Evaporation residue cross-sections in $^{19}F+^{159}Tb$ system

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Introduction

In the last few decades several experiments have been carried out to explore the mechanism of incomplete fusion (ICF) reactions which involve partial capture of the projectile by the target nucleus. Various models were proposed to explain in complete fusion reaction e.g. sum rule model of wilczynski et al. [1], breakup fusion model [2,3], overlap model [4,5], the promptly emitted particle model and the multi-step direct reaction theory [6]. But, none of the models explain all the experimental observables.

According to the Sum rule model the ICF products are mainly formed from the collision trajectories with angular momentum (l) greater or equal to critical angular momentum (l_{cr}) for CF processes. Sum-rule model successfully explained the cross section for incomplete fusion at higher beam energies (~>10 MeV/nucleon). However, in several studies [7-9], significant incomplete fusion cross sections have been observed at lower beam energies for which maximum angular momentum is lower or close to the critical angular momentum for CF. These observations suggested ICF contribution from low l-waves. Recently, sum-rule model was modified to incorporate the contribution from ICF for collision trajectories with $l<l_{cr}$(CF) [8] to explain ICF at lower beam energies. More studies are required to understand the contribution from ICF at lower beam energies.

In the present study, the excitation functions of the evaporation residues (ERs) in the reaction of ^{19}F on ^{159}Tb were measured and their cross section data are analysed in terms of statistical and sum-rule models to investigate this aspect.

Experimental

The experiments were carried out at the BARC-TIFR pelletron accelerator facility, TIFR Mumbai. Self-supporting Terbium foils (>99%) of ~ 2mg/cm^2 were bombarded with ^{19}F beam in the energy range of 83-103 MeV. The ERs were monitored using off-line gamma-ray spectrometry. The gamma-ray spectra were analyzed using PHAST. ERs were identified by their gamma-ray energies and half-lives. Evaporation residue cross sections were calculated from the observed peak areas after correcting for the variations in beam current during irradiation.

Results and Discussion

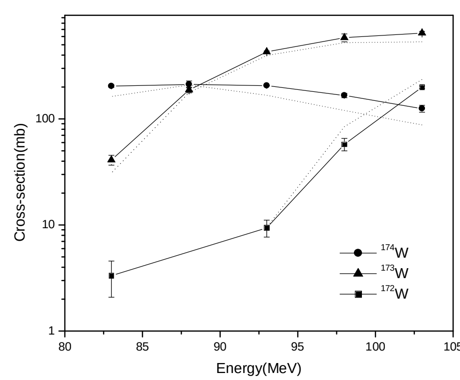

Fig.1.Experimental (solid line) and statistical model (dotted line) cross sections of neutron evaporation channels in $^{19}F+^{159}Tb$.

The ER cross sections were measured in the beam energy range of 83-103 MeV in lab. The excitation functions of ERs formed in the neutron evaporation and αn channels are given in Figs 1 and 2 as solid lines. Statistical model calculations of ER cross sections have been carried out using PACE2 code. The l-distribution at each energy was generated using CCFUS and given as input to PACE2. The other variable parameters in PACE2 were varied to reproduce the neutron evaporation channels which are expected to be formed from CF. The cross sections of ERs calculated using statistical model are shown in Figs 1 and 2 as dotted lines.

It is seen from the figures that the cross sections of ERs formed in neutron evaporation channel match well (Fig.1) while the alpha emission channel cross sections are largely underestimated (Fig.2) indicating that these are formed in non-statistical processes. Similar observations have been made in the excitation functions involving emission of heavier projectile like fragments (PLFs).

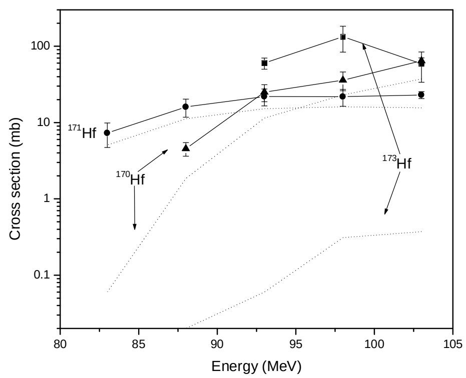

Fig.2.Experimental (solid line) and statistical model (dotted line) cross sections of αxn evaporation channels in $^{19}F+^{159}Tb$.

Sum-rule model calculation:

ER cross sections have been summed according to the Z values of the evaporated / ejected particles. The cross sections for the probability of emission of various fragments in the reaction have been estimated using sum rule model. The values of nuclear temperature (T) and radius parameter (r_0) are used as those used by Wilczynski et al. [1]. This grossly underestimates the probability of emission of higher Z-PLFs or fusion of light fragments. Reproduction of ER cross section data by sum-rule model required very high temperature of about 8 MeV. However, cross section data could be reproduced with T=3.5 MeV as used by Wilczynski et al. [1] after considering the contribution from lower *l*-waves as was done in earlier studies [8]. The typical plot of the sum rule model calculations at E_{lab}=103 MeV are given in Fig.3.

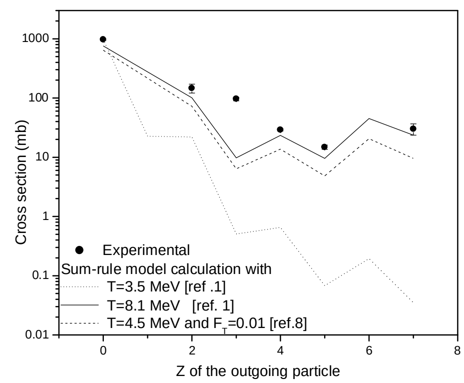

Fig.3. Sum-rule model calculation of cross sections at E_{lab} =103 MeV

Conclusion

Excitation functions of ERs have been measured in $^{19}F^{+159}Tb$ reaction in the beam energy range of 83-103 MeV. The cross section data showed significant contribution from incomplete fusion process as indicated from the statistical model calculations at these low beam energies. Sum-rule model required very high temperature to explain the experimental data. However, after incorporating the ICF contribution from low *l*-waves, ICF cross sections could be reasonably reproduced with lower temperature value as used in ref [1].

References

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