Systematic dependence of product $(E(2^+_\gamma) * B(E2)\uparrow)$ on asymmetry parameter γ_0

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Introduction

Davydov and Filippov [1] introduced the Asymmetric Rotor Model (ARM) to determine the energy level spacing and transition probabilities of excited states in few even-even nuclei. The Hamiltonian operator H used in ARM is given by:

$$H = \frac{1}{2}\sum J^2_\lambda Sin^{-1}(\gamma - \lambda\frac{2\pi}{3})$$

where J_λ are the projections of the operators of the total angular momentum along the axes of coordinate system fixed in the nucleus. In mass region of deformed nuclei, $150 \leq A \leq 190$ and $A \geq 222$, the theoretical calculations were found to be in good agreement with experimental values. In mass region of spherical nuclei, $70 \leq A \leq 130$, the ARM model also showed good agreement with experimental data for some nuclei. The asymmetry parameter γ_0 of ARM varies between 0 and $\pi/3$ and it mainly determines the deviation of shape of the nucleus from axial symmetry. In ARM model, the $B(E2)\uparrow$ value is related with γ_0

$$B(E2, 2^+_1 \rightarrow 0^+_1) = \frac{1}{2}(1 + \frac{3-2\sin^2(3\gamma_0)}{(9-8\sin^2(3\gamma_0))^{1/2}})$$

in units of $\frac{e^2Q_0^2}{16\pi}$.

The reduced excitation strength, $B(E2)\uparrow$ value is also of great interest in nuclear physics, as the collective effects in low-lying energy states are quadrupole in nature. Recently, a systematic study of $B(E2)\uparrow$ value with asymmetry parameter γ_0 have been presented by R. Kumar et al., [2]. Earlier, Gupta and Sharma [3] and Mittal et al., [4] gave correlation between the $B(E2)$ ratio and the asymmetry parameter γ_0 for medium and light nuclei. Grodzins [5] illustrates a close relationship between energy of first excited state $E(2^+_1)$ and reduced excitation strength, $B(E2)\uparrow$ values. In nuclear energy spectra, with increasing the valence neutron and proton pairs, the collectivity also increases, which yields an decrease in $E(2^+_1)$ and increase in $B(E2)\uparrow$, Grodzins gave this relation

$$(E(2^+_1) * B(E2)\uparrow) \sim constant(Z^2/A)$$

Recently, Gupta [6] concluded that the constancy of Grodzins product rule breaks down in the combined effect of the Z=64 subshell effect and the shape transition.

In the present work, we replace the first excited state energy E(2^+_1) with second excited E(2^+_γ) energy state, and now the equation becomes

$$(E(2^+_\gamma) * B(E2)\uparrow)$$

and study the systematics of the product $(E(2^+_\gamma) * B(E2)\uparrow)$ with asymmetry parameter γ_0 for the first time. This study provides a new insight in nuclear physics. The values of B(E2)↑ are taken from Ref. [7].

Method of determining γ_0

There are many methods to find γ_0, but the most relevant way [1] is by using $R_\gamma(= E_{2\gamma}/E_{2g})$ in equation:

$$\gamma_0 = \frac{1}{3}Sin^{-1}(\frac{9}{8}(1 - (\frac{R_\gamma - 1}{R_\gamma + 1})^2))^{1/2}$$

The values of E_{2g} and $E_{2\gamma}$ are taken from National Nuclear Data Centre website [8].

Results and discussion

Here, we use a simple rule of dividing the major shell space (Z=50-82, N=82-126) based on the hole and particle boson subshell space

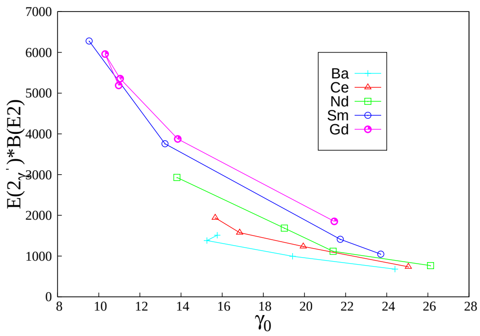

FIG. 1: The plot of energy $(E(2^+_\gamma) * B(E2) \uparrow)$ *vs.* asymmetry parameter (γ_0) for Ba-Gd nuclei.

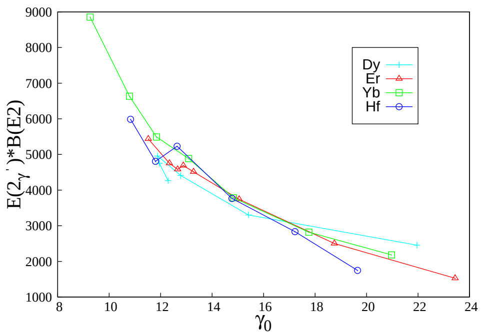

FIG. 2: The plot of $(E(2^+_\gamma) * B(E2) \uparrow)$ *vs.* asymmetry parameter (γ_0) for Dy-Hf nuclei.

given earlier by Gupta et al., [9]. The variation of $(E(2^+_\gamma) * B(E2) \uparrow)$ with asymmetry parameter γ_0 are shown in Figs.1-3. In quadrant-I, the graph of $(E(2^+_\gamma) * B(E2) \uparrow)$ vs. γ_0 is shown in Fig.1 for Ba-Gd nuclei. The plot shows monotonic fall of $(E(2^+_\gamma) * B(E2) \uparrow)$ with increasing γ_0, which reflects the smooth decrease of nuclear deformation. For quadrant-II, the plot is shown in Fig. 2 for nuclei Dy-Hf and it indicates that the $(E(2^+_\gamma) * B(E2) \uparrow)$ values show linear dependency on the asymmetry parameter γ_0. Fig.3 indicates that the value of $(E(2^+_\gamma) * B(E2) \uparrow)$ decreases with increasing value of asymmetry parameter γ_0 for Hf-Pt nuclei.

Conclusion

The product $(E(2^+_\gamma) * B(E2) \uparrow)$ provides a good measure of deformation in mass region

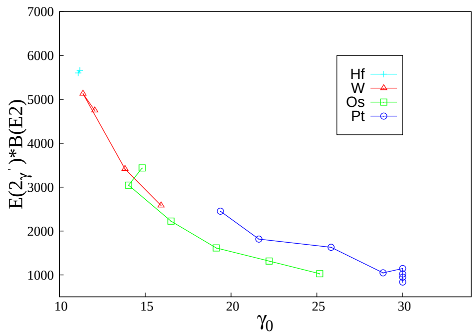

FIG. 3: The plot of $(E(2^+_\gamma) * B(E2) \uparrow)$ *vs.* asymmetry parameter (γ_0) for Hf-Pt nuclei.

A=120-200. In three quadrants, the product $(E(2^+_\gamma) * B(E2) \uparrow)$ shows systematic dependence on the asymmetry parameter γ_0.

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