Nuclear Structure Investigations close to A $\sim$ 70 and 150 regions: Search for High Spin Phenomena.

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Introduction

One of the remarkable aspects of nuclear structure investigation is the comprehension of the various high spin phenomenon at the extreme condition of angular momentum, which measures the structural properties of the nucleus. The nuclei with few valence nucleons are spherical in nature and exhibit single-particle properties. However, when additional nucleons are added beyond the closed shells, the residual interaction plays a significant role in configuration mixing. Due to this configuration mixing, the nucleus looses its single-particle behavior, and collectivity starts to build up, ultimately creating permanent structural deformation at the mid-shell region. In particular, for A $\approx$ 70 and 150 mass region, protons and neutrons occupy intruder orbitals ($g_{9/2}$ for mass 70 region and $i_{13/2}$ for mass 150 region) which show opposite shape driving effects near the Fermi surface. The available valence protons lie in the lower part of the intruder orbital, whereas valence neutrons lie in the middle to the upper part. Thus, the level structure of excited nuclei in these regions provides a plethora of information on the coexisting collective levels and single-particle levels along with rotational bands. To accomplish this objective, extensive experimental and theoretical investigations were carried out to study the level structure of ^{73}Br, ^{68}Ge, and ^{149}Pm nuclei using different γ- ray spectroscopic techniques.

Experimental Details

The present thesis utilizes data from three sets of experiments to investigate exotic nuclear phenomena. Two experiments were performed using the Indian National Gamma Array (INGA) facility at IUAC, New Delhi, and one experiment was conducted at TIFR, Mumbai, using the INGA setup [1, 2].

In the first experiment, the heavy-ion fusion evaporation reaction ^{50}Cr(^{28}Si, αp) was used to populate the high spin states in ^{73}Br nucleus. The ^{28}Si beam of 90-MeV energy, provided by the 15UD Pelletron accelerator at IUAC, New Delhi, was bombarded on a ^{50}Cr target of thickness 550 μg/cm^2 backed with 12 mg/cm^2 gold. The de-exciting γ- rays were detected using seventeen no of Compton-suppressed clover detectors at the time of the experiment.

The second experiment was performed with Indian National Gamma Array (INGA) at Tata Institute of Fundamental Research (TIFR), Mumbai, using ^{58}Ni(^{16}O, α2p)^{68}Ge reaction. The ^{16}O beam of 85-MeV energy was bombarded on ^{58}Ni target of thickness 1.08 mg/cm^2 backed with 12 mg/cm^2 Au. The γ- rays were detected using fifteen Compton-suppressed clover detectors during the experiment.

While, in the third experiment, a 750 μg/cm^2 thick ^{148}Nd target backed with 10 mg/cm^2 gold was bombarded by ^{7}Li projectile with the energy of 30 MeV delivered from 15UD pelletron accelerator at IUAC, New Delhi. The high spin states in the ^{149}Pm nucleus were populated through the (^{7}Li, α2n) reaction. It has been observed that the triton capture followed by 2n evaporation is the dominant reaction channel along with CF processes in the experiment. The de-exciting γ- rays were detected using sixteen Compton-suppressed clover detectors and two low-energy photon scattering (LEPS) detectors.

Results and Discussion

The present thesis work focuses on the detailed study of high spin states in ^{73}Br, ^{68}Ge, and ^{149}Pm nuclei using γ- ray spectroscopic techniques.

(i) The level structure of ^{73}Br nucleus has been updated significantly by placing twenty-seven new γ- ray transitions consisting of two ΔI=2 bands. The spin and parity of the states were

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assigned from the R_{DCO}, R_{ADO}, gated angular distribution, and polarization measurements. The presence of Z = 35 in ^{73}Br nucleus, makes it prone to reflection-asymmetric features, hence the identification of $\Delta I = 1$ inter-connecting transitions between the opposite-parity bands along with enhanced B(*E1*) transition strength and B(*E1*)/B(*E2*) ratio indicate the existence of octupole correlations at lower spin states. Moreover, being in the transitional region, the $g_{9/2}$ shape driving orbital plays a vital role in the structural evolution of ^{73}Br nucleus. The lifetime of the isomeric $9/2^+$ state has been measured from the variation in the intensity of delayed γ- ray transition. The extracted monopole transition strength $\rho^2(E0)$ provides evidence for shape coexistence between the prolate rotational band and oblate deformed band [5]. In the previous study three rotational bands were known up to $63/2\hbar$ state [4]. We have measured the lifetime of excited states of these bands using the Dopplarshift attenuation method. From the lifetime values, transition quadrupole moment has been extracted, which is decreasing with spin, showing the loss of collectivity indicating band termination in this nucleus. The experimental results are well-interpreted interns of cranked Nilsson Strutinsky (CNS) and total Routhian surface (TRS) calculations.

(ii) The low-lying level structure of ^{68}Ge nucleus has been extended up to 8^+ state at an excitation energy 5.052 MeV. The spin and parity of states were assigned from the comprehensive set of spectroscopic measurements, including R_{DCO}, gated angular distribution, and linear polarization measurements. The mixing probabilities of ΔI=0, *E2/M1* transitions between yrast and excited bands establish the shape coexistence due to the intruder excitation of 4p-2h configuration, which has also been interpreted using the large scale shell model calculations. Further, the quasi-γ- vibrational bands have been established from the γ- softness behaviors of the 2_2^+ band and its signature partner band. An intruder γ- vibrational band has been predicted from the mixing probabilities of the inter-connecting transitions between excited 2_3^+ band and both the yrast as well as intruder excited 0^+ band. The comparison of energy systematics of level structure along with IBA model calculations ensures the possible E(5) critical point symmetry in ^{68}Ge nucleus. The theoretical calculations performed in the framework of large scale shell model and interacting boson approximation calculations reasonably agree with the experimental results of the ^{68}Ge nucleus [6].

(iii) The level structure of ^{149}Pm nucleus has been significantly updated through the (^{7}Li, α2n) reaction at beam energy of 30 MeV. It has been observed that the triton capture followed by 2n evaporation is the dominant reaction channel along with CF processes. In this experiment, two new signature partner bands along with inter-connecting enhanced *E1* transitions have been observed for the first time in ^{149}Pm nucleus. The DCO measurement assigns the spin and multipolarity of the γ- ray transitions in the level structure. The variation of δE and ω^-/ω^+ as a function of spin provide the evidence for octupole collectivity in this nucleus. Further, the measured B(*E1*)/B(*E2*) ratio lies in the range of 10^{-8} fm^{-2} which is comparable with the other nuclei in this mass region where octupole collectivity is already established. The experimental level structure has been compared with the TRS calculations in the framework of Woods-Saxon potential.

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