A study on the effect of shell closure in the fusion enhancement of ^{86}Kr + ^{100}Mo reaction

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Introduction

It has been established that the fusion probability between two massive nuclei depends on the charge product of the colliding partners [1]. This is because as the charge product increases, the Coulomb repulsion between them increases, reducing the chances of fusion. That is, even if the projectile energy is high enough to overcome the fusion barrier, a compound nucleus is not always formed. The relative distance between the mass centers of the colliding partners at touching configuration with respect to saddle point decides the fusion of the massive systems. For massive systems, this contact point lies outside the saddle and this reduces the fusion probability. The dependence of fusion probability on charge product can be qualitatively studied by comparing two systems forming the same compound nucleus such that the fusion probability of the symmetric system is expected to show a dip.

In the reactions involving heavy systems, the fusion probability is significantly suppressed due to quasi fission (QF) [2,3]. Quasi-fission is a dynamical non-equilibrium process that takes place when the composite system, formed after the capture of the projectile by the target, breaks apart before the formation of a compact compound nucleus. QF occurs in the early stage of the collision when the two reactants are linked by a neck. The two fragments then re-separate with more mass symmetry than the entrance channel, without forming a compound nucleus. The probability of QF is determined by the diffusive motion of the nucleons over a multi dimensional potential energy surface. This motion results either in the formation of a compact shape resulting in fusion or in an elongated di-nuclear shape leading to QF. The fusion between massive nuclei depends not only on the charge product but also on the nuclear structure of projectile and target. The number of valence electrons outside a major shell is found to be affecting the nuclear fusion probability [4]. The work of Oganessian et al [5] also suggest that shell structure of the interacting nuclei plays an important role in the low energy fusion process. Also, a proper understanding of the intricacies involved in the heavy ion reaction is the need of the hour to make super heavy elements. The role of shell effect in the entrance channel is undertaken in the present paper.

Present Study

The influence of shell closure effect in the fusion of heavy ion induced reactions has gained attention in the recent times. In the present study, the two reactions, 86Kr + 100Mo [6] and 32S + 154Sm [7], both forming same compound nucleus 186Pt, are compared to study the effect of entrance channel shell effects. The evaporation residue (ER) cross sections of the two systems are compared and is shown in Fig.1. When two heavy mass systems (one symmetric and another asymmetric) interact with each other, system with higher charge product suffers more Coulomb repulsion and it decreases the fusion probability. Fusion cross section is the sum of ER and fission cross sections. Since fission is generally not expected just above the Coulomb barrier for heavy systems, fusion will lead to ER decay channel. Thus, the symmetric system is expected to show a reduced ER than the asymmetric system because of the large Coulomb repulsion between the interacting nuclei, that reduces fusion probability. But as shown in Fig.1, there is no ER suppression for 86Kr + 100Mo and in fact a fusion enhancement as compared to 32S + 154Sm reaction is noticed. The probable reasons for this unexpected phenomenon is investigated to get a new insight in the field of heavy mass reactions.

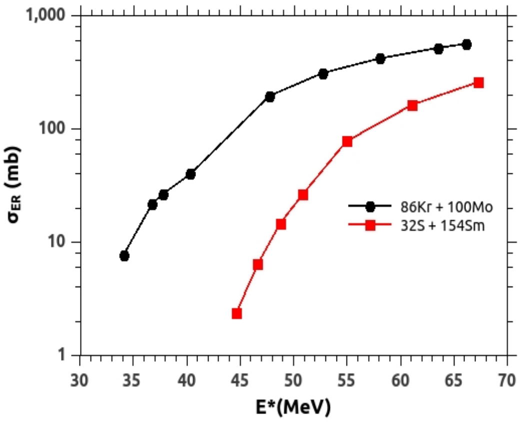

Fig.1. Experimental ER cross section of two systems forming the same compound nucleus is compared.

Discussion

Even though both symmetric and asymmetric reactions are forming the same compound nucleus, the projectile has a neutron magicity of N = 50 in the 86Kr + 100Mo reaction. The presence of magic shells in the entrance channel is found to enhance the fusion probability [8,9]. This is because magic nuclei are difficult to excite and thus it reduces the energy dissipation allowing the formation of a more compact di-nuclear system [10]. A compact di-nuclear system always proceeds towards the complete fusion between the projectile and target. Also, magic nuclei are expected to generate cold valleys in the potential energy surface, favouring the formation of a more compact compound nucleus [11]. The effect of shell effect is found to be decreasing at higher excitation energies.

So it may be concluded that even though the Coulomb repulsion is more for symmetric system, it favours fusion enhancement just above the Coulomb barrier due to the presence of neutron shell closure in the entrance channel. More studies are required to find the other influencing factors such as deformation of the colliding partners, orientation of the projectile while hitting the target, isospin asymmetry of the colliding partners etc, which may also enhance the fusion probability of this symmetric system.

To achieve a comprehensive picture of the reaction dynamics involving heavy mass systems, a thorough understanding of the interplay between the above mentioned factors is important.

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