

The evaporation residue cross-sections calculations for ^{194}Hg compound nuclei using statistical code.

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Introduction

The stability of heavy nuclei leading to the formation of super heavy elements (SHE) is a topic of considerable interest in last twenty years. The synthesis of SHE is very difficult due to onset of various non-compound nuclear (NCN) processes that reduces the fusion probability dramatically. For properly understanding it, the detailed study of decay of compound nuclei (CN) into evaporation residues (ER's), CN fission fragments and other NCN processes like quasi-fission (QF) is necessary. Both fusion enhancement and fusion hindrance phenomenon has been observed near the Coulomb barrier due to the coupling of various nuclear degrees of freedom.

In this work, we have presented the theoretical calculations for ER cross-sections for $^{40}\text{Ar} + ^{154}\text{Sm}$ system leading to the $^{194}\text{Hg}^*$ CN, to study the effect of quasi-fission in heavy CN formation using statistical code [1]. The experimental data for this system has been reported in the ref. [2] and [3] respectively.

Theoretical calculations

In order to examine the consistency of the experimental results with the theoretical values, the statistical model calculations were performed with the assumption that whole nuclear flux leads to the CN formation. The light particle and fission decay widths were obtained from the Weisskopf formula [4]. One of the important input of this code is the spin distribution of the fused system, which was obtained by reproducing the experimental fusion cross-sections using coupled channel code CCFULL [5]. The input parameters used in CCFULL code are tabulated in table 1. Here, both projectile ^{40}Ar target ^{154}Sm are both deformed in nature. The vibrational and rotational couplings were assumed in projectile and target nucleus, respectively. In these calculations, β , β_2 , β_4 are the deformation, quadrupole and hexadecapole deformation

parameters. E_P , E_{2T} , E_{T2} are the excitation energies for the first and second mode of excitations in the projectile and target nucleus.

The experimental fusion cross-sections were fitted by adjusting the values of V_0 is the depth parameter of Woods Saxon potential, r_0 is the radius parameter, and a_0 is the surface diffuseness parameter. The values obtained are given in table. After fitting, CCFULL gives the spin distribution as an output file and this file has been used for the spin distribution of compound nucleus in the statistical code.

Table 1. The input parameters used in CCFULL calculations. The double columns under each system indicate the strength values associated with the projectile (left) and target (right).

Projectile (Vibrator)	Target (Rotor)
β - 0.26	β_2 - 0.27
E_P (MeV) - 1.46	E_{2T} (MeV) - 0.82
	β_4 - 0.113
	β - 0.08
	E_{T2} (MeV) - 0.27
V_0 (MeV)	- 77.32
r_0 (fm)	- 1.18
a_0 (fm)	- 0.68

Finally, the statistical model calculations were performed using Bohr-Wheeler formalism by adjusting the barrier factor (K) to reproduce the ER cross-sections with and without including the shell effects in the level density and in the barrier height in the measured energy range in center-of-mass frame as shown in figures 1 and 2. For reproducing the data, different values of scaling factor (K) in the range 0.70-1.10 has been used.

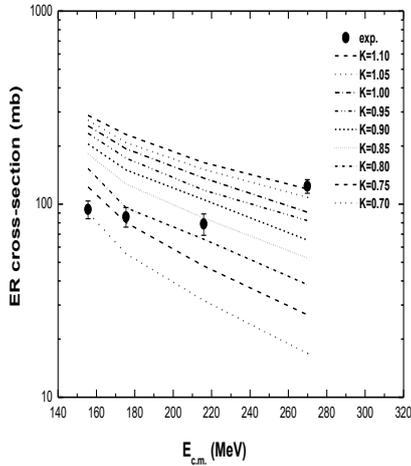


Fig. 1 The statistical model calculations for $^{40}\text{Ar} + ^{154}\text{Sm}$ system including shell effects. Dots are the experimental data and different lines are the theoretical calculations for different scaling factor, K .

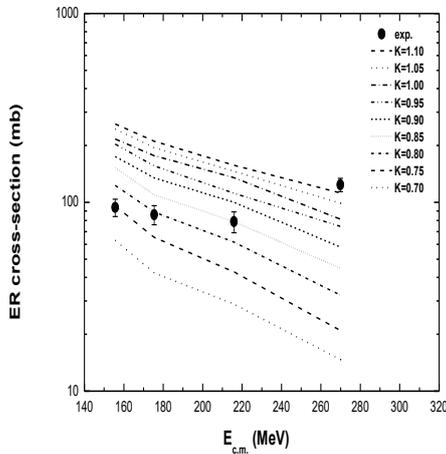


Fig. 2 The statistical model calculations for $^{40}\text{Ar} + ^{154}\text{Sm}$ system without including shell effects. Dots are the experimental data and different lines are the theoretical calculations for different scaling factor, K .

Results and discussions

The evaporation residue cross-sections for the system $^{40}\text{Ar} + ^{154}\text{Sm}$ system has been estimated using the statistical code in the center of mass energies ranging from 150-270 MeV. It is observed that a single value of K cannot fit the ER cross-sections for entire energy range. At energies around the Coulomb barrier, the statistical code results over predicts the experimental ER cross-sections. The fission barrier have been decreased to match the experimental values and it has been found that the value of K about 0.7-0.8 gives good fit when shell corrections were included and the K value lie in the range 0.75-0.85, when shell corrections were not considered.

On the other hand, for the energy very above the Coulomb barrier, we have increased the fission barrier ($K = 1.10$ for both cases) to match the larger ER cross-section. A barrier scaling factor less than the unity can be interpreted as a signature of NCN processes. More measurements are necessary to understand the effect of quasi-fission in the formation of heavy elements and shell effect in detail. We are planning to do such experiments to measure ER cross-sections for $^{48}\text{Ti} + ^{140,142}\text{Ce}$ systems.

References

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