On the low energy nucleon-nucleus and nucleus-nucleus elastic scattering

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The nuclear interaction is accountable for holding neutrons and protons together in an atomic nucleus. With the knowledge of interacting potentials, those fit experimental data, one is able to study the nuclear properties with more or less success where quantum mechanics is hard to be used. One first tries to investigate the nucleon-nucleon force from the two nucleon properties, and then utilize it to investigate the nuclear many-body interaction. The modern theory of interactions through the exchange of particle is made possible by the development of quantum field theory. However, if one is interested in the low-energy region where internally the nucleons hardly get excited, one can treat the nucleons as inert, structureless elementary particles. In such circumstances, many properties of the multi-nucleon systems can be understood by the fundamental nucleon-nucleon interactions. Also, one can assume the interaction is non-relativistic at low energies and hence the concept of interacting potential becomes more useful.

In this dissertation the nucleon-nucleus and nucleus-nucleus on-shell interactions are investigated at low energies through different theoretical approaches adapted within the framework of nonrelativistic time independent scattering theory. In contrast to the traditional method of representing the nuclear interaction by the short-range local potential, we discuss the problem within the formalism of the nonlocal separable model. There is no loss of generality in replacing the short-range nuclear potential by a finite rank of separable nonlocal one. One can represent the short-range local potential by finite rank separable potentials in the mathematically well-defined sense [1]. Also, for the nuclear part of the proton-proton interaction realistic separable model has been successfully proposed by Graz Group [2,3] in various angular momentum states.

Our understanding of the physical phenomenon in the microscopic world is largely based on quantum scattering theory. In this context, to fit scattering phase parameters, the use of separable nonlocal potential approximated to a short-range local potential has been well accepted. Now, attention is being directed towards the development of methods to construct equivalent energy-dependent local potentials to nonlocal ones which may lead to a greater understanding of these interactions. An equivalent local potential is generally applied in optical model studies. In this model, people compare the phase parameters and T-matrix elements obtained from the parent nonlocal potentials and equivalent local ones. Previously several groups [4, 5-8] have made attempt to construct energy dependent potential to the nonlocal potential. Coz. et al. [5] proposed a more precise way to obtain an equivalent potential from the two independent solutions of the nonlocal interaction in which the constructed potential is independent upon the boundary conditions imposed on the solutions. Following the approach of ref. [4, 5] we have constructed equivalent local potential for the rank-1 Graz separable nonlocal interaction. As the method requires any two convenient pair of nonlocal solutions, we adapt Green's function technique to find two independent solutions to the nonlocal Schrödinger equation.

For a given partial wave, it is expected that the phase equivalent potentials reproduce the same phase shifts for all energies. But certain differences are observed in reality. In order to avoid these ambiguities raised by certain differences, it is important to explore all possible forms of the interactions equivalent to a given one. In this context, a simple approach is prescribed to develop an equivalent local potential by rearranging Schrödinger's wave equation for the combined effect of Coulomb plus finite rank separable potential. We have addressed the localization process for all partial waves to construct energy-dependent potentials in terms of the regular solution. It is conjectured that local Coulomb-like potential is equally applicable for the traditional phase function method. In both localization processes scattering phase shifts for the nonlocal potential are computed via the Fredholm determinant and for equivalent local potential the same are calculated through the phase function method for nucleon-nucleon and alpha-nucleon systems for reasonable comparative study. We achieve excellent agreement with the standard data up to partial wave $\ell = 2$. It is observed that these methods of constructing equivalent local potentials work satisfactorily for few lower partial waves.

The physical processes, like (α-C^{12}), (α-H^3), (α-He^3), etc., which play major roles in stellar nucleosynthesis can be modelled within the framework of nonlocal potential. In the recent past, various models like effective field theory [9], R-matrix approach [10] etc. have been employed to study the (α-C^{12}) elastic scattering at low energies. Mohr et al. [11,12] analyzed (α-H^3) and (α-He^3) interactions through optical model using double folded potentials. However, we have proposed alternative theoretical model for α-C^{12}, α-$H^3$and α-He^3 scattering by introducing an additive interaction, Graz separable potential as nuclear part of interaction and Coulomb/screened Coulomb as electromagnetic potential, to study phase shifts and binding energies of the related states for $\ell = 0,1 \,\&\, 2$. These phase parameters and binding energies are computed by exploiting the closed form expression of the Fredholm determinant which in turn are derived from the double integral transformation of the Green's function for motion in a Coulomb/screened Coulomb-distorted separable nuclear potential by direct integrating the outgoing wave Green's function for the Coulomb/screened Coulomb potential by the nonlocal potential form factors.

These versions of the effective interaction generate satisfactory results of all physical quantities associated with nucleon-nucleon and nucleon-nucleus scattering. In contrast to previous studies [9-11, 13] made in the recent past, our method of analyzing such systems at low energies within the separable model of interaction are more convenient.

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