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Yrast Band Description of ^{150}Sm, ^{152}Sm, ^{154}Gd and ^{192}Os Nuclei Using VAVMNS Model

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Abstract

In the frame work of the concept of softness parameter σ of nuclei a new formulation of the variable a harmonic vibrator model (VAVM) is formulated , which is denoted by (VAVMNS) The model is used in calculating the energies of rotational ground bands of ^{150}Sm,^{152}Sm, ^{154}Gd and ^{192}Os nuclei . The predicted results of the (VAVMNS) are in close agreements with experimental data and other theoretical ones.

Key words: rotational bands; variable a harmonic variable moment of inertia (VAVM); angular momentum, softness parameter (σ).

1. Introduction:

Many models have achieved a significant success for the representations of the energies of ground bands of well deformed nuclei, like the variable moment of inertia model (VMI) [1-3] and variable anharmonic variable moment of inertia model (VAVM) [4]. Generalized variable of inertia model (GVMI) [4, 5]. Cranking model [6] and its phenomenological equivalent [7, 8, 9].

The nuclear softness (NS) is well accepted concept in nuclear study especially in even- even nuclei. This concept is used through the softness parameter σ which is the relative increase of moment of inertia with angular momentum J. Batra and Gupta [10, 11] have extended the NS model concept to the VAVMNS model

The purpose of this work is to extend the concept of NS to the VAVM model (referred as VAVMNS). The VAVMNS model is tested by applying it on the chosen nuclei which gives good results compared with experimental data and other theoretical ones.

2. Theory:

The ground state rotational band of deformed nuclei was described by the semi classical formula [1]:

$$E(J) = \frac{\hbar^2}{2\theta(J)} J(J+1) \dots\dots (1)$$

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Where $\theta(J)$ is the nuclear moment of inertia, and J is the angular momentum, which takes the sequence $J^{\pi} = 2^{+}, 4^{+}, 6^{+}, \ldots$

For higher spin states, Eq. (1) deviates from experimental data, this deviation may be attributed to the change in moment of inertia $\theta(J)$

So, the energy is written as:

$$E(J) = \frac{\hbar^2}{2\theta(J)} J(J+1) + \frac{1}{2} C(\theta(J) - \theta_0)^2 \ldots \ldots (2)$$

Where the first term represents the rotational energy and the second represents the vibrational energy. Eq.(2) is well known variable moment of inertia model (VMI)

Batra and Gupta [11] have reformulated the VMI in terms of nuclear softness parameter which is called VMINS model.

Klein et al [4]; developed the (VMI) by proposed VAVM

$$E(J) = AJ + \frac{J(J-2)}{\theta(J)} + \frac{1}{2} C(\theta(J) - \theta_0)^2 \ldots \ldots (3)$$

where A, C and θ_o are fitting parameters. Also. Klein et al; [2] proposed the generalized variable moment of inertia model (GVMI) which written as:

$$E(J) = \frac{J + xJ(J-2)}{\theta(J)} + \frac{1}{2} K(\theta(J) - \theta_0)^2 \ldots \ldots \quad (4)$$

Where x , θ_0 and K are parameters. For $x = 1/3$ GVMI model Eq.(4) reduces to VMI model Eq.(2).

Since the formulation of VMI model in terms of nuclear softness (VMINS) model, which is deduced by Batra and Gupta [11] gives good agreement with experimental data and since VAVM model is special case of generalized model (GVMI), this encourages one to formulate VAVM model in terms of softness parameter.

By using Taylor expansion the moment of inertia as:

$$\theta(J) = \theta_0(1 + \sigma_1 J + \sigma_2 J^2 + \sigma_3 J^3 + \cdots) \ldots \ldots \quad (5)$$

Where σ_n is the softness parameter

$$\sigma_n = \frac{1}{n!} \frac{\delta^n \theta(J)}{\delta J^n}\bigg|_{J=0} \ldots \ldots \quad (6)$$

$$n = 1, 2, 3, \ldots$$

Takes only $n = 1$, the first approximation, and substitute in Eq (3), one gets

$$E(J) = AJ + \frac{J(J-2)}{\theta_0(1 + \sigma_1 J)} + \frac{1}{2} C(\theta_0 \sigma_1 J)^2 \ldots \ldots (7)$$

Using the experimental excitations energies $E(2)$, $E(4), E(6)$ and $E(8)$ and the Equation (7) one can find the parameters σ_1, θ_0, A and C as follows:

$$\sigma_1 = \frac{\left[\frac{9E(2) - 9E(4) + 3E(6)}{3E(4) - E(2) + E(8) - 3E(6)} - 3\right]}{24} \dots \dots \qquad (8)$$

$$\theta_0 = \frac{-48\sigma_1}{[3E(2) - 3E(4) + E(6)][1 + 4\sigma_1][1 + 6\sigma_1]} \dots \quad \dots (9)$$

$$A = \frac{1}{24}\left[\frac{48}{\theta_0(1 + 8\sigma_1)} + 16E(2) - E(8)\right] \dots \dots \qquad (10)$$

$$C = \frac{1}{2}\left[\frac{E(2) - 2A}{(\theta_0\sigma_1)^2}\right] \dots \qquad \dots (11)$$

3. Results and Discussion:

Using the experimental excitation energies E(2), E(4), E(6) & E(8) and Equations (8,9,10 &11), the parameters σ_1, θ_0, A and C are calculated. Using Eq (7) "VAVMNS model " and the given parameters σ_1, θ_0, A &C ,we predicted the energies for chosen nuclei ^{150}Sm ,^{152}Sm ,^{154}Gd and ^{192}Os .which is listed in table (2). The deviation from experimental data $\tau = \frac{1}{N}\sum_{i=1}^{N}\left(E_{Cal} - E_{exp}\right)^2$.

Table (1): The fitting parameters of VAVMNS model as in Eq. (7)

Nucleus	Parameters			
	σ_1	θ_0	A	$C \times 10^{-4}$
^{150}Sm	0.261	60.024	0.157	0.412
^{152}Sm	0.068	67.091	0.054	3.490
^{154}Gd	0.049	58.304	0.059	3.087
^{192}Os	0.068	52.231	0.091	9.564

The calculated results for the ground state rotational bands are given systematically in table 2. From this table we notice that the calculations are carried out for ^{150}Sm,^{152}Sm, ^{154}Gd and ^{192}Os nuclei whose yrast bands are observed experimentally up to $J^{\pi} = 16^{+}$for ^{150}Sm, up to $J^{\pi} = 14^{+}$ for ^{152}Sm, up to $J^{\pi} = 18^{+}$ for ^{154}Gd and $J^{\pi} = 12^{+}$ up to for ^{192}Os nuclei. And the energies calculated according to (VAVMNS) model in comparison with experimental data [14] and the energies calculated by VAVM model for the chosen nuclei. As can be seen, the results are excellent for all nuclei, in the vast majority nuclei, results of VAVMNS better than those predicted by the VAVM model. So from this table we notice that the agreements between the calculated and observed data are excellent.

The present study can also be useful in study the third term of equation (7) i.e. potential energy term with spin of the nucleons and with ground state of moment of inertia. The variation of potential energy term based on the valence particle and hole pairs consideration [8] with spin has been shown in fig. (1), it is clear that the value of potential energy term is increasing almost linear with increasing spin for all nuclei. It is apparent from fig. (2), that the potential energy term is decreases almost exponentially with ground state of moment of inertia.

Table (2): Experimental and Theoretical Energies in (Mev) of the Yrast band s of ^{150}Sm, ^{152}Sm, ^{154}Gd and ^{192}Os nuclei.

^{150}Sm Nucleus			
Spin J^{π}	$E_{experimental}$ (Mev)	E_{VAVM} (Mev)	E_{VAVMNS} (Mev)
2^+	0.340	0.340	0.340
4^+	0.774	0.774	0.774
6^+	1.279	1.279	1.279
8^+	1.837	1.837	1.837
10^+	2.432	2.417	2.443
12^+	3.043	3.034	3.093
14^+	3.646	4.676	3.787
16^+	4.305	4.340	4.523
Mean Deviation		0.019	0.052

^{152}Sm Nucleus			
Spin J^{π}	$E_{experimental}$ (Mev)	E_{VAVM} (Mev)	E_{VAVMNS} (Mev)
2^+	0.122	0.122	0.122
4^+	0.367	0.366	0.367
6^+	0.707	0.698	0.707
8^+	1.125	1.120	1.125
10^+	1.609	1.591	1.610
12^+	2.149	2.111	2.152
14^+	2.736	2.671	2.747
Mean Deviation		0.056	0.001

^{154}Gd Nucleus			
Spin J^{π}	$E_{experimental}$ (Mev)	E_{VAVM} (Mev)	E_{VAVMNS} (Mev)
2^+	0.123	0.123	0.123
4^+	0.371	0.371	0.371
6^+	0.718	0.718	0.718
8^+	1.145	1. 140	1.145
10^+	1.637	1.622	1.638
12^+	2.185	2.154	2.187
14^+	2.778	2.730	2.784
16^+	3.405	3.343	3.422
18^+	4.017	3.992	4.098
Mean Deviation		0.026	0.008

^{192}Os Nucleus			
Spin J^{π}	$E_{experimental}$ (Mev)	E_{VAVM} (Mev)	E_{VAVMNS} (Mev)
2^+	0.206	0.206	0.206
4^+	0.580	0.580	0.580
6^+	1.089	1.089	1.089
8^+	1.708	1.700	1.708
10^+	2.411	2.393	2.424
12^+	3.212	3.154	3.224
Mean Deviation		0.031	0.002

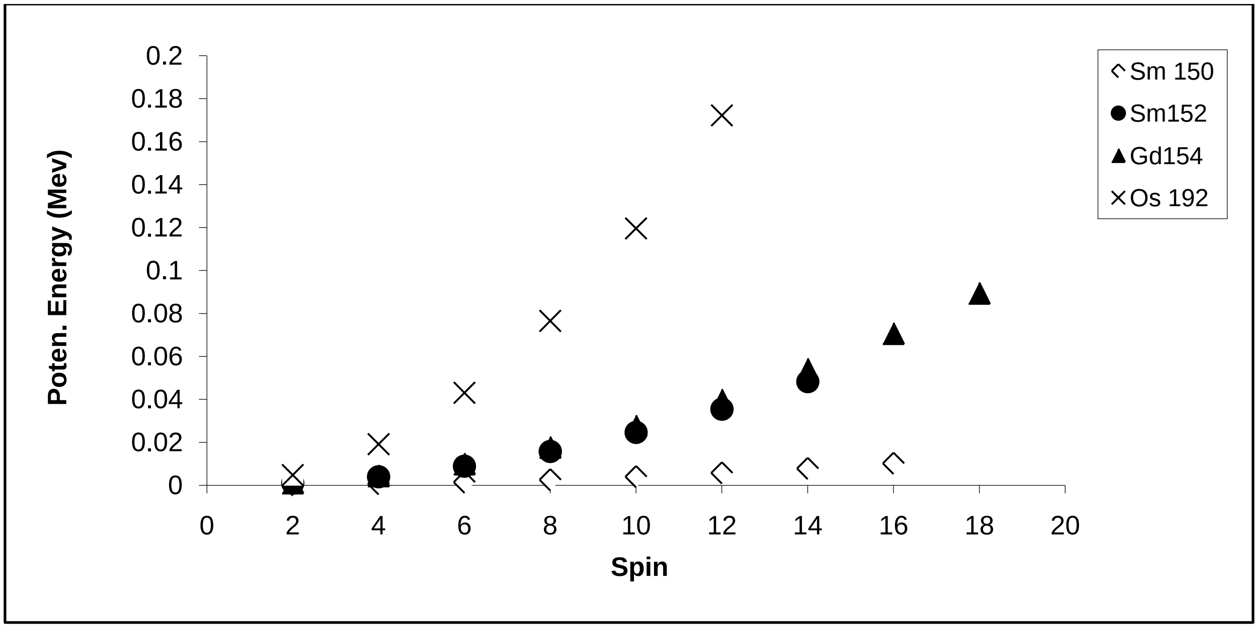

Fig. (1): The variation of potential energy term with spin.

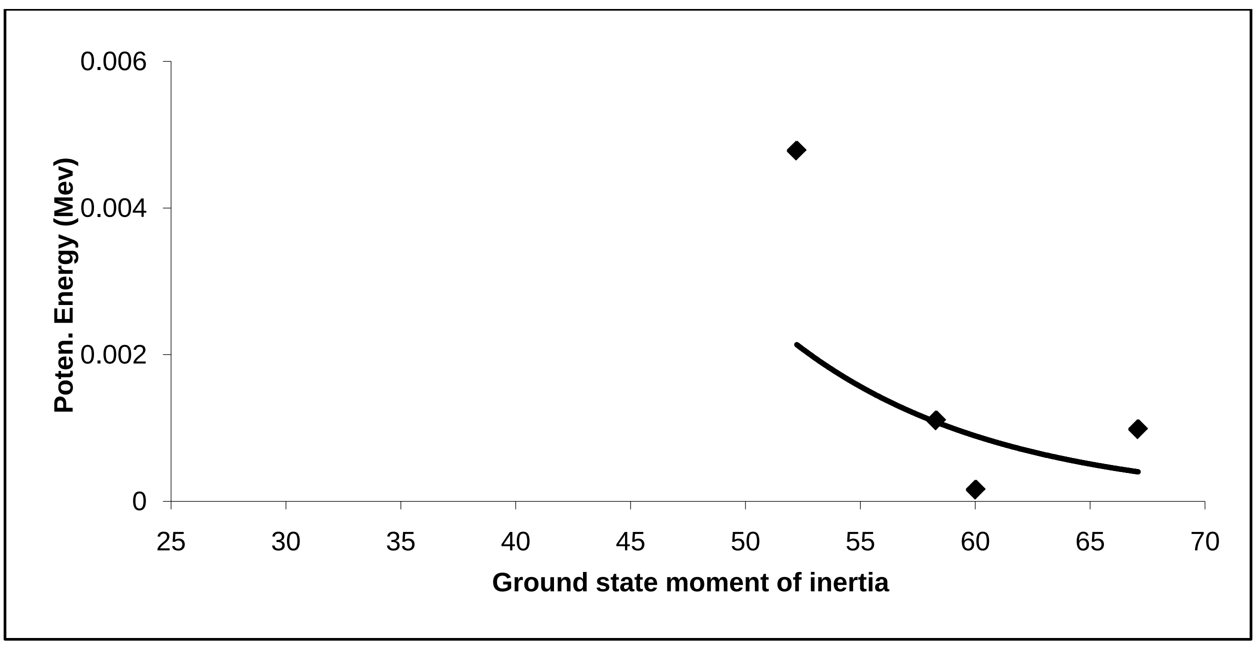

Fig. (2): The variation of potential energy term with ground state moment of inertia.

4. Conclusion

The present VAVMNS model Eq. (7) is practically fit to predict the ground state rotational bands of deformed even-even nuclei, and can also be applied to other nuclei. It includes three parameters which are determined straight forward using Equations 8, 9, 10 and 11. On the other hand, we observe that correlation between potential energy and spin, moment of inertia. The results of our calculation show good agreement with experimental data.

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