Ground State MoI and Softness parameter from the Nuclear Softness Model

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Introduction:

Among the various formulae for ground state band energies [1, 2] of even Z, even N atomic nuclei, the nuclear softness model (NSM) was fairly successful in reproducing the ground band energies with reasonable accuracy up to spin J=12 [1, 3]. In the spirit of centrifugal stretching of the nuclear core with increasing spin J, the Nuclear Softness Model (NSM) assumes the linear increase of Moment of Inertia

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

with spin J.

In the two parameter nuclear softness (NSM) model [1], the energy expression is given by the formula

$$E(J)=\hbar J\,(J+1)/\{2\theta_0(1+\sigma J).\} \qquad (2)$$

Recently, Eq. 1 was also adopted by Brentano et al. [4] to derive Eq. (2) and is called the Soft Rotor Formula (SRF). After solving equation (2) for softness parameter σ, we get the following expression

$$\sigma = (10-3R_4)/(12R_4-20). \qquad (3)$$

Here, $R_4 = E_4/E_2$.

After substituting the value of σ in equation (2), for θ_0 we get the expression (assuming $\hbar$=1)

$$\theta_0 = (6\,R_4-10)\,/E_4. \qquad (4)$$

Calculation:

From equation (3) and (4) and by knowing the energies of first two levels from the reference [4], we calculated the softness parameter σ and ground state moment of inertia θ_0 for the shape transitional even-even nuclei ranging from Ba to Dy in quadrant-1 of the major shell i.e. Z=56–66, and N=86–100.

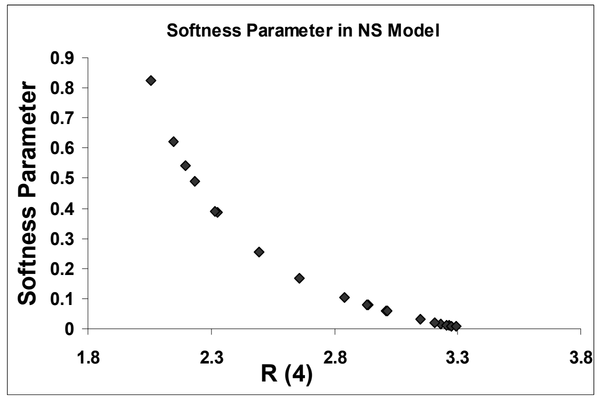

Fig. (1) The nuclear softness vs $R_{4/2}$ in NSM.

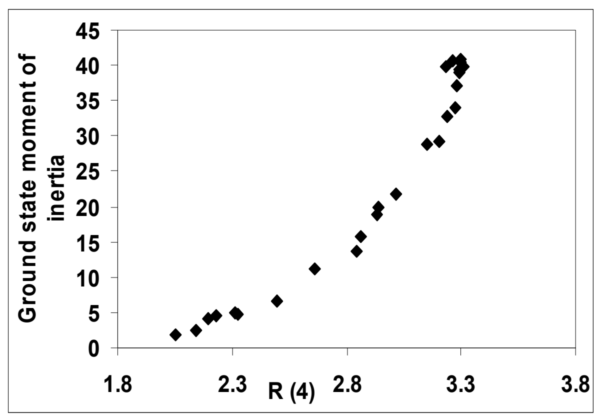

Fig. (2) The ground state MoI vs $R_{4/2}$ in NSM.

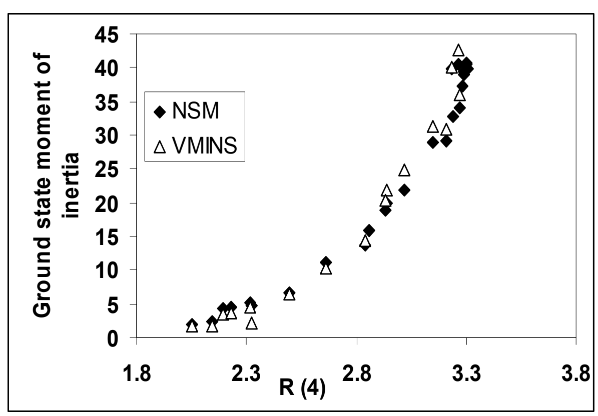

Fig. (3) Comparison between ground state MoI of NSM and VMINS Model.

Result and Discussion:

In graph (1) we plot the nuclear softness parameter σ versus energy ratio $R_{4/2}$, while in the graph (2) a plot of ground state moment of inertia θ_0 versus the energy ratio $R_{4/2}$ is shown. In graph (3) we compare the ground state moment of inertia (θ_0^{NSM}) with the (θ_0^{VMINS}) [6, 7].

From the figure (1 and 2), it is apparent that the minimum value of θ_0 and maximum value of softness parameter σ is found at $R_{4/2}$=2.05. After that on increasing $R_{4/2}$, the value of σ decreases exponentially and becomes minimum at $R_{4/2}$=3.33, when the nucleus gets well deformed. While at the same energy ratio, the ground state moment of inertia θ_0 has maximum value. The value of softness parameter σ varies between 0 and 1 ($0<\sigma<1$). For any nucleus, if σ =0 then the nucleus will be well deformed and is called rigid rotor. At σ=1 the nucleus will be beta soft, i.e. the nucleus would be just a harmonic vibrator.

In figure (3) the comparison between the moment of inertia of VMINS model and that of NS model is shown. The VMINS model [6, 7] is a modification of the Variable Moment of Inertia (VMI) model using Eq. (1). The moment of inertia θ_0 (Fig. 2, 3) initially increases slowly with increasing $R_{4/2}$ up to about 3.0, while above this, θ_0 increases faster. It is because of the corresponding decreasing rate of σ. This represents the corresponding values of MoI from VMINS and NS model. Both models are valid in this region equally. The region above $R_{4/2}$ >3.0 is called the deformed region.

Level energies calculated in NSM with parameters obtained from the first two levels yielded energies within a relative error of 5% of the experimental values. The RMS fit can give further enhanced accuracy.

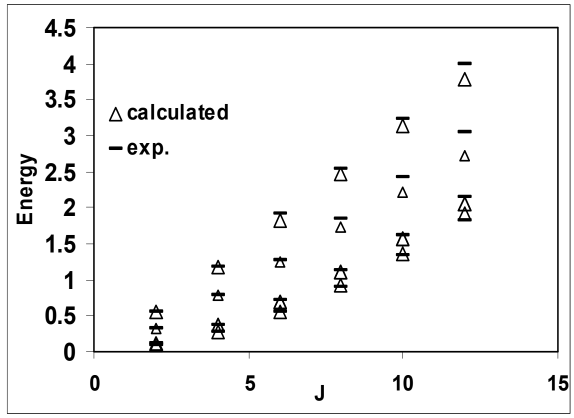

Fig.(4) Plot of calculated level energies for $^{148-154}$Sm (Δ) with experiment (-).

In Figure 4 a comparison of calculated level energies for $^{148-154}$Sm (Δ) with experiment (−) is given to illustrate the usefulness of the NSM expression.

Acknowledgement

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