Measurement and analysis of mass distribution of fission like events in ^{19}F + ^{169}Tm system at low energies

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Study of fission like events associated with high spin matter produced in heavy ion (HI) interactions at high and intermediate energies has been a topic of interest during the last couple of decades. Recent experimental data [1] shows the presence of nuclear fission like events even at low energies, where fusion is expected to be the dominating process. Depending upon the available excitation energy and other entrance channel parameters [2], the formation of heavy systems may take place via two channels viz., (i) complete fusion (CF) and (ii) incomplete fusion process. The heavy composite system so formed may undergo fission [3] leading to the intermediate mass fragments. During the last decade or so considerable attention has been paid to investigate the fusion-fission reactions at relatively lower energies. Experimental study of fission like events at low energies have been carried out covering a wide range of fissility factor (Z^2/A), excitation energy, angular momentum and other entrance channel parameters, leading to the development of various theoretical models [4]. However, due to lack of experimental data, in particular, around actinide region, a proper systematics for fission dynamics in HI interactions is still unclear and requires a comprehensive investigation with more projectile and target combinations.

In the present work, the cross-sections of 22 fission like residues ($67 \leq A \leq 156$) likely to be populated in ^{19}F + ^{169}Tm system via fission of residues populated through CF and/or ICF processes at three incident energies viz., 92.0 ± 1.8 MeV, 102.5 ± 1.5 and 105.2 ± 1. 6 MeV have been measured. From the analysis, isotopic yield and the mass distribution of fission like residues have been deduced. The deduced mass variance of the fission like residues have been compared with literature data and its dependence on various entrance channels parameters has been studied. The excitation functions (EFs) of evaporation residues (ERs) populated in ^{19}F + ^{169}Tm via CF and/or ICF processes have also been measured and analyzed within the framework of statistical model code PACE4 and reported in Ref. [5].

To measure the production cross-sections of fission like residues populated in ^{19}F + ^{169}Tm system, the experiments were carried out at the Inter University Accelerator Centre (IUAC), New Delhi. The ^{19}F beam produced by the 15UD pelletron accelerator is allowed to focus on ^{169}Tm targets. An activation technique followed by off-line gamma ray spectroscopy has been used. Isotopically pure ^{169}Tm targets (thickness ≈ 1.0-2.0mg/cm^2) and Al-catcher foils (thickness ≈ 1.5-2.5mg/cm^2) were prepared by the rolling technique. In the present experiment, three stacks (each consisting of three target-catchers foils assemblies) were irradiated separately at incident energies 92.0 ± 1.8 MeV, 102.5 ± 1.5 and 105.2

± 1. 6 MeV. The target foils that got irradiated at the highest energy of each stack were used for analyzing the fission fragments. The irradiations were carried out in the General Purpose Scattering Chamber (GPSC) [6]. The activities induced in the samples have been recorded separately using a pre-calibrated single HPGe detector coupled to a CAMAC based data acquisition system CANDLE. The detailed description of experimental methodology is reported in Ref. [4]

In the present work, the cross-sections of 22 fission products (67 ≤ A ≤ 156) likely to be populated in ^{19}F + ^{169}Tm system via fissioning of residues populated via CF and/or ICF processes have been identified and their production cross-section have been measured. The analysis of data has been done to obtain the dispersion parameters to study the isotopic yield and isobaric charge distribution of Indium (In) and Neodymium (Nd) isotopes. The mass distribution of fission fragments which is an important post fission observable that directly related to the collective dynamics of fission process is found to be symmetric and broad which manifest the production of these fission like residues via de-excitation of the compound nucleus. A strong dependence of mass variance of fission like residues on excitation energy and entrance channel mass asymmetry has been observed. Further, the dependence of fission fragments mass variance on grazing angular momentum (ℓ_{graz}) and excitation energy (E^*) for the two system ^{12}C + ^{169}Tm [7] and ^{19}F +^{169}Tm [4] has also been studied. It has been observed that at same value of excitation energy and grazing angular momentum (ℓ_{graz}), the deduced mass variance for the two systems are distinctly different. This may be due to the entrance channel effects, if any. Fig. 1 presents the distribution of production cross-section of all identified residues formed in the interaction of ^{19}F + ^{169}Tm system. In HI induced reactions, the variation of cross-section with atomic mass number 'A' may have three components due to (i) CF and/or ICF residues, (ii) fission-like residues, and (iii) few nucleon transfer residues or projectile-like fragments (PLFs). As can be seen from this figure, at lower mass region, the PLFs could not be detected due to their relatively higher-energy and very short half-lives. However, at intermediate range masses, the distribution is found to be broad and symmetric, whereas, the narrow peak at higher masses indicates the formation of residues via CF and/or ICF. Further details regarding measurements and analysis will be presented.

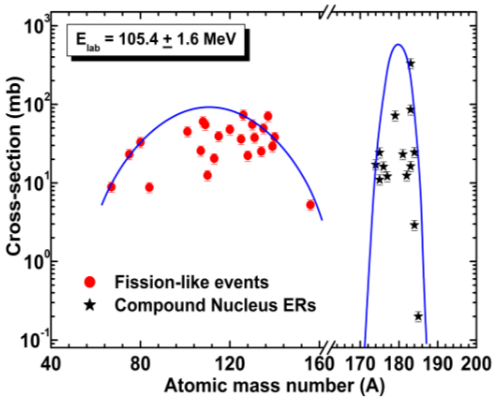

Fig.1 Mass distribution of identified fission fragments and evaporation residues populated via complete fusion and/or incomplete fusion at E_{lab} = 105.2 ± 1.6 MeV. The solid line is the Gaussian fitting.

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