Systematic study of \((R_{4/2} \ast B(E2) \uparrow)\) 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:

\[
(E(2^+_1) \ast B(E2) \uparrow) \sim \text{constant}.
\]

Gupta [9] concluded that the constancy of \((E(2^+_1) \ast B(E2) \uparrow)\) breaks down in the combined effect of the \(Z = 64\) subshell effect and the shape transition. Kumari and Mittal [10] studied the correlation between \((E(2^+_1) \ast B(E2) \uparrow)\) and \(N_pN_n\) product, and further extended their work to study the dependence of \((E(2^+_1) \ast B(E2) \uparrow)\) with the asymmetry parameter \(\gamma_0\) [11]. The study of the new product \(((E(2^+_2)/E(2^+_1)) \ast B(E2) \uparrow)\) 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

\[
(R_{4/2} \ast B(E2) \uparrow)
\]

and for the first time, we study the systematics dependence of the product \((R_{4/2} \ast B(E2) \uparrow)\) with \(N_pN_n\) product. The study of the product \((R_{4/2} \ast B(E2) \uparrow)\) 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 \((R_{4/2} \ast B(E2) \uparrow)\) with \(N_pN_n\) product are shown in Figs. 1-3. The graph of \((R_{4/2} \ast B(E2) \uparrow)\) vs. \(N_pN_n\) product is shown in Fig. 1 for Ba – Gd nuclei.

![FIG. 1: The plot of energy \((R_{4/2} \ast B(E2) \uparrow)\) vs. \(N_pN_n\) product for Ba – Gd nuclei.](https://www.sympnp.org/proceedings)
The plot shows monotonic rise of $(R_{4/2} \ast B(E2) \uparrow)$ 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 $(R_{4/2} \ast B(E2) \uparrow)$ values show linear dependency on the $N_pN_n$ product. Fig. 3 indicates that the value of $(R_{4/2} \ast B(E2) \uparrow)$ increases with increasing value of $N_pN_n$ product for $Hf - Pt$ nuclei.

**Conclusion**

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

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**References**