	0.34 (7)	-
952.12 (2)	(Po)	0.10 (3)	-	-	-	-	0.17 (3)	-
1073.6 (2)	(Po)	) 0.63 (5)	) 0.79 (3)	-	-	-	~ 0.01	
1078.63 (10)	(Po)	)	)	0.45 (6)	-	-	0.50 (7)	-
1512.70 (8)	(Po)	0.31(3)	0.27 (2)	-	-	0.36 (5)	0.29 (4)	-
1620.738 (10)	(Po)	1.80 (13)	1.57 (5)	1.9 (4)	-	1.74 (18)	1.4 (1)	-
1679.450 (14)	(Po)	-	-	-	-	0.083 (3)¶	0.06 (1)	-
1800.9 (2)	(Po)	-	-	-	-	-	-	-
1805.96 (10)	(Po)	0.11 (2)	0.11 (2)	0.32 (6)	-	0.15 (4)	0.09 (2)¶	-

Absolute gamma-ray emission probabilities per 100 disintegrations of ^{212}Bi (cont.).

E_γ (keV)		P_γ^{abs} (cont.)					
		1982Sa36	1983Sc13	1983Va22	1984Ge07	1992Li05	Recommended value*
39.858 (4)	(Tl)	0.9 (1)	-	-	1.07 (9)	-	1.07 (1)†
43 (3)	(Tl)	-	-	-	-	-	-**
143 (3)	(Tl)	-	-	-	-	-	-**
144 (2)	(Tl)	-	-	-	-	-	-**
164.80 (6)	(Tl)	-	-	-	-	-	0.0055 (6)‡
180.2 (2)	(Po)	-	-	-	-	-	0.0031 (12)
267 (2)	(Tl)	-	-	-	-	-	-**
287 (2)	(Tl)	-	-	-	-	-	-**
288.18 (5)	(Tl)	0.32 (3)	0.274 (23)	-	0.339 (3)¶	0.389 (57)	0.32 (2)
289 (2)	(Tl)	-	-	-	-	-	-**
310 (2)	(Tl)	-	-	-	-	-	-**
328.04 (5)	(Tl)	-	0.120 (4)¶	-	0.129 (6)	3.23 (12)Ψ	0.121 (3)
433.5 (4)	(Tl)	-	-	-	-	-	0.011 (1)‡
452.98 (4)	(Tl)	0.43 (5)	0.256 (23)	-	0.365 (3)¶	0.370 (49)	0.34 (3)
473.4 (4)	(Tl)	-	-	-	-	-	0.044 (3)
492.84 (4)	(Tl)	-	-	-	-	-	0.039 (10)‡
580.5 (3)	(Tl)	-	-	-	-	-	0.0011 (2)‡
620.4 (3)	(Tl)	-	-	-	-	-	0.0038 (4)‡
727.330 (9)	(Po)	7.0 (4)	6.56 (15)	7.00 (18)	6.62 (4)¶	6.93 (18)Ψ	6.65 (4)
785.37 (9)	(Po)	1.02 (7)	1.07 (5)	-	1.11 (1)	1.05 (5)	1.11 (1)
893.408 (14)	(Po)	0.50 (8)§	0.352 (36)	-	0.383 (18)	-	0.38 (1)
952.12 (2)	(Po)	-	-	-	-	-	0.14 (4)
1073.6 (2)	(Po)	-	-	-	-	-	0.0154 (6)#
1078.63 (10)	(Po)	-	0.58 (4)	-	0.566 (18)¶	0.555 (41)	0.55 (2)
1512.70 (8)	(Po)	-	0.276 (42)	-	-	-	0.29 (1)
1620.738 (10)	(Po)	-	1.38 (8)	-	1.49 (3)¶	1.44 (9)	1.51 (3)
1679.450 (14)	(Po)	-	-	-	-	-	0.07 (1)
1800.9 (2)	(Po)	-	-	-	-	-	-
1805.96 (10)	(Po)	-	-	-	-	-	0.12 (3)

* Weighted mean values adopted when appropriate; remainder derived from proposed decay scheme (see other footnotes).
** Gamma rays with emission probabilities denoted by a dash (–) are believed to be relevant to the α branch of the decay scheme, but could not be quantified in terms of absolute P_γ, and are omitted from the final recommendations.
† Determined directly from proposed decay scheme (calculated transition probability and total theoretical internal conversion coefficient).
‡ Calculated from low-intensity alpha-particle emission probabilities of 1960Wa14.
\# Estimated from 1982Be09 measurement of Pγ(1078.63 keV) / Pγ(1073.6 keV) = 35.7 (35) to give Pγ(1073.6 keV) of 0.55 (2) / 35.7 (35) = 0.0154 (6) , which was used to define the Pγ of the 180.2-keV gamma emission and the TPγ of the 1800.9-keV gamma transition.
¶ Uncertainty increased so that weighting does not exceed 50 %.
§ Datum rejected as outlier, and not included in weighted mean analysis.
Ψ Unresolved overlap with other gamma-ray emission(s); data not included in the weighted-mean analysis.

Placements of gamma-ray transitions.

Adopted Eγ (keV)	Proposed location in decay scheme of β^- branch (^{212}Po nuclear levels)	Adopted Eγ (keV)	Proposed location in decay scheme of α branch (^{208}Tl nuclear levels)
180.2 (2)	1800.9 (2) – 1620.738 (10)	39.858 (4)	39.858 (4) – 0
727.330 (9)	727.330 (9) – 0	43 (3)	803 (2) – 760 (2)
785.37 (9)	1512.70 (8) – 727.330 (9)	143 (3)	760 (2) – 617 (2)
893.408 (14)	1620.738 (10) – 727.330 (9)	144 (2)	617 (2) – 473.4 (4)
952.12 (2)	1679.450 (14) – 727.330 (9)	164.80 (6)	492.84 (4) – 328.04 (5)
1073.6 (2)	1800.9 (2) – 727.330 (9)	267 (2)	760 (2) – 492.84 (4)
1078.63 (10)	1805.96 (10) – 727.330 (9)	287 (2)	760 (2) – 473.4 (4)
1512.70 (8)	1512.70 (8) – 0	288.18 (5)	328.04 (5) – 39.858 (4)
1620.738 (10)	1620.738 (10) – 0	289 (2)	617 (2) – 328.04 (5)
1679.450 (14)	1679.450 (14) – 0	310 (2)	803 (2) – 492.84 (4)
1800.9 (2)	1800.9 (2) – 0	328.04 (5)	328.04 (5) – 0
1805.96 (10)	1805.96 (10) – 0	433.5 (4)	473.4 (4) – 39.858 (4)
		452.98 (4)	492.84 (4) – 39.858 (4)
		473.4 (4)	473.4 (4) – 0
		492.84 (4)	492.84 (4) – 0
		580.5 (3)	620.4 (3) – 39.858 (4)
		620.4 (3)	620.4 (3) – 0

A number of the gamma transitions required to create a reasonably comprehensive decay scheme cannot be quantified in terms of absolute P_γ because measured data are lacking – these particular gamma rays are denoted by a dash (–) in the "Recommended value" column of the table entitled "Absolute gamma-ray emission probabilities per 100 disintegrations of ^{212}Bi" (see above).

Multipolarities and Internal Conversion Coefficients

Many of the M1 + E2 gamma transitions in the alpha-decay mode were assumed to be close to 100 % M1, based on the studies of 1978Av01 and 1982Be09; both the 473.4- and 620.4-keV gamma transitions were arbitrarily defined as 50 % M1 + 50 % E2. Although some contradictions did occur, other mixing ratios were adopted from the studies of 1966KlZZ, 1978Av01 and 1982Be09:

99.36 % M1 + 0.64 % E2 for 288.08-keV,
99.2 % M1 + 0.8 % E2 for 785.37-keV,
99.8 % M1 + 0.2 % E2 for 893.41-keV,
70 % M1 + 30 % E2 for 952.12-keV,
98.2 % M1 + 1.8 % E2 for 1078.63-keV gamma rays.

Multipolarity assignments

Reference	E_γ (keV)	Multipolarity
1978Av01	288.08 (6) [α decay]	M1 + E2
	452.8 (1) [α decay]	72 % M1 + 28 % E2
	727.33 (1) [β^- decay]	E2
	785.37 (9) [β^- decay]	98 % M1 + 2 % E2
1982Be09	785.37 (9) [β^- decay]	99.2 % M1 + 0.8 % E2
	893.41 (2) [β^- decay]	M1 (+ ≤ 0.25 % E2)
	952.12 (2) [β^- decay]	70 % M1 + 30 % E2
	1078.63 (11) [β^- decay]	98.2 % M1 + 1.8 % E2

Recommended internal conversion coefficients have been determined from the frozen orbital approximation of Kibédi *et al.* (2008Ki07), based on the theoretical model of Band *et al.* (2002Ba85, 2002Ra45). Ion-pair formation coefficients were calculated by means of the methodology described by Kibedi *et al.* (2008Ki07).

Gamma-ray emissions: multipolarities, theoretical internal conversion coefficients (frozen orbital approximation) and ion-pair formation coefficients.

E_γ (keV)		Multipolarity	α_K	α_L	α_{M+}	α_{IPF}	α_{total}
39.858 (4)	(Tl)	(M1)	–	17.81 (25)	5.49 (6)	–	23.3 (4)
43 (3)	(Tl)	–	–	–	–	–	–
143 (3)	(Tl)	–	–	–	–	–	–
144 (2)	(Tl)	–	–	–	–	–	–
164.80 (6)	(Tl)	(E2)	0.263 (4)	0.413 (6)	0.140 (2)	–	0.816 (12)
267 (2)	(Tl)	–	–	–	–	–	–
287 (2)	(Tl)	–	–	–	–	–	–
288.18 (5)	(Tl)	99.36 % M1 + 0.64 % E2 δ = 0.080	0.357 (5)	0.060 5 (9)	0.0185 (2)	–	0.436 (7)
289 (2)	(Tl)	–	–	–	–	–	–
310 (2)	(Tl)	–	–	–	–	–	–
328.04 (5)	(Tl)	(M1)	0.252 (4)	0.042 5 (6)	0.013 5 (2)	–	0.308 (5)
433.5 (4)	(Tl)	(M1)	0.119 3 (17)	0.019 9 (3)	0.006 1 (1)	–	0.145 3 (21)
452.98 (4)	(Tl)	(M1)	0.106 1 (15)	0.017 72 (25)	0.005 48 (6)	–	0.129 3 (18)
473.4 (4)	(Tl)	50 % M1 + 50 % E2 δ = 1.0 (2)	0.059 (8)	0.011 5 (10)	0.003 5 (2)	–	0.074 (10)
492.84 (4)	(Tl)	E2	0.020 7 (3)	0.006 33 (9)	0.002 07 (3)	–	0.029 1 (4)
580.5 (3)	(Tl)	E2	0.014 70 (21)	0.003 88 (6)	0.001 22 (2)	–	0.019 8 (3)
620.4 (3)	(Tl)	50 % M1 + 50 % E2 δ = 1.0 (2)	0.030 (4)	0.005 4 (5)	0.001 6 (2)	–	0.037 (5)
180.2 (2)	(Po)	(M1)	1.692 (25)	0.298 (5)	0.090 0 (10)	–	2.08 (3)
727.330 (9)	(Po)	E2	0.010 54 (15)	0.002 57 (4)	0.000 82 (1)	–	0.013 93 (20)
785.37 (9)	(Po)	99.2 % M1 + 0.8 % E2 δ = 0.090	0.031 6 (5)	0.005 39 (8)	0.001 71 (2)	–	0.038 7 (6)
893.408 (14)	(Po)	99.8 % M1 + 0.2 % E2 δ = 0.045	0.022 7 (4)	0.003 86 (6)	0.001 24 (2)	–	0.027 8 (4)
952.12 (2)	(Po)	70 % M1 + 30 % E2 δ = 0.65	0.015 48 (22)	0.002 69 (4)	0.000 83 (1)	–	0.019 0 (3)
1073.6 (2)	(Po)	E2	0.005 10 (8)	0.001 002 (14)	0.000 318 (4)	–	0.006 42 (9)
1078.63 (10)	(Po)	98.2 % M1 + 1.8 % E2 δ = 0.135	0.013 86 (20)	0.002 34 (4)	0.000 72 (1)	–	0.016 92 (24)
1512.70 (8)	(Po)	E2	0.002 74 (4)	0.000 483 (7)	0.000 150 7 (16)	0.000 066 3 (10)	0.003 44 (5)
1620.738 (10)	(Po)	(M1)	0.004 94 (7)	0.000 824 (12)	0.000 251 (3)	0.000 185 (3)	0.006 20 (9)
1679.450 (14)	(Po)	E2	0.002 27 (4)	0.000 391 (6)	0.000 123 8 (14)	0.000 125 2 (18)	0.002 91 (4)
1800.9 (2)	(Po)	E0	–	–	–	–	–
1805.96 (10)	(Po)	E2	0.002 00 (3)	0.000 338 (5)	0.000 096 2 (12)	0.000 175 8 (25)	0.002 61 (4)

Reasonable consistency was achieved from the proposed gamma-ray emission probabilities, internal conversion coefficients and alpha-particle emission probabilities. The 39.858-keV gamma ray is particularly important in the alpha branch, and further measurements are required to determine the emission probability of this transition with greater confidence. A value of 1.07 (1) % (0.0107 (1)) was adopted on the basis of the relevant alpha-particle emission probability, gamma-ray transition probability and a total internal conversion coefficient of 23.3 (4).

Atomic Data

The x-ray data have been calculated using the evaluated gamma-ray data, and the atomic data from 1996Sc06, 1998ScZM and 1999ScZX. Both the x-ray and Auger-electron emission probabilities were determined by means of the EMISSION computer program (version 4.01, 28 January 2003). This program incorporates atomic data from 1996Sc06 and the evaluated gamma-ray data.

K and L X-ray emission probabilities per 100 disintegrations of ^{212}Bi.

			Energy (keV)	Photons per 100 disint.
XL		(Tl)	8.953 – 14.738	7.1 (3)
	XL_l	(Tl)	8.953	0.171 (6)
	XL_α	(Tl)	10.172 – 10.268	3.30 (10)
	XL_η	(Tl)	10.994	0.023 0 (7)
	XL_β	(Tl)	11.812 – 12.643	2.76 (5)
	XL_γ	(Tl)	14.291 – 14.738	0.579 (9)
XK_α	$XK_{\alpha2}$	(Tl)	70.8325 (8)	0.052 5 (23)
	$XK_{\alpha1}$	(Tl)	72.8725 (8)	0.089 (4)
$XK'_{\beta1}$	$XK_{\beta3}$	(Tl)	82.118 }	
	$XK_{\beta1}$	(Tl)	82.577 }	0.030 1 (14)
	$XK''_{\beta5}$	(Tl)	83.115 }	
$XK'_{\beta2}$	$XK_{\beta2}$	(Tl)	84.838 }	
	$XK_{\beta4}$	(Tl)	85.134 }	0.008 9 (5)
	$XKO_{2,3}$	(Tl)	85.444 }	
XL		(Po)	9.658 – 16.213	0.056 3 (24)
	XL_l	(Po)	9.658	0.001 38 (4)
	XL_α	(Po)	11.016 – 11.130	0.025 3 (7)
	XL_η	(Po)	12.085	0.000 440 (13)
	XL_β	(Po)	12.823 – 13.778	0.024 1 (6)
	XL_γ	(Po)	15.742 – 16.213	0.004 77 (11)
XK_α	$XK_{\alpha2}$	(Po)	76.864 (4)	0.038 8 (8)
	$XK_{\alpha1}$	(Po)	79.293 (5)	0.064 7 (13)
$XK'_{\beta1}$	$XK_{\beta3}$	(Po)	89.256 }	
	$XK_{\beta1}$	(Po)	89.807 }	0.022 3 (6)
	$XK''_{\beta5}$	(Po)	90.363 }	
$XK'_{\beta2}$	$XK_{\beta2}$	(Po)	92.263 }	
	$XK_{\beta4}$	(Po)	92.618 }	0.006 93 (20)
	$XKO_{2,3}$	(Po)	92.983 }	

Electron energies were determined from electron binding energies tabulated by Larkins (1977La19) and the evaluated gamma-ray energies. Absolute electron emission probabilities were calculated from the evaluated absolute gamma-ray emission probabilities and associated internal conversion coefficients.

Data Consistency

An effective Q-value of 3674.4 (11) keV has been adopted from the atomic mass evaluation of Audi *et al*. (2003Au03) while in the course of formulating the decay scheme of ^{212}Bi. This value has subsequently been compared with the Q-value calculated by summing the contributions of the individual emissions to the ^{212}Bi alpha- and beta-decay processes (i.e. α, β^-, conversion electrons, γ, etc.):

$$\text{calculated Q-value} = \sum (E_i \times P_i) = 3670\ (9)\ \text{keV}$$

Percentage deviation from the effective Q-value of Audi *et al.* is (0.12 ± 0.24) %, which supports the derivation of a highly consistent decay scheme.

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