Study of collective nuclear structure of some light and medium mass nuclei

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The present thesis is an empirical study to understand the collectivity of nuclear structure of light and medium mass nuclei for A=100-200 region. These nuclei lie between the close shells i.e. at Z = 50 & 82 and N = 50, 82 & 126. The nuclear structure varies with the change on valence nucleon numbers, i.e. with N, Z, N_B, and N_pN_n [1]. The nuclear structure is studied using the empirical, phenomenological, geometrical, microscopic and group theoretical models. Large amount of nuclear data is accumulated from experimental work with improvement in technology and theoretical calculations are updated. New models are also evolving.

In chapter I, a brief description of the various models such as Shell Model, Bohr-Mottelson Collective Model, Rigid triaxial rotor (RTR) model, Dynamic Pairing- Plus-Quadruple (DPPQ) model, Interacting boson model (IBM-1) is given and their successes and limitation are pointed out. The detailed study of these models is presented in chapter-II.

In chapter-III, the study of ground state rotational band has been carried out to understand the nuclear structure variation with N, Z for A=100-200 region**.** In this chapter, we illustrate that a great deal of physics of the collective nuclear structure patterns of atomic nuclei (vibrational to rotational) can be derived, by studying the energy level structures of the ground state band in the first instance. We also find that the quadrant wise presentation of observables of collectivity and deformation i.e. the energies of 2_1^+ states $E(2^+)$, energy ratio R_4 $(=E_4^+/E_2^+)$, $B(E2;0_1^+\rightarrow2_1^+)$ values and the ground state band moment of inertia $(3/E_2^+)$ leads to better information. For example, the systematic dependence of MoI with N illustrates the formation of isotonic multiplets in quadrant-I, with N_pN_n of the F-spin multiplets in quadrant-II and with Z, isotopic multiplets in quadrant-III [2].

In chapter-IV, we have illustrated the dependence of the collective nuclear structure on the N_PN_n product (where N_p and N_n are the valence proton and neutron numbers respectively). In this chapter we presented the collectivity and deformation of nuclear structure using the observables: $E(2_1^+)$, ratio R_4, $B(E2;0_1^+\rightarrow2_1^+)$, MoI and $E(2_\gamma)$ as a function of N_pN_n. A systematic dependence of $E(2_1^+)$ on N_pN_n is explored to all three quadrants. In Q-1, the anomalies in the Nd-Dy nuclei are related to be the Z= 64 sub-shell effect. The systematic dependence of R_4 on N_pN_n showed the correlation of deformation of nuclear core on N_pN_n product in all three quadrants [3]. The dependence of $B(E2;0_1^+\rightarrow2_1^+)$ on N_pN_n is also studied quadrant wise. All these show a close relationship with collectivity. The systematics of $K^\pi=2^+$, γ-band head, i.e. $E_{2\gamma}$ vis-a-vis N_pN_n is also explored quadrant wise.

The Power Index Formula proposed by Gupta et al. [4], provides a new method of expressing collective level energies. In this formula, they [4], replaced the concept of an arithmetic mean of the two terms used in anharmonic vibrator model by the geometric mean of the two terms. Here $E= a\, I^b$, in which 'b' is a non-integer (1.0 to 2.0). Application of this formula is the subject of chapter-V. The index ‘b’ is related to the slope of the log(E_I) versus log(I) and the intercept yields average ‘a’.

Gupta and Hamilton [5] applied this formula to point out that the absolute slopes of the kinetic MoI versus spin I, using expression $J^{(1)} = (2I-1)/E_\gamma$, does not represent the physical reality, especially for nearly spherical nuclei. Instead, the change in slope with spin I represents the variation of nuclear structure with spin I. In chapter V, we illustrate this aspect of nuclear structure by looking at the correspondence of the variation of kinetic moment of inertia $J^{(1)}$ with spin and the value of ‘b’ in the power index formula. We illustrate this correspondence in a few nuclei of Ba-Nd and also tested this correspondence in the differentials of MoI and index ‘b’ [6].

The group theoretical Interacting Boson model (IBM-1) proposed by Arima and Iachello [7] enables the study of collective structure of nuclei. In chapter-VI, we studied some even-even nuclei ($^{122-134}$Ba, $^{146-154}$Sm and ^{154}Gd) using IBM-1.

Gupta et al [8] analyzed the decay pattern of the low lying levels in the shape transitional nucleus ^{150}Sm and discussed the alternative view of an anharmonic vibrator and a soft rotor. In ^{150}Sm, we observed that the IBM-1 calculations for energy values and B(E2) values give good agreement with experimental data [9]. In IBM calculations for $^{122-134}$Ba, the bunching of levels as observed in the energy level diagram of experimental data was reproduced. In $^{146-154}$Sm, the ground band level energies decreases monotonically with increasing valence nucleons and the calculated energy values in IBM have good agreement with experimental data. In ^{154}Gd, the IBM-1 was used to reproduced the energy spectrum, B(E2) values and B(E2) ratios for g-, β- and γ-bands[10].

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