The Nilsson-Potential Parameters for Neutrons at $A \approx 100$ and New Deformation Values for $^{103}$Mo and $^{105}$Mo

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The half-lives of the first excited levels in odd-neutron nuclei $^{103}$Mo and $^{105}$Mo have been measured. From these data, values of the deformation parameter of $\varepsilon=0.31 \pm 0.05$ and $0.29 \pm 0.06$ for $^{103}$Mo and $^{105}$Mo, respectively, have been deduced assuming prolate spheroidal shapes. The present results in combination with previously determined properties of the ground-state bands of these nuclei are used to determine $\mu$, the magnitude of the coefficient of the $1^2$ term, in the Nilsson Hamiltonian, for the new region of deformation at $A \approx 100$.

1. Introduction

Recently rotational structures have been revealed in several odd-mass nuclei in the new region of deformation at $A \approx 100$. Thus, ground-state rotational bands in $^{103}$Mo and $^{105}$Mo have been observed [1] in the study of the $\beta^-$ decays of $^{103}$Nb and $^{105}$Nb using the fission-product separators JOSEF and LOHENGRIN. The properties of these bands are in accordance with the assignment of the [411 3/2] Nilsson orbital to the 61st and the 63rd neutrons of $^{103}$Mo and $^{105}$Mo, respectively. There has been, however, the puzzle that this orbital is expected to be at the Fermi surface only for larger deformations [2] than $\beta=0.19$ and $\beta=0.24$ which were deduced [1] for $^{103}$Mo and $^{105}$Mo, respectively, from the published half-life values [3, 4] of the first excited states. Moreover, these values of the deformation parameter are smaller than those for the neighboring even-even nuclei. In order to resolve these discrepancies, measurements of the half-lives of the first excited states in $^{103}$Mo and $^{105}$Mo have been performed at JOSEF [5]. The experimental results provide information on the Nilsson-potential parameter $\mu$ for neutrons at $A \approx 100$. In the Nilsson model the $1^2$-term has been introduced to correct the curved shape of the harmonic-well potential inside the nucleus. The parameter $\mu$, which expresses the magnitude of this correction, is chosen to fit the experimental energy levels. Thus, the value of $\mu$ has been well established in the rare-earth and actinide regions, and is considered to be known for $A=25$, but little, if any, experimental information is available for the new deformed region at $A \approx 100$.

Our present results clearly remove the above-mentioned discrepancies about the deformation of $^{103}$Mo and $^{105}$Mo, and moreover, they are used to determine the value of the parameter $\mu$ for neutrons at $A \approx 100$. 
2. Half-Life Determinations

Gamma-gamma-time measurements were performed using two intrinsic Ge detectors with a surface of 19 cm² each and a Ge(Li) diode with a volume of 61 cm³. The half-lives were determined from the timing distributions of the \(\gamma-\gamma\) cascades \([1]\) of 139–103 keV and 539–103 keV for \(^{103}\text{Mo}\) and 138–95 keV and 254–95 keV for \(^{105}\text{Mo}\), see insert in Fig. 1. The centroid-shift method was applied. The positions of the centroids for prompt \(\gamma-\gamma\) cascades as a function of the \(\gamma\)-ray energies were deduced from the timing results for cascades in \(^{99}\text{Nb}\) and \(^{97}\text{Zr}\) which involve \(\gamma\)-ray energies between 56 and 1103 keV \([6, 7]\). A smooth interpolation between these experimental points was used to deduce the prompt centroids for any \(\gamma\)-ray energy. The uncertainty which may arise from this procedure is estimated to be less than 0.16 ns.

For each \(\gamma\)-ray cascade which was used for the half-life determination a pair of centroid positions was obtained since both \(\gamma\) rays were used to start or stop the time-to-amplitude converter. The difference of these positions is equal to twice the mean life of the investigated state if the energy dependence of the timing distributions has been taken into consideration. An example of the data we obtained is shown in Fig. 1.

The results of the half-life determinations are compiled in Table 1 together with the values simultaneously obtained for the 0+ and 2+ levels of \(^{106}\text{Mo}\) and \(^{104}\text{Mo}\), respectively. The given uncertainties (1 standard deviation) represent the statistical ones and a possible systematic error from the positions of the prompt centroids. Good agreement with the published half-life values is obtained for even-even Mo isotopes. However, the half-life of the 102.6 keV level in \(^{103}\text{Mo}\) is much shorter than the value of \([3]\), where a contamination through the half-lives of higher-lying levels may have occurred \([1]\). For \(^{105}\text{Mo}\), the present result is smaller than the value given in \([4]\) but it does agree, within the experimental uncertainty, with the value given in \([3]\).

3. Discussion

3.1. Deformation and Ground-State Band Properties of \(^{103}\text{Mo}\) and \(^{105}\text{Mo}\)

The new values for the half-life of the first excited states indicate larger deformation of \(^{103}\text{Mo}\) and \(^{105}\text{Mo}\) than reported before \([1]\). The values of the electromagnetic properties deduced by us are compiled in Table 2. The magnitude and the sign of \((g_K - g_R)/Q_0\) have been obtained from the relative intensities of the intraband transitions and the angular correlation coefficients, respectively \([1]\). By combining this ratio and the new value of the half-life, the values of \(B(E2)\) and \(B(M1)\) for the 102.6 keV and 94.8 keV transitions in \(^{103}\text{Mo}\) and \(^{105}\text{Mo}\), respectively, have been deduced. The intrinsic properties \(Q_0, (e)\) and \(g_K - g_R\) have been obtained from the \(B(E2)\) and \(B(M1)\) values, respectively, using the rotational-model formulae.

![Fig. 1a and b. Time distributions of delayed coincidences showing the difference between a centroid for a combination of starting and stopping \(\gamma\) rays and the one for the reversed combination (1 ch. = 4.65 ns); a for the 139–103 keV cascade in \(^{103}\text{Mo}\) and b for the 138–95 keV cascade in \(^{105}\text{Mo}\)](image-url)