Above barrier fusion excitation of ^{6}Li+^{28}Si

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Introduction

The fusion behaviour induced by loosely bound nuclei like ^{6,7}Li, ^{9}Be with targets of different mass region at different projectile energies exhibits conflicting picture regarding the magnitude of fusion cross section and their dependence on the bombarding energy. Theoretical and experimental studies of fusion induced by stable loosely bound nuclei at near barrier energies, provide new insights into reaction dynamics and structure effects caused by interplay between fusion, loose structure, transfer and breakup to the continuum. Though there exist a number of precise measurements of fusion of stable weakly bound projectiles with heavy mass targets, there are very few experimental attempts in the target mass range A$\sim$ 20-30 at sub-barrier energies and very few data exist at above barrier energies. Moreover ^{6}Li being more loosely bound than ^{7}Li it will be instructive to compare coupling effects on fusion in these two cases. So more experiments are necessary to understand the reaction dynamics of loosely bound projectiles not only at sub barrier energies but also at higher energies.

However the present authors made a consistent attempt [1] to experimentally explore the fusion behaviour for ^{7}Li+^{28}Si starting from sub to well above (upto$\sim$ $3V_b$) the barrier region. We mainly observed the signature of small fusion hindrance at energies beyond twice the barrier, findings which are corroborated by theoretical predictions [2]. In this work we have experimentally measured fusion for ^{6}Li+^{28}Si at above barrier energies, E_{lab}=11-24 MeV, using the characteristic γ-ray method.

Experimental Details & Analysis

We measured the total fusion (TF) cross sections for ^{6}Li+^{28}Si at above barrier energies *viz.*, E_{lab}= 11, 12, 14, 16, 18, 20, 22 and 24 MeV. This experiment was conducted at the 14 MV Pelletron accelerator facility of TIFR-BARC (at Mumbai) with ^{6}Li (3^{+}) beams (2-10 pnA). The target consisted of natural silicon (192 μg/cm^{2}) sandwiched between two thin gold layers (40 & 100 μg/cm^{2}) in order to prevent oxidation. The characteristic γ-rays emitted from the evaporation residues were detected using a Compton suppressed Clover detector placed at 55^{o} with respect to the beam direction. The details of experimental setup and efficiency of the detector was discussed elsewhere [1].

The evaporation residues resulting from the fusion of ^{6}Li+^{28}Si were identified by their characteristic γ-rays and γ-ray cross sections (σ_{γ}) were extracted after analysing the γ-ray spectra. The important residues at energies E_{lab}= 11-24 MeV are ^{29}Si, ^{32}S, ^{28}Si, ^{31}P and ^{26}Al. The cumulative contributions from all of the above channels estimated by the statistical model code CASCADE account for nearly 83-90% of the total fusion cross section. Main contributions to fusion come from αp+^{29}Si, pn+^{32}S, d+^{31}P and αd+^{28}Si channels. Some of the prominent identified γ-rays are 1273+1266 keV (^{29}Si+^{31}P), 2028 keV (^{29}Si), 2230+2233 keV (^{32}S+^{31}P), 1779+1794 keV (^{28}Si+^{29}Si), 416 keV (^{26}Al).

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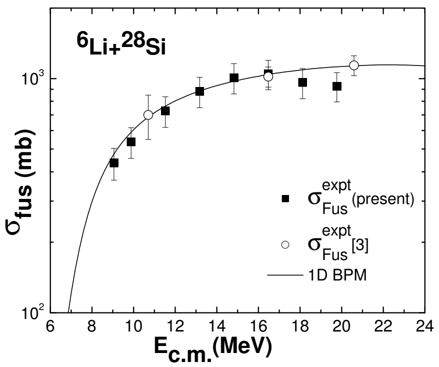

FIG. 1: Fusion excitation function for the system ^{6}Li+^{28}Si at $E_{c.m.}$= 9.06-19.76 MeV. The present measurement (solid squares) and measurement by [3], are also shown (open circles) for comparison. The solid curve shows 1D BPM estimation.

Result & Discussion

The total γ-ray cross section was obtained by summing over all the above mentioned γ-ray cross sections. The total fusion cross section was then estimated as the ratio of the above total γ-ray cross sections and the total branching factor F_γ which was estimated using the code CASCADE. The calculated value of F_γ varies from 0.46-0.57 in the energy region under study with uncertainty about 10%. We obtained the total fusion cross section uncertainty to be varying between 14-15.5%. The total fusion excitation at above barrier energies is shown in Fig. 1. We compared our fusion data with one dimensional barrier penetration model (1D BPM) calculations obtained from the code CCFULL used in the no coupling mode, where the optical model parameters were taken from [1]. The present fusion data were also compared with the previous measurement of ^{7}Li+^{28}Si [1] with 1D BPM in Fig. 2.

Our total fusion (TF) measurements showed good agreement with 1D BPM estimates and with previous measurement by [3] using the evaporation α measurement method, except at two higher energy points at $E_{c.m.} \geq 2V_b$. In this higher energy region 1D BPM overpredicts our experimental fusion data by about 12-17%, almost similar to our previous observation in the case of ^{7}Li+^{28}Si [1]. Similar observations are also reported by [4] for the systems ^{6,7}Li+^{12}C,^{9}Be. This decrease might be due to smaller probability of ICF (formed by breakup followed by fusion) at this high energy regime. Also in this region fusion excitation changes very slowly with bombarding energy and this suggests that interaction barrier has less effect on fusion phenomenon relevant here. As we could not identify ICF events separately, it is necessary to perform exclusive coincidence measurements and this will also help identifying the effect of other coupling channls.

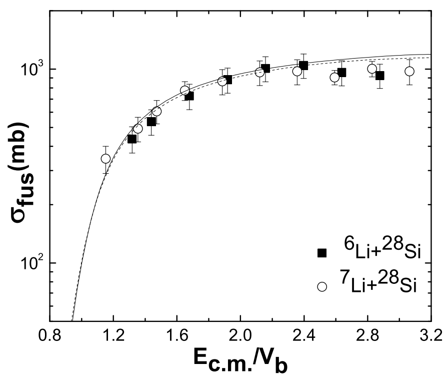

FIG. 2: Measured σ_{fus} vs $E_{c.m.}/V_b$ for the systems, ^{6}Li+^{28}Si (solid squares) and ^{7}Li+^{28}Si (open circles). The solid and dashed curves represent the 1D BPM for the ^{7}Li and ^{6}Li systems and values of V_b (c.m.) are 6.79 and 6.87 MeV, respectively.

References

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