CHAPTER - I

INTRODUCTION

To understand nuclear structure, one needs to know the energy, spin, parity, electric, and magnetic multipole moments. These quantities can be determined by means of different experimental techniques such as nuclear reactions, radioactive decay, and Coulomb excitation.

The process by which nuclear levels can be excited in the varying electric field caused by close passage of a charged particle is called 'Coulomb excitation'. Whether or not the target nucleus and projectile come within the range of nuclear forces, Coulomb excitation will occur; however if the initial kinetic energy of the projectile is sufficiently low, so that mutual electrostatic repulsion ensures that nuclear forces play no role, then Coulomb excitation, which has become a powerful tool in understanding nuclear structure, will be the only mechanism for exciting levels in the target nuclei.

In the Coulomb excitation process the nuclear properties enter only through the matrix element of electric and magnetic multipole moments, which are the same as those involved in radiative transitions between the same nuclear states. Since the electromagnetic coupling is very well understood in
Physics, the information about nuclear structure viz. energies, spins, parities and transition moments of the excited states of nuclei can be obtained by means of Coulomb excitation without solving nuclear force problem.

Most of the excited states observed in Coulomb excitation studies are collective states, that is rotational members of the ground state band in deformed nuclei and vibrational states in spherical nuclei. The reason for this is that the transition moments connecting these collective states with the ground state are greatly enhanced and correspondingly the probability for excitation is large. On the other hand, transition moments between most other states and the ground state are much smaller and probability for Coulomb excitation is thus so small that the states are usually not observed.

It is well known that the spectroscopy of stable nuclei is difficult. This is mainly due to past experimental difficulties. Some stable nuclei have been studied by \((n,n' r)\), \((p,p' r)\), transfer reactions, and Coulomb excitation studies, but there exist many stable nuclei for whom not much information about electromagnetic properties is available.

**SURVEY OF THE LITERATURE**

The survey of the literature shows that there is a
scarcity of the adequate experimental data about the nuclear level structure of $^{53}\text{Cr}$, $^{61}\text{Ni}$, $^{121,123}\text{Sb}$ and $^{159}\text{Tb}$. The reduced $E_2$ transition probabilities of $^{53}\text{Cr}$, $^{61}\text{Ni}$ and $^{121,123}\text{Sb}$ have been measured by Galperin et al. (1) using $^{12}\text{C}$ and $^{14}\text{N}$ ions. More recently Andreev et al. (2) have measured $B(E_2)$ values for $^{61}\text{Ni}$. The $B(E_2)$ values of $^{159}\text{Tb}$ have been found by Diamond et al. (3) and Seaman et al. (4). These nuclei have also been studied theoretically by different model calculations. No results have yet been published about $M_1$ transition probabilities and mixing ratios of the excited states of $^{53}\text{Cr}$, $^{61}\text{Ni}$, $^{121,123}\text{Sb}$ nuclei. In addition to it, no Coulomb excitation study of higher excited states in these nuclei have been reported and also for some nuclear levels definite spin and parity assignments are not known.

**OBJECTIVES OF THE PRESENT WORK**

To date, there exist very few recent experiments which were performed to study gamma transition strengths, branching ratios, and mixing ratios in a single experiment. So it was decided to investigate the nuclear level structure of $^{53}\text{Cr}$, $^{61}\text{Ni}$, $^{121,123}\text{Sb}$, and $^{159}\text{Tb}$ via Coulomb excitation studies. In previous Coulomb excitation studies of $^{53}\text{Cr}$, $^{61}\text{Ni}$, and $^{121,123}\text{Sb}$ only $B(E_2)$ values have been measured (1,2,5,6) with heavy ions like $^{12}\text{C}$, $^{14}\text{N}$, and $^{160}$. With heavy ions
multipole Coulomb excitation is important and it is difficult to extract $B(E_2)$ values from the gamma ray yields because the states can be populated by multistep processes. Interference between these processes gives rise to ambiguity in the $B(E_2)$ value. So it was decided to use protons and $^4$He ions as projectiles in the present Coulomb excitation work. With these projectiles, direct $E_2$ excitation is usually dominant process and the $B(E_2)$ values can be extracted unambiguously from the gamma ray yields.

In addition to it the $E_2$ and $M_4$ transition probabilities of $^{53}$Cr have been calculated theoretically by Carola et al.\(^{(7)}\) based on intermediate coupling model. The electromagnetic properties of odd-A Sb nuclei have also been calculated theoretically by Berghe and co-workers \(^{(8,9)}\) by taking into account $2p-1h$ states and their interaction with single particle and phonon coupled states. In order to test these calculations the study of electromagnetic properties of $^{53}$Cr and $^{121,123}$Sb was undertaken via Coulomb excitation studies.

The Coulomb excitation experiments were undertaken with the aid of Bhabha Atomic Research Centre (BARC), Trombay, 5.5 MeV Van de Graaff accelerator. Natural, thick targets of chromium, nickel, antimony and terbium oxide were bombarded
with 2.5 to 4.5 MeV protons and 4.0 to 5.5 MeV $^4$He ions to produce sources of excited levels. It was possible to excite nuclear states of excitation energy up to approximately 2.3, 1.6, 1.43 and 0.6 MeV, respectively, in $^{53}$Cr, $^{61}$Ni, $^{121,123}$Sb and $^{159}$Tb. The de-excited gamma rays were observed with a high resolution 30 cm$^3$ Ge(Li) detector using conventional electronics. Thick target gamma ray yields were measured as a function of bombarding energy of the projectiles. Chapter III covers the details of the electronics and experimental procedure. The gamma ray angular distributions were also measured with protons and $^4$He ions in deducing multipole mixing ratios and spin values.

The yield per incident particle (proton or $^4$He) was obtained from the charge collected and gamma ray intensity. The $B(E_2)$ values were extracted from the thick target yields using the first order perturbation theory of Alder et al. (10). The theoretical details are given in Chapter II. The gamma ray angular distributions were used in assigning spins and in extracting mixing ratios. The reduced $M_1$ transition probabilities $B(M_1)$ were calculated with the knowledge of $B(E_2)_\downarrow$ and mixing ratios $\delta = (E_2/M_1)^{1/2}$ for each state.

In summary, there were several objectives to this investigation: First, to measure the thick target gamma ray
yields and excitation functions as a function of bombarding energy; second, to determine gamma ray angular distributions in obtaining spins and mixing ratios; third, to extract $B(E_2)$ and $B(M_1)$ values; fourth, to test the available theoretical calculations; and finally to, observe and explain if possible, any additional features of interest.