Preface

The field of hadron physics contains the study of strongly interacting matter in all its manifestations and understanding of its properties and interactions in terms of the underlying fundamental theory, Quantum Chromodynamics (QCD). The primary goal of hadron physics are to determine the relevant degrees of freedom that govern the hadron phenomena at all scales, to establish the connection of these degrees of freedom to the parameters and fundamental fields of QCD, to quantitatively describe a wide array of hadron phenomena ranging from its spectroscopy to their decay properties. Spectroscopy is a powerful tool in physics as it provides a mean to understand the essential degree of freedom involved in molecules, atoms, nucleus and the hadrons. For example, the color degree of freedom emerged from detailed baryon spectroscopy and flavor symmetry was first seen clearly in hadron spectroscopy. Hadron spectroscopy will continue to be a key tool in our efforts to understand the long-wavelength degrees of freedom in Quantum Chromodynamics (QCD). The long-range properties of QCD are central to the issues of this subfield, bringing into play its full complexity and a set of rich phenomena in strong interactions. The properties of QCD and the nature of confinement are among the few outstanding open problems in hadron physics.

The copious production of heavy quarks at LEP, Fermilab Tevatron, CERN and B factories, opened up rich spectroscopic study of heavy hadrons. Thus heavy flavour hadrons play an important role in several high energy experiments as well as in the understanding of the theories like QCD, NRQCD and effective field theories. The BES at the Beijing Electron Positron Collider (BEPC), E835 at Fermilab, and CLEO at the Cornell Electron Storage Ring (CESR) are able to collect huge data on heavy flavour hadrons. All these experiments are capable of observing new states, new
production mechanisms, new decays and transitions, and in general to the collection of high statistics and high precision data sample. In near future, even larger data samples are expected from the BES-III upgraded experiment, and the B factories will continue to supply valuable data for more years to come. Now, the LHC experiments at CERN, Panda at GSI etc., are capable of offering future opportunities and challenges in this field of heavy flavour physics.

Though the experimental and theoretical data on the properties of heavy flavour mesons are available in literature, the masses of all the heavy baryons have not been measured yet experimentally. Thus the recent predictions about the heavy baryon mass spectrum have become a subject of renewed interest due to the experimental facilities at Belle, BABAR, DELPHI, CLEO, CDF etc. These experimental groups have been successful in discovering heavy baryonic states along with other heavy flavour mesonic states and it is expected that more heavy flavour baryon states will be detected in near future. Most of the new states are within the heavy flavour sector with one or more heavy flavour content and some of them are far from most of the theoretical predictions. Though there are consensus among the theoretical predictions on the ground state masses, there are very little agreement among the model predictions of the properties like spin-hyperfine splitting among the $J^P = \frac{1}{2}^+$ and $J^P = \frac{3}{2}^+$ baryons, the form factors, magnetic moments etc; On the other hand, baryons are not only the interesting systems to study the quark dynamics and their properties but are also interesting from the point of view of simple systems to study three body problems. There exist many approaches vis a vis QCD sum rules, Potential models, Lattice QCD, the Bethe-Salpeter method, Feynman-Hellmann theorem and semi-empirical mass formula within the framework of a nonrelativistic constituent quark model, heavy quark effective theory (HQET), the vacuum correlators etc., that provide the low lying baryon spectra with one or two heavy flavour quarks. Though many of these theoretical attempts successfully predict the masses, there is no consensus among the theoretical predictions of the properties like spin-parity, the form factors, magnetic moments and transition properties etc.; All these reasons make the study of heavy flavour baryon spectroscopy extremely important and interesting. Heavy baryons further provide excellent laboratory to understand the dynamics of
light quarks in the vicinity of heavy flavour quarks. Such an attempt would test the predictions of different phenomenological approaches. For example, lattice QCD calculations suggest the importance of the three body forces in baryon spectroscopy.

The study included in the thesis is particularly addressed to the baryons, hypernuclei and their properties which are presented in different chapters. Chapter 1 is devoted to review the present experimental and theoretical status in the field of the baryons and hypernuclei.

Baryons as composition of three quarks are being studied with light flavour (u,d,s) composition in chapter 2. The confinement potential is assumed in the Jacobi co-ordinates of the hypercentral coulomb plus power potential ($hCPP_\nu$) form. It is to be noted that, hypercentral potential implicitly takes into account of the effects of three body force. For the computations of static as well as dynamic properties of octet and decuplet baryons, we consider the variational scheme with the hyper Coulomb trial wave function. The spin hyperfine interactions with the radial part expressed in terms of the hyper co-ordinate $x$ has been used with explicit mass dependence of the constituting quarks in the present study. The magnetic moments of octet and decuplet baryons are computed based on the nonrelativistic quark model using the spin-flavour wave functions of the constituting quarks and their effective masses within the baryon. In the present study, we compute the effective masses of the constituent quarks within the baryons. We repeat our computations by varying the confinement potential power index $\nu$ from 0.5 to 2.0. It is important to see that the baryon mass do not change appreciably beyond the potential power index $\nu > 1.0$. The inter-quark interactions within the baryons are considered in the calculation of magnetic moments through the definition of effective mass of the constituent quarks within the baryon. It is interesting to note that the magnetic moments predicted in our model do not vary appreciably with different choices of $\nu$ running from 0.5 to 2.0. Our predicted magnetic moments of octet and decuplet baryons are in good agreement with experiments as well as other theoretical model predictions. Apart from this static property, we calculate transition magnetic moments ($\mu_{N^+\rightarrow\Omega^+}$), radiative decay widths ($\Gamma_{\text{decuplet-\rightarrow octet}}$) and their branching ratios. Our predictions are then
In chapter 3, we study the static properties of heavy flavour baryons containing one heavy flavour quarks (c,b). To study the three-body problem of the single \((gqQ)\) heavy flavour baryons the effective interacting potential is assumed in the same way as in the case of light flavour baryons. Here we solve the Schrödinger equation numerically in six dimensions with the \(hc\rho\nu\) potential for the spin average mass and hypercentral wave function numerically. With the help of spin-spin, spin-orbit and tensor interactions, we compute the mass spectra of the chosen baryon state. We then predict the heavy baryon masses for few higher orbital and radial excitations. Further, we verify the Regge trajectories of heavy baryons for radial excitations. The \(JP\) quantum numbers for most excited heavy baryons have not been determined experimentally, but are assigned by the Particle Data Group on the basis of quark model predictions. So it is very interesting to assign quantum numbers to excited heavy baryons according to our hypercentral quark model. Using the spin-flavour structure of the constituting quarks and by defining an effective confined mass (dynamic constituent quark mass) of the quarks within the baryons, the magnetic moments are computed.

Chapter 4 deals with the dynamic properties of baryons containing heavy quarks. The dynamic properties include the transitions magnetic moments, radiative decay widths and strong decay widths. The spectroscopic parameters deduced from the static properties studied in the previous chapters are being employed to study the dynamic properties. Though many of the single heavy flavour baryons are known experimentally, the double heavy and triple heavy flavour baryons are yet to be observed experimentally. Thus, due to the lack of experimental data for heavy flavour baryons, we concentrate largely on the electromagnetic and strong decay properties of the single heavy flavour baryons.

In chapter 5, we present our study on hypernuclear physics where a nucleon in compared with the existing theoretical and experimental results.
a nucleus is replaced by a hyperon (with a strange quark). Here we consider nuclei embedded with a strange hyperon. Such cases of strange matter as well as of charm matter are of recent interest experimentally and theoretically. We study the binding energy of hypernuclei containing single Λ-hyperon in the framework of non-relativistic Schrödinger equation. We use Wood-Saxon potential to study the binding energy of hyperon within nuclei. We also study the decay properties of hypernuclei. For example the alpha decay rates of heavy Λ-hypernuclei compared to its normal α-emitter nuclei of thorium series and uranium series using the WKB approximation are being studied. The Λ-separation energies of Λ-hypernuclei whose mass number, A > 56 are employed to estimate the Λ-separation energies of the heavy Λ-hypernuclei of the thorium and uranium series. As expected for the normal α-emitter nuclei, the Geiger-Nuttal law is found to be valid in the case of Λ-hypernuclei also.

In chapter 6, we make a comprehensive summary of the work done and draw important conclusions of the present study. Future prospects in the light of latest experimental and theoretical status will be discussed. The decay widths of several heavy flavour baryons studied in the thesis play a crucial role in the precision measurements of the CKM matrix elements. Many of the predictions presented in the thesis are expected to be supported by the experimental data coming from high energy machine such as LHC, B-factories, CLEO, BaBar, SELEX and Tevatron with high luminosities. It might be possible to observe new states of hadrons containing heavy flavours and the predicted excited states can throw light on their status as conventional quark combinations for baryons mesons and multiquarks or other exotic states. Looking for such high energy projects, reliable theoretical predictions for their properties of heavy baryons are useful for experimental searches. Many of these studies also invoke new physics beyond the standard model. And it provides wider scope for the future developments in the field of hadron physics and processes that require physics beyond the standard model.