Search for fusion hindrance at deep-sub barrier energies in ^{7}Li + ^{198}Pt

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Introduction

Measurements with medium-heavy nuclei highlighted 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 calculation at deep sub-barrier energies [1]. Dasso and Pollarolo [2] 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.

Unlike the sharp change in slope of L(E) as observed in symmetric medium-heavy systems, recent measurements with medium-light systems showed unsystematic trend in fusion cross-section in nearby systems at these energies [3]. This unexpected observation shows importance of accurate measurement of fusion cross sections at energies deep below the barrier with different entrance channels to understand the phenomenon of fusion hindrance. The fusion of weakly bound nuclei, which is a subject of current interest, has recently been investigated at energies far below the barrier for the weakly bound projectile ^{6}Li on ^{198}Pt [4]. For this system the coupled channels calculations successfully explain the fusion excitation function along with the average angular momentum and L(E), implying absence of the fusion hindrance at deep sub-barrier energies. In order to investigate this phenomenon further for another weakly bound system, fusion cross-section measurements with ^{7}Li+^{198}Pt have been carried out extending our earlier measurement 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 ^{7}Li+^{198}Pt using off-beam γ-ray counting method. On-line γ-ray measurement were performed to detect residues from α-capture. For the offline measurement, ^{198}Pt targets were irradiated with beams of ^{7}Li from Pelletron-LINAC Facility-Mumbai in the range of 20 to 35 MeV. The targets were self supporting rolled foils of ^{198}Pt (95.7% enriched, $\sim$ 1.3 mg/cm^2 thick) followed by an Al catcher foil of thickness $\sim$ 1 mg/cm^2. Two efficiency calibrated HPGe detectors with an Al- window were used for offline γ-ray counting. The measurements were performed in a low background setup with a graded shielding. The residues in the case of fusion ($^{199-202}$Tl) were identified by performing KX-γ-ray coincidence of the decay radiations from the irradiated sample with detectors placed face to face. Further details of the coincidence method can be found in Ref. [4]. Fusion excitation function for this system is plotted in Fig. 1(a). The γ-ray yields for

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residues formed after t-capture ($^{198-200}$Au) and neutron transfer reactions (^{197,199,200}Pt) were extracted from inclusive γ-ray measurements. The error on the data points in Fig. 1 is due to the statistics. The cross-sections for the t-capture are found to be much larger than those for fusion at deep sub-barrier energies and those for the neutron transfer at all energies (Fig.1 (b)). The cross-section for α-capture forming ^{202}Hg could not be measured as the resulting residues are stable (except ^{199m}Hg). These cross-sections were deduced from the measurement of online prompt gamma transition using four efficiency calibrated and Compton suppressed clover detectors placed at 14.3 cm from the target position at beam energies of 29 and 45 MeV. (Fig. 1(a)). The cross-sections for alpha capture are smaller than those for triton capture at both energies. This can be understood in terms of breakup fusion picture where interaction barrier between α and target is larger than that for triton after breakup of the ^{7}Li projectile. A comparison between fragment-capture cross-sections was made between ^{6}Li + ^{198}Pt and ^{7}Li + ^{198}Pt . Larger cross-section of d -capture with ^{6}Li compared to t-capture with ^{7}Li projectile as shown in Fig. 1(c), could be a consequence of the lower breakup threshold of ^{6}Li and lower interaction barrier for d+^{198}Pt.

Analysis and Summary

Calculations performed using the coupled-channels (CC) code CCFULL [5] included the quadrupole excitation in ^{198}Pt considering coupling in the vibrational model and first excited state of ^{7}Li in rotational mode. The results of the calculation with and without the inclusion of the couplings are shown in Fig. 1(a). As can be seen in the figure, the CC calculations reproduce the data for energies around and well below the barrier. Fusion hindrance has not been observed in this system in the measured energy range with cross-section at the lowest energy $\approx$ 200 nb. The threshold energy (V$_T$) for observing fusion hindrance is $\sim$ 21 MeV and is above the lowest beam energy in the present measurement. This study shows the absence of fusion hindrance, suggesting modifications in models that explain deep sub barrier fusion data to incorporate weakly bound asymmetric systems.

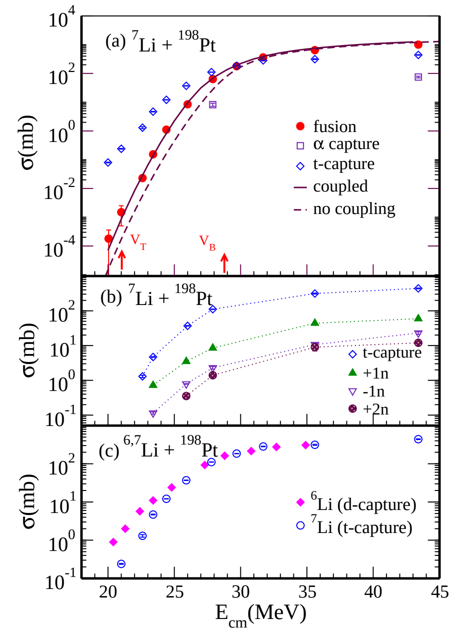

FIG. 1: Excitation function (a) complete fusion, α and t-capture with CC calculations(b) t capture, neutron -transfer reaction.(c) Comparison between d and t capture in ^{6,7}Li+^{198}Pt

Acknowledgments

We thank Mumbai Pelltron accelerator staff for providing steady and uninterrupted beam.

References

[1] C.L. Jiang et al., Phys. Rev. Lett. **89**, 052701 (2002).

[2] C. H. Dasso and G. Pollarolo, Phys. Rev. C **68**, 054604 (2003).

[3] C. L. Jiang *et al.*, Phys. Rev. C **82**, 041601 (2010) (R); A.M. Stefanini *et al.*, Phys. Rev. C **82**, 017601 (2010).

[4] A. Shrivastava *et al.*, Phys. Rev. Letts. **103**, 232702 (2009).

[5] K. Hagino *et al.*, Comp. Phys. Comm. **123**, 143 (1999).