Structure of ^{152}Nd nucleus in IBM

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Introduction

The Nd isotopes lie in the region of shape phase transition from spherical ($^{144,146}Nd$) to well deformed (^{154}Nd) nuclei. Many experimental and theoretical studies were performed to organise the information about energy level spacings and transition rates of Nd isotopes [1, 2, 3]. The recent experimental data of these isotopes is available on nndc website [4]. An important aspect of nuclear structure is exposed by collective potential energy surface (PES), which shows the potential energy of a nucleus as a function of the shape parameter (β, γ) or (a_0, a_2) in quadrupole deformations. The shape parameter β is the distance of a point from the origin, it indicates the deformations and γ is the angle with the prolate axis, it measures the deviation of axial symmetry. Because of the symmetry properties we focus on $0^0 \leq \gamma \leq 60^0$. In this paper, the nuclear structure of ^{152}Nd nucleus is studied in the framework of Interacting Boson Model (IBM). The classical limit of the IBM Hamiltonian has been used to generate the PES for the ^{152}Nd nucleus.

Theory

The phenomenological IBM model was introduced by Arima and Iachello [5] was successful in describing the properties of medium and heavy mass nuclei. The IBM model was based on the assumption that the low lying collective states of even-even nuclei can be calculated by a system of interacting s-boson and d-boson having the angular momentum 0 and 2, respectively. The three symmetries of IBM are harmonic vibrator SU(5), axially symmetric deformed rotor SU(3) and the triaxial soft rotor O(6). The nuclei may show behaviour near these idealized IBM limits and now Iachello [6, 7] proposed the critical point symmetries X(5) and E(5) corresponds to the first order and the second order phase transition, respectively. The X(5) symmetry [7] is related to the critical point between the U(5) and SU(3) dynamical symmetry limits. The E(5) symmetry [6] corresponds to the phase transition region between the U(5) and O(6) dynamical symmetries. The IBM Hamiltonian for SU(3) [8] and its corresponding classical limit of can be written as:

$$SU(6) \supset SU(3) \supset O(3)$$

$$H = -\kappa_1 Q.Q - \kappa_2 L.L \tag{1}$$

$$E(\beta,\gamma) = -\kappa_1 \left[\frac{n}{1+\beta^2} \left(5 + \frac{11\beta^2}{4} \right) + \frac{n(n-1)}{(1+\beta^2)^2} \left(\frac{\beta^4}{2} + 2\sqrt{2}\beta^3 \cos(3\gamma) + 4\beta^2 \right) \right] - \kappa_2 \left[\frac{6n\beta^2}{1+\beta^2} \right] \tag{2}$$

Results and Discussion

The comparison of experimental data with theoretical results using IBM is plotted in Fig. 1 for ^{152}Nd nucleus. For ground-state energy band, the levels up to spin 12^+ are taken in the calculations. We find that the calculated data matches excellently with experimental data. For β-band, we have further measured the levels up to spin 4^+ in the fitting. The theoretical results show very good agreement with experimental results for the ground-band and $\beta-$band.

In the SU(3) limit, the equilibrium shape of the ^{152}Nd nucleus can be obtained by minimizing $E(\beta, \gamma)$ of Eq. (2) with respect to the

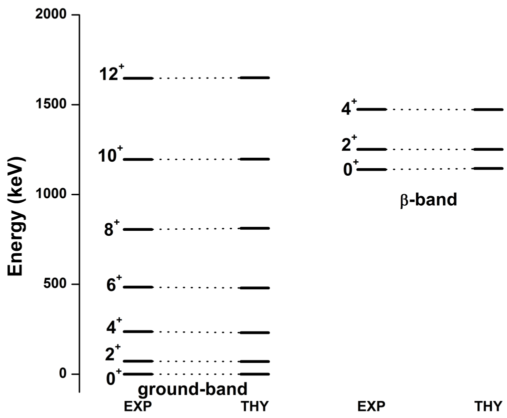

FIG. 1: Results of calculated energies of ground and β-band for ^{152}Nd nucleus. The parameters ϵ = 469.0, QQ = -59.2, ELL = -11.1, PAIR = -15.1 keV.

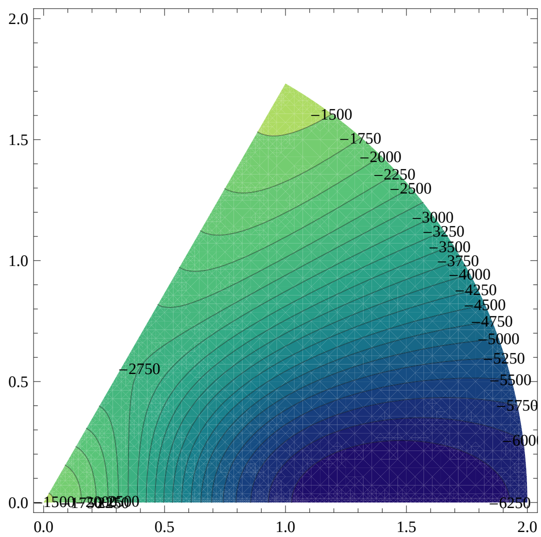

FIG. 2: The potential energy surface for the SU(3) nucleus $^{152}Nd_{92}$. The contour lines are marked in keV. The β varies from 0.0 to 2.0 on X-and Y-axes.

shape parameters β and γ. From Eq. (2), it can be seen that for the realistic values of κ_1, $E(\beta,\gamma)$ reaches a minimum for $\gamma = 0^0$. We illustrate the PES for ^{152}Nd nucleus with $\kappa_1 = 29.6$ keV and $\kappa_2 = 5.5$ keV in Fig. 2. With these values of κ_1 and κ_2 and minimising the Eq. (2), we get the values of $\beta = 1.38$ and $\gamma = 0^0$.

Conclusion

The structure of the ^{152}Nd nucleus is close to the SU(3) symmetry of IBM model. The comparison between the experimental and theoretical nuclear data related to the ground band and β-band is shown in Fig. 1. Less spectroscopic data is available for deformed ^{152}Nd nucleus in additional to that of the ground band. Indeed, only 1 yrast band energy state was identified, i.e., the 0^+ energy state at 1139 keV. Its energy is close to that predicted for the 0_2^+ state (1145 keV). The geometric picture of the ^{152}Nd nucleus is visualize by plotting the PES.

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