Systematic study of $(R_{4/2} * B(E2) \uparrow)$ product with N_pN_n

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Introduction

The nucleon-nucleon interactions have been studied widely to understand the shape phase transition and sudden onset of deformation [1–3]. The proton-neutron interactions mostly emphasized on the valence protons and neutrons and can be estimated by N_pN_n product. The N_pN_n product was introduced using the Interacting Boson Model proposed by Iachello and Arima [4]. Casten [5] showed the systematics of first excited energy state, $E(2_1^+)$ and the energy ratio, $R_{4/2}$ on the total boson number N_B and N_pN_n product. Gupta *et al.* [6] illustrated the shape phase transition using $E(2_1^+)$ on N_B and N_pN_n product. Zhang *et al.* [7] illustrated a correlation between integrated p-n interactions and N_pN_n product for odd-odd nuclei.

Grodzins [8] demonstrated a very close relationship between $E(2_1^+)$ and reduced excitation strength, $B(E2) \uparrow$ values. In nuclear physics, the collectivity increases with increasing the valence neutron and proton pairs in closed shell, which yields decrease in $E(2_1^+)$ and increase in $B(E2) \uparrow$, Grodzins product can be written as:

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

Gupta [9] concluded that the constancy of $(E(2_1^+) * B(E2) \uparrow)$ breaks down in the combined effect of the $Z = 64$ subshell effect and the shape transition. Kumari and Mittal [10] studied the correlation between $(E(2_1^+) * B(E2) \uparrow)$ and N_pN_n product, and further extended their work to study the dependence of $(E(2_1^+) * B(E2) \uparrow)$ with the asymmetry parameter γ_0 [11]. The study of the new product $((E(2_2^+)/E(2_1^+)) * B(E2) \uparrow)$ within the framework of Asymmetric Rotor Model (ARM) has been discussed in Ref. [12].

In the present work, we replace $E(2_1^+)$ of the Grodzins product 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 N_pN_n product. The study of the product $(R_{4/2} * B(E2) \uparrow)$ in the framework of ARM has been illustrated in Ref. [13]. The $B(E2) \uparrow$ values are taken from Ref. [14]. The energy $E(2_1^+)$ data are taken from National Nuclear Data Centre website [15].

Results and Discussion

We use a simple rule of dividing the major shell space $(Z = 50 - 82, N = 82 - 126)$ based on the hole and particle nucleons sub-space into four quadrants as proposed by in Ref. [16]. The variations of product $(R_{4/2} * B(E2) \uparrow)$ with N_pN_n product are shown in Figs. 1-3. In quadrant-I, the graph of $(R_{4/2} * B(E2) \uparrow)$ vs. N_pN_n product is shown in Fig. 1 for $Ba - Gd$ nuclei.

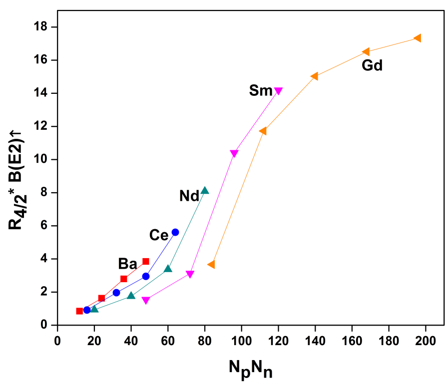

FIG. 1: The plot of energy $(R_{4/2} * B(E2) \uparrow)$ *vs.* N_pN_n product for $Ba - Gd$ nuclei.

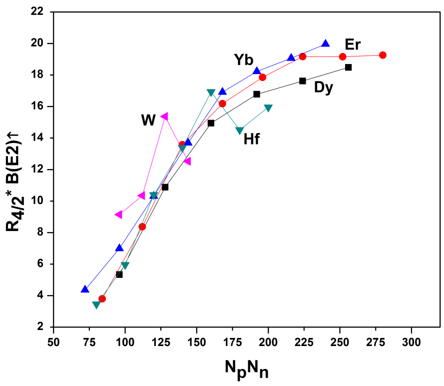

FIG. 2: The plot of $(R_{4/2} * B(E2) \uparrow)$ *vs.* N_pN_n product for $Dy - Hf$ nuclei.

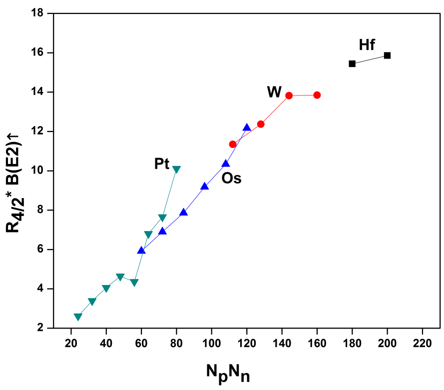

FIG. 3: The plot of $(R_{4/2} * B(E2) \uparrow)$ *vs.* N_pN_n product for $Hf - Pt$ nuclei.

The plot shows monotonic rise of $(R_{4/2} * B(E2) \uparrow)$ with increasing N_pN_n, 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 N_pN_n product. Fig. 3 indicates that the value of $(R_{4/2} * B(E2) \uparrow)$ increases with increasing value of N_pN_n product 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 N_pN_n product.

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