Angular momentum population in incomplete fusion reactions

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Introduction

It has been established that several reaction mechanisms occur in heavy ion-induced reactions having projectile energy below 10 MeV/A. Among these mechanisms, dominant ones are complete fusion, deep-inelastic collision and quasi-elastic collision [1]. As the projectile energy increases to 5-10 MeV/A and above, incomplete fusion reactions start competing with complete fusion reactions.

In incomplete fusion reactions, projectile breaks up into two fragments before fusing with the target [2]. After the break-up, one part of the projectile completely fuses with the target while the other escapes at forward angle as a spectator. Such reactions are also known as breakup fusion or massive transfer reactions. In recent years, the incomplete-fusion reaction mechanism has attracted considerable attention as it can be used to produce states at higher angular momentum in relatively neutron-rich nuclei [3, 4].

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Experimental details

The experiment was performed to understand the incomplete fusion reaction mechanism using ^{93}Nb(^{20}Ne, $xnyp$) reaction with 150 MeV at Variable Energy Cyclotron Centre, Kolkata. The gamma rays following the reaction were detected using the Indian National Gamma Array (INGA), which consisted an array of 8 Compton-suppressed Clover detectors at the time of the experiment.

The data were sorted in usual $4k - 4k\,\gamma - \gamma$ matrices. These matrices were further analyzed using RADWARE [5].

Results and Discussion

Although complete fusion was the dominant process, some residual nuclei were produced only via incomplete fusion reactions. Such nuclei were selected for further investigations. From the data and existing spectroscopic information on the nuclei, we have determined the highest angular momentum upto which residual nuclei were populated.

The probability of splitting ^{20}Ne, in the vicinity of the target (^{93}Nb), into various channels was determined using an approach described in Ref. [3]. It was observed that only a few channels occur with considerable

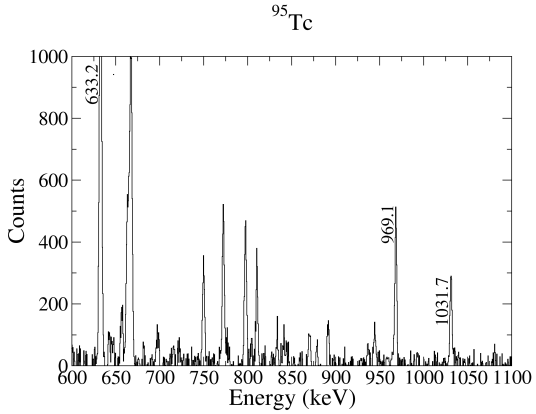

FIG. 1: Spectrum of ^{95}Tc obtained using 882 keV gate. Transitions of ^{95}Tc are shown with their respective energies, remaining transitions are the contaminants.

probability and were suitable for the study. The cross-section obtained from the above approach was used as an input parameter to the statistical model code PACE4 [6]. For the reaction under consideration, incomplete fusion reaction can proceed via 41 channels. Among these channels, only light-ion fusion channels were considered for analysis as the residual nuclei form in this way cannot be produced via complete fusion, and the two reaction mechanisms can be distinguished. The channels include - neutron, proton, deuteron, triton, alpha, ^{6}Li, ^{7}Li, ^{9}Be, ^{10}B and ^{11}B fusing with ^{93}Nb after escaping ^{19}Ne, ^{19}F, ^{18}F, ^{17}F, ^{16}O, ^{14}N, ^{13}N, ^{11}C, ^{10}B, ^{9}B, respectively from ^{20}Ne projectile.

TABLE I: The highest angular momentum values for some of the residual nuclei populated via incomplete fusion reactions.

Residual nuclei	Observed spin
^{93}Mo	$27/2^{-}$
^{95}Mo	$25/2^{+}$
^{95}Tc	$31/2^{+}$

Residual nuclei formed via the above mentioned channels, after particle evaporation decay to ground state by emission of γ-ray cascade. The highest spin state of a particular residual was then determined by setting a gate on the most intense γ transition and analyzing the resulting spectrum. Figure 1 shows such a spectrum of ^{95}Tc obtained by setting a gate on 882 keV transition. The spectrum reveals that ^{95}Tc was populated upto $31/2^{+}$.

The observed highest spin states for some of the residual nuclei, populated via incomplete fusion channels are mentioned in Table I. More information will yield from further data analysis.

This study indicates that incomplete fusion reactions competes with complete fusion reaction at projectile energy of 7.5 MeV/A. Also, it is apparent that the incomplete-fusion reaction are capable of populating nuclei at high angular momentum, and can be utilized to study relatively neutron-rich nuclei in the vicinity of stable nuclei.

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