

Measurement of Fusion Cross-sections for $^{28}\text{Si} + ^{62}\text{Ni}$ System

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Introduction

The study of fusion reaction dynamics near and below the Coulomb barrier has attracted significant attention in recent years. The enhancement of fusion cross sections at sub-barrier energies is primarily attributed to couplings between the relative motion and intrinsic nuclear degrees of freedom, including static and dynamic deformations, neck formation, and positive Q-value nucleon transfer (PQNT) channels [1-2]. Nevertheless, at much lower energies, a contrasting phenomenon known as fusion hindrance has attracted significant attention [3]. This hindrance is characterized by a sharp reduction in measured fusion cross sections compared to theoretical predictions. In the present work, an attempt has been made to study the influence of PQNT on fusion excitation function. In this respect, fusion cross section for the $^{28}\text{Si} + ^{62}\text{Ni}$ system have been measured within the energy region $0.87 V_B$ to $1.18 V_B$.

Experimental Methodology

The measurement of fusion cross section in $^{28}\text{Si} + ^{62}\text{Ni}$ system has been carried out using the Heavy Ion Reaction Analyser (HIRA) at Inter-University Accelerator Centre (IUAC), New Delhi, India. A pulsed ^{28}Si beam, with a pulse separation of $2\mu\text{s}$ was obtained from the 15UD Pelletron accelerator and incident on spectroscopically pure ^{62}Ni target (purity $\approx 99.80\%$). The energy of the ^{28}Si beam ranged from $E_{\text{Lab}} \approx 66$ to 92 MeV. The evaporation

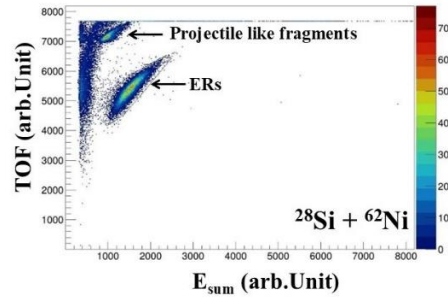


Fig.1. Two-dimensional E_{Sum} versus TOF spectrum for the $^{28}\text{Si} + ^{62}\text{Ni}$ system measured at ≈ 91 MeV.

residues (ERs) populated in the interaction of ^{28}Si with ^{62}Ni target were detected at the focal plane of the HIRA by a multi-wire proportional counter (MWPC) and an Ionization Chamber (IC). A clear separation between ER events from projectile like fragments (PLFs) has been achieved by comparing their total energy loss in ionization chamber (E_{Sum}) [4] and time of flight. Fig. 1 displays the two-dimensional E_{Sum} versus TOF spectrum for the $^{28}\text{Si} + ^{62}\text{Ni}$ systems measured at 91 MeV. Data acquisition has been accomplished by IUAC's in-house software NIAS-MARS [5], based on the ROOT framework. Data analysis was also performed using ROOT.

Analysis and Result

The counts corresponding to ER events were obtained by applying an appropriate gate in the two-dimensional E_{Sum} -TOF spectrum. These were normalized using monitor detector counts. Besides that, the transmission efficiency was

calculated using a semi-microscopic Monte Carlo code [6]. The fusion cross sections were determined at each energy using the standard formula given in [7]. It is noteworthy that, earlier studies of the $^{28}\text{Si} + ^{62}\text{Ni}$ system covered 0.91 to $1.08 V_B$ with a minimum cross section of 0.113 mb [8]. In contrast, the present study extends the energy range from 0.87 to $1.18 V_B$, achieving a minimum cross section of 0.0095 mb at the lowest energy point. Figure 2 illustrates a comparison

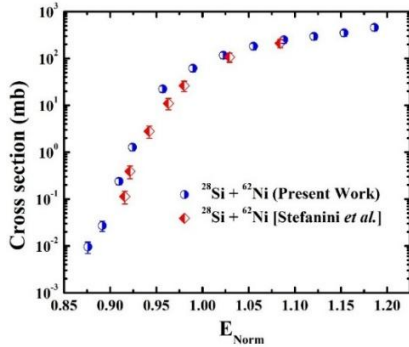


Fig.2. Fusion cross sections for $^{28}\text{Si} + ^{62}\text{Ni}$ as a function of normalized energy ($E_{\text{Norm}} = E_{\text{c.m.}}/V_B$). Blue points: present data; red points: previously reported results [8].

between earlier measurements and the present data. To further interpret the results, coupled-channels (CC) calculations were performed using the CCFULL code [9], which incorporates all

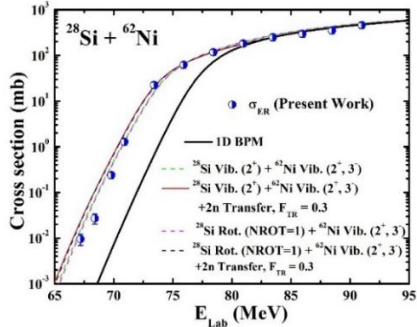


Fig.3. Fusion cross sections for the $^{28}\text{Si} + ^{62}\text{Ni}$ system as a function of projectile energy (E_{Lab}) presented alongside CCFULL calculations MeV.

orders of inelastic couplings. The Woods–Saxon potential parameters ($V_0 = 62.83$ MeV, $r_0 = 1.17$

fm, $a = 0.65$ fm) for $^{28}\text{Si} + ^{62}\text{Ni}$ were obtained using Akyüz–Winther parametrization [10]. CCFULL calculations yielded uncoupled barrier parameters ($V_B = 52.85$ MeV, $R_B = 9.94$ fm, $\hbar\omega = 3.75$ MeV). Fig. 3 display the measured fusion cross sections alongside theoretical predictions obtained from CCFULL calculations across different projectile energies. At energies above the Coulomb barrier, the experimental cross sections agree well with the one-dimensional barrier penetration model (1D-BPM), which assumes the projectile and target nuclei as inert. However, at sub-barrier energies, the measured cross sections substantially exceed 1D-BPM predictions. Incorporating vibrational excitations of the ^{62}Ni target and both vibrational and rotational (NROT = 1) couplings of the ^{28}Si projectile improved the theoretical description, though discrepancies remained. However, by incorporating positive-Q two-neutron transfer ($F_{\text{IR}}=0.3$) with collective excitations, reproduces the measured fusion cross section in below barrier region quite well. Interestingly, the fusion cross sections at $E_{\text{Lab}} = 67\text{--}71$ MeV lie below theoretical predictions, indicating a possible signature of fusion hindrance. A detailed investigation of this phenomenon is currently in progress.

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