Isomers in ^{130}Cd and ^{206}Hg

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Introduction

Existence of isomers across the full nuclear landscape provides us a unique probe to explore the nuclear structural peculiarities [1]. Many systematic features have been observed and explained by us in semi-magic nuclei using the generalized seniority approach [2]. As a result, we could establish a new kind of seniority isomers [2]. Seniority isomers may work as a stepping stone in to the unexplored regions near the nuclear drip-lines. For example, the 6^+ isomers beyond ^{132}Sn were studied by us by using the large scale shell model (LSSM) calculations, where we were forced to modify the realistic effective interaction to explain the seniority mixing in ^{136}Sn [3].

In this paper, we study the 8^+ isomer in ^{130}Cd (Z=48 and N=82), known to be arising from pure seniority $g_{9/2}^{-2}$ (two proton holes). We further compare it to the 10^+ isomer in ^{206}Hg (Z=80 and N=126), known to be arising from pure seniority $h_{11/2}^{-2}$ (two proton holes). Both the isomers result as the maximally aligned states from their respective dominant orbital. The new information in this region is limited due to the difficulties in populating large angular momenta for the neutron-rich nuclei.

We present LSSM calculations and the results in the following sections, for the 8^+ isomer in ^{130}Cd and the 10^+ isomer in ^{206}Hg. The calculated excitation energies are found to be over/under estimating the experimental data without modifying the realistic interactions. The experimental and calculated B(E2) values come out to be in order, and remain unaltered after the said marginal modification since there is no chance of seniority mixing in these yrast states.

Shell model calculations

We have used the NUSHELL code of Brown et al.[4] for LSSM calculations. The used realistic interactions for both ^{130}Cd and ^{206}Hg are derived from the Charge Dependent Bonn potential through the renormalized G matrix method of Hjorth-Jensen; all the details are given in ref. [5]. The interaction "jj45pna" used for ^{130}Cd assumes the doubly closed Z=28, N=50, ^{78}Ni as a core. The active valence space (Z=28-50) consists of four proton [$1f_{5/2}$, $2p_{3/2}$, $2p_{1/2}$, $1g_{9/2}$] orbitals having their single-particle energies as -0.7166, 1.1184, 1.1262, 0.1785 MeV, respectively. On the other hand, the interaction "cwg" used for ^{206}Hg assumes Z = 50, N = 82, ^{132}Sn as an inert core. The valence space (Z=50-82) consists of five proton [$1g_{7/2}$, $2d_{5/2}$, $2d_{3/2}$, $3s_{1/2}$, $1h_{11/2}$] orbitals with their single-particle energies as -9.6630, -8.7010, -6.9950, -7.3230, -6.8700 MeV, respectively. The harmonic oscillator potential is chosen with an oscillator parameter $\hbar\omega = 45A^{-1/3} - 25A^{-2/3}$. The effective charges of protons and neutrons are taken as 1.5 and 0.5, respectively, for calculating the B(E2) values in both the cases.

Results

Fig. 1 shows the shell model calculated level energies for ^{130}Cd with the experimental data. We can see that the 2^+ to 8^+ states have been overestimated by the calculations. However, the calculated ratio $E(4^+)/E(2^+)$ of 1.377 matches quite well with the experimental value of 1.406. This highlights that the energy band is not collective in nature. It is mainly based on the single-particle structure arising from pure $\Pi g_{9/2}^{-2}$ (seniority =2) configuration.

The E2 decay energy for the 8^+ state is low and gives rise to long half-life, i.e. the isomeric nature. The experimental and calculated E2 decay energies are of similar order as 135 and 145 keV respectively. The experimental [6] and calculated B(E2) values come out to be 50 and 46 e^2fm^4, respectively. The matching of level energies can be achieved if we increase the two-body diagonal matrix elements of $\Pi g_{9/2}^{-2}$ by 100 keV only; results will be shown in the full paper.

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Besides, the 8^+ isomer in ^{128}Pd (the last known even-even N=82 nucleus below ^{132}Sn) may also be understood by similar analogy. The half-life of the 8^+ isomer in ^{128}Pd is larger than ^{130}Cd [7], as expected from the seniority scheme. No evidence for N=82 shell quenching is found in ^{130}Cd. The seniority scheme predicts the 8^+ isomer in lighter isotopes till Z=42 (with N=82), if accessible in future. Melting of the N=82 shell closure below ^{132}Sn can only be addressed when lighter waiting-point nuclei become accessible in future.

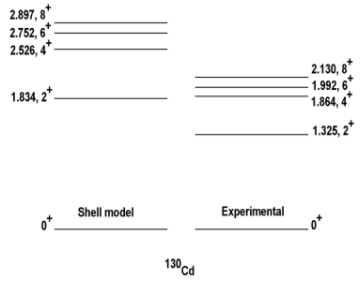

Fig. 1 Calculated and Exp.[7] level energies for ^{130}Cd.

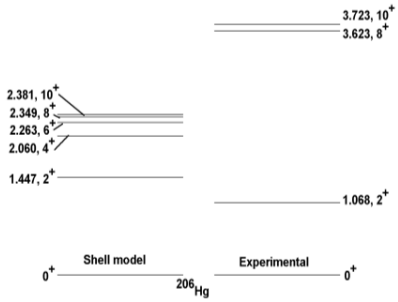

Fig. 2 Same as Fig.1, but for ^{206}Hg.

We plot the shell model calculated and the experimental level energies for ^{206}Hg in Fig. 2, where we see that the calculated 2^+ state is overestimated by 379 keV, while the 8^+ and 10^+ states are underestimated by more than 1 MeV. The remaining 4^+ and 6^+ states are still not known experimentally. The calculated ratio $E(4^+)/E(2^+)$ of 1.423 again suggests a single-particle structure of this band. The calculated E2 decay energy for the 10^+ state is estimated very low if compared to the experimental value (100 keV). The experimental [7] and calculated B(E2) values for this isomer are nearly in order as 72 and 62 e^2fm^4 , respectively. However, the reduction in the two-body diagonal matrix elements of $\Pi h_{11/2}^{-2}$ by 100 keV brings up the calculated level energies closer to the experimental data, which will be discussed in the upcoming full paper. The B(E2) values in both the cases remain unaltered after the modification due to no chance of seniority mixing.

Conclusion

The maximally aligned 8^+ and 10^+ isomers have been studied as seniority=2 isomers in ^{130}Cd and ^{206}Hg, respectively. LSSM calculations have been used to understand their origin and the related nuclear structural properties. We can further use these studies to answer the question, "how far can the seniority scheme be stretched away from semi-magic nuclei?" Complete work is in progress and will be reported soon.

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