Chapter 1

Introduction

1.1 Introduction

Atomic nuclei occupy a unique position in nature. It is a playground of three of the four basic interactions present in nature. Of these interactions, the strong and weak interactions owing to their short range are present only inside the nucleus. This feature places nuclei apart from other systems, e.g. biological systems, chemical systems, astro-physical systems etc., where the interactions between the constituents are Predominantly-dominantly of long range character. The atomic nuclei exhibit varied type of phenomenon like rotation, vibration, superdeformation, magnetic rotation, chirality, identical bands, band termination etc. These phenomenon provides an opportunity to study several aspects of physics inside the nucleus.

One of the important topics for the study in the nuclear structure has been the investigation of nuclear properties and their evolution at extreme conditions such as high temperature or high excitation energy, high spin, exotic proton to neutron ratio and large distortion of nuclear shape. The present work concentrate on the study of high spin aspect of nucleus. The advent of heavy-ion accelerators has made it possible to populate a large number of nuclei, throughout the nuclear chart, to a very high spin state. Furthermore, with the advancement in the detection techniques, it has now been possible to detect the $\gamma$ transitions decaying from these high spin states efficiently and carry out measurements, like lifetime measurements, which need high statistics.
1.2 The A ∼ 110 mass region

Nuclei in this mass region lie in the close proximity to $Z = N = 50$ shell closure and therefore their low spin states are dominated by single particle excitations. In the last decade, considerable attention has been given to the study of high spin states in this region. This is primarily due to the discovery of novel phenomena of 'magnetic rotation' and 'smooth band termination'. These phenomena provide an alternative mechanism to collective rotation and single particle excitations in the generation of angular momentum.

The discovery of magnetic rotation in the lead region in early 90's provided an impetus for its discovery in other mass regions of the nuclear chart near magic numbers. In A ∼ 110 mass region, an intensive investigation of the phenomenon has been carried out in Cd, Sn, Sb, Ag and In isotopes. Several $\Delta I = 1, M1$, bands have been discovered and were identified as a case of magnetic rotation.

The phenomenon of magnetic rotation is often competed by other mechanisms in the generation of angular momentum along the band. The nuclei with neutron number $N > 58$ have sufficient deformation ($\beta > 0.1$) to have collective rotation along with the magnetic rotation. With the increase in deformation due to the increase in neutron number, the relative contribution of collective rotation increases. It is still not clear at what neutron number the magnetic rotation is completely overtaken by the collective rotation. On the other hand, approaching close to $N = 50$ the phenomenon of magnetic rotation is competed by single particle excitations. Studies carried out by Jenkins et. al. [1] in Cd isotopes and Deo et. al. [2] in Ag isotopes indicate that the lower boundary for the appearance of 'magnetic rotation' is expected at $N = 56$. For $N < 56$ neutron number no regular $M1$ transitions are observed in these isotopes\footnote{Exception is $^{106}$Sn where a magnetic band build on $\pi|g_{9/2}^{-1}g_{7/2}\otimes\nu(h_{11/2})^2$ excitation is found.}. However, in low mass odd-Indium isotopes, i.e. $^{103,105,107}$In, several $\Delta I = 1, M1$ sequences have been identified by Kownacki et. al. [4]. It will be fruitful to investigate these sequences for the existence of magnetic rotation. This will help in elucidating the lower limit of the existence of this phenomenon in In isotopes. In the present work, $^{107}$In and $^{109}$In nuclei have been investigated. The results of these investigation will be presented and discussed in the framework of tilted
axis cranking (TAC) and semi-classical models.

The nuclei in this mass region are also a host of another interesting phenomenon of 'smooth band termination' of collective bands. The conditions for the appearance of smooth terminating bands (STB) in this mass region are favorable due to the limited number of valence particles or holes of around 10-15 outside the $^{100}$Sn core [5]. The number is sufficiently large to induce collectivity and at the same time not high enough to make the terminating spin outside the range of spin accessible in the experiment. Further, the states of the band are yrast or near yrast over a large spin range. For these reasons, various nuclei, especially in the vicinity of $^{109}$Sb, have been extensively studied for the phenomenon.

As the number of valence particles outside the core is reduced, the terminating spin is expected to be small and therefore will easily be accessible for the experimental study. However, the induced deformation, in this case will be small and it is not clear whether a deformed terminating band will be formed or not. It will therefore be interesting to search and analyze STB in nuclei close to $^{100}$Sn. In addition, this will also provide a systematic study of STB based on specific configurations. In the present work, $^{107}$In nucleus has been investigated for the presence of this phenomenon. Another important fact is that these bands are often observed at the limit of experimental sensitivity. As a result, one of the key experimental observables, the transition quadrupole moment $Q_t$ of the states of the band is difficult to determine experimentally. Therefore, this particular information, especially for the states close to band termination, is scarce. In this work, the transition quadrupole moment $Q_t$ of few of the states of a deformed band, identified as STB, has been determined through the lifetime measurements.

1.3 Overview of present work

The present work has been aimed at the detailed spectroscopy of $^{107}$In and $^{109}$In. Two experiments were performed with the Indian National Gamma Array (INGA) at Inter University Accelerator University (IUAC), New Delhi, using the beam from the 15 UD Pelletron. The following reactions were used:
1. $^{94}$Mo($^{16}$O, p$^{2}$n)$^{107}$In at a beam energy of 70 MeV. The target thickness was 0.9 mg/cm$^2$ with a 6.5 mg/cm$^2$ thick $^{197}$Au backing.

2. $^{96}$Zr($^{13}$F, 6n)$^{109}$In at a beam energy of 105 MeV. The target thickness was 1.0 mg/cm$^2$ with a 20 mg/cm$^2$ thick natural Pb backing.

In the following chapter, a brief of the nuclear models pertinent to the present work are reviewed. The properties of electromagnetic transitions decaying from an excited nucleus are reviewed briefly in the Chapter 3. The details of the set up and other experimental details along with the methods of data analysis used are described in Chapters 4 and 5. In Chapters 6 and 7, the results of the experiments mentioned above are presented and discussed. Finally, the summary of the work is presented in Chapter 8.
Bibliography


