Study of nuclear structure of some nuclei in medium mass region

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The medium mass region i.e. A=150-200, provides a rich ground of testing the understanding of collective nuclear structure of doubly even nuclei [1]. In this work, the collective nuclear structures of some medium mass nuclei have been analyzed, using empirical studies, phenomenological, geometrical, group theoretical models. Basically the present study is theoretical in convention to the experimental studies of nuclei, which are mostly particle accelerator based. Fortunately, high speed computers with large memory (RAM) and internet facilities are available now and used for the numerical calculations.

The research work is divided into five Chapters. The Introduction is given in the Chapter I and Nuclear Models are discussed in Chapter II.

In Chapter III, the values of asymmetry parameter (γ) of asymmetric rotor model (ARM) [2] are calculated using the experimental energies of $E2_2^+$ and $E2_1^+$ states; which are taken from [3]; for 50≤Z≤82 and 82≤N≤126 region. The whole calculated data is divided into four quadrants as suggested in ref. [4]. The Quadrant I (Q-I) is for 50≤Z≤66 and 82≤N≤104 shell space with particle like proton-bosons and neutron-bosons and it is forming the p-p space. The Quadrant II (Q-II) is for 66≤Z≤82 and 82≤N≤104 shell space, with hole like proton-bosons space and particle like neutron-bosons space and it is forming the h-p space. The Quadrant III (Q-III) is for 66≤Z≤82 and 104≤N≤126 region shell space, with hole like proton-bosons and neutron-bosons and it is forming h-h space. The quadrant IV (Q-IV) is for 50≤Z≤66 and 104≤N≤126 shell space with particle like proton-bosons and hole like neutron-bosons and it is forming the p-h space. The study of systematic dependence of γ on N, N_B and NpNn has been carried out on *quadrant wise basis* to find out the role of valence nucleons and holes on the nuclear structure. The role of Z=64 subshell effect for N≤90 region is also discussed.

The NpNn scheme is very useful in considering the systematic behavior of asymmetry parameter which gives the information of nuclear structure of atomic nuclei in a medium and light mass region, i.e. change in product NpNn are correlated with the change in nuclear structure. The NpNn product is a good measure of its effect in producing the deformation in atomic nuclei [5].

In quadrant-I and quadrant-II, the γ decreases; from 30^0 in Q-I and from 22^0 in Q-II to 9^0- 10^0; with increasing N from 82 to 104 (i.e. the mid of N=82 to 126 neutron shell), signifying that the nuclear deformation (β) is increasing, while the energy ratio R_4 increases from 2 (for harmonic vibrators or SU(5) type nuclei) to 10/3 (for good rotors or SU(3) type nuclei). This indicates that in this region the nuclear structure depends much more on Z. The γ shows the shape phase transition at N=88-90 in Q-I. In Q-II and Q-III; γ has a systematic dependence with N, but with different patterns [6].

In quadrant-I, the γ is having more correlated dependence on N, rather than on NpNn. Also in quadrant- I, the Z=64 sub-shell effect for N≤90 nuclei affect the variation of γ with N and NpNn product [7]. The smooth dependence of various observables was obtained earlier with NpNn by adopting effective number of Np for N≤90 nuclei. This was indeed a very useful procedure for obtaining the universal smooth curves for various regions with NpNn. The existence of X(5) symmetry in N=90 isotones established in recent works supports the formation of isotonic multiplets in this work. The calculated values of γ are almost constant for N=90 isotones e.g. 13.8^0 for Nd, 13.24^0 for Sm and 13.86^0 for Gd; which supports the constant nuclear structure findings for N=90 isotones. The present work confirms the existence of isotonic multiplets in quadrant-I as reported earlier.

The systematic dependence of γ on NpNn has strong dependence in quadrant-II. In Q-II, the line of β- stability runs nearly diagonally, i.e. parallel to N_B (where, N_B is the sum of proton hole bosons and neutron particle bosons) and leading to the formation of F-spin multiplets. The same feature had been observed earlier for the energy of first excited state i.e. E2g. In quadrant-III, the variation of asymmetry parameter is different from quadrant I and II because the γ increases sharply from 9^0 - 10^0 to 30^0 with increasing N from 104 to 126. This is signifying that the nuclear deformation (β) is decreasing and the nuclear structure changes from pure rotor SU(3) type to vibrational SU(5) or γ-unstable O(6) type. Further, the γ for different elements has smooth curve with NpNn with almost same slopes except for Hg isotopes [8].

In Chapter IV, the predictions of ARM [2] for B(E2;4g→2g)/B(E2;2g→0g) branching ratio are compared with the experimental data [3] in medium mass region. It is found [9] that the observed data point of this ratio for N=88 isotones (Nd, Sm, Gd, Er) are indicating the shape phase transition from an ideal spherical harmonic vibrator or SU(5) to an axially symmetric deformed rotor or SU(3). It is also noted that this B(E2) ratio is anomalously small in case of two non- magic nuclei i.e., ${}^{198}_{80}Hg_{118}$ [=0.375(18)] and ${}^{144}_{60}Nd_{84}$ [=0.73(9)] with only two vacancy of protons for Z =82 and two valence neutrons outside N=82, respectively. The data points for other nuclei are lying between SU(5) and SU(3) limits. The calculated B(E2) ratios of ARM are very close to the SU(3) limit of IBM [10] indicating that it can explain the structure of only well deformed nuclei. Therefore the ARM is partially successful in explaining this branching ratio [9, 10].

The variation of experimental B(E2; 4g→2g)/ B(E2;2g→0g) branching ratio with N and Z is carried out for Nd–Hg nuclei. It is found [11] that the there is shape phase transition for N=88 and 90 isotones (Nd, Sm, Gd, Er) from an ideal spherical harmonic vibrator or SU(5) to an axially symmetric deformed rotor or SU(3). The present study supports the subshell closer effect around Z=64, for N≤ 90 and the constant nuclear structure of N=90 isotones.

Finally, in Chapter V, the interacting Boson Model-1(IBM-1) [11] is used to study the nuclear structure of ^{152,154}Sm nuclei. The ^{152}Sm is chosen for study, because it is a best example of recently discovered X(5) symmetry of IBM and ^{154}Sm is a rotor type i.e. SU(3) symmetry. The bunching of various levels in ^{152,154}Sm is reproduced well in present calculation and is in agreement with the observed energy level diagram of experimental data. In ^{152,154}Sm, the B(E2) branching values and B(E2) branching ratios are calculated for inter-band and intra-band transitions for g-, β-, γ- and $β_2$- bands and the calculated results are in good agreement with experimental data. In ^{152,154}Sm nuclei, the IBM-1 Hamiltonian reproduce the energy spectrum, B(E2) values and B(E2) ratios for g-, β- and γ– bands [12]. Present calculation supports that ^{152}Sm is as a best example of X(5) symmetry and ^{154}Sm is a SU(3) type in nature.

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