Effect of loosely bound ^{7}Li projectile on the fusion cross section due to increasing target mass

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Introduction

Reactions involving loosely bound projectiles have been studied or are being investigated further for a better understanding of their nuclear reaction mechanism. Fusion cross sections σ_{fus} with loosely bound projectiles have been a subject of great interest for many years. Fusion enhancement or suppression around the Coulomb barrier have been observed and lot of experiential data are available, including fusion and breakup cross sections [1]. Many theoretical efforts have been made to study the nuclear phenomenon in reactions induced by loosely bound projectiles. The fast paced development in the accelerator technology is further instigating the novel theoretical probes for investigating the available experimental data and beyond.

In this paper, following our recent work [2] on loosely bound projectiles (LBP) at fixed laboratory energy E_{lab} within the framework of dynamical cluster-decay model (DCM) of Gupta and collabrators [3], we present here the fusion cross sections σ_{fus} induced by LBP ^{7}Li on different targets at energies around the Coulomb barrier. The experimental data for ^{7}Li+^{59}Co, ^{7}Li+^{27}Al, ^{7}Li+^{28}Si reactions are available [1] for σ_{fus}. Also, we have studied some other reactions with the same projectile and incident energy on some other stable targets, namely ^{32}S, ^{40}Ca, and ^{48}Ti. It is important to note that the neck length parameter, ΔR^{emp} is fixed empirically for ^{7}Li projectile at a given E_{lab} energy, and σ_{fus} of all the reactions for ^{7}Li projectile with different targets are calculated. Apparently, this procedure is used for predicting σ_{fus} of reactions for which experimental data are not available.

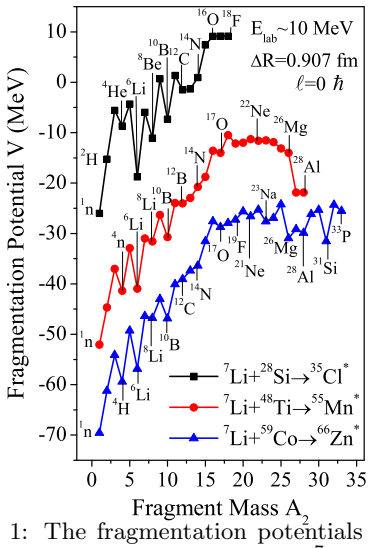

FIG. 1: The fragmentation potentials for different compound systems formed in ^{7}Li induced reactions at ℓ=0 $\hbar$.

Methodology

The DCM [3], worked out in terms of collective co-ordinates of mass (and charge) asymmetries, for ℓ-partial waves, gives the compound nucleus (CN) decay cross-section as

$$\sigma = \frac{\pi}{k^2}\sum_{l=0}^{l_{max}}(2l+1)P_0P; \qquad k=\sqrt{\frac{2\mu E_{c.m.}}{\hbar^2}} \tag{1}$$

where, $\mu = [A_1A_2/(A_1+A_2)]m$ is the reduced mass, with m as the nucleon mass and ℓ_{max} is the maximum angular momentum. P is penetrability of interaction barrier (of the preformed clusters with preformation probability P_0), calculated as the WKB tunneling probability, around the Coulomb barrier.

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TABLE I: The DCM calculated σ_{fus} and their comparison with the avaialble experimental data for ^{7}Li induced reactions at incident energy $E_{lab} \sim 10$ MeV and for the same $\Delta R^{emp.}$=0.907 fm [2]. The barrier modification factor $\Delta V_B = V(R_a) - V_B$ at the respective ℓ_{max} values of all the compound systems given here for the respective ^{6}Li decay channel. † represents extrapolated value.

Reaction	$E_{c.m.}$ (MeV)	E^*_{CN} (MeV)	T (MeV)	ℓ_{max} ($\hbar$)	ΔV_B (MeV)	σ_{fus} (mb) DCM	Expt.
^{7}Li+^{27}Al→^{34}S*	7.941	35.58	3.203	30	-2.691	437.13	415 ± 67 [1]
^{7}Li+^{28}Si→^{35}Cl*	7.79	30.23	2.919	31	-2.735	352.64	352.81 ± 8 [1]
^{7}Li+^{32}S→^{39}K*	8.205	30.90	2.788	30	-2.297	264.5	-
^{7}Li+^{40}Ca→^{47}V*	8.51	30.57	2.519	34	-2.889	97.05	-
^{7}Li+^{48}Ti→^{55}Mn*	8.72	32.88	2.402	39	-3.182	48.52	-
^{7}Li+^{59}Co→^{66}Zn*	9.883	30.74	2.116	44	-3.805	2.82	3.97 [1]†

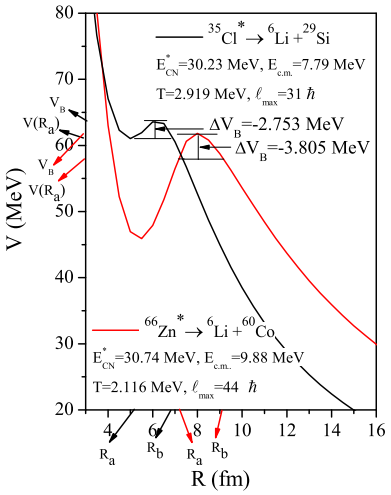

FIG. 2: Scattering potentials of ^{35}Cl* and ^{66}Zn* with the respective ^{6}Li exit channel at ℓ_{max}.

Calculations and discussions

Fig. 1 presents the effect of increasing target mass for ^{7}Li induced reactions at $E_{lab} \sim 10$ MeV, on the fragmentation profile at $\ell = 0\hbar$. We see that with increase in mass of target (equivalently, CN mass), the fragmentation potential energy surface lies lower. This happens because the temperature T decreases with increase in the mass of target (or CN). Hence, the compound system (CS) having lower fragmentation potential (being energetically more stable) has lower decay probability, i.e., the heavier CS has lower decay probability (equivalently, lower σ_{fus}), compared to the lighter CS, as is also illustrated in Table I [2].

Fig. 2 gives the first and second turning points for the scattering potentials $V(R)$ of ^{35}Cl* and ^{66}Zn* CN with exit channels ^{6}Li+^{29}Si and ^{6}Li+^{60}Co, respectively. We notice that the area under the curve for the case of ^{35}Cl* is less as compared to the case of ^{66}Zn*, consequently, penetration probability P is more for the former case, and hence gives the larger σ_{fus} for the lighter compound system ^{35}Cl* as compared to the heavier CN ^{66}Zn*. The barrier lowering parameter ΔV_B is also shown in Fig.2. We see that the barrier lowering parameter remains almost constant for ^{35}Cl* and ^{66}Zn*. This observation concludes that if the reactions induced by the same projectile at fixed incident energy, the barrier lowering is almost constant for such reactions [2]. Table I shows that the DCM calculated σ_{fus} are in good agreement with the available experimental data. The σ_{fus} is also predicted here for reactions where the experimental data are not available [2].

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References

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