Estimating fusion probability for the ^{28}Si+^{178}Hf reaction.

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Introduction

Experimental and theoretical investigations of compound nucleus (CN) formation mechanism in heavy-ion-induced reactions are of great interest. It is very important to understand fusion and fusion probabilities in finer details as it is the only established route to produce super heavy elements. Fusion probability varies significantly over different reactions and is found to depend on many variables. It is the least understood factor that determines the formation cross sections of heavy systems. Even though a number of prescriptions exist in literature, the model predictions vary significantly across the nuclear chart. Here we present the P_{CN} calculation for the ^{28}Si+^{178}Hf reaction using the dinuclear system (DNS) model [1].

DNS model analysis

DNS model estimates the capture, fusion, evaporation residue (ER) cross sections and P_{CN} [1, 2]. Capture occurs when the projectile energy is enough to overcome the Coulomb barrier and rotational energy in the entrance channel. The capture and full dissipation of kinetic energy of the interacting nuclei results in a DNS and the capture process leading to DNS have long lifetime, unlike deep inelastic capture process [3]. The evolution of the DNS occurs by transfer of nucleons from one nucleus to the other and the exit channels of massive DNS are either CN formation channel or quasifission (QF) channel [4]. The competition between these two processes normally defines the P_{CN} in a given reaction.

DNS that survive QF process lead to the fully equilibrated CN [3]. The formed CN survive against fission leads to the to the ER by particle emission from the CN. Angular momentum populated in the reaction plays an important role in the evolution of the CN from the mononucleus. Larger value of angular momentum causes the decrease of fission barrier height and thus results fast fission (FF).

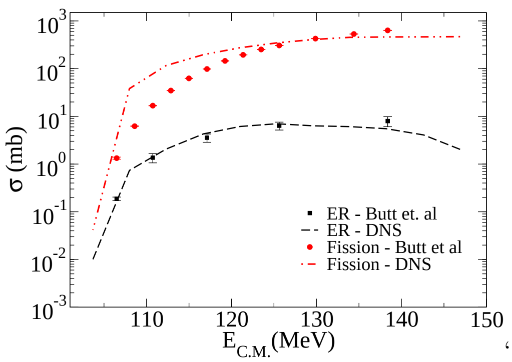

FIG. 1: DNS model predictions of fission and total ER cross sections for the reaction ^{28}Si+^{178}Hf compared with experimental results [6].

The partial capture and complete fusion cross sections are calculated by averaging the contributions from different orientation angles (relative to the beam direction) of the projectile and target nuclei [1]. DNS frame work estimates the fusion cross section by using capture cross section and P_{CN} according to the

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relation.

$$\sigma_{Fusion} = \sigma_{Capture} P_{CN} \quad (1)$$

where

$$\sigma_{Capture} = \sigma_{Fusion} + \sigma_{FF} + \sigma_{QF} \quad (2)$$

Here, $\sigma_{Capture}$, σ_{Fusion}, σ_{FF} and σ_{QF} are respectively the cross sections corresponding to the capture, fusion, FF and QF. The capture probability and the highest value of orbital angular momentum, leading to capture at the given values of the orientation angles of projectile and target, are obtained by solving equations of the relative motion of nuclei and orbital angular momentum of collision [1, 5].

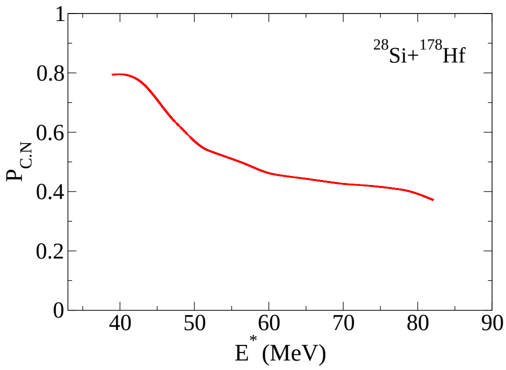

FIG. 2: P_{CN} as a function of excitation energy for the ^{28}Si+^{178}Hf reaction.

Butt et al [6] measured the fission and ER cross sections for the ^{28}Si+^{178}Hf reaction forming the CN ^{206}Rn. Here we compared the experimental fission and ER cross sections with DNS model predictions in FIG.1. The model predictions are in reasonable agreement with the experimental results. With increase in beam energy, the ER cross section increases because of the increase in capture and fusion cross sections. This is due to the increase in number of partial waves in the capture process. And at higher excitation energies fission as well as QF dominates and the ER cross section decreases.

The calculated P_{CN} values for the ^{28}Si+^{178}Hf reaction is shown in FIG.2. P_{CN} values deviates significantly from unity indicating a strong role of QF channel in the reaction considered in this work.

The contribution from FF is estimated to be negligible in the energy range considered in this work. P_{CN} is observed to be unity in asymmetric reactions populating other isotopes of Rn [7]. The DNS formed in such reactions fully evolves to CN, unlike the more symmetric system presented in this contribution where QF process dominates and hinders the complete fusion.

Conclusion

We calculated the P_{CN} for the ^{28}Si+^{178}Hf reaction using DNS model. ER and fission data were taken from literature [6]. P_{CN} values are observed to be lower than 1 for made reaction. Similar observation have been seen for the ^{28,30}Si+^{180}Hf reactions from the ER data [8]. The decrease of P_{CN} with increase in excitation energy indicates the dominance of QF channels at higher beam energy.

Acknowledgments

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