Systematic of $\pi h_{11/2} \otimes \nu h_{11/2}$ configuration and shapes of N = 79 isotones in A ~ 130 mass region

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Introduction

A rich variety of structural phenomena are observed for the neutron deficient nuclei in mass region A ~ 130. The nuclei with proton and/or neutron numbers close to the magic shell gaps 50 and 82 are spherical at ground state. As the proton and neutron Fermi levels move away slightly from these shell closures, deformed shapes appear which varies in an isotopic or isotonic chain. Calculations show a transition from prolate to oblate shape for neutron number N = 73 to N = 75 [1]. Moreover, because of the different shape driving effects for protons and neutrons, many of the nuclei in this region are triaxial which leads to band structures with novel angular momentum coupling schemes like chiral bands, magnetic rotational bands etc. [2,3].

A low-lying 8^- isomer with $\pi d_{5/2} \otimes \nu h_{11/2}$ has been observed in many of the odd-odd nuclei in this region. The $\pi h_{11/2} \otimes \nu h_{11/2}$ configuration also becomes accessible at moderate excitation energy and deformation for the nuclei with Z > 51. Rotational bands based on this configuration have been observed for the La, Pr etc. nuclei with N = 79. The deformation of the bands in these isotones varies with the proton number.

The results of the calculations of excitation energy and shapes of the bands based on $\pi h_{11/2} \otimes \nu h_{11/2}$ configuration vis-à-vis the normal –ve parity ground state configuration are reported here. The total energy surfaces are calculated using the Hartee-Fock-Bogoliubov code of Nazarewicz et al. [4]. The procedure has been outlined in reference [5, 6]. Deformed Woods-Saxon potential and pairing interaction was used with Strutinsky shell corrections method. Total energies are calculated in β_2-γ deformation mesh points (minimized in β_4) at different rotational frequency ω and for different configurations.

Results and Discussion

The total energies of the ground state and the $\pi h_{11/2} \otimes \nu h_{11/2}$ configurations are performed for various N = 79 nuclei from Iodine (Z = 53) to Tb (Z = 65). The excitation energy of the above configuration for these nuclei is obtained from the difference of total energies (minimized in β_2, γ, β_4) for this configuration and that of the ground state configuration with the odd proton in $g_{7/2}$ or $d_{5/2}$ and the odd neutron in the $h_{11/2}$ orbital. The excitation energies thus obtained are shown in Fig 1 as a function of atomic number Z by the symbol 'x' connected with dashed line along with the experimental values.

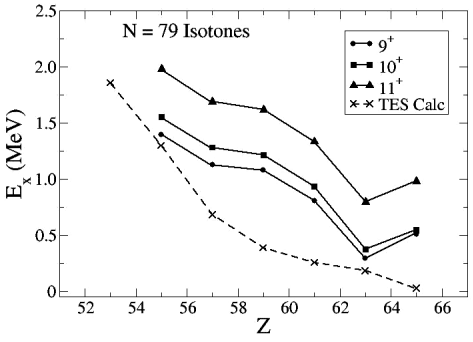

Fig. 1 Systematic of calculated and observed excitation energy of $\pi h_{11/2} \otimes \nu h_{11/2}$ configuration.

It can be seen that the calculated excitation energy of this configuration increases as Z decreases following the trend of the observed values. As Z approaches the 50 shell closure the spherical shape starts dominating and the $\pi h_{11/2}$ orbital becomes energetically less favored, thereby, increasing the excitation energy. The contour plots of the total energy in the β_2-γ plane show minimum around near- spherical shapes for

both the ground state and the $\pi h_{11/2} \otimes \nu h_{11/2}$ configurations in these nuclei.

The agreement is, however, not as good for the transitional nuclei between Z = 57 and 61. This can be understood by looking at the equilibrium shape of these nuclei obtained from the total energy surface calculations. The contour plots of the equipotentials are shown in Fig 2 for the nucleus ^{138}Pr (Z = 59) as calculated for the ground state and the $\pi h_{11/2} \otimes \nu h_{11/2}$ configurations in (a) and (b) respectively. The separation between the contours is 250 keV.

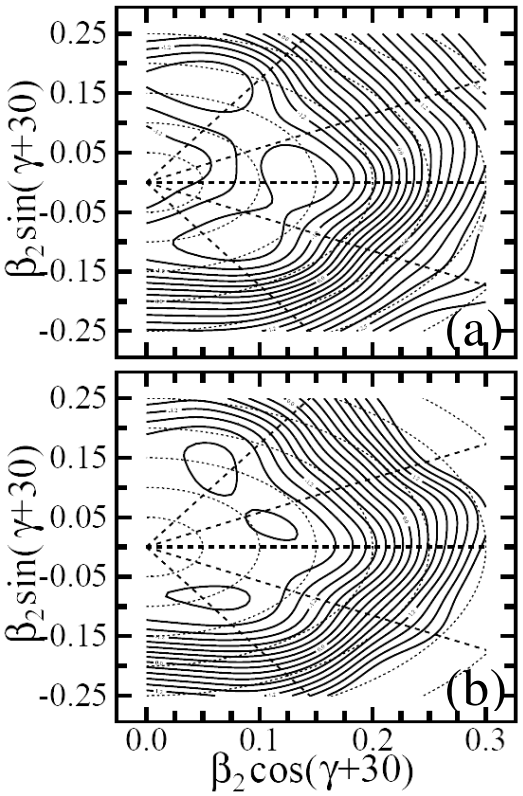

Fig. 2 Total energy surfaces of ^{138}Pr for ground state (a) and $\pi h_{11/2} \otimes \nu h_{11/2}$ (b) configurations.

Above figure shows rather complicated shape for ^{138}Pr for the two configurations. It is γ-soft at the ground state with a broad minimum which spreads between $\gamma = 0^o$ (prolate) and -90^o (triaxial) through oblate shape at $\gamma = -60^o$. There lies another broad minimum at triaxial shape around $\gamma = -30^o$. The surface in Fig 2(b) has three distinct minima at prolate, oblate and triaxial deformations. Interactions between the levels of these shapes will have the effect of increasing the excitation energy of the $\pi h_{11/2} \otimes \nu h_{11/2}$ configuration compared to the calculated one which is obtained for one of the shapes. Similar complicated structures are obtained for the other isotones i.e in ^{136}La (Z=57) and ^{140}Pm (Z=61) for which theory under predicts the experimental values. On the other hand, there is good agreement between the calculated and the observed excitation energy for ^{142}Eu (Z=63). For this nucleus, stable triaxial deformed shapes are obtained at both the configurations. Similarly for ^{134}Cs (Z=55), the ground state shape is near spherical and an oblate shape with small β_2 is obtained for the $\pi h_{11/2} \otimes \nu h_{11/2}$ configuration. The predicted excitation energy of ^{134}Cs for this configuration agrees well (see Fig 1) with the experimental value obtained recently [7]. The experimental data for ^{132}I (Z=53), the calculation of which is shown in Fig 1, is not available yet.

In summary, the excitation energy of the $\pi h_{11/2} \otimes \nu h_{11/2}$ configuration in the N = 79 isotones in mass region A ~ 130 is reasonably explained by the configuration dependent total energy calculations in the deformed Woods-Saxon potential. The disagreement for the transitional nuclei is attributed to their γ-softness and mixing of different shapes as obtained in the calculations. The calculations also suggest a rapid change of shape with excitation energy and particle number in this region. It warrants a systematic experimental investigation of this structural change in this region.

References

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