Empirical and phenomenological studies of nuclear structure of A=120-200 mass nuclei

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Understanding the structure of the atomic nucleus is one of the central problem in nuclear physics. As we are dealing with a many-body problem of great complexity, therefore in the absence of a comprehensive nuclear theory we turn to the construction of nuclear models. A nuclear model is a simple way of looking at a nucleus that gives a physical insight in the range of its properties as possible. The usefulness of a model is tested by its ability to provide predictions that can be verified theoretically and experimentally. Now a days with advancement of experimental work in different labs all over the world, sufficient data is available for analysis, making many problems of current interest. This can be possible by doing intensive research and gaining detailed knowledge of various nuclear models such as Shell Model, Bohr-Mottelson Unified Collective Model, Asymmetric Rotor Model (ARM) and Interacting Boson Model (IBM).

In present work we study the four problems based on the study of nuclear structure for A=120-200 mass region. Gupta et al. [1] divide the major shell space of Z=50-82, N=82-126 into four quadrants. First quadrant (Q-I) of $N > 82$ is of Z=50-82, with particle (p) like proton-bosons space and neutron-bosons space forming the p-p space. Second quadrant (Q-II) of $82 \leq N \leq 104$ is of Z=50-82 shell space, with hole (h) like proton-bosons space and particle like neutron-bosons space forming the h-p space. Third quadrant (Q-III) of $104 \leq N < 126$ of Z=50-82 shell space, with hole like proton-bosons and neutron-bosons forming h-h space. The fourth quadrant (Q-IV) of $N < 82$ of Z=50-82 shell space with particle like proton-bosons and hole like neutron-bosons forming the p-h space. We studied various models, viz, the geometrical, empirical and group theoretical models. The predictions of these models have been compared with available experimental data. These experimental data are taken from [2, 3].

Gupta et al. [4] studied the single term expression of ground band level energies of a soft rotor. They replaced the concept of an arithmetic mean of the two terms used in Bohr-Mottelson expression by geometric mean and introduces a two parameter formula called power law $E(J) = aJ^b$. We study the single term energy formula ($E = aJ^b$), for the ground band energies of Xe-Gd nuclei. The neutron deficient ($N < 82$) light mass (Xe-Gd) rare earth nuclei lying far from the β-stability line (see Fig.1) has been of current interest in nuclear structure theory. The level pattern of these even Z-even N nuclei differ from $N > 82$ nuclei in the degree of deformation. Here in $N < 82$ region the energy ratio

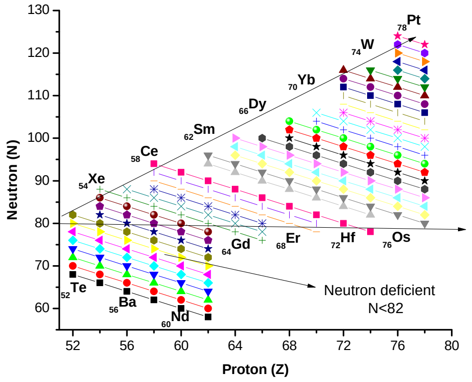

FIG. 1: The $N < 82$ nuclei lie far from the β-stability line.

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$R_{4/2}$ lies between 2.0-3.1 and most of nuclei are γ-soft [5]. We study the variation of constant parameters a and b with J to check the constancy of the power law . We also compare the results of the power law with other two parameters formulae such as ab formula of Holmberg and Lipas [6] pq formula of Zeng et al. [7], Ejiri [8] formula , and soft rotor formula (SRF)of von Brentano [9] to find the accuracy of the power law. The comparative study is carried out for A=120-200 mass region nuclei.

In second part we study the odd-even staggering (OES) and calculate the gamma band energies of A=120-200 mass region. In this work the OES in the γ-band help to distinguish between its rigid triaxial rotor and γ-soft vibrator. The variation of S(J) with $R_{4/2}$ signify a smooth shape effect. The study of gamma band energies is carried out with the help of SRF [9]. The new gamma band energy levels are helpful for the experimentalist. In third part we search the identical band spectra of Xe-Gd nuclei. The occurrence of identical bands in neighboring even-even nuclei requires that the moment of inertia in the two bands should be identical. In short the phenomenon of identical bands has assumed a more general character spanning a very wide region of nuclear deformation and spin. In many nuclei the collective levels have been described by IBM-1 [10]. A very important concept of F-spin plays an important role to understand the structure of nuclei. It was natural to assume that the nuclei with equal total boson number $N_B = N_p + N_n$ should have the same deformation and identical spectra. The number of valence proton N_p and number of valence neutron N_n has a total $N = (N_p + N_n)/2 = N_\pi + N_\nu$ bosons. In this calculation part we see the variation of $E(2_1^+)$ energy with N_pN_n, N_B, p- factor (e.g p=$\frac{N_pN_n}{N_p+N_n}$ in all the four quadrants. The study is carried out by the concept of F-spin multiplet.

In next section the interacting boson model (IBM-1) is applied to study the energy spectra of $^{122-132}$Xe and $^{126-136}$Ba nuclei. The IBM-1 initially introduces by Arima and Iachello [11] has been rather successful in describing the collective properties of several medium and heavy nuclei. In the first approximation, only pairs with angular momentum L=0 (called s-bosons and L=2 (called d-bosons) are considered. This model has associated with it an inherent group structure. In spite of its simplicity it is capable of providing a beautiful theoretical explanation of the observed spectra exhibited by many nuclei. The IBM-1 model led to the U(6) group algebra which yields three dynamical symmetries : SU(5), SU(3) and O(6) which corresponds to anharmonic vibrator, deformed rotor and γ- unstable nuclei respectively. In this part we study the O(6) symmetry of $N < 82$ region. The IBM-1 is also applied to study the g-,β-,γ- spectra and the B(E2) ratios of the nuclei.

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