Fusion studies in $^{35,37}Cl + ^{181}Ta$ reactions via evaporation residue cross section measurements

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The fusion evaporation residue (ER) excitation function has been measured for $^{35,37}Cl + ^{181}Ta$ reactions at energies above the Coulomb barrier. The measurements were performed using the HYbrid Recoil mass Analyzer at IUAC, New Delhi. Comparable ER cross sections have been observed in both reactions and there is no isotopic dependence. Measured ER cross sections were compared with theoretical calculations employing the dinuclear system model at projectile and target nuclei interaction and statistical model for the deexcitation of the formed compound nucleus. Larger ER cross sections at the complete deexcitation cascade of the formed compound nucleus are noticed in both reactions at higher excitation energies ($E^* > 80$ MeV) over the calculated results. Fusion probability varies from 95% to 40% in the excitation energy range of the study. No appreciable difference in the fusion probability is noticed in the two reactions. Comparison of our results with other reactions populating ^{216}Th shows a very strong entrance channel dependence.

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I. INTRODUCTION

The identification of the residual nucleus known as evaporation residue (ER) is the definite confirmation of the production of heavy and superheavy nuclei in superheavy element research [1–3]. While the formation cross sections of the ERs are of the order of hundreds of millibarns in medium heavy nuclei, they drop to picobarns or femtobarns in the superheavy region. Though fission is the dominant decay mode in heavy nuclei, very low ER production cross section in heavy and superheavy nuclei is not solely due to this fission competition.

The formation of ERs is often regarded as a three-step process for simplicity: the capture, fusion, and survival of the fused system against fission [4]. Hence, the ER formation cross section ($\sigma_{\rm ER}$) can be written as $\sigma_{\rm ER} = \sigma_{\rm cap} \times P_{\rm CN} \times W_{\rm sur}$, where $\sigma_{\rm cap}$, $P_{\rm CN}$, and $W_{\rm sur}$ represent the capture cross section, probability of the compound nucleus (CN) formation, and the survival probability of CN against fission, respectively. While capture and fusion cross sections are of similar magnitude in lighter systems ($P_{\rm CN} = 1$), significant hindrance in fusion is observed in heavy systems ($P_{\rm CN} < 1$). This hindrance is attributed to the presence of noncompound nuclear (NCN) processes such as quasifission [5–9], fast fission [10–12], and preequilibrium fission [13]. The survival probability against fission also varies from $W_{\rm sur} = 1$ to $W_{\rm sur} < 1$, with increasing mass, excitation energy, angular momentum, etc.

Onset of NCN processes reduces the fusion probability. Reduction in ER cross section [6,14,15] is also noticed in more symmetric reactions compared to the asymmetric projectile-target combinations forming the same CN. Among the different NCN processes, quasifission is a dominant process at energies near the Coulomb barrier and competes strongly with fusion. The competition between the NCN processes and fusion defines $P_{\rm CN}$. Though there are different prescriptions available for estimating the $P_{\rm CN}$ [16–20], the results of such calculations vary significantly from experimental results. Significant variations in $P_{\rm CN}$ have also been observed with increasing mass and excitation energy of the nuclei of interest. A systematic study using available ER cross section data in the 170–220 a.m.u. [20] mass region outlined approximate boundaries from where $P_{\rm CN}$ deviates from unity.

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