Role of Entrance Channel In Fusion Reactions

Kavita Rani[1],* B.R.Behera[1], and Akhil Jhingan[2]
[1]*Department of Physics, Panjab University, Chandigarh-160014 and*
[2]*Inter University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi - 110067, INDIA*

Introduction

Nuclear reactions at sub barrier energies is of utmost importance being responsible for many phenomena occuring in nature such as creation of new elements. In heavy-ion reactions, sub barrier fusion is strongly affected by the coupling to various different channels. The interplay between the relative motion and various intrinsic degrees of freedom such as static deformation, rotational and vibrational excitation, transfer, breakup etc. results in the enhancement of fusion cross-section at near barrier energies.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. Single barrier penetration model fails to account for this increase due to the 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.

In this work, we have studied theoretically the role of entrance channel coupling by studying and comparing the fusion excitation function for two systems, ^{16}O+^{144}Nd and ^{28}Si+^{144}Nd having the same target by performing the Coupled channel calculations and taking the experimental data from [2, 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. 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[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 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.

Results and Discussions

The target i.e. ^{144}Nd is a spherical nucleus whereas the projectile ^{16}O is spherical but ^{28}Si is deformed in its ground state with β_2 value of 0.407 and β_4 value as 0.10.Experimental excitation function for both the systems as a function of E_{cm} is shown in Fig. 1 and Fig. 2, where E_{cm} is the energy in the centre of mass frame. Lines represent the coupled channel calculations.

For the system ^{16}O+ ^{144}Nd, the low-energy level schemes of ^{144}Nd are characterized by strong vibrational quadrupole (2^+) and oc-

*Electronic address: kavita.arora298@gmail.com

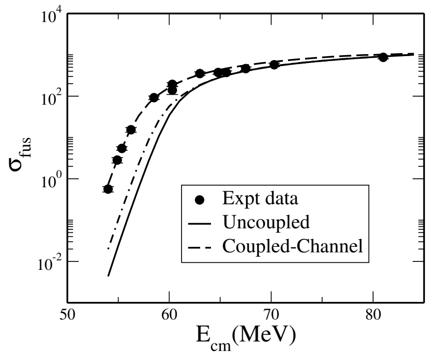

FIG. 1: Excitation Function for different coupling of target(^{144}Nd) and projectile(^{16}O).

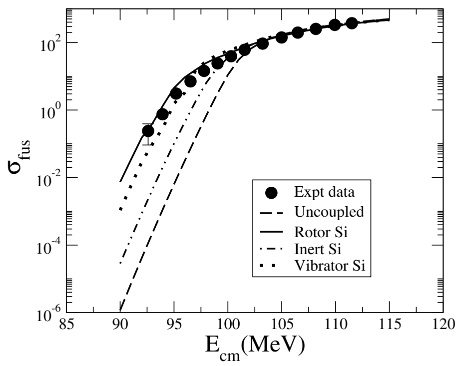

FIG. 2: Excitation Function for different coupling of target(^{144}Nd) and projectile(^{28}Si).

tupole (3^-) excitations that can be included along with the single phonon excitation of 2^+ state in ^{16}O in the coupled channel calculations. In case of ^{28} Si+^{144}Nd, in addition to the strong vibrational quadrupole (2^+) and octupole (3^-) excitations , the rotational coupling of ^{28}Si are required to reproduce the experimental data as shown by dashed line in Fig. 2. The comparison of fusion excitation function for two systems shows large enhancement of fusion cross section below the barrier for the system ^{28}Si+ ^{144}Nd as compared to that for other system. This can be clearly depicted from Fig. 3 which shows the comparison of fusion cross-section of both the systems as a function of E_{cm} -V_b.

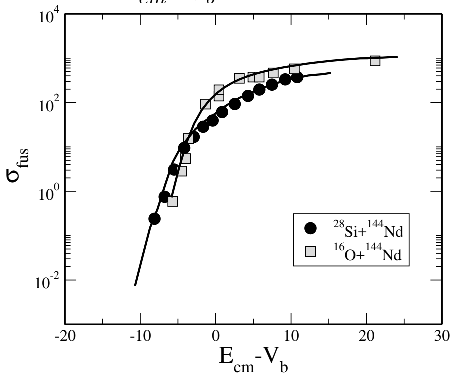

FIG. 3: Comparison of fusion excitation function for both the systems.Dots are the experimental data and lines represent the coupled channel calculations. Error bars are within the size of the dots.

Conclusions

The sub-barrier enhancement with respect to the uncoupled calculations, is far larger in the case of ^{28}Si+ ^{144}Nd as compared to enhancement with respect to the uncoupled calculations, for ^{16}O+ ^{144}Nd . The rotational coupling of ^{28}Si may be contributing to the larger enhancement.Fusion barrier distribution measurements may be performed to get a better insight for these systems

Acknowledgments

One of the author Kavita Rani would like to acknowledge the financial assistance from DST-INSPIRE programme of DST, Govt. of India

References

[1] J.R. Leigh et al., Phys. Rev. C **52**, 3151 (1995).

[2] G. Duchene, P. Romain, F.A. Beck et al.,Phys. Rev. C **47**, 2043(1993).

[3] A.K. Sinha, L.T. Baby, N. Badiger et al.,Journal of Physics G **23**, 1331(1997)

[4] K.Hagino et al., Comput. Phys. Commun.,**123**,143 (1999).