^{209}Tl- Comments on Evaluation of Decay Data

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1. Decay Scheme

The nuclide ^{209}Tl ($J^{\pi}=1/2^{+}$) disintegrates 100 % by β^{-} emissions. The strongest β^{-}-decay branch of 97.70 (15) % populates the $J^{\pi}=1/2^{-}$ excited state at 2149.29 keV of the daughter nuclide ^{209}Pb. The decay scheme of ^{209}Tl was constructed by the evaluator, based on the work of Gromov (2000Gr35) and Ardisson (1998Ar03). The ENSDF evaluation of Martin (1991Ma16) was consulted for J^{π} and mutipolarity assignments to levels in ^{209}Pb.

2. Nuclear Data

Adopted Q(β^{-}) value of 3976 (8) keV is taken from the evaluation of Audi *et al.* (2003Au03).

The experimental data for the half-life of the ^{209}Tl ground state are very scarce. The value of 2.161 (7) min (1998Ar03) is adopted in the present evaluation. It is in agreement with the other known, but less precise, value of 2.20 (17) min (1950Ha64).

2.1. β^{-} Transitions

The values for the maximum β^{-}-decay energies, $E_{\beta-,max}$, presented in Table 1, were deduced from Q(β^{-}) = 3976 (8) keV (2003Au03) and the level energies deduced in the present evaluation, as detailed in section 2.2. The β^{-}-decay transition probabilities, P_{β}, were deduced from the decay scheme and the corresponding absolute γ–ray transition probabilities. The sum of the β- intensities to levels above 2149 keV is 2.30 (15) %. Then the β- feeding to the 2149-keV level is (100 - 2.30 (15)) % = 97.70 (15) %. The log *ft* values were calculated using the LOGFT program from the ENSDF evaluation package. The log *f* values are based on the work of Gove and Martin (1971Go40).

2.2. Gamma Transitions and Electron Internal Conversion Coefficients

The γ–ray transition energy data are presented in Table 2. Statistical analysis using the LWEIGHT program has been performed and the corresponding gamma-ray energies were deduced (the last column of Table 2). With those energies, the level scheme was fitted using the *gtol* program from the ENSDF analysis package and new level energies (shown in Table 1) were obtained.

The γ–ray transition multipolarities were taken from the ENSDF evaluation of Martin (1991Ma16) and the recent work of Gromov (2000Gr35) and Ardisson (1998Ar03). The electron conversion coefficients were calculated using the BrIcc code (2008Ki07).

Table 1. Level energies, quantum numbers, $E_{\beta 0,t\ max}$, P_{β} and log *ft* values in decay of ^{209}Tl ($J^{\pi}=1/2^{+}$)

Level energy (keV)	J^{π}	$E_{\beta-\ max}$ (keV)	P_{β} (%)	Nature	log *ft*
3388.96 (13)	(1/2,3/2)	587 (8)	0.420 (22)		
3361.36 (17)	(1/2,3/2)	615 (8)	0.10 (3)		
3069.72 (13)	3/2-	906 (8)	0.645 (16)	first forbidden	6.3
2905.14 (25)	3/2-	1071 (8)	0.70 (9)	first forbidden	6.5
2524.14 (25)	(1/2,3/2)+	1451 (8)	0.070 (15)	allowed	8.0
2460.8 (3)	(5/2)-	1515 (8)	0.031 (16)	first forbidden unique	9.2

2315.68 (13)	(3/2)-	1660 (8)	0.32 (11)	first forbidden	7.5
2149.29 (6)	1/2-	1827 (8)	97.70 (15)	first forbidden	5.2
2032.07 (6)	1/2+	1944 (8)	<0.1	allowed	> 8.3
1566.94 (5)	5/2+				
0.0	9/2+				

The gamma-ray emission probability data are presented in Table 3. The unplaced gamma rays and their emission probabilities are presented in Table 4. Future work is merited to obtain a more complete decay scheme of ^{209}Tl.

3. Atomic Data

The Atomic data (Fluorescence yields, X-Ray energies and Relative probabilities, and Auger electrons energies and Relative probabilities) were provided by the Saisinuc software (2008DuZX). Details regarding the origin of these data can be found in 1996Sc06, 1998ScZM, 1999ScZX, 2000Sc47 and 2003De44.

Table 2. Measured, deduced and adopted gamma-ray energies in β^-–decay of ^{209}Tl

2003ChZV	2000Gr35	1999GrZT	1998Ar03	1993El08	1989Ko26	1986He06	1981Di14	1977Vy02	adopted
	117.18 (10)	117.1 (3)	117.24 (5)	117.24 (1)	117.21 (1)		117.25 (5)	117.211 (21)	117.224 (7)
			284.04 (23)	284.04 (25)					284.04 (23)
			311.5 (3)	311.5 (3)					311.5 (3)
			375.5 (2)	375.5 (2)					375.5 (2)
465.2	465.21 (4)	465.0 (4)	465.10 (5)	465.10 (1)	465.14 (1)	465.4 (1)	465.1 (2)	465.065 (25)	465.128 (24)
582.4	582.4 (2)								582.4 (2)
	748.5 (3)		748.0 (3)	748.0 (3)					748.3 (2)
	755.6 (3)								755.6(3)
	873.5 (4)								873.5 (4)
920.2	920.8 (1)	919.9 (3)	920.34 (9)	920.34 (7)	920.2 (3)				920.43 (11)
1239.8	1239.7 (2)	1239.2 (3)	1239.76 (15)	1239.76 (15)					1239.66 (11)
1329.2	1329.3 (3)	1329.6 (3)	1329.3 (3)	1329.3 (3)	1239.5 (5)				1329.29 (16)
1566.9	1566.9 (3)	1566.7 (3)	1566.96 (5)	1566.96 (1)	1567.11 (2)		1566.9 (2)	1566.95 (6)	1566.93 (5)
	2149.0 (10)								2149.0 (10)
2315.9	2315.9 (3)	2315.7 (3)							2315.80 (21)

Table 3. Measured, deduced and adopted γ–ray emission probabilities for γ–ray transitions in β^-–decay of ^{209}Tl

Eg, keV	2003ChZV	2000Gr35	1999GrZT	1998Ar03	1993El08	1989Ko26	1981Di14	1977Vy02	adopted
117.24 (1)		78 (4)	74 (2)	73 (4)	73 (1)	85 (4) *	85.6 (59) *	84 (2) *	77.22 (27) [a]
284.04 (25)				0.14 (7)	0.14 (7)				0.14 (7)
311.5 (3)				0.028 (14)	0.028 (14)				0.028 (14)
375.5 (2)				0.070 (15)	0.070 (15)				0.070 (15)
465.10 (1)	80.4 (21) *	97 (5)	93.2 (16) *	95 (5)	95 (5)	96 (4)	99.1 (64)	100 (3) *	96.62 (5) [a]
582.4	0.33 (3)	0.28 (4)							0.312 (24)
748.5 (3)		0.07 (3)		0.09 (3)	0.086 (30)				0.080 (21)
755.6(3)		0.11 (2)							0.11 (2)
873.5 (4)		0.59 (8)							0.59 (8)
920.8 (1)	0.62 (3)	0.63 (5)	0.63 (2)	0.70 (7)	0.70 (7)	0.63 (6)			0.631 (15)
1239.8	0.45 (4)	0.42 (7)	0.41 (3)	0.31 (12)	0.31 (12)				0.420 (22)
1329.2	0.14	0.10 (3)	0.21 (3)	0.026 (5)	0.026 (5)	0.42 (4)			0.10 (3)
1566.9	100 (1)	100 (5)	100.0 (8)	100 (5)	100 (5)	100 (4)	100.6 (64)	93 (3) *	99.707 (5) [a]
2149.0 (10)	<0.0006	0.015 (5)							0.015 (5)
2315.9 (3)	0.0284 (24)	0.03 (1)	0.030 (5)						0.0288 (21)

* not included in the statistical analysis

[a] deduced from $100/(1+\alpha_T)$ due to cascading.

Table 4. Gamma-ray energies and emission probabilities for transitions in β^-–decay of ^{209}Tl, which were not placed in the decay scheme

2003ChZV		2000Gr35		1999GrZT		1998Ar03	
		469.9	0.12 (3)			469.7 (3)	0.03 (2)
		860.5 (3)	0.26 (4)				
		890.0 (4)	0.12 (3)				
		902.8 (4)	0.10 (2)				
970.3	0.054 (15)						
		1661.1 (5)	0.10 (2)				
		1673.2 (4)	0.48 (4)				
		1781.7 (5)	0.04 (2)				
				2005.3 (2)	0.020 (5)		
2032.1	<0.019	2032.1 (5)	0.001				
2548.2	0.015 (6)						

4. References

1950Ha64 F. Hagemann. Phys. Rev. 79 (1950) 534
(Half-life)

1971Go40 N.B. Gove, M.J. Martin. Nucl. Data Tables A10 (1971) 205
(Log ft values)

1977Vy02 T. Vylov, N.A. Golovkov, B.S. Dzhelepov, R.B. Ivanov, M.A. Mikhailova, Y.V. Norseev, V.G. Chumin. Bull. Acad. Sci. USSR, Phys.Ser. 41 (1977) 85
(Gamma-ray emission energies and probabilities)

1981Di14 J.K. Dickens, J.W. McConnell. Radiochem. Radioanal. Lett. 47 (1981) 331
(Gamma-ray emission energies and probabilities)

1986He06 R.G. Helmer, C.W. Reich, M.A. Lee, I. Ahmad. Appl. Radiat. Isot. 37 (1986) 139
(Gamma-ray emission energies and probabilities)

1989Ko26 M.C. Kouassi, A. Hachem, C. Ardisson, G. Ardisson. Nucl. Instrum. Methods Phys. Res. A280 (1989) 424
(Gamma-ray emission energies and probabilities)

1991Ma16 M.J. Martin. Nucl. Data Sheets 63 (1991) 723
(Nuclear levels, multipolarities)

1993El08 O. El Samad, J. Dalmasso, G. Barci-Funel, G. Ardisson. Radiochim. Acta 62 (1993) 65
(Gamma-ray emission energies and probabilities)

1996Sc06 E. Schönfeld, H. Janssen. Nucl. Instrum. Methods Phys. Res. A369 (1996) 527
(K-shell fluorescence yields)

1998ScZM E. Schönfeld, G. Rodloff. Report PTB-6.11-98-1 Braunschweig (1998)
(K Auger electron energies)

1988Ar03 G. Ardisson, V. Barci, O. El Samad. Phys. Rev. C57 (1998) 612
(Gamma-ray emission energies and probabilities)

1999GrZT K.Ya. Gromov, Sh.R. Malikov, T.M. Muminov, Zh.K. Samatov, Zh. Sehrehehtehr, V.I. Fominykh, V.V. Tsupko-Sitnikov, V.G. Chumin. Proc. 49th Ann. Conf. Nucl. Spectrosc. Struct. At. Nuclei, Dubna (1999) 117
(Gamma-ray emission energies and probabilities)

1999Sc47 E. Schönfeld, G. Rodloff. Report PTB-6.11-1999-1 Braunschweig (1999)
(K X-ray energies and relative emission probabilities)

2000Sc47 E. Schönfeld, H. Janssen. Appl. Radiat. Isot. 52 (2000) 595
(EMISSION program and X-ray and Auger electron emission probabilities)

2000Gr35 K.Ya. Gromov, S.A. Kudrya, Sh.R. Malikov, T.M. Muminov, Zh.K. Samatov, Zh. Sereeter, V.I. Fominykh, V.G. Chumin. Bull. Rus. Acad. Sci. Phys. 64 (2000) 1770
(Gamma-ray emission energies and probabilities)

2003Au03 G. Audi, A.H. Wapstra, C. Thibault. Nucl. Phys. A729 (2003) 337
(Q value)

2003De44 R.D. Deslattes, E.G. Kessler Jr., P. Indelicato, L. de Billy, E. Lindroth, J. Anton. Rev. Mod. Phys. 75 (2003) 35
(K and L X-ray energies)

2003ChZV V.G. Chumin, V.I. Fominykh, K.Ya. Gromov, A.A. Klimenko, S.A. Kudrya, A.A. Smolnikov, S.I. Vasiliev. Proc. 53rd Ann. Conf. Nucl. Spectrosc. Struct. At. Nuclei, Moscow (2003) 105
(Gamma-ray emission energies and probabilities)

2008Ki07 T. Kibédi, T.W. Burrows, M.B. Trzhaskovskaya, P.M. Davidson, C.W. Nestor Jr.. Nucl. Instrum. Methods Phys. Res. A589 (2008) 202
(Theoretical ICCs)

2008DuZX C. Dulieu, M.M. Bé, V. Chisté. Proc. Int. Conf. on Nuclear Data for Science and Technology, Nice, France, 22-27 April 2007 (2008) 97
(SAISINUC software)