1.1 DISCOVERY OF ANTIPROTON.

Dirac’s theory of electron appeared to be of very general validity after the discovery of positrons, positive and negative, pions and muons. The theory suggested, that all the elementary particles of spin $1/2$, should have charge-conjugate or antiparticles, and an encounter between the particles of any such pair, should commonly lead to their mutual annihilation. For many years, these considerations led to speculations about anti-nucleons and searches for evidence of their existence. For a long time the search was confined to experiments with cosmic radiation until the great accelerators were developed. An antinucleon is always produced in pair with a nucleon, the necessary energy for production of the pair of nucleons being nearly 2 Gev. Minimum kinetic energy necessary for a proton, to produce a proton-antiproton pair ($\bar{p}p$), in the collision with a proton at rest, is nearly 6 Gev.

Before the existence of antiprotons was finally established in Counter experiments, two observations were suspected to show the evidence of the particle. The experiments were made by Bridge et al\textsuperscript{1} and Amaldi et al\textsuperscript{2}. However, the mass and charge of the particle could not be ascertained.
Chamberlain et al. in 1955, discovered antiproton of mean momentum 1.19 GeV/c by bombarding copper target with 6.2 GeV protons, in Berkeley Accelerator, the bevatron. Identification was made by allowing the antiproton beam to pass through a number of scintillation and Cerenkov counters. Later Chamberlain et al. and Barkas et al. made experiments with photographic emulsions by allowing the beam to pass through stacks of emulsions. These experiments proved beyond doubt the existence of antiprotons from the fact that the release of energy in the disintegration produced by one of them at the end of its range was greater than the total rest energy of the particle.

1.2 EARLY EXPERIMENTS WITH ANTIPROTONS.

The early experiments were carried on with antiprotons of lower momentum >700 MeV/c because of nonavailability of a pure beam at higher energy. In the experiment of Barkas et al., only thirty five disintegrations were found in an extensive search of several stacks. Their detailed analysis permitted many properties of antiprotons to be established. A more detailed analysis of 653 disintegrations with emulsion nuclei over the energy interval 10 to 230 MeV were made by Amaldi et al.

Unlike protons, antiprotons may undergo charge-exchange and annihilations. Study of these two aspects are very essential to understand antiproton interactions with nuclei. In an experiment performed by Cork et al. in the
hydrogen bubble chamber, with antiproton of momentum 45 Mev/c to 245 Mev/c, they observed that total as well as charge-exchange and annihilation cross-sections decreased rapidly with increasing incident momenta. Apostolakis et al.'s experiment on annihilations of antiprotons on protons and neutrons, showed that the ratio of the probabilities of annihilation on these were unity. But characteristics of annihilation with light nuclei differed from that with heavy nuclei. This was because secondary interactions took place in heavy nuclei leading to absorption or charge-exchange of secondary mesons. The observed probability of absorption was $(0.28 \pm 0.04)$ for incident antiproton of 200 Mev.

Later experiments with antiprotons at higher energy were mostly carried on in the hydrogen bubble chamber. These include mainly the study of cross-sections in various channels, nucleon and antinucleon isobar production and production of strange particles. In the experiment performed by Xuong et al., it was shown that at low energy, annihilation plays the most dominant role over the charge-exchange and other inelastic cross-sections. At 1.6 Gev/c incident momentum, total annihilation cross-section was $51 \pm 3$ mb while total inelastic cross-section(non-annihilation) was only 5.3 mb. With increased incident momentum the total cross-section decreased due to decrease of both cha-
rge-exchange and annihilation cross-sections.

Among the strange particles emitted in the interactions of antiprotons, kaons are the most copiously produced ones. In the experiment of Yeh et al.\(^{21}\) cross-sections for annihilation into kaons were found to be decreasing with incident momenta from 5.2 mb at 1.6 Gev/c to 2.5 mb at 7.1 Gev/c. A comparison of production cross-section of hyperons from 1.6 to 7.0 Gev/c in antiproton-proton interactions was made by Fisher et al.\(^{22}\).

Coming to the interactions of antiprotons(\(\bar{P}\)) with complex nuclei, it can be said that investigations made in this line are far less than those made in the hydrogen bubble chamber. Agnew et al.\(^{23}\) were the first to make a systematic study of interaction of antiprotons with complex nuclei - oxygen, copper, silver and lead. Their study revealed that at 450 Mev incident energy, the ratio of proton-antiproton reaction cross-sections varied from 1.74 for oxygen to 1.39 for silver. Comparison of antiproton-nucleon and proton-nucleon-total, elastic and inelastic cross-sections at similar energies showed ample differences between these cross-sections.\(^{24}\) Interaction cross-sections for antiprotons are much higher and they also deposit a larger amount of energy to the target nucleus, particularly due to annihilation process, than a proton at similar energy does. In the study of interaction of protons with complex nuclei eg silver and bromine of nuclear
by Baker et al.\textsuperscript{25} it was revealed that at higher excitation energy, in addition to evaporation, fragmentation and fission of target nucleus took place more easily. So it is expected and also found to be true\textsuperscript{24} that antiproton interactions with complex nuclei gives a valuable tool for study of emission mechanism of heavier fragments ($Z > 3$).

L. Hussain and S. Katcoff\textsuperscript{26} had studied the interaction of 2.5 Gev/c antiprotons with uranium, bismuth and gold by the help of mica detectors. Their investigation showed that $\bar{p}$ - induced fission cross-sections are higher by a factor of 2 than $p$ - induced and $\pi$ - induced fission.

1.3 AIM OF THIS STUDY

So far as its behaviour during high energy is concerned, the nucleus offers the biggest challenge to the physicists. Now a days, these problems have been tackled mostly by disintegrating the nucleus with the help of highly energetic nuclear particles obtained from large accelerators. These nuclear particles with very small associated wavelength, sometimes even smaller than the range of the nuclear force, penetrate deep into the nucleus and reveal finer details about it. Innumerable research works, gathering more details on energy levels and nuclear shapes and other nuclear properties, show that our knowledge about the nucleus is still far from complete. Further research is still capable of
throwing up considerable surprises. Recently a powerful device for particle acceleration, known as "Intersecting storage ring", has been built at CERN (Geneva), which will supply nuclear particles of momentum in the range of thousands of Gev/c. Bombarding nuclei with these extremely energetic particles and studying the disintegration, it is expected that some of the mysteries will be solved.

With antiprotons, fairly large number of experiments have been performed, most of which are carried on in the hydrogen bubble chamber. These include mainly determination of cross-sections in different channels and of production cross-section of nucleon and antinucleon isobars. Because of lack of suitable theoretical model, antiproton interactions with complex nuclei have not been studied except in a few experiments made with photographic emulsions and mica detectors.

The present experiment has been performed to study some aspects of high energy disintegration of complex nuclei like silver and bromine, by antiprotons of 5 Gev/c. Our particular interest lies in the study of the following specific points.

(1) General characteristics of interactions - We could study a few characteristics viz. mean number of black, grey and shower particles per interaction, their energy and angular distributions, variations of average number of shower particles with total number of black, grey and shower particles etc.
Annihilation of antiprotons - It is observed that there are ample differences between annihilations with a proton studied in the hydrogen bubble chamber and those with a nucleon inside a complex nucleus studied in emulsion or in mica detectors. In the interaction with a nucleus one must take into account the secondary interactions caused by shower particles produced in the first encounter. The secondary interactions increase with atomic number. In this experiment, we observed decrease of number of pions due to absorption inside the nucleus during annihilation leading to violent disruption of the nucleus with emission of comparatively larger number of heavily ionised particles.

We have studied the emission of heavy fragments with charge, \( Z > 3 \). Innumerable experiments made in this line, revealed that several processes are responsible for the fragment emission. From the point of physical interest, it is necessary to see if the characteristics of fragment emission change when the interactions are with antiparticles. In our experiment, some of the target nuclei avail of a large amount of energy due to annihilation. It is expected that due to high excitation, emission of heavy fragments would be more prevalent in these interactions. It appeared from our observation that pion absorption might have some role to play in the complete disintegration of a nucleus. From the decay characteristics, we suspected one heavy fragment to be \( \text{He}^8 \), undergoing decay.
into its rare decay mode to Li$^7$ and neutron. We have also
studied the hyperfragments emitted at this incident momen-
tum of antiprotons. Attempts have been made to find out
the emission frequency and probable mode of decay of these
hyperfragments.

Apart from general physical interest, it is
expected that the problems studied will be helpful in inter-
preting various problems in astrophysics.