Validity of Power index formula for odd-A nuclei in A~130 mass region

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Introduction

Numerous empirical formulae are present in the literature for the study of ground state rotational bands of even-even nuclei. The earliest expression for rotational spectra is

$$E(I) - \frac{\hbar^2}{2\mathcal{J}} I(I+1) \quad (1)$$

Where, $\mathcal{J}$ and I are the moment of inertia and spin respectively [1]. Most of the well deformed nuclei follow the above relation, however, they couldn't map the experimental energies precisely. Later, considering various factors, the relation (1) is expanded in powers of I(I+1),

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

Where, A, B and C have their usual meaning [2]. The energy of vibrational excitations is expressed by

$$E(I) = aI \quad (3)$$

For anharmonic excitations, the expression is further modified as [3],

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

For a well deformed nucleus, the rotational characteristics of the band is confirmed by the ratio of $E_{4+}/E_{2+}(R_4) \approx 3.33$. But the observed energy spectrum of transitional nuclei shows deviation from above relations. Gupta et al. [4] proposed the single term formula known as the power index formula (5) for these nuclei

$$E(I) = aI^b \quad (5)$$

This formula with two variable parameters 'a' and 'b' is based on the geometric means of vibrational energy (3) and rotational energy (1) for shape transitional nuclei. The coefficient 'a' was related to the inverse moment of inertia and the power index 'b' was interpreted as core deformation [4]. The expressions for a_I and b_I are given as

$$b_I = \frac{\log(R_I)}{\log(\frac{I}{2})} \quad and \quad a_I = \frac{E_I}{I^b}$$

Validity of this formula was evinced for the ground state bands of even-even nuclei for A=150-200 region and value of these two parameters were found nearly constant and independent of spin below the alignment of pair of nucleons [4]. In further study of nuclei near N=82 shell closure, the b was found smoothly varying with N_pN_n and interpreted as the variation of nuclear deformation with increasing N_p or N_n [5]. The kinetic moment of inertia was correlated with 'b' in the study of nuclei from 100≤A≤150 mass region [6].

All above studies are carried out in even-even nuclei. In the present work we have tested its validity for odd-A Te, Xe, Ba and Ce nuclei from the A~130 mass region for the first time. The energy of rotational states in these nuclei is interpreted via particle + core coupling model. We have taken the decoupled band of odd-A nuclei (band based on $h_{11/2}$ orbital) in present study.

Results

The value of coefficient 'a' and index 'b' has been determined for odd mass Te, Xe, Ba and Ce nuclei by fitting the expression (5). Effectiveness of the power index formula is tested for negative parity $\pi h_{11/2}$ rotational band as shown in fig (1-4). The variation of power index 'b' as a function of spin (I) is shown in fig(1), which shows that 'b' remains nearly independent of spin (I). Similar trend of 'b' was also reported for even-even nuclei [4].

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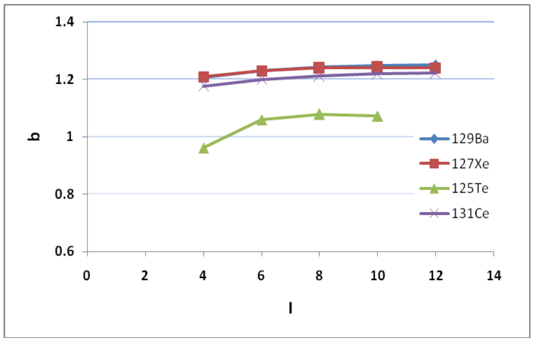

Fig 1: *Plot of power index b versus spin (I) for N=73 isotone.*

The variations of 'a_{avg}' and 'b_{avg}' w.r.t ***N*** are shown in fig (2 and 3). b_{avg} decreases with the increasing ***N***, which suggests the decreasing deformation as the number of valence nucleons is less near to the shell closure. But a_{avg} behaves in a reverse sense to that of b_{avg}.

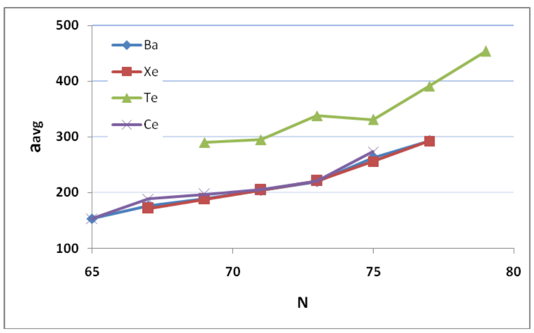

Fig 2: *Plot of a_{avg}(keV) for each nuclide versus N.*

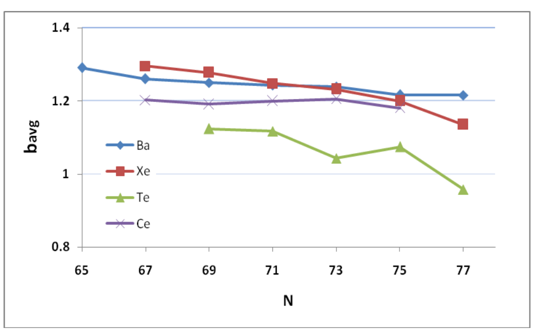

Fig 3: *Plot of b_{avg} (average of b over all spin values) for each nuclide versus N.*

Fig 4 illustrates the role of atomic number with b_{avg}. Variation of power index 'b' is found independent of N for the Ce nuclei but shows considerable changes for Te, Xe and Ba.

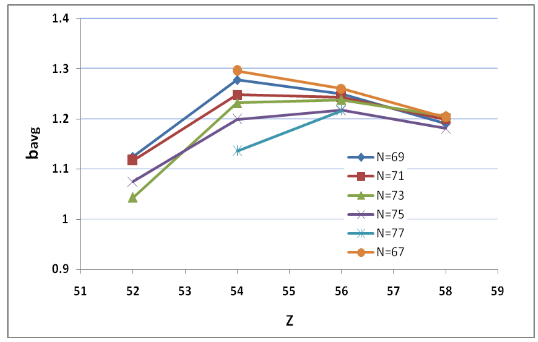

Fig 4: *Plots of b_{avg} versus Z for each nuclide. Data of same N are linked together.*

Experimental level energies compared with the energies calculated using the power index formula and are found in agreement (within the rms error of less than 6%).

Discussion

In present systematic investigation, the 'a_{avg}' is found varying with a function of N but no significant change is observed for the 'b_{avg}' (fig. 2, 3). However, the value of b_{avg} is found almost same for all of Ce nuclei (fig 4).

Similar trend of 'b_{avg}' was also reported for Cd nuclei [6] and was interpreted that the nuclei possess spherical shape. Hence low lying band structures of Ce nuclei are also associated with low deformation.

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