Systematic Dependence of $R_4$ on $NpNn$ Product for Light and Medium Mass Nuclei

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Introduction

The study of nuclear structure with $N$, $Z$, $N_a$ and $NpNn$ provide a deep understanding of nuclear interactions involved. Various studies had been carried to study the systematic dependence of various nuclear properties on $NpNn$. Casten et al [1] presented a review on the evaluation of nuclear structure on the bases of $NpNn$; this phenomenon has been called the $NpNn$ scheme. Gupta et al [2] presented a systematic dependence of the $\gamma - g$ $B(E2)$ ratios on the $NpNn$ in different parts of the major shell space $Z = 50 - 82$, $N < 82$ and $N = 82 - 126$ and demonstrated that the interband $B(E2)$ ratios were smooth functions of $NpNn$. Further, Gupta et al [3] pointed out the limitations of the F-spin and $NpNn$ scheme in reproducing the overall $E_{2g}^+$ systematics in the major shell space $Z = 50 - 82$, $N = 82 - 126$ into four quadrants. The quadrant- I has $Z = 50 - 66$, $N = 82 - 104$ (p-p), in quadrant- II, $Z = 66 - 82$, $N = 82 -104$ (p-h), quadrant – III, $Z = 66 - 82$, $N = 104 - 126$ (h-h), and quadrant- IV, $Z = 50 - 66$, $N = 104 - 126$, (p-h), where, p = valence particle, proton or neutron and $h$ = hole. The quadrant-IV does not has any data point, thus it is empty.

Result and Discussion

In this work, we adopt a grouping based on the valance particle and hole pairs consideration [12]. Thus the $Z = 50 - 82$, $N = 82 -126$, major shell space is partitioned into four quadrants. The quadrant- I has $Z = 50 - 66$, $N = 82 - 104$ (p-p), in quadrant- II, $Z = 66 - 82$, $N = 82 -104$ (p-h), quadrant – III, $Z = 66 - 82$, $N = 104 - 126$ (h-h), and quadrant- IV, $Z = 50 - 66$, $N = 104 - 126$, (p-h), where, p = valence particle, proton or neutron and $h$ = hole. The quadrant-IV does not has any data point, thus it is empty.

Dependence of $R_4$

In the IBM-1[13], a useful measure of collectivity is $R_4$ for rotational nuclei this ratio $R_4 = 3.33$ and the region $3 < R_4 < 3.33$ is called the rotational region and for the vibrational nuclei $R_4 = 2$ and the region $2 < R_4 < 2.4$ is called the vibrational region while the region $2.4 < R_4 < 3$ is called the transition region. The transition region contains nuclei with structure intermediate between vibration and rotational. For simplicity, we divide the whole data of ratio $R_4$ as function of $NpNn$ into four quadrants as above. First we consider quadrant-I, Fig. 1 shows the ratio $R_4$ for even-even nuclei as function of $NpNn$. In this fig. for Xe -Dy nuclei with $N=82-104$ (p-p region).The $R_4 < 1.5$ for $NpNn = 0$ (i.e. magic nuclei) and $R_4$ varies smoothly with $NpNn \leq 30$. These nuclei have a shape change vibrational to transitional because $1.9 \leq R_4 \leq 3$ and finally $R_4$ remains unchanged when $NpNn \geq 30$ these nuclei are called rational nuclei because $R_4 = 3.33$.

From Fig 2 for Dy -Pt nuclei with $N = 82-104$ (h-p boson), i.e. quadrant-II here most of the data...
points lie on a smooth curve that rises with increasing $NpNn$ product. In this region most of nuclei have rotational nature because $3 \leq R_4 \leq 3.33$ except few data points of Er, Dy and Pt.

From fig. 3, for Yb -Hg nuclei with $N = 104-126$ (h-h boson region) i.e. quadrant III, in this region the dependence of $R_4$ on $NpNn$ is again smooth for Yb -Os these nuclei are in rotational region because $3 \leq R_4 \leq 3.33$ and the data point of Pt and Hg indicates a new signature of vibrational nature because $R_4 = 2.5$.

This systematic dependence of $R_4$ for ground state in all three regions on the $NpNn$ indicates its close relationship to the shape deformation of the nuclear core.

**Conclusions**

The present study reflects that the ratio $R_4$ depends upon $NpNn$. The variation of $R_4$ shows the average dependence on $NpNn$ for shape deformation in all three quadrants except Pt and Hg isotopes in quadrant-III. Here a complexity of nuclear structure is exhibited between $NpNn$ and $R_4$.

**References**
