^{93}Zr - Comments on evaluation of decay data

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This evaluation was completed in September 2013. Literature cutoff date: September 2013.

Limitation of Relative Statistical Weights Method (LWM) was applied to average the decay data when appropriate (unless otherwise stated) by use of the LWEIGHT program and/or the Excel implementation of same. All uncertainties are given as the combined uncertainty to one standard deviation.

The ^{93}Zr samples used in the various measurements were produced either by chemical extraction from irradiated uranium fuel (^{93}Zr is a major fission product), or via activation of the zircaloy cladding of modern PWR fuel.

Impurities and/or interfering nuclei include ^{95}Zr, ^{93m}Nb (the decay daughter), ^{93}Mo and ^{55}Fe (this latter particularly for liquid scintillation measurements). The presence of ^{95}Zr is easily dealt with as it has a comparatively short half-life (~ 64 d) and so extracted samples are kept to allow the activity of this nuclide to decay away. Radiochemical separation and mass spectrometry were performed before measurements in almost all of the published reports in order to remove these impurities.

The most important complication in measuring the decay properties for this nuclide are linked to it being a pure beta emitter and also a severe lack of knowledge of the decay scheme, particularly the beta branching fraction to the metastable state and ground state of the daughter, ^{93}Nb. Observation of the 30.77 keV γ ray from ^{93m}Nb, following β^--decay of ^{93}Zr, only becomes possible once equilibrium is reached, i.e. > 80 a.

1 Decay Scheme

^{93}Zr decays 100 % via two β^--transitions to ^{93m}Nb (16.12 (15) a) and ^{93}Nb (stable).

The overall decay scheme presented is complete and consistent. Its overall consistency is verified by the comparison between Q_{calc} (90 (6) keV) and Q_{β^-} (90,3 (15) keV) from the 2012 atomic mass evaluation of M. Wang *et al.* (2012Wa38). The level energy of ^{93m}Nb, along with the spins and parities, are taken from 2004BeZQ.

2 Nuclear Data

2.1. Half-life

The experimental half-life values of ^{93}Zr are given in Table 1, resulting in a recommended value of **1,61 (6) × 10^6 a**.

Table 1: Experimental values of ^{93}Zr half-life (in x 10^6 a)

Reference	$T_{1/2}$ values (10^6 a)	Uncertainty
1950St90[†]	1,5 – 8,5	
1952Gl**[†]	0,93	0,05
1953Gl31[†]	0,95	0,05
1972FlZM[a]	1,53	0,1
2010Ya01[b]	1,13	0,11
2010Ca01	1,64	0,06
Recommended[c]	**1,61**	**0,06**
LWEIGHT reduced χ^2 = 0,89 (critical χ^2 = 6,63)		

[†] Superseded by 1972FlZM

[a] Private communication from K.F. Flynn (ANL) to D. Kocher (ORNL) claiming to include their "best information" concerning ^{93}Zr/^{93}Nb, so supersedes 1950St90, 1952Gl** and 1953Gl31

[b] The LSC measurement method is questionable (definition of quenching factor, use of ^{63}Zn spectral shape for normalisation, etc.), and so this value has been excluded from the dataset

[c] Recommended value is the weighted mean of 1972FlZm and 2010Ca01, where the value of 2010Ca01 amounts to 73 % of the total weight, due to its far lower uncertainty. This uncertainty is adopted for the recommended value.

The recommended half-life for ^{93m}Nb is **16,12 (15) a**, taken from 2004BeZQ.

2.2. Beta Transitions

Energies and Emission Probabilities

Beta-particle energies were determined from the difference between the adopted Q-value and the final level energies of the daughter ^{93}Nb. A level energy of 30,77 (2) keV has been adopted from 2004BeZQ. Beta-particle transition probabilities were taken from 2010Ca01, who used an iterative approach to look at the in-growth of ^{93m}Nb over a three year period, determined from X-ray measurements, and hence deduced the beta transition probabilities to ^{93m}Nb (73 (5) %) and ^{93}Nb (27 (5) %) respectively. Note the uncertainty of 5 % on each is from the text of the report, not Figure 7, which shows 6 %. It is noteworthy that these values are significantly different from those given in 1972FlZM ($\geq$ 95 % and $\leq$ 5 %, respectively), but due to the earlier measurements only quoting limits, and that the later measurements used an iterative fitting approach, it is felt they are more reliable.

References

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