Calculation of nuclear softness parameter (σ) in VMINS model

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Introduction:

It is possible to describe the ground state band of medium mass even-even nuclei, away from closed nucleon shell, by means of a simple semi-classical model. In the study of ground state bands ranging from 'rotational' to 'vibrational', Mariscotti et al. [1, 2] suggested a different model called, Variable Moment of Inertia (VMI) model, which is equivalent to the Centrifugal Stretching (CS) model for well deformed nuclei. In the original variable moment of inertia (VMI) [1, 2] model, the excitation energy of the member of the ground-state band with angular momentum J is given by

$$E(J) = \{J\,(J+1)/2I\}+c(I-I_0)^2/2 \qquad (1)$$

Here the potential term is added to the usual rotational term. The coefficients c and I_0 are parameters, characteristic for each nucleus. Where I_0 is called the ground state moment of inertia and c is denoted as stiffness parameter.

Gupta et al. [4, 5] expressed the variable moment of inertia (VMI) model for the ground state band in even-even nuclei in terms of his nuclear softness (NS) model [3]. In NS model the variation of moment of inertia θ with J is given by

$$\theta = \theta_0(1 + \sigma J) \qquad (2)$$

Where θ_0 is the ground state moment of inertia and σ is the softness parameter.

In the present paper we calculate the nuclear softness parameter (σ) from VMINS model. The energy expression in VMINS model is given by

$$E\,(J) = AJ(J+1)/(1+\sigma J)+BJ^2 \qquad (1)$$

Where $A= \hbar^2/2\theta_0$ and $B = K\sigma^2 = C\theta_0^2\sigma^2/2$

This involves three parameters.

(i) Ground State Moment of Inertia 'θ_0'
(ii) Stretching Constant 'C'
(iii) Softness Parameter 'σ'

Two of the parameters (θ_0 and C) correspond to the parameters of the original VMI model (I_0 and c), while the third parameter σ is an addition variable.

By elimination of A and B from equation (1) for J= 2^+, 4^+ and 6^+ one gets a quadratic equation in σ:

$$a\sigma^2+b\sigma+c=0, \qquad (2)$$

where, the coefficients a, b and c are given by:

$$a = 84\,E(6) + 204\,E(2) - 240\,E(4)$$
$$b = 20\,E(6) + 108E(2) - 72\,E(4)$$
$$c = E\,(6) + 3\,E\,(2) - 3\,E\,(4).$$

The solution of equation (2) yields two real or complex roots. If complex root is obtained, this implies the inapplicability of VMINS model to the given nucleus. For a proper choice of σ value we set a constraint on it to yield a positive value of the coefficients B and K in equation (1), since C, θ_0, and σ are all positive. Also, out of two roots (if both yield positive), the smaller one is preferred, since a lower σ represents a smaller correction to θ_0 as Gupta et al. [6] suggested earlier.

Result and Discussion:

The results of this work are presented in figure (1, 2 and 3). In the fig.1 we plot nuclear softness parameter against the energy ratio R_4, (for nuclei having Z=58 to 66 and N=90 to 100). It shows that the nuclear softness parameter decreases with increasing R_4. In fig.2 we show the variation of energy ratio R_4 of different nuclei (having Z=56 to 66 and N=88 to 100) with the product of boson numbers=(NpNn). The fig 2 indicates that the value of R_4 initially increases for all the nuclei and after that it is saturated (i.e.R_4= 3.33) at NpNn nearly equal to 30.

In the figure.3 we study the nuclear softness in the scheme of N_pN_n. The plot of softness parameter versus the product (N_pN_n) present for different nuclei (having Z=56 to 66 and N=88 to 100). This figure shows the softness parameter decreases with increasing N_pN_n value.

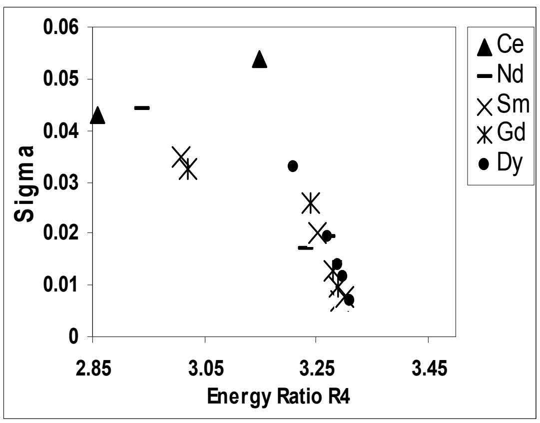

Fig.1: The variation of softness parameter in VMINS model versus energy ratio R_4

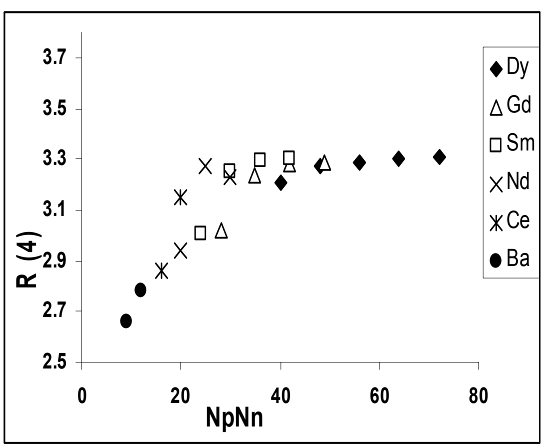

Fig. 2: The variation of R_4 versus N_pN_n.

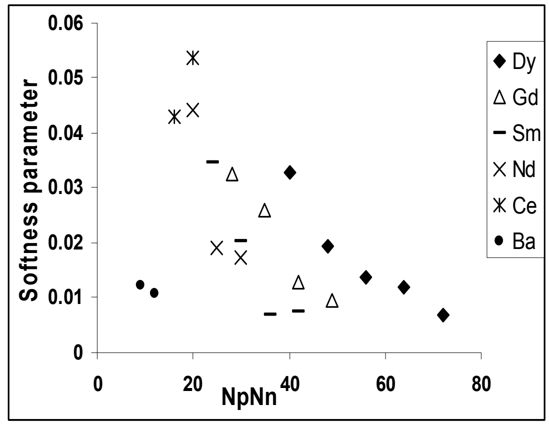

Fig. 3: The variation of nuclear softness parameter versus N_pN_n .

$^+$Associated.

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