Competition between fusion-fission and quasifission processes in the ^{30}Si+^{182,184,186}W systems

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Introduction

The dynamics of fusion-fission processes in heavy-ion collisions has been extensively investigated, both theoretically and experimentally, in recent years. The time evolution of the composite system formed after interaction, and parameters on which the dynamics depends etc., are still not fully understood. Studies on dynamical processes in heavy ion collisions at the near-Coulomb-barrier energies have shown that complete fusion does not occur immediately in the case of massive nuclei collisions [1]. Among various competing processess, quasifission (QF) is the dominant non-compound nuclear process. Theoretically QF is predicted when the charge product $Z_pZ_t > 1600$ [2]. A number of recent studies on many systems with Z_pZ_t even less than 1000 revealed the onset of these QF events at near and around the Coulomb barrier energies [3].

We, here report the di-nuclear system (DNS) [4] model predictions of capture, fusion and quasifission cross sections for ^{30}Si+^{182,184,186}W systems in the centre-of-mass energy range 113 MeV to 163 MeV. A proposal to measure the fission angular and mass distributions, neutron multiplicities and evaporation residues for ^{30}Si+^{182,184,186}W sytems has been sanctioned at IUAC, NewDelhi and the experiments will be performed soon with the availability of LINAC beam.

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Theory and discussion

In the DNS model [4], the partial capture and complete fusion cross sections are obtained by averaging the contributions from the different orientation angles α_1 and α_2 (relative to the beam direction) of the projectile and targ-

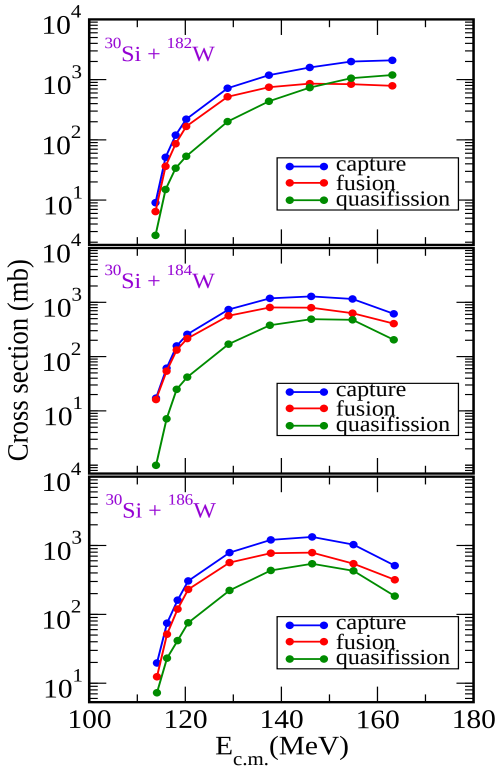

FIG. 1: DNS model predictions of capture, fusion and quasifission cross sections for different systems. Solid lines are guide to eye.

et nuclei, respectively. The capture cross section in the framework of the DNS model is equal to the sum of the quasifission, fusion fission, and fast fission cross sections:

$$\sigma_{cap}(E_{c.m}) = \sigma_{qf}(E_{c.m}) + \sigma_{fus}(E_{c.m}) + \sigma_{ff}(E_{c.m}) \quad (1)$$

The fast fission cross section is calculated by summing the contributions of the partial waves corresponding to the angular momentum range $l_f \leq l \leq l_d$ leading to the formation of the mononucleus, where l_f is a value of l at which the fission barrier of the corresponding compound nucleus (CN) disappears and l_d is the maximum l of DNS. The QF process can take place in the whole range of the orbital angular momentum values leading to capture, including central collisions.

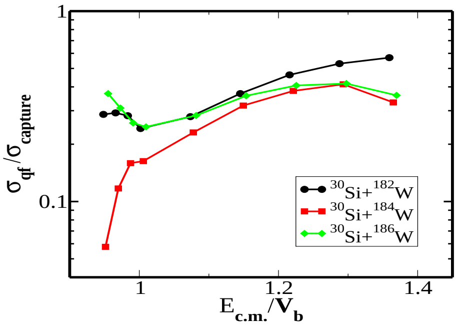

FIG. 2: Comparison of the quasifission cross section normalised with respect to the capture cross section for different reactions.

During the evolution of di-nuclear system, an intense mass transfer takes place and, depending on the landscape of potential energy surface and entrance channel, the mass asymmetry degree of freedom may be fully or partially equilibrated. The duration of the QF is an order of magnitude larger than the time needed to reach the thermal equilibrium. It is estimated to be more than 5×10^{-21} s by few experiments [6].

The capture, fusion and quasifission cross sections for the three reactions at different centre-of-mass energies are shown in FIG.1. Ratio of QF cross section to capture cross section versus $E_{c.m.}/V_b$ for the three reactions are shown in FIG. 2. The results of the present model indicate that the reaction with ^{184}W target is more favorable to CN formation in comparison with ^{182}W and ^{186}W targets. This may be due to the fact that the P_{cn} [5] depends on the the quasifission barrier B_{qf} and intrinsic fusion barrier B_{fus}. Usually the neutron rich system has more attractive B_{qf} but B_{fus} may also be larger.

Conclusion

The capture, fusion and QF cross sections are calculated using DNS model. The decrease of complete fusion probability at large collision energies is connected with the increase of QF and fast fission. An increase in the QF contribution at large beam energies is attributed with the angular momentum dependence of the B_{qf} and B_{fus} barriers: at large angular momentum of the DNS, B_{qf} decreases and B_{fus} increases. The results of the present model indicate that the reaction with ^{184}W target is more favorable to CN formation in comparison with ^{182}W and ^{186}W. The small B_{qf} decreases the lifetime of the DNS, decreasing its possibility to be transformed into a CN.

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