Experimental study of shape evolution in nuclei near Z=82

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1. Introduction

Atomic nucleus is a complex many body quantum system which shows different nuclear shapes based on the proton and neutron numbers and their excitations. The atomic nuclei possess mainly either spherical or axially deformed (prolate/oblate) shape [1]. Whereas, the non-axial γ deformed shape in atomic nucleus is rare to find.

In this thesis work, we have experimentally investigated ^{197}Tl, ^{183}Au, and ^{187}Os nuclei which belong to the transitional region between spherical ^{208}Pb and axially deformed rare earth nuclei. The experimental investigation of these transitional nuclei can give an insight on the evolution of nuclear shape from axially symmetric to spherical shape. In case of very few nuclei, it has been already found that a change in shape from prolate to oblate takes place through triaxial deformation [2].

2. Experimental details and Analysis

Three sets of experiments were performed in this thesis work to populate the excited states of ^{197}Tl, ^{183}Au, and ^{187}Os. The excited states were populated by fusion evaporation reactions using light-ion (α) beam for ^{197}Tl and ^{187}Os nuclei and heavy ion (^{20}Ne) beam for the neutron deficient ^{183}Au nucleus. The experiments were performed at VECC. The gamma rays were detected using INGA and VENUS clover HPGe detector arrays. In this thesis work, a total of 136 new γ transitions have been observed and placed in the level schemes of the three nuclei. The γ-ray coincidence relation, DCO ratio and γ-ray polarization asymmetry ratio were used to assign new levels, definite spin and parity of the excited levels.

3. Results and Discussions

A new level scheme of ^{197}Tl has been proposed with the placement of 28 new γ transitions [3]. Evolution of shape from 3-qp and 5-qp chiral bands in ^{195}Tl to new 3-qp and 5-qp magnetic rotational bands in ^{197}Tl has been observed in this work (Fig-1). The main rotational band in ^{197}Tl based on intruder $\pi h_{9/2}$ orbital has been extended beyond the first particle alignment and the our newly observed data established complete two neutron alignment in $\nu i_{13/2}$ orbital.

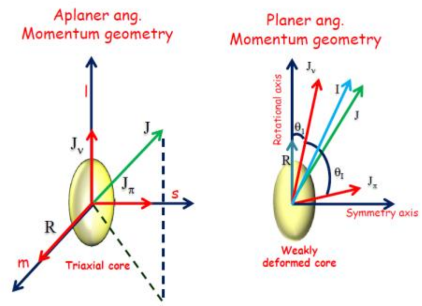

Fig. 1 Shape evolution from chiral geometry (triaxial core) in ^{195}Tl to shears geometry (weakly deformed core) in ^{197}Tl

The level scheme of neutron deficient ^{183}Au with 14 new γ transitions has been reported from this thesis work [4]. Multiple transverse wobbling bands (TW) based on intruder $\pi h_{9/2}$ and $\pi i_{13/2}$ orbitals with decreasing and increasing wobbling frequency behavior in ^{183}Au nucleus is the first such observation in any atomic nuclei so far (Fig-2). The wobbling excitation is a very unique manifestation of stable triaxial shape in atomic nuclei which is analogous to classical motion of an asymmetric top. The experimental observation of increasing wobbling frequency with spin for transverse wobbling band complete our general understanding of wobbling phenomena and a new concept of an angular momentum I_m has been put forward in order to distinguish between longitudinal and transverse wobbling bands.

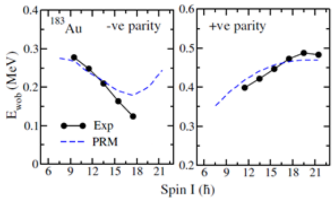

Fig. 2 Experimental wobbling energy E_{wob} as a function of angular momentum I for the negative parity and the positive parity bands in ^{183}Au manifest decreasing and increasing behavior.

In ^{187}Os, the bands based on $1/2^-[510]$ and $3/2^-[512]$, $11/2^+[615]$, and $7/2^-[503]$ configurations have been extended up to first pair alignment [5] and the new proposed level scheme contains 94 new transitions. The bands based on $1/2^-[510]$ and $3/2^-[512]$ configurations have been identified as a twin bands and it shows very good level energy degeneracy with spin compared to the similar bands in neighboring ^{185}Os. Whereas, the high spin data in heavier ^{189}Os nucleus is not present.

The negative parity band based on $\nu h_{9/2}$ orbital shows delayed crossing due the presence of N=110 deformed shell gap. The intrinsic quadrupole moment has been extracted from experimental B(M1)/B(E2) values and compared with calculated quadrupole moment using β_2 and γ values from total Routhian surface (TRS) calculations. TRS calculations show stable triaxial minimum with $\gamma = -100^\circ$ to -90° has been obtained for this configuration and it indicates a stable triaxial rotation around long axis.

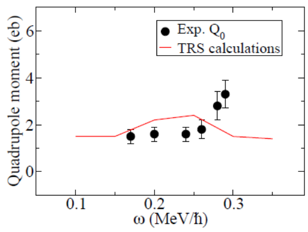

Fig. 3 Quadrupole moments vs rotational frequency (ω) for the $\nu 7/2^-[503]$ band in ^{187}Os. Experimental valus are compared with the results obtained from the TRS calculations.

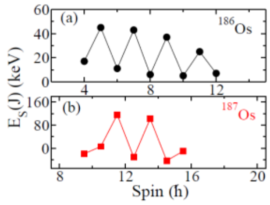

Fig. 4 Plot of double energy differences, $E_S(J)$ as a function of spin for the gamma bands in ^{186}Os (a) and ^{187}Os (b).

The positive parity bands based on $11/2^+[615]$ configuration has been extended up to first particle alignment and it shows large energy staggering with increasing spin which may indicate the presence of γ deformation. In this work, two new γ and $\gamma\gamma$ bands have been reported for the first time. The gamma band of a nucleus is resulted due its non-axial shape, either due to a rigid triaxial shape or a gamma-soft (or gamma unstable) shape. Emperically these can be distinguished from the double energy differences of the levels of the gamma band, $E_S(J)$, involving three consecutive levels of spins J, J-1 and J-2. The values of $E_S(J)$ are shown in Fig.4 as a function of spin for the gamma bands in the even-even core ^{186}Os and in ^{187}Os. It can be seen that the phases of the variation of $E_S(J)$ with spin are opposite in the two cases; while it corresponds to a gamma-soft shape for ^{186}Os, a gamma rigid shape is apparent for ^{187}Os.

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