Study of the product ($R_{4/2} * B(E2)\uparrow$) through Asymmetric rotor model

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Introduction

The Asymmetric Rotor Model (ARM) was initiated by Davydov and Filippov [1] to determine the energy level spacing and transition probabilities of excited states in few even-even nuclei. They also explained the structure of transitional nuclei and obtained results better than other models. In case of spherical and deformed nuclei, the theoretical results were found to be in good agreement with experimental values. 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. The $B(E2)\uparrow$ value is related with γ_0, as shown below:

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

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 $B(E2)\uparrow$ values with asymmetry parameter γ_0 have been presented in Ref. [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.

Theory

Grodzins [5] demonstrated a very close relationship between energy of first excited state $E(2_1^+)$ and reduced excitation strength, $B(E2)\uparrow$ values. In nuclear physics, the collectivity also increases with increasing the valence neutron and proton pairs which yields an decrease in $E(2_1^+)$ and increase in $B(E2)\uparrow$, Grodzins product can be written as:

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

Gupta [6] concluded that the constancy of Grodzins product breaks down in the combined effect of the $Z = 64$ subshell effect and the shape transition. Very recently, Kumari and Mittal [7] discussed about the systematic dependence of the product $((E(2_2^+)/E(2_1^+)) * B(E2)\uparrow)$ on the asymmetry parameter γ_0. In the present work, we replace the first excited state energy $E(2_1^+)$ with energy ratio $R_{4/2}$ $[= E(4_1^+)/E(2_1^+)]$ and now the equation for product becomes

$$(R_{4/2} * B(E2)\uparrow)$$

and for the first time, we study the systematics dependence of the product $(R_{4/2} * B(E2)\uparrow)$ with the asymmetry parameter γ_0.

Method of determining γ_0

The asymmetry parameter γ_0 value has been calculated by the most relevant way [1], i.e. 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 $B(E2)\uparrow$ values are taken from Ref. [8]. The energy of first 2^+ state, E_{2g} and $E_{2\gamma}$ data are taken from National Nuclear Data Centre website [9].

Results and Discussions

We use a simple rule of dividing the major shell space ($Z = 50 - 82, N = 82 - 126$) based on the hole and particle boson sub-space into four quadrants as proposed by Gupta *et al.*, [10]. The quadrant-IV contains no nucleus. The variations of product $(R_{4/2} * B(E2)\uparrow)$ with asymmetry parameter γ_0 are shown in Figs.1-3. In quadrant-I, the graph of

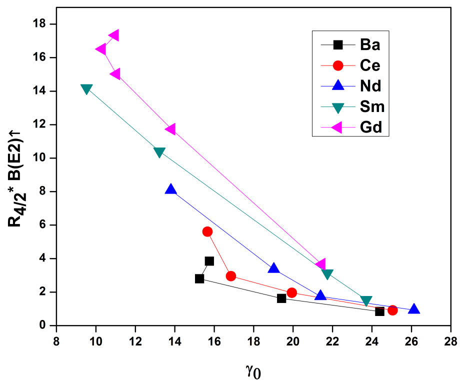

FIG. 1: The plot of energy ($R_{4/2} * B(E2) \uparrow$) *vs.* asymmetry parameter (γ_0) for Ba-Gd nuclei.

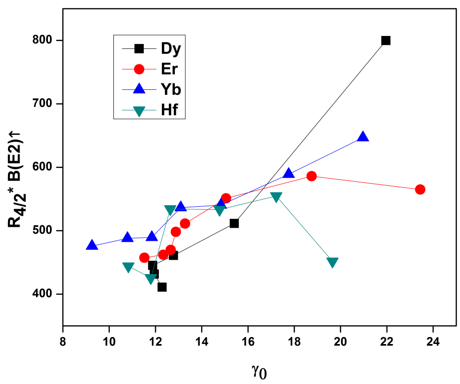

FIG. 2: The plot of ($R_{4/2} * B(E2) \uparrow$) *vs.* asymmetry parameter (γ_0) for Dy-Hf nuclei.

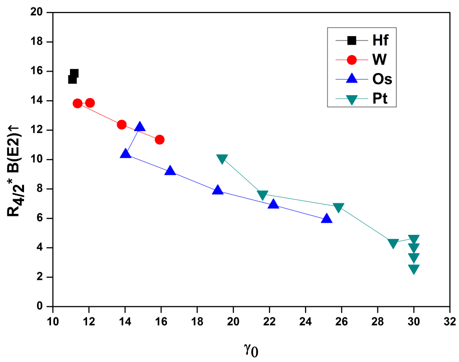

FIG. 3: The plot of ($R_{4/2} * B(E2) \uparrow$) *vs.* asymmetry parameter (γ_0) for Hf-Pt nuclei.

($R_{4/2} * B(E2) \uparrow$) vs. γ_0 is shown in Fig.1 for $Ba-Gd$ nuclei. The plot shows monotonic fall of ($R_{4/2} * B(E2) \uparrow$) 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 ($R_{4/2} * B(E2) \uparrow$) values show linear dependency on the asymmetry parameter γ_0. Fig.3 indicates that the value of ($R_{4/2} * B(E2) \uparrow$) decreases with increasing value of asymmetry parameter γ_0 for $Hf - Pt$ nuclei.

Conclusion

The product ($R_{4/2} * B(E2) \uparrow$) provides a good measure of deformation in mass region A=120-200. In three quadrants, the product ($R_{4/2} * B(E2) \uparrow$) shows systematic dependence on the asymmetry parameter γ_0.

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