Role of diffuseness coefficient in reaction dynamics using collective clusterization method

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Introduction

The formation and decay of compound systems formed in massive heavy ion reactions have been exploited quite extensively to understand nuclear dynamics and related properties. The measured fusion cross sections for such reactions may show hindrance phenomena at sub barrier energies when compared with coupled channel calculations. Various approaches have been employed to address this phenomena. In an experiment [1], the fusion cross sections for the reaction ^{58}Ni+^{54}Fe$\rightarrow^{112}$Xe* were measured, where the fusion cross sections mainly consist of the evaporation residue component and the fission cross sections are observed to be negligibly small.

In the present work, the decay of compound nucleus ^{112}Xe* is studied using the dynamical cluster decay model (DCM) [2] over a wide range of energies. The issue of fusion hindrance is addressed within DCM in terms of its inbuilt property of barrier lowering which helps to account for the data at sub barrier region. The barrier modification phenomena comes into picture through the neck length parameter (ΔR) of the model. The neck-length parameter $\Delta R(T)$ related to the first turning point (R_a) as $R_a = R_1(\alpha_1, T) + R_2(\alpha_2, T) + \Delta R(T)$, defines, the "barrier lowering" parameter, ΔV_B, which inturn relates $V(R_a, \ell)$ and the top of the barrier $V_B(\ell)$, for each ℓ as $\Delta V_B(\ell)$=$V(R_a, \ell)$-$V_B(\ell)$.

Dynamical Cluster Decay Model

The DCM [2] is worked out using partial wave analysis and the decay cross sections are calculated in terms of preformation factor (P_0) and barrier penetrability P. The P_0 is the solution of stationary schrödinger equation in η coordinate:

$$\{-\frac{\hbar^2}{2\sqrt{B}_{\eta\eta}}\frac{\partial}{\partial\eta}\frac{1}{\sqrt{B}_{\eta\eta}}\frac{\partial}{\partial\eta}+V(\eta,T)\}\psi^\nu = E^\nu\psi^\nu,$$

and P is the WKB penetrability of preformed fragments in R-motion. The fragmentation potential V(η,T) in above equation, consists of binding energies, Coulomb potential (V_c), proximity potential (V_p), angular momentum dependent potential (V_ℓ). All ingredients of potential V(η,T) are well understood except for proximity interaction V_p whose various versions are available in the literature [3–5]. We have used here pocket formula of Blocki [3], with

$$V_p = 4\pi\bar{R}(T)\gamma b(T)\Phi(s_0(T))$$

where Φ is the universal function which depends upon the minimum separation distance s_0. $\overline{R}$ is the mean curvature radius of the reaction partners, γ is the specific nuclear surface tension, b is the surface width or diffuseness coefficient and temperature dependent diffuseness of the nuclear surface is given by

$$b(T) = a(1 + 0.009T^2)$$

In present work different choices of diffuseness coefficient b are employed by taking various values of a.

Calculations and results

The decay of ^{112}Xe* compound system is investigated and the DCM calculated decay cross sections are found to be in nice agreement with the measured data [1] at above as well as below barrier energies. The better

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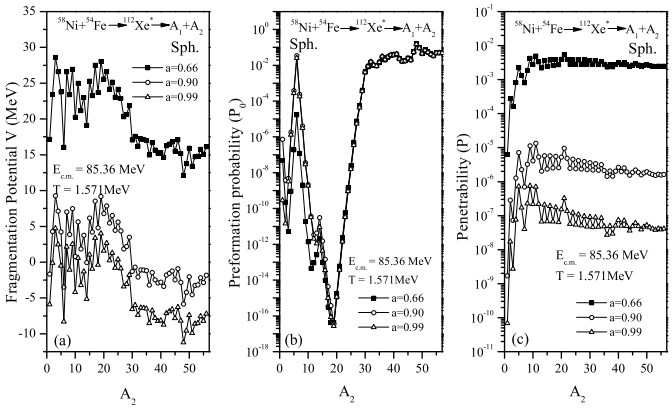

FIG. 1: (a), (b) and (c) shows the fragmentation potential, preformation probability and penetrability as a function of fragment mass for the decay of ^{112}Xe* considering different values for the diffuseness parameter.

agreement at near and sub barrier region is attributed to the modification in barrier profile termed as barrier modification "ΔV_B". It has been observed that ΔV_B is larger at below barrier energies and decreases with increase in energy.

Another quantity of interest in the present calculations is the diffuseness parameter. It is the thickness of the surface in which the density profile changes. It is observed that the cross sections are larger for lower diffuseness value. Following [1], we have explored effect of diffuseness coefficient by taking a=0.60, 0.90, 0.99, later being more frequent choice in DCM based calculations. Fig.1 shows the variation of fragmentation potential, preformation probability and barrier penetrability as a function of fragment mass for three different choices of diffuseness. One can observe from Fig. 1(a) that the structure of fragmentation potential remain same however the magnitude increases with the decrease in diffuseness. Fig. 1(b) shows that preformation probability remains almost same for various diffuseness choices. On the other hand, the penetrability plotted in Fig. 1(c) shows much larger value for the lower diffuseness coefficient and as cross section depends linearly on penetrability so the larger cross sections at lower diffuseness can be understood in terms of increased magnitude of penetrability. In summary, the decay of ^{112}Xe* is investigated, where in addition to above barrier, the data at sub barrier energies are fitted nicely within DCM because of its barrier lowering property. The diffuseness parameter does not change the fragmentation structure though change in magnitude is observed. The larger cross sections for lower diffuseness coefficient are attributed to increasing magnitude of penetrability with decrease in diffuseness. The preformation probability on the otherhand remain silent to the various choices of diffuseness coefficients.

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