Observation of fission-like events in ^{193}Ir(^{12}C,x)^{205}Bi system at moderate excitation energies

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A comprehensive understanding of heavy ion-induced fusion-fission dynamics is vital for synthesizing new super-heavy elements, nuclear astrophysics, and producing new isotopes for medical applications. Generally, fusion-fission, transfer/breakup triggered fission, and incomplete fusion-fission dominate at energies around 8-10 MeV/A. In heavier systems, however, the excited compound nucleus may undergo fission and become more dominant as the fissility (Z^2/A) of the composite system increases. Bohr and Wheeler [1] were the first to explain the main characteristics of nuclear fission using the liquid drop model. However, the observation of asymmetric fission fragment mass distribution with actinide targets [2] highlighted the limitations of this model in fully explaining the fission. This discrepancy was resolved by incorporating shell effects.

Further, the shell effects gradually wash off with an increase in excitation energy, leading to symmetric mass distribution. The entrance-channel parameters such as mass-asymmetry, shape-deformation, and coulomb factor ($Z_P Z_T$) also affect the dynamics of fusion-fission. Despite significant work carried out for a wide range of fissility and excitation energy, a comprehensive understanding of fission at low excitation energy is still missing. The literature survey highlights the scarcity of fusion-fission studies in the pre-actinide region. In this work, several fission-like events have been measured in ^{12}C+^{193}Ir system at energies below 8 MeV/A.

The experiment has been performed at IUAC, New Delhi using the ^{12}C as a projectile bombarded on ^{193}Ir target of thickness 17-60 μg/cm^2 [3] at E_{lab} = 83.98, 80.99, 74.81 and 70.08 MeV. Al catcher foils of sufficient thickness were used to sandwich the target so that the recoiling products could be stopped in the catcher foil thickness. Considering the half-lives of interest, the irradiation was carried out for 6-8 hours in the General Purpose Scattering Chamber (GPSC). After the irradiation, the induced activities were measured by using a pre-calibrated HPGe clover detector. The irradiated samples were counted continuously for about a week to detect long-lived residues. The preliminary identification of residues was done by characteristic γ lines, which were further confirmed by the decay curve analysis.

In the present work, the production cross-sections of fission-like events in the mass range 67≤A≤134 have been measured using the standard formulation given in ref. [4]. Mass distribution of fission fragments is one of the fascinating post-fission observables that provides information about the collective dynamics of fission. In HI-induced reactions, the compound nucleus is formed well above the fission barrier; hence, the mass distribution is found to be symmetric. The mass distribution of fission-like events has been obtained at four studied energies. The mass distribution is found to be symmetric and fitted with a Gaussian function with a peak position centered approximately at half the mass of the compound nucleus. This symmetric Gaussian mass distribution indicates the formation of these fission-like events from the decay of the

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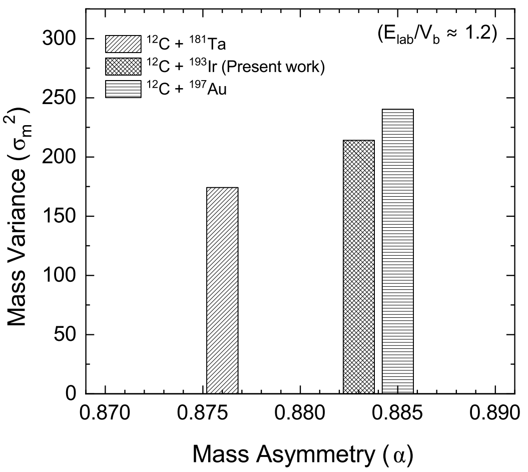

FIG. 1: A comparison of mass variance (σ_m^2) as a function of mass-asymmetry (α) for three systems ^{12}C + ^{181}Ta [6], ^{12}C + ^{193}Ir (Present system) and ^{12}C + ^{197}Au [7] at constant normalized energy ($E_{\rm lab}/V_b \approx 1.2$).

compound nucleus. The variance of mass distribution shows an increase with an increase in excitation energy. This trend in mass variance with excitation energy aligns with previous findings by Ghosh et al.[5].

In order to understand the role of the entrance channel on the mass distribution of fission-like fragments, the effect of mass asymmetry on the mass variance (σ_m^2) has been studied. The mass variance of fission-like residues for the same ^{12}C projectile with different targets, plotted as a function of mass asymmetry (α=(M_T−M_P)/(M_T+M_P)), is presented in a bar diagram in Fig. 1. This figure demonstrates that for three projectile-target combinations— ^{12}C + ^{181}Ta [6], ^{12}C + ^{193}Ir (present work) and ^{12}C + ^{197}Au [7] at a constant normalized energy ($E_{\rm lab}/V_b \approx 1.2$), there is a linear increase in mass variance with increasing mass asymmetry in the entrance channel. This indicates a broader mass distribution of fission-like residues for more mass asymmetric systems. Similar observations have been made by Shuaib et al. [8]. The study of σ_m^2 over a wide range of projectile-target combination insight into the dependence of σ_m^2 on α.

In summary, the present work suggests that fission is one of the competing deexcitation modes at low excitation energies other than particle and γ-rays emission. The symmetric distribution concludes the formation of fission-like residues through the compound nucleus mechanism. At constant normalized energy ($E_{\rm lab}/V_b \approx 1.2$), mass variance increases with an increase in mass asymmetry of the entrance channel. Detailed results and analysis of this investigation will be presented during the symposium.

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