Prediction of quasifission for ^{18}O+^{232}Th reactions

K. Rahul[1],* B. Satheesh[1],† and C. Raghu[1]
[1]*National Institute of Technology Calicut, Kozhikode - 673601, Kerala, INDIA*

Introduction

The quasifission covers a transition region between deep inelastic and compound nucleus formation so as to represent a link between different aspects of related phenomena, useful for an extended understanding of nuclear dynamics. The important observables are: (1) use of **heavy composite systems** and moderate bombarding energies above the barrier, so that the attractive nuclear forces are mainly counter - balanced by the repulsive Coulomb forces (as opposed to light system at high incident energies, for which the balance of forces is reached by adding centrifugal forces). (2) large **mass-asymmetry** of the initial target - projectile system so that a broad mass range between the target - projectile distributions of the deep - inelastic products and a symmetric fragmentation as in fusion - fission is open to the observation of quasifission. (3) **systematic studies** which cover, as a function of target mass (charge) and bombarding energy, the full range of reaction processes including, on the one extreme, the compound nucleus formation and on the other extreme, the deep - inelastic collisions. (4) a detailed measurement of the **mass versus angle correlation** of the binary products covering the dependence on systems and bombarding energies: it gives the best signature of the mass rearrangement in quasifission and allows to extract, over trajectory calculations, the time scale of mass equilibration. (5) the bombardment of a (**heavy projectile** ^{208}Pb, ^{238}U) on light targets (^{16}O, ^{24}Mg, ^{27}Al,......,^{48}Ca,.....,^{89}Y) combined with a coincidence measurement, in the forward hemisphere, of the velocity vectors of both binary products, offers the best possibility for a complete recording and for a reconstruction of the primary product distributions $\frac{d^3\sigma}{(dA.d\theta.dE)}$ [1].

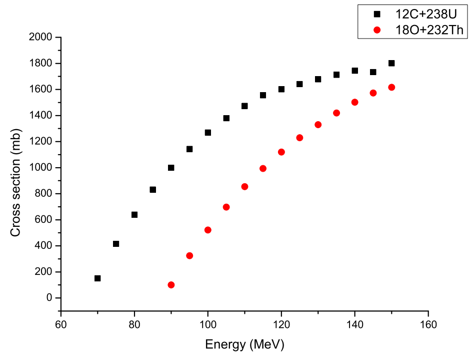

FIG. 1: The theoretical predictions using the statistical model code PACE4 for the systems ^{18}O+^{232}Th and ^{12}C+^{238}U.

Present study

Many studies have already established the presence of quasifission. For example, the reactions ^{32}S+^{238}U ($Z_P Z_T$=1472) and ^{32}S+^{208}Pb ($Z_P Z_T$=1312) [2] and we are well aware of the signatures sufficient enough to determine the occurrence of quasifission for a particular reaction channel. Present studies also have focused on how these signatures arise from the nuclear structure of the reaction channel. In particular, the role of the deformation and orientation of a heavy target, as well as the entrance channel magicity and isospin on quasifission were investigated with theoretical and experimental approaches by measuring mass-angle distributions (MAD) or mass ratio distribution of the fragments. Experimental MAD for reactions with small isospin asymmetry show that magic numbers in the entrance channel reduce quasi-fission, while non-magic systems show more quasi-

*Electronic address: `rahul.kaiwart@gmail.com`
†Electronic address: `satheesh.b4@gmail.com`

fission. With a large initial isospin asymmetry, a rapid N/Z equilibration occurs in the early stage of the reaction, modifying the identities of the collision partners. This is the case for ^{40}Ca+^{208}Pb, which, as far as the competition between fusion and quasi-fission is concerned, behaves more like a non-magic system, i.e., with increased quasifission [3]. Fission fragment anisotropies and mass distributions measurements for the ^{16}O + ^{238}U reaction suggest collisions with the tips of the deformed U-238 target nuclei lead to quasifission [4].

TABLE I: Reaction Q-values, charge products of the projectile and target proton numbers $Z_P Z_T$, interaction barriers according to the Bass prediction α and entrance channel mass asymmetries α $=\frac{Z_P - Z_T}{Z_P + Z_T}$ [5]are given.

Reaction	CN	Q-Value	V_{Bass}	$Z_P Z_T$	α
^{18}O+^{232}Th	^{250}Cf*	-36.51	81.62	720	0.856
^{12}C+^{238}U	^{250}Cf*	-23.86	64.22	552	0.904

Results and analysis

The theoretical predictions using the statistical model code PACE4 for the systems ^{18}O+^{232}Th and ^{12}C+^{238}U are shown in Fig.2. It can be indicate the presence of quasifission in the ^{18}O+^{232}Th system. It is evident from the Fig.2 that we expect suppression of fusion cross section for the channel ^{18}O+^{232}Th ($Z_P Z_T$=720)compared to that of ^{12}C+^{238}U ($Z_P Z_T$=552) from the energy interval ranging from 70 MeV to 150 MeV. One way to justify this experimental result is to consider the magicity of the entrance channel. channel (1) ^{12}C+^{238}U contains no magic number but channel (2) ^{18}O + ^{232}Th contains magic number-8 in oxygen nucleus so according to the previous discussion channel (1) can be expected to show more quasifission compared to channel (2) but our theoretical result is just converse. This can be understood by Time-dependent HartreeFock calculations which predict fast equilibration of N/Z in the two fragments early in the collision. This transfer of nucleons breaks the shell effect, causing this reaction to behave more like a non-magic one in the competition between fusion and quasi-fission [3]. Another way to explain the suppression in cross section is that the two colliding nuclei forming a two-centre quantum system fail to reach an equilibration of the all degrees of freedom. Such non-equilibrium systems can reseparate into two fragments (quasifission) due to the strong Coulomb repulsion ($Z_P Z_T$) between the collision partners. Therefore, different projectile and target combinations leading to the formation of the same CN can drastically influence the ER cross sections. As it is obvious that system ^{18}O+^{232}Th has larger ($Z_P Z_T$=720)value compared to that of ^{12}C+^{238}U which is ($Z_P Z_T$=552) and hence the more coulombic repulsion between the nucleus leading to the reseparation of the fragments before the equilibrium is achieved which manifest itself as reduction of cross section. Table 1. shows reaction Q-values, charge products of the projectile and target proton numbers $Z_P Z_T$, interaction barriers according to the Bass prediction (V_{Bass}) and entrance channel mass asymmetries α. Detailed will be present.

Conclusion

In this report we have shown theoretically that even for the ($Z_P Z_T$=720) we observed the qusifission in particular with ^{18}O+^{232}Th. Thus equilibrium can effectively be influenced by the magicity of reaction channel. Charge product of the reaction channel is itself not enough to determine the occurrence of quasiffision.

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