Nuclear shape evolution near $Z = 82$

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Introduction

The stable Hg and Tl nuclei with proton number around the heaviest known proton and neutron shell closures at $Z = 82$ and $N = 126$ are spherical in shape. This spherical symmetry is broken for the lighter isotopes when the neutron Fermi level lies close to the $\nu i_{13/2}$ orbital away from the shell closure. The high-j neutron and the high-j proton orbitals ($\pi h_{9/2}$ and $\nu i_{13/2}$) play important roles in determining the shape of the neutron deficient Hg and Tl nuclei. These nuclei in the A = 180 - 200 mass region develop shape coexistence, γ-softness and triaxiality. The interplay of single-particle and collective degrees of freedom induces several interesting phenomena in such nuclei, *e.g.*, magnetic rotation and chirality. Therefore, to make a prediction and to interpret the data on these nuclei, it is important to calculate the nuclear shape and wave function for different quasi-particle configurations.

In this work we performed the model calculations to study the effect of single particle orbitals on the nuclear shape for different configurations, systematically as a function of neutron Fermi level, excitation energy and angular momenta.

Theoretical background

The total Routhian surface (TRS) calculations were performed for the odd-A Hg and Tl isotopes in the mass region A = 180-200. The quasiparticle energies have been calculated using deformed Woods-Saxon potential with BCS pairing & the total energies are calculated using the Strutinsky shell correction method. The TRSs were calculated for several values of the deformation parameters β_2, γ and β_4 at different rotational frequency $\hbar\omega$. The β_2 and γ values corresponding to the minimum of the TRS have taken as the deformation of a nucleus. The TRS code of Nazarewicz *et al.*[1, 2] was used for the calculations. In this code $\gamma = 0°$ correspond to a prolate shape where as $\gamma = \pm 60°$ corresponds to an oblate shape. Any intermediate values of γ correspond to a triaxial shape. The detailed procedure has been described in Refs. [3, 4].

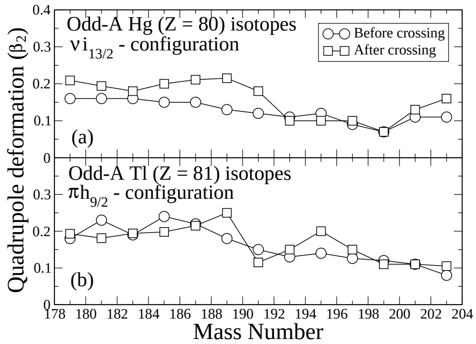

FIG. 1: Variation of β_2 with mass number, as obtained from the TRS calculations, for odd-A Hg (upper panel) and Tl (lower panel) isotopes.

Results and Discussion

TRS calculations for odd-A Hg and odd-A Tl isotopes were performed. In case of Hg isotopes the odd-neutron was kept in the positive-parity, positive signature state corresponding to the $\nu i_{13/2}$ configuration where as for Tl isotopes the odd-proton was in the negative-parity positive signature, corresponding to the $\pi h_{9/2}$ configuration. The calculated values of β_2 & γ are shown in Fig. 1 &

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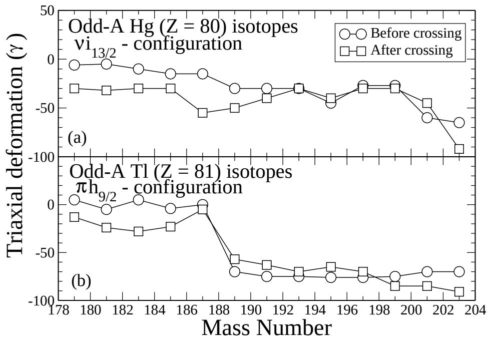

FIG. 2: Variation of γ with mass number, as obtained from the TRS calculations, for odd-A Hg (upper panel) and Tl (lower panel) isotopes.

Fig. 2, respectively, as a function of the mass number for Hg & Tl isotopes. The calculations were done for both before & after the neutron alignment frequencies. The calculated crossing frequencies for odd-A Hg and odd-A Tl isotopes are shown in Fig. 3. From Fig. 1 it is observed that the quadrupole deformation (β_2) decreases, for both the Hg & Tl isotopes, with increase in neutron number, *i.e.* as the neutron number approaches towards the neutron close shell $N = 126$. The calculated deformation, after the crossing frequency, increases for $^{187-191}$Hg & ^{189}Tl isotopes. Interestingly, ^{201,203}Hg isotopes shows a little enhancement in β_2 for both before and after crossing.

From Fig. 2 it is evident that the nuclear shapes of odd-A Hg and Tl isotopes are changing from near prolate to near oblate through intermediate triaxial shapes as one goes from lighter to heavier isotopes. Before crossing, lighter odd-A Hg & Tl isotopes $^{179-187}$ remains near prolate shape which possibly due the presence of $N = 106$ neutron shell gap which restrict the shape driving effect. Further increase in neutron number, *i.e.* beyond mass number $A = 187$ the shape changes to near oblate shape (Tl isotopes) via intermediate triaxial shape (Hg isotopes).

From the calculations after the crossing frequency, lighter isotopes of Hg & Tl (for A = 179-185) show triaxial behaviour. A triaxial nuclear shape is a necessary condition for the realization on nuclear chirality. Therefore, lighter Hg & Tl isotopes might be possible candidates for nuclear chirality. Mercury isotopes for A = 187-191 shows a shape driving effect beyond $N = 106$ shell gap towards near oblate shape. Heavier isotopes of Hg (A = 193-203) show triaxial shapes followed by near oblate. Similarly, for heavier Tl isotopes (A = 189-203) the shape driving effect is stronger and the nuclear shape remains near oblate. This may be due the strong effect of intruder $\pi h_{9/2}$ orbital.

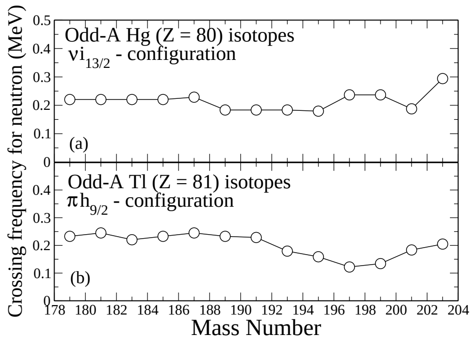

FIG. 3: Variation of crossing frequency (ω_c), for neutrons, with mass number, as obtained from the single particle Routhian calculations, for odd-A Hg (upper panel) and Tl (lower panel) isotopes.

The results obtained from both TRS and crossing frequency calculations would be discussed, in light of the alignment and hence the nuclear shape change for different nuclei, during the presentation.

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References

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