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

\[ E(J) = \left\{ J(J+1)/2I \right\} + c(I-I_0)^2/2 \]  \hspace{1cm} (1)

Here the potential term is added to the usual rotational term. The coefficients c and I₀ are parameters, characteristic for each nucleus. Where I₀ 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

\[ \theta = \theta_0(1 + \sigma J) \]  \hspace{1cm} (2)

Where θ₀ 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

\[ E(J) = AJ(J+1)/(1+\sigma J)+BJ^2 \]  \hspace{1cm} (1)

Where A= h²/2θ₀ and B = Kσ²= Cθ₀²σ²/2

This involves three parameters.

(i) Ground State Moment of Inertia ‘θ₀’
(ii) Stretching Constant ‘C’
(iii) Softness Parameter ‘σ’

Two of the parameters (θ₀ and C) correspond to the parameters of the original VMI model (I₀ 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:

\[ a\sigma^2+b\sigma+c=0, \]  \hspace{1cm} (2)

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

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

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, θ₀, 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 θ₀ 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 R₄, (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 ($N_pN_n$). 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 $N_pN_n$ 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. 1](image1.png)

Fig. 2: The variation of $R_4$ versus $N_pN_n$.

![Fig. 2](image2.png)

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

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References: