The empirical study of the energy spin relationship in the ground bands of even-even nuclei

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Introduction

Our understanding of nuclear structure is framed within the context of a number of idealized benchmarks. These include the axial rotor [1], the anharmonic vibrator [2] and γ-soft deformed nuclei [3, 4]. The simplest well-known expression for rotational spectra is

$$E = \frac{\hbar^2}{2\Im} J(J+1) \tag{1}$$

where $\Im$ and J are the moment of inertia and spin of the nuclei. Holmberg and Lipas [5] gave the two-parameter ab formula

$$E(J) = a\left[\sqrt{1 + bJ(J+1)} - 1\right] \tag{2}$$

Further, Brentano et al., [6] noted that MI depends on the spin (J) and energy (E):

$$\Im = \Im_0(1 + aJ + bE) \tag{3}$$

Brentano et al., obtained the two-parameter formula, called the soft rotor formula (SRF)

$$E = \frac{1}{\Im_0(1+\alpha J)} J(J+1) \tag{4}$$

Gupta et al., [7] suggested a single- term expression for ground band level energies of a soft-rotor. They replaced the concept of the arithmetic mean of the two terms used in the Bohr-Mottelson expression by the geometric mean and introduced a two-parameter formula called the power law

$$E = aJ^b. \tag{5}$$

By using eq.(5) for any J index b can be determined from the ratio

$$R_J = E(J)/E(2) = (J/2)^b \tag{6}$$

Taking log on both sides

$$b_J = log(R_J)/log(J/2), \tag{7}$$

by using eq.(7), one can evaluate the value of index b for different J in any given nucleus.

Results and Discussion

The results obtained by fitting the two parameters are summarized in Figure 1. We compared the power law with experimental energy values, ab formula, the SRF and Ejiri expression. The comparison shows that power law is valid for both deformed and soft nuclei. In some well deformed nuclei having $R_{4/2}$=3.3, the SRF formula describes the data better than the power law [8]. This is not surprising, because the SRF formula has one parameter more than power law. The power law shows good agreement with all the compared values.

Figure 2 and 3 represent the variation of index 'a' and 'b' with spin J for N=24, 38 and 40. The variation of a is fairly constant against J but for N=36 the variation is large. The variation in a that relates to the MI of the nuclear core is smaller as compared to index b. This implies that the dependence of energy $E(J)$ on spin J is observed in the index b itself and MI is relatively constant in a given nuclide. This is in contrast to the variable moment of inertia (VMI) model expression where MI varies continuously with spin even at low spin values. However, we remark that this holds true for low spin only.

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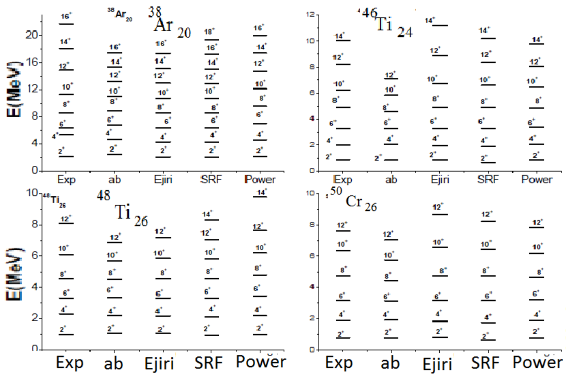

FIG. 1: Comparison between experimental energy with ab, Ejiri, SRF and power law for ^{38}Ar, $^{46-48}$Ti and ^{50}Cr nuclei.

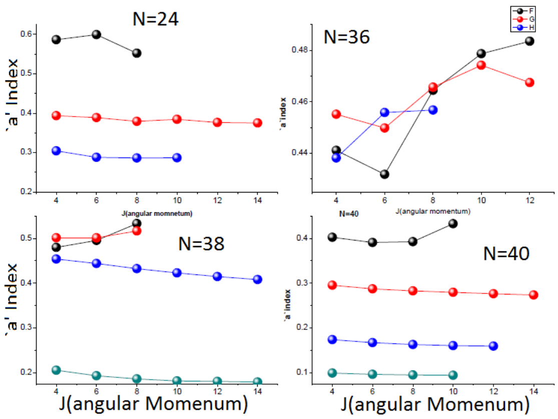

FIG. 2: Plot of index 'a' in various groups of isotones for N=24, 36, 38 and 40. Same symbols are used for different elements in all parts of the figure.

Conclusion

To summarize, we studied the power law, which is applicable for both deformed and soft nuclei. The value b is fairly constant and is independent of spin J. The point at which the value b exhibits a sharp drop is an indication of the shape phase change in the nucleus. The coefficient a which is related to MI is relatively constant or is slowly varying in contrast to the VMI model expression where MI increases fast

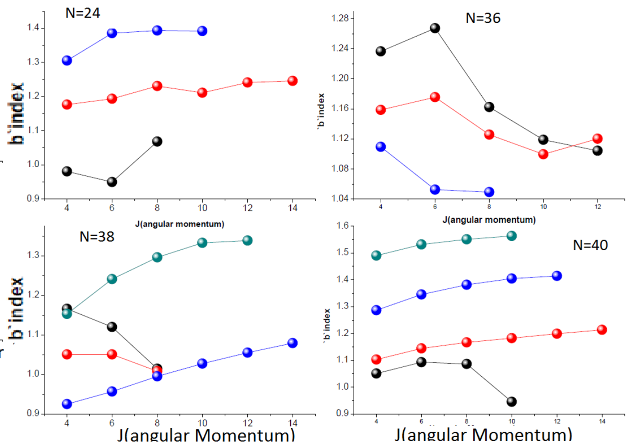

FIG. 3: Plot of index 'b' in various groups of isotones for N=24, 36, 38 and 40. Same symbols are used for different elements in all parts of the figure.

with spin.

Acknowledgments

The first author thanks to IET Bhaddal, Ropar, for providing research facility.

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