The study of the energy spin relationship in ground bands of even-even nuclei in the frame work of Power Law

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Introduction

There are a number of idealized paradigms to study and understand the nuclear structure, which involve axial rotor [1], anharmonic vibrator [2] and γ-soft deformed nuclei [3, 4]. These models predict energy sequences and $B(E2)$ values.
There are several empirical formulae to express the ground state band level energies of nuclei. The simplest well-known examples are the expression for rotational spectra,

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

(here $\Im$ and J are the moment of inertia and spin of the nuclei, respectively), and the Bohr-Mottelson energy expansion in powers of $J(J+1)$ for deformed nuclei [5], i.e.,

$$E = AJ(J+1) + B(J(J+1))^2 + C(J(J+1))^3. \qquad (2)$$

Gupta et. al [6] 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

$$E = aJ^b \qquad (3)$$

By using Eq.(3) for any spin (J) the value of b can be determined from the ratio

$$R_J = E/E(2) = (J/2)^b. \qquad (4)$$

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Result and Discussion

Constancy of a

The variation of a is fairly constant against J for N=42-44 isotones (see Fig.1). At N=36,46-48 the variation is larger. Also, the rise or fall in a is in the reverse sense as compared to the b.

The variation of a in relation to the MI of the nuclear core is smaller as compared to the value of b. This implies that the dependence of energy $E(J)$ on spin J is observed in the b itself and MI is relatively constant in a given nuclide.

For ^{74}Se, ^{76}Kr and ^{78}Sr, the b values show constant straight behavior with J and values lie within 1.1 and 1.2, 1.3 and 1.4 and at 1.5, respectively.

Constancy of b

At N=42, the value of b, for isotones of ^{76}Se, ^{78}Kr, ^{80}Sr and ^{82}Zr, lies within the range of 1.24-1.25, 1.28-1.35, 1.33-1.40 and 1.35-1.40, respectively. In case of ^{80}Sr the value of b increases up to a fixed value and then there is a sudden fall in the value.
At N=44, for isotones of ^{78}Se, ^{80}Kr, ^{82}Sr and ^{84}Zr nuclei, the value of b lie in the range of 1.29-1.20, 1.21-1.22, 1.21-1.25 and 1.22-1.26, respectively.

At N=46, for isotones of ^{82}Kr, ^{84}Sr and ^{86}Zr nuclei, the value of b lie within the range of 1.22-1.14, 1.15-1.25 and 1.14-1.09.
At N=48, for isotones of ^{84}Kr, ^{86}Se and ^{88}Zr nuclei the value of b lie within the range of 1.24-0.93, 1.05-0.96 and 1.01-0.89, respectively.

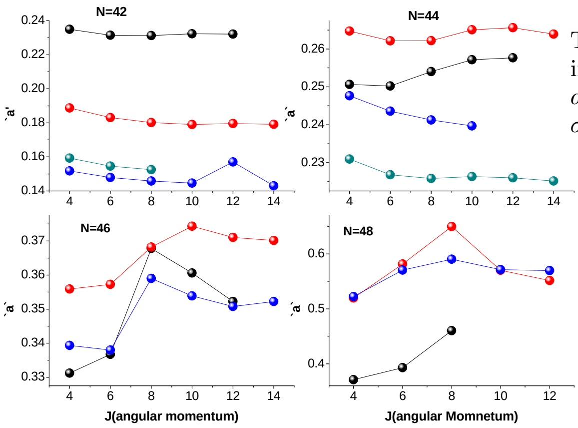

FIG. 1: Plot of coefficient a in various groups of isotones for N=42-48. The same symbols have been used for different elements in all parts of the figure.

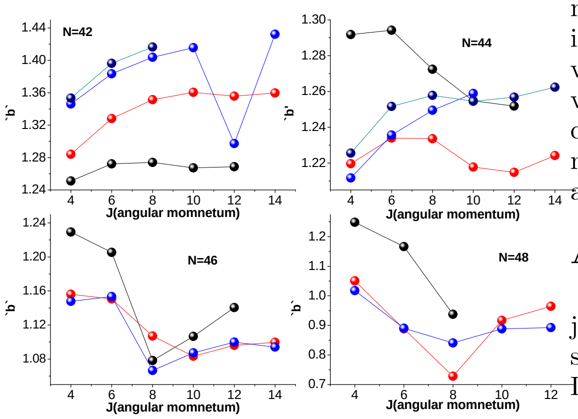

FIG. 2: Plot of b in various groups of isotones for N=42-48. The same symbols have been used for different elements in all parts of the figure.

Conclusion

To summarize, we studied the power law, which is applicable for both deformed and soft nuclei. The formula is particularly successful in soft rotor and deformed nuclei with $2.8 \le R_{4/2} \le 3.3$. In this work we try to apply the power law for those nuclei with $2.8 \le R_{4/2} \le 3.3$. The power law gives good fit of the data for b and a derived either from 2^+, 4^+ or 6^+, 8^+ energy levels. It represents an alternate expression for energies in the rotation-vibration K^π=0^+ ground bands in deformed nuclei. The value of b is fairly constant and independent of spin J, at least for low spin values ($J^\pi < 12^+$). The point at which the value of b exhibits a sharp drop is an indication of the shape and phase change in the nucleus. The power formula is an alternative approach to the perturbation expansion.

TABLE I: Theoretical and experimental gsb levels in MeV for Mg-Zr nuclei. The fitting parameters a, b in Eq.(3) are given in MeV. The RMS factor σ is also given in MeV.

Nuclei	a	b	σ	E_{exp}	$E_{th.}$
^{40}Ar	-0.1475	0.8075	0.0633	1.4608	1.5102
^{42}Ca	-0.0272	0.6914	0.0577	1.5246	1.5716
^{44}Ca	-0.5963	1.0373	0.0514	1.157	1.1305
^{44}Ti	-0.7176	1.1798	0.0795	1.083	1.1053
^{46}Ti	-1.0092	1.2463	0.0241	0.8893	0.8647
^{48}Ti	-0.8042	1.1418	0.0415	0.9834	0.9873
^{50}Ti	-0.6072	0.9856	0.057	1.0471	1.0789
^{48}Cr	-1.2787	1.4014	0.0234	0.752	0.7354
^{50}Cr	-1.1403	1.2865	0.0188	0.7833	0.7799
^{52}Cr	-0.2469	0.8243	0.0702	1.4341	1.3833

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