Role of entrance channel parameters on fusion incompleteness

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Introduction

It is now well established fact that several reaction mechanisms are active in reaction induced by light-heavy projectiles ($5\leq$ Z ≤ 10) at energies well above the Coulomb barrier[1]. These possible reaction mechanisms may be categorized into two major groups on the basis of degree of momentum transferred from the incident projectile to the target like fragments. These two types of reaction mechanisms are: i) complete fusion (CF), involving complete transfer of momentum from the incident projectile to the target; and ii) incomplete fusion (ICF), in which only a fraction of the incident projectile's momentum, essentially proportional to the mass of the fusing fragment, is transfered to the projectile.

The fate of resulting compound system relies a lot on entrance channel parameters. The pre-requisite condition for the capture of incident projectile by the target nuclei is that energy of the incoming projectile should be large enough to surmount the fusion barrier which is the resultant of three forces viz. Coulomb, nuclear and centrifugal. After capture of projectile by the target nuclei, the dinuclear system will equilibrate its mass distribution and shape while evolving towards a compact mononucleus by the emission of γ-rays, neutrons and/or light charge particles. If the compound nucleus (CN) is heavy or deformed enough then fission process in which the CN split itself into two symmetric nuclei under the influence of excess Coulomb repulsion, competes with the particle evaporation.

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The fusion cross section of the populated ERs can be disintegrated over partial waves (ℓ) and factorized as [2]

$$\sigma_{fus} = \sigma_{cap} P_{CN} W_{sur} \quad (1)$$

where σ_{cap} is the capture cross section, P_{CN} and W_{sur} are the probability of formation and survival of compound nucleus against the fission process, respectively. Capture cross section is the sum of quassifission, fast fission, fusion-fission and fusion evaporation residues cross section. Capture cross section, σ_{cap} may be given as [2],

$$\sigma_{cap} = \frac{\pi\hbar^2}{2\mu E}\Sigma_{\ell=0}^{\infty}(2\ell+1)T(E,\ell). \quad (2)$$

Here, $\frac{\pi\hbar^2}{2\mu E}$ is the reduced de Broglie wavelength and T(E,ℓ) is the probability of colliding nuclei to overcome the potential barrier.

In this paper we follow the approach prescribed by Sham et al. [3] to establish a systematic of P_{CN} using ER excitation function data of heavy ion induced reactions.

Calculation

A. Fusion Probability

Sahm et al [3] estimated the P_{CN} by comparing the measured σ_{ER} to the calculated σ_{ER} for a given system. Sahm et al [3] suggested that angular momentum averaged fusion probability for a given nuclear reaction can be defined as

$$P_{CN} = \frac{\sigma_{ER}}{\sigma_{ER}^{max}}. \quad (3)$$

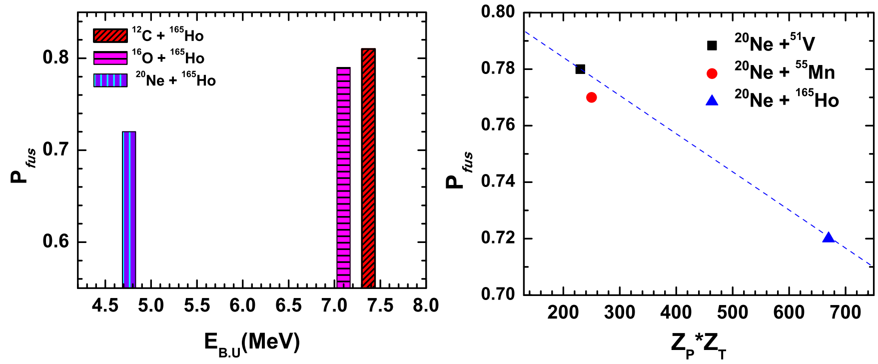

FIG. 1: Fusion probability (P_{fus}) as a function of (a) breakup threshold energy of the projectile ($E_{B.U}$) and (b) charge product ($Z_P{}^*Z_T$) of projectile-target system.

Here, σ_{ER} is obtained from the analysis of experimental data where as σ_{ER}^{max} is taken from the couple channel calculation, which inherently assumes that $P_{CN} = 1$. It is to be noted that both σ_{ER} and σ_{ER}^{max} are taken at same excitation energy.

B. Capture cross section

σ_{ER}^{max} is obtained from couple channel calculation using CCFULL[4]. By using the statistical model code PACE4 [5], ratio R = $\Sigma\sigma_{pxn}^{PACE4}/\Sigma\sigma_{fus}^{PACE4}$ is calculated and using this ratio experimental fusion cross section is calculated as $\sigma_{fus} = \Sigma\sigma_{pxn}^{exp}/R$.

We have compared the calculated σ_{ER}^{max} using the CCFULL code with the experimental fusion cross section (σ_{fus}) data for ^{20}Ne induced reactions over different targets. It was observed that experimental fusion cross section is suppressed as compared to the theoretical CF cross section calculated using the code CCFULL.

Results and Discussion

We have analyzed the fusion suppression for the ^{20}Ne induced reaction over different targets. Theoretical couple channel calculation has been carried out using the code CCFULL. Fusion probability for each reaction is determined by comparing the measured and calculated fusion cross section. The systematic study of the given five systems reveals that fusion probability depends strongly on entrance channel parameters namely breakup threshold energy of the incident projectile and charge product of the projectile and target, $Z_P{}^*Z_T$.

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