Theoretical quasi-elastic excitation function and barrier distribution with different diffuseness parameter for ^{19}F + ^{208,209}Pb

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Introduction

For the description of nuclear collision, it is important to know the nature of potential between the colliding nuclei. Potential barrier between the colliding nuclei is created by the interplay of the repulsive Coulomb force and the attractive nuclear interaction. According to eigen channel approximation [1], this barrier splits into a distribution of barriers due to the couplings of relative motion of intrinsic degrees of freedom. Nuclear potential can be studied through either fusion or quasi-elastic scattering (QE) excitation functions. QE scattering is the sum of the elastic, inelastic and transfer reaction. It is basically related to reflection probability whereas fusion is related to the transmission probability.

Fusion barrier distribution (D_{fus}) is another parameter which can be extracted from the fusion excitation function σ_{fus} (E_{cm}) by taking the second derivative of $E_{cm}\sigma_{fus}(E_{cm})$ i.e. $d^2(E_{cm}\sigma_{fus}(E_{cm}))/dE^2_{cm}$. This method was first proposed by Rowley et al. [1]. But QE barrier distribution (D_q) is extracted from the first derivative of the QE scattering excitation function ($d\sigma_q/d\sigma_R$) which is given by $-d(d\sigma_q/d\sigma_R)/dE$. Timmers et al. first proposed this method [2]. Here σ_q and σ_R are the QE scattering cross-section and Rutherford cross-section respectively. Hence, there lies the advantage of finding barrier distribution using QE scattering over that of the fusion as it requires lesser precise data [3]. It is much easier to see the detailed effects of the coupling through the barrier distribution [4]. QE scattering barrier distribution also carries the significant importance towards the information on the synthesis of super heavy elements. [5]

In order to explain such QE scattering excitation functions theoretically, the coupled channels calculations with different target-projectile coupling schemes can be performed using a scattering version of the CCFULL program [6]. Hence the theoretical barrier distributions can be extracted using the method described above. In the program, the nuclear potential has real and imaginary components, both of which are assumed to have a Woods-Saxon form. The imaginary part simulates compound nucleus processes, and we have used a depth parameter of 30 MeV, radius parameter of 1.0 fm, and various surface diffuseness parameter. This choice of parameters confines the imaginary potential inside the Coulomb barrier with a negligible strength in the surface region. As long as the imaginary potential is confined inside the Coulomb barrier with sufficiently large strength, the results are insensitive to details of its parameters. On the other hand, for the Coulomb barrier of lesser strength, the diffuseness parameter seems to be sensitive towards the excitation functions and hence the barrier distributions. Thus, an attempt is being made in this paper to see such effect for different systems, viz, ^{19}F + ^{208,209}Pb below the Coulomb barrier from energy range of 80 MeV to 104 MeV at a scattering angle 150^0.

Results and Discussions

The interaction potential (V) for projectile and target are the sum of the long-range coulomb potential (V_C), centrifugal potential (V_{CEN}) and the short-range nuclear potential (V_N), i.e.,

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$$V = V_C + V_N + V_{CEN} \tag{1}$$

where

$$\mathrm{V_{CEN}} = \frac{\hbar^2 \mathrm{l}(\mathrm{l}+1)}{2\mu \mathrm{r}^2} \tag{2}$$

$$V_C = \begin{cases} \dfrac{Z_P Z_T e^2}{2r_c}\left(3 - \dfrac{r^2}{r_c^2}\right), & \text{if } r \leq r_c \\ \dfrac{Z_P Z_T e^2}{r}, & \text{if } r > r_c \end{cases} \tag{3}$$

$$V_N = -\frac{V_0}{1 + e^{\frac{r_r - R}{a_r}}} - i\frac{W_0}{1 + e^{\frac{r_i - R}{a_i}}} \tag{4}$$

Here V_0, W_0, r_r and r_i are the Wood-Saxon potential parameters whereas a_r and a_i are the respective real and imaginary diffusion parameters. The first term in equation (4) represents real potential which is the reason for reflection and the second term represents imaginary potential which gives absorption. We found out excitation function and barrier distribution for various diffusion parameter in this Wood Saxon potential for ^{19}F + ^{208,209}Pb. We have taken the values of V_0, W_0, r_r, r_i as 105 MeV, 30 MeV, 1.1 fm and 1 fm.

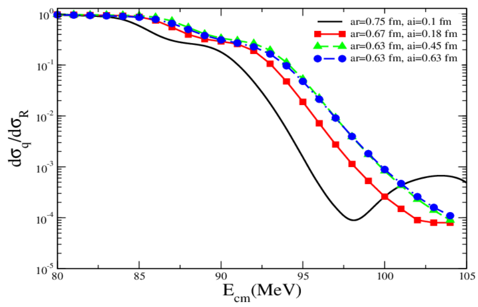

FIG. 1: Excitation Function of ^{19}F + ^{208}Pb

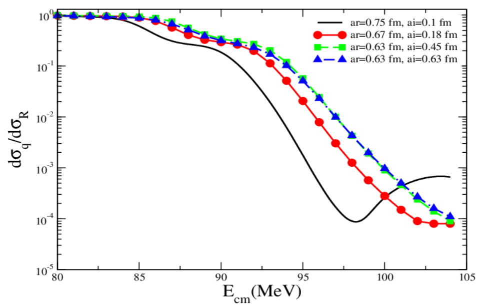

FIG. 2: Excitation Function of ^{19}F + ^{209}Pb

Figs. 1 and 2 depict the excitation function for different a_r and a_i values for both the systems, which shows that with increasing a_r and decreasing a_i, the excitation function decreases for both the systems towards higher energy regime; and figures 3 and 4 show their corresponding barrier distributions which shows the decrease in barrier height along with its shift towards the higher energy side with increasing a_r and decreasing a_i for both the systems. Hence from this work it was seen that diffuseness parameter is indeed a sensitive parameter with regard to the distribution function. Hence it needs to be chosen wisely.

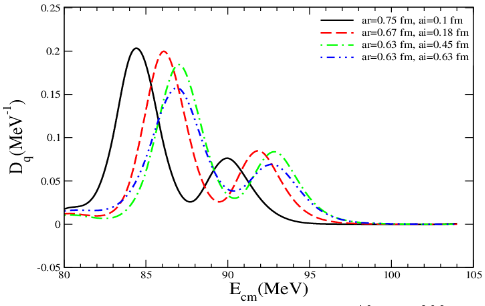

FIG. 3: Barrier Distribution of ^{19}F + ^{208}Pb

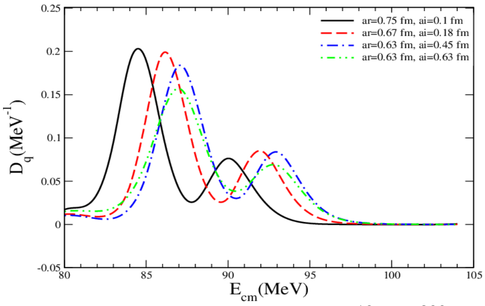

FIG. 4: Barrier Distribution of ^{19}F + ^{209}Pb

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