Behaviour of entrance channel potential energy in heavy ion induced fusion reactions

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Introduction

The interaction potential energy of the target-projectile combination is an important ingredient to determine the compound nuclear formation probability in heavy-ion induced reactions. Presently, we study the sensitivity of this potential energy on the dynamical coordinates that are relevant for a dinuclear system (DNS). This work is initiated with an ultimate goal to study the entrance channel dynamics explicitly using the stochastic Langevin equations [1].

Model

To calculate the potential energy, we closely follow the model described in [2]. The separation between the target and projectile, $\vec{R}\,(R,\Theta,\Phi)$ is used as dynamical coordinates where R, Θ and Φ define the spherical polar coordinates with the center of the target nucleus at origin. Evidently, the potential energy V is a function of all the three coordinates. However, for spherical target and projectile, two angles reduce to the one defined by impact parameter. The potential V can be expressed as: $V(\vec{R}) = V_{nucl}(\vec{R}) + V_{coul}(\vec{R}) + V_{rot}(\vec{R})$, consisting of nuclear, Coulomb and rotational potentials, respectively, as indicated. For the present purpose, we do not consider the rotational energy since its coordinate dependence is rather simpler than the other two. The expressions for the nuclear and Coulomb potentials are given in [2]. In this model, only the axial deformations (defined by β) of the target and projectile are considered which is a good approximation for all practical purposes. These deformations change as the system approaches more compact shapes. Therefore, βs must be treated as independent dynamical variables. However, in the present work, βs are kept fixed at the ground state values to extract precisely the dependence on $\vec{R}$.

Results and Discussions

We consider two different target-projectile combinations near the opposite extremes of target-projectile mass asymmetry. At the one end, the $^{16}O+^{208}Pb$ system is well studied to contribute mostly in the compound nucleus formation at moderate excitation energies. In contrast, the $^{60}Ni+^{154}Sm$ is presumed to contribute substantially in the non-compound channels.

In Fig. 1, we show the R dependence of the DNS for fixed values of Θ and Φ. The barrier faced by the system as it evolves toward lower R (indicated by the arrow in Fig. 1) is called the capture-barrier. After a successful capture, the complete fusion of a DNS depends on the depth of the potential pocket where it is captured.

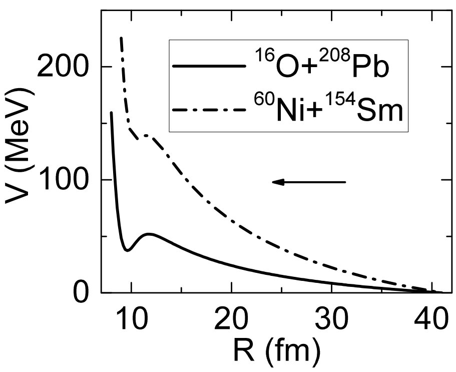

Fig. 1 Variation of entrance channel potential with R.

Evidently, as shown in Fig. 1, the capture-barrier is comparatively larger for the more symmetric system and, also, this barrier suggests a lower survival probability for the captured DNS. The strong R dependence resulting from the target-projectile mass asymmetry is a major deciding factor for the compound nucleus formation.

The Θ and Φ dependence of V for the ^{60}Ni+^{154}Sm system is plotted in Fig. 2. The contours in Fig. 2 are calculated as a function of R and Θ (Φ) keeping Φ (Θ) constant. A similar plot for the ^{16}O+^{208}Pb system is given in Fig. 3. The values of β for all the four nuclei are: 0.364 (^{16}O), 0.055 (^{208}Pb), 0.207 (^{60}Ni) and 0.27 (^{154}Sm).

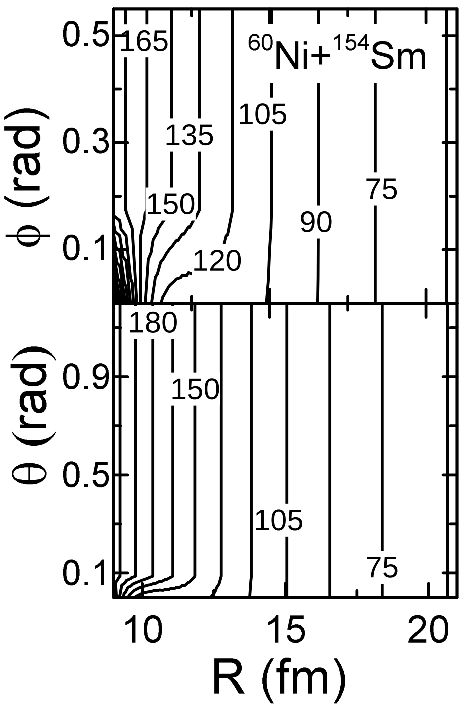

Fig. 2 Potential contours for the more mass-symmetric system. Value of the potential is in MeV.

According to Fig. 2 and Fig. 3, apart from very small *R*, the angular dependences of the potential energy are very weak even for moderate deformations of the target and projectile. Also, this dependence is almost independent of the target-projectile mass asymmetry. This finding is very significant for the modeling of entrance channel dynamics. It essentially simplifies the dynamics as we can neglect the driving forces due to V along Θ and Φ.

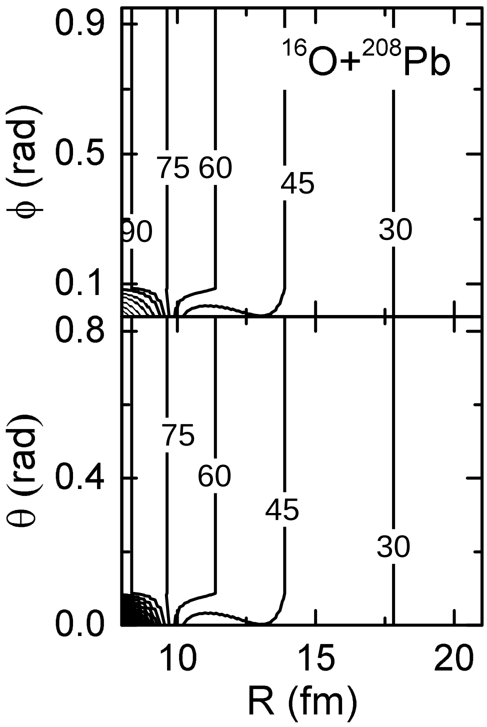

Fig. 3 Similar to Fig. 2, for the more mass-asymmetric system.

In conclusion, the coordinate dependences of the entrance channel potential are analyzed systematically. It is demonstrated that the potential remains almost unchanged as the angles between the target and projectile evolves.

References

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[2] A. Nasirov, et al., Nucl. Phys. A 759 (2005) 342.