Evidence of the Quasi Fission from potential energy surface calculations

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Introduction

Recently, the formation of super heavy elements(SHE) has been achieved by fusion of heavy nuclei. However, the electrostatic energy of such systems is very large, so although the two nuclei initially may captured by the nuclear potential, rather than fusing , they almost always separate after transfer of mass to the lighter nucleus. This process is called quasi-fission(QF), can inhibit fusion by many orders of magnitude. Understanding this inhibition may hold the key to forming more SHE. According to the calculations within the macroscopic-microscopic model of Swiatecki[1], the inhibition is predicted when the product $Z_P Z_T$ of the charges of projectile and target nuclei is larger than about 1600. From the anlysis of a large set of experimental fission data in the reactions with heavy ions, it was found that for the composite systems with $Z_{CN} = 80$ the threshold value for the QF appearence is $Z_P Z_T$= 1450± 100[2]. In addition, the criterion based on the entrance channel mass asymmetry states that QF appears for systems with entrance channel mass asymmetry(α) lower than the mass asymmetry associated with the Businaro-Gallone point(α_{BG}). The entrance-channel mass asymmetry is smaller than α_{BG} =0 . 83 for the $^{36}Ar+^{144}Sm$ and $^{68}Zn+^{112}Sn$ reactions[5, 6]. However, for the $^{36}Ar+^{144}Sm$ reaction QF was not observed. In the case of $^{68}Zn+^{112}Sn$ reaction, the projectile like and target like fragments has been observed from the measurement of mass-tke distributions. They have reported that the mass division is due to the presence of QF. In order to understand the reaction mechanism, we calculated the potential energies as a function of fragment mass by using the two centre shell model approach and the web base nuclear reaction video (NRV) code[4].

Methodology

The code NRV is based on the[4], provides the possibility to calculate potential energy(diabatic or adiabatic) of binary nuclear system. The potential energy depends on the several variables such as distance between mass centers of two halves of the system(r), deformations of the projectile(δ_P) and target(δ_T), the mass asymmetry($\alpha = \frac{(A_2-A_1)}{(A_2+A_1)}$), and the neck parameter(ϵ =0.35 for the fission case). In order to calculate the adiabatic potentiacl energy of the heavy nuclei, we have used an extended version of the two centered shell model. This approach predicts the proper value of nuclear potential in the asymptotic region of separated fragments and in the region of nuclear contact. The deformation parameters of projectile and target are listed in the Table I for the three entrance channels.

TABLE I: Deformation parameters for the potential energy calculations

Parameter	$^{36}Ar+^{144}Sm$	$^{68}Zn+^{112}Sn$	$^{90}Zn+^{90}Zn$
δ_P	0.2573	0.2015	0.0907
δ_T	0.0869	0.1207	0.0907

Results and Discussion

The Fig. 1 shows the driving potential as a function of fission fragment mass at contact configuration for the ^{180}Hg nucleus, which is populated via three distinct entrance channels: $^{36}Ar+^{144}Sm$, $^{68}Zn+^{112}Sn$ and

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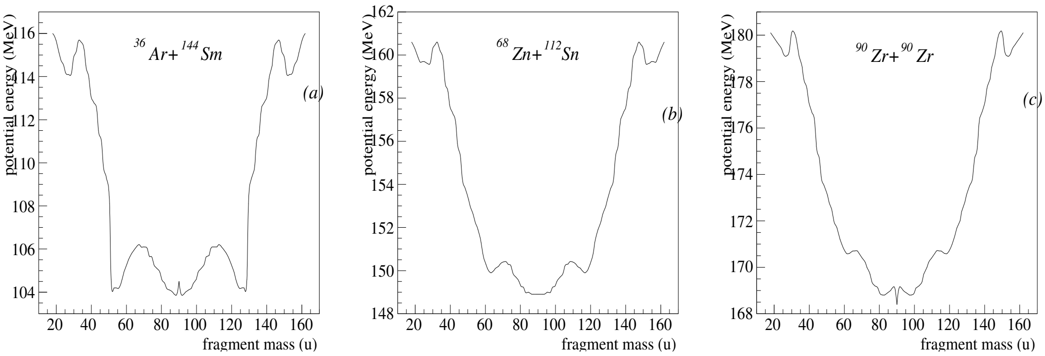

FIG. 1: Two center shell model calculation for the three systems studied in this work. The potential energy as a function of fission fragment mass.

$^{90}Zr +^{90} Zr$ have α=0.6, 0.24 and 0.0 rspectively. There is a plateau in the region A_L=70-88 and A_H=92-110 in Fig.1(a), as well as a small maxima at symmetry. This plateau and the small maxima can be accounted for the flat top mass distribution with a small dip at symmetry, observed for a wide range of CN initial excitation energies, reported by [5]. In addition, two minima are appeared at A_L = 55 and A_H = 125, indicating the presence of deformed proton shell closure of Z = 56 in the fission fragment mass distribution. Consequently, it is confirmed that the entrance channel $^{36}Ar +^{144} Sm$ followed only the CNF path. For $^{68}Zn +^{112} Sn$, there are two additional minima on either side of the central minimum. These two minima are found at A_L = 63 and A_H = 117, which related to projectile like and target like masses, respectively. It reveals that this entrance channel traversed the PES via CNF and QF paths. For $^{90}Zr +^{90} Zr$, a deep minimum is observed at symmetry, it indicates that the contribution of symmetric QF is prominant. The current findings are consistent with the fact that the entrance channel with lower mass asymmetry and higher $Z_P Z_T$ causes quasifission. These findings suggest that studying nuclear driving potential at the scission point is an additional tool for studying the QF and can be used to predict SHE synthesis.

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