Structural evolution in ^{125}I, ^{123}I and ^{122}I with increasing angular momentum

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The interplay between collective and single-particle degrees of freedom in atomic nuclei is one of the most interesting and intriguing aspects of nuclear structure studies. For a deeper understanding of these features, investigations have been carried out up to the limits of angular momentum that nuclei can withstand before undergoing fission. In fact, the quest to observe ever increasing high-spin states in nuclei has driven the field of gamma-ray nuclear spectroscopy for several decades. These studies have revealed a lot of exciting information about the competing behaviour of both collective and non-collective modes of excitations in the nuclei.

This thesis investigates the angular momentum induced structural changes in ^{125}I, ^{123}I, and ^{122}I nuclei. Three separate experiments were performed to acquire the requisite data. The high spin states in ^{125}I and ^{123}I were studied using the heavy-ion fusion evaporation reactions ^{82,80}Se(^{48}Ca,p4n)^{125,123}I with the Gammasphere array. The nucleus ^{122}I was investigated using the reaction ^{116}Cd(^{11}B,5n)^{122}I with the Indian National Gamma Array (INGA) spectrometer. Detailed level scheme, for both positive and negative parities, have been established in the study of all the three nuclei. The study of the level structure of these nuclei with increasing angular momentum values has revealed the following interesting observations:

A. Ground state to $I \sim 30\hbar$: Transition from collective to non-collective regime in ^{125}I, ^{123}I, and ^{122}I

The low-energy states in Iodine isotopes ($Z = 53$) have been explained in terms of odd particle coupled to the levels of neighboring even-even Te nuclei. Rotational bands of low collectivity have been observed up to the medium-spin region. At higher energies, however, these nuclei exhibit a more complex structure with coexisting weakly collective and non-collective quasiparticle-aligned configurations. Non-collective oblate states have been identified at spin $I \sim 30\hbar$ in all the three nuclei [1–3]. These states are favored in energy relative to a rotating liquid drop reference. A comparison with Cranked Nilsson Strutinsky (CNS) calculations suggests that these states are maximally aligned states, formed by aligning all valence particle above the ^{114}Sn core, along a common rotation axis. Their configurations have been understood as $\pi[(g_{7/2}d_{5/2})^2 h_{11/2}] \otimes \nu[(h_{11/2})^5]$ for positive parity and $\pi[(g_{7/2}d_{5/2})^2 h_{11/2}] \otimes \nu[(h_{11/2})^n]$ for negative parity, where n is 6 for ^{125}I, and 4 for ^{123}I and ^{122}I. In addition, favored non-collective states, where the spin vectors of one or two particles are anti-aligned, have also been identified at $I \sim 20 - 22\hbar$. A particularly interesting observation was a two-particle anti-aligned state in ^{125}I, which is, to our knowledge, the first observation of a state with such structure. The experimental results are in good agreement with the theoretical predictions.

B. High-spin regime $I \sim 30 - 32\hbar$: Core-excitations beyond maximally-aligned configurations in ^{123}I and ^{122}I

Several dipole transitions of energies in the range of $1.0 - 1.7$ MeV have been observed feeding the energetically favored terminating states in ^{123}I [2] and ^{122}I [3]. CNS calculations indicate that these weak feeding transitions originate from the configurations involving a core-breaking neutron particle-hole ex-

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citation from the $g_{7/2}d_{5/2}$ to the $d_{3/2}s_{1/2}$ or $h_{11/2}$ orbitals across the semi-magic $N = 64$ shell gap. The calculated core-excited states lie in the order 1.5 MeV or more above the terminating states when drawn with a rotating liquid drop reference subtracted. In comparison, the observed states appear at a lower energy. This indicates that the $N = 64$ neutron gap is calculated ~ 1 MeV large with the present parameters in the model.

C. High-spin regime $I > 30\hbar$: Highly-deformed high-spin bands in ^{125}I and ^{123}I

At high-spin, rotational bands extending upto $I \sim 50\hbar$ have been observed in ^{125}I [4] and ^{123}I [5]. The properties of these newly identified bands are similar to those of the highly deformed bands recently discovered in neighboring nuclei [6–8]. Moreover, the band in ^{125}I is found to be 'identical' to one of the bands in ^{126}Xe. This suggests almost similar configuration for the two bands. However, their excitation energies, relative to the rotating liquid drop energies, has been observed to differ by $\simeq 1$ MeV, which is surprisingly large for collective bands in neighboring nuclei.

CNS calculations have been carried out for the bands in ^{125}I, ^{123}I and ^{126}Xe. The properties of the configurations, expected at low energy theoretically, are not in reasonable agreement with those of the new band in ^{125}I and its 'identical partner' band in ^{126}Xe [4]. It remains a puzzle, why the theoretically expected lowest-energy configurations are not observed experimentally. However, a comparison of various features of the bands with the results of the calculations suggests the involvement of both $\pi g_{9/2}$ and $\nu i_{13/2}$ orbitals in the configuration of these bands [4]. Similar results have also been observed for the bands in ^{123}I.

These observations suggest that down-sloping neutron orbitals alone cannot explain the occurrence of highly-deformed structures in mass $A \approx 125$ region. The relevant configurations are obtained only if the proton core is broken and one or two protons are excited from the $g_{9/2}$ subshell.

Moreover, it can be concluded that the present CNS calculations are unable to describe the experimental data at very high-spin in a satisfactory way. Similar discrepancies between experiment and calculations have been observed for ^{124}Ba [8], ^{125}Xe [6], and for the other high-spin bands in ^{126}Xe [7]. This is difficult to understand considering the successful description of high-spin data within the CNS approach in various regions of the nuclear chart and should be further explored.

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