Measurement of complete and incomplete fusion excitation functions in ^{12}C+^{130}Te system at E$_{lab}$ = 52 − 81 MeV

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Introduction

During the last few decades, investigating fusion reactions using α-cluster projectiles has sparked renewed interest in exploring heavy-ion (HI) induced reactions [1, 2]. Fusion reactions initiated by these projectiles may lead to significant mass transfer from the projectile to the target nucleus through various fusion processes. In the complete fusion (CF) process, the projectile might merge with the target nucleus as a single entity with all nucleonic degrees of freedom of projectile and target. However, in the case of an incomplete fusion (ICF) process, only a portion of the incident projectile fuses with the target nucleus, and the remnant continues moving in the forward cone as a spectator. Several theoretical models, including the breakup fusion (BUF), exciton, and sum-rule models, have been proposed for a comprehensive understanding of CF and ICF reactions. These models satisfactorily explain ICF data at energies $\geq$ 10 MeV/nucleon but are unable to explain at lower energies (3–7 MeV/nucleon) [3]. To gain a deeper understanding, an experiment was performed with the ^{12}C + ^{130}Te system, at E$_{lab}$ = 52 − 81 MeV.

Experimental details

In the experiment, target foils of ^{130}Te of thickness ($\sim$ 139 − 260 $\mu g/cm^2$) were fabricated on carbon backing using a resistive evaporation technique [4]. The stacks of targets followed by Al foils are prepared, where Al foils serve as a catcher for Evaporation Residues (ERs) recoiling out of the target foil and degrading the beam energy for subsequent stacks. A beam of ^{12}C was used to irradiate the ^{130}Te target-catcher assemblies in the General Purpose Scattering Chamber at the Inter-University Accelerator Centre (IUAC) in New Delhi, India.

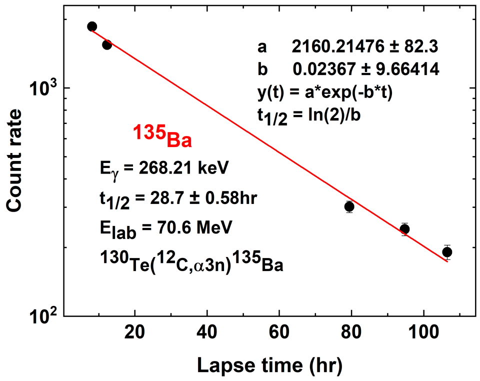

FIG. 1: Decay curve reveals a half-life of 28.7 ± 0.58 hr corresponding to ^{135}Ba residue.

After irradiation, the target catcher assemblies were removed from GPSC using an in-vacuum transfer facility. Offline γ counting was performed using pre-calibrated high-purity germanium (HPGe) clover detectors coupled with a CAMAC-based DAQ system.

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The γ-ray spectra were analyzed using the CANDLE software. The energy and efficiency calibration of the HPGe clovers was performed using a standard ^{152}Eu multi γ-ray source. The reaction residues were identified using their characteristic γ-ray and confirmed through the decay curve analysis. Fig. 1 shows the decay curve of ^{135}Ba at E_{lab} = 70.6 MeV.

Results and Analysis

Fusion of the ^{12}C projectile with the ^{130}Te target leads to the formation of an excited intermediate compound system ^{142}Ce*, which further decays via the emission of light nuclear particles and γ-rays to the formation of the ERs. In the initial examination of the ^{12}C + ^{130}Te reaction data, we have identified four ERs populated via decay of ^{142}Ce* and compared with the theoretical model code PACE4 [5]. Fig. 2 and Fig. 3 show the experimentally measured Excitation Functions (EFs) of the ^{137}Ce and ^{135}Ba residues populated via 5n and α3n channels, respectively, and compared with the PACE4 calculations for different values of K = 8, 10, 12. It is clear from the Fig. 2 that the cross-sections of ^{137}Ce(5n) are well reproduced by the PACE4 predictions for a = A/10 MeV^{-1} within the experimental uncertainties indicating the population of ^{137}Ce via CF channel.

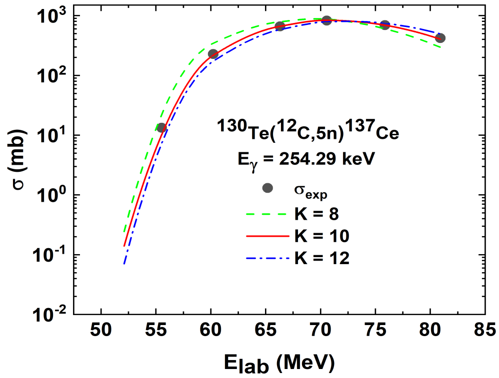

FIG. 2: Experimentally measured EF of ^{137}Ce(5n) residue is compared with the PACE4 calculations for different values of K = 8, 10, 12.

In contrast, the measured cross-sections for ^{135}Ba in the α3n channel are significantly higher than those predicted by PACE4 calculations, as shown in Fig 3, suggesting the initiation of ICF processes. The formation of ^{135}Ba could result from CF and ICF, potentially involving the breakup of ^{12}C into α and ^8Be. It is evident from Fig. 3 that experimental EF increases as incident energy increases, and the increasing trend of EF implies that the breakup probability of ^{12}C increases with incident energy. Further analysis will be conducted to explore the role of ICF in this system. The detailed results and analysis will be presented during the symposium.

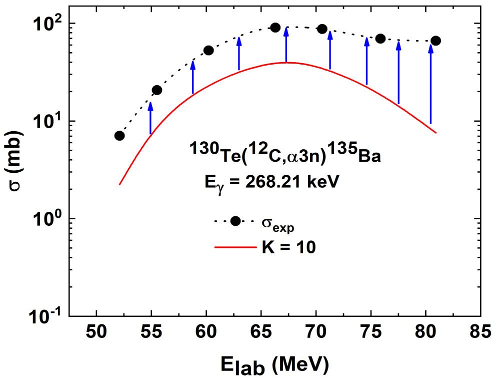

FIG. 3: The measured EF of ^{135}Ba (α3n) is compared with the PACE4 calculations for K = 10

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Acknowledgments

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References

[1] M. Gull et al., Phys. Rev. C 98, 034603 (2018).

[2] S. Ali et al., Eur. Phys. J. A 54, 56 (2018).

[3] M. S. Asnain et al., Phys. Rev. C 106, 064607 (2022).

[4] R N. Sahoo et al., Nucl. Inst. and Meth. in Phys. Res., A 935, 103-109 (2019).

[5] LISE++, https://lise.nscl.msu.edu/lise.html.