Measurement of cross section of projectile like fragments in $^{19}F+^{159}Tb$ reaction at E_{lab}=5.1 MeV/nucleon

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Introduction

Incomplete fusion reactions at lower beam energies (E_{lab}<10 MeV/nucleon) have been actively investigated in the recent past. Observation of significant cross sections for incomplete fusion at beam energies around ~ 5 MeV/nucleon indicate the contribution from l-waves lower than the critical angular momentum for complete fusion (l_{crit}(CF)) as maximum angular momentum populated at these beam energies is lower than l_{crit}(CF). Recently, sum-rule model [1,2] was modified to allow effective competition from incomplete fusion for lower l-waves to explain the experimental cross sections of projectile like fragments (PLFs) in $^{19}F+^{66}Zn$ reaction [3] and evaporation residue cross sections in $^{19}F+^{159}Tb$ reaction [4]. Various mechanisms such as quasi-elastic transfer (QET), massive transfer or incomplete fusion (ICF) reactions and deep inelastic collisions contribute to the formation of projectile like fragments [5]. Contribution from different mechanisms mainly depends on the projectile-target combination, beam energy and amount of mass transfer.

In the present work, on-line measurement of angular distributions of PLFs (Z=2-8) was carried out at E_{lab}=97.7 MeV to investigate the mechanism of formation of PLFs in different transfer channels. Elastic scattering measurements were carried out to determine the grazing angle and total reaction cross section. PLF cross sections have been compared with the cross sections for the corresponding incomplete fusion channels, obtained from the measurement of evaporation residue cross section [4].

Experimental details

Experiments were carried out at BARC-TIFR pelletron accelerator facility, Mumbai, India. Self supporting ^{159}Tb foil of thickness 1.39 mg/cm^2 was bombarded with 100 MeV ^{19}F beam. Due to the energy degradation, average energy at the center of the target was 97.7 MeV. The angular distributions of PLFs were measured using two silicon detector based ΔE-E telescopes. The lab angular distributions were measured in the range 20^0-100^0 degree at the step of 5^0. Elastic scattering measurements were carried out in steps of 2^0. A monitor detector was kept at 20^0 to monitor the elastically scattered beam particles. The data of monitor detectors was used to normalize the telescope counts for target thickness and beam intensity to obtain absolute PLF cross sections. Elastic scattering data (normalized by Rutherford cross sections) at forward angles were normalized to unity to remove systematic uncertainty due to the solid angles of various detectors. The energy calibrations of the telescopes were carried using elastically scattered ^{19}F and ^7Li beam particles from ^{159}Tb and ^{93}Nb targets.

Results and discussion

The lab angular distributions of projectile like fragments were transformed in to centre of mass frame of reference using the average centre of mass (CM) kinetic energies of corresponding PLFs. In order to obtain average CM kinetic energies of PLFs, CM kinetic energy spectra for a given PLF at various CM angles were superimposed to improve the statistics. The CM angular distributions of PLFs (Z=3-8) are shown in Fig. 1. It can be seen from Fig. 1 that the angular distribution of heavier PLFs such as O and N formed in small mass transfer peaks close to the grazing angle of 82^0 as obtained from elastic scattering data. This indicates quasi-elastic transfer to be the dominant mechanism in the formation of these PLFs. With decreasing Z of the PLFs, angular distribution becomes more and more forward peaked. This indicates increasing role of nuclear force with increasing mass transfer, suggesting significant overlap of the projectile and the target nuclei in incomplete or massive transfer reactions.

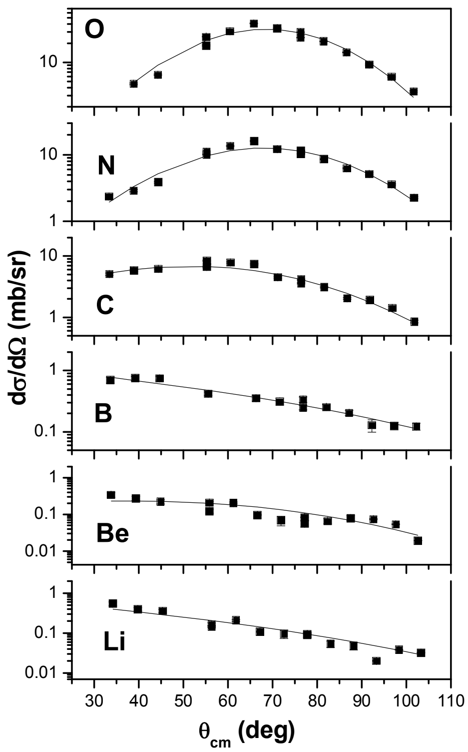

Fig. 1 Centre of mass angular distributions of PLFs formed in $^{19}F+^{159}Tb$ reaction at E_{lab}=97.7 MeV

In order to obtain the cross sections of PLFs, plots of '$d\sigma/d\Omega.2\pi\sin\theta d\theta$' vs θ were fitted to Gaussian function. The fitted functions were integrated from 0^0-180^0 to obtain PLF cross sections. A plot of cross sections of PLFs with Z=3-8 is shown in Fig. 2. PLF cross sections represent the total cross sections for different break-up channels. Incomplete fusion cross sections obtained from evaporation residue measurements are also shown in this figure for comparison. In view of the approximations involved in the extraction of cross sections of lighter PLFs with very forward peaked angular distributions and also, due to the break-up of ^{8}Be, comparison is meaningful for PLFs with $Z_{PLF} \geq 5$. It can be seen from the figure that the PLF cross sections are of the same order as that of the corresponding incomplete fusion / transfer channel measured through evaporation residue measurement. This observation suggests that incomplete fusion / transfer constitutes significant fraction of the total break-up cross section.

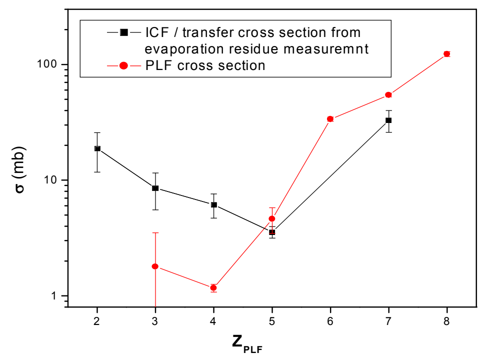

Fig. 2 Comparison of PLF cross sections with ICF cross sections obtained from ER measurement [4].

In summary, measurement of angular distributions of PLFs with Z=3-8 and elastic scattering was carried out at E_{lab}=97.7 MeV. Angular distributions of PLFs with Z=7 and 8 peaked close to the grazing angle, indicating their predominant formation in quasi-elastic transfer reactions. Angular distributions of lighter PLFs formed in massive transfer or incomplete fusion reactions became more and more forward peaked with increasing mass transfer. Cross sections of PLFs obtained by integrating the centre of mass angular distributions were of the similar order as those obtained from evaporation residue measurement.

References

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