Entrance channel effect in the fusion-fission time scale in ^{16}O + ^{185}Re and ^{31}P + ^{170}Er interactions

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Introduction

Heavy ion-induced fusion-fission dynamics is a prominent area of the current research area in nuclear physics. There have been studied many experimental and theoretical calculations in the past to examine the role of entrance channel mass asymmetry(α = A$_t$-A$_p$/A$_t$+A$_p$) in the fusion dynamics of heavy ion-induced reactions[1]. It has been observed that depending on the various parameters like entrance channel properties like mass asymmetry and charge product, target deformation, excitation energy, etc, in heavy reaction mechanism is not only fusion-fission but some other non-compound nucleus processes (NCNF) such as quasi- fission are also found which decreases the probability of formation of the compound nucleus. After the amalgamation of colliding particles (projectile and target), a compact compound nucleus(CN) is formed after achieving the equilibration in all degrees of freedom. But sometimes, the full equilibration does not take place in all degrees of freedom and the formed dinuclear system dissociates into asymmetric mass fragments. The various processes such as quasi-fission(QF), fast-fission (FF), and pre-equilibration fission are classified as the non-compound nucleus process (NCNF). The presence of NCNF hinders the fusion of heavy nuclei and reduces the probability of formation of a fully equilibrated nucleus i.e. CN. QF and fusion-fission, however, follow different reaction trajectories resulting in different time scales of QF and fusion-fission from touching point to scission point. This fission encumbrance can be understood in the terms of fission delay time and dissipation coefficient. The fission delay time can be categorized into three parts which are as follows. First, due to nuclear de-excitation, a great number of neutrons will be emitted from a non-equilibrated nucleus during its formation towards a compact CN which is known to be formation time (τ_{fr}). Second, the delay is transient delay (τ_{tr}) and the third is the dynamical evolution from the saddle to the scission point termed as the saddle to scission transient time (τ_{ssc}).

Classical Dynamical Model (HICOl)

We used the model of Feldmeier et al[2] where the colliding nuclei are behaving as two fermi gases which exchange momentum, partcles and entropy through a window in the mean single particle potential. The time evolution of the collinding dynamics are calculated by solving a Langevin equation including a dissipative fluctuating force.The properties of the fluctuating force are determined from a microscopic picture of particle exchange between two nuclei. The macroscopic shapes of the nuclear system are represented by axially symmetric configurations with sharp surfaces. These shapes are uniquely determined by three macroscopic degrees of freedom: the distance between the nuclei (s), the neck coordinate (σ) and the mass asymmetry (Δ) is defined as:

$$s = \text{distance between two sphere centres} \quad (1)$$

$$\sigma = \frac{[V_0 - (\frac{4\pi}{3})R_1^3 - (\frac{4\pi}{3})R_2^3]}{V_0} \quad (2)$$

$$\Delta = \frac{[R_1 - R_2]}{[R_1 + R_2]} \quad (3)$$

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*Electronic address: `dhandaneha999@gmail.com` where V_0 is the volume of total nuclei after interacting the target and projectile. R_1 is the radius of target whereas R_2 is the radius of the projectile.

Results and Discussion

We have done the dynamical trajectory calculations for ^{16}O + ^{185}Re and ^{31}P + ^{170}Er systems at E_{lab} = 120 and 170 MeV respectively which correspond to the nearly same compound nucleus excitation energy for both the systems.Figure 1 and 2 show the typical fusion and nonfusion trajectories in the (s,σ) plane for selected angular momentum values for ^{16}O +^{185}Re and ^{31}P +^{170}Er reactions.For ^{31}P +^{170}Er reaction, it is observed that the trajectories for l=42$\hbar$, 44$\hbar$, 46$\hbar$, 48$\hbar$, 52$\hbar$, 60$\hbar$, 65$\hbar$ correspond to typical fusion kind for which calculated trajectories would be ended when the minimum elongation is reached.The case of l=70$\hbar$ corresponds to non fusing trajectory. For the system ^{16}O + ^{185}Re ,it is observed that for l=68$\hbar$, 69$\hbar$ and 70$\hbar$ correspond to quasielastic trajectories showing very little mass exchange.

It is found that the time dependece of the elongation and neck coordinate is quite different for both the reactions.The fusion time τ_{fr} (time taken from the begining of interactions to CN formation) for l = 50$\hbar$ is 17.07 × 10^{-22} sec for ^{16}O + ^{185}Re and for ^{31}P + ^{170}Er is 45.65× 10^{-22} sec.By observing the figures ,one can distinct visualise the differences in formation time to be realted to the change in the entrance channel mass asymmtery.

Conclusion

These dynamical trajectory calculations are based on particle exchange and are found to be very effective in describing the dissipative transport phenomena involved in the heavy ion induced reaction leading to fusion.The average compound nucleus formation time is found to be higher for ^{31}P +^{170}Er system compared to ^{16}O +^{185}Re.

In summary,the present calculations show that the mass asymmetry plays an important role in deciding the reaction dynamics and the fusion time scales in heavy ion reaction.

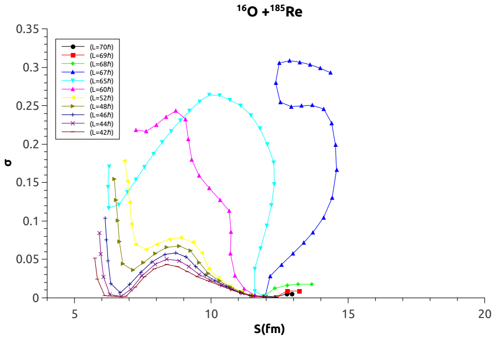

FIG. 1: Neck coordiante versus elongation for ^{16}O + ^{185}Re .

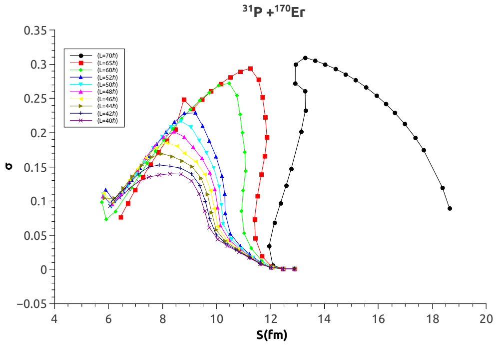

FIG. 2: Neck coordiante versus elongation for ^{31}P +^{170}Er .

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