Fusion incompleteness in reaction induced by ^{20}Ne at energy ≈ 4-7 MeV/A

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Introduction

Study of nuclear reactions induced by heavy ions (Z≥2) is a quite lively topic of study during the last few decades. Classically, the energy of incident projectile should be high enough to overcome the effective potential barrier, which is the sum of Coulomb, nuclear and centrifugal potentials. The mechanism involved in heavy ion induced reaction can be broadly classified between the two extremes: reactions involving complete fusion (CF) of projectile with the target nucleus followed by particle evaporation and incomplete fusion (ICF) in which only a part of the projectile fuses with the target nucleus due to break-up of the incident projectile prior to fusion [1]. The formation of evaporation residues (ERs) in heavy ion induced reactions is considered to be a two step process: in the first step a compound nucleus is formed and in the second step ERs are formed by the emission of γ-rays, nucleons, α-particles and other light particles.

Zebelman and Miller [2] experimentally observed that ICF reaction cross section get influenced by the entrance channel parameters viz. mass asymmetry of the projectile-target system, incident energy of the projectile and break-up threshold energy of the projectile. In the present work, study of fusion incompleteness using the ^{20}Ne projectile over ^{51}V, ^{91}Nb and ^{165}Ho and targets has been carried out in the energy range ≈ 4-7 MeV/A.

Experimental Details

The experiment were performed at VECC, Kolkata, India. The target foils of ^{51}V, ^{91}Nb and ^{165}Ho of thickness range 1.19-1.56 mg/cm^2 were prepared by depositing on Aluminum backing of thickness range 2.06-3.78 gm/cm^2 by the vacuum evaporation technique at target lab of VECC. A stack of six foils each of ^{51}V, ^{91}Nb and ^{165}Ho targets were irradiated for ≈ 11 hrs, 7 hrs and 16 hrs, respectively, by ^{20}Ne^{6+} beam at ≈ 145 MeV. The energy of the ^{20}Ne ion beam incident on each target foil was calculated from the energy degradation of the initial beam energy using stopping power software SRIM[3]. The γ-ray activities produced in each target foil along with its catcher were recorded by using pre-calibrated 60 cc HPGe detector coupled to PC based data acquisition system. Further details related to experimental arrangement, formulae used and error analysis are available in Ref. [4]. The overall error in the present work is estimated to be ≤20%.

Results and Discussion

In the ^{20}Ne + ^{51}V, ^{91}Nb and ^{165}Ho reactions at E_{lab} ≈ 4-7 MeV/A, number of residues were observed to be populated through *xn*, *pxn* and α-channels. The observed residues were likely to be populated via CF and/or ICF processes. In order to determine the extent of CF and ICF contributions in the population of observed ERs, the excitation functions (EFs) of ERs were compared with the theoretical values predicted by the statistical model

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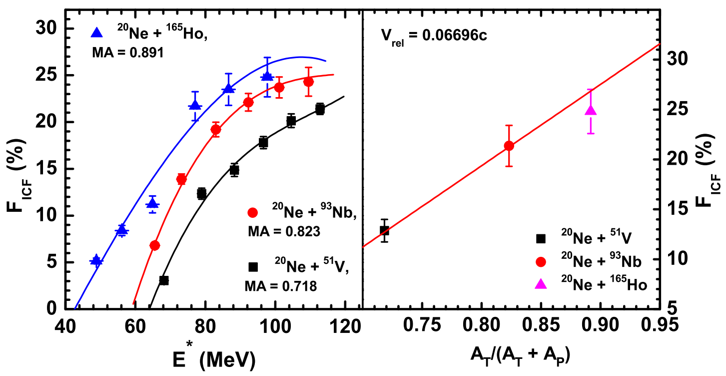

FIG. 1: (a) F_{ICF} vs E* (excitation energy) and (b) F_{ICF} vs Mass asymmetry for the ^{20}Ne + ^{51}V, ^{91}Nb and ^{165}Ho systems.

code PACE4 [5]. PACE4 gives the CF cross section of the ERs in a given nuclear reaction. The experimental EFs of *xn* and *pxn* channels were found to be agreed well with the PACE4 values suggesting their population through the CF reaction only. On the other hand, the experimental EFs of α-channel show an enhancement over the PACE4 values indicating contribution from ICF process in addition to CF.

Mass asymmetry effect

It has been reported by Morgenstern et al. [6] that initiation of incomplete fusion reaction is governed by the relative velocity between the projectile and the target as well as on the mass-asymmetry of the interacting partners. The relative velocity, V_{rel} is given by;

$$V_{rel} = \sqrt{2(E_{c.m} - V_B)/M_{red}} \qquad (1)$$

In order to test the systematic as suggested by Morgenstern et al., and to analyze the dependence of ICF fraction (F_{ICF}) on the mass asymmetry (μ) of the interacting partners, which is given by;

$$\mu = A_T/(A_T + A_P) \qquad (2)$$

a graph of F_{ICF}(%) vs E*(Excitation energy) is plotted for the three systems. As can be seen from Fig. 1(a), the F_{ICF} value for the more asymmetric (^{20}Ne + ^{165}Ho) system is high as compare to less asymmetric system (^{20}Ne + ^{51}V). Fig 1(b) shows the variation of F_{ICF}(%) with mass asymmetry (μ) for the three system at V_{rel} = 0.06696c. As can be seen from Fig. 1(b), F_{ICF} increases almost linearly with the mass asymmetry of the systems.

Conclusion

In the present work it was observed that mass asymmetry of the system highly influences the ICF fraction. It was found that F_{ICF} for the more mass asymmetric system remains higher through out the energy range as compare to less mass asymmetric system. Moreover, F_{ICF} increases almost linearly with the mass asymmetry of the system at a given V_{rel} as suggested by the Morgenstern at al.

References

[1] T. Udagawa and T. Tamura, Phys. Rev. Lett. **45**, 1311 (1980).
[2] A. M. Zebelman and J. M. Miller, Phys. Rev. Lett. **30**, 27 (1973).
[3] J. F. Ziegler, SRIM-2006 [http://www.srim.org/SRIM/SRIMLEGL.htm]
[4] Sabir Ali et al., J. Mod. Phys. **5**, 02063 (2014).
[5] A. Gavron, Phys. Rev.C **21**, 230 (1980).
[6] H. Morgenstern et al., Phys. Lett. B **113**, 463 (1982).