Study of fission dynamics of multinucleon transfer induced fission for the ^{28}Si+^{232}Th reaction at 191.6 MeV

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Introduction

The study of transfer or breakup induced fission reactions not only plays an important role in understanding the complete picture of a fission reaction involving a heavy-ion projectile, but is also used to simultaneously obtain a lot of information on the fission of several interesting surrogate reaction channels. In recent studies Nishio et. al studied the multi nucleon transfer channels of the reactions ^{18}O+ ^{232}Th, ^{238}U in normal kinematics to obtain fission fragments mass distributions (FFMDs) and their excitation- energy dependence for various isotopes [1] and they can populate various neutron rich nuclei, which was populated for the first time by such direct reaction channel. Fission barrier, fission probability and mass distribution can be measured using the multinucleon transfer induced fission. The presence of quasi-fission (QF) inhibits the fusion of heavy nuclei and therefore reduces the fusion cross-section of super-heavy elements (SHE). So, it becomes important to study these non-compound nucleus (NCN) processes. Compound nucleus (CN) fission and QF both are distinguishable based on the experimental observations like mass and energy distribution, mass and angular distribution and width of the mass distribution

The scope of the present work is to explore the potential of the multinucleon transfer (MNT) reactions to measure the FFMDs and their excitation energy dependence for the neutron-rich nuclei, which cannot be accessed by particle-capture and/or heavy-ion fusion reactions.

Experimental setup

The experiment is carried out using the ^{28}Si beam accelerated to energy of 191.6 MeV using pelletron + LINAC facility at IUAC, New Delhi. Typical beam intensity was about 0.3-0.8 particle-nA. The thickness of ^{232}Th target was 250 μg/cm^2 with 80 μg/cm^2 fluorine backing. Both fission fragments were detected in coincidence using position sensitive multi wire proportional counters (MWPCs) with an active area of 20 cm in horizontal and 10 cm in the vertical direction. Forward Detector was placed at 25.1cm at 42^o and backward detector was placed at 20.2cm at 135^o. Both detectors were operated with isobutane gas at 4.5 torr pressure. For the detection of transfer products ΔE- E Si strip detectors were used. Si strip detectors were put at the grazing angle of 80^o.

Data Analysis and Discussion

In the analysis, we separated fission events where the momentum of the projectile was fully transferred to the composite system [full momentum transfer (FMT)] by constructing the folding angle $\theta_{fold} = \theta_1 + \theta_2$ and the sum of out-of-plane angles $\varphi_{sum} = \varphi_1 + \varphi_2$, from the fission fragments from nuclei around ^{232}Th produced by multi nucleon transfer reactions [2].

From the folding angle distribution of fission fragments (Fig.1), full momentum transfer events are separated from the transfer induced events. The full momentum transfer fissions are located at the folding angle of 150.2^0 while the transfer induced fissions have larger folding angle. It has been found that, ~7% of fission is led by incomplete momentum transfer.

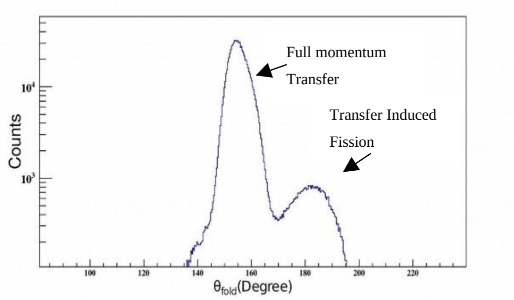

Fig.1 Folding angle distribution for $^{28}Si + ^{232}Th$ at 191.6 MeV.

In the first step, mass distribution and mass energy distribution are extracted from the MWPCs position and TOF signals. Conventional two-body kinematics was used for the data processing [3,4]. The emission angles were extracted from the calibrated X and Y position spectra of the fission fragments and velocities of the fission fragments were determined from the obtained TOF and angles (θ, φ). Two body kinematics, based on the

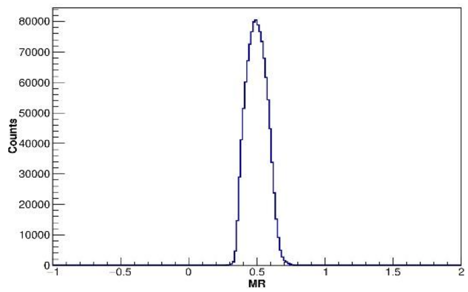

Fig.2 Mass ratio (MR) distribution of the fission fragments at 191.6 MeV.

conservation laws of linear momentum and mass conservation, was used to determine the primary masses and energies of the fission fragments [5]. The mass ratio (M_R) has been calculated using the relation:

$$M_R = \frac{m_1}{m_1 + m_2} = \frac{V_1}{V_1 + V_2}$$

where, m_1 and m_2 are masses and V_1 and V_2 are the velocities of fragments measured in center-of-mass. Fig.2 represents the mass ratio distribution for the reaction $^{28}Si + ^{232}Th$. It is symmetric about 0.5 indicating equal mass split after fission. It has been found that in present study mass width is lesser that of $^{48}Ti + ^{208}Pb$ [5] populating the same Rf compound nuclei.

The center-of-mass total kinetic energy (TKE) of the fission fragments has been deduced from the final masses and velocities of the fission fragments. The scatter plot of mass and TKE has been shown in Fig.3. Energy corrections in Mylar foil at the entrance of MWPC and half target thickness have been applied while calculating the final TKE of fragments. It has been found mass is mostly dominated by symmetric fission and no QF is observed.

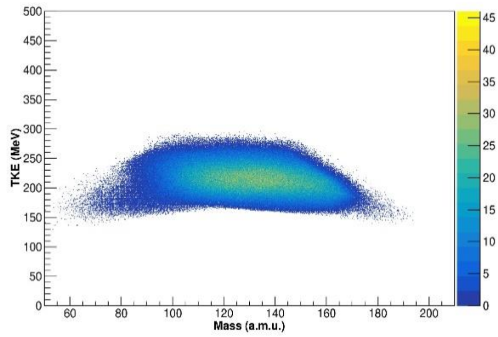

Fig.3. Scattered plot of mass and TKE.

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