Study of identical band with N_pN_n scheme in A=120-140 mass region

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Introduction

The neutron deficient (N<82) light rare-earth nuclei lie far from β-stability line on the N-Z chart. The level pattern of these even Z-even N nuclei differs from N>82 nuclei in the degree of deformation. Here the energy ratio $R_{4/2}(= E(4_1^+)/E(2_1^+)) \leq 3.06$ as compared to 3.3 for the latter. Also most of these are γ-soft which follow the condition of O(6) nuclei. Brentano et al. [1] gives a two parameter formula that is particularly successful in soft rotors with $2.8 \leq R_{4/2} \leq 3.2$. Bihari et al. [2] used the soft rotor energy formula suggested by Brentano et al. [1] for the yrast band to calculate the perturbed energies of an anomalous rotational band generated by rotation of a rigid asymmetric atomic nucleus. The study of the existence of identical bands in pairs of even-even nuclei is one of the most important study in nuclear structure physics [3]. In the Interacting Boson Model (IBM), the valence nucleon pair bosons are counted from the nearest close shell number as stated by Arima and Iachello [4].The particle pair boson and hole pair bosons are treated on the same footing. Then 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 valance neutron N_n has a total $N = (N_p + N_n)/2 = N_\pi + N_\mu$ bosons. These N_π and N_μ are assigned an F-spin, F=1/2 having projections $F_0 = 1/2$ and $F_0 = -1/2$ respectively. The projection of these nuclei is denoted as $F_0 = (N_\pi - N_\mu)/2$. Fig. 1 shows the light nuclei region grouped into F-spin multiplets that exhibits $\pm F_0$ symmetry shown in each block corresponding to a nucleus are F_0, (N_π, N_μ) and the N_pN_n product.

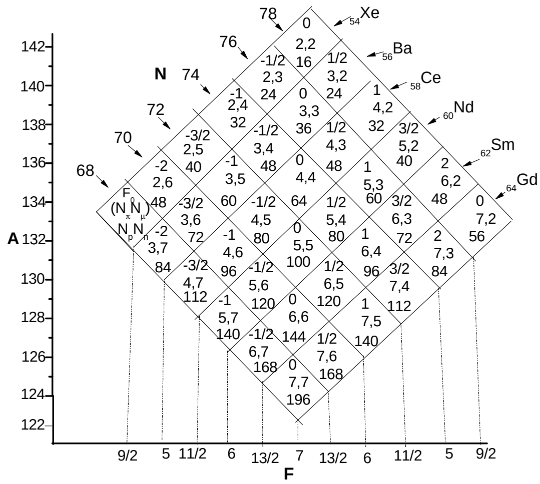

FIG. 1: A set of light nuclei that exhibit a symmetry in their N_pN_n product as well as $|F_0|$ values across the Xe-Gd nuclei.

Saha and Sen [5] explained that the low spin identical bands have a general character spanning a very wide region of nuclear deformation and spin in rare earth nuclei. It may be observed that in many cases nuclei exhibiting the identical energy ratios have nearly identical product. Proceeding as above one expects to find the F-spin multiplets in the quadrant of proton particle-bosons and neutron hole-bosons Z=50-66, N=66-82 space. In the present study we search for the identical ground-bands in this quadrant (Q-IV) for Xe-Gd nuclei.

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Calculation

It is assumed that moment of inertia is mass dependent. Saha and Sen [5] used the relationship between moment of inertia and the number of valence proton and valence neutron as

$$\theta_k \propto [f(N_p N_n)]^{1/k} \qquad k = 1, 2$$

where

$$\theta_1 = \frac{3}{\hbar^2} E_2, \qquad \theta_2 = \frac{4}{\hbar^2}(E_4 - 2E_2)$$

and

$$f(N_p N_n) = N_p N_n (N_p + N_n) \qquad (1)$$

The function $f(N_p N_n)$ is also denoted as saturation factor (SF). With the help of this $f(N_p N_n)_{max}$ we calculated the saturation parameter (SP) as

$$SP = \left(1 + \frac{SF}{SF_{max}}\right)^{-1} \qquad (2)$$

Result

When full major shell space of Z=50-82 and N=82-126 was divided in four quadrants, the valid F-spin multiplets exist only in the particle-hole boson space of quadrant-II (Q-II). In the quadrant-1 (Q-1), isotonic multiplets had better identical bands and in hole-hole space of quadrant-III (Q-III) isotopic multiplets had nearly identical bands, as opposed to F-spin multiplets in Q-II as given by Gupta et al. [6]. The ^{124}Xe, ^{126}Ba, ^{128}Ce, ^{128}Ba and ^{130}Ce are identical in structure factor (SF) with ^{140}Sm, ^{138}Sm, ^{136}Sm, ^{136}Nd and ^{134}Nd respectively. Also the experimental energy of these nuclei are approximately equal to calculated energy.

Conclusion

The rare earth nuclei which are in the multiplets of $N_p N_n$ show identical band. Nuclei in an F-spin multiplet have $F_0(N_p - N_n)/4$ values from -F to +F. According to above classification we observed that the nuclei ^{128}Ba, ^{136}Nd and ^{130}Ba, ^{134}Ce respectively have equal saturation factor (SF) and saturation parameter (SP) which further means that these nuclei show identical bands and hence reproducing the experimental $E(2_1^+)$ value within a reasonable accuracy [7] states the symmetry of N_p and N_n in total boson number N_B, $N_p N_n$ and p-factor holds well for above cases.

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