CHAPTER I

INTRODUCTION

The deformed Hartree-Fock (HF) formalism has proved to be a particularly convenient and physically meaningful way to calculate intrinsic ground state and spectroscopic properties of nuclei. HF formalism gives rise to an average field corresponding to the one assumed in shell model, in which each nucleon moves independently of each other. From the deformed HF solution, good angular momentum states can be projected out employing the standard projection formalism of Peierls and Yoccoz[1] to explain the spectroscopic properties of nuclei like energy spectra and electromagnetic transitions. If there are two or more deformed HF intrinsic states lying close in energy and giving rise to different bands of good angular momentum states, it becomes necessary to orthogonalize the states belonging to different bands. This projected HF approach is found to be a good approximation to the shell model approach. Moreover, the Shell model calculations become prohibitively complex when the number of nucleons and the configuration space become large.

The calculation of the effective interaction to be used in the nuclear structure calculations in terms of the interaction between two nucleons in free space requires the framework of Brueckner's theory[2-7] in the local density approximation. The effective interaction is given by the nuclear matter G-matrix calculated at the density of the centre-of-mass of the interacting nucleon pair. The calculation of G-matrix and its application to study nuclear properties is somewhat complex and hence it is desirable to parametrize it as a whole. Skyrme interaction[8] can be regarded as a simple phenomenological representation of G-matrix. It has a two-body part and a three-body contact interaction part that simulates a density dependent two-body interaction in the HF calculations of even-even nuclei[9]. Skyrme interaction has the rare distinction of achieving a phenomenal success in explaining the bulk properties of nuclei all over the periodic table with only a few parameters[9,10]. In spite of this success, there has been very little effort[11,12] in calculating spectroscopic properties such as energy spectra, transition rates etc. using Skyrme-type interactions. One can obtain a better understanding of the wide variety of phenomena observed in nuclei through the spectroscopic calculations and this is precisely what motivated us to perform spectroscopic calculations with Skyrme-type interactions.

Sussex interaction[13] is a realistic interaction derived directly from the observed N-N phase-shifts and is an elegant way of obtaining G-matrix. This interaction, however, underbinds nuclei and gives too small radii. We used this interaction also in our aalculations.

In our deformed HF calculations, we have employed a large model space consisting of first four major shells to avoid the complications and uncertainties arising from the core-polarization effects and the renormalization of the effective interaction when the calculations are performed in small model spaces, say as in the case of single major shell HF calculations.

Of late, HF calculations with Skyrme-type forces have become quite popular. However, when three-body contact force is used in Skyrme interaction, it is well-known[14)] that it gives rise to the overbinding of odd and odd-odd nuclei and produces unstable spin-aligned HF ground states in nuclear matter and even-even nuclei. The two-body density dependent interaction is therefore preferred to a three-body contact force. Since we are dealing with deformed nuclei, the densities are also deformed which make the Hamiltonian rotationally non-invariant rendering it unsuitable for spectroscopic calculations. We therefore propose a modification of the Skyrme interactión which makes the Hamiltonian rotationally invariant and suitable for rigorous spectroscopic calculations.

Interactions employed in the present work i.e. Skyrme and Sussex interactions are discussed in the next chapter.

The need to perform spectroscopic calculations with the Skyrme interaction also is discussed.

HF formalism for density independent forces is reviewed in the third chapter incorporating the centre-of-mass motion. The nuclei studied are ^{8}Li, ^{8}Be, ^{8}B, ^{12}C, ^{16}O and ^{20}Ne with the interaction SV, a Skyrme variant with no density dependence and the Sussex interaction. HF results for these nuclei are presented in this chapter.

We discuss in the fourth chapter the density dependent HF theory for time-reversal invariant even-even nuclei. We propose in this chapter the modification in Skyrme interaction so as to make the spectroscopic calculations feasible. We present the results of HF calculations for the nuclei ^{8}Be, ^{12}C and ^{20}Ne with the interaction BASIV defined in this chapter.

Projection formalism is reviewed in the fifth chapter and applied to calculate nuclear spectra and other properties with the interactions discussed above. The importance of density dependence of the Skyrme interaction in spectroscopic calculations is discussed. We also compare the electromagnetic properties calculated for the above nuclei with experiment.

In the sixth and last chapter, summary, conclusions and future scope of the present work is discussed.

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