Theoretical study of band structure of odd-odd ^{96}Rb isotope

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Introduction

The region of neutron-rich nuclei with A~100 is characterized by a sudden transition from spherical to deformed nuclear shapes at N = 59. The study of excited states of neutron-rich nuclei helps to test the nuclear structure models for nuclei far from stability. In the recent years, the newly developed experimental facilities have allowed to study the doubly-odd neutron excess nuclei. With these experimental techniques, the effect of addition of excess of neutrons to the magic nuclei on nuclear structure properties of the doubly odd nuclei has also been investigated. Doubly odd nuclei are unique candidates to study proton-neutron coupling schemes, proton-neutron interactions and for the investigation of phenomena such as the delay in the band crossing frequency due to the possibility of performing double-blocking experiments [1]. Another remarkable effect that has been observed in odd-odd nuclei is signature inversion which also makes these nuclei quite interesting to study. The occurrence of this phenomenon has been found in bands of high *j* origin throughout the chart of nuclides. The experimental as well as theoretical investigations on the Rb nuclei lying in the mass region A~100 are quite attention-grabbing as the valence neutrons lie in the neighbourhood of *N*~56 spherical sub-shell gap, thereby, offering a wide view-point to study the role of proton-neutron correlations. For Z < 38 nuclei, ^{78}Ni, which is doubly magic nucleus, can be considered as best core for describing the nuclear structure of these set of nuclei within the context of single particle deformed Nilsson potential. Such deformed Nilsson basis can be then used to predict various nuclear structure properties of exotic nuclei lying in the vicinity of ^{78}Ni core. In particular, for the even-even ^{38}Sr and ^{40}Zr isotopes, a sudden onset of strong deformation is observed at N = 60, whereas lighter isotopes upto N = 58 are rather spherical and the isotones with N = 59 neutrons are of special interest because they are just at the border of the two regions. Previous experiments have shown that their ground and low-lying states are rather spherical, whereas deformed state appears at ~500 keV as shown for ^{96}Rb [2]. Thus, the present study is devoted to investigate the yrast structure and various other nuclear structure properties related to yrast line of the doubly-odd ^{96}Rb nucleus by employing a quantum mechanical phenomenological framework- Projected Shell Model (PSM).

The Theory

The detailed description of applied framework Projected Shell Model (PSM) can be found in a review article [3]. Projected Shell Model is the natural extension of the Shell Model, which basically begins with the deformed Nilsson single-particle states at a deformation ε_2. It uses angular-momentum projection technique in order to project out energies from the deformed Nilsson basis and hence makes Shell Model type of calculations possible for deformed nuclei. Pairing correlations are incorporated into the Nilsson states by BCS calculations. Finally, a two-body Shell Model Hamiltonian is diagonalized in the projected basis, thereby, obtaining the yrast energy levels for a given spin. A brief account on the Hamiltonian along with the important input parameters used in the present calculations is given hereunder. The Hamiltonian used for the present PSM calculations is

$$\hat{H} = \mathrm{H}_{o} - \frac{1}{2}\chi\sum_{\mu} \hat{Q}^{\dagger}_{\mu}\hat{Q}_{\mu} - G_{M}\hat{P}^{\dagger}\hat{P} - G_{Q}\sum_{\mu}\hat{P}^{\dagger}_{\mu}\hat{P}_{\mu}$$

where H_o represents the spherical single particle Shell Model Hamiltonian, involving spin-orbit interactions while the second, third and fourth terms represent the quadrupole-quadrupole, monopole and quadrupole pairing interactions respectively. χ denotes the strength of quadrupole-quadrupole two-body interaction and is adjusted with the quadrupole deformation parameter, ε_2. For the present set of PSM calculations, three major shells (N = 2, 3, 4) for both protons and neutrons have been used. The Shell Model space is truncated at deformation parameters, $\varepsilon_2 \sim -0.122$ and $\varepsilon_4 \sim -0.048$ for ^{96}Rb nucleus.

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 doubly-odd ^{96}Rb nucleus have been investigated.

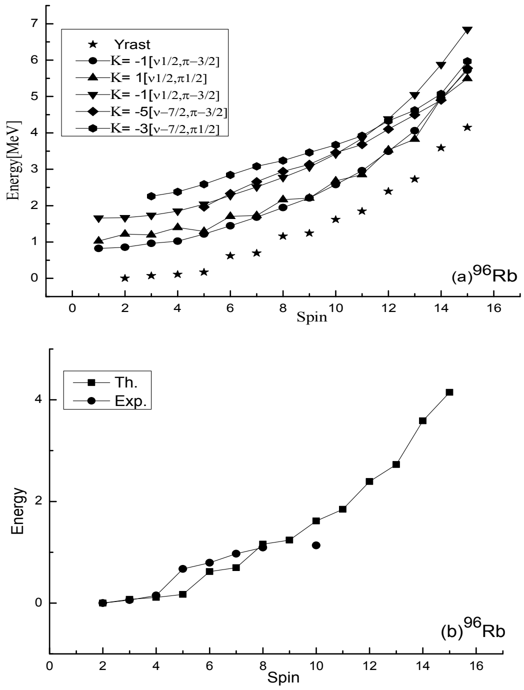

Fig. 1 (a) Band diagram of ^{96}Rb (b) Yrast energy states of the ^{96}Rb nucleus.

From Fig. 1(a), the low lying yrast band has been obtained from the two 2-qp bands with configurations K = -1[ν1/2, π-3/2] and K = 1[ν1/2, π1/2]. At spin 14$^-$, a set of another two bands with K = -5[ν-7/2, π-3/2] and K = -3[ν-7/2, π1/2] gets mixed with the above cited two 2-qp bands and hence result in the yrast formation upto the last calculated spin. Furthermore, Fig. 1(b) presents the yrast spectra of ^{96}Rb. The experimental data (taken from Ref.[4]) has been reproduced with an overall good agreement by the calculated values of energy for ^{96}Rb. The energy differences (E[I]-E[I-1]) between the adjacent spin states and moment of inertia have also been compared with the measured value for ^{96}Rb isotope and are shown in Figs. 2(a) and 2(b) respectively. The figures depict an overall good agreement in both form of data.

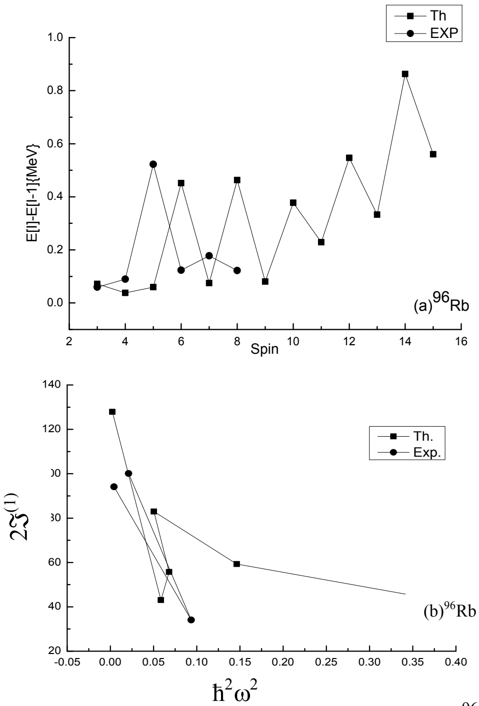

Fig. 2 (a) Transition energies versus spin plot of ^{96}Rb (b) Back-bending in moment of inertia of ^{96}Rb nucleus.

Summary

The neutron rich doubly-odd ^{96}Rb isotope has been studied within a theoretical microscopic technique-Projected Shell Model. The composition of the yrast levels from various multi-quasi-particle configurations for doubly-odd ^{96}Rb isotope has been well described. Further, the comparison of the yrast levels with the available experimental data has also been made and good level of agreement has been obtained. Also, the calculated transition energy values vary almost in a similar fashion as the experimental transition energies.

References

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