Effect of Entrance Channel on Fusion: Study through Fusion Excitation Function and Barrier Distribution

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Introduction

Nuclear reactions at sub barrier energies is of extreme importance being responsible for the fundamental aspects of the creation of new elements. Sub-barrier fusion depends on many factors such as incident energy and projectile target combination which cannot be accounted by standard one-dimensional barrier penetration model. The internal degrees of freedom i.e., static and dynamical deformations, transfer effect, break up of the colliding nuclei play an important role in the sub-barrier fusion. The coupling can be described in terms of changes in the potential barrier between interacting bodies, leading to its splitting into several components i.e. distribution of barrier. Distinctive signatures of the nuclear properties can be observed in the barrier distribution (BD) formed due to this coupling and the information about this BD can be extracted from the fusion excitation function [1]. 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. Hence, Fusion excitation function and BD acts as an fingerprint for a fusion reaction. 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 this work, we have studied the entrance channel effect by comparing the fusion excitation function and barrier distribution for two systems, $^{16}O+^{182}W$ and $^{28}Si+^{170}Er$, leading to the same compound nucleus, ^{198}Pb by theoretically performing the Coupled channel calculations and taking the experimental data from Ref. [2,3,4].

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. Static deformation, vibrational states and also transfer and breakup channels are all included in these couplings. 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 [5] 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 channels 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 value. From calculated fusion cross section, barrier distributions were obtained by taking the second derivative of the product Ecm and σcm, w.r.t. Ecm. Numerically this was calculated using a point difference formula.

Results and Discussions

The targets ^{182}W and ^{170}Er are deformed having definite value of deformation parameter. The value of β_2 for ^{182}W and ^{170}Er is nearly 0.25 and 0.30, respectively. For the system $^{16}O+^{182}Wr$, the projectile ^{16}O is an inert nuclei. whereas in other system i.e. $^{28}Si+^{170}Er$, vibrational excitation of ^{28}Si are considered. Experimental excitation function for both the

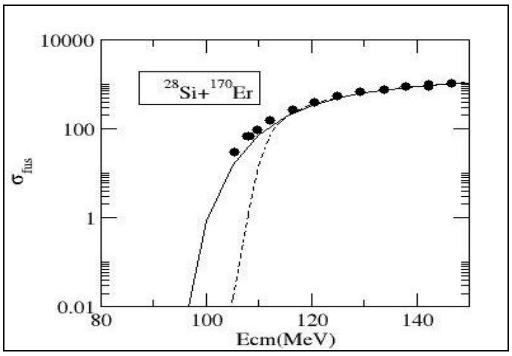

Fig. 1 Excitation Function for ^{28}**Si+**^{170}**Er**. Dashed lines represent the uncoupled excitation function and solid represent the coupled channels calculations. Circles corresponds to experimental data.

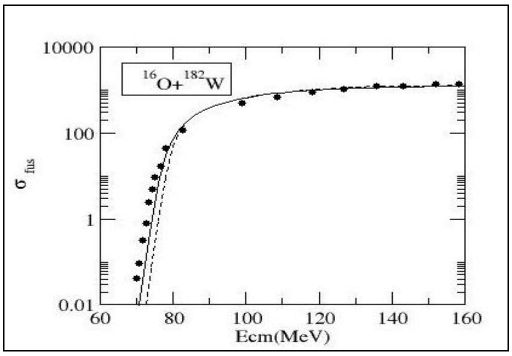

Fig. 2 Excitation Function for ^{16}**O+**^{182}**W**. Dashed lines, solid lines and circles represent the uncoupled excitation function, coupled channels calculations and experimental data.

systems as a function of (Ecm) is shown in Fig. 1 and Fig.2, where Ecm is the energy in centre of mass frame. Lines represent the coupled channel calculations. For the system ^{16}O+^{182}W, 3 rotational states of ^{182}W have been included in the coupled channel calculation (shown by dashed line). In case of ^{28}Si+^{170}Er, in addition to the rotational coupling of ^{170}Er the quadrupole vibrations of ^{28}Si are required to reproduce the experimental data as shown by dashed line in Fig1. The comparison of fusion excitation function for two systems shows large enhancement of fusion cross section below the barrier for the system ^{28}Si+^{170}Er as compared to that for other system.

The BD extracted (as a function of Ecm-Vb where Vb is ackyuz-winther barrier) from the theoretical fusion excitation function are

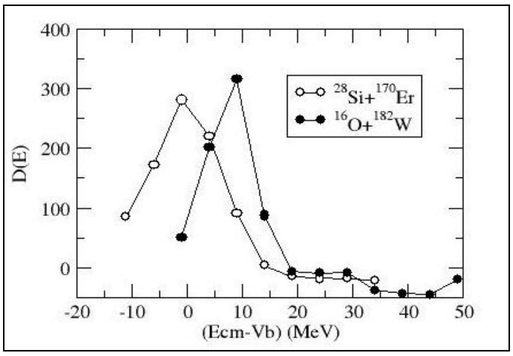

Fig.3 Comparison of Theoretical Barrier Distribution (**$D(E)=d^2(E_{cm}\sigma_{fus})/dE^2$**) for both the systems.

compared in Fig. 3. It is evident from the plot that distribution is wider for ^{28}Si+^{170}Er. This is an indication of the low energy fusion barriers present for this systems, which are responsible for the larger enhancement as compared to that for ^{16}O+^{182}W.

Conclusions

The sub-barrier enhancement with respect to the uncoupled calculations, is far larger in the case of ^{28}Si+^{170}Er as compared to enhancement with respect to the uncoupled calculations, for ^{16}O+^{182}W . 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.

References

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