Band structure of ^{109,111}Tc isotopes

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Introduction

The study of neutron rich nuclei in A~100 region has been at the forefront of nuclear structure research due to existence of both the spherical and deformed shapes. The intrinsic configurations such as shape coexistence, and shape transitions in the neutron-rich nuclei with Z>40, N>58 have drawn much attention in the past. In the nuclei lying in the A~100 mass region, it has been found that proton orbitals originating from the $\pi g_{9/2}$ subshell closest to the fermi level are affected in special nuclear shapes (β_2) [1]. Neutron states from the $\nu h_{11/2}$ subshell strongly drive nuclei in this region to prolate deformation, since the neutron fermi level is below or near the bottom of the $\nu h_{11/2}$ subshell. The neutron-rich Tc isotopes with Z = 43 lie in this region with active Z = 38, 40 and N = 56 subshell closures. The shape of these nuclei is strongly affected by the presence of these subshell closures. The existence of such interesting nuclear structure properties in Tc isotopes has attracted various research groups and moreover, with the development in experimental techniques, a large amount of experimental data has been made available for these isotopes to test the theoretical models.

The main goal of the present research work is to investigate, in a phenomenological way, the structure of ^{109,111}Tc nuclei employing the quantum-mechanical framework known as Projected Shell Model (PSM), which can well describe the properties of deformed nuclei including energy levels, prediction of back-bending, signature splitting [2,3]. Here, we have presented the results on band structure, yrast spectra, and back-bending.

Outline of the Framework

In PSM [4], the rotationally invariant Hamiltonian is taken to be

$$\hat{H} = \hat{H}_0 - \frac{\chi}{2}\sum_{\mu} \hat{Q}^{\dagger}_{\mu}\hat{Q}_{\mu} - G_M \hat{P}^{\dagger}\hat{P} - G_Q \sum_{\mu} \hat{P}^{\dagger}_{\mu}\hat{P}_{\mu}$$

where the first term is the spherical single-particle energy and the remaining terms are quadrupole-quadrupole, monopole pairing, and quadrupole pairing interactions, respectively.

Further, the QQ-force strength χ is determined such that it holds a self-consistent relation with the quadrupole deformation. The hexadecapole deformation, ε_4, has also been included in the mean-field Nilsson potential to reproduce experimental energies correctly. The deformation parameters, ε_2 and ε_4, used in the present calculations are listed in Table 1.

The monopole pairing strength G_M is adjusted to give the known energy gaps and is of the form

$$G_M = (G_1 \mp G_2 \frac{N-Z}{A})\frac{1}{A}(MeV)$$

with '-' for neutrons and '+' for protons. Here, G_1 and G_2 are the coupling constants which are adjusted to yield the known odd-even mass differences and in the present calculations, these are taken as 19.70 and 10.00, respectively. The quadrupole pairing strength G_Q is assumed to be proportional to G_M, with the proportionality constant being fixed to be 0.16 for the nucleus considered in the present work. In these calculations, the configuration space consists of the three major shells for each kind of nucleon: N = 2, 3 and 4, for protons and N = 3, 4 and 5 for neutrons and to truncate the valence space, an energy window of 3.5 MeV is chosen around the Fermi surface. The present calculations are carried out with the same set of input parameters for all the isotopes under study.

Results and Discussions

Some nuclear structure properties such as band structure, yrast spectra and back-bending for ^{109,111}Tc nuclei have been calculated and are compared with the available experimental data. The calculated data for various nuclear structure properties are found to be in good agreement with the corresponding experimental data.

From the results of the calculations, it is found that:

- The experimental yrast states are very well reproduced by the present PSM calculations.
- From the band diagrams, one can see that the yrast spectra at lower spins is formed by 1-qp bands and for higher spins, the yrast spectra arises as a result of contribution from various 3-qp bands.
- For ^{109}Tc and ^{111}Tc, in Figs. 3(a) and 3(b) respectively, both theoretical and experimental result show up-bendings at spin $I = 25/2^+$, but the theoretical one is not as sharp as experimental trend. This may be due to the limitation of present configuration space that does not contain 3-proton qp states.

Table 1

Parameters ε_2 and ε_4 used in calculations

	^{109}Tc	^{111}Tc
ε_2	0.279	0.287
ε_4	0.027	0.000

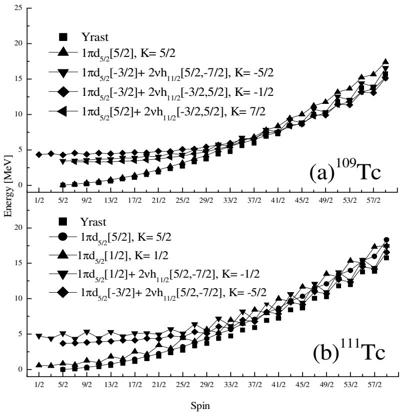

Fig. 1 Band diagrams of (a) ^{109}Tc and (b) ^{111}Tc.

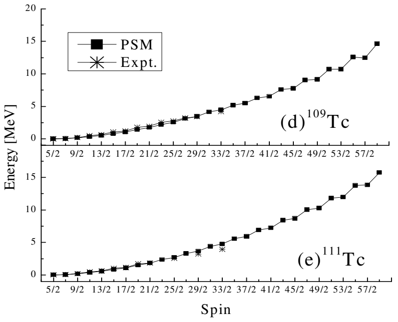

Fig. 2 Calculated positive-parity yrast band energies (PSM) in comparison with the available experimental data for (a) ^{109}Tc and (b) ^{111}Tc. The experimental data are taken from Refs.5 and6.

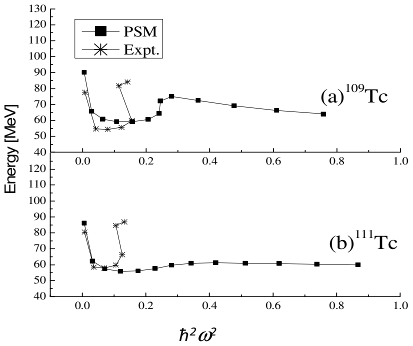

Fig. 3 The PSM results for twice the kinetic moment of inertia $[2\Im^{(1)}(\hbar^2\mathrm{MeV}^{-1})]$ plotted against the angular frequency squared $(\hbar^2\omega^2)$ for (a) ^{109}Tc and (b) ^{111}Tc. The experimental data [5,6] are also shown for comparison.

References

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