Complete and incomplete fusion for ^{7}Li+^{93}Nb reaction

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Introduction

In case of nuclear reactions involving weakly bound nuclei, direct breakup of the projectile (non capture- breakup), breakup followed by capture of one of the fragments (incomplete fusion), and transfer followed by breakup (transfer-breakup) have a strong influence on reaction dynamics. Experimentally it is challenging to separate reaction products arising from these reaction channels and exclusive measurements are required. We have performed coincidence measurements to detect outgoing fragments for studying relative importance of non capture breakup and transfer-breakup processes [1, 2] and recently particle-gamma coincidence measurement to study mechanism of fragment capture in ^{7}Li+^{93}Nb system. In order to get consistent understanding of the inter-connectivity among various reaction channels and to constrain the parameters of the theoretical models [3, 4], cross-sections of complete fusion and incomplete fusion are required. With this motivations we have carried out cross-section measurements for fusion excitation function using in-beam gamma method along with the particle-γ coincidence measurements for ^{7}Li+^{93}Nb system.

Experimental Details

The experiment was carried out using 14UD BARC-TIFR Pelletron Linac facility at Mumbai. The Indian National Gamma Array (INGA) consisting of 18 Compton suppressed Clover detectors was used for the detection of the gamma rays. Three Si surface barrier telescope (thicknesses $\Delta E \sim$ 15-30 μm, $E \sim$ 300-5000 μm) and one monitor detector (thickness $\sim$ 300 μm), kept inside the scattering chamber, were used for the detection of charged particles. The measurements were carried out at beam energies 24, 26, 28 and 30 MeV. Time-stamped data were acquired using digital data acquisition system with one and two fold mode. For measurement of fusion cross-section one-fold mode was used. The efficiency and energy calibration of the Clover detectors were done using a ^{152}Eu and ^{133}Ba gamma ray sources of known strength.

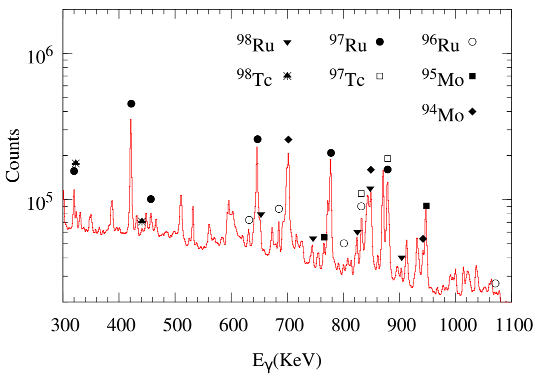

FIG. 1: In beam γ-ray spectrum for ^{7}Li+^{93}Nb reaction at E_{beam}=28 MeV. The γ transitions from the residues following CF and ICF are labeled.

Analysis and Result

The residues were identified by detecting their characteristic γ-rays. A typical γ-ray spectrum at E_{beam}=28 MeV is shown in Fig.1 with the photo peaks of different residues labeled. Excitation function of evaporation residues resulting from complete fusion are presented in Fig.2(a) along with the predictions of the statistical model code (PACE). The calculations indicate that the measured 2n, 3n, 4n, pn and p2n evaporation channels

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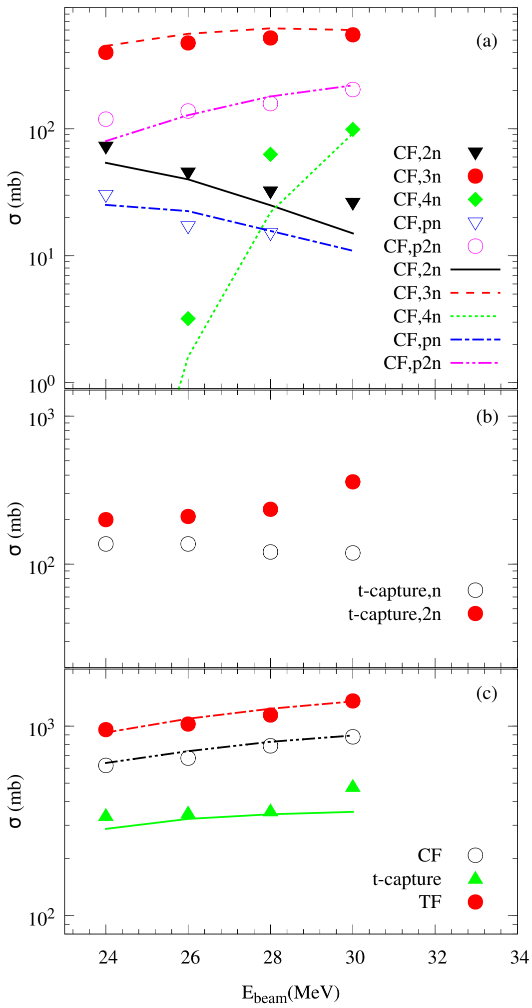

FIG. 2: (Color online) Measured cross-sections for ^{7}Li+^{93}Nb system. (a) Residues after 2n, 3n, 4n, pn and p2n evaporation. The lines correspond to statistical model (PACE) calculations. (b) Residue after t-capture followed by 1n and 2n evaporation. (c) complete fusion, t-capture and total fusion. The lines correspond to coupled channel calculations.

comprise ∼95% of the complete fusion. Measured residues cross-section due to t-capture are shown in Fig.2(b). As most of the residues formed after α-capture, populate isomeric states, these cross-sections could not be measured by online γ counting technique. Plotted in Fig.2(c) are the excitation functions for complete, incomplete and total fusion. The total fusion (TF) was obtained by adding CF and t-capture cross-sections.

Continuum discretized coupled channels calculations (CDCC) were performed using the code FRESCO to explain the fusion cross-sections presented in Fig.2(c). In the CDCC formalism ^{7}Li nucleus was considered as α+triton cluster. The required optical potentials were generated using the cluster folding method, where α-target (V_α) and triton-target (V_t) optical model potentials at 4/7 and 3/7 of the incident ^{7}Li energy were folded. The Wood-Saxon potential parameter for V_α and V_t were taken from global optical model potential. The total absorption cross-sections shown by dot-dashed line in Fig.2(c), agrees well with the total fusion cross-sections. The complete fusion cross-sections, were calculated by changing the imaginary potential to short range with (r_w=0.6 fm) for both V_α and V_t. The t-capture cross-sections were calculated with the short range conditions and switching off the imaginary part of the V_α potential [5]. Calculated CF and t-capture cross-sections are shown by dot-dot-dashed and solid line in Fig.2(c), respectively.

Summary

In summary, measured residue cross-sections from complete fusion for ^{7}Li+^{93}Nb are presented and compared with the statistical model calculations. Measured excitation functions for CF, t-capture and TF are in good agreement with the coupled channels calculations. Analysis of exclusive data for the different fragment capture reactions are in progress. The present measurements will constrain the model parameters of the stochastic breakup calculations [4] to understand the reaction dynamics.

Acknowledgments

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