# Dependence of incomplete fusion reaction on projectile structure

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## Introduction

Heavy ion ($Z \geq 2$)induced reaction has been a subject of great concern over the last few decades and this field is still quite alive as periodically new findings were published. Initially, due to the unavailability of large accelerator facility, most of the work related to the heavy ion induced reactions was confined to the energy below the Coulomb barrier. With the development of new accelerator facility around the world, the region of study has also spanned beyond the Coulomb barrier and the phenomena like incomplete fusion reactions (ICF) and break-up reactions come into light. If the incident projectile, on over coming the Coulomb barrier, is able to transfer the total incident momentum to the target nucleus then it is called complete fusion (CF). However, in some cases, especially with weekly bound projectile, the incident projectile breaks-up near the periphery of the target nucleus prior to fusion, leading to an incomplete transfer of momentum from the projectile to the target. Such type of reactions involving incomplete transfer of momentum are called ICF reactions. ICF reaction was first observed by Britt and Quinton in the year 1961 [1]. Since then several models were proposed to explain the dynamics of ICF reactions. The break-up fusion model of Udagawa and Tamura [2] proved to be most effective in explaining the ICF reaction dynamics. According to the break-up fusion model of Udagawa and Tamura, ICF is usually understood as a two step process: break-up of the incident projectile in the vicinity of the target followed by the fusion of one of the projectile fragment with the target nucleus, while the other escapes. In the present work CF and ICF reactions were studied for the $^{20}$Ne + $^{93}$Nb system at lab energy, $E_{lab}$ 91-145 MeV.

## Experimental Details

The experiment was performed at VECC, Kolkata, India. The targets of thickness range 1.19-1.50 mg/cm$^2$ of spectroscopically pure $^{93}$Nb (purity 99.99%) were prepared by depositing on aluminum backing of thickness range 2.06-3.78 gm/cm$^2$ by the vacuum evaporation technique at the target lab of VECC. A stack of six $^{93}$Nb targets was irradiated for $\approx$ 16 hrs by $^{20}$Ne$^{6+}$ beam at $\approx$ 145 MeV. The irradiation of the stack covered the desired energy range of 91-145 MeV. The beam current was kept 20-40 nA during the irradiation hours. The incident flux of $^{20}$Ne was determined from the charge collected in Faraday cup. The energy of the $^{20}$Ne ion beam incident on each target foil was calculated from the energy degradation of the initial beam energy using stopping power software SRIM[3]. The $\gamma$-ray activities produced in each target foil along with its catcher were recorded using pre-calibrated 60 cc HPGe detector coupled to PC based data acquisition system. The $\gamma$-ray spectroscopy software package RADWARE was used for analyzing the spectrum. Further details related to the experimental arrangement, formulae used and error analy-

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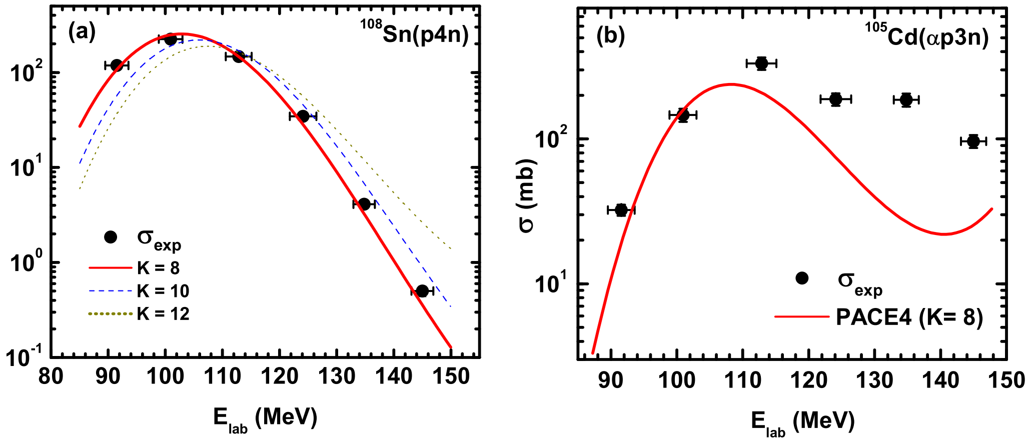

FIG. 1: Experimentally measured and theoretically calculated, using statistical model code PACE4, EFs of (a)$^{108}$Sn($p4n$) and (b)$^{105}$Cd($\alpha p3n$).

sis are available in Ref. [4]. The overall error in the present work is estimated to be ≤20%.

## Results and Discussion

In the $^{20}$Ne + $^{93}$Nb reaction at E$_{lab}$ of 91-145 MeV, total 12 residues were observed to be populated. Several radionuclides having half-lives either too short or too long were not observed due to the constraint imposed by the available experimental facilities. The observed residues were likely to be populated via CF and/or ICF processes. In order to determine the extent of CF and ICF contributions in the population of observed residues, the excitation functions (EFs) of observed residues were compared with the theoretical values predicted by the code PACE4[5]. PACE4 is based on the Hauser-Feshbach theory of compound nucleus decay and gives the CF cross section of the populated ERs in a given nuclear reaction. Fig. 1(a) and (b) show the experimental and PACE4 calculated EFs of ERs $^{108}$Sn and $^{105}$Cd, respectively. The theoretical and experimental EFs of $pxn$ channels were found to agree well with each other suggesting the population of these residues through the CF reactions only. On the other hand, the experimental EFs of ERs populated through $\alpha$-emitting channels shows an enhancement over the values predicted by the statistical model code PACE4. Since the PACE4 calculations do not take ICF reactions into account, the residues populated through $\alpha$-emitting channels are expected to have contributions arising from the ICF process in addition to CF.

## Conclusion

In the present work the EFs of 12 radionuclides, populated in the $^{20}$Ne + $^{93}$Nb reaction at E$_{lab}$ of 91-145 MeV, have been studied. It has been observed through the study of EFs of $pxn$ ($x$ = 3,4) channels that these residues were populated through the CF reactions only. On the other hand, the EFs of ERs populated through $\alpha$-emitting channels suggest the population of these residues through the combined effect of CF and ICF processes.

## References

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