Validity of single term energy formula for β-band

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There are various empirical formulae to study the level structure of ground band of medium mass nuclei. The expression for rotational spectra is:

$$E(I) = (\hbar^2/2\theta)\, I(I+1). \quad (1)$$

Where θ and I are the moment of inertia and spin respectively [1]. The deviation from eq. 1 has been observed for almost all the nuclei because of centrifugal stretching etc. which can be taken into account only up to some extent [2, 3] ($3.1 \leq R_4 \leq 3.33$) by apply an expansion in power of I(I + 1), i.e.

$$E(I) = A\; I(I+1) + B[I(I+1)]^2 + C[I(I+1)]^3 + \cdots \quad (2)$$

where A, B and C have their usual meaning. For harmonic vibrator, the energy can be written as:

$$E(I) = a\, I. \quad (3)$$

Das et. al. [4] suggested the energy expression for anharmonic vibrator:

$$E(I) = aI + bI(I-2). \quad (4)$$

The energy spectrum of ground band in well deformed nuclei ($R_4 \approx 3.33$) exhibit rotational characteristics and for shape transitional nuclei large deviations have been observed. In the literature, one finds quite a few variants, which involve two, three or more terms in terms of spins. Gupta et al [5] observed that the values of fitting parameters often depended on the number of levels used for calculation. They [5] suggested a very different form of energy expression in the form of a single term energy formula called power law:

$$E(I) = a\, I^b \quad (5)$$

where the coefficient “a” and index “b” are the constants for the band. Also b is a non-integer. The values of a_I and b_I are given below:

$b_I = \log(R_I)/\log(I/2)$ and $a_I = E_I / I^b$.

This is the most-simple expression among all the other formulae. The validity of this formula was well proved for the medium mass nuclei. Recently, it was also tested for the light N < 82 region. This formula was equally successful in expressing the ground band energies in the A=150-200 region [5]. Mittal et. al [6] verified its validity for light mass Xe-Sm nuclei. Recently, Kumar et. al [7] and Kumar [8] presented correlation of kinetic moment inertia with power formula index in $100 \leq A \leq 150$ region. Gupta and Hamilton [9] also illustrated the use of this formula to determine the degree of deformation of shape transitional nuclei.

Considering its simplicity, we have taken a project to test the validity and utility of power law in various bands of even –even nuclei. Here, we discuss the advantages of this formula in predicting the nuclear structure of β-band in a few nuclei.

The validity of this expression (Equation 5) for β-band would be tested by a check of the constancy of “b” and “a” with the spin I. It is also tested by plotting log (E_I) against log (I).

In the present work, we search for the constancy of “b” and “a” coefficients with the spin (I) for β-band. In figure 1, we have plotted log(E_I) against log(I) for isotopes of different deformation (N = 88, 90) for β-band levels which indicates that the log(E_I) is linearly dependent on log(I). This is also a good measure to test constancy of level energies with spin (I). Here, almost linear dependence (Fig. 1) would be an indication of the constancy of index “b” and coefficient “a” with spin (I).

To test the above hypothesis for constancy of index “b” and “a” of single term energy formula (Equation 5) for β band, we look at the N = 88, 90 (^{152}Sm, ^{152}Gd and ^{154}Gd) isotones in Fig. 2 and Fig. 3 respectively. In ^{152}Sm and ^{154}Gd, the value of ‘b’ is almost constant near 0.5 (see Fig. 2). Thus the almost constancy of index 'b' of this formula in β band, illustrates the test of nuclear shape deformation with spin for excited bands. The coefficient "a" is plotted versus spin (I) in Fig.3 for these three isotopes and the fig. indicating that "a" is linearly dependent on spin and decreases on increasing the spin. Also the slopes for ^{152}Sm and ^{154}Gd are almost same.

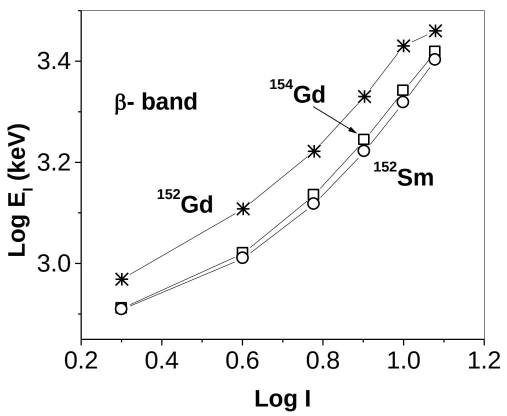

Fig. 1 The variation of Log E_I vs. Log I for β-band.

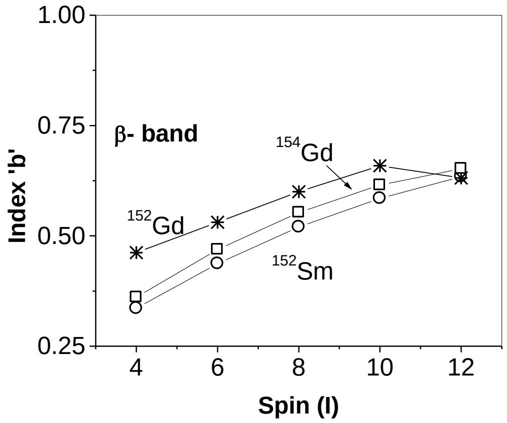

Fig. 2 The variation of index 'b' vs. Spin (I).

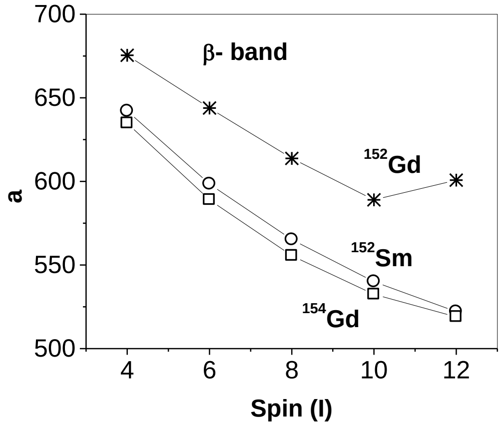

Fig. 3 The variation of coefficient 'a' vs. Spin (I).

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