CHAPTER VI

CONCLUSION
(6.1) Conclusion:

In the previous chapters we have been mainly concerned with the calculation of nuclear matter optical potential, nuclear matter binding energy, nuclear matter incompressibility and the construction of nucleon-nucleus optical potential from effective t-matrices in the lowest order Brueckner theory starting from realistic interactions.

In chapter II we first described a detailed calculational technique to obtain nuclear matter optical potential, nuclear matter binding energy and nuclear matter incompressibility in the first order Brueckner theory using local Urbana V14 soft core\textsuperscript{1)} and Hamada-Johnston hard core\textsuperscript{2)} interactions. Our calculation of nuclear matter optical potential at several densities indicates that if one uses a simple local density approximation\textsuperscript{3,4)} to calculate optical potential for finite nuclei one would obtain a shape resembling the wine-bottle bottom type of real potential at incident energy in the transition region. Further, the radial shape of real potential changes substantially with increasing energy. The behaviour of the nuclear matter potential at various densities indicates a mild surface enhancement in the imaginary potential at low incident energies. At high energies the imaginary potential has no surface peaking in the calculated optical potential.

We have seen that the lowest order Brueckner theory with the use of Urbana V14\textsuperscript{1)} realistic interaction predicts a large
saturation density and an overbinding of the infinite nuclear matter. Whereas HJ \(^2\) interaction predicts a saturation density quite close to the empirical one \(^5\), however the predicted binding energy is too low as compared with the empirical value. Thus the saturation density is correct but the system is underbound. Finally, the results obtained from two different approaches - the Brueckner theory and the variational approach \(^6\) - using Urbana V14 \(^1\) realistic interaction are qualitatively similar. Both approaches give rise to a large saturation density and an overbinding of the nuclear matter. In particular, Brueckner theory compared with the variational approach \(^6\) predicts greater binding energy (by about 2 MeV per particle) at a comparatively lower saturation density.

Our calculation using Urbana V14 \(^1\) interaction gives rise to nuclear matter incompressibility which is in fair agreement with the results using variational approach \(^6\) with the same two-body interaction. This is quite satisfying and it strengthens our confidence in the calculational procedure. Both the above results are in fair agreement with the empirical value. However, the use of HJ \(^2\) interaction gives rise to a nuclear matter incompressibility which is quite low as compared with empirical one.

Thus we conclude that the first order Brueckner theory can be successfully employed to calculate nuclear matter optical potential from a realistic interaction. The main
features of the calculated potential are in fair agreement with the empirical results. Further, the use of first order Brueckner theory gives results which are qualitatively similar to the results of variational approach\(^6\). The disagreement with the saturation density seems to be due to the neglect of higher order effects as shown by the variational calculation\(^6\).

Chapter III has been concerned with the construction of nucleon-nucleus optical potential for finite nuclei from the effective t-matrices calculated in the lowest order Brueckner theory of infinite nuclear matter starting from realistic interaction following the folding procedure of Brieva and Rook\(^3,4\)\). It should be pointed out that we do not use the generalized reference spectrum method\(^7\) but solve the integral equation using matrix inversion technique. In this chapter we have first described in detail the method of calculation of different components (direct central, exchange central, direct spin-orbit and exchange spin-orbit parts) of the nucleon-nucleus optical potential. We have also presented a new formulation of obtaining the effective mass correction to the optical potential, which slightly differs from others\(^8-10\)\). Our new approach not only modifies the central imaginary part but also gives a feedback term in the real central part and modifies the real spin-orbit and imaginary spin-orbit parts of the calculated optical potential. We have
performed calculations for obtaining nucleon-nucleus optical potential using both the Urbana V14 soft core\textsuperscript{1) and HJ hard core\textsuperscript{2)}} realistic interactions. The results show that the calculated potentials are in reasonable agreement with the ones required to fit the scattering data. In particular we have found that the real part of our calculated optical potential resembles in shape with the wine-bottle bottom type of potential at an incident energy in the transition region. The radial shape of real optical potential changes substantially with increasing energy. We have seen that at low incident energy the calculated optical potential contains a mild surface enhancement in the imaginary part. At high incident energies the imaginary potential has no surface peaking in the calculated potential. Further, at low incident energies the central optical potential using V14\textsuperscript{1)} interaction in the interior region is more attractive (by about 8 MeV in case of real part and by about 2-4 MeV in case of imaginary part) as compared with that using HJ\textsuperscript{2)} interaction. Further, at low incident energies HJ\textsuperscript{2)} interaction gives a pronounced surface enhancement whereas V14\textsuperscript{1)} interaction gives a milder surface enhancement in the imaginary central potential.

In chapter IV we have investigated the approximations used to calculate the central exchange part of the potential where we have shown that this part of the potential can be written as a series whose first term corresponds to that used
by all previous authors \(^3,11-14\). We have calculated the first three terms of the series which seems to converge fairly rapidly. Our calculations have shown that the additional two terms of the series contribute significantly only to the imaginary part of the central potential. The effect of these additional terms on the real part of central potential is only marginal. In particular, we have shown that as a result of these additional terms the surface peaking in the imaginary potential is enhanced to some extent at low incident nucleon energies. This surface peaking at low incident nucleon energies has often been suggested by purely empirical analyses \(^15\). Its absence in all microscopic calculations starting from basic nucleon interaction has been a problem. The size of the imaginary part of the central potential, particularly in the nuclear interior is not substantially reduced by the inclusion of the two additional terms of the series as required by the low energy scattering data. Thus the calculated potential remains about 40\% larger than the one required for obtaining good agreement with the scattering data.

In chapter V we have investigated the calculation of spin-orbit part of the nucleon-nucleus potential. Our investigations lead us to the following conclusions. First we consider the direct part of the spin-orbit potential. Previous calculations used series expansions and made use of various
approximations to sum the series. In particular, we have shown that the series of Greenlees et al.\textsuperscript{16-17)} and that of Scheerbaum\textsuperscript{18)} are formally equivalent. Further, we have shown that the convergence of the series is doubtful, that is, the second term of the series is almost as large as the first term. We have shown that one can easily calculate the direct part of the spin-orbit potential exactly. Our calculations show that the approximation of using just the first term of the series underestimates the direct part of the spin-orbit potential at short distances and overestimates it at large distances. However, the volume integrals calculated from the first order term of the series and that from the exact expression are very similar. For the exchange part of the spin-orbit potential, our calculations show that the approximations made earlier are more severe. We have presented, in this chapter, a method of calculating the exchange part without making any approximation. In particular, we find that the calculations following the approximate method of Brieva and Rook\textsuperscript{4)} overestimate the exchange part of the spin-orbit potential by about 30%. Thus the total spin-orbit potential is reduced by 15% as a result of our exact calculations.

We have made analyses of the differential cross sections and polarization data of elastic scattering of protons from \textsuperscript{40}Ca at several energies in low and intermediate energy
regions using the new potentials of chapter IV and chapter V. The agreement obtained using the calculated potential is reasonable. However, the calculated central imaginary part is still appreciably large as in earlier calculations. Calculations of the central imaginary part of the potential using three nucleon correlation terms\textsuperscript{19) in the Brueckner theory shows a promise of substantially affecting the strength of the central imaginary potential. The results indicate that the inclusion of such higher order terms reduces the calculated potential by about 10-15\% and further enhances the surface peaking. Further, the use of off-shell prescription\textsuperscript{20) for calculating the energies of the intermediate state nucleons also reduces the strength of the imaginary potential at low energies. However, in the present thesis, we have not investigated the effect of these three nucleon correlation terms or the off-shell effects. We shall pursue these investigations in future. Further, from this analysis the calculated spin-orbit part is too small (about 30\%). We think that this feature and the size of the imaginary central part are the present major discrepancies at lower energies in calculations of the type described here.

In conclusion we feel satisfied that we have been able to make substantial improvement in the calculational procedure for obtaining both the central and spin-orbit part of the microscopic optical potential for spherical nuclei.
References:
5) B. D. Day; Rev. Mod. Phys. 39(1967)719.


