Role of neutron-transfer channels in Sub-barrier fusion enhancement for ^{32} S+^{130}Te Reaction.

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Introduction

Enhancement of cross sections in heavy ion fusion reactions at energies below the Coulomb barrier had been a topic of interest ever since the observation of large enhancements in fusion cross sections in excess of quantum tunneling. Earlier theoretical attempts had been successfully accounted the enhancements by invoking the channel couplings in addition to the relative motion degrees of freedom in the entrance channel. In those attempts, collective vibration and collective rotation degrees of freedom was observed to have significant effect on the enhancements at around barrier region.

Later it was understood that, transfer of one or two neutrons between projectile and target nuclei will contribute to the enhancements observed in near barrier region. Neutron transfer channels are expected to act as doorway to fusion process and thus contribute to the observed enhancements.

In recent decade, there has been a revived interest on the role of multi-neutron transfer channels with positive Q values in sub-barrier fusion [1]. To investigate the role of such positive Q-value neutron transfer channels on sub-barrier fusion process, a systematic study of several reactions with positive Q-value channels is required.

In the present study, ^{32}S+^{130}Te reaction is selected, as it has positive Q-values neutron transfer channels from 1n to 6n and the target is a vibrational nucleus.

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Experimental Details

Fusion cross section measurement was carried out for the system ^{32}S + ^{130}Te at beam energies below and above the Coulomb barrier using pulsed ^{32}S beam with a repetition rate of 2μs delivered by the 15UD Pelletron accelerator facility at IUAC, New Delhi [2]. Isotopically enriched ^{130}Te target of thickness $\sim$ 350 μg/cm^2) was deposited on 49 μg/cm^2 carbon backing by electron beam evaporation method in the target lab at IUAC [3]. Two silicon surface barrier detectors were mounted, in the target chamber, at angles of 15^o relative to the beam direction to monitor the variations in the beam current, for normalization of cross-sections.

A carbon foil of 30 μg/cm^2 thickness was positioned downstream the target for restoring the charge state equilibration of fusion evaporation residues recoiling out of the thin target foil. These fusion product nuclei are separated from the intense flux of uninteracted beam component at 0^o and elastically scattered beam particles at small angles around 0^o, using electromagnetic separator, namely Heavy Ion Reaction Analyzer (HIRA). A position sensitive multi-wire proportional counter (MWPC) detector of 150x50 mm^2 active area was used at the focal plane of HIRA to detect the evoparation residues nuclei.

A time of flight (ToF) signal, between the timing signal from anode of MWPC and delayed signal from the TWD used for background suppression. Measurements were performed at laboratory energies from 110 to 140 MeV in steps of 2 MeV. This energy range covers 12% below to 10% above the Coulomb barrier. HIRA fields were set for optimum transmission of fusion product nuclei. Transmission efficiency of HIRA was estimated using TERS code [4, 5] at each energy to obtain the accurate fusion cross-section.

Data Analysis & Results

In the data analysis, yield of fusion product nuclei is obtained from the two dimensional projection spectra ΔE vs ToF. This 2-D Projection spectrum gives us the background free data. At each energy fusion yield was normalized to the Rutherford scattering cross section measured by the monitor detectors.

The evaporation residue cross section obtained as a function of center of mass energy for the ^{32}S+^{130}Te reaction is presented in FIG. 1. The experimental fusion excitation function is compared with the theoretical predictions obtained using the semi-empirical coupled channel model [6] calculations within Zagrebaev framework . The experimental fusion cross sections have significantly enhanced at sub-barrier energies with respect to the simple barrier penetration model(1D-BPM).

An attempt is made to explain the experimental enhancements observed by performing Coupled Channel calculations. Wood-Saxon form of potential with Akyuz-Winther(AW) parameterization has been used in the present calculations. Inelastic excitations of projectile and target have been included in the initial state. These include 2^+ state for ^{32}S and 2^+ & 3^- states for ^{130}Te up to two phonon excitations which is shown as green line in figure 1. The excitation energies and deformation parameters data for ^{32}S and ^{130}Te are adopted from Refs [7, 8]. Afterwards, individual positive Q-value transfer channels are included one by one up to four-neutron transfer channels. These calculations were performed using standard potential parameters still underpredicts cross section which can be seen from the figure. Further data analysis is under progress

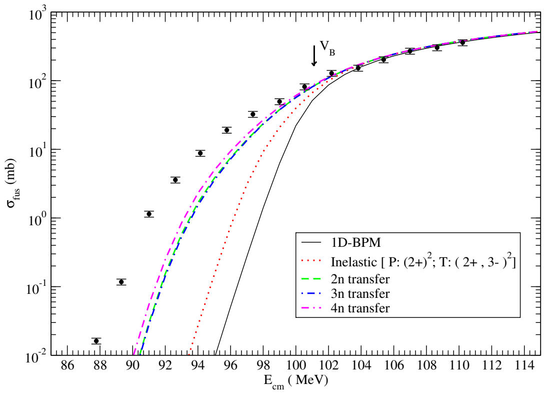

FIG. 1: Experimental fusion excitation function of ^{32}S+^{130}Te. The lines illustrate the results of the theoretical calculations.

to understand the enhancement of sub-barrier fusion cross section. Detailed results and analysis will be presented.

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References

[1] H. Q. Zang, C. J. Lin et al, Phy.Rev.C 82, 054609 (2010)

[2] A. K. Sinha et al, Nucl.Instrum.Methods A 339 54 (1994).

[3] Rudra N.sahoo et al Nucl .Instrum.Methods A 935 103 (2019)

[4] S.Nath Comput.Phys.Commun. 179 492 2008.

[5] S.Nath Comput.Phys.Commun. 180 2392 (2009).

[6] V. I. Zagrebaev, Phys.Rev.C 67, 061601(R) (2003).

[7] S. Raman, C. W. Nestor,Jr., and P.Tikkanen, At.Data Nucl. Data Tables 78,1(2001).

[8] T. Kibedi and R.H. Spear, At.Data Nucl.Data Tables 80,35(2002).