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A STUDY OF COMPLETEAND INCOMPLETE REACTIONS IN OF ^{12}C +^{169}TM SYSTEM AT ENERGY RANGE ≈ 3.6–7.5 MEV/NUCLEON

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Abstract

Excitation functions of ^{169}Tm(12 C, 4n) ^{177}Re, ^{169}Tm(^{12}C, 5n) ^{176}Re, ^{169}Tm(^{12}C, n) ^{176}Ta , 169 Tm(^{12}C, 2n) ^{175}Ta , ^{169}Tm(12 C, 3n) ^{174}Ta , ^{169}Tm(^{12}C, 4n) ^{173}Ta , and ^{169}Tm(^{12}C, 22n) ^{171}Lu reaction channels populated in the interaction of ^{12}C projectile with ^{169}Tm target were considered in order to investigate the mechanisms of complete and incomplete fusion reactions. The theoretically predicted excitation functions using PACE4 code were compared with the previously measured excitation functions. For non–α emitting channels cross-section values predicted by PACE 4 in general were found to be in good agreement with the experimentally measured values. However, for α-emitting channels the measured cross-section values were found to be higher than the values predicted by PACE4. The observed disagreement may be credited to projectile break-up in the vicinity of n-n interaction.

Keywords: alpha emitted, CF reaction, excitation functions, heavy-ion fusion, ICF reaction, non-alpha emitted

1. Introduction

The study of nuclear reactions induced by heavy-ions has become a rich and growing area of nuclear physics, with future possibilities in basic and applied sciences. It provides opportunity to study exotic nuclei far from the stability line, having short-lives and small cross- sections. It is now a well-established fact that several reaction mechanisms are active in reactions induced by light-heavy projectiles, heavy-heavy projectiles at energies well above the Coulomb barrier and centrifugal potential. To establish reaction analyzing with nuclear decays and reactions we encounter lengths of the order of 10 -15m. However in nuclear particle sizes are ranging from about 1 fm for a single nucleon to about 7fm for the heaviest nuclei [1, 2].

Then now most nuclear reactions are studied by inducing a collision between two nuclei (nucleon- nucleon reaction) where one of the reacting nuclei is at rest (the target nucleus) while the other nucleus (the projectile nucleus) is in motion. Projectiles heavier than α-particle (i.e A≥4) are commonly regarded as heavy ions and become used for bombarding the target nuclei. Classically, a nuclear reaction takes place when the heavy ions are projected with sufficiently high kinetic energy to overcome the Coulomb barrier (CB) and interact with the target nuclei to understand the reaction dynamics.

One of the important aspects of HI reactions is that nuclei with large amount of angular momentum can be produced far away from the stability line. Two heavy ion interact through the Coulomb field can be scattered elastically or in-elastically with the Coulomb excitation. Nuclear interactions can only take place if the two-ion of mass with energy E_{cm} in their center-of-mass system is high enough to overcome the Coulomb barrier. Heavy ion reactions may be understood in term of an interaction potential between the centers of mass of the two colliding nuclei consisting of a repulsive Coulomb and a short range attractive nuclear forces. The understanding of the fusion reaction mechanism is one of the most important and challenging subjects of nuclear physics. It is now generally recognized that several reaction mechanisms are operative in heavy ion-induced reactions below 10 MeV/nucleon. In fact the cluster structure has been suggested as one of the factors leading to forward peaked α particles in ICF reactions. CF has been experimentally defined as the capture of total charge or mass of the incident projectile by the target nucleus. However, the first evidence of ICF reactions was presented by Kauffmann and Wolfgang [3], by studying ^{12}C+ ^{102}Rh system at energy range of 7-10 MeV/nucleon, where strongly forward peaked angular distributions of light-nuclear-particles were observed. Britt and Quinton [4], found similar observations in the ^{16}O+ ^{209}Bi reactions at energies range 7-10 MeV/nucleon. In these measurements, significantly large yield of direct α-particles of mean energy roughly corresponding to the projectile velocity at the forward cone has been observed [5 - 9].

Predominantly recent measurements of excitation function (EF), forward recoil range distribution (FRRD), spin distribution (SD) of evaporation residues etc., for a large number of ER produced in heavy ion (HI) reaction in various projectile-target combination have indicated the importance of CF and ICF processes at energies above the coulomb barrier and below 10Mev/nucleon.

In the past various studies were done on the mechanism of CF and ICF reactions. Recently Amanuel et al [10] studied the role of break up process in the fusion of the $^{12}C + ^{52}Cr$ system at several beam energies from ≈ 4-7MeV/nucleon. It was found that from non-α-emitting channels the experimentally measured excitation functions were, in general found to be in good agreement with ACE4 predicted. However, for α-emitting channels the measure EFs were higher than PACE4 predicted which is attributable for ICF reactions. Further the incomplete fusion reaction contribution was found to be sensitive to the projectile energy and mass-asymmetry of the entrance channels.

A number of studies in the past were confined to beam energies greater than 10 MeV/nucleon and the reaction mechanism have been reasonably explained by the available models. Despite a number of attempts in the past none of the available models are able to reproduce the experimental data obtained at energies as low as ≈ 4-8Mev/nucleon. There is no fully investigation is conducted on ICF processes, that is why still needs further study, especially at relatively low bombarding energy 10MeV/nucleon since a clear systematic study and complied data are available for only a few projectile target systems.

In this work the experimentally measured (EXFOR data) EFs for reactions $^{169}Tm(^{12}C, 4n)^{177}Re$, $^{169}Tm(^{12}C, 5n)^{176}Re$, $^{169}Tm(^{12}C, \alpha n)^{176}Ta$, $^{169}Tm(^{12}C, \alpha 2n)^{175}Ta$, $^{169}Tm(^{12}C, \alpha 3n)^{174}Ta$, $^{169}Tm(^{12}C, \alpha 4n)^{173}Ta$, and $^{169}Tm(^{12}C, 2\alpha 2n)^{171}Lu$ in the incident energy range 50 - 90MeV were compared with theoretical predictions based on PACE 4 [11] codes. . For predication of the measured excitation function the theoretical model of PACE 4 was used with 100000 cascades.

2. *COMPUTER CODE AND FORMULATION*

There are various computer codes such as PACE 4, CASCADE, COMPLETE CODE (modified of ALIC- 91) which are available to perform such statistical model calculations. The PACE 4 [12] code was chosen to be used in the present work since it is easily available and proved to be one of the most reliable and promising theoretical model for the compound nuclear reactions. And analysis with computer code PACE4 within the consideration of Hauser-Feshbach formulation also discussed in this section.

2.1 2.1. PACE4

The statistical model code PACE 4 (Projection Angular Momentum Coupled Evaporation 4) [11] is a modified version of JULIAN, the Hillman–Eyal evaporation code using a Monte Carlo code coupling angular momentum. The program has been ported to Windows from FORTRAN to C++ and incorporated in the LISE++ package under the name PACE 4 [12]. PACE 4 uses Monte Carlo procedure to determine the decay sequence of an excited nucleus using the Hauser Feshbach formalism [13]. The main advantage of Monte Carlo calculations is to provide correlations between various quantities, such as particles and gamma-rays or angular distribution of particles. Sequential decays are considered until any further decay is prohibited due to the energy and angular momentum conservation laws. A random number selection determines the actual final state to which the nucleus decays to and the process is, then, repeated for other cascades until all the nuclei reach the ground state [14].

To compare the measured EF's with theoretical predication obtained from PACE4 for possible residues populated in reaction. Cross-section is deduced using Morgenstern et al [15].

$$\sum \sigma_{CF}^{theo} = \sum \sigma_{non-\alpha\ emit}^{exp} + \sum \sigma_{\alpha\ emit}^{theo} \qquad 1$$

In order to extract more information regarding how ICF contributes to total fusion reaction cross-section is given by:

$$\sigma_{TF} = \sum \sigma_{CF}^{theo} + \sum \sigma_{ICF} \qquad 2$$

From this cross-section the total ICF cross-section can be found using an expression of

$$\sum \sigma_{ICF} = \sigma_{TF} - \sum \sigma_{CF}^{theo} \qquad 3$$

The enhancement from the theoretical predictions points towards the presence of ICF process in the formation of all ERs, the contribution of ICF in the formation of all α −emitting channels has been calculated as

$$\sum \sigma_{ICF} = \sum \sigma_{\alpha\ emit}^{exp} - \sum \sigma_{\alpha\ emit}^{theo} \qquad 4$$

The contribution of ICF in the formation of all $non-\alpha$ −emitting channels has not been observed due to no α cluster is populated by break up process.

$\sum \sigma_{ICF} = \sum \sigma^{exp}_{non-\alpha\ emit} - \sum \sigma^{theo}_{non-\alpha\ emit}$, but for non α emitting channel $\sum \sigma_{ICF} = 0$

i.e $\sum \sigma^{exp}_{non-\alpha\ emit} = \sum \sigma^{theo}_{non-\alpha\ emit} \Longrightarrow \sigma^{exp}_{non-\alpha\ emit} = \sigma^{theo}_{non-\alpha\ emit}$, and it is true for each individual ERs.

3. RESULT AND DISCUSSIONS

In this work the excitation functions for seven residues produced in the ^{12}C +^{169}Tm system were studied. $^{169}Tm(^{12}C, 4n)^{177}Re$, $^{169}Tm(^{12}C, 5n)^{176}Re$, $^{169}Tm(^{12}C, \alpha n)^{176}Ta$, $^{169}Tm(^{12}C, \alpha 2n)^{175}Ta$, $^{169}Tm(^{12}C, \alpha 3n)^{174}Ta$, $^{169}Tm(^{12}C, \alpha 4n)^{173}Ta$, and $^{169}Tm(^{12}C, 2\alpha 2n)^{171}Lu$ reaction channels populated via CF and ICF $\approx$50 -90MeV in the interaction of ^{12}C projectile and ^{169}Tm target. The experimentally measured excitation functions were compared with the theoretical predictions obtained from the code PACE4. The experimental cross-section and energy are obtained from IAEA data source (EXFOR) Library.

In order to show the effect of variation of *K* on calculated EFs, different values of K= 8, 10, 12 and 14 have been tested, and are shown in Fig.1 (a). Therefore in this work, a value of *K* = 8 is found to give a satisfactory reproduction of experimental data for CF-channels within the experimental uncertainties and have been chosen confidentially for other α-emitting channels. *Further list of reactions and evaporation residues which are detected in the present reaction system are given in table below.*

System of reaction	Produced Residues
$^{169}Tm(^{12}C, 4n)^{177}Re$	^{177}Re
$^{169}Tm(^{12}C, 5n)^{176}Re$	^{176}Re
$^{169}Tm(^{12}C, \alpha n)^{176}Ta$	^{176}Ta
$^{169}Tm(^{12}C, \alpha 2n)^{175}Ta$	^{175}Ta
$^{169}Tm(^{12}C, \alpha 3n)^{174}Ta$	^{174}Ta
$^{169}Tm(^{12}C, \alpha 4n)^{173}Ta$	^{173}Ta
$^{169}Tm(^{12}C, 2\alpha 2n)^{171}Lu$	^{171}Lu

Table1:- reaction and evaporation residues in interaction of ^{12}C+^{169}Tm system

3.1. Evaporation Residues Populated Through Non-α-Emitting (12C, xn) Channels

A) (^{12}C, 4n) channel

For the representative (^{12}C, 4n) channel values of the level density parameter K (K=8, 10, 12 and 14) were varied to fit the experimental data and the results are displayed in figure 4.1. The ^{177}Re residue was produced when ^{12}C projectile completely fused with ^{169}Tm target lead to the formation of excited compound nucleus $^{181}Re^*$. The excited CN, $^{181}Re^*$, decay through the emission of four neutrons that leads to the formation of isotope ^{177}Re. In reaction equation form, it is written as:

$$^{12}C + ^{169}Tm \rightarrow [^{181}Re]^* \rightarrow ^{177}Re + 4n$$

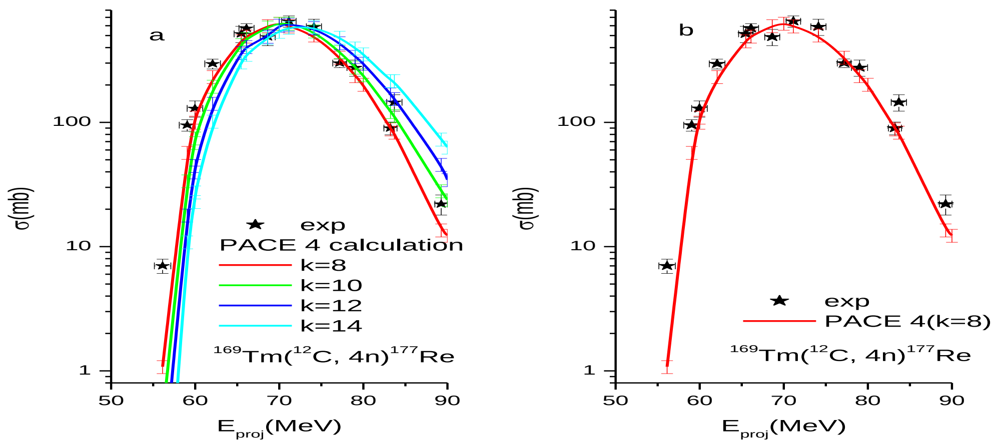

Fig 1. Experimentally Excitation function for the $^{169}Tm(^{12}C, 4n)$ ^{177}Re reaction used for studying the effect of the value of k on theoretically calculated results expected to be populated by CF compared with their theoretical prediction (PACE4) a) at different k value and b) at k=8 that has been best fitted within the energy range ≈ 3.6–7.5 MeV/nucleon.

As can see from Fig 4.1 the theoretically calculated excitation function corresponding to the level density parameter K=8 in general satisfactorily reproduced the experimentally measured EFs for residue ^{177}Re produced in the CF of ^{12}C projectile with ^{169}Tm target. In the present calculation a value of K=8 will be used for all other residues populated in $^{12}C + ^{169}Tm$ system. Further it may be mentioned that the general trends and shape of the measured EFs for the CF residues populated 4n channels are satisfactorily reproduced by PACE 4 calculations with uncertainties for entire energy region as shown in Fig1.

B) (^{12}C, 5n) channel

The ^{176}Re residue was produced when ^{12}C projectile completely fused with ^{169}Tm target lead to the formation of excited compound nucleus ^{181}Re*. The excited CN, ^{181}Re*, decay through the emission of five neutrons that leads to the formation of isotope ^{176}Re. In reaction equation form, it is written as:

$$^{12}\mathrm{C} + ^{169}\mathrm{Tm} \rightarrow [^{181}\mathrm{Re}]^{*} \rightarrow ^{176}\mathrm{Re} + 5\mathrm{n}$$

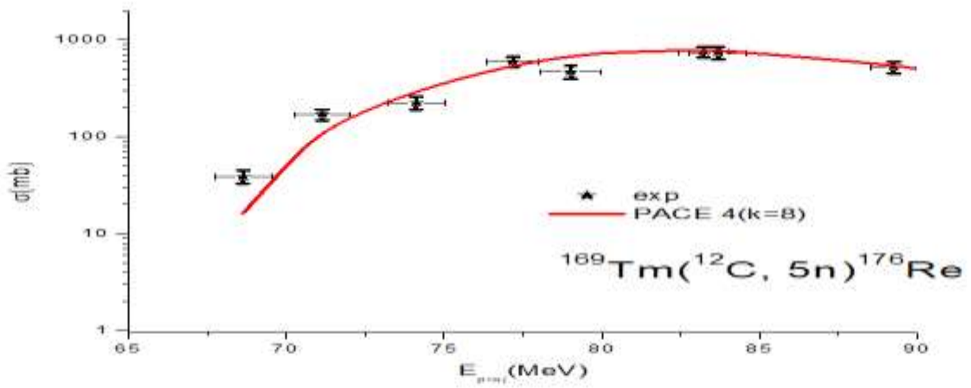

Fig 2. Experimentally Excitation function for the ^{169}Tm(^{12}C, 5n) ^{176}Re reaction populated by CF compared with their theoretical prediction (PACE4) at k=8 within the energy range ≈ 3.6–7.5 MeV/nucleon.

The experimentally measured EFs along with theoretical predictions obtained using the PACE 4 code residues populated via non α-emitting channels (^{12}C, 5n) is shown in Fig2. The theoretically calculated excitation function corresponding to the level density parameter K=8 in general satisfactorily reproduced the experimentally measured EFs for residue ^{176}Re produced via the CF of ^{12}C projectile with ^{169}Tm target.

Evaporation Residues Populated Through α- emitting (^{12}C, αxn) channels

A) (^{12}C, αn) channel

The ^{176}Ta residue was produced when ^{12}C projectile completely fused with ^{169}Tm target lead to the formation of excited compound nucleus ^{181}Re* and ^{12}C incompletely fused with ^{169}Tm lead to the formation of composite system ^{177}Ta. This residue may be formed via CF and/or ICF in interaction of ^{12}C with ^{169}Tm following two processes. i). In case of CF, the composite system ^{181}Re*, decay through the emission of one α cluster and one neutrons that leads to the formation of isotope ^{176}Ta. ii) The same residue is formed by ICF of ^{12}C breaks in to α+^{8}Be and ^{8}Be fuses with the target leaving α as spectator to form an incompletely fused composite system [^{177}Ta]* may then decay via one neutrons (n).

In reaction equation form, it is written as:

I. Complete fusion (CF) of ^{12}C:

$^{12}C + {}^{169}Tm \rightarrow [{}^{181}Re]^* \rightarrow {}^{176}Ta + \alpha\ n$

Where α is as participant, not as spectator.

II. Incomplete fusion (ICF) of ^{12}C

$^{12}C(8Be + \alpha) + {}^{169}Tm \rightarrow \alpha + [{}^{177}Ta]^* \rightarrow {}^{176}Ta + \alpha + n$

(α as a spectator which is not participate on the reaction).

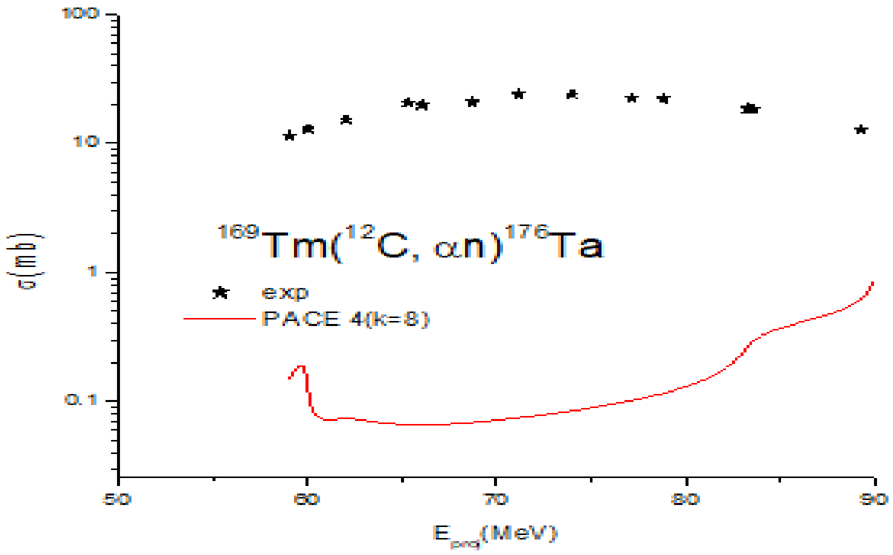

Fig 3. Experimentally Excitation function for the ^{169}Tm(^{12}C, αn)^{176}Ta reaction compared with their theoretical prediction (PACE 4).

As can be seen from Fig 3, the experimentally measured EFs are higher as compared to the theoretical predictions. Since the PACE 4 code doesn't take ICF in to account, therefore the enhancement in the experimentally measured cross sections are attribute to the contribution of ICF of ^{12}C with ^{169}Tm target.

B) (^{12}C, $\alpha 2n$) channel

The ^{175}Ta residue was produced when ^{12}C projectile completely fused with ^{169}Tm target lead to the formation of excited compound nucleus $^{181}Re^*$ and ^{12}C incompletely fused with ^{169}Tm lead to the formation of composite system ^{177}Ta. This residue may be formed via CF and/or ICF in interaction of ^{12}C with ^{169}Tm following two processes. i) In case of CF, the composite system $^{181}Re^*$, decay through the emission of one α cluster and two neutrons that leads to the formation of isotope ^{175}Ta. ii) The same residue is formed by ICF of ^{12}C breaks in to α+^{8}Be and ^{8}Be fuses with the target leaving α as spectator to form an incompletely fused composite system $[^{177}Ta]^*$ may then decay via two neutrons (2n).

In reaction equation form, it is written as:

I Complete fusion(CF) of ^{12}C:

$$^{12}C + {}^{169}Tm \longrightarrow [^{181}Re]^* \longrightarrow {}^{175}Ta + \alpha 2n$$

(α is as participant in the reaction, not as spectator)

II Incomplete fusion(ICF) of ^{12}C:

$$^{12}C(^{8}Be + \alpha) + {}^{169}Tm \longrightarrow \alpha + [^{177}Ta]^* \longrightarrow {}^{155}Ta + \alpha + 2n$$

(α as a spectator , which is not participate on the reaction).

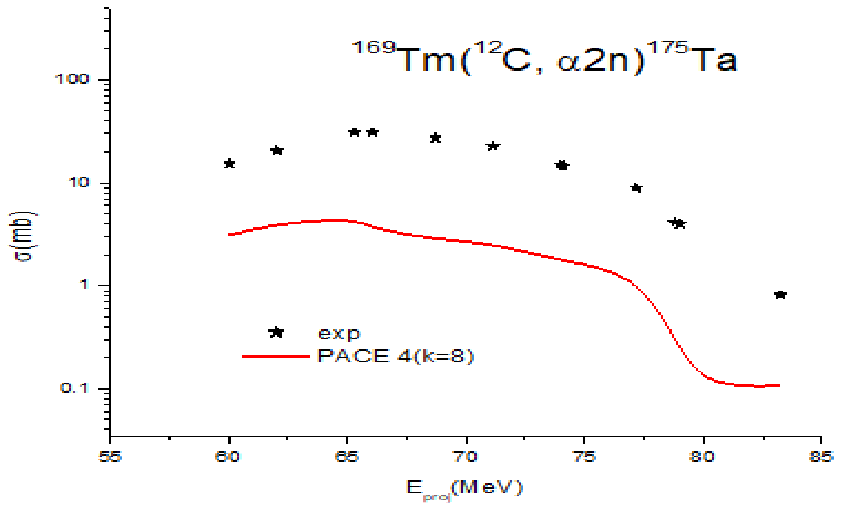

Fig 4. Experimentally Excitation function for the $^{169}Tm(^{12}C, \alpha 2n)^{175}Ta$ reaction compared with their theoretical prediction (PACE4).

As can be seen from Fig 4, the experimentally measured EFs are higher as compared to the theoretical predictions. As such, it may again be inferred that major contribution of the enhancement for the production of these residues comes from ICF processes, which are not considered in these calculations in the interaction of ^{12}C with ^{169}Tm target.

C) (^{12}C, $\alpha 3n$) channel

The ^{174}Ta residue was produced when ^{12}C projectile completely fused with ^{169}Tm target lead to the formation of excited compound nucleus $^{181}Re^*$ and ^{12}C incompletely fused with ^{169}Tm lead to the formation of composite system ^{177}Ta. This residue may be formed via CF and/or ICF in interaction of ^{12}C with ^{169}Tm following two processes. i) In case of CF, the composite system $^{181}Re^*$, decay through the emission of one α cluster and three neutrons that leads to the formation of isotope ^{174}Ta. ii) The same residue is formed by ICF of ^{12}C breaks in to α+^{8}Be and ^{8}Be fuses with the target leaving α as spectator to form an incompletely fused composite system $[^{177}Ta]^*$ may then decay via two neutrons (3n).

In reaction equation form, it is written as:

I Complete fusion (CF) of ^{12}C:

$$^{12}C + {}^{169}Tm \longrightarrow [^{181}Re]^* \longrightarrow {}^{174}Ta + \alpha 3n$$

(α is as participant, not as spectator).

II Incomplete fusion(ICF) of ^{12}C:

$$^{12}C(8Be + \alpha) + {}^{169}Tm \rightarrow \alpha + [^{177}Ta]^* \rightarrow {}^{174}Ta + \alpha + 3n$$

(α as a spectator which is not participate on the reaction).

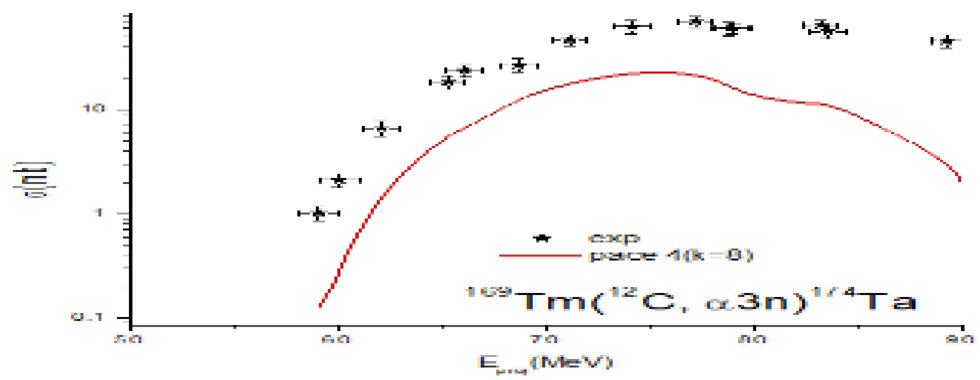

Fig 5. Experimentally Excitation function for the $^{169}Tm(^{12}C, \alpha 3n)^{174}Ta$ reaction compared

with their theoretical prediction (PACE4).

The experimentally measured cross-section is relatively higher than the theoretical predictions as shown from Fig 5. Since the code PACE4 doesn't take ICF into account, therefore the enhancement in the experimentally measured cross-sections are attributable to the contributions of ICF of ^{12}C with ^{169}Tm target.

D) (^{12}C, α4n) channel

The ^{173}Ta residue was produced when ^{12}C projectile completely fused with ^{169}Tm target lead to the formation of excited compound nucleus $^{181}Re^{*}$ and ^{12}C incompletely fused with ^{169}Tm lead to the formation of composite system ^{177}Ta. This residue may be formed via CF and/or ICF in interaction of ^{12}C with ^{169}Tm following two processes. i) In case of CF, the composite system $^{181}Re^{*}$, decay through the emission of one α cluster and four neutrons that leads to the formation of isotope ^{173}Ta. ii) The same residue is formed by ICF of ^{12}C breaks in to α+^{8}Be and ^{8}Be fuses with the target leaving α as spectator to form an incompletely fused composite system $[^{177}Ta]^{*}$ may then decay via four neutrons (4n).

In reaction equation form, it is written as:

I. Complete fusion(CF) of ^{12}C

$$^{12}C + {}^{169}Tm \longrightarrow [^{181}Re]^{*} \longrightarrow {}^{173}Ta + \alpha 4n$$

Where α is as participant not as spectator.

II. Incomplete fusion(ICF) of ^{12}C

$$^{12}C(^{8}Be + \alpha) + {}^{169}Tm \longrightarrow \alpha + [^{177}Ta]^{*} \longrightarrow {}^{173}Ta + \alpha + 4n$$

α as a spectator which is not participate on the reaction(act as observer).

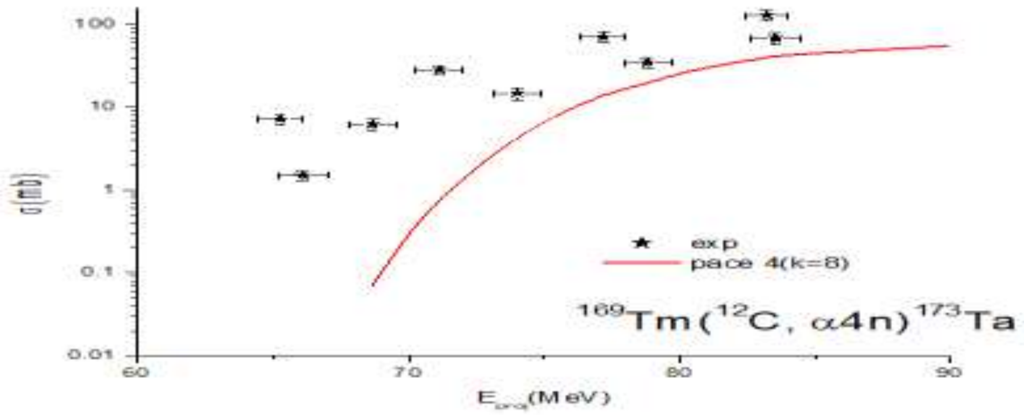

Fig 6. Experimentally Excitation function for the ^{169}Tm(^{12}C, α4n)^{173}Ta reaction compared with their theoretical prediction (PACE4).

The experimentally measured cross-section exhibit a significant enhancement compared to the theoretical predictions as can be seen from fig 6. As such, it may again be inferred that major contribution of this enhancement comes from ICF processes, which are not considered in these calculations.

E) (^{12}C, $2\alpha 2n$) channel

The ^{171}Lu residue was produced when ^{12}C projectile completely fused with ^{169}Tm target lead to the formation of excited compound nucleus ^{181}Re* and ^{12}C incompletely fused with ^{169}Tm lead to the formation of composite system ^{173}Lu. This residue may be formed via CF and/or ICF in interaction of ^{12}C with ^{169}Tm following two processes. i) In case of CF, the composite system ^{181}Re*, decay through the emission of one 2α cluster and two neutrons that leads to the formation of isotope ^{171}Lu. ii) The same residue is formed by ICF of ^{12}C breaks in to ^{8}Be($\alpha + \alpha$) $+\alpha$ and α fuses with the target leaving ^{8}Be as spectator to form an incompletely fused composite system [^{173}Lu]* may then decay via two neutrons (2n).

In reaction equation form, it is written as:

I. Complete fusion (CF) of ^{12}C:

$$^{12}\mathrm{C} + {}^{169}\mathrm{Tm} \longrightarrow [^{181}\mathrm{Re}]^{*} \longrightarrow {}^{171}\mathrm{Lu} + 2\alpha 2\ \mathrm{n}$$

(2α is as participant in the reaction system, not as spectator).

II. Incomplete fusion (ICF) of ^{12}C:

$$^{12}C(\ \alpha + {}^{8}Be(\alpha\ + \alpha\ )) + {}^{169}Tm \longrightarrow 2\alpha\ + [^{173}Lu]^{*} \longrightarrow {}^{171}Lu + 2\alpha\ + 2n$$

(2α as a spectator which is not participate on the reaction)

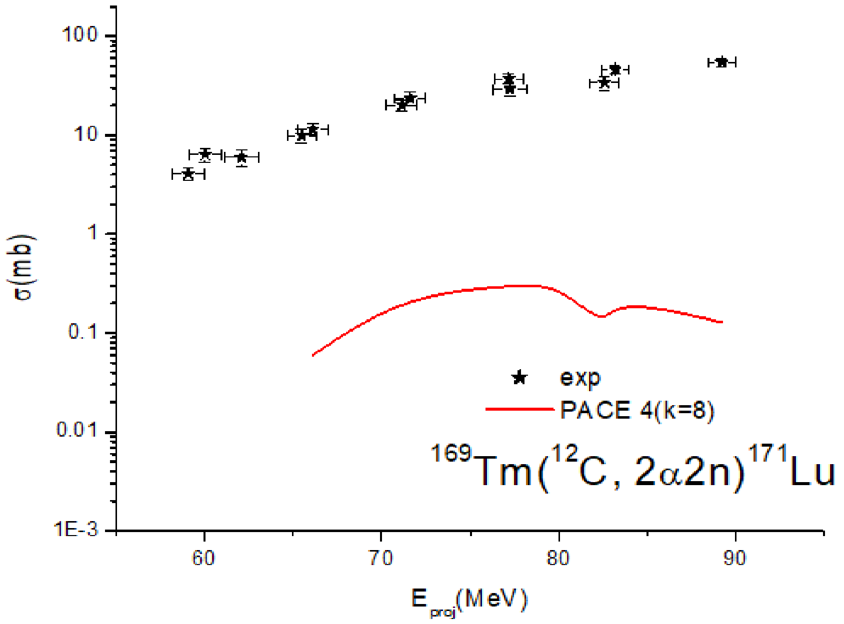

Fig 7. Experimentally Excitation function for the $^{169}Tm(^{12}C,\ 2\alpha 2n)^{171}Lu$ reaction compared with their theoretical prediction (PACE4).

In case of reaction $^{169}Tm(^{12}C,\ 2\alpha 2n)^{171}Lu$, as can been seen from Fig.7 the experimentally measured EF exceeds the theoretical EF, which again indicates that ICF plays an important role. Since, theoretical calculations of PACE 4 does not take into account the ICF, it may be inferred that a significant part of these reactions involving 2α -emission channels go through ICF largely, at these energies.

Further it is obvious that α-emitting channels have contributions coming from ICF reactions. Fig 8.displayed the sum of experimentally measured cross section $\sum \sigma_{\alpha}(\text{exp})$, along with the sum of PACE4 cross section $\sum \sigma_{\alpha}(\text{Theo})$, As can be seen from this figure there is a clear gap between these two values which is attributable to the contribution coming from ICF reactions. Further from this figure the increasing separation between $\sum \sigma_{\alpha}(\text{exp})$ and $\sum \sigma_{\alpha}(\text{Theo})$ indicates that when projectile energy is increased the contribution of the ICF also relatively increased.

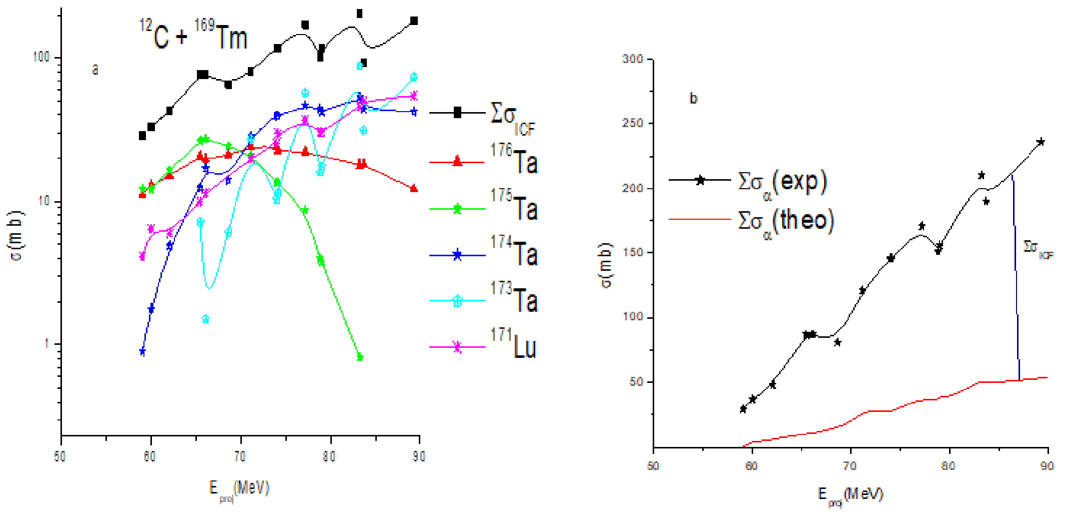

Fig 8. Sum of experimentally measured EFs of channels ($\sum \sigma_{\alpha xn+2\alpha 2n}^{exp}$) are compared with that predicted by statistical model code PACE4 ($\sum \sigma_{\alpha xn+2\alpha 2n}^{pace\ 4}$).

4. ***CONCLUSION***

In this work, the excitation function of $^{176,\ 177}$Re, ^{173,174,175,176}T a and ^{171}Lu evaporation residues produced via CF and/or ICF reactions in the interaction of ^{12}C projectile with 169Tm target at energies ≈ 4.67 - 7.5MeV/nucleon were studied. The experimentally measured EFs were compared with theoretical calculations done using the PACE4 code. For non-α emitting channels the experimentally measured production cross-sections were found to be in good agreement with theoretical. In such reactions a case we expect the projectile is completely fused with the target, which is a mechanism that can be effectively described by PACE4. However for α emitting channel the theoretical predictions did not reproduce the experimental measured EFs. The observed enhancement may be attributed to the ICF processes from break-up of ^{12}C projectile. ^{12}C projectile breaks into ^{8}Be and an- particle, and ^{8}Be fragment fuses with ^{169}Tm, forming the incompletely composite nucleus, followed by the emission of neutrons and α-particle. The present analysis showed that in heavy-ion induced reaction mechanisms study, the contribution from ICF is an important component of fusion reactions in particular at higher energy points. Furthermore, the present study showed ICF cross-section in general increases with increase in projectile energy. So it may be possible to conclude that complete and incomplete fusion reaction play important roles in heavy ion induced reaction mechanism studies.

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