Measurement of fusion evaporation residue cross sections in the ^{48}Ti + ^{138}Ba reaction

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Evaporation residue cross sections are measured for the reaction ^{48}Ti + ^{138}Ba which forms the compound nucleus ^{186}Pt*. The cross sections are measured at beam energies in the range of 189.3–234.4 MeV. The experimental evaporation residue cross sections are compared with the dynamical model which employs one-dimensional Langevin dynamical calculations. The dissipation strength of the Langevin equation is calculated using both chaos weighted wall formula and a constant reduced dissipation function. The measured ER cross sections are found to be much less than the theoretical predictions. Further, the measured ER cross sections for the system ^{48}Ti + ^{138}Ba are compared with those of ^{32}S + ^{154}Sm forming the same compound nucleus. The suppression in the evaporation residue cross sections of the former reaction may be attributed to the increasing competition from quasifission. The quasifission reaction is found to have superseded any effect of neutron shell closure ($N = 82$) of the target in the present study.

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I. INTRODUCTION

The synthesis of heavier elements using heavy ion beams is severely hindered by fission and fission-like processes [1,2]. Experimental efforts for the formation of such elements are extremely challenging as evaporation residues (ER) for such reactions are heavily suppressed by a nonequilibrium process called quasifission (QF) [3–5]. In the case of QF, after the capture of projectile by the target nuclei, the system reseparates before the formation of a completely equilibrated compound nucleus (CN). The investigation into the major factors promoting this reseparation is not yet complete. Thus, a deep understanding of the various factors that can suppress a non-compound-nuclear reaction like QF and the techniques to enhance the production of super heavy elements (SHE) are the need of the hour.

The main evidence for QF are (i) strong mass-angle correlation in the mass-angle distribution of fission fragments [6–8], (ii) broader mass distributions compared to that of CN fission [7–10], (iii) anomalously large angular anisotropies compared to statistical model predictions [11–13], (iv) lower ER yield [9,14], and (v) unexpected γ ray multiplicity [15]. The presence of any of these signatures will indicate the reaction to be QF. The competition between fusion and QF determines the probability of formation of a completely equilibrated CN.

The major factors that influence QF process are entrance channel mass asymmetry [9,16–18], deformation of colliding partners [6,19–21], shell closure effect [22,23], and neutron excess of projectile and target [14]. Among the factors influencing QF, the entrance channel mass asymmetry is closely related to the product of projectile and target atomic numbers Z_pZ_t (where Z_p is the atomic number of projectile and Z_t is the atomic number of target) [7]. The dynamical models have predicted the onset of QF when the charge product $Z_pZ_t > 1600$ [3]. However, the onset of QF has been reported for the systems even with charge product $Z_pZ_t \sim 540$ [24–26].

The pre-equilibrium model suggests that, in heavy ion induced reactions, in addition to normal fusion-fission process, a significant fraction of the non-compound-nuclear reaction is also present [27]. According to this model, if the critical mass asymmetry (α) is greater than the Businaro-Gallone mass asymmetry (α_{BG}) then the flux flow is from the lighter nucleus to heavier nucleus and it leads to CN formation. On the other hand, if $\alpha < \alpha_{BG}$, the flux flow is from heavier to lighter nucleus and the system reseparates before the formation of CN. However, contradicting results are also reported where $\alpha < \alpha_{BG}$ results in fusion-fission and $\alpha > \alpha_{BG}$ leads to QF [28].

In a classical experiment for the production of ^{293,294}Ts through ^{48}Ca induced reaction on ^{249}Bk, it required 70 d of beam time to detect one nucleus [29]. The cross section for the reaction is less than 1 pb. The main reason for the hindrance

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