Incomplete fusion studies in ^{14}N + ^{175}Lu system

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Introduction

Heavy ion (HI) reactions involve interaction of large amount of nuclear matter giving rise to a variety of phenomena [1]. Fusion in the HI collisions has got a central importance and has been studied extensively spanning large range of kinematical quantities [2]. In case of complete fusion (CF), a fully equilibrated compound nucleus (CN) with the entrance channel kinetic energy and angular momentum getting distributed among all the accessible degrees of freedom of the composite system is formed. Here, due to the small driving input angular momentum ($\ell \leq \ell_{crit}$), projectile completely fuses with the target nucleus involving entire mass, charge and linear momentum transfer. However, if the angular momentum (ℓ) of the composite system is not sustainable, the projectile breaks-up into constituents. One of the fragments fuses with the target nucleus while the remnant goes on moving in the forward cone as spectator. This type of process is referred to as break-up fusion (BUF) or incomplete fusion (ICF) [3]. Being a very stable and tightly bound structure, α-particle is generally favored as an emitted particle in ICF reactions. As such, the residues populated in HI interaction via α-emission are and remain the candidates for the quantitative studies of ICF. With a view to investigate low energy incomplete fusion reactions, excitation functions (EFs) for several *xn, pxn, αxn, 2αxn* and *2αpxn*-channels populated in ^{14}N + ^{175}Lu system have been measured at ≈ 4-7 MeV/A energies and analyzed in the framework of theoretical model code PACE4 [4]. It may be remarked that this system has been studied for the first time.

Experimental Methodology

The experiments were performed at the Inter University Accelerator Centre, New Delhi using the 15UD pelletron accelerator facility. Beam of ^{14}N was bombarded on the stack of ^{175}Lu target foils of thickness ≈ 1.5 mg/cm^2 backed by Al-catcher foils of sufficient thickness. Three stacks each consisting of four target foils were irradiated separately to cover a broad energy range. The stacked foil activation technique followed with offline γ-ray spectroscopy has been used.

Results and Discussion

The EFs of ten reactions viz., ^{175}Lu(^{14}N, 3n)^{186}Pt, ^{175}Lu(^{14}N, 4n)^{185}Pt$^{(g+m)}$, ^{175}Lu(^{14}N, 5n)^{184}Pt, ^{175}Lu(^{14}N, p3n)^{185}Ir, ^{175}Lu(^{14}N, p4n)^{184}Ir, ^{175}Lu(^{14}N, α2n)^{183}Os, ^{175}Lu(^{14}N, α3n)^{182}Os, ^{175}Lu(^{14}N, αp3n)^{181}Re, ^{175}Lu(^{14}N, 2α4n)^{177}W, and ^{175}Lu(^{14}N, 2αp2n)^{178m}Ta have been measured. The measured EFs have been compared with the calculations done using the statistical model code PACE4 to separate out the ICF contribution as it takes into account CF only. To reproduce the EFs of xn-channels using

PACE4, different values of the level density parameter K were tested by varying it. The best results for the reproduction of EFs were obtained for K = 8 especially for *4n* and *5n*-channels. An enhancement in the high energy tail portion in the EF of ^{186}Pt (3n)-channel has been observed and may be attributed due to pre-equilibrium emission. Further, the experimental EFs of all the α-emitting channels are found to be enhanced as compared to the theoretical calculations, of PACE4, carried out using the same set of parameters as that used for reproducing EFs of *xn*-channels. Of all the EFs obtained for the five *α*-emitting channels, PACE4 underpredicted the cross-sections for three channels ^{175}Lu(^{14}N, α2n)^{183}Os, ^{175}Lu(^{14}N, α3n)^{182}Os and ^{175}Lu(^{14}N, αp3n)^{181}Re, whereas negligible cross-sections were provided by the code for the other two reactions populated by 2α-emission i.e., ^{175}Lu(^{14}N, 2α4n)^{177}W and ^{175}Lu(^{14}N, 2αp2n)^{178m}Ta. The population of these two residues may be attributed entirely due to the ICF process. As a typical example, EF for ^{182}Os (*α3n*)-channel is shown in Fig. 1. The observed enhancement in the experimental EFs is a reminiscent of the fact that ICF process is at play in populating the α-channels besides the usually considered process of CF. In the same way significant enhancement has been observed for all the α-emitting channels.

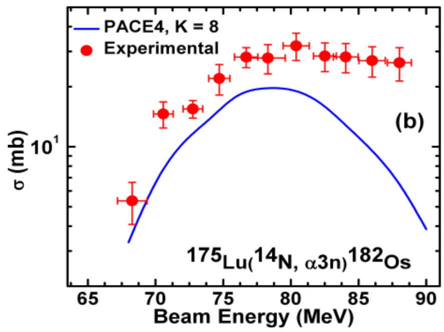

Fig. 1 Experimental EF for ^{182}Os (α3n) showing enhancement in comparison to PACE4.

In order to get the contribution of ICF process in the population of the *α*-emitting channels, the theoretically calculated cross-sections (CF values) were subtracted from their corresponding experimental data. The relative probability of ICF in fusion dynamics, obtained in terms of incomplete fusion strength function (F_{ICF}) has also been deduced. A plot of F_{ICF} as a function of effective relative velocity of collision (v_{rel}) is shown in Fig. 2. As can be seen from the figure, the ICF contribution is distributed over the entire range with different magnitudes and increases to ≈ 12% at the highest studied energy. Comparative analysis of ICF probability of the present system were performed with other systems $^{12, 13}$C ,^{19}F + ^{175}Lu in terms of the procedure suggested by Morgenstern *et al.* [5]. The effect of Q_α-value of the projectile on ICF was found to be in line with the literature[6] indicating the effect of projectile structure on the probability of occurrence of ICF for the present system as well. Further details will be presented.

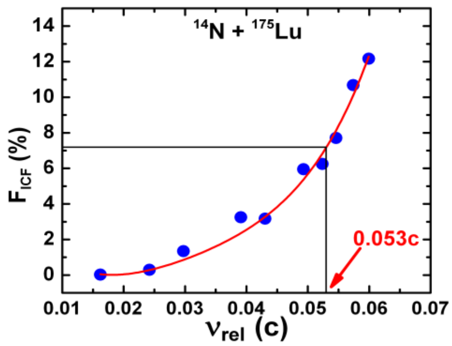

Fig. 2 F_{ICF} deduced from the analysis of EFs has been plotted as a function of effective relative velocity.

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