^{220}Rn – Comments on evaluation of decay data
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Evaluated: July/August 2001
Re-evaluated: January 2004 and April 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
A simple decay scheme has been derived from the gamma-ray studies of 1972DaZA (1973Da38), 1977Ku15, and 1984Ge07. The single 549.76-keV gamma ray had a weighted mean emission probability of 0.115 (15) % (0.001 15 (15)), and this value and theoretical internal conversion coefficients were used to calculate the absolute emission probabilities of the 5748.46- and 6288.22-keV alpha particles to the 549.76-keV and ground states of ^{216}Po, respectively. Alpha-particle studies are required to confirm the validity of the proposed decay scheme.

Nuclear Data
^{228}Th decay chain is important in quantifying the environmental impact of the decay of naturally-occurring ^{232}Th.

Half-life
The recommended half-life is the weighted mean of measurements by 1955Sc81, 1961Ro14, 1963Gi17 and 1966Hu20. Further studies are merited to confirm the studies of 1963Gi17 and 1966Hu20.

Reference	Half-life (s)
1955Sc81	51.5 (10)*
1961Ro14	56.6 (8)
	56.3 (2)
1963Gi17	55.3 (3)
1966Hu20	55.61 (4)#
Recommended value	55.8 (3)

* Defined as outlier.
\# Uncertainty adjusted to ± 0.16 to reduce weighting below 50 %.

There is no evidence of any change in the half-life of ^{220}Rn 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
<u>Energies</u>
Alpha-particle energies were calculated from the structural details of the proposed decay scheme. The nuclear level energies of 2007Wu02 and evaluated Q-value of 6404.67 (10) keV (2003Au03) were used to determine the energies and uncertainties of the alpha-particle transitions, while allowing for the significant recoil components.

Emission Probabilities

Both alpha-particle emission probabilities were derived from the weighted mean emission probability of the single gamma transition and theoretical internal conversion coefficients (see below). A hindrance factor (HF) of 1.00 for the 6288.22-keV alpha-particle emission yields r_0(^{216}Po) of 1.5553 (3) which was adopted in the equivalent calculation of HF for the other emission.

Alpha-particle emission probabilities per 100 disintegrations of ^{220}Rn, and hindrance factors.

E_α(keV)	P_α			HF
	1962Wa28	1977Ku15#	Recommended value*	
5748.46 (11)	0.07 (2)	0.097 (8)	0.118 (15)	3.10
6288.22 (10)	~ 100	99.9	99.882 (15)	1.00

Data were deduced from gamma-ray studies.

* Recommended emission probabilities derived from evaluated gamma-ray emission probability and theoretical internal conversion coefficients.

Gamma Ray

Energy

The single gamma-ray energy was based on the nuclear level energy of 549.76 (4) keV from 2007Wu02.

Emission Probability

The absolute emission probability of the 549.76 (4)-keV gamma ray was determined from measurements by 1972DaZA (1973Da38), 1977Ku15 and 1984Ge07. A weighted mean value of 0.115 (15) % (0.001 15 (15)) was derived by means of the LWEIGHT code.

Published gamma-ray emission probability.

E_γ (keV)	P_γ			
	1956Ma28†	1972DaZA‡	1977Ku15¶	1984Ge07#
549.76 (4)	0.025	0.29 (9)	0.0950 (80)	0.43 (4)

† Defined as accurate to within a factor of 2; rejected from evaluation.

‡ Relative to P_γ(2614.511 keV) of ^{208}Tl.

¶ Absolute value in measurements that include P_γ(240.986 keV) of 3.95 % for ^{224}Ra.

Relative to P_γ(583.19 keV) of ^{208}Tl.

Absolute gamma-ray emission probability per 100 disintegrations of ^{220}Rn.

E_γ (keV)	P_γ^{abs}			
	1972DaZA†	1977Ku15†	1984Ge07†	Recommended value*
549.76 (4)	0.104 (32)	0.0991 (83)	0.130 (3)#	0.115 (15)

† Data adjusted on the basis of the footnotes given above.

Uncertainty increased by a factor of 2.7 from ± 0.003 to ± 0.008 in order to reduce weighting to 50 %.

* Weighted mean value adopted, with the recommended uncertainty increased so that the range includes the most precise value of 0.130.

Multipolarity and Internal Conversion Coefficients

The decay scheme specified by 1997Ar04 and 2007Wu02 has been used to define the multipolarity of the gamma transition on the basis of the known spins and parities of the two nuclear levels. 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).

Gamma-ray emission: multipolarity and theoretical internal conversion coefficients (frozen orbital approximation).

E_γ (keV)	Multipolarity	α_K	α_L	α_{M+}	α_{total}
549.76 (4)	E2	0.018 3 (3)	0.005 61 (8)	0.001 79 (2)	0.025 7 (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 ^{220}Rn.

			Energy (keV)	Photons per 100 disint.
XL		(Po)	9.658 – 16.213	0.000 94 (8)
	XL_l	(Po)	9.658	0.000 022 2 (22)
	XL_α	(Po)	11.016 – 11.130	0.000 41 (4)
	XL_η	(Po)	12.085	0.000 008 1 (9)
	XL_β	(Po)	12.823 – 13.778	0.000 42 (4)
	XL_γ	(Po)	15.742 – 16.213	0.000 086 (7)
XK_α	$XK_{\alpha2}$	(Po)	76.864	0.000 59 (8)
	$XK_{\alpha1}$	(Po)	79.293	0.000 99 (13)
$XK'_{\beta1}$	$XK_{\beta3}$	(Po)	89.256	}
	$XK_{\beta1}$	(Po)	89.807	} 0.000 34 (5)
	$XK''_{\beta5}$	(Po)	90.363	}
$XK'_{\beta2}$	$XK_{\beta2}$	(Po)	92.263	}
	$XK_{\beta4}$	(Po)	92.618	} 0.000 106 (15)
	$XKO_{2,3}$	(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

A Q_α-value of 6404.67 (10) keV has been adopted from the atomic mass evaluation of Audi *et al.* (2003Au03) while in the course of formulating the decay scheme of ^{220}Rn. This value has subsequently been compared with the Q-value calculated by summing the contributions of the individual emissions to the ^{220}Rn alpha-decay process (i.e. α, electron, γ, etc.):

$$\text{calculated Q-value} = \sum (E_i \times P_i) = 6404.7\ (13)\ \text{keV}$$

Percentage deviation from the Q-value of Audi *et al.* is – (0.001 ± 0.020) %, which supports the derivation of a highly consistent decay scheme.

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