# $^{93m}$Nb – Comments on evaluation of decay data by V.P. Chechev and N.K. Kuzmenko

This evaluation was originally completed in May 2001 and was updated in October 2013 by M.A. Kellett (CEA/LNE-LNHB) to include new internal conversion coefficients and thus the associated atomic data (X-ray emissions, conversion- and Auger-electrons). No new references have been published during the intervening period.

## 1 Decay scheme

The $^{93m}$Nb decay scheme is very simple. It includes the single 30.77 keV gamma transition with the well-established multipolarity of M4 (1972Ko59, 1997Ba13).

## 2 Nuclear Data

Q(IT) value is the energy of the isomeric transition to the ground state of $^{93}$Nb (1977Mo07).

There are available seven measurements of the $^{93m}$Nb half-life, in years:

| Half-life | Reference | Comment |
|---|---|---|
| ~ 4 | 1954Sc74 | Omitted (approximate) |
| 13.6 (3) | 1965Fl02 | Omitted (low precision) |
| 11.4 (9) | 1976He** | Omitted (low precision) |
| 16.4 (4) | 1977Ll01 | Omitted (preliminary) |
| 15.3 (13) | 1980Va** | Omitted (preliminary) |
| 16.10 (19) | 1981Ll01 | |
| 16.13 (15) | 1983Va25 | |
| **16.12 (15)** | Recommended value (weighted mean) | |

The measurement result of 1954Sc74 was omitted as only approximate. The 1977Ll01 and 1980Va** values, measured by Lloret and Vaninbroukx, respectively, were only preliminary results. They were obtained from observations over relatively short periods – in both cases the measurements continued over only about four or so years. Consequently only the final values of 1981Ll01 and 1983Va25 have been used by the evaluator for statistical processing. The lower values of 1965Fl02 and 1976He** were omitted as being less precise and they disagree with the two more precise measurements of 1981Ll01 and 1983Va25.

Averaging of these latter values gives a weighted mean of 16.12 with an internal uncertainty of 0.12 and an external uncertainty of 0.01. As the measurement method was the same in both cases, the minimum input uncertainty of 0.15 has been chosen for the final uncertainty of the weighted mean. Thus, the evaluated $^{93m}$Nb half-life is **16.12 (15) years**.

### 2.1 Gamma Transition and Internal Conversion Coefficients.

The energy of the gamma transition, 30.77 (2) keV, has been taken from the 1977Mo07 measurement. The 1972FlZM measurement value of 30.4 (3) keV is significantly less accurate.

The multipolarity of the gamma transition, M4, is determined confidently from measured subshell ratios:

K/(L+M) = 0.18 (2) (1964Ho08),

K/L = 0.21 (2) (1964Ho08),

K/(L+M+…) = 0.19 (2) (1982Re09),

L/(M+N+…) = 3.8 (4) (1982Re09).

The internal conversion coefficient ($\alpha_K$) is obtained by interpolation of the ICC tables using the BrIcc code of Kibédi (2008Ki07). The relative uncertainty of $\alpha_K$ has been adopted as 1.5 % in accordance with the available estimations of the reliability of the calculations of the theoretical ICC with a pure multipolarity (see 2008Ki07). The $\alpha_K$ adopted value of 2.60 (4) $10^4$ agrees well with the measured value of 2.58 (15) $10^4$ (1976Ju04) and the evaluated value of 2.63 (6) $10^4$ (1987La**), but disagrees with the value of 1.7 (3) $10^4$ calculated in (1977Mo07) from the measured ratio $P_\gamma/Px_K$= 8 (1) $10^{-5}$.

The adopted value of $\alpha_K$ is supported by the measurement result of 2.4 (9) $10^4$ obtained by the quite different method – investigation of "electron bridge" in $^{93m}$Nb decay (1999ZhZY).

The evaluated $\alpha_L$, $\alpha_M$, $\alpha_T$ are also theoretical values for M4 multipolarity.

## 3 Atomic Data

### 3.1 Fluorescence yields

The fluorescence yields are taken from 1996Sc06 (Schönfeld and Janβen).

### 3.2 X Radiations

The X-ray energies are based on the wave lengths in the compilation of 1967Be65 (Bearden). The relative K X-ray emission probabilities are taken from 1999ScZX.

### 3.3 Auger Electrons

The energies of Auger electrons are from 1977La19 (Larkins) and 1987La** (Lagoutine, Table de Radionucléides).

The ratios P(KLX)/P(KLL) and P(KXY)/P(KLL) are taken from 1996Sc06.

## 4 Photon Emissions

### 4.1 X-Ray Emissions

The total K X-ray absolute emission probability computed with use of the ICC $\alpha_T$, $\alpha_K$ and the K-fluorescence yield $\omega_K$ = 0.751 (4) is 11.54 (26) per 100 disintegrations. It is consistent with the measurements of 11.6 (4) (1978Ba**, 1980Va**) and 11.5 (3) (1983Va25). (See these references also in 1991BaZS). Other measured values include 10.7 (3) (1982Al**), 11.04 (28) (1985Ge**), and 11.12 (22) (1990Co17). The adopted value of the total K X-ray absolute emission probability is thus 11.54 (26).

The absolute emission probabilities of the K X-ray components have been computed from $P_{XK}$ using the relative probabilities from 1996Sc06.

The total L X-ray absolute emission probability has been computed with use of the ICC $\alpha_L$ and the atomic data of $\varpi_L$ = 0.0347 (9), $n_{KL}$ = 1.045 (4) from 1996Sc06.

### 4.2 Gamma Emissions

The energy of the gamma ray, 30.77 (2) keV, is from the 1977Mo07.

The absolute emission probability of the gamma ray, 5.91 (9) $10^{-4}$ per 100 disintegrations, is computed from the decay scheme using the ICC $\alpha_T$.

## 5 Electron Emissions

The energies of the conversion electrons have been calculated from the gamma-transition energies given in 2.1 and the electron binding energies using the computer program EMISSION (v3.10, 28-Jan-2003) described in 2000Sc47.

The total emission probability of the conversion electrons, 99.999 409 (9), has been obtained as $P(_{ec1,0\ T}) = 100 - P_\gamma$ (per 100 disintegrations). The emission probabilities of the K-, L-, M-, NO-conversion electrons have been calculated using the conversion coefficients given in 2.1.

The values of the emission probabilities of K-Auger electrons have been calculated using the gamma transition probability given in 2.1, the atomic data given in 3, and the conversion coefficients given in 2.1 also using the computer program EMISSION (v3.10, 28-Jan-2003) described in 2000Sc47.

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