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

1 Decay scheme

The ^{93}Nb^{m} 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 the seven measurements of the ^{93}Nb^{m} half-life, in years:

~ 4	1954Sc74
13,6(3)	1965Fl02
11,4(9)	1976Hegedues
16,4(4)	1977Ll01
15,3(13)	1980Vaninbroukx
16,11(19)	1981Ll01
16,16(15)	1983Va25

The measurement result of 1954Sc74 was omitted as crude. The 1977Ll01 and 1980Vaninbroukx values measured by Lloret and by Vaninbroukx, respectively, were only preliminary results. They were obtained from observations over relatively short periods. In both cases the measurements have been continued over about four more years. Consequently only the final values of 1981Ll01 and 1983Va25 have been used by the evaluator for statistical processing. Then, the low values of 1965Fl02 and 1976Hegedues were omitted as less precise and disagreed with the two best measurements of 1981Ll01 and 1983Va25.

Averaging of these latter values gives the unweighted mean of 16,12(1) and the 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 chosen for the final uncertainty of the weighted mean. Thus, the evaluated ^{93}Nb^{m} 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 (α_K) is obtained by the interpolation from the ICC tables of 1978Ro22 using database IC4 of 2000Co05. The relative uncertainty of α_K has been adopted as 3% in accordance with the available estimations of the reliability of the calculations of the theoretical ICC with a pure multipolarity (see 2000Co05). The adopted value of α_K conforms well to α_K(experimental) = 2,58 (15) 10^4 (1976Ju04) and disagrees with α_K(experimental) = 1,7 (3) 10^4 calculated in (1977Mo07) from the measured ratio P_γ/Px_K= 8(1) 10^{-5}. See also 1987Table : α_K = 2,63 (6) 10^4

The adopted value of α_K is supported by the recent measurement result of 2,4(9)$\cdot 10^4$ obtained by the quite different method–investigation of "electron bridge" in ^{93}Nb^{m} decay (1999ZhZY).

The evaluated α_L, α_M, α_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 1999Schönfeld.

3.3. Auger Electrons

The energies of Auger electrons are from 1977La19 (Larkins) and 1987Table (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 α_T, α_K and the K-fluorescence yield ω_K=0,751(4) is 10,99(40) per 100 disintegrations. It coincides with the averaged value [10,99(22)] of three measurement results of 10,7(3) (1982Alberts), 11,04(28) (1985Gehrke), 11,12(22) (1990Co17). The other measurements have given slightly higher values: 11,6(4) (1978Bambynek, 1980Vaninbroukx) and 11,5(3) (1983Va25). (See these references also in 1991BaZS).

The adopted value of the total K X-ray absolute emission probability is 10,99(22).

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 α_L and the atomic data of ϖ_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 is computed from the decay scheme using the ICC α_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.

The total emission probability of the conversion electrons 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.

6. References

1954SC74 - R. P. Schuman, Phys. Rev. 96(1954)121 (Half-life)
1964Ho08 - K. Hohmuth, G. Muller, J. Schinthmeister, Nucl. Phys. 52(1964)590 (ICC subshell ratios)
1965Fl02 - K. F. Flynn, L. E. Glendenin, E. P. Steinberg, Nucl. Sci. Eng. 22(1965)416 (Half-life)
1967Be65 - J. A. Bearden, Rev. Mod. Phys. 39(1967)78. (X-ray energies)
1972FLZM - K. F. Flynn, (1972): No title. (Priv Comm) (Gamma-ray energies)
1972Ko59 – D .C .Kocher, Nucl. Data Sheets 8(1972)527 (multipolarity)
1976Hegedues - F. Hegedues, Report EUR 5667E I(1976)757 (Half-life)
1976Ju04 - M. Jurcevic, A. Ljubicic, D. Rendic, Fizika (Zagreb) 8(1976)81 (K ICC)
1977La19 - F. P. Larkins, Atomic Data and Nuclear Data Tables 20(1977)313 (Auger electron energies)
1977Ll01 - R. L. Lloret, Radiochem. Radioanal. Lett. 29(1977)165 (Half-life)
1977Mo07 - J. Morel, J.-P. Pérolat, N. Coursol, Compt. Rend. B284(1977)223 (X-ray and gamma-ray energies and emission probabilities, K ICC)
1978Bambynek - W. Bambynek, D. Reher, R. Vaninbroukx, Proc. Int. Conf. on Neutron Physics and Nuclear Data for Reactors and other Applied Purposes, Harwell, September 1978, OECD Nuclear Energy Agency, Paris,(1978)778 (K X-ray emission probability)
1978Ro22F - Rosel et al., Atomic Data Nuclear Data Tables 21(1978)92 (ICC)
1980Vaninbroubx - R. Vaninbroukx, Liquid Scintillation Counting (D. L. Horrockx, E. L. Alpen Eds.) Academic Press, New York, Vol.1(1980)43 (K X-ray emission probability)

1981Ll01 - R. Lloret, Radiochem. Radioanal. Lett. 50(1981)113 (Half-life)
1982Alberts -W. G. Alberts, R. Hollnagel, K. Knauf, W. Pessara. Proc. 4th ASTM-EURATOM Symposium on Reactor Dosimetry (F.B.K. Kam Ed.), NUREG/CP-0029, Gaithensburg 1(1982)433 (K X-ray emission probability)
1982Re09 - D. Reher, Int. J. Appl. Radiat. Isotop. 33, 537 (1982) (ICC subshell ratios, multipolarity)
1983Va25 - R. Vaninbroukx, Int. J. Appl. Radiat. Isotopes 34(1983)1211 (Half-life, K X-ray emission probability)
1985Gehrke - R. J. Gehrke, J. W. Rogers, J. D. Baker, Proc. 5th ASTM-EURATOM Symposium on Reactor Dosimetry, Geesthacht, FRG, 24-28 September 1984, Dordrecht 1(1985)319 (K X-ray emission probability)
1987Table - F.Lagoutine, N. Coursol, J. Legrand, Table de Radionucleides. ISBN-2-7272-0078-1. LMRI, 1982-1987, BP 52, 91 191 Gif-sur-Yvette Cedex, France (ICC, multipolarity)
1990Co17 - B. M. Coursey et al, Nuclear Instrument Methods A290(1990)537 (K X-ray emission probability)
1991BaZS - W. Bambynek, T. Barta, R. Jedlovszky, P. Christmas, N. Coursol, K. Debertin, R. G. Helmer, A. L. Nichols, F. J. Schima, Y. Yoshizawa, TECDOC-619, IAEA. X-ray and gamma-ray standards for detector calibration. Vienna (1991) (K X-ray emission probability)
1996Sc06 - E. Schönfeld, H. Janβen, Nuclear Instrument Methods Phys. Res. A369(1996)527 (Atomic data)
1997Ba13 - E. Baglin, Nuclear Data Sheets 80(1997)1 (Decay scheme)
1999Schönfeld - E. Schönfeld, G. Rodloff, Report PTB-6 11-1999-1 (1999) (Atomic data)
1999ZhZY - V. A. Zheltonozhsky, A. G. Zelinsky, Yu. M. Shevchenko, E. G. Shemchuk, Program and Thesis, Proc.49th Ann. Conf. Nucl. Spectrosc. Struct. At Nuclei, Dubna, p.100 (1999) (Electron, X-ray and gamma-ray emission probabilities, K ICC)
2000Co05 - N. Coursol, V. M. Gorozhankin, E. A. Yakushev, C. Briancon, Ts. Vylov, Appl. Radiat. Isot. 52, 557 (2000) (ICC)