Incomplete Fusion in ^{19}F+^{175}Lu interactions at energies ≈ 4 – 6 MeV/A

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Introduction

The study of heavy-ion (HI) induced reactions has been used as an important tool to understand the reaction mechanism at energies near and above the Coulomb barrier [1-7]. The complete fusion (CF) and incomplete fusion (ICF) have been found to be important reaction processes at projectile energies ≈ 4 -6 MeV/A, where CF is expected to be the sole contributor. In case of CF, two HIs interact to form a statistically equilibrated compound nucleus (CN), which may further decay by the emission of particles followed by gamma transitions. On the other hand, in case of ICF, the projectile may break up into fragments, one of the fragment fuses with the target nucleus and forms an incompletely fused composite system, while the other one moves at forward angles with almost the projectile velocity. Many experimentalists reported [3-7] a large fraction of ICF at projectile energies ≈ 4 -6 MeV/A. Hence, the presence of ICF at slightly above barrier energies triggered the great interest to study ICF at these energies. The first evidence of ICF reaction in terms of massive transfer reactions was presented by Kauffmann and Wolfgang for the system ^{12}C + ^{nat}Rh at energies ≈ 7-10 MeV/nucleon [8]. In order to understand such massive transfer or ICF reactions, several models and theories have been proposed. These explanations fit with data up to some extent at energies ≤ 10MeV/A, but at relatively low bombarding energies these theories do not give satisfactory reproduction of experimental data. Due to the lack of reliable theoretical models at low projectile energies, the investigation of ICF reaction dynamics is still an interesting area for nuclear research. For better understanding of ICF over CF processes at low energies it is required to have large amount of precise data for different projectile-target combinations. In the present work, our recently performed experiment for the ^{19}F + ^{175}Lu system and results from it are presented in the energy range ≈ 4-6 MeV/A. It may be pointed out that there is no theoretical model available to explain the ICF data satisfactorily.

Experimental Methodology

The experiments have been performed at the Inter University Accelerator Centre (IUAC), New Delhi, India. Energetic $^{19}F^{8+}$ beam was obtained from the 15UD pelletron accelerator and spectroscopically pure targets (^{175}Lu) of thickness ≈ 1.2-2.0 mg/cm^2 were used. The stacked foil activation technique is used to measure the excitation functions (EFs). Each target of ^{175}Lu was backed with an Aluminum foil of suitable thickness. The thickness of targets and catcher foils was measured by the α-transmission method. Irradiations were carried out in the General Purpose Scattering Chamber (GPSC) which has an invacuum transfer facility (ITF). In the present work two stacks were irradiated at two different energies. The first stack had four catcher-foil assemblies, therefore at a single irradiation, we have four energies at the center of the targets i.e. 110 ± 1.4, 101.72 ± 1.7, 93.08 ± 1.3 and 84.93 ± 1.6 MeV. Whereas, the other stack had three catcher foils assemblies to have energies 105 ± 1.3, 96.82 ± 1.3 and 87.72 ± 1.4 MeV on the targets. The produced activities were recorded by a pre-calibrated

HPGe detector of 100 c.c. active volume coupled to a PC through CAMAC based candle software for data acqution. The reaction residues produced in the interaction of ^{19}F + ^{175}Lu were identified by their characteristic γ rays and further confirmed by decay curve analysis.

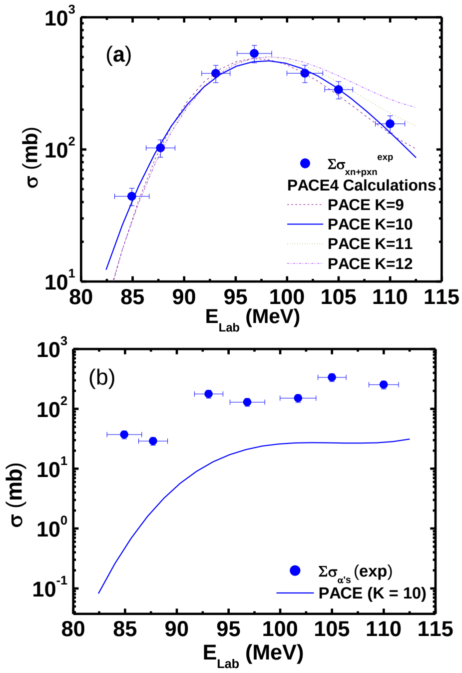

Fig. 1 (a) Sum of CF cross-sections for the xn and pxn channels. (b) Sum of cross-sections for the α emitting channels as a function of projectile energy for the system ^{19}F + ^{175}Lu .

Results and Discussions

In the present work several reaction residues populated via CF and/or ICF viz; $^{175}Lu(^{19}F,3n)$ ^{191}Hg , ^{175}Lu $(^{19}F,4n)$ ^{190}Hg , ^{175}Lu $(^{19}F,5n)$ ^{189}Hg , ^{175}Lu $(^{19}F,p4n)$ ^{189}Au, ^{175}Lu $(^{19}F,\alpha2n)$ ^{188}Pt , ^{175}Lu $(^{19}F,\alpha3n)$ ^{187}Pt , ^{175}Lu $(^{19}F,\alpha4n)$ ^{186}Pt, $^{175}Lu(^{19}F,2\alpha3n)^{183}Os$, ^{175}Lu $(^{19}F,2\alpha4n)^{182}Os$, ^{175}Lu $(^{19}F,2\alpha p3n)^{182}Re$ and ^{175}Lu $(^{19}F,2\alpha p4n)$ ^{181}Re have been identified. The experimental cross sections have been measured and compared with the theoretical calculations done with the code PACE4 for several values of level density parameter (a = A/K). It may be mentioned that the PACE4 is based on Hauser-Feschbach theory of CN decay. It uses the statistical approach of CN de-excitation by Monte – Carlo procedure. In PACE4 the level density parameter a (=A/K) is an important parameter. In the present work, we tested level density parameter values from K = 9 to K = 12. It has been found that for K = 10, the sum of experimental cross sections for xn and pxn channels satisfactorily matches with the PACE4 calculations. For the sake of completeness, the $\sum\sigma^{exp}_{(xn+pxn)}$ and corresponding $\sum\sigma_{PACE4}$ values are shown in Fig. 1(a), where predictions of PACE4 with K = 10 are found to be reproduced well. This confirms the production of these residues by the CF mode only. However, the sum of experimentally measured cross-sections for the α emitting channels i.e. $\sum\sigma(^{exp)}_{(\alpha's)}$ are found to be significantly enhanced over the theoretically calculated values by PACE4 as shown in Fig 1(b). This enhancement may be attributed due to the ICF process. The further analysis is underway. The details of findings will be presented.

Acknowledgements

The authors thank to the Chairperson, Department of Physics & the Director, IUAC, New Delhi, India for providing all the necessary facilities. V.R.S, B.P.S, A.V.A and M.S. thanks to the DST (SR/S2/HEP-30/2012) for financial assistance.

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