A simultaneous study of elastic scattering and fusion in ^{7}Li+^{27}Al reaction

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Introduction

A subject of breakup and transfer coupling effects on different reaction channels for stable weakly bound nuclei (^{6,7}Li, ^{9}Be) play a key role in various research fields such as astrophysics, nuclear structure and production of super heavy elements. There have been many measurements involving tightly as well as weakly bound nuclei to study the entrance channel coupling effects on different reaction channels mainly elastic and fusion, in different mass region [1]. The observation of threshold anomaly in elastic scattering involving stable and tightly bound projectiles [2] is correlated with the observation of sub barrier fusion cross section enhancement around the Coulomb barrier in comparison to the prediction of one-dimensional barrier penetration model. This phenomenon has been well understood in terms of the coupling of elastic channel to the direct reaction channels that generates an additional attractive real dynamic polarization potential. Similarly, for loosely bound projectiles the suppression (if any) in the fusion cross sections around the Coulomb barrier energies [3] is related to the repulsive real dynamic polarization potential generated due to coupling of breakup channels to the elastic channel. Thus, a simultaneous study of elastic and fusion reactions is most desirable to understand the underlying reaction mechanism and the coupling effects of different reaction channels such as inelastic, breakup and transfer channels on fusion. With this aim, measurements for both fusion cross section and elastic scattering are carried out for ^{7}Li + ^{27}Al system from below to above the Coulomb barrier energies (E_{lab} $\sim$ 8.0 MeV $\leq V_b \leq$ 16.0 MeV). The results have been studied in terms of detailed continuum discretized coupled-channels (CDCC) model and finite range DWBA model employing FRESCO code.

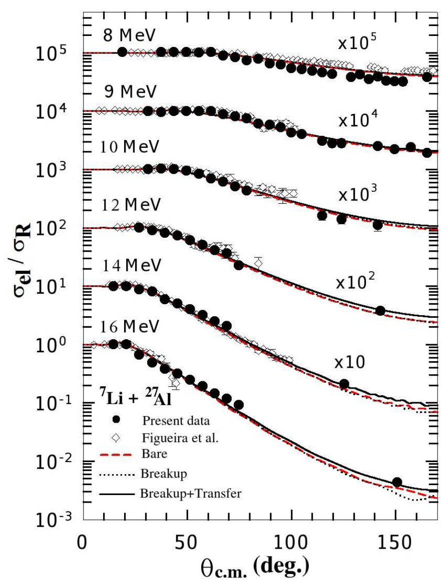

FIG. 1: Elastic scattering cross sections normalized to the Rutherford cross sections as a function of $\theta_{c.m.}$ for the ^{7}Li + ^{27}Al system.

The experiment was performed with ^{7}Li (3^+) beam using Folded Tandem Ion Accelerator (FOTIA) facility at BARC, Mumbai, India. A self supported ^{27}Al target having thickness $\sim 100\ \mu$g/cm^2 was used in the experiments, except for 9 MeV beam energy measurement where a target of thickness $\sim$ 220 μg/cm^2 was used. Three telescopes ($\Delta E - E$)

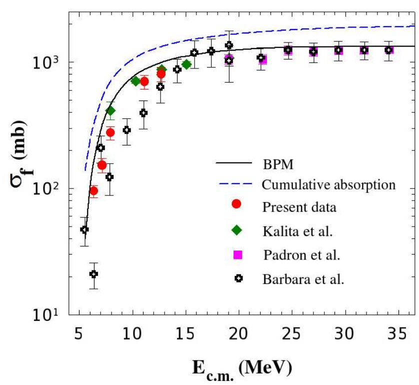

FIG. 2: Comparison of fusion cross sections obtained from the coupled-channels calculations for the ^{7}Li + ^{27}Al reaction with the present measurement and the data from the literatures [6–8]. The solid and dashed lines represent the BPM fusion and cumulative absorption cross sections respectively obtained from the CDCC calculations with breakup+transfer couplings using FRESCO.

of silicon surface barrier detectors of thicknesses 22 μm + 1.5 mm, 17 μm + 1 mm and 15 μm + 300 μm respectively with the separation of 10^0 have been used, to identify different events such as elastic and α-particle spectrum. The fusion cross-sections have been extracted at five different bombarding energies by comparing the α-particle energy spectra with the calculation from statistical model code PACE [4] at backward angles.

Results and Discussion

The results for both the elastic scattering and fusion cross sections from the coupled-channels calculations (CDCC + 1-n stripping transfer) employing FRESCO code, are compared with the present experimental data as well as from the literatures [5] and [6–8] respectively. It is observed that the calculations reproduce the measured elastic data reasonably well over the entire energy range of our measurement with the dominance of transfer than that of the breakup couplings as shown in Fig. 1. From the Fig. 2 it is observed that the Cumulative absorption cross section overestimate the data by a large fraction. This could be due to the long range imaginary potentials used for the fragment-target potentials to calculate the cluster-folded nuclear potential. Since the elastic scattering data is reproduced by the same coupled-channels calculations, the flux removed from the entrance channel (i.e., reaction cross section) must be equal to the cumulative absorption by the imaginary potentials plus non-zero cross sections of non-elastic channels. Thus calculated cumulative absorption cross section equals to the sum of cross sections for fusion and a few non-elastic channels that are not included in the coupling scheme but simulated by long range imaginary potentials. The channels which are not included in the couplings consist of target inelastic, many transfer channels and breakup channels with very high excitation energies. Fusion cross section was also obtained from FRESCO using the barrier penetration model (BPM) calculations and shown in Fig. 2 as a solid line. The calculated BPM fusion was found to be much closer to the experimental data. The BPM fusion at above-barrier energies was found to agree reasonably well with the experimental data [6] but it overestimates the measured data at near-barrier energies.

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