PREFACE.

The study of the structure of nuclei has passed through the various stages of development. Whenever, a large body of experimental data became available, a model was suggested. Then came other models as a natural consequence of its modifications since, by definition, a model is a greatly simplified physical system and can, in general, explain only a part of our experimental knowledge. In turn better success of a model is based on its getting some theoretical basis. In spite of all these developments during the last few decades, the problem is still far from a complete solution.

The problem of nuclear structure is that of the distribution of Z-protons and N-neutrons inside a nucleus consisting of \( A = N + Z \) particles. Thus the nucleus is a many-body system which is not very easy to solve in practice. This gave rise to the evolution of various approximate methods or so-called models, to explain the various nuclear properties like nuclear binding energies, spin, parity and excitation energies of various levels, magnetic and electric moments, transition probabilities etc. The collection and systematisation of a large amount of data on some of these properties gave rise to a very simplified picture of the nucleus in 1949, known as the single-particle model based on the assumption that the nuclear properties are given only by the last unpaired nucleon. However such a simple model, which does not consider the nucleon correlations, cannot be a very realistic approximation. On this model the different states, which can be formed by a number of particles having same quantum numbers \( n, \ell, \) and \( j, \) will be
degenerate. In other words, all possible states of a number of nucleons in a given shell, i.e., states of a given configuration, will have the same energy; the so-called single-particle energy. Such degeneracies do not occur in actual nuclei. Such a situation demands the introduction of the nucleon correlations, also known as the 'residual interaction'. This has been done in two different ways, giving us the two different models: shell model and collective model.

In shell model, the nucleons in closed shells form an inert core and only particles in unfilled orbits are considered. It is assumed that the interaction of such extra nucleons is strong enough to remove the degeneracies such that $j$ remains a good quantum number ($jj$ - coupling)\(^1,2\). In other words, the central field cannot replace exactly the two-body interaction and in the next approximation, if we take into account the residual two-body interaction, we find that the different states have different energies. Such an assumption explains the nuclear spectra very nicely in various regions of periodic table in addition to the various other successes of the single-particle model but fails to account for the large quadrupole moments and enhanced transition probabilities over the single-particle estimate. Evidently such effects can result only if a large number of nucleons take part. This was first suggested by Rainwater\(^3\) in 1950 and later on developed by Bohr, Mottelson and various collaborators\(^4-7\). This, however, gives another way of introducing the nucleon correlation as the collective motion. The nucleus is considered to have a core as a non-viscous incompressible drop of liquid which interacts with the particles
outside it. Using the adiabatic approximation for the motion of these particles they are able to show that one obtains a large axially symmetric deformation of the drop compared to its zero point vibration and that this deformation increases with the number of particles outside the core or closed shells. This leads to a low energy rotational spectrum. Such an approach is given the name 'Collective Model'. Alternatively one may consider an extended shell model which considers the shell model potential to be deformed rather than spherical and Pauli principle is used to fill such a deformed well. In the present study we shall be interested only in the first type of approach. The collective effects can also be considered in spherical nuclei\(^3\). In the language of shell model, such a procedure is called 'configuration mixing'.

Part I of this work deals with the shell model calculations for spherical nuclei with configuration mixing forming an interesting part of the study. The force which removes the degeneracy of the shell model states is commonly known as 'effective interaction'. Since its exact form is hard to calculate, various attempts have been made by different authors to determine it in different cases (Chapter I). Shell model calculations can be made for nuclei having two or three particles (or holes) outside the core. Such nuclei are known as 'spherical nuclei'. Only two-body forces for even-even nuclei, are considered here. Chapter II gives the method of calculations and the parameters used. The consideration of collective motion in such nuclei through configuration mixing may give us some idea about the effective two-body forces. Chapters III and IV give the results of our study of \(^{58}\)Ni and \(^{14}\)C respectively within this framework.
Part II deals with nuclei having large number of particles outside the closed shells. Such nuclei are said to be 'deformed' and are found to possess rotational spectra. In such nuclei the effects of collective motions of the nucleons on nuclear spectra have been the subject of intensive study within the framework of the hydrodynamical model of Bohr and Mottelson\textsuperscript{4,5}, assuming an axially symmetric deformed shape for nuclei in certain regions (Chapter I). Early reviews\textsuperscript{3} of the spectacular success of this approach appeared in 1956. Later, as the microscopic theory of collective motions was developed, the existence of the excited rotational bands on vibrational states in such nuclei was noted and theoretical investigations of the rotation-vibration interaction were undertaken. An early review\textsuperscript{2} of this study appeared in 1960. Since then a lot of more experimental information on the rotational as well as vibrational states in deformed nuclei has become available and various detailed models, have been advanced. Our study concerns the interpretation of such levels in even-even deformed nuclei. In Chapter II the systematics of the various properties signifying the collective behaviour of the nucleons inside the nuclei are examined to demarcate the spherical and deformed regions. The nature and the point of the transition from one region to the other has been a subject of controversy recently.

The study of nuclear spectra for the rotational region is taken up under two heads. Firstly the corrections to the ground state rotational bands are investigated and the importance of including the second order correction is pointed out (Chapter III). Secondly we take up the investigation of the excited bands in these nuclei. The rotational constants for these bands are
evaluated and the internal structure of these bands is discussed (Chapter IV).

In addition to the study of well established rotational nuclei, we look for evidence of such spectra in other regions of spherical nuclei (Chapter V). Such studies have been of great interest recently. It may be mentioned that rotational bands have been reported\(^{10}\) to exist at high excitation even in the doubly magic nuclei \(^{0}\).

In Chapter VI we discuss the collective model interpretation of even-even nuclei in Id-2s shell and compare the results with those derived on the basis of the non-axial rotor model, due to Davydov and Filippov\(^{11}\). A remark may, however, be added about the non-axiality of the nuclei. It has, recently, been suggested by Mottelson\(^{12}\) that one can expect an axial and non-axial considerations to be applicable in one and the same nuclei. If the nucleus is axial in its ground state (ground state rotational bands) it may go over to non-axial in the excited band.

So far, no mention has been made of the mixing of the bands and of the transition probabilities. A determination of the band mixing parameter from the experimental energy spectrum and the gamma-ray intensities is given in Appendix II for \(^{160}\) Dy.

Finally, the shell effects and collective effects in light nuclei (been derived from electron scattering results and are given in Appendix I.

Although the study of both these models at the present stage needs no elaborate discussion, yet a brief introduction, outlining the relevant background, formulae, method of calculations and parameters used, has been added to both parts of this thesis. This has been done to make the study self consistent. A large
number of reviews are now available. Some of these are mentioned as references\(^4-9, 13-19\)}. In addition some very good books\(^{20-24}\)} have been published during the last two-three years, giving a comprehensive study of nuclear models.