Preequilibrium analysis of ^{11}B-induced reaction on ^{nat}Y and ^{nat}Nb

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Introduction

Investigation of light fast particle emissions, termed as preequilibrium (PEQ) particles, prior to statistical equilibrium (EQ) from the fused excited nucleus is an excellent tool to study the dynamics of nucleon-nucleon interaction, their energy dissipation during the early stage of equilibration process and evolution towards thermodynamic equilibrium. Investigations of heavy-ion induced reaction on the medium/heavy mass nuclei have reported the evidence of significant PEQ emissions, complete-incomplete fusion (CF–ICF), and nucleon transfer processes slightly above the Coulomb barrier in α-cluster and weakly bound projectiles [1–4].

The PEQ emission of neutrons was observed in the $3n$-channel of ^{12}C, ^{16}O, ^{11}B, ^{7}Li induced reactions on ^{159}Tb, ^{169}Tm, ^{181}Ta, ^{89}Y, ^{93}Nb targets in the low energy region, within 4–7 MeV/A, where pure evaporation process is greatly favoured [1–3]. ICF has also been witnessed via α-emitting channels of ^{7}Li+^{nat}Mo reaction in this energy region recently [4]. However, further investigations are necessary to understand the dependence of PEQ emissions on the projectile energy and type, threshold for the PEQ emissions for different target-projectile combinations, and cross-section distribution between PEQ and CF-ICF processes, etc. from slightly above the Coulomb barrier to well above it. In this report, PEQ fraction of ^{97}Ru and ^{101}Pd radionuclides have been reported from ^{11}B+^{89}Y and ^{11}B+^{93}Nb reactions, respectively, within $\sim$ 4–5.5 MeV/A energy range.

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Experimental

The self-supporting ^{nat}Y and ^{nat}Nb metal foils having uniform thickness of 0.84–2.9 mg/cm^2 and 1.2–2.1 mg/cm^2, respectively, were bombarded by the ^{11}B beams delivered at the BARC-TIFR Pelletron facility, Mumbai, India. Each target foils (^{nat}Y / ^{nat}Nb) were backed by 1.5–2 mg/cm^2 thin aluminum foils worked as catcher and energy damper. After the end of bombardment (EOB), each irradiated target foils were analysed offline with the help of an HPGe detector and software assembly. The measurement of activity of the residues from the background subtracted peak area count rate was used to determine the cross-section of the corresponding reaction channel.

Results and discussion

The PEQ analysis of ^{97}Ru and ^{101}Pd radionuclides populated via $3n$ channel in the ^{11}B-induced reactions on ^{nat}Y and ^{nat}Nb targets, respectively, was carried out by comparing with the theoretical model code PACE4, which considers only evaporation of nucleons/clusters from a statistically equilibrated compound nucleus. Significant PEQ emission of neutrons over the evaporation was observed in the $\sim$ 45–63 MeV energy window of the excitation functions, as manifested in Fig 1(a). It is expected, as emission of one PEQ neutron with two evaporation neutrons is probable in the low energy range.

Furthermore, the amount of PEQ emission of neutrons relative to the total evaporated and non-evaporated emissions (i.e., sum of PEQ and EQ contributions), known as preequilibrium fraction ($F_{\rm PEQ}$), has been calculated at different projectile energies for ^{89}Y(^{11}B,3n)^{97}Ru and ^{93}Nb(^{11}B,3n)^{101}Pd reactions, as depicted in Fig 1(b). The $F_{\rm PEQ}$ can be estimated as $[(\sigma_{\rm expt} - \sigma_{\rm PACE})/\sigma_{\rm expt}] \times$

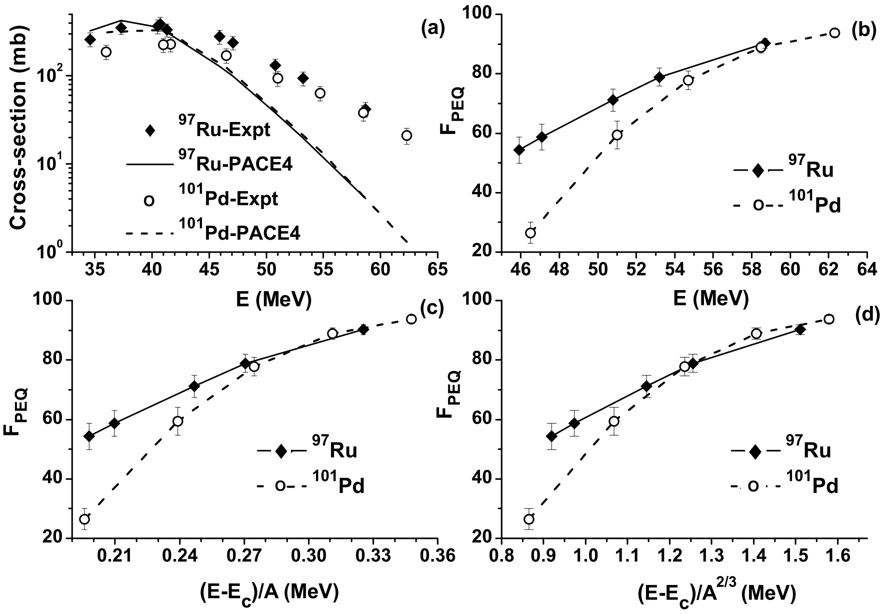

FIG. 1: Variation of cross-sections of ^{97}Ru, ^{101}Pd and their PEQ fractions at various projectile energies.

100%, where experimentally measured cross-section ($\sigma_{\rm expt}$) is the sum of both PEQ and EQ contributions and PACE4 estimation ($\sigma_{\rm PACE}$) only considers equilibrated neutrons. The Fig 1(b) demonstrates the rapid increase of PEQ emission of neutrons with the increasing projectile energies and becomes saturated above a certain energy which seem to depend on composite nucleus mass number. Moreover, threshold for PEQ emission is found lower for low mass target, ^{89}Y, compared to ^{93}Nb, as observed in other heavy-ion induced reactions [3]. In order to eliminate the effect of Coulomb barrier ($\mathrm{E}_{\mathbf{c}}$), the $F_{\rm PEQ}$ is plotted against the excess excitation energy above the barrier relative to total nucleons and surface nucleons of the composite nuclear system, i.e., (E-$\mathrm{E}_{\mathbf{c}}$)/A and (E-$\mathrm{E}_{\mathbf{c}}$)/A$^{2/3}$, shown in Fig 1(c) and 1(d), respectively. Perhaps due to the similar composite nucleus mass in these reactions, no systematic trend in PEQ neutrons was observed apart from the reduction in spreading of the two curves when plotted against per unit surface nucleons (Fig 1(d)), which might be due to the dependence of PEQ emissions on the surface nucleons.

Conclusion

Since the measured cross section data of the residues could only be explained by proper admixture of the PEQ and EQ contributions [2], substantial contribution of PEQ neutrons has been confirmed in 3n channel of ^{11}B+^{89}Y & ^{93}Nb reactions within $\sim$ 4–5.5 MeV/A energy. It is also revealed that $F_{\rm PEQ}$ increases with increasing projectile energy until it saturates where compound evaporation is negligible.

Acknowledgments

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References

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