Analysis of elastic α-nucleus scattering data at 240 MeV

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Working within the framework of the Coulomb modified Glauber model we fit the elastic differential scattering cross section of 240 MeV α particle on ^{58}Ni using the effective N-α amplitude with one adjustable parameter. It is found that once the effective amplitude is calibrated on ^{58}Ni by varying the adjustable parameter, it very nicely reproduces the available elastic α scattering data on other nuclei at the same energy.

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I. INTRODUCTION

During the past several years, the acceleration of light ions at low and intermediate energies has been the subject of much interest in the field of nucleus-nucleus collision which is complementary to nucleon-nucleus scattering. The α particle, due to its zero spin and i-spin and of relatively large binding energy per nucleon, has naturally appeared prominently in the list of light ion nuclear scattering experiments. As a result, an adequate amount of α-nucleus elastic and inelastic scattering data at several energies are available in literature [1–4].

Generally, two theoretical approaches have been used for analyzing α-nucleus elastic scattering data. One is at low and medium energies by using the phenomenological optical model potential. At these energies the behavior of α-nucleus scattering cross sections is dominated by strong absorption in the nuclear surface region. More explicitly, the cross section depends mainly on a small number of phase shifts (δ_l), i.e., to those where l-values correspond to impact parameters in the region of nuclear surface. Since a different interior wave function can generate the same phase shifts, the optical model parametrization of the interaction leads to ambiguous information regarding the optical potential. This has been found to give the existence of discrete and continuous ambiguities as well as to the uncertainty in the general shapes of the real and imaginary potentials [2,5,6].

The other approach which has frequently been used is the Glauber model [7] using optical limit approximation or the rigid projectile model (RPM) [1,8–12]. It is found that the Glauber model, though based on the high energy approximation, works reasonably well even at some lower energies provided, it is modified to account for the deviation of projectile trajectory due to Coulomb field [13–16].

The fact that the evaluation of the full Glauber amplitude for a realistic description of nuclei is a computationally difficult task, Ahmad and Alvi [17] proposed a simple semiphenomenological method of analysis for α-nucleus elastic scattering data at medium and high energies. The method consists of using an effective N-α amplitude with one adjustable parameter instead of the generally used N-α elastic scattering amplitude in the usual RPM. The small momentum transfer (q) part of the effective amplitude is fixed from N-α scattering experiments while the large q part which is assumed to simulate the nuclear medium effect as well as the use of RPM approximation, is treated phenomenologically. Using this amplitude and the realistic ground state target densities, they found excellent agreement with elastic α-nucleus scattering data at 1.37 GeV.

In the recent past, the differential cross section for elastic scattering of the α particle is measured [3] at the incident energy of 60 MeV/nucleon for ^{58}Ni, ^{116}Sn, and ^{197}Au. An optical model analysis has also been performed that shows energy dependence as well as ambiguities in parameters of the optical potential.

In this paper, motivated from the success and simplicity, we use the method of the effective N-α amplitude [17] to analyze the α-nucleus elastic scattering data [3] at 60 MeV/nucleon within the framework of Coulomb modified Glauber model. As we will see shortly, a very satisfactory description of α-nucleus elastic scattering data is achieved.

II. FORMULATION

In the rigid projectile model assuming that the effect of correlations in the target nucleus is small [10], the S-matrix element $S_N(b)$ for the elastic α-nucleus scattering may approximately be written as

$$S_N(b) \approx [1 - \Gamma_\alpha(b)]^A \tag{1}$$

with

$$\Gamma_\alpha(b) = \frac{1}{ik}\int q\,dq\,J_0(qb) f_{N\alpha}(q) F_A(q), \tag{2}$$

where k is the nucleon momentum corresponding to the α particle kinetic energy per nucleon, $f_{N\alpha}(q)$ is the N-α scattering amplitude, and $F_A(q)$ is the target form factor. In all our calculations, the nuclear form factors are parametrized as a sum of Gaussians:

$$F_A(q) = \sum_{j=1} a_j\, e^{-b_j q^2}, \tag{3}$$

where a_j and b_j are the parameters. The advantage of using this parametrization is that the phase-shift function for the Coulomb potential due to the finite charge distribution of the colliding nuclei can be evaluated analytically. The parameter values of the nuclear form factors for ^{58}Ni, ^{116}Sn, and ^{197}Au are

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