Dynamics of ^9Be induced reactions on ^{144}Sm and ^{208}Pb targets

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Introduction

The reaction dynamics of heavy ion induced reactions is strongly influenced by the shape and structure of colliding nuclei. The neck between two interacting nuclei plays a significant role in reaction dynamics. Gupta and collaborators have successfully presented the interaction barrier modification characteristics within Dynamical Cluster Decay model (DCM) through the neck length parameter (ΔR) [1]. Recently the total fusion cross section (σ_{fus}) in the reactions induced by a loosely bound projectile ^9Be, on different targets were studied by employing unique value of neck length parameter (ΔR) within DCM approach [2, 3]. However, the study was confined to complete fusion process only.
Now, the effects of loosely bound projectile ^9Be on the reaction dynamics have been extended to include incomplete fusion component also. Two processes complete fusion (CF) and incomplete fusion (ICF) have been observed experimentally in ^9Be + ^{144}Sm and ^9Be + ^{208}Pb reactions [4, 5]. We have calculated the CF cross section for ^9Be + ^{144}Sm reaction by using particular value of empirically fixed ΔR^{CF} at given incident energy E_{lab}=37 MeV [6]. The same value of ΔR^{CF} has been used to calculate the CF cross section of ^9Be + ^{208}Pb at same incident energy. It is relevant to mention here that ^9Be is loosely bound projectile, it may break into ^4He + (n + ^4He). Subsequently, ^4He fuses with the ^{144}Sm with reduced E_{lab}=16.44 MeV, i.e. the ICF process takes place.

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Methodology

The DCM, quantum mechanical fragmentation theory (QMFT) based cluster model is different from another statistical models as it treats the evaporation residues (ERs)/ light particles (LPs), intermediate mass fragments (IMFs), heavy mass fragments (HMFs) and fusion fission (ff) on equal footings. The missing nuclear structure information of compound nucleus (CN) in statistical model enters in DCM via preformation probability P_0 of the fragments and is calculated by solving Schrodinger equation in η co-ordinate. For ℓ-partial waves, the compound nucleus decay cross-section is given by

$$\sigma = \frac{\pi}{k^2}\sum_{\ell=0}^{\ell_{max}}(2\ell+1)P_0P;\ k=\sqrt{\frac{2\mu E_{c.m.}}{\hbar^2}} \quad (1)$$

where μ= $[A_1A_2/\ (A_1+A_2)]$m, is reduced mass, with m as the nucleon mass and ℓ_{max} is the maximum angular momentum. The angular momentum ℓ_{max} is fixed for vanishing the fusion barrier of incoming channel η_i or light particles cross-section σ_{LPs}. The total fusion cross-section within this model is given by

$$\sigma_{fus} = \sigma_{ER} + \sigma_{IMF} + \sigma_{ff} + \sigma_{nCN} \quad (2)$$

where σ_{ER}, σ_{ff} and σ_{nCN} are respectively evaporation residue/LPs, IMFs, ff and non-compound nucleus cross sections which sum up to give fusion cross section σ_{fus}. In Eq. (1), the preformation probability P_0 is obtained by solving the stationary Schrodinger equation in η, at a fixed R = R_a. The structure information of the compound nucleus enters via preformation probability P_0/ fragmentation potential. The penetration probability, P is calculated using the WKB tunneling probability.

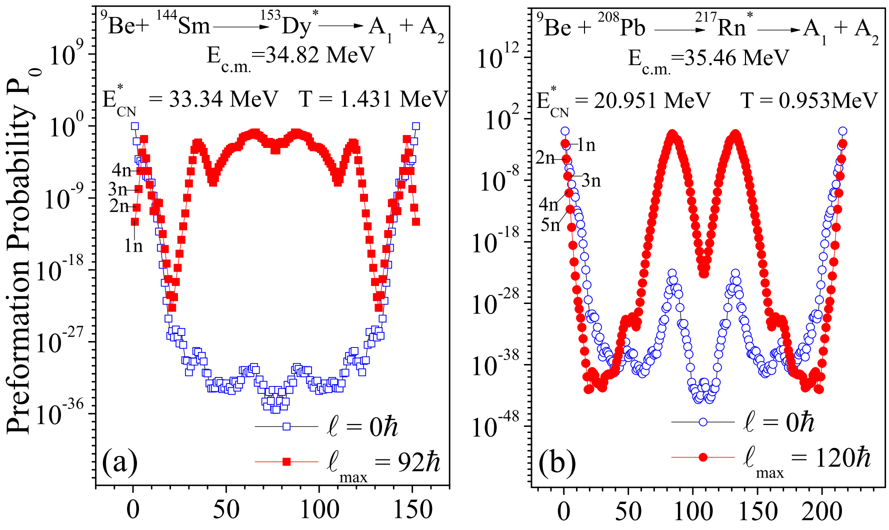

FIG. 1: The variation of P_0 with fragment mass A for the decay of compound nuclei a) $^{153}Dy^*$ and b) $^{217}Rn^*$, at the best fitted $\Delta R = 1.655$ fm for both the cases.

Calculations and discussions

In reference to our previous studies [2, 3], we have investigated the role of ΔR in CF for the reactions induced by same projectile (^9Be) at same incident energy (E_{lab}=37 MeV) on two different targets ^{144}Sm and ^{208}Pb. The most favoured fragments via P_0 have been explored in the decay of compound nuclei $^{153}Dy^*$ and $^{217}Rn^*$, formed in these reactions. Fig.1 gives the variation of P_0 with fragment mass (A) for compound nuclei a) $^{153}Dy^*$ and b) $^{217}Rn^*$, for two extreme ℓ-values. We see that LPs having A≤4, are more favorable (higher P_0) at lower ℓ-values for both the cases, in comparison to another competing fragments (IMFs, HMFs and ff fragments). But at higher ℓ-values they are in strong competition with LPs. Here, it is interesting to note that LPs are favoured at both the ℓ-values in the decay of CN $^{217}Rn^*$. We observe that the contribution of symmetric fission fragments is significantly suppressed for the case of ^9Be+^{208}Pb reaction as compared to that for ^9Be+^{144}Sm. The fission mass distribution is clearly asymmetric in the former case (Fig. 1(b)) which becomes broader and relatively symmetric for the later one (Fig. 1(a)).

The σ_{fus} has been calculated for the reaction ^9Be+^{144}Sm by fitting the ΔR^{CF}, within DCM, as detailed in the methodology section. The same ΔR^{CF} so obtained has been used to calculate the σ_{fus} for another reaction ^9Be+^{208}Pb. Quite interestingly, the DCM calculated σ_{fus} for the compound nuclei $^{153}Dy^*$ and $^{217}Rn^*$ are 293.3 mb and 2.25, respectively, which are in good comparison with the experimental data [4, 5] i.e. 295±21 and 2.79±0.43. Further work is in progress to see the effects of ΔR on ICF of these ^9Be induced reactions.

References

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