^{90}Y - Comments on evaluation of decay data by V. Chisté and M.M. Bé

This evaluation was completed in 2005. Updated version in November 2006 and the literature available by this date included. This evaluation was updated in February 2015 to include new Q value and new electron-positron pair measurement results.

1 Decay Scheme

^{90}Y disintegrates by β^- emission mainly (99.983 %) to the stable ^{90}Zr ground state level. The decay scheme and level energies, spins and parities are based on the evaluation of E. Browne (1997Br34).
A weak beta branch occurs to the 1760 keV excited level which decays by a E0 gamma transition. This 0+ - 0+ transition undergoes with the emission of two particles materialized by the emission of two gamma, or an electron-positron pair, or internal conversion.

2 Nuclear Data

The Q value is from the atomic mass evaluation of Wang *et al.* (2012Wa38).

The half-life of the ^{90}Y ground state has been evaluated from the following data (in hours):

1937Po04	57.6 (24)
1937St01	60.5 (20)
1938Sa**	66 (3)
1940Sa08	66 (2)
1946Bo09	61 (1)
1954Ch05	64.60 (43)
1955Sa13	64.029 (24)
1955Vo03	64.24 (30)
1956He77	64.8 (2)
1957Pe09	63.97 (10)
1961He09	64.10 (8)
1963Vo02	63.74 (10)
1966Ri01	64.06 (11)
1967Bi02	64.6 (8)
1968La10	64.21 (8)
1969Gr38	63.46 (13)
2004Ko18	64.053 (20)
Adopted	**64.041 (31) h** or **2.6684 (13) d**

The weighted average has been calculated with LWEIGHT computer program (version 3).

The evaluator has chosen to take into account the twelve most precise values for the calculation, since the 50's: 1954Ch05, 1955Sa13, 1955Vo03, 1956He77, 1957Pe09, 1961He09, 1963Vo02, 1966Ri01, 1967Bi02, 1968La10, 1969Gr38 and 2004Ko18. The evaluator's choice is supported by the fact that in preliminary calculation with LWEIGHT program, the 1937Po04, 1937St01 and 1946Bo09 values have been rejected based on the Chauvenet's criterion.

With the data set of twelve values, the largest contribution to the weighted average comes from the value of Kossert amounting to 51 %. The LWEIGHT program has increased the uncertainty of the 2004Ko18

value from 0.020 to 0.0202 in order to reduce its relative weight from 51 % to 50 %.

The weighted average of 64.041 h and the external uncertainty of 0.031 h is the half-life adopted value. The reduced-χ^2 value is 4.7.

2.1 β^- Transitions

The maximum energy of the β^- transitions in the decay of ^{90}Y to excited states in ^{90}Zr has been calculated from the relation of

$$E_{\beta^-} = Q_{\beta^-}(\text{from 2012Wa38}) - E_{\text{level in Zr-90}}(\text{from 1997Br34})$$

In the case of the transition $\beta_{0,0}$ (to the ground state), many experimental values of E_{β^-} have been found in literature (measured with β-ray spectrometer), as shown in the following table (Table 1). It can be noted that the adopted value, 2278.7 (16) keV, is in agreement with the experimental values.

Table 1: Experimental and adopted energy of the $\beta^-_{0,0}$ transition

Reference	E_{β^-} (keV)
T. Yuasa and J. Laberrigue-Frolow (1957Yu06)	2265 (5)
O. E. Johnson et al. (1958Jo33)	2261 (3)
R. T. Nichols et al. (1961Ni02)	2271 (2)
S. André and P. Depommier (1964An12)	2268 (2)
L. M. Langer et al. (1964La13)	2273 (5)
H. Daniel et al. (1964Da16)	2284 (5)
P. G. Hansen et al. (1966Ha15)	2275 (5)
P. Riehs (1966Ri01)	2280 (5)
T. Nagarajan et al. (1971Na09)	2288 (3)
H. Hansen (1983Ha35)	2279.5 (29)
C. Greenwood and M. H. Putnam (1993Gr17)	2274.8 (30)
Adopted value	**2278.7 (16)**

For the probabilities of the β^- transitions, the available published data are given in Table 2:

Table 2: Measured and adopted probabilities of β^- transitions in %.

Populated level (keV)	**1957Yu06**	**1961La07**	**1976Gr16**	**Adopted values**
ground state	99.9786 (31)	99.9885 (15)		**99.983 (7)**
1760.72	0.0214 (31)	0.0115 (15)		**0.017 (7)**
2186.282			0.000 001 4 (3)	**0.000 001 4 (3)**

1957Yu06 measured the ratios I_{pair}/I_{β^-} and I_{ce}/I_{pair} and deduced $I_{ce}+I_{pair} = 0.0214$ (31) %.
1961La07 deduced the β^- transition probability to the 1760 keV level from their measured ratio of I_{pair}/I_{β^-} and the ratio $I_{ce}/I_{pair} = 2.38$ (8) of (1962Ne02).
For the 1760.72-keV β transition, the simple mean of the two results is 0.017 (5) % with an uncertainty which covers both values.
The adopted value is the sum of the intensities of the conversion electrons and of the electron-positron pair as determined below: $I_{ce} + I_{pair} = 0.014$ (7) + 0.0036 (7) = 0.017 (7) %.

The log ft values have been calculated with the LOGFT program (version 7.2a).

2.2 γ Transitions

The 2186-keV γ transition probability has been deduced from the emission intensity of 0.000 001 4 (3) % (§ 5.1) and the theoretical α_T (2002Ba85, 2008Ki07) for a E2 transition.
The 1760 γ transition probability is 0.017 (7) % (below).

Multipolarities of these γ-ray transitions are from 1997Br34.

The intensity of the conversion electrons was measured: 1.6 (3) 10^{-2} % (1957Yu06); 1.3 (7) × 10^{-2} % (1972Le**). The adopted value is the simple mean 1.4 (7) 10^{-2} % with the uncertainty given by Legrand (1972Le**) which seems more reasonable.

The ratio of the conversion electron number to the number of e^--e^+ pairs was measured: I_{ec}/I_{pair} = 2.38 (8) (1962Ne02); 3.0 (11) (1957Yu06).

The probability of one-photon decay, occurring during the 0^+ - 0^+ gamma transition, relative to the probability of internal conversion is 5 (2) 10^{-7} (1990Zh20).

The ratio of two-photon decay $P_{\gamma\gamma}$, occurring during the 0+ - 0+ gamma transition, to the sum of internal-pair decay I_{pair} and internal-conversion decay P_{ic} : $P_{\gamma\gamma}$ / (I_{pair} + P_{ic}) is 0.040 (5) (1997Br34).

3 Atomic Data

Atomic values, ω_K, ϖ_L and n_K, are from Schönfeld and Janβen (1996Sc06).

5 Photon emissions

5.1 γ-ray Emissions

The 2186-keV γ-ray was observed by Zheltonozhskii (1990Zh20) with an intensity of 1.12 (6) 10^{-6} % and by Griffin (1976Gr16) who gave 1.4 (3) 10^{-6} %. Only this latter value is accepted because derived from activity measurements.

The number of pair positrons-electrons (leading to the emission of the 511 keV annihilation peak) has been measured and are listed in the table below.

Reference	**I_{pair} (10^{-4}) %**	**Uncertainty**
Greenberg (1956Gr21)	36	9
Langhoff (1961La07)	34	4
Selwyn (2007Se01)	31.86	0.47
Stanicek (2007St**)	34.5	8
Chi2 crit.:	3.8	
Chi2 :	0.2	
UWM	34.09	
WM	31.91	
uc(WM)int. :	0.46	
uc(WM)ext. :	0.21	
Adopted	**31.9**	**0.5**

The adopted value of the internal pair production intensity is: I_{pair} = 31.9 (5) 10^{-4} %. Then the intensity of the 511 γ emission is 0.006 38 (10) %.

5.2 X-ray Emissions

The intensity of the X-ray Kα was measured by Legrand (1972Le**) being 3.7 (5) × 10^{-2} %.

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