

Study of Complete and Incomplete Fusion Reaction in the Interaction of $^{12}\text{C} + ^{128}\text{Te}$ and $^{14}\text{N} + ^{128}\text{Te}$ system below 7 MeV/A.

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Abstract

In this paper, an attempt was made to measure the excitation function for the disappearance residues recognized in the interaction of $^{12}\text{C} + ^{128}\text{Te}$ and $^{14}\text{N} + ^{128}\text{Te}$ system with the observation to investigating the complete and incomplete fusion reaction dynamics in heavy ion induced reaction. The incentive of this study was break up of ^{12}C and ^{14}N in reaction below 7MeV/A and associate the excitation function for ^{12}C and ^{14}N with the same target ^{128}Te prominent different compound system. PACE-4 were used for analysis of the system, and the measured excitation functions for precise decay channel in two case i.e. ($^{12}\text{C} + ^{128}\text{Te}$ and $^{14}\text{N} + ^{128}\text{Te}$) have been associated and established in Bohr assumption in case of complete fusion channels. The properties of coulomb barrier and other entrance channel parameters were established to be relatively significant in decisive the decay mode of composite system. Additionally the incomplete fusion dynamics were also perceived to be of significant importance in present energy section.

Keywords: Complete Fusion, Incomplete fusion, non- α -emitting, α -emitting

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1. Introduction

Investigating of different reaction mechanism involved in the heavy ion (HI) induced reaction, complete (CF), incomplete fusion (ICF) and direct reaction etc sunil et al [1]. The direct reactions play an important role at higher values of impact parameter, leading to few nucleon transfer processes. However, at smaller values, complete fusion(CF) reaction in which Projectile is completely fused with the target nucleus and highly excited compound nucleus decays by evaporating low-energy nucleons and α particles, incomplete fusion(ICF) in which only a part of the projectile fuses with the target nucleus, leading to the formation of an excited incompletely fused composite system with a mass and/or charge lower than that of the CN, while the remaining part escape sin forward cone with approximately the beam velocity[2]. Various dynamical models, such as, Sum rule model [3],break-up fusion (BUF) model [4] and promptly emitted particle model [5] have been proposed to explain the mechanism of ICF reactions. However, no theoretical model is available so far fully to explain the gross features of experimental data available below $E/A=10$ MeV/nucleon. And none of the proposed models is able to reproduce the experimental data obtained at energies as low as $\approx 4-8$ MeV/nucleon. Abhishek *et al* [6] studied effect of entrance channel properties in the incomplete fusion of $^{12}\text{C} + ^{159}\text{Te}$ at energies $\approx 4-7$ MeV/A. The results indicated that incomplete fusion contribution found to be sensitive to the projectile type, energy and entrance channel mass-asymmetry.

Pushpendra *et al* [7] studied the dynamics of incomplete fusion by spin distribution of $^{16}\text{O} + ^{169}\text{Tm}$ system at ≈ 5.6 MeV/nucleon. The result showed that the measured normalized production yields of fusion-evaporation xn/ α xn-channels in good agreement with the predictions of theoretical model code PACE4. Further the study indicated that residues from the complete fusion process are strongly fed over a broad spin range, while residues from incomplete fusion process are found to be less fed and/or the populations of lower spin states are strongly hindered.

2. Formulations and computer code

There are different computer codes to calculate the theoretical excitation functions. Those are PACE4, CASCADE, ALIC-91 AND COMPLET codes. However, PACE4 predictions were found to be in good agreement for complete fusion channels for the present projectile-target system. And analysis with computer code PACE4 within consideration of Hauser-Feshbach formulation also discussed in this section [8].

2.1 PACE4 code

An analysis of experimentally measured excitation functions was also made using the theoretical predictions of the PACE4 code. The code PACE4 is based on Hauser Feshbach theory for CN-decay and uses statistical approach of CN de-excitation by Monte Carlo procedure. The code uses the BASS model for CF cross section calculation. The default optical model parameters for neutrons, protons and α -particles are used. In addition code has been modified to take into account the excitation energy dependence of the level density parameter using the prescription Kataria *et al* [9]. It should be pointed out that the ICF and PE-emission are not taken into consideration in this code. The process of de-excitation of the excited nuclei was calculated using code PACE4 which follows the correct

procedure for angular momentum coupling at each stage of de-excitation. The code PACE4 used as Monte Carlo procedure to determine the decay of sequence of an excited nucleus using Hauser-Feshbach formalism. To compare the measured EF's with theoretical predication obtained from PACE4 for possible residues populated in reaction. Cross-section are deduced using Morgenstern et al [10].

$$\sum \delta CF^{(theo)} = \sum \delta non \alpha - emit^{(exp)} + \sum \delta \alpha - emit^{(theo)} \dots \dots \dots (1)$$

$$\delta_{TF} (exp) = \sum \delta CF^{(theo)} + \sum \delta_{ICF} \dots \dots \dots (2)$$

From this cross-section of ICF

$$\sum \delta_{ICF} = \delta_{TF}(exp) - \sum \delta CF^{(theo)} \dots \dots \dots (3)$$

The ICF fraction which tells the contribution of ICF in the total process is calculated

$$P_{ICF}(\%) = \frac{\sum \delta_{ICF}}{\delta_{TF}} \times 100 \dots \dots \dots (4)$$

To see the correlations between the deduced incomplete fusion fraction and entrance channel properties (normalized projectile energy, mass-asymmetry and projectile structure) Instead of projectile energy (E_p) we used the normalized projectile energy (E_p/V_{CB}) that swallowed the effect coming from different coulomb barrier.

$$V_{CB} = \left[\frac{Z_p Z_T}{A_p^{\frac{1}{3}} + A_T^{\frac{1}{3}}} \right] \dots \dots \dots (5)$$

To see the correlation between P_{ICF} with normalized projectile velocity (V_{rel}/c)

$$V_{rel} = \sqrt{\frac{2(E_{cm} - V_{CB})}{\mu_A}} \dots \dots \dots (6)$$

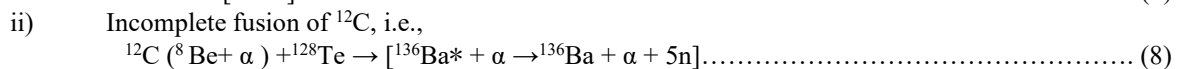
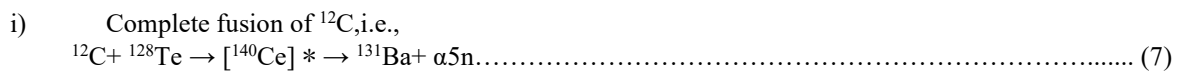
Where $\mu_A = \frac{A_p A_T}{A_T + A_p}$ And $E_{cm} = \frac{A_T}{A_T + A_p} E_{lab}$.

3 Result and Discussion

3.1 System with ^{12}C projectile

C) $^{12}\text{C} + ^{128}\text{Te}$ systems

In this system the values of the level density parameter ($K=8, 10, 12$), were diverse to fit to the experimentally restrained EFs for a illustrative of non- α -emitting ($^{12}\text{C}, 5n$) channel, in this channel also there is no probability of ICF reaction arising and consequently, this channel is inhabited only by CF process. As can be perceived from Fig. 1 (a) the PACE4 predication with $K=10$ in general imitated suitably the experimentally restrained EFs. For all conceivable channels in the reaction $^{12}\text{C} + ^{128}\text{Te}$ system all calculations and analysis existed done constantly using $K=10$. The measured EFs beside with the PACE4 estimate for illustrative residue inhabited through- α -emitting channel is displayed in Fig. 1 (b). A illustrative ^{131}Ba residue may be inhabited through CF and/or ICF processes as:



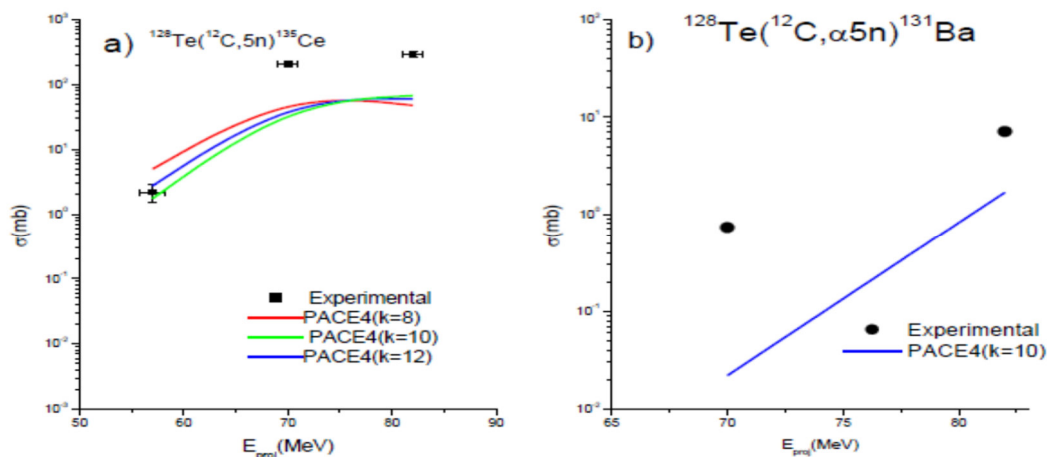


Fig.1 (a) non- α - emitted channels for (^{12}C , $5n$) and (b) alpha emitted channels for (^{12}C , $\alpha 5n$).

3.2 System with ^{14}N projectile

E) $^{14}\text{N} + ^{128}\text{Te}$ system

In $^{14}\text{N} + ^{128}\text{Te}$ system the values of the level density parameter ($K=8, 10, 12$) were varied to fit to the experimentally measured EFs for a representative non- α emitting, (^{14}N , $4n$) channel. In this channel also there is no prospect of ICF reaction occurring and therefore, this channel is populated only by CF process. As can be seen from this Fig. 2 (a) the PACE-4 prediction with $K = 12$ in general reproduced satisfactorily the experimentally measured EFs. For all possible channels in the interaction $^{14}\text{N} + ^{128}\text{Te}$ system all calculations and analysis were done consistently using $K = 12$. The measured EFs along with the PACE-4 prediction for representative residue populated via α -emitting channel is shown in Fig.2 (b). A representative ^{133}La residue may be populated through CF and/or ICF processes as:

i). Complete fusion of ^{14}N , i.e.,

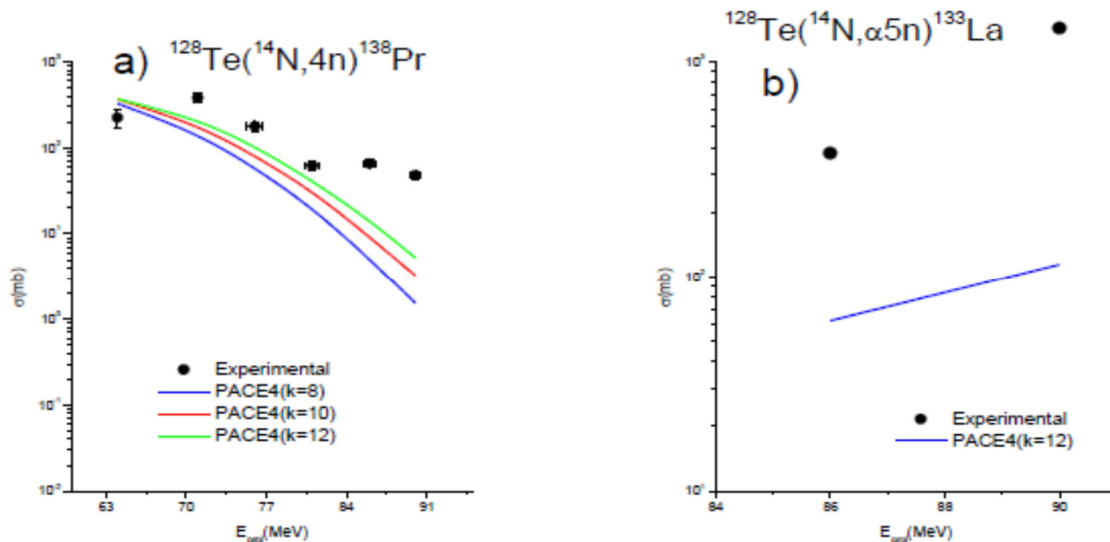
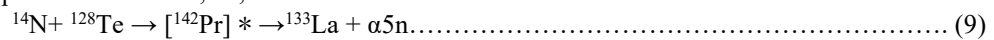
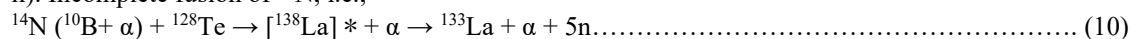


Fig.2: (a) non-alpha contaminated channels (^{14}N , $4n$) vs projectile energy and (b) alpha contaminated channel vs projectile energy (^{14}N , $\alpha 5n$).

ii). Incomplete fusion of ^{14}N , i.e.,



(α -as spectators).

3.3 Incomplete fusion contributions

In this section an attempt has been made to separate out the influences of ICF in all α -emitting channels populated in the interactions of a ^{12}C , and ^{14}N projectiles with ^{128}Te targets. The sum of the ICF cross-section for the respective systems, $\sum \delta_{ICF}$, was assigned to the difference between the higher charged isobaric precursor decay

corrected measured cross-section for possible α emitting channels, $\sum \delta \alpha^{(exp)}$ and the calculated cross-section $\sum \delta \alpha^{(theo)}$ for best fitted K value. It is clearly seen in Fig. 3 from (d) to (e) that ICF production cross-section $\delta_{ICF} = \sum \delta \alpha^{(exp)} - \sum \delta \alpha^{(theo)}$ increase significantly with increase in beam energy

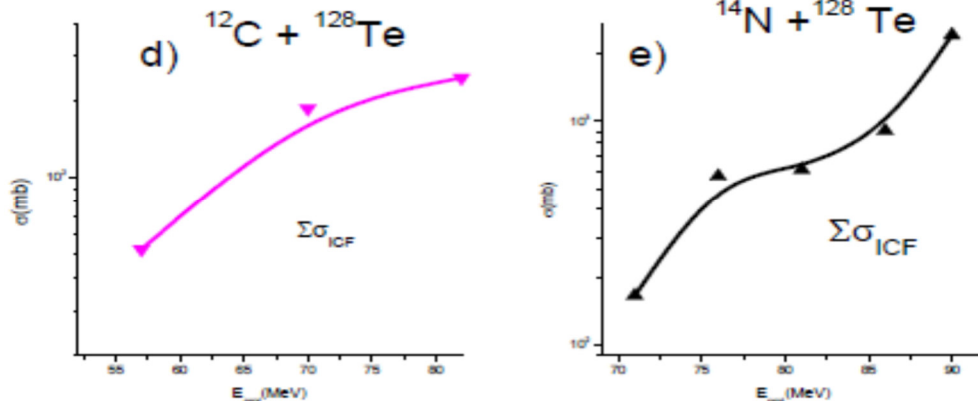


Fig.3: $\sum \delta_{ICF}$ versus E_{proj} .

It has been mentioned that all the α -emitting channels identified in the present systems are expected to have significant contributions from ICF reactions. Fig. 4 (d) and (e) displayed the sum of contributions coming from all ICF channels $\sum \delta_{ICF}$ and the sum of all CF channels $\sum \delta CF$ were plotted along with the total fusion cross-section $\sigma_{TF} = \sum \delta_{ICF} + \sum \delta CF$ for all α and non- α emitting channels in $^{12}C + ^{128}Te$ systems. As can be observed from these figure the CF components have dominant contribution up to ≈ 72 MeV, and ≈ 75 MeV for $^{14}N + ^{128}Te$, $^{12}C + ^{128}Te$ systems, respectively, while ICF contribution seems start to influence from these points

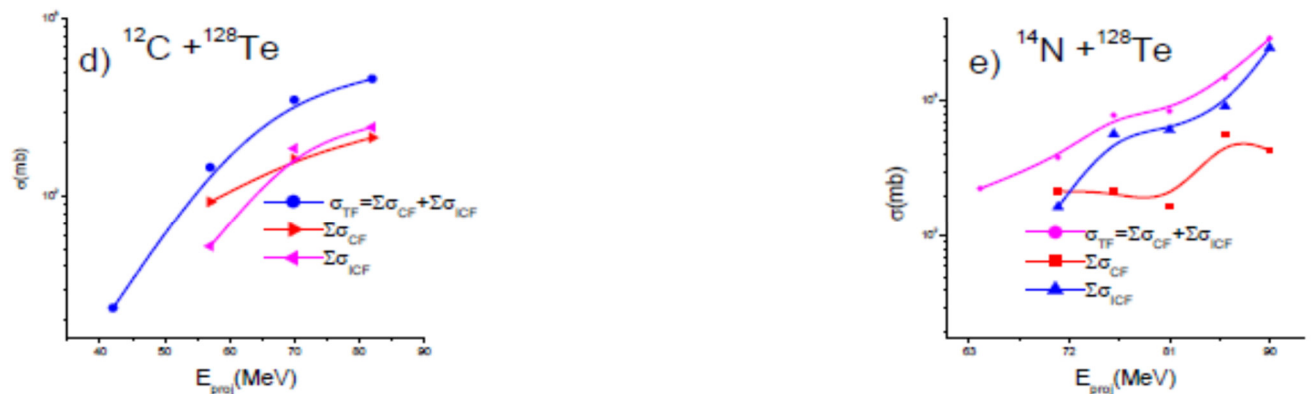


Fig.4: The total sum of the measured, σ_{TF} and the total sum of the CF cross-sections, $\sum \delta CF$ along with the total sum of ICF cross-sections, $\sum \delta_{ICF}$ at various energies. Further, except for $^{14}N + ^{128}Te$ system it is clearly seen from these figures that the separation between the plots of $\sum \delta_{ICF}$ and $\sum \sigma_{TF}$ in general decreases significantly from these points onwards with an increase in projectile energy, which indicates that the ICF contribution becomes larger at higher energy points in the respective systems. This may be due to an increase in the probability of projectile break up into α -clusters ^{14}N ($^{10}B + \alpha$) and ^{12}C ($^8Be + \alpha \rightarrow \alpha + \alpha + \alpha$) as the projectile energy increases

Conclusion

In present work, the excitation function of several evaporation residue populated through complete and incomplete fusion channels have been measured in the energy range of 3-7 MeV/A. The measured data available were compared with calculation done using the statistical model code PACE4. For illustrative of non- α -emitting channel from the experimental measured excitation functions, after correcting them for possible contributions from higher charger isobaric precursor decays, was in general found to be good agreement with the theoretical predications. However, for α -emitting channels, the measured excitation functions after correcting the HCIP contribution (if any) were significantly higher than the values predicted by PACE4.

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