Vibrational structures of nuclei near Z=50 shell closure

Prithwijita Ray[1*]
Nuclear Physics Division, Saha Institute of Nuclear Physics, Kolkata - 700064, INDIA and Homi Bhabha National Institute, Training School Complex, Anushaktinagar, Mumbai 400094, INDIA

Introduction

The atomic nucleus as a many-body finite quantal system is so complex that its detailed structure is yet to learn completely. A plethora of nuclear phenomena, both collective and non-collective, have been observed generating the angular momentum states near the closed-shell nuclei. The present thesis is aimed at exploring the low-lying collective excitation modes specifically vibrational excitation in nuclei near Z=50 shell closure.

Apart from the pure harmonic vibrational structure of these nuclei, deviations due to mixing with the quasi-particle states or intruder rotational states are possible modes of excitation. There is also a different class of shape vibration termed as γ-vibration where the axial symmetry of the corresponding nucleus is broken, as established in some nuclei near the same mass region. Hence, to elucidate further into the structural aspects, the following experiments were done.

Experiments

Two experiments were performed in the Indian National Gamma Array (INGA) campaign at Variable Energy Cyclotron Centre (VECC), Kolkata, where seven Compton suppressed clover detectors, at 40°, 90° and 125° with respect to the beam axis, were used. The α-beam, supplied from K-130 cyclotron at VECC were used to populate nuclei via fusion evaporation mechanism. In one of the experiments, a self-supporting ^{112}Sn target of thickness 4.5 mg/cm^2 was bombarded by 37-MeV α-beam. The details of the preparation of this target are discussed in ref. [1]. Similarly for the other experiment, ^{114}Cd target of thickness 6.2 mg/cm^2 was bombarded upon by 34-MeV α-beam to populate ^{115,116}Sn nuclei.

*Electronic address: prithwijitaray@gmail.com;
[1]Present address: Department of Physics, ABN Seal College, Coochbehar 736101, INDIA.

Results and Discussions

A. ^{114}Te

The experimental results on ^{114}Te associated with the first experiment as mentioned before will now be discussed for the γ-vibration which has been previously reported in nuclei near the said mass region.

Here, the low-lying level scheme has been modified with the insertion of eight new γ-transitions and grouped into three bands (FIG. 1). The placement of nearly situated levels has been thoroughly checked and the spin-parity of both existing and new levels has been investigated and modified accordingly. All three bands have been seen to have similar structural aspects. Band II and III, subsequently, formed the quasi-γ band structure in ^{114}Te as seen from the odd-even spin staggering. Since our experimental level scheme is up to a limited spin value, it can not be firmly asserted, based on the experimental staggering, whether this quasi-γ band has been arising for vibrational or γ-soft nuclei. Hence, the theoretical model calculations namely, the Interacting Boson Model (IBM) and Triaxial Projected Shell Model (TPSM) calculation have been done. The IBM-1 Hamiltonian has been fitted for the experimental energies and the extracted parameters indicate the nuclei to lie between U(5) and O(6) symmetry limits. The Hamiltonian is further mapped on the Casten triangle and the calculated radial components indicate the nuclei to lie closer to the O(6)limit. The multi-quasiparticle TPSM approach has also been incorporated and the

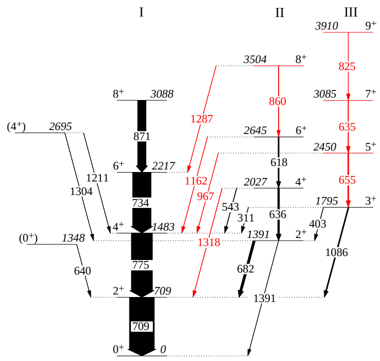

FIG. 1: The low-lying partial level scheme of ^{114}Te as obtained in the present work. Newly identified γ-rays/levels are marked in red (gray) colour.

energy values, thus obtained, are in excellent agreement with the experimental energies indicating ^{114}Te to be a γ-soft nucleus [2].

B. ^{116}Sn

In the case of the other experiment, ^{116}Sn has been studied for any possible existence of three-phonon quintuplet structures. Even though many yrast and non-yrast transitions have been observed throughout the entire energy regime, the focus of this thesis has been on the low-lying phonon vibrational character. Here, the main problem lies in the identification and extraction of the comparatively weaker transitions associated with the phonon states compared with the strong intruder rotational level transitions that exist near the same energy region and having the same spin-parities.

The associated low-lying level structure has been modified with the inclusion of three new γ-transitions. The well-investigated one- and two-phonon states have also been identified in the present study. For the three-phonon quintuplets, 3277.9-, 3046.7-, 2996.5-, 3089.1- and 2791- keV levels have been assembled and the spin-parities have been found to be 6^+_{3ph}, 4^+_{3ph}, 3^+_{3ph}, 2^+_{3ph} and 0^+_{3ph}, respectively. The 0^+_{3ph} has been taken from literature to complete the three-phonon picture as there have been no γ-transitions observed associated with the level. The observation of the pure harmonic vibrational model indicates that transitions from the quintet favor decay to the two-phonon triplet over any other decays consistent with the present proposed level scheme. Notably, ΔI=0 type of transitions are showing high mixing ratios as well. The experimentally observed three-phonon quintuplets energy values have been calculated using the two-phonon and one-phonon energy values as inputs for comparison [3]. The same has also been seen to match quite well. However, the energy values obtained from the analytical formulation incorporating IBM calculation in the U(5) limit matches well with the experimentally obtained two-phonon triplets but fail to predict the three-phonon quintuplets and this deviation could be due to the mixing with the 2p-2h intruder band. As the experimental determination of transition rates is beyond the scope of the present experimental arrangement, the same has been tested using microscopic shell model calculation where the experimentally available B(E2) values have been reasonably reproduced for one- and two-phonon states and are predicted for the three-phonon states [4].

Acknowledgments

The help received from the INGA collaborators and operating staff of VECC for providing the best possible environment during the experiments is appreciated. The support of the UGC-NET fellowship is also acknowledged.

References

[1] H. Pai, Prithwijita Ray et al., Vacuum **167**, 393 (2019).

[2] Prithwijita Ray et al., Phys. Rev. C **101**, 064313 (2020).

[3] D. Bandyopadhyay et al., Nuclear Physics A **747**, 206 (2005).

[4] Prithwijita Ray et al., Nuclear Physics A (Under Review).