^{232}Th – Comments on evaluation of decay data
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This evaluation was completed in September 2008 and has a literature cut off date of April 2008. The weighted mean was applied to determine recommended values throughout the evaluation where the data were in statistical agreement. Where the data were not in statistical agreement, the Limitation of Relative Statistical Weights (LRSW) was used.

1. Decay Scheme

The nuclide ^{232}Th disintegrates by alpha emission to two excited levels and to the ground state of ^{228}Ra. The spin, parity, half-life of first excited state, multipolarities and level energies of ^{228}Ra are based on the mass-chain evaluation of A. Artna-Cohen (1997Ar08).

Spontaneous fission and cluster decay of $^{24-26}$Ne have been observed by R. Bonetti (1995Bo18) with a partial half-life of 1.22 10^{21} years for the spontaneous fission and a partial half-life greater than 5.04 10^{21} years for the cluster decay. However, these decay modes were not taken into account in this evaluation.

2. Nuclear data

The Q(a) value of 4081.6 (14) keV is taken from the evaluation of Audi *et al.* (2003Au03). The effective Q-value calculated from decay scheme data is 4070 (70) keV.

The experimental half-life values are given in table 1.

Table 1. Experimental half-life values of ^{232}Th

Reference	**Half-life (10^{10} years)**	**Comments**
1963Le21	1.401 (7)	
1960Fa07	1.410 (14)	
1956Ma43	1.45 (5)	Rejected by Chauvenet's criterion
1956Pi42	1.39 (3)	
1956Se17	1.42 (7)	
1938Ko01	1.39 (3)	
Recommended value	**1.402 (6)**	

The value of R. Macklin (1956Ma43) was excluded from the data analysis by Chauvenet's criterion. The data set is consistent and the recommended value, which is the weighted average of 5 remaining values, is 1.402 (6) 10^{10} years. The reduced chi-square value is 0.18 which is smaller than the critical value 3.32.

2.1 Alpha Transitions and emissions

The alpha transition and emission energies have been determined from the Q-value and level energies. Published alpha emission energies are given in table 2.

Table 2. Published alpha emission energies (keV)

Transition	$a_{0,0}$	$a_{0,1}$	$a_{0,2}$
1954Philbert[1]	4014 (20)	3939 (20)	
1957Ha08[2]	4012.3 (50)		
1961Ko11[2]	4013.6 (50)[4]	3950 (8)	3825 (10)
1962Ko12[2]	4013.4 (50)		
1989Sa01	4012.3 (14)	3947.2 (20)	
Mean experimental emission values	4012.4 (14)	3947.3 (20)	3825 (10)
Calculated values[3]	4011.2 (14)	3948.5 (14)	3810.0 (14)
Recommended Values	**4011.2 (14)**	**3948.5 (14)**	**3810.0 (14)**

[1] The values were adjusted by the evaluator for changes in the calibration energy.
[2] The values were adjusted as suggested by A. Rytz (1991Ry01)
[3] Calculated from alpha transition energies taking into account the recoil of the alpha particle
[4] For the $a_{0,0}$ transition, the value from 1961Ko11 was not taken into account as the same author published an updated value in 1962Ko12

Alpha hindrance factors were calculated using the ALPHAD computer program. A summary of the adopted level, alpha transition and emission values is presented in table 3.

Table 3. Adopted level, alpha particle transition and emission energies

Transition	**Level Energy (keV)**	**Alpha Transition Energy (keV)**	**Alpha Emission Energy (keV)**	**HF**
$a_{0,0}$	0.0	4081.6 (14)	4011.2 (14)	1.000
$a_{0,1}$	63.823 (20)	4017.8 (14)	3948.5 (14)	1.02 (7)
$a_{0,2}$	204.68 (3)	3876.9 (14)	3810.0 (14)	16 (5)

2.2 Gamma Transitions and Internal Conversion Coefficients

The recommended $\gamma_{1,0}$ transition energy of 63.811 (10) keV was calculated by taking the weighted mean of 63.81 (7) keV (1973Ta25), 63.81 (1) keV (1983Mi30) and 63.84 (6) keV (1989Sa01). The recommended $\gamma_{2,1}$ transition energy of 140.880 (10) keV was calculated by taking the weighted mean of 140.88 (1) keV (1983Mi30) and 140.83 (15) keV (1989Sa01).

Internal conversion coefficients were calculated using the BrIcc code (T.Kibédi, 2005KiZW), which uses interpolated values of Band *et al.* (2002Ba85).

The γ-ray transition energies, multipolarities and electron internal conversion coefficients are presented in table 4.

Table 4. Energies, multipolarities and electron internal conversion coefficients for gamma transitions

Transition	**Transition Energy (keV)**	**Multipolarity**	**a_T**	**a_K**	**a_L**	**a_M**
$g_{1,0}$	63.811 (10)	E2	80.4 (12)	-	59.1 (9)	16.05 (23)
$g_{2,1}$	140.880 (10)	E2	2.26 (4)	0.283 (4)	1.450 (21)	0.394 (6)

3. Alpha particle emissions

The alpha particle emission intensities were deduced from the decay scheme and can be viewed in table 5.

Table 5. Alpha particle emission energies and probabilities

Transition	Emission Energy (keV)	Emission intensity (%)
$a_{0,0}$	4012.4 (14)	78.9 (13)
$a_{0,1}$	3947.3 (20)	21.0 (13)
$a_{0,2}$	3810.0 (14)	0.068 (20)

The values calculated using the balancing of the decay scheme are in good agreement with the experimental values (table 6) but the former values have been used as they are more precise.

Table 6: Reported values on alpha particle emission intensities

Reference	$a_{0,0}$	$a_{0,1}$	$a_{0,2}$	Comments
1952Du12		24 (3)		See note 1)
1956Al30		22 (2)		See note 1)
1959Ko58		23 (3)	0.20 (8)	See note 2)
1961Ko11	77	23	0.2	No uncertainties. See note 2)
1983Mi30	77 (3)	23 (2)	0.066 (7)	See 3)
1989Sa01	100	33 (5)		

Notes:

1) The values found in the publications of D. Dunlavey (1952Du12) and G. Albouy (1956Al30) represent the percentage of conversion electron accompanying alpha decays ($a_{0,1}$ and $a_{0,2}$).
2) The values published by G. Kocharov in 1959Ko58 and 1961Ko11 appear to be from the same experiment.
3) The values from T. Mitsugashira (1983Mi30) are deduced by the author from the gamma emission probabilities measured by the author.

4. Gamma-ray emissions

The published data for the gamma-ray emissions can be viewed in table 7.

Table 7: Experimental data on gamma-ray emission probabilities

Reference	Absolute values (%) 63 keV	Absolute values (%) 140 keV	Ratio of 140 keV/63 keV
1982Sa36	0.29[1] (2)		
1983Mi30	0.24 (3)	0.018 (2)	0.075 (13)
1983Ro23	0.247[2] (15)		0.102 (9)
1989Sa01			0.055 (10)

[1]Value recalculated using the new DDEP recommended value for $\gamma_{1,0}$(84 keV) of ^{228}Th decay.
[2]Value recalculated using the new DDEP recommended value for $\gamma_{2,0}$(238 keV) of ^{212}Pb decay.

The recommended 63 keV emission intensity of 0.259 (15) % was calculated by taking the weighted mean of 0.29 (2) % (1982Sa36), 0.24 (3) % (1983Mi30) and 0.247 (15) % (1983Ro23).
The recommended ratio 140 keV/63 keV of 0.080 (22) was calculated by taking the weighted mean of 0.075 (13) (1983Mi30), 0.102 (9) (1983Ro23) and 0.055 (10) (1989Sa01). The spread in the results is

quite significant and the reduced chi-square is larger than the critical chi-square. This may be due to the low probability of the gamma combined with the low specific activity of ^{232}Th. The recommended emission probability for the 140 keV line, calculated from the above ratio and the 63 keV emission probability, is 0.021 (6) %.

Transition	**Recommended Values**	**Gamma-ray emission intensity (%)**	$\mathbf{a_T}$
$g_{1,0}$	63.811 (10)	0.259 (15)	80.4 (12)
$g_{2,1}$	140.880 (10)	0.021 (6)	2.26 (4)

5. Atomic data

The values of ω_K, ω_L and n_{KL} relative probabilities of the X-ray and Auger emissions are from Schönfeld and Janßen (1996Sc06).

The energies and relative emission probabilities of the X-ray and Auger electrons have been calculated by using the computer code EMISSION.

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