Kinetic energy spectra and angular distributions of projectile like fragments in $^{19}F+^{93}Nb$ reaction

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Introduction

Investigation of heavy ion induced reactions involving incomplete mass exchange between target and projectile are active area of research in recent years [1-2]. These transfer reactions includes quasi-elastic transfer reactions (QET), Deep Inelastic collision (DIC), massive transfer or incomplete fusion (ICF) reactions [3]. The important observables which are used to characterize these different types of incomplete mass transfer reactions are the kinetic energy spectra, angular distributions of the projectile like fragments (PLFs), evaporation residue cross sections etc. These reactions are governed by various entrance channel parameters like mass asymmetry [4], incident projectile energy [1], projectile and target structure [5,6] and also the Q_{gg} value of the respective transfer channel. Studies by Sodaye *et al.* showed that Transfer/ICF reactions

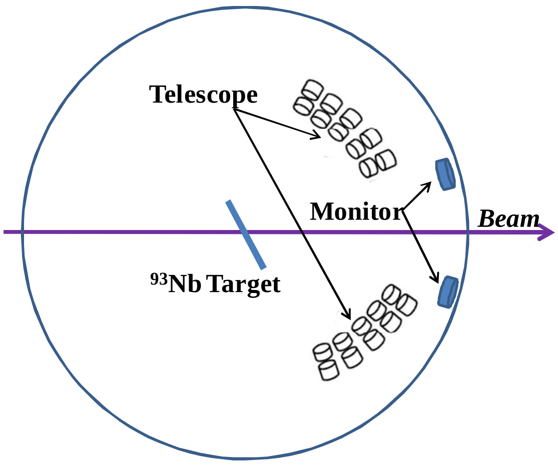

***Fig. 1** Schematic diagram of detector setup inside a general purpose scattering chamber.*

dominated in the systems with larger entrance channel mass asymmetry [4]. Studies by Tripathi *et al.* showed that projectile structure with $n\alpha$ (n = integer) cluster leads to enhancement in the yield of certain PLFs which is not observed in the case of the projectile having non α cluster structure. Although there are various studies showing the role of projectile structure on incomplete mass transfer reactions, however limited studies are there regarding the role of target structure on incomplete mass exchange reactions between target and projectile. In our recent study on kinetic energy spectra and angular distribution of projectile like fragments in $^{12}C+^{93}Nb$ reaction, observed an

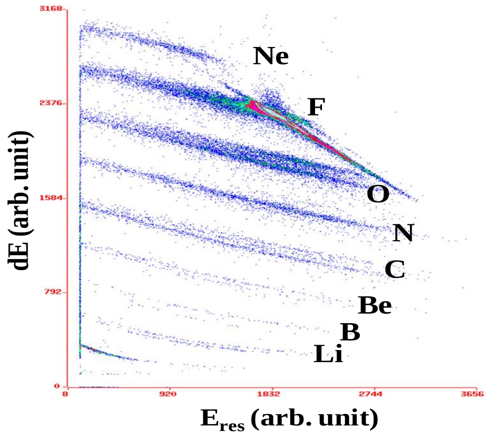

***Fig. 2** A typical 2 dimensional spectrum of the PLFs formed in ^{19}F + ^{93}Nb reaction at E_{lab} = 88 MeV at $\theta_{lab} = 35^0$.*

enhancement in the yield of "1p+2n" pickup channel leading to the formation of PLF ^{15}N along with the target like product ^{90}Zr with 40 protons and 50 neutrons indicating the role of target shell closure on incomplete mass transfer reactions. The Q_{gg} value for "1p+2n" pickup channel in $^{12}C+^{93}Nb$ reaction is ≈ 1.5 MeV, where as in $^{19}F+^{93}Nb$ reaction the Q_{gg} for this channel is ≈ 8.10 MeV. So it is expected to observe more enhancements in the yield of "1p+2n" pickup channel in $^{19}F+^{93}Nb$ reaction as compared to the $^{12}C+^{93}Nb$ system.

With an objective to determine the yields in different transfer reactions, kinetic energy spectra and angular distribution of the projectile like fragments have been measured in $^{19}F+^{93}Nb$ reaction.

Experimental Details

Experiments have been performed at BARC-TIFR Pelletron LINAC facility TIFR Mumbai. A self-supporting target of ^{93}Nb (Thickness: 200 μg/cm^2) was bombarded with 88 MeV ^{19}F beam. A schematic diagram of the detector setup used in a general purpose scattering chamber is shown in Fig. 1. It can be seen from Fig. 1 that ten telescopes were used to detect the outgoing PLFs which were formed in various transfer/pickup reactions in $^{19}F+^{93}Nb$ reaction. Two monitor detectors were placed at ± 20^0 to detect the elastically scattered beam particles.

Results and Discussions

Figure 2 shows a typical two dimensional (ΔE versus $E_{residual}$) spectrum for different PLFs formed in $^{19}F+^{93}Nb$ reaction in various transfer/pickup reactions. Particle identifier (PI) spectra have been obtained after relative gain

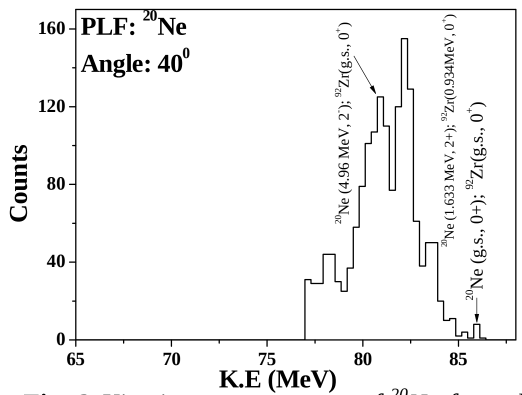

Fig. 3 Kinetic energy spectra of ^{20}Ne formed in ^{19}F + ^{93}Nb reaction for θ_{lab} = 40^0 at E_{lab} = 88 MeV.

matching of the E-ΔE spectra which were used to identify the PLFs (Z = 3-10) formed in $^{19}F+^{93}Nb$ reaction. It has been observed from the PI spectra that "1p+2n" pick up channel, which leads to formation of ^{22}Ne was found to be absent in the present reaction system, however in our earlier measurement in $^{12}C+^{93}Nb$ system there was an enhancement in the yield of "1p+2n" pickup channel indicating the role of shell closure in the target like fragment [6]. This is possibly due to the larger entrance channel Coulomb barrier and N/Z ratio in $^{19}F+^{93}Nb$ system as compared to the $^{12}C+^{93}Nb$ reaction system. From the Kinetic energy spectra of the PLFs various specific states of outgoing PLFs and target like fragment (TLF) were identified which were populated in various transfer reactions. Figure 3 shows the kinetic energy spectra of the ^{20}Ne PLF formed in one proton pickup. It could be seen from Fig. 3 that significant population of ^{20}Ne (4.96 MeV, 2^+) along with ^{92}Zr (g.s., 0^+) was observed. From the kinetic energy spectra of ^{20}F formed in one neutron pick up, specific states involving PLF ^{20}F (0.656 MeV, 3^+) and TLF ^{92}Nb (g.s, 7^+) was also identified which is not shown here.

From the elastic scattering data, the grazing angle was observed to be 56.3^0 for the present reaction system at 88 MeV beam energy. The elastic scattering data points at forward angle in the flat region were normalized to unity and the normalization factor was subsequently used in the scaling up of the PLF angular distribution. The PLF angular distribution in the laboratory frame of references were transformed into centre-of-mass (c.m.) frame of references using standard kinematic equations. The c.m. angular distributions were determined for the PLFs (Z = 3-10), however in the present paper it has been shown for the PLF Z = 6-10. It can be seen from Fig. 4 that the angular distribution became more forward peaked for the lighter PLFs indicating the larger projectile target

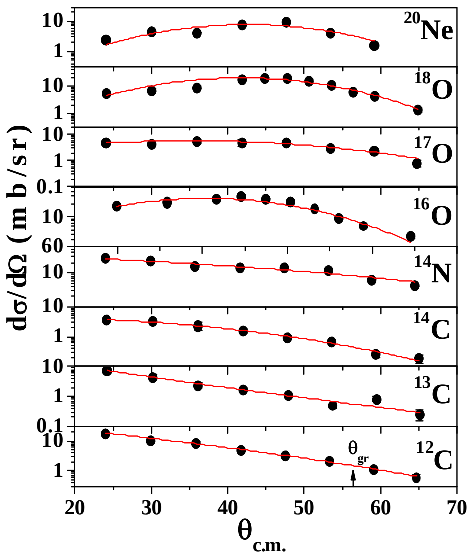

Fig. 4 The angular distributions of the PLFs with Z = 6-10 in ^{19}F + ^{93}Nb reaction at E_{lab} = 88 MeV.

overlap in formation of the lighter PLFs. Angular distributions of the PLFs were used to get the yield of the PLFs in different transfer reactions and those yield can be correlated to their respective Q_{gg} value.

Conclusion

Kinetic energy spectra and angular distribution of the PLFs were measured in $^{19}F+^{93}Nb$ reaction. Unlike in $^{12}C+^{93}Nb$ system "1p+2n" pickup channel was found to be absent in the present system possibly due to the larger Coulomb repulsion and N/Z ratio in $^{19}F+^{93}Nb$ as compared to $^{12}C+^{93}Nb$ system. From PLF kinetic energy spectra various states of PLF/TLF were identified. Yield of different transfer channels were obtained from the PLF angular distribution and those yields can be correlated to the Q_{gg} value for the respective transfer channel.

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