Analysis of the ^{28}Si(α,α)^{28}Si elastic scattering at energies from 12.7 to 50.5 MeV

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Abstract. The available experimental elastic scattering angular distributions data of α-particles on ^{28}Si nucleus have been reanalyzed in the energy range from 12.7 to 50.5 MeV. The analysis performed within the context of optical model (OM) potential. In the framework of double-folding model (DFM), we created the real part of optical potential using a density dependent version BDM3Y1-Paris interaction model.

1. Introduction

The study of nuclear reactions is of particular interest, where it gives us information about the nuclei structure and interaction mechanisms [1]. In the theory of nuclear reactions, the optical model is one of the most important theoretical models widely used for the analysis of nuclear reactions. A complex central potential, which describes the complicated interaction between an incident projectile and a target nucleus is known as optical model potential (OMP) [2]. To eliminate the shortcoming of ambiguities resulted from (OMP) parameters, we have used a microscopic double folding model. The basic inputs in the (DFM) are the nuclear matter densities of both the projectile and target nuclei with the effective nucleon-nucleon (NN) interaction potential. By studying the elastic scattering of α-particles from ^{28}Si target, we have observed an unusual enhancement of cross section at back angles, which commonly referred to anomalous large angle scattering (ALAS) phenomenon [3,4] for energies below 50.5 MeV. This study aims to extract a reliable information about the optical potential parameters for elastic scattering of ^{28}Si(α,α)^{28}Si nuclear system in a wide range of energies from 12.7 to 50.5 MeV using optical model (OM) and double folding model (DFM).

2. Theoretical Outline

Within the framework of optical model (OM), the potential between the two interacting nuclei U(r) consists of two terms a) coulomb potential V_C(r) and b) nuclear potential V_N(r), which given as follow:

$$U(r) = V_C(r) + V_N(r) = V_C(r) - \frac{V_0}{1 + exp(\frac{r-R_V}{a_V})} - i \cdot \frac{W_V}{1 + exp(\frac{r-R_W}{a_W})} \quad (1)$$

Where $R_i = r_i(A_t^{1/3})$, A_t-represent target mass number, i=V,W,C. Here, V_0 and W_V are represents the depths of real and imaginary parts of optical potential respectively in MeV; r_i and a_i are the reduced radii and diffuseness parameters associated with them respectively in fm.

Within the framework of (DFM), the folding potential V^{DF}(r)given by

$$V^{DF}(r) = \int \rho_p(r_p)\rho_t(r_t)\upsilon_{NN}(r_{pt})d^3r_pd^3r_t, \quad r_{pt} = |\mathbf{r} + \mathbf{r_t} - \mathbf{r_p}| \tag{2}$$

Where r_{pt}, is the nucleon-nucleon separation in (fm). Thus, the total local optical potential U(r) is written as

$$U(r) = N_rV^{DF}(r) + iW(r) + V_C(r) \tag{3}$$

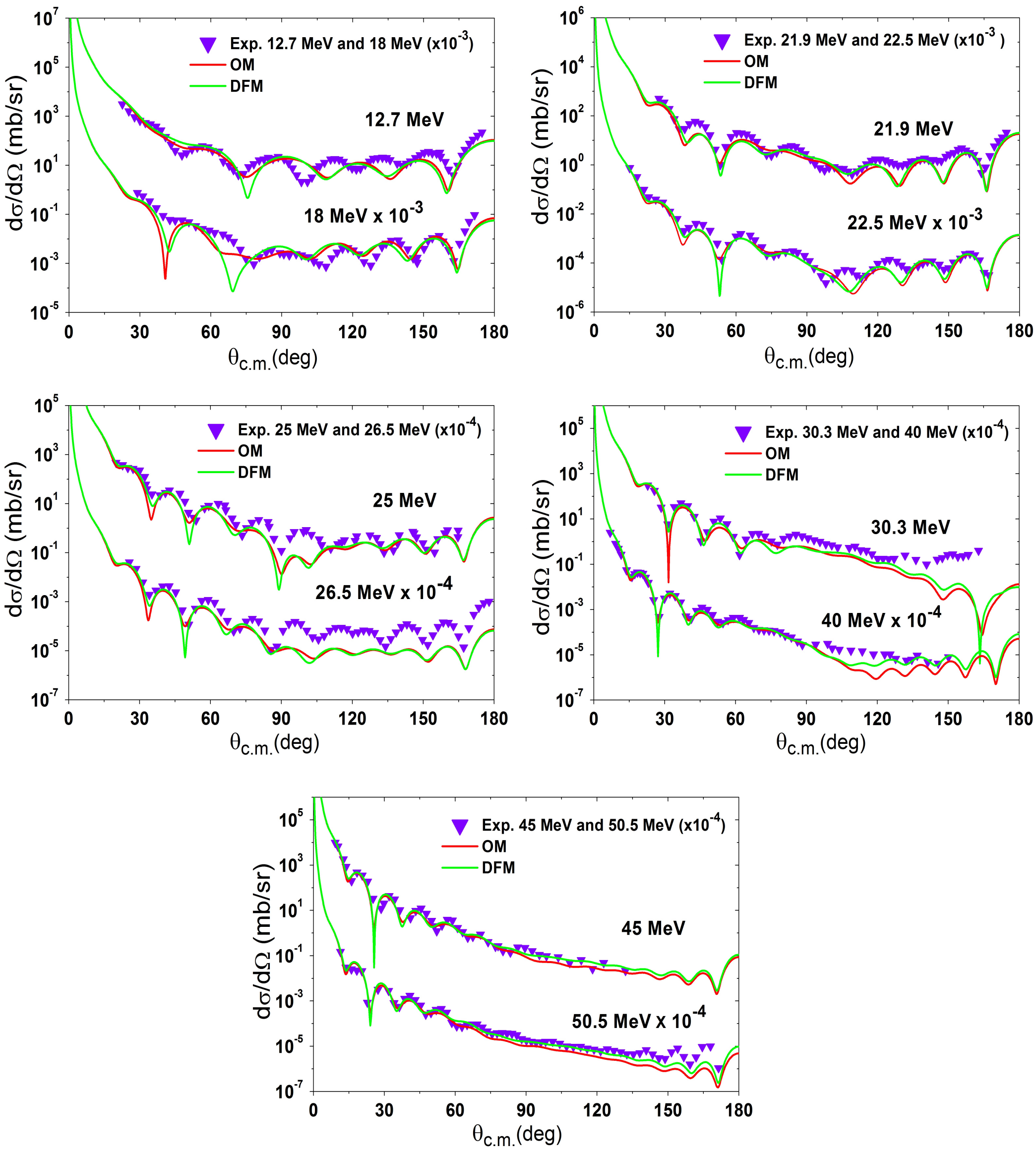

Figure 1: The comparison between the experimental data (solid triangles) for α+^{28}Si elastic scattering at energies (12.7, 18, 21.9, 22.5, 25, 26.5, 30.3, 40, 45 and 50.5 MeV) and the theoretical calculations within the framework of OM and DFM (solid colored lines)

We have been used a Gaussian density distribution of α-particles [5]and two parameter fermi (**2PF**) for ^{28}Si nucleus[6]. Finally, the generated folding potentials were fed into the computer code FRESCO [7].

3. Results and discussion

The comparison between the experimental angular distribution data for elastic scattering of α-particles from ^{28}Si nucleus at energies 12.7 MeV [8], 18 MeV [9], 21.9 MeV [10], 22.5 MeV [11], 25 MeV [12], 26.5 MeV [13], 30.3 MeV [14], 40,45 MeV [15] and 50.5 MeV [16] is shown in Figure 1. In the OM calculations, we used potential which is a combination of real volume part plus imaginary volume part. The potential was used to reproduce the experimental data in the forward hemisphere $\theta \leq 90°$ with the fixed values of radii (r_V=1.245 fm and r_W=1.57 fm) and diffuseness (a_V=0.791 fm and a_W=0.631 fm) of real and imaginary potential parts, respectively [17]; The optimal potential parameters for the imaginary part extracted from the OM were kept fixed in DFM calculations. In other words, the fitting process was performed using only one free parameter N_r "renormalization factor for the real part". The radius parameter for the Coulomb potential r_C was fixed at 1.3 fm. The optimal potential parameters extracted from both OM and DFM calculations, the values of real J_V and imaginary J_W volume integrals as well as the values of reaction cross sections are listed in Table I.

Table 1: Optical and double folding potential parameters for α -particles elastically scattered from ^{28}Si nucleus at different energies.

E_α, MeV	Set	N_r	V_0, MeV	J_V, MeV*fm^3	W_V, MeV	J_W, MeV*fm^3	σ_R, mb	χ^2/N
12.7	OM		132.04	382.25	4.22	20.08	935.4	20.33
	DFM	1.04		391.39			877.1	58.41
18	OM		135.07	391.03	6.35	30.21	1138	30.4
	DFM	1.05		392.69			1097	42.94
21.9	OM		120.60	349.13	8.59	40.81	1179	0.21
	DFM	1.0		371.10			1176	0.21
22.5	OM		120.63	349.23	9.45	44.92	1190	17.48
	DFM	0.98		361.89			1183	15.43
25	OM		120.99	350.27	13.48	64.09	1232	31.54
	DFM	0.99		364.45			1224	30.69
26.5	OM		124.86	361.45	16.96	80.61	1265	29.61
	DFM	1.03		378.85			1258	27.77
30.3	OM		113.02	327.19	16.69	79.34	1248	36.95
	DFM	0.98		357.69			1255	25.46
40	OM		120.89	349.99	18.00	85.58	1270	8.08
	DFM	1.02		366.59			1272	11.52
45	OM		117.84	341.13	22.93	108.99	1294	27.51
	DFM	1.0		354.81			1294	37.05
50.5	OM		117.58	340.39	23.10	109.81	1289	25.31
	DFM	1.06		372.52			1298	23.98

4. Summary

Ten data sets of α-particles elastically scattered from ^{28}Si target nucleus have been reanalyzed in utilizing both OM and DFM with real part of potential derived on the basis of DFM using BDM3Y1 Paris interaction model. We obtained a Physically reasonable parameters of interaction potentials in fitting the experimental data in a wide range of energies of α-particles projectile. The renormalization factor for a real part of optical potential and the total reaction cross section manifests a strong correlation with the projectile energies.

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