Investigation of the role of break up processes in the fusion of the ^{20}Ne + ^{51}V system

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Introduction

There are certain aspects far from being completely understood. As such, the study of competition between Complete Fusion (CF) and Incomplete Fusion (ICF) is still an open area of investigation in nuclear physics. Thus more and more experimental data is required to determine the optimum irradiation conditions for the production yield of various radioisotopes for better understanding of the phenomena of CF and ICF of heavy ion (HI) systems, formed in HI reactions. There are some observables, e.g., excitation functions, recoil range distributions, angular distributions and spin distributions which are related to CF and ICF.

With a view to study the reaction dynamics in HI interactions, a program of precise measurement of excitation functions (EFs) for the production of residues due to the CF and ICF processes has been undertaken by our group. In these measurements, special care was taken to remove the precursor decay contribution in the production of several evaporation residues to get the independent production cross-sections of the residues. Measured EFs were then compared with the production of the statistical model code Pace2 [1], and the analysis of the results have been discussed. The dependence of ICF fraction with projectile energy has also been discussed. Moreover, entrance channel mass-asymmetry dependence of the ICF fraction has been investigated.

Experimental Details

The experiment was performed at the Variable Energy Cyclotron Centre (VECC), Kolkata, India. Specpure ^{51}V targets of thickness ~1.19-1.50 mg/cm^2 range were prepared by Vacuum Evaporation Technique on Al-backing of thickness ~ 1.47-1.64 gm/cm^2. A stack of six ^{51}V targets was irradiated for ~11 hours by $^{20}Ne^{6+}$ beam, of beam current ~40 nA at ~145 MeV. The incident flux of ^{20}Ne was determined from the charge collected in Faraday cup. ^{152}Eu source of known strength was used to determine the efficiency of the detector. The γ-ray activities produced in each target foil were recorded using pre-calibrated HPGe detector coupled to a PC based data acquisition system. The γ-ray spectroscopy software package RADWARE was used for analyzing the spectrum.

Results and Discussion

The excitation functions (EFs) for several evaporation residues populated via pxn (x = 3, 4), αxn(x= 1,2), 2αxn(x= 2,3), αpxn(x= 3,4) and 3α4n channels have been measured in the energy range ~82-145 MeV. The level density parameter constant K, in the PACE2 calculations was varied to match the experimental results.

In the case of pxn channel reactions, the residue ^{66,67}Ge may form directly through the CF of ^{20}Ne with ^{51}V. It may also be populated via β^+ decay of the higher charge isobar precursor. The independent cross-ection, σ_{ind}, for the residue ^{67}Ge has been extracted from the measured cumulative cross section, σ_{cum}, [2].

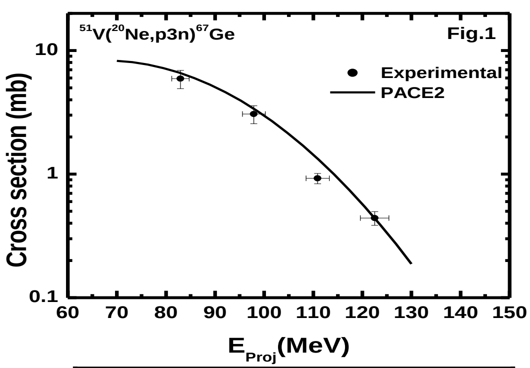
$$\sigma_{cum}(^{67}\text{Ge}) = \sigma_{ind}(^{67}\text{Ge}) + 1.0389\, \sigma_{prec}^{PACE2}(^{67}\text{As})$$

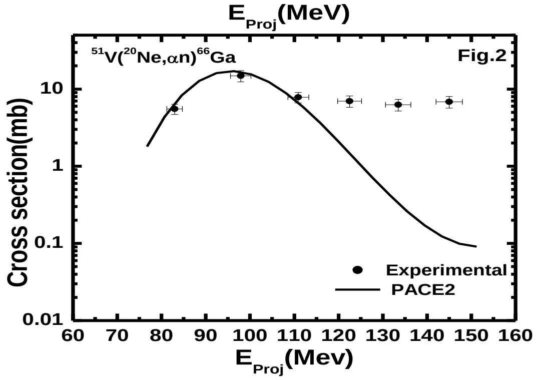
As a representative case shown in Fig.1, the measured independent cross-ection values for ^{67}Ge agree well with the PACE2 values. Fig.2 shows an enhancement of the measured EFs for αn channel over the PACE2 predictions at higher projectile energies. This enhancement in EFs

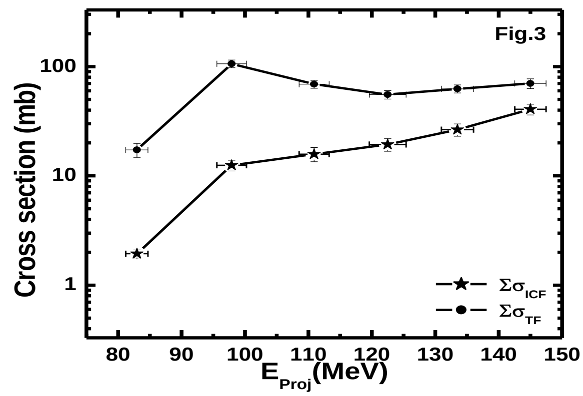
$\Sigma\sigma^{PACE2}_{\alpha-channel}$, which is shown as $\Sigma\sigma_{ICF}$ in Fig.3, was found to increase with E_{Proj}, suggesting an increased significance of ICF process at higher energies. In order to investigate the energy dependence of the ICF cross-section (σ_{ICF}) contribution to the total cross-section (σ_{TF}), the percentage fraction of ICF process, P_{ICF}, (P_{ICF} = Σ σ_{ICF}/σ_{TF} x 100%) was calculated. Fig.4 shows the variation of P_{ICF} with E_{Proj}/V_{CB} for three different target-projectile systems. As can be seen from figure, P_{ICF} is more for higher mass-asymmetric system and also increases with increase in normalized projectile energy for all the systems [3, 4]. Moreover, in order to study the dependence of P_{ICF} on the entrance channel mass-asymmetry, a pair of P_{ICF} is plotted in Fig.5 as a function of normalized relative velocity, V_{rel}/c, for ^{20}Ne + ^{51}V and ^{12}C + ^{52}Cr systems

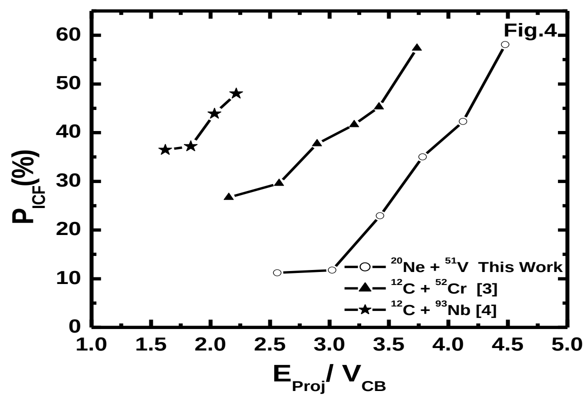
$$V_{rel} = \sqrt{2(E_{CM} - V_{CB})/\mu} \ ,$$

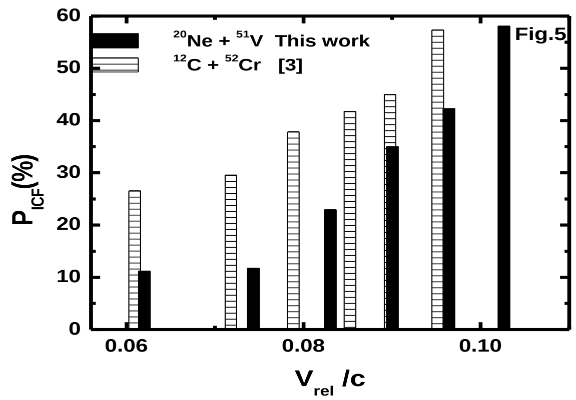
where μ is the reduced mass of the system, E_{CM} is the centre of mass energy and V_{CB} is the Coulomb barrier. Further, the data suggest that the probability of ICF is more in a mass-asymmetric system than in a mass-symmetric system which is consistent with the results of Ref. [3,5].











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