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Radioactive equilibrium: ^{99}Mo/^{99m}Tc decay characteristics

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HIGHLIGHTS

- We examine the ^{99}Mo/^{99m}Tc radioactive equilibrium mixture decay.
- Specific features of this decay are underlined.
- Absolute intensities of all emissions have been evaluated.
- Normalization factor has been deduced using intensity balance relations.
- The literature available by 2013 has been included.

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ABSTRACT

Within the Decay Data Evaluation Project, as an example of a radioactive equilibrium with isomer, the ^{99}Mo/^{99m}Tc equilibrium mixture decay characteristics are examined. The results of a new decay data evaluation are presented for ^{99}Mo/^{99m}Tc decay to nuclear levels in ^{99}Tc. These evaluated data have been obtained using information published up to 2013.

1. Introduction

^{99}Mo and its daughter ^{99m}Tc are important radionuclides for different applications, especially in medicine. Their decay characteristics are used in determining the concentration of ^{99m}Tc in ^{99}Mo/^{99m}Tc radionuclide generator devices and in measurements of gamma rays for various purposes including fission yield determination. Therefore high-quality evaluated decay data are merited for these nuclides. Radioactive equilibrium between a parent nuclide and one or more daughters always creates a problem in the determination of the intensities of gamma rays occurring in their decays, and the ^{99}Mo/^{99m}Tc decay data evaluation is an example of solving such a problem when the daughter nuclide has a long lived isomeric state and when the parent nuclide decays to the ground state of the daughter through the isomer and at the same time bypassing it.

This assessment was carried out within the Decay Data Evaluation Project (DDEP) (Helmer et al., 2002). The previous evaluation of ^{99}Mo/^{99m}Tc decay data was jointly undertaken in 2000 by researchers from LNHB and KRI. We present a revised evaluation using Band-Raman internal conversion coefficients (Kibèdi et al., 2008) instead of those of Rösel et al. (1978) and taking into account new experimental results, in particular, the measurements of Lashko and Lashko (2003) for γ-rays with energies greater than 150 keV. The statistical data processing has been now carried out using the LWEIGHT computer program (Browne, 1998), which includes the Limitation of Relative Statistical Weight method (Zijp, 1985). In this evaluation, the uncertainty assigned to the recommended value is always greater than, or equal to, the smallest uncertainty on any of the experimental values used in the statistical processing.

The following decay characteristics of ^{99}Mo in equilibrium with ^{99m}Tc have been evaluated: half-lives, decay energy, energies and probabilities of beta transitions (E_β, P_β) and gamma transitions (E_γ, $P(\gamma+ce)$), internal conversion coefficients (ICC), absolute emission intensities of γ-rays (I_γ) and conversion electrons (Ice), energies and absolute emission intensities of X-rays and Auger electrons. Specific evaluated decay data for the isomeric and ground states of technetium-99 (^{99m}Tc and ^{99}Tc) are available on the DDEP web site:

(http://www.nucleide.org/DDEP_WG/DDEPdata.htm) maintained by CEA-LNE/LNHB and published for ^{99}Tc in the BIPM Monographie (Bé et al., 2011).

The current evaluation takes into account all experimental data and other information published for ^{99}Mo/^{99m}Tc up to 2013. In this

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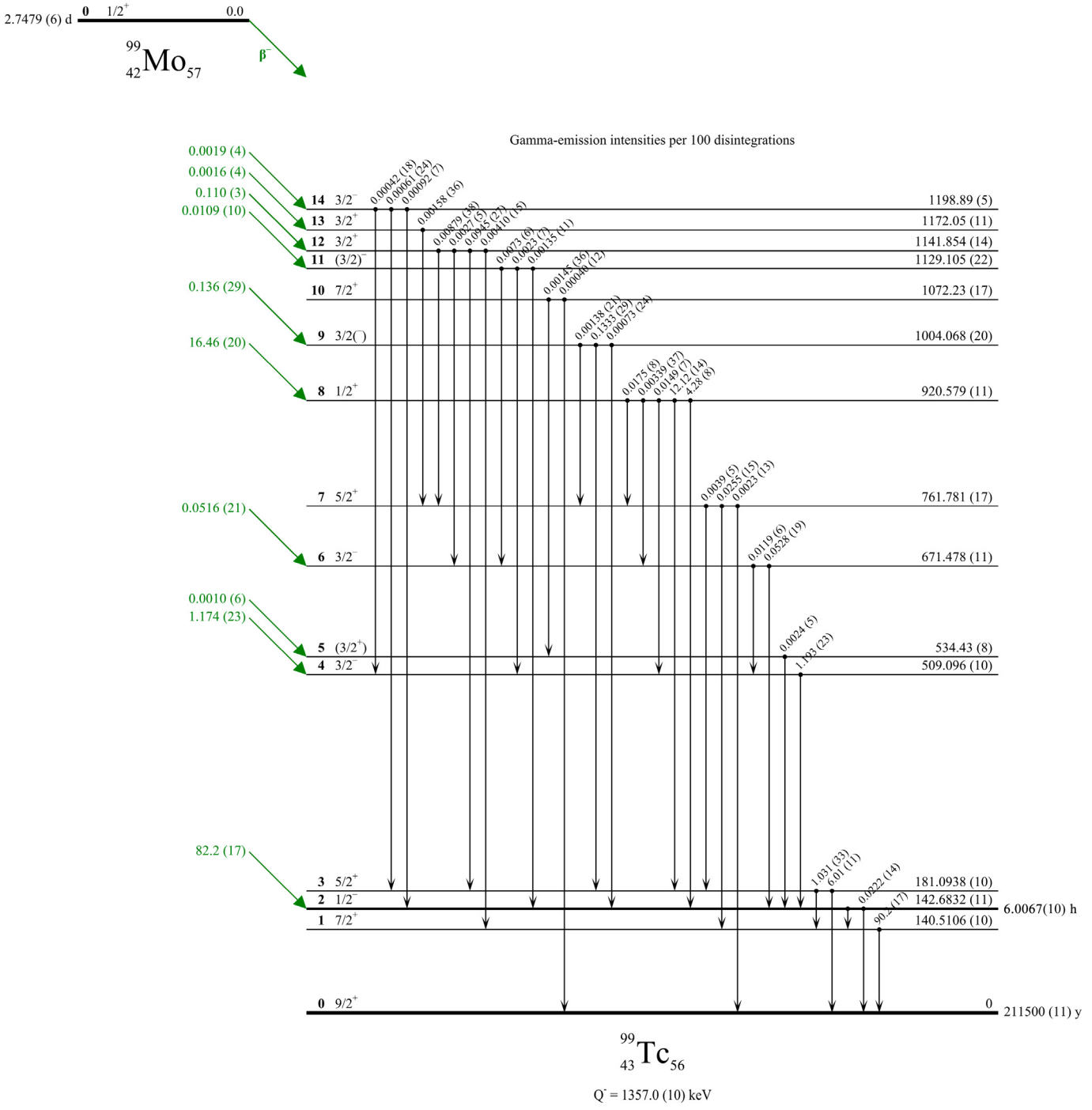

Fig. 1. ^{99}Mo/^{99m}Tc decay scheme.

paper the new recommended values are given for the main decay characteristics of ^{99}Mo/^{99m}Tc and re-evaluated decay data are discussed.

2. Radioactive equilibrium: General remarks

Radioactive equilibrium of two (or more) radionuclides composing a radioactive series is achieved when the half-life of the daughter (T_2) is shorter than that of the parent (T_1). At equilibrium, the ratio of the number of daughter atoms to that of parent atoms and then the ratio of their activities (A_2/A_1) is approximately constant. Strictly speaking, the exact radioactive equilibrium ($A_2/A_1 = T_1/(T_1 - T_2) = \text{const}$) is achieved only to infinity ($t \to \infty$) ($t = 0$ corresponds to the pure parent radionuclide): $A_2/A_1 = [T_1/(T_1 - T_2)] \times \{1 - \exp[-0.693\ (1/T_2 - 1/T_1)\ t]\}$. However, if $T_1 > T_2$, the second factor in this expression is close to unity after several half-lives of the daughter. Generally, equilibrium is considered to be established approximately by $10T_2$.