Fusion hindrance for asymmetric systems at extreme sub barrier energies

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Introduction

Recent measurements with medium-heavy nuclei accentuated phenomenon of fusion hindrance, observed as a steep change of slope in fusion excitation function and its logarithmic derivative (L(E)) with respect to the coupled channels (CC) calculation at deep sub-barrier energies [1]. At present there are two successful models to explain the deep sub-barrier fusion data - model suggested by Mişicu and Esbensen [2] based on sudden approximation using M3Y potential with repulsive core and a dynamical two-step model proposed by Ichikawa *et al.* [3] based on an adiabatic picture. Currently experimental studies at these low energies have been restricted mainly to the measurement of fusion cross sections of symmetric systems with the exception of ^{16}O + ^{204,208}Pb [4] and ^{6}Li+^{198}Pt [5]. Unlike the sharp change in slope of L(E) as observed in symmetric medium-heavy systems, a saturation in the slope of L(E) was observed for asymmetric ^{16}O + ^{208}Pb system [4]. In case of very asymmetric system involving light weakly bound projectile ^{6}Li+^{198}Pt [5] absence of fusion hindrance was reported. In the present work we investigate whether absence of fusion hindrance in ^{6}Li+^{198}Pt system arises from the effect of weakly bound cluster structure or it is a property of the very asymmetric systems. For this purpose we selected one weakly bound (^{7}Li) and a tightly bound (^{12}C) projectile on the same target. The data is analysed with standard coupled channels and the adiabatic model of fusion to understand the underlying mechanism at deep sub barrier energies.

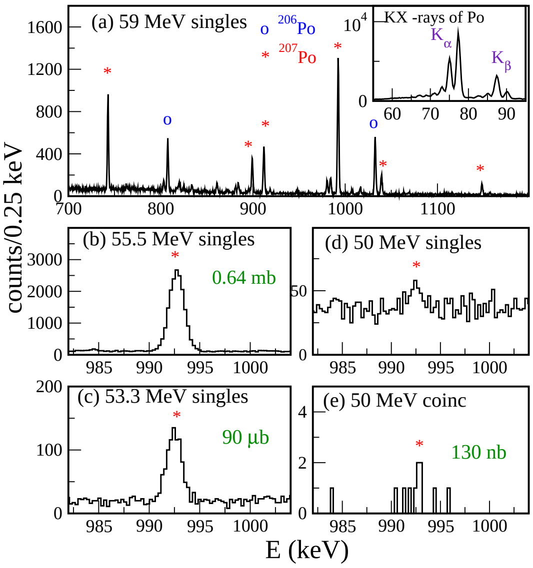

FIG. 1: Activation γ-ray spectra for the ^{12}C+^{198}Pt system (a) inclusive spectrum at E_{lab} of 59 MeV. Inset shows X-ray region of the spectrum. The dominant γ-rays arising from the evaporation residues are labeled (b)-(d) inclusive spectra showing photo-peak at 992.3 keV, corresponding to the residue ^{207}Po (e) same as (d) but in coincidence with the K_αX rays shown in the inset of (a).

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Experimental Details

The experiment was performed at Pelletron Linac Facility-Mumbai, using beams of ^{7}Li (20 - 35 MeV) and ^{12}C (50 to 64 MeV) on a ^{198}Pt target with beam current in the range of 10 to 35 pnA. The targets were self supporting rolled foils of enriched ^{198}Pt ($\sim$ 1.3 mg/cm^2 thick) followed by an Al catcher foil. Two efficiency calibrated HPGe detectors - one with Al window for detection of γ-rays and another with a Be window for detection of KX-rays were used for performing KX-γ-ray coincidence. The measurements were performed in a low background setup with a graded shielding. The evaporation residues were uniquely identified by means of their characteristic γ-ray energies and half-lives. The residues populated are $^{205-207}$Po in case of ^{12}C+^{198}Pt and $^{200-202}$Tl in case of ^{7}Li+^{198}Pt. Typical inclusive γ-ray spectra resulting from the residues of ^{12}C+^{198}Pt are plotted in Fig. 1(a) -(d) at different beam energies. The γ-ray yields at lowest energies were extracted by gating on their KX-ray transitions. Due to the increased sensitivity of the KX-γ-ray coincidence method, cross-section down to a few nano-barns could be measured (Fig. 1(e)).

Analysis and Summary

The data were analysed using the standard coupled-channels (CC) calculations and the adiabatic model that simulates a smooth transition between the two-body and the adiabatic one-body states by damping gradually the off-diagonal part of the coupling potential [6]. The standard CC calculations for both the systems were performed including the quadrupole excitation in ^{198}Pt in the vibrational mode. Projectiles ^{7}Li and ^{12}C were coupled in the rotational mode. In case of ^{7}Li+^{198}Pt, fusion hindrance was not observed as the CC calculations nicely reproduce the data for energies around and well below the barrier in the measured energy range. A change in slope in fusion excitation function and L(E) as compared to CC calculations was clearly observed for ^{12}C+^{198}Pt, at lowest energies indicating onset of fusion hindrance. In order to explain the fusion data at energies deep below the barrier in case of ^{12}C + ^{198}Pt system, calculations were performed using the adiabatic model of Ref. [6]. On inclusion of damping in the adiabatic framework an excellent agreement with the fusion and L(E) data was observed as shown in Fig. 2. These results are relevant to fusion hindrance at deep sub-barrier energies with respect to observations from ^{6,7}Li + ^{198}Pt, ^{16}O + ^{208}Pb and systems with different mass asymmetry.

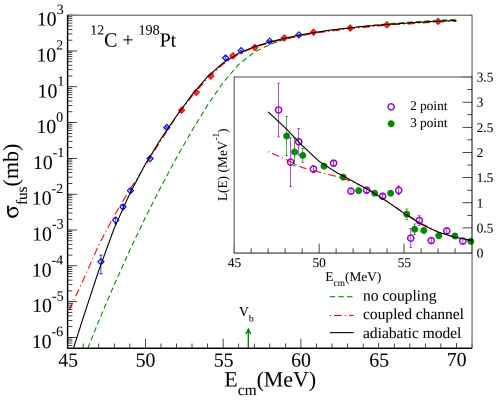

FIG. 2: Fusion excitation function and L(E) for ^{12}C + ^{198}Pt. CC calculations with and without inclusion of coupling along with adiabatic model calculations are shown.

Acknowledgments

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