Unified description of the low lying states of the ground bands of Xe-Gd nuclei

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Introduction

The data of nuclear physics are so rich that a phenomenon identified in one context is often subsequently recognized, or recalled, in another. The low-lying parts of the even-even nuclei is the richest and best known part of experimental data in the nuclear structure physics. The interest in its theoretical investigation [1] does not diminish due to the possibility to investigate some general features of atomic nuclei on the basis of an appropriate systematics. The Interacting Boson Model (IBM) have been successful to describe the collective levels of many nuclei. This is also the basis behind the highly successful $N_\pi N_\mu$ scheme of Casten [2] and the well known proton-neutron version of IBM [3, 4]. Ganev et al. [5] studied the energy systematics of low-lying collective states within the framework of the interacting boson model. Georgieva et al. [6] introduced a new classification scheme for the even-even nuclei in the similar way to the scheme of elementary particles. Drenska et al. [1] combined this approach with practical notion of group of dynamical symmetry (DG) and introduced the concept of generalized dynamical group (GDG) [6] which describe the spectrum of collective states not of one but of a sequence of nuclei

$$GDG \supset CG \otimes DG$$

GDG contains the classification group (CG), (DG) and also gives the description of the low lying states of the ground bands of even-even nuclei by using Sp(4,R) group as a CG for the even-even nuclei. The Sp(4,R) algebra simply constructed by creation (π^+, μ^+) and annihilation (π, μ) operators [7]. The operator

$$N = N_\pi + N_\mu, \quad N_\pi = \frac{1}{2}(N_p - N_p^{mag}) \quad (1)$$

$$N_\mu = \frac{1}{2}(N_n - N_n^{mag}) \quad (2)$$

where N_p and N_n are the total number of protons and neutrons of the nucleus and N_p^{mag} and N_n^{mag} are the corresponding magic numbers of the shell to which it belongs. The boson representation of Sp(4,R) also contains the components $F_\pm$ and

$$F_0 = \frac{1}{2}(N_\pi - N_\mu) \quad (3)$$

of the operator of the F spin. The purpose of this work is to investigate the general features of the low-lying collective states of Xe-Gd nuclei as possible. This requires the systematics, in which the physical observable of the collective models show a smooth and unified behavior.

Result and Discussion

The ground band energies can be described by the three types of nuclear collectivity [6] vibrational nuclei, rotational nuclei and transitional nuclei. The classification of the quantum number related to the shell model quantum numbers are

$$\begin{aligned} A_p &= N_p^{(1)} + N_p^{(2)}, A_n = N_n^{(1)} + N_n^{(2)}, \\ N &= N_\pi + N_\mu, F_0 = \frac{1}{2}(N_\pi - N_\mu), \\ \bar{N} &= \bar{N_\pi} + \bar{N_\mu}, \bar{F_0} = \frac{1}{2}(\bar{N_\pi} - \bar{\mu}), \end{aligned} \quad (4)$$

$(N_p^{(1)} N_n^{(1)})$ and $(N_p^{(2)} N_n^{(2)})$ which denote the proton and neutron magic numbers of the

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nucleus at the beginning and at the end of the shell, respectively ($N_p^{(2)} > N_p^{(1)} \quad N_n^{(2)} > N_n^{(1)}$). The expression of low-lying yrast energies for all the even-even nuclei is

$$E_J = KJ(J+\omega) \tag{5}$$

where

$$\omega = \frac{4E(2_1^+)}{\epsilon 4} - 2 \quad \text{and} \quad \epsilon 4 = \mathrm{E}(4_1^+) - 2\mathrm{E}(2_1^+)$$

with the experimental ones for each nuclei. The values of K is calculated from [1]

$$K(A_p, A_n, N, F_0, \bar{N}, \bar{F_0}) = D_1 + D_2N + D_3\bar{N} + D_4 F_0 + D_5\bar{F_0} + D_6N^2 + D_7\bar{N}^2 + D_8F_0^2 + D_9\bar{F}_0^2 + D_{10}NF_0 + D_{11}\overline{NF_0} + D_{12}A_p + D13A_n \tag{6}$$

The value of $D_1, D_2, D_3, D_4, D_5, D_6, D_7, D_8, D_9, D_{10}, D_{11}, D_{12}$ and D_{13} are taken from [1].

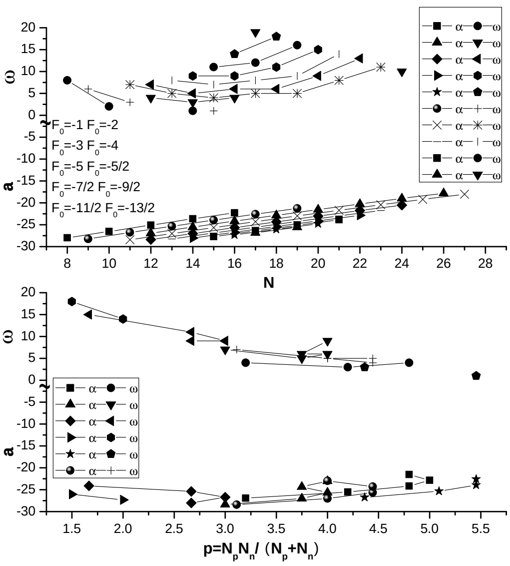

FIG. 1: Value of the dynamical coefficient α and geometrical parameter ω as function of N and p at each fixed value of F_0.

For the calculation of K parameter the experimental data are taken from [8, 9]. The eq.(6) provides the unified description of the ground-band energies of all nuclei. When we see the variation of α with neutron number for $(50, 50|82, 82)$ shell that contains both vibrational and rotational nuclei. In this case ω has highest value and α attain the negative value (see Fig. 1).

Conclusion

The results obtained by the symplectic classification scheme, a smooth variation of the experimental energies of the ground-state bands of the even-even nuclei are observed. From the above classification we observed that both these methods are based on the N_pN_n scheme and helpful to understand the physics behind the nuclear structure.

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