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Study of Helium Induced Elastic Scattering Reactions

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Abstract: ***The study reports details of Helium induced elastic scattering reactions for various targets focusing on angular distribution studies. The key findings reveal a high differential cross section at low scattering angles indicating the chances of Coulomb forces being dominant at the given laboratory frame of energies. The chance of absorption of projectile is minimal as revealed by the shape of the distribution curves.***

Keywords: Elastic scattering, Coulomb interaction, differential cross section, scattering angle

1. Introduction

The interaction between two nuclei without change in energy and internal states is termed elastic scattering reaction. However, the direction and momentum of the incident particle changes resulting in a distribution of particles as a function of scattering angle. The angular distribution may also be defined as the ratio of the differential cross section to the scattering angle. The differential cross section ($d\sigma/d\Omega$), is the probability of scattering of incident particles over a specific range of angles and it depends on several parameters such as nuclear potential, Coulomb interaction, nuclear radius and density, angular momentum and shape of the nucleus. Analysis of such distributions helps us in understanding the structure of the nuclei involved and provides insights into nuclear forces [1].

2. Methodology

The study focuses on the scattering of Helium nuclei, and Helium isotopes i.e. ^{3}He and ^{6}He, by different target nuclei. ^{3}He is stable but less abundant and weakly bound compared to ^{4}He. ^{6}He is a combination of (^{4}He+2n halo) and is radioactive [1]. The experimental data for the present study are obtained from the Nuclear Reactions Video (NRV) Project. The NRV database uses a quantum mechanical optical model to determine the scattering amplitude. The elastic differential cross section can be found from the scattering amplitude. The quantum mechanical optical model uses a combination of complex potentials such as the Coulomb interaction potential, nuclear potential, Woods-Saxon volume and surface potentials. In every projectile – target interaction, there is a possibility of scattering and absorption. To find the scattering amplitude the total wave function has to be decomposed into partial waves. The elastic scattering is characterized by the S matrix. S matrix is particularly useful as information about the outgoing state (after interaction) can be obtained [2]. The reactions considered for the study along with their sources are listed in Table 1.

3. Results and Discussions

Figures 1 and 2, show angular distribution of helium nuclei for various target nuclei. It is clear from the figures that the differential cross section is higher at low scattering angles. The optimum angle refers to the scattering angle, at which the differential cross section is maximum/optimal. The optimal angle and optimal differential cross section data are obtained from the plotted distribution curves. At small scattering angles, the projectile suffers Coulomb repulsion as it passes outside the nuclear surface. The probability of such interactions is high hence the differential cross section is higher. At intermediate scattering angles, the projectile passes close to the nuclear surface and experiences Coulomb-Nuclear interference forces, which produce the oscillatory patterns in the differential cross section with maxima and minima as shown in (He + Mg) reaction. At large scattering angles, the angular distribution curve shows broad maxima and minima and a decreasing cross section. The decreasing reaction cross section indicates the probability of projectile absorption resulting in a nuclear reaction. This depends on the strength of the nuclear potential, surface diffuseness and the size of the target nucleus.

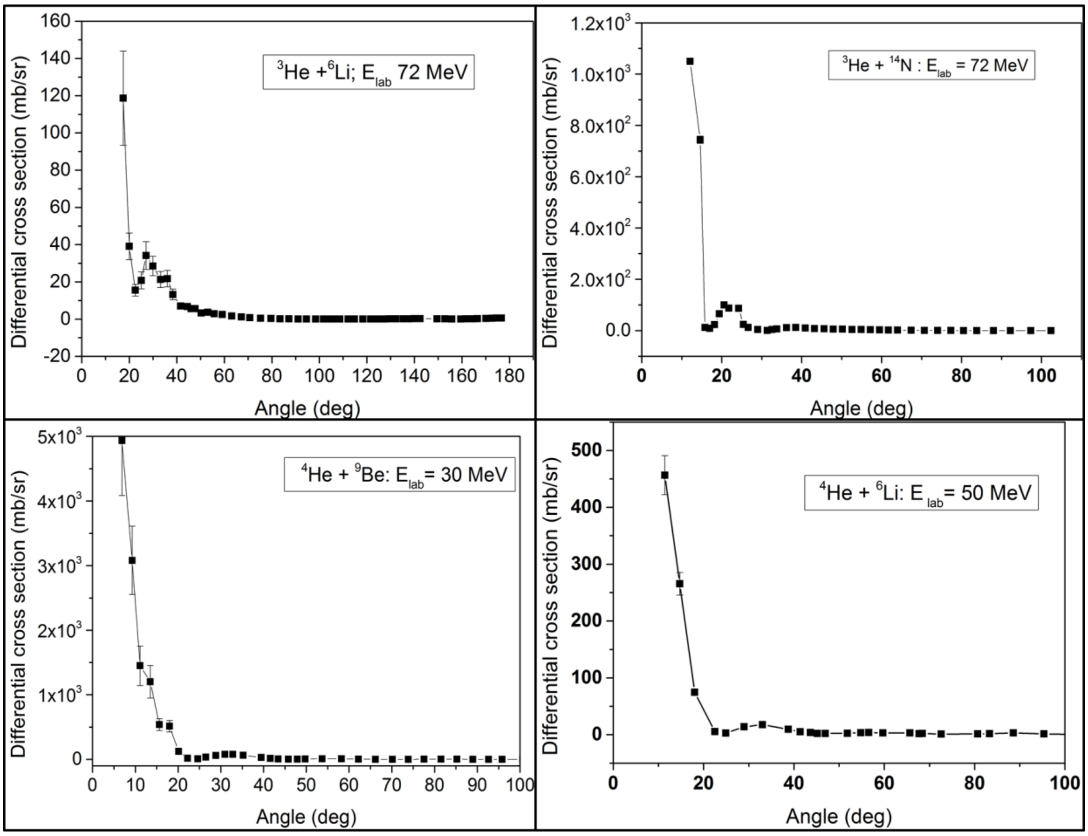

Figure 1: Angular distribution of Helium nuclei due to scattering by different target nuclei

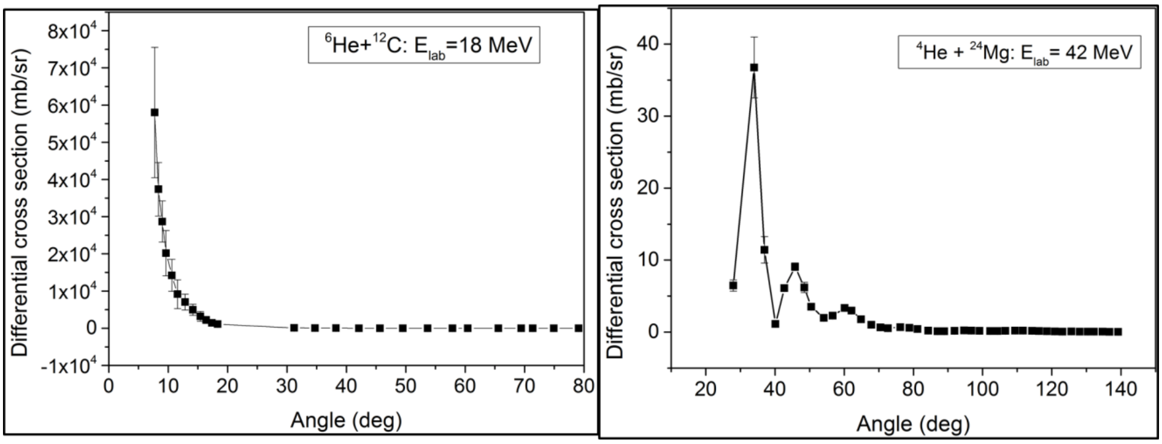

Figure 2: Angular distribution of Helium nuclei due to scattering by different target nuclei

The total cross section in Table 1, obtained from the NRV database, using optical model analysis refers to the combined contribution of all energetically feasible processes including elastic and inelastic reactions. Hence the shape of the angular distribution curve contains important information about nuclear radius, shape and nuclear potential [3, 4].

Table 1: List of Helium induced Elastic scattering reaction parameters

Reaction	E_{lab} MeV	E_{cm} MeV	Optimal angle (deg)	Optimal Diff. Cross section (mb/sr)	Total cross section (mb)
^{3}He + ^{6}Li [5]	72	48.00	17.48	118.17	2133.74
^{3}He + ^{14}N [6]	72	59.29	12.10	1050.00	2455.86
^{4}He + ^{6}Li [7]	50	30.00	11.41	455.76	1792.20
^{4}He + ^{9}Be [8]	30	20.77	6.92	4951.27	1995.39
^{6}He + ^{12}C [9]	18	12.00	7.84	57826.64	2235.71
^{4}He + ^{24}Mg [10]	42	36.00	34.40	36.61	2372.67

4. Summary and Conclusion

Elastic scattering angular distribution studies have been carried out for Helium and Helium isotopes using different target nuclei. The enhanced differential cross sections were observed at low scattering angles indicating the dominance of Coulomb forces and in some cases (Li, N and Mg targets) Coulomb-Nuclear interference forces. The chances of projectile absorption are minimal as shown in the distribution curves.

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