Spectroscopic Investigations of Different Modes of Excitation in Transitional Nuclei

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Introduction

A nucleus with few nucleons outside the closed-shell is spherical in structure and exhibits single-particle properties. However, when additional nucleons are added beyond the closed shells, the residual interaction plays a significant role which leads to the configuration mixing. Due to this configuration mixing single-particle behavior diminishes and collectivity starts to build up, and ultimately nucleus gets permanently deformed at the mid-shell region. In particular, the transitional nuclei lying in the vicinity of A ≈70 and 150 mass regions exhibit various structural features due to the presence of competing shell gaps and unique parity intruder orbital. The availability of valence nucleons in the corresponding intruder orbitals leads to the occurrence of coexisting collective levels and single-particle levels along with rotational bands. Thus, the present thesis focuses on understanding the physics behind the occurrence of unique shape-related phenomena in the transitional nuclei by exploring and upgrading the level schemes of ^{72}Se and ^{151}Eu nuclei with the help of in-beam γ-ray spectroscopic measurements. Further, the observed novel characteristics of these nuclei are carefully discussed in terms of various theoretical microscopic and macroscopic models.

Discussion

To accomplish the objectives of thesis, ^{72}Se and ^{151}Eu nuclei have been studied using Indian National Gamma Array (INGA) facility at IUAC, New Delhi.

The shape-related features of the ^{72}Se nucleus have been studied using the ^{50}Cr(^{28}Si, α2p)^{72}Se reaction at the beam energy of 90 MeV, and the deexciting γ-rays were detected using the Indian National Gamma Array (INGA) comprising 17 Compton-suppressed clover detectors during the experiment [1, 2]. The γ-γ coincidence technique has been used to extend the excited K$^{\pi}$= 0_2^+ band in ^{72}Se nucleus up to (10^+) state at the excitation energy of 5.473 MeV. Three new γ -ray transitions have been placed in the cascade along with four new crossover transitions between the yrast band and excited K$^{\pi}$= 0_2^+ band. The directional correlation of oriented nuclei (DCO) ratio, angular distribution from oriented nuclei (ADO), and linear polarization measurements have been carried out to assign the spin and parity of the states. The R_{DCO} -polarization method has been employed to determine the mixing ratio $\delta = -5(3)$ of the interconnecting 454.5 keV transition decaying from $2_2^+ \rightarrow 2_1^+$ states. Moreover, the high value of B($E2$; $2_2^+ \rightarrow 2_1^+$) = 108(5) W.u. calculated in the present study indicates the coexistence of two different configurations, where the ground state is probably slightly oblate deformed but soft to vibrations, while the excited levels are built on considerable prolate deformation. The experimental results of ^{72}Se nucleus were discussed in terms of TRS and CSM calculations and compared with other neighboring Se isotopes.

Further, the asymmetric structural properties of the ^{72}Se nucleus have also been studied in this work using the data of the same experiment. The low-spin γ- band has been extended up to 3.128 MeV excitation energy using the γ-γ coincidence technique. Two new states in the γ- band have been identified and placed, along with the interconnecting dipole transitions, between the negative parity band and the excited 0^+ band. The enhanced $E1$ transitions decaying from the levels in the lowest negative-parity band (band D) to both the yrast and excited 0^+ positive parity bands have been reported for the first time in A $\sim$ 70 mass region. The spin and parity of the excited states in these bands have been assigned using DCO, ADO, and linear polarization measurements. The degree of octupole deformation is estimated from

the frequency ratio (ω^-/ω^+) of the positive and negative parity bands. The value of this ratio in ^{72}Se, lying within the range of 0.7 to 0.9, has been compared to other established octupole collective nuclei. The measured values of the transition strength ratio B(*E1*)/B(*E2*) and transition strength B(*E1*) lie in the range of 10^{-6} fm^{-2} and 10^{-4} W.u. respectively, showing the enhancement of *E1* transitions in the ^{72}Se nucleus. Moreover, the value of the measured staggering parameter S(4) = − 1.36 for the γ-band lying close to unity suggests the vibrator-like structure of ^{72}Se nucleus. The experimental observables were interpreted in terms of the interacting boson approximation (IBA) model, which also supports the presence of a vibrator-like structure.

The presence of wobbling motion in the ^{151}Eu nucleus have been studied using the ^{148}Nd(^{7}Li, 4n)^{151}Eu fusion evaporation reaction at 30 MeV beam energy [3]. The deexciting γ-rays were detected using INGA array at IUAC consisting of 16 Compton-suppressed clovers and two ancillary LEPS detectors. In this work, three new inter-connecting γ-ray transitions between the two negative parity bands have been identified and placed in ^{151}Eu nucleus. The spin and parity have been modified and assigned to the signature partner of the yrast band using the directional correlation of oriented nuclei (DCO) ratio and linear polarization measurements. Further, to determine the dominance of *E2/M1* characteristics, the mixing ratios of the inter-connecting transitions between the yrast band and its corresponding favoured and unfavoured signature partner bands have been calculated . The values of mixing ratio establish the dominant *E2* character of the interconnecting transitions between the yrast and the first phonon wobbling band while the interlinking transition between the yrast and its signature partner band shows dominant *M1* characteristics. Further, the decreasing pattern of the wobbling energy as a function of spin, establishes ^{151}Eu nucleus to be the first candidate exhibiting transverse wobbling in A $\approx$ 150 mass region. The experimental results were well interpreted in terms of theoretical Triaxial Prsojected Shell Model (TPSM) calculation.

In summary, the structural features of ^{72}Se and ^{151}Eu nuclei have been rigorously studied using the detailed in-beam γ- ray spectroscopic techniques. In ^{72}Se nucleus, shape-coexistence and octupole correlations have been established where the enhancement of the the decaying *E1* interlinking transitions have been reported between the negative and both K^{pi} = 0$^+$ bands. On the other hand, the experimental evidences confirm the presence of transverse wobbling in ^{151}Eu nucleus, exploring its triaxial characteristics.

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