Study of Entrance Channel Effect through Fusion Excitation Function and Barrrier Distribution

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Introduction

Sub-barrier fusion depends on incident energy and projectile target combination in a way that cannot be explained by standard one-dimensional barrier penetration model. The internal degrees of freedom i.e., static and dynamical deformations of the colliding system play an important role in the sub-barrier fusion. Other influencing processes are transfer induced fusion, and neck formation. These effects may be clearly visualized through the fusion excitation function and the barrier distribution studies. In case of system with deformed nuclei, the nuclear potential depends on the orientation of the deformed nucleus [1] and gives rise to the distribution of barriers. The concept of barrier distribution (BD) can be extended also to systems with a non-deformed target [2], where the coupling between the relative motion and vibrational excitations in the colliding nuclei and/or transfer processes gives rise to the distribution. The fusion cross section is then given by an average over the contributions from each fusion barrier with appropriate weight factors. Thus, the shape of the BD can be directly linked to the coupling of channels that are important in governing the fusion around the barrier. It will be interesting to study the BD of different systems producing the same compound nucleus in order to see the effect of entrance channel on fusion cross section.

In the present work, we have theoretically studied the entrance channel effect by comparing the fusion excitation function and barrier distributions for two systems, ^{16}O+^{166}Er and ^{28}Si+^{154}Sm, leading to the same compound nucleus, ^{182}Os. Coupled channel calculations have been performed taking the experimental data from the Ref. [3].

Theoretical Calculations

From a theoretical point of view, the standard way to address the influence of coupling between the relative motion and the nuclear intrinsic degrees of freedom is through the use of the coupled-channels formalism. This includes couplings to static deformation, vibrational states and also transfer and breakup channels. In case of heavier nuclei, strength of the coupling is more and it is necessary to include higher-order terms in this expansion. Since heavy nuclei were involved in our system it is not advisable to limit the expansion of coupling potential to the linear term of the deformation parameter. So, CCFULL code [4] has been implemented here to get the theoretical fusion cross sections which treats the excitation energies of the coupled states correctly. The nuclear potential in the entrance channel is defined by parameters V_0, R_0 and A_0; where V_0 is the depth parameter of the Woods-Saxon potential, R_0 is the radius parameter, and A_0 is the surface diffuseness parameter. These parameters are obtained by fitting the excitation function above the barrier.

From experimental and calculated fusion cross section, barrier distributions were obtained by taking the second derivative of the product $E_{c.m}\sigma_{c.m}$, w.r.t. $E_{c.m}$. Numerically this was calculated using a point difference formula. The details about the method of extracting the BD has been reported in Ref. [5].

Results and Discussion

Both the targets ^{166}Er and ^{154}Sm are deformed having almost same value of deformation parameter. The value of β_2 for ^{166}Er and ^{154}Sm is 0.342 and 0.341, respectively. For the system ^{16}O+^{166}Er, the projectile ^{16}O is an inert nuclei whereas in other system i.e.

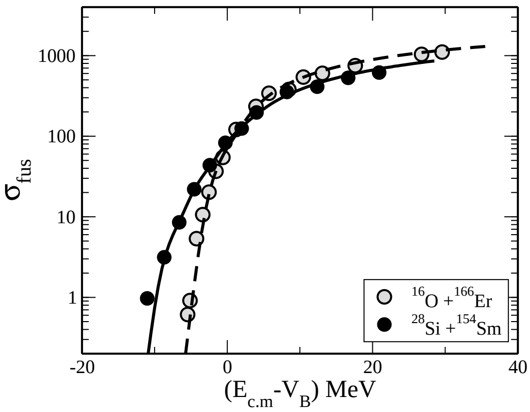

FIG. 1: Comparison of fusion excitation function for the system $^{16}O+^{166}Er$ and $^{28}Si+^{154}Sm$. Dots are the experimental data and lines represent the coupled channel calculations. Error bars are within the size of the dots.

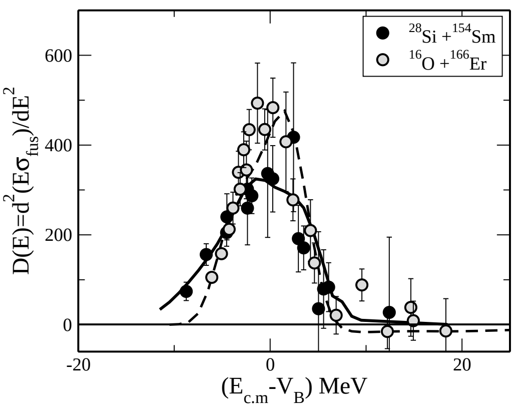

FIG. 2: Comparison of fusion barrier distributions for the system $^{16}O+^{166}Er$ and $^{28}Si+^{154}Sm$. Dots are the experimental data and lines represent the coupled channel calculations.

$^{28}Si+^{154}Sm$, vibrational excitation of ^{28}Si are considered. Experimental excitation function for both the systems as a function of $(E_{c.m} - V_B)$ is shown in FIG. 1, where $E_{c.m}$ is the energy in centre of mass frame and V_B is the ackyuz-winther barrier. Lines represent the coupled channel calculations. For the system $^{16}O+^{166}Er$, 2^+ rotational and octupole vibrational excitations of ^{166}Er have been included in the coupled channel calculation (shown by dashed line). In case of $^{28}Si+^{154}Sm$, in addition to the rotational coupling of ^{154}Sm the quadrupole and octupole vibrations of ^{28}Si are required to reproduce the experimental data as shown by solid line. Details of BD calculation for the system $^{28}Si+^{154}Sm$ are reported in Ref. [6]. As targets in two systems are of same deformation, so w.r.t the single barrier peneration model the enchancement should be same for both the cases. The comparison of fusion excitation function for two systems shows large enchancement of fusion cross section below the barrier for the system $^{28}Si+^{154}Sm$ as compared to that for other system.

The BD extracted from the theoretical and experimental fusion excitation function are compared in FIG. 2. For $^{28}Si+^{154}Sm$, the distribution is wider as compared to other. This indicates the low energy fusion barriers present for this systems, which are responsible for the larger enchancement as compared to that for $^{16}O+^{166}Er$.

Conclusions

The sub-barrier enhancement with respect to the uncoupled calculations, is far larger in the case of $^{28}Si+^{154}Sm$ as compared to that for $^{16}O+^{166}Er$, as it is to be expected since the coupling strengths are proportional to Z_1Z_2. The vibrational excitation of ^{28}Si may be contributing to the larger enchancement. This lead us to conclude that the formation of compound nucleus depends on the choice of incoming channel.

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