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

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Introduction

The study of nuclear structure with N, Z, N_B 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 γ – 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}^+ systematic in the major shell space Z = 50 - 82, N = 82 -126 into four quadrants and predicted the position of the β-stability line on the N-Z chart to explains the existence of isotonic (isotopic) multiplets.

Recently, most work related to the NpNn scheme mainly concentrate on P- factor [=NpNn/(Np + Nn)] [ref. 1], and β_2 [ref. 4, 5, 6], systematic law of E_{2g}^+ for heavy nuclei[7], excitation energy of first 2^+ state of all even-even nuclei [8, 9] and odd-even staggering [10]. The systematic dependence of R_4 on NpNn in major shell- space has not been studied sufficiently. The present study of dependence of R_4 on NpNn is interesting to investigate new insight. Recent experimental data have been taken ref. [11]. In the present work, we focus on the systematic dependence of R_4 on NpNn in even - even nuclei for Z = 50 - 82, N = 82 – 126 region, by dividing the whole space into four quadrants.

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 $3 \leq R_4 \leq 3.33$ is called the rotational region and for the vibrational nuclei R_4 =2 and the region $2 \leq R_4 \leq 2.4$ is called the vibrational region while the region $2.4 \leq R_4 \leq 3$ 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 of 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 ≤30. These nuclei have a shape change vibrational to transitional because $1.9 \leqq R_4 \leqq 3$ and finally R_4 remains unchanged when NpNn ≧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.

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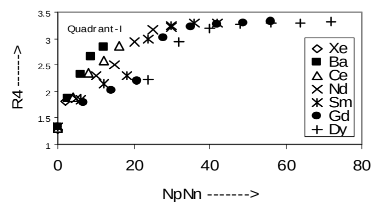

Fig. 1. Experimental data for R_4 for even – even nuclei as a function of NpNn product for Z = 50 - 66, N = 82 - 104 i.e., quadrant – I.

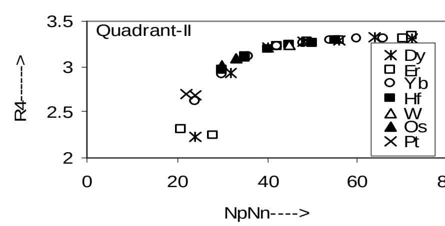

Fig.2. Same as fig.1 for Z= 66 - 82, N = 82 - 104, i.e, quadrant –II.

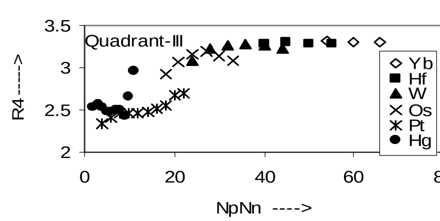

Fig. 3. Same as fig. 1 for Z = 66 - 82, N = 104 - 126, i.e., quadrant –III.