^{186}Re - Comments on evaluation of decay data by E. Schönfeld and R. Dersch

This evaluation was completed in November 1998 and the half-life value has been updated in May 2004.

1 Decay Scheme

The decay scheme is taken from Baglin (1997). It is based mainly on the work of Fogelberg (1972), Seegmiller et al. (1972) and Maly et al. (1964). The latter two authors did not only study gammas, but also conversion electrons. There are EC branches to the 122 keV level and the ground state of ^{186}W (together 7,53 %) and beta branches to the ground state (70,9 %) and the excited states (21,5 %) in ^{186}Os. Spins and parities of the levels are taken from Baglin (1997), also the half-lives of the excited levels in ^{186}Os. The splitting into the EC and the beta part was calculated from the measured total W K-X ray emission probability. Beside the four excited levels of ^{186}Os given in the decay scheme, there is a level at 868,94(4) keV (6+). A direct beta transition to this level would be fifth forbidden and, therefore, would be too weak to be observed. The next higher level in ^{186}Os is at 1070,5 keV which is already above the adopted $Q_{\beta-}$ value if the latter is correct.

^{186}W has below the Q_{EC} value a further level at 396,26 keV (4+; 36 ps). An EC transition to this level would be third forbidden, so this branch will be very weak, thus the decay scheme given on page 1 can be considered to be complete.

2 Nuclear Data

The following values of the half-life have been considered ($T_{1/2}$ in d):

1	3,750	Sinma et al. (1939); Fajans et al. (1940); Chu (1950)
2	3,792	Cork et al. (1940); Grant *et al.* (1945); Dybvig *et al.* (1950)
3	3,867(8)	Yamasaki et al. (1940)
4	3,867(8)	Goodman and Pool (1947)
5	3,704(8)	Porter et al. (1956)
6	3,775(13)	Gueben and Govaerts (1958)
7	3,777(4)	Michel and Herpers (1971)
8	3,775(1)	Abzouzi et al. (1989)
9	3,7187(29)	Unterweger et al. (1992)
10	3,7183(11)	Schönfeld et al. (1994) ; superseded by 11
11	3,7186(5)	Schrader (2004)
12	3,7186(17)	by the present evaluator adopted value

The adopted value is mainly based on values 9 and 11. The values 1 to 4 are considered to be only of historical interest. The remaining six values are discrepant: there is a group of three low values (5, 9, 11) and three high values (6, 7, 8). If values 6, 7 and 8 would be included in an averaging procedure, the mean value would be larger than value 12 and also its uncertainty. The present evaluator has not included values 6, 7 and 8 into the averaging procedure because of the well agreeing values 9, 10 and 11 which were measured in well equiped national instituts by experienced scientists whereas the consideration of radioactive impurities and other systematical uncertainties is not convincing in the papers 7 and 8. The value 10 is superseded by value 11 and was then not used for the mean.

Both Q values are taken from Audi and Wapstra (1995).

2.1 b^{-} Transitions

The maximum beta energy of the transition to the 137 keV level have been measured to be (values in keV)

1	934,3(13)	Porter et al. (1956)
2	927(2)	Johns et al. (1956)
3	937(14)	Bashandi and El Nesr (1963)
4	939(3)	Maly et al. (1964)
5	927(3)	Andre and Liaut (1968)
6	945(5)	Trudel et al. (1970)
7	932,8(21)	weighted mean

By adding the level energy of 137,1 keV to the weighted mean we obtain 1069,9 keV for the Q value which is in good agreement with the value given for $Q_{\beta-}$ by Audi and Wapstra: 1069,5(9) keV.

The energy of the $\beta_{0,1}$ transition in table 2.1 is deduced from the adopted Q_β value and the gamma ray energy. The spectra of the β transitions to the ground state and to the 137 keV level which are both non-unique first forbidden were found to have an almost allowed shapes. The total beta emission probability is calculated by subtracting the total EC probability (Section 2.2) from 1.

2.2 Electron Capture Transitions

The fractional capture probabilities of the transitions $\varepsilon_{0,1}$ and $\varepsilon_{0,0}$ were calculated using the data of Schönfeld (1998). The energies are derived from the Q values and the level energies. From the emission probability of the 122 keV γ ray (which was found to be 0,00603(6); original value of Schönfeld et al., 1994) and the conversion coefficient of this transition, the transition probability $P_{\gamma+ce}$ (which is also the transition probability of the electron capture branch to the 122 keV level) is obtained to be $P_{\gamma+ce} = P_{EC}$ (0,1) = 0,0169(3).

The transition probability of the electron capture transition feeding the ground state of ^{186}W can be calculated from the total emission probability of W KX rays. This emission probability is given by

$$P(\mathrm{W\ KX}) = \left\{ P_{EC}(0{,}1)\left[P_K(0{,}1) + a_K / \left(1 + a_t\right)\right] + P_{EC}(0{,}0)\, P_K(0{,}0)\right\} w_K \,.$$

Using the known values for P_K (Table 2.2), the conversion coefficients a_K and a_t (Table 2.3), and the fluorescence yield w_K for tungsten, the transition probability $P_{EC}(0,0)$ can be extracted from the above expression. Using P(W KX) = 0,0602(8) as determined by Schönfeld et al. (1994), one obtains $P_{EC}(0,0)$ = 0,0584(12).

Thus, the total electron capture probability amounts to $P_{EC}(0,1) + P_{EC}(0,0)$ = 0,0169(3) + 0,0584(12) = 0,0753(12).

2.3 Gamma Transitions

Concerning the energies see Sect. 4.2. The transition probabilities $P\gamma$+ce are calculated from the emission probabilities (Sect.4.2) and the total conversion coefficients. The conversion coefficients were interpolated from the tables of Rösel et al. (1978). Maly et al. have determined the K conversion coefficients as follows: α_K (122 keV) = 0,53(5), α_K (137 keV) = 0,44(2). Both are pure E2 transitions.

These values are in agreement with the theoretical ones. Maly et al. have also determined the ratios K/L/M/N for these two transitions. Mixing ratios for the transitions $\gamma_{4,3}$, $\gamma_{4,2}$, $\gamma_{3,1}$ and $\gamma_{4,1}$ were taken from Baglin (1997).

3 Atomic Data

The atomic data are taken from Schönfeld and Janßen (1996).

3.1 X Radiation

The energy values are calculated from the wave lengths in Å* as given by Bearden (1967). The relative emission probabilities of K X rays are taken from Schönfeld and Janßen (1996). The relative emission probabilities of L X rays is calculated from the absolute emission probability given in Table 4.2 setting $P(\mathrm{K}_{a_1}) = 1$.

3.2 Auger Electrons

The energy values are taken from Larkins (1977) (KLL) and the Table de Radionucléides (LMRI 1982) (KLX, KXY). The relative emission probabilities of K Auger electrons are taken from Schönfeld and Janßen (1996). The relative emission probabilities of the L Auger electrons is calculated from the value in the table 4.1 putting *P*(KLL) = 1.

4 Radiation Emission

4.1 Electron Emission

The energies of the Auger electrons are the same as in 3.2. The energies of the conversion electrons are calculated from the transition energy (2.2) and the binding energies.

The emission probabilities of the conversion electrons are calculated using the conversion coefficients given in 2.2. The values of the emission probabilities of the Auger electrons are calculated using the transition probabilities given in 2.1 and 2.2, the atomic data given in 3, and the conversion coefficients given in 2.2 using the Programm EMISSION.

4.2 Photon Emission

The energy of the X rays are from 3.1. The energy of the 137 keV gamma rays was determined by Marklund and Lindström (1963) using a curved-crystal spectrometer. The energies of the other γ rays are taken from Baglin (1997) who took into account also coulomb excitation and n,γ reactions.

The emission probability (photons per disintegration) of the 137 keV γ rays in ^{186}Os has been determined to be 0,0945(16) by Coursey et al. (1991) and 0,0939(9) by Schönfeld et al. (1994). Together with Baglin (1997) we take the unweighted mean 0,0942(6) as adopted value in the present evaluation in order to compare the results of different authors who carried out relative measurements. Then we have (normalized to this value) the following emission probabilities:

	1	2	3	4	5
W L X	0,0308(?)	-	-	0,0192(2)	0,0166(4)
W K_{α_2}	0,0178(4)	-	0,0172(5)	0,0176(4)	0,01736(30)
W K_{α_1}	0,0312(4)	-	0,0297(8)	0,0303(6)	0,0302(5)
W K_{α}	0,0490(6)	0,0445(13)	0,0469(10)	0,0479(8)	0,0475(8)
W K'_{β_1}	0,0109(2)	-	0,0099(4)	0,00989(20)	0,01000(23)
W K'_{β_2}	0,0034(2)	-	0,0026(2)	0,00269(6)	0,00274(8)
W K_{β}	0,0143(3)	-	0,0125(4)	0,01258(21)	0,1273(29)
W K X	0,0633(7)	-	0,0594(11)	0,0605(8)	0,0603(10)
Os L X	0,0300(3)	-	-	0,0306(34)	0,0299(7)
Os K_{α_2}	0,0114(2)	-	0,0113(4)	0,0112(3)	0,01128(26)
Os K_{α_1}	0,0199(4)	-	0,0193(6)	0,0196(4)	0,0194(5)
Os K_{α}	0,0313(5)	0,0286(6)	0,0306(7)	0,0308(5)	0,0307(7)
Os K'_{β_1}	0,0067(2)	-	0,0066(3)	0,00635(14)	0,00650(18)
Os K'_{β_2}	0,00198(20)	-	0,00170(6)	0,00186(4)	0,00182(6)
Os K_{β}	0,0087(2)	-	0,0083(3)	0,00821(15)	0,00833(23)
Os K X	0,0400(6)	-	0,0389(7)	0,0390(5)	0,0390(9)
W γ 122	0,00603(20)	0,00598(10)	0,00604(23)	0,00605(6)	0,00603(6)
Os γ 137	≡0,0942(6)	≡0,0942(6)	≡0,0942(6)	≡0,0942(6)	≡0,0942(6)
Os γ 630	-	0,00032(3)	0,000292(6)	0,000294(6)	0,000293(6)
Os γ 767	-	0,00037(4)	0,000324(7)	0,000328(6)	0,000327(6)

1 Seegmiller et al. (1972)
2 Coursey et al. (1991)
3 Goswamy et al. (1991)
4 Schönfeld et al. (1994)
5 calculated with EMISSION (X rays); values adopted by the present evaluator (gammas)

In all cases there is excellent agreement. Relative values for the emission probabilities of the gamma rays were also determined by Johns et al. (1956), Maly et al. (1964) and Rao et al. (1969). These values are less accurate and were not taken into account in the present evaluation. The emission probabilities and the energies of the gamma rays of the very weak gamma transitions in ^{186}Os (not contained in the above table) were determined by Fogelberg (1972) which is the only one to report these values.

Multiplying the adopted value for $P_{\gamma}(122)$ by 1 + $\alpha_t(122)$ we obtain, in agreement with table 2.2, $P_{EC}(122)$ = 0,0169.

Values, recently measured by Miyahara *et al.* (2000) and Woods *et al.* (2000) are also in good agreement with the here adopted values.

5 Main Production Modes

Taken from the „Table des Radionucléides“, LMRI, 1982.

6 References

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For additional references see also § References in the Tables Part.