Collectivity and isomeric states in Hg isotopes

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Introduction

The Hg isotopes serve as some of the key examples to study various structural properties like shape coexistence, shape staggering and deformations, etc. [1]. The lighter Hg isotopes are dominated by such effects due to the interplay between normal and intruder configurations, while in the heavier Hg isotopes ($A \geq 190$), the mixing between these configurations is significantly reduced. The recent experiments have largely focused on studying the collective properties in the heavier Hg isotopes. The reduced transition strengths between various states are measured from the lifetimes studies using $\gamma - \gamma$ spectroscopy [2] and GRIFFIN spectrometer [3]. The high spin states and the half-lives of the isomeric states were measured in [4].

On the theoretical side, these isotopes are addressed through the Interacting Boson Model (IBM) [1]. The shell model (SM) has been exceptionally successful in describing the nuclear observables from the underlying NN interaction across the entire nuclear chart [5, 6]. The SM studies in this region are avoided because of the computational challenges associated with the large-scale shell model diagonalization. However, with the advancement of computational facilities, SM calculations can be performed by applying suitable truncation on the model space. With the availability of numerous experimental data, we aim to provide a theoretical estimate of these measured observables using SM formalism. We have performed an in-depth analysis of various nuclear properties, such as the low-energy excitation spectrum, reduced transition strengths, quadrupole, and magnetic moments of the Hg isotopes. The lifetimes of the isomeric states recently measured in [4] are calculated from SM. The results are compared with the corresponding experimental data. We have also calculated these structure properties where the experimental data are not available yet.

The Hg nuclei were studied in the model space with Z$\leq$ 82 and N$\leq$ 126 above the $^{132}_{50}$Sn core using KHHE interaction. The SM calculations in the complete model space are beyond the reach of conventional shell model diagonalization techniques. Hence, the SM calculations were carried out by applying suitable truncation in the model space.

Results and Discussion

The order of positive and negative parity yrast states are well reproduced in the SM results. The calculated energy differences among the yrast states fairly agree with the experimental data. We found that the high spin states are observed at slightly lower energies than the corresponding measured values. As an example, we have shown the low-energy excitation spectra of ^{198}Hg in Fig. 1 and presented a discussion on it. In the ^{198}Hg shell-model calculation, we have completely filled $\nu h_{9/2}$ orbital. The spin-parity of the state appearing at 1.548 MeV is not confirmed in ^{198}Hg, with experimental predictions as either 1^+ or 2^+. From the SM calculated spectra, this state may be associated with the 2^+_3 state since the computed 1^+_1 and 2^+_3 states appeared at 1.624 and 1.530 MeV, respectively. Similar spin-parity predictions are made in other cases where experimental spin-parities lack confirmation. The energy systematics of both positive and negative parity states are studied along the Hg chain. The calculated results follow the same behavior as the measured ones

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and imply $\nu i_{13/2}$ sub-shell closure at ^{200}Hg.

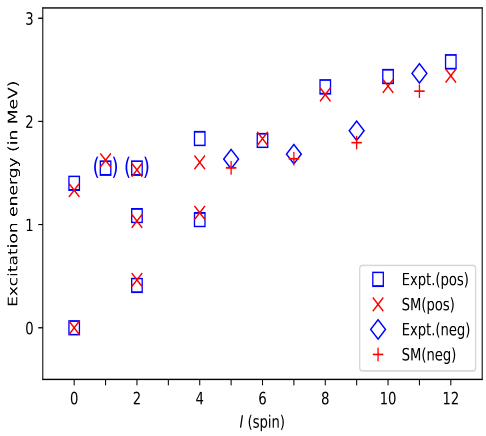

FIG. 1: Comparison between calculated and experimental energy levels for ^{198}Hg.

The collective properties of the Hg isotopes were studied by calculating the reduced $E2$ strengths, quadrupole, and magnetic moments of various states. The experimental $B(E2; 2_1^+ \rightarrow 0_1^+)$ values are 28(4) and 26(2) W.u. in ^{198,200}Hg while the SM calculated values are very close to it i.e., 26.9 and 24.3 W.u., respectively. The $E2$ strengths are calculated for a wide range of transitions involving both low and high-spin yrast states. These SM results are in reasonable agreement with the experimental data.

TABLE I: The calculated half-life ($T_{1/2}$) of metastable states of ^{198}Hg in comparison with the experimental data.

Nucleus	J^π	Expt. $T_{1/2}$	SM $T_{1/2}$
^{198}Hg	7_1^-	0.28(5) ns	0.3 ns
	9_1^-	6.9(2) ns	7.9 ns
	10_1^-	1.92(9) ns	3.3 ns
	12_1^-	1.38(4) ns	1.5 ns

The 7_1^-, 9_1^-, 10_1^+, and 12_1^+ states show isomeric nature in the heavier Hg isotopes. From SM, these states arise from a large mixing of all possible configurations in the model space. The calculated half-lives ($T_{1/2}$) of these isomeric states lie very close to the measured values. Table - I compares the calculated half-lives of the isomeric states of ^{198}Hg with the corresponding experimental data. Additionally, we have predicted the $T_{1/2}$ of these isomeric states for Hg isotopes where the experimental measurements face technical difficulties.

The experimental data on quadrupole (Q) and magnetic moments (μ) for Hg isotopes in this region are limited. We have computed the Q and μ values for both low-lying states and isomeric states. The SM results agree well with the available experimental data, and our predicted results will be beneficial for comparison with future experimental data. The evolutions of the above nuclear observables are studied along the chain with their physical implications. All the concerned data for the Hg chain will be presented at the conference.

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