Fusion hindrance at deep-sub barrier energies in ^{11}B + ^{197}Au

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Introduction

The phenomenon of fusion hindrance has been observed as a steep change of slope in the fusion excitation function and its logarithmic derivative (L(E)) with respect to coupled channels calculations in measurements with medium-heavy nuclei at deep sub-barrier energies [1]. The models suggested to explain this behavior have different physical origins, based on sudden and adiabatic approaches [2]. Dasso and Pollarolo [3] pointed out that the cross-sections at deep sub-barrier energies depend on the shape of the inner part of the inter nuclear potential and could be used as an unique tool to obtain the value of the nuclear potential at small distances.

The data corresponding to asymmetric systems, presently scarce, are important to establish the generic nature of fusion hindrance and for the improvement of current theoretical models [4, 5]. In a recent work [6], we investigated the evolution of fusion hindrance with increasing mass and charge of relatively light projectiles (^{6,7}Li, ^{12}C, ^{16}O) on heavy targets. Occurrence of fusion hindrance has been clearly observed in case of ^{12}C + ^{198}Pt and ^{16}O+ ^{208}Pb systems. On the other hand fusion hindrance has not been observed in case of ^{6,7}Li + ^{198}Pt, within the measured energy range. Hence it is interesting to investigate onset of fusion hindrance in case of light projectiles between ^{12}C and ^{6,7}Li on heavy targets. With this aim, in the present work we have selected ^{11}B + ^{197}Au system to investigate this phenomenon by carrying out measurement for fusion cross-sections down to energies where hindrance in fusion is expected to occur.

Experimental Details

Measurement of the excitation function of residues resulting from fusion and direct reactions were performed for ^{11}B+^{197}Au using a sensitive and selective off-beam γ-ray counting method. The ^{197}Au targets were irradiated with beams of ^{11}B from Pelletron-LINAC Facility-Mumbai in the range of 40 to 65 MeV. The targets were self supporting rolled foils of ^{197}Au ($\sim$ 1.3 to 2 mg/cm^2 thick) followed by an Al catcher foil of thickness $\sim$ 1 mg/cm^2. Two efficiency calibrated HPGe detectors - one with an Al window for detection of γ-rays and another with a Be window for detection of Kx-rays, having an active volume 180cc were placed face to face to measure Kx-γ-ray coincidence of the decay radiations from the irradiated sample. The measurements were performed in a low background setup with graded shielding. The residues arising from fusion reaction ($^{203-205}$Po) were identified from the characteristic-γ-radiation emitted by their daughter nuclei and following the half life. Due to the increased sensitivity of the Kx-γ-ray coincidence method, cross-section down to 300 nano-barns could be measured. The fusion cross-sections were obtained from the sum of the measured evaporation residue cross-sections. The fission cross-section was also taken into account using data from Ref. [7], up to the beam energy where fission cross-section was 0.5% of the fusion cross-section. Fusion excitation function for this system is plotted in

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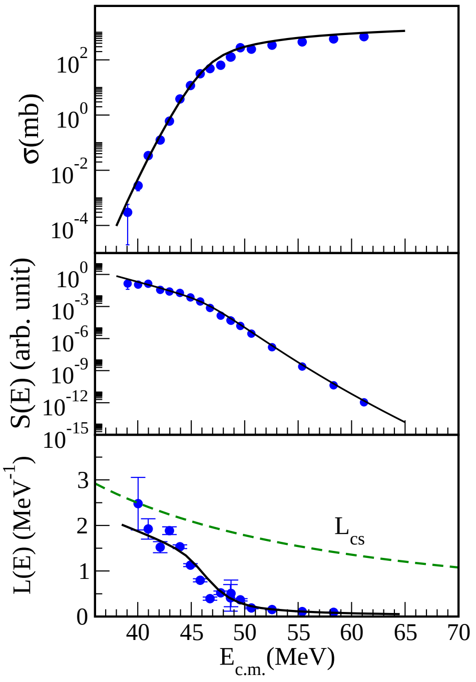

FIG. 1: (a) Fusion excitation function along with CC calculations(b) S-factor representation (S(E)) and (c) logerithmic derivative (L(E)) of fusion excitation function for ^{11}B+^{197}Au. The L(E) values corresponding to a constant S-factor (L_{cs}) are shown as dashed lines

Fig. 1(a). Errors shown are due to counting statistics. Statistical model calculations for the compound nuclear decay were performed using PACE2 to reproduce the residue cross-sections as well as fission cross-sections at all energies. The astrophysical S-factor representation (S(E)) of the experimental data is shown in Fig. 1(b). Plotted in Fig.1(c) is the logarithmic derivative of the fusion cross-section (L(E)=d[ln(σE)]/dE), as determined from three consecutive data points. The observed S-factor maximum is not as pronounced as found in the case of the symmetric systems involving medium mass nuclei, but similar to that for ^{12}C + ^{198}Pt and ^{16}O + ^{208}Pb systems.

Analysis and Summary

Calculations performed using the coupled-channels (CC) code CCFULL [8], included the quadrupole excitation in ^{197}Au considering coupling in the vibrational model and the first excited state of ^{11}B also in vibrational mode. The results of the calculation with inclusion of the couplings described above are shown in Fig. 1(a). As can be seen in the figure, the CC calculations reproduce the data well except at the lowest energy. Role of fusion hindrance has been found to be weak in this system in the measured energy range with cross-section at the lowest energy ≈ 300 nb. The threshold energy (V_T) for observing fusion hindrance is ∼ 41 MeV and is above the lowest beam energy in the present measurement. Further a correlation has been obtained between the degree of hindrance and the charge product [6] over a wide range of target-projectile combinations. The results for the present system are consistent with the systematics of Ref. [6] and confirm that the observed trend reveals a weaker influence of hindrance on fusion involving lighter nuclei.

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