Single Particle and Collective Excitations near Z = 50

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Nuclei, having few proton particles above Z = 50, and few neutron holes in the N = 82 shell provide valuable information about the effective nucleon-nucleon interactions and various coupling schemes between the valance nucleons [1]. The presence of the unique parity, high-j $h_{11/2}$ orbital, in both Z, N = 50 − 82 shell, makes these nuclei more fascinating in order to explore the shape driving effects of the $h_{11/2}$ orbital over a chain of isotopes from near stability to neutron-rich side of the nuclear chart. The contribution of the $h_{11/2}$ orbital in the high spin generation mechanism is also one of the major interests of this thesis. The study of the nuclei, having proton number near Z = 50, also helps to understand the competition between the collective and the single particle excitations. On the contrary, if one moves towards N = 82, with Z∼50, the exciting domain of neutron rich nuclei around ^{132}Sn becomes accessible [2, 3]. The present thesis aims to study the single particle and collective excitations of nuclei, both near stability as well as towards the neutron-rich side, having atomic number around the Z = 50 shell closure. The deformation driving behavior of the high-j $h_{11/2}$ orbital has also been explored in the neutron rich domain.

This thesis reports the results from the study of excited states of total eight nuclei, namely, ^{117}Sb (Z = 51), having valance neutrons in the mid-shell of N = 50−82, and ^{131,134}Xe (Z = 54), $^{130-134}$I (Z = 53), having few valance neutron holes in the N = 82 shell. In the present work, different reaction mechanisms, such as, fusion evaporation, fission and β-decay have been appropriately employed to populate the nuclei of interest in their excited states. The measurements, related to the present thesis, are carried out using different HPGe detector arrays, available within India, as well as at other international labs. VECC Array for Nuclear Spectroscopy (VENUS) and Indian National Gamma Array (INGA), set up at VECC, are used for experiments carried out in India. The state of art Advanced Gamma Ray Tracking Array (AGATA), coupled with VAMOS++ large acceptance magnetic spectrometer and segmented clover HPGe detectors (EXOGAM) are used to study isotopically (A, Z) identified neutron-rich nuclei, produced in fission, at GANIL, France.

The rotational band structures as well as the low-lying single-particle excitations in ^{117}Sb have been studied via the reaction ^{115}In (α, 2n) ^{117}Sb with α beam of 28 MeV from K-130 cyclotron at VECC, using the VENUS setup. The existing level scheme of ^{117}Sb is extended with the placement of 31 new γ-ray transitions [4]. The signature partner of the band, based on the $\pi g_{7/2}$ configuration and coupled to the 2p-2h structure of the ^{116}Sn core, has been established for the first time in ^{117}Sb. The level energies and the observed large signature splitting are well reproduced by the Particle Rotor Model (PRM) calculations. The PRM calculations also indicate a low-Ω π1/2[431] Nilsson configuration for this band, which is consistent with its large signature splitting. Several new non-yrast levels have been identified at the low and medium spins. The low-lying positive-parity states have been interpreted in terms of the large scale shell model calculations, using the code OXBASH.

Excited states of ^{131}Xe have been investigated using the reaction ^{130}Te (α, 3n) ^{131}Xe at 38 MeV energy of α beam and the INGA setup at VECC. A rich variety of new band structures have been obtained with the observation of 72 new γ rays [5]. The identification of the bands, based on different quasiparticle (qp) configurations, reveals the transitional nature of ^{131}Xe at N=77. The new data on the signature splitting and the single-particle alignment of the lowest negative-parity 1-qp $\nu h_{11/2}$ band indicate a triaxial shape, with the involvement of a high-Ω Nilsson orbital. The lowest positive parity band has also been substantially extended and shows a signature inversion at moderate spin. This observation, along with a large signature splitting after the inversion, indicates a change in the structure. Two new band structures, a 3-qp band having configuration $\pi(g_{7/2}h_{11/2}) \otimes \nu f_{7/2}$ with large staggering and a 5-qp dipole band having configuration $\pi(g_{7/2}d_{5/2})^3 h_{11/2} \otimes \nu h_{11/2}$, have also been identified. Theoretical TRS calculations for the 1-qp and 3-qp configuration bands suggest interesting structural evolution, which corroborates well with the experimental findings. Triaxial shape and γ-softness are obtained for the 3-qp configurations. New sets of states have been identified which are found to decay to these bands. This gives interesting prospects of the observation of γ bands, which needs to be further investigated. Magnetic Rotational band is also identified in this nucleus and discussed using the semi-classical model and Shears mechanism with the Principal Axis Cranking (SPAC) model calculations [6].

The prompt-delayed spectroscopy of the neutron-rich iodine isotopes $^{130\text{-}134}$I have been carried out after producing the nuclei in fusion-fission and transfer induced fission reaction of ^{9}Be(^{238}U, f), in inverse kinematics, at a beam energy of 6.2 MeV/u. The complete (A, Z) identification of the fission fragments was possible from the reconstruction of kinematical angles, magnetic rigidity of each fragment passing through the spectrometer. The Doppler corrected prompt γ ray spectra were obtained from the angle between the velocity of each fragment and γ ray tracked with AGATA. The delayed γ rays were detected with EXOGAM segmented clover detectors, placed behind the focal plane of the VAMOS++ spectrometer. The prompt γ-ray transitions above the 8^- long lived isomers in odd-odd ^{130,132}I are identified for the first time and a new isomer in ^{132}I is also reported [4] from prompt-delayed correlation. The level structure of ^{134}I is also extended. The high-spin level structures of ^{131,133}I are also investigated with the placement of the new prompt transitions above the $19/2^-$ isomers from the prompt-delayed coincidence techniques [7]. The proposed level schemes are interpreted in terms of the systematics and the large scale shell model calculations using NuShellX. It is found that, the hole occupancy in the $\nu h_{11/2}$ orbital plays a dominant role in generating the high-spin negative parity states in these neutron-rich iodine isotopes. It is seen that only the $\pi g_{7/2}$, $\pi d_{5/2}$ and $\nu h_{11/2}$ orbitals contribute in the spin generation for both even-A iodine and for the states above the $19/2^-$ isomer in odd-A iodine. From the shell model calculations, it is also observed that, for ^{130,132}I, dominant contribution is from $\nu h_{11/2}^{-1}$ and $\nu h_{11/2}^{-3}$ contributes at higher spin. In odd-A ^{133}I, the $\nu h_{11/2}^{-1}$ configuration is found to be almost pure. But in ^{131}I, the $\nu h_{11/2}^{-1}$ configuration dominates only upto $25/2^-$ spin, beyond that, proton excitation to the $\pi h_{11/2}$ orbital takes place.

The low lying excited levels of ^{134}Xe have also been studied from the β-decay of ^{134}I. The neutron-rich nuclei around ^{132}Sn were produced in α induced fission of $^{Nat.}$U at the beam energy of 32 MeV at VECC, followed by radiochemical separation of Iodine from other fission fragments. The low lying states of ^{134}Xe has been studied with an offline setup of four clovers and 2 LEPS detectors. A total of 17 new γ-ray transitions are observed and placed in the new proposed level scheme. The observed levels are interpreted using the large scale shell model calculations using OXBASH and it is found that the low lying states are highly fragmented.

The present thesis reports new results, manifesting various new structural phenomena in the nuclei around Z = 50, both near stability and towards neutron-rich side. The competition between the collective and single particle degrees of freedom is explored. Though, such competitions are expected in the mid-shell nuclei only (such as, in ^{117}Sb), the same is also observed in ^{131}Xe isotope, which is nearer to the N=82 shell closure. The nature of coupling of the valence orbital outside the Z = 50 with the core are also explored from the observation of the strongly coupled $g_{9/2}$ and weakly coupled $g_{7/2}$ bands in ^{117}Sb. It is also found that, for ^{131}Xe, deformation is induced by the high-j, unique parity $h_{11/2}$ orbital. This orbital plays the crucial role in generation of the high spins in ^{131}Xe and $^{130-134}$I. The involvement of the $h_{11/2}$ orbital gives rise to novel excitation modes, such as Magnetic Rotational (MR) bands, as observed in ^{131}Xe. Towards the neutron rich side around ^{132}Sn, the single particle excitations are found to dominate for the states both below and above the high spin isomers in $^{130-134}$I. It is also found that, the hole occupancy in the $h_{11/2}$ orbital plays the dominant role in generating the high spin negative parity states in these neutron rich iodine isotopes.

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