Structural evolution of proton-hole Indium nuclei

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Introduction

The nucleus as a unique many-body system possesses a rich variety of quantum-mechanical excitations. Important factors in the determination of the nuclear structure results from the competition between the single particle and collective degrees of freedom. The single-particle structure that exists for spherical nuclei near closed shells gives way to more collective rotational structure for deformed nuclei that have a large number of valence nucleons outside closed shells. Such nuclei with Z ~ 50 and N ≥ 50 are of great interest because of the several shape transitions which occur in the A ~ 100 mass region. Different types of deformation (e.g. prolate, oblate, triaxial) are observed and can coexist in a same nucleus in accordance with the underlying interplay between orbitals. For Z ≥ 44, the active intruder orbitals are near the top of the $\pi g_{9/2}$ subshell [1], which drives shapes towards oblate deformation. On the other hand, when the neutron Fermi level lies below or near the bottom of the $\nu h_{11/2}$ subshell, the shape is driven towards the prolate deformation. Thus, the shape of the nuclei lying in this region is not determined by the proton or neutron orbital only but also by the interplay or interaction between these orbitals. Hence, with this motive in mind, the present work has been mainly focused on studying the interplay between the proton and neutron orbitals in evaluating the structure of some odd-mass ^{117,119}In nuclei.

In recent years, great effort has been made in identification and theoretical interpretation of rotational bands in the *A* ~ 100 mass regions. This mass region is well known for its complicated interplay between single-particle and collective degrees of freedom. Spherical structures coexist with more deformed shapes associated with the proton intruder $g_{9/2}$ orbital [2]. In order to explain the structure of nuclei around Z~50, an attempt has been made in the present work to elucidate the structure of odd-mass ^{117,119}In (Z = 49) nuclei in the PSM and the present PSM calculations have been found to explain most of the experimental observation quite successfully in ^{117,119}In nuclei.

The Theory of the Applied Model

To carry out the nuclear structure calculations for ^{117,119}In nuclei, Projected Shell Model [3,4] is employed, which is the modified form of the shell model approach. However, unlike the conventional shell model, the PSM begins with the deformed (Nilsson-type) single particle basis. Such a shell model basis violates the rotational symmetry, but it can be restored by the standard angular-momentum projection technique. In this section, we are giving a brief introduction of the PSM. The total Hamiltonian is of the form

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

where, H_o represents the spherical single particle Shell Model Hamiltonian, 2nd, 3rd and 4th terms in the Hamiltonian denote the two-body interactions: quadrupole-quadrupole, monopole-pairing and quadrupole-pairing forces, respectively. χ denotes the Q.Q force strength and its value is adjusted via self-consistent conditions with a given quadrupole deformation ε_2. The choice of the strengths G_1 and G_2 depends on the size of the single particle gaps in the calculations. The quadrupole pairing strength, G_Q, is supposed to be proportional to G_M and is adjusted to be 0.16. For the present calculations, pairing strengths G_1 and G_2 are adjusted as 22.50 and 12.12 respectively. The other set of deformation parameters, quadrupole (ε_2) and hexadecapole (ε_4) are set as 0.210 and 0.000 and 0.200 and 0.000 for ^{117,119}In nuclei, respectively.

Results and Discussions

To extract structural information from the PSM calculations, it is useful to discuss the energies in terms of band diagram. Also, band diagram plays a crucial role for the interpretation of the yrast states, which is the lowest band and is obtained after configuration mixing of various multi quasi-particle configurations. In the present study, the yrast levels and their composition i.e., band structures from multi-quasi-particle configurations for ^{117,119}In nuclei have been investigated.

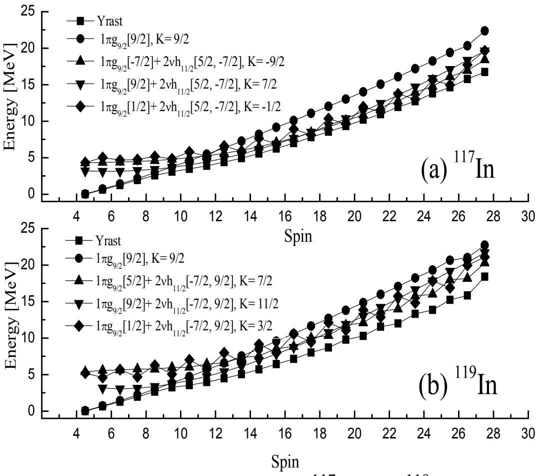

Fig. 1 Band diagrams of (a) ^{117}In, (b) ^{119}In

For ^{117}In isotope (fig. 1(a)), the yrast band arises from a 1-*qp* band having configuration $1\pi g_{9/2}[9/2]$, $K = 9/2$ up to spin $17/2^+$. At the next spin i.e.$19/2^+$, this band is crossed by another 3-*qp* band $1\pi g_{9/2}\,[9/2] + 2\upsilon h_{11/2}[5/2,\ -7/2]$, $K = 7/2$ which forms the yrast band up to spin $31/2^+$. At this spin, this band gets superimposed by two more 3-*qp* bands identified as: $1\pi g_{9/2}[1/2] + 2\upsilon h_{11/2}[5/2,\ -7/2]$, $K = -1/2$ and $1\pi g_{9/2}[-7/2] + 2\upsilon h_{11/2}[5/2,\ -7/2]$, $K = -9/2$ and this set of superimposed 3-*qp* bands then altogether contributes to the formation of yrast spectra for all the next calculated spins. Finally, in case of ^{119}In (fig. 1(b)), upto the spin $17/2^+$, the yrast spectra arises from 1-*qp* band identified as $1\pi g_{9/2}[9/2]$, $K = 9/2$. At the next spin i.e. $19/2^+$, there occurs a band crossing and the above mentioned 1-*qp* band is crossed by a 3-*qp* band having configuration $1\pi g_{9/2}[9/2] + 2\upsilon h_{11/2}\,[-7/2,\ 9/2]$, $K = 11/2$ and contributes to the formation of yrast band upto the spin value of $35/2^+$. At the next spin, above mentioned 3-*qp* band moves higher in energy and two superimposed 3-*qp* bands with configurations: $1\pi g_{9/2}[5/2] + 2\upsilon h_{11/2}\,[-7/2,\ 9/2]$, $K = 7/2$, $1\pi g_{9/2}[1/2] + 2\upsilon h_{11/2}\,[-7/2,\ 9/2]$, $K = 3/2$ move lower in energy and their mixture contributes to the formation of yrast band upto the last calculated spin. Furthermore, Fig. 1(b) presents the yrast spectra of ^{117,119}In. The experimental data (taken from Ref.[5]) has been reproduced with an overall good agreement by the calculated values of energy for ^{117,119}In.

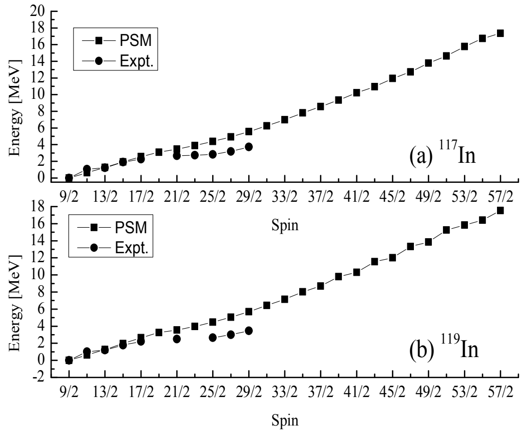

Fig. 2 Comparison of the Experimental and PSM yrast spectra for (a) ^{117}In, (b) ^{119}In

Summary

The neutron rich ^{117,119}In nuclei have been studied within a theoretical microscopic technique-Projected Shell Model. The composition of the yrast levels from various multi-quasi-particle configurations for ^{117,119}In nuclei has been well described. Further, the comparison of the yrast levels with the available experimental data has also been made and a good level of agreement has been obtained. Also, the reduced electromagnetic transition probabilities, $B(E2)$ and $B(M1)$, for yrast states are also predicted for various transitions in these In isotopes for which there is no experimental data available and this data would be presented at the time of presentation in the symposium.

References

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