Low energy fusion dynamics in alpha induced reactions: A systematic study of pre-compound emission

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Investigation on low energy reaction dynamics over a wide range of atomic mass number *(A)* nuclei have enunciated clearly a strong competition between the compound (CN) and pre-compound (PCN) emission in α-particle induced reactions. At low energy the compound nucleus process is expected to play an important role in such reactions, however, recent findings give a considerable recognition to the pre-compound emission as an important de-excitation process even at energies as low as ≈4-5 MeV/nucleon. In the pre-compound emission process the emission of particles takes place at any stage during the redistribution of energy of the incoming particle among the nuclear degrees of freedom through a chain of particle-hole excitations before the establishment of statistical equilibrium[1–3]. The particles which are emitted before to the establishment of statistical equilibrium are known as pre-compound particles[4].

In literature, several experimental methods are available to investigate the PCN process but the measurement and analysis of excitation functions (EFs) is more important and is widely used to deduce the contribution of PCN process. The low energy portion of the EFs is dominated by the CN mechanism, however, with the increase in projectile energy, the strength of the PCN process becomes relatively more. Though, a plenty of experimental data on measurements of EFs for the PCN emission is available, but only a few attempt is made to get a systematic trend on the concerning process with mass number of target nuclei[5]. With the motivation to develop a systematics in the PCN process, a detailed analysis of EFs for reactions ^{63}Cu(α, n)^{66}Ga, ^{65}Cu(α, n)^{68}Ga, ^{69}Ga(α, n)^{72}As, ^{71}Ga(α, n)^{74}As, ^{85}Rb(α, n)^{88}Y, ^{89}Y(α, n)^{92}Nb, ^{93}Nb(α, n)^{96}Tc, ^{103}Rh(α, n)^{106}Ag,^{107}Ag(α,n)^{110}In, ^{109}Ag(α,n)^{112}In, ^{113}In(α,n)^{116}Sb, ^{115}In(α,n)^{118}Sb, ^{121}Sb(α, n)^{124}I and ^{123}Sb(α,n)^{126}I respectively has been performed with PACE code[6]. It may be pointed out that EFs for all the above reactions have been measured by using stacked foil activation technique and their details are available at the EXFOR library[7].

In order to utilize the available exclusive experimental cross section data for establishing a mass number dependence systematics trend of pre-compound emission of neutrons, the energy dependent contribution of pre-compound emission has been deduced[5]. This can be achieved by a precise analysis of measured excitation functions with a consistent set of parameter in odd Z (=29-51) and odd A (=63-103) target nuclei viz., ^{63}Cu,^{65}Cu,^{69}Ga,^{71}Ga,^{85}Rb,^{89}Y,^{93}Nb, ^{103}Rh, ^{107}Ag, ^{109}Ag, ^{113}In, ^{115}In, ^{121}Sb and ^{123}Sb respectively. In this analysis, the enhancement of measured cross-section as compared to cal-

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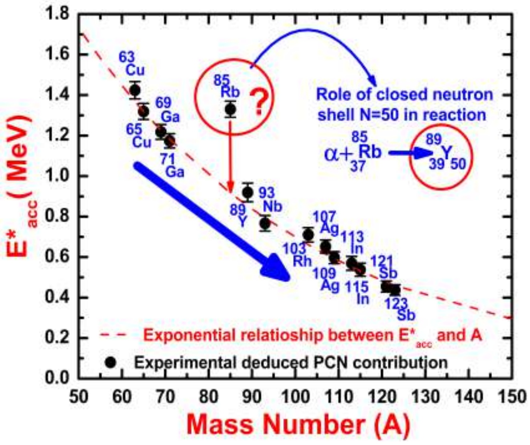

FIG. 1. A plot of E^*_{acc} vs mass number *(A)* of the target nuclei

culations performed with statistical model code PACE has been attributed to the pre-compound contribution. Further, the effect of closed neutron shell on pre-compound emission process, which is significantly important, has also been explored.

The deduced pre-compound contribution is found to be systematically depending on beam energy and atomic mass number (A) of the target nuclei, where the role of surface neutrons from the periphery of a non-equilibrated compound nucleus is also found to be important. Present observations on PCN emission are found to be consistent and systematic for target nuclei in a wide mass region A= 63-123.

It has been observed that the parameter accessible excitation energy (E^*_{acc}) which is the excitation energy over the Coulomb barrier (E*-V$_b$) per surface nucleon of composite system may greatly affect the pre-compound emission process. A plot of E^*_{acc} vs mass number *(A)* of the target nuclei is shown in Fig.1. As can be seen from this figure that the accessible excitation energy (E^*_{acc}) decreases exponentially with mass number *(A)* of the target nuclei. As such, a smaller values of E^*_{acc} is required for emitting one neutron as pre-compound particle from higher mass target nuclei from the excited nucleus. This may be mainly due to the fact that one neutron (1n) separation energy is relatively less for the higher mass numbers. The observed exponential relationship in the PCN emission process is significantly important and gives the way to correlate the pre-compound contribution for (α,n) reactions at low energies, where the CN emission is generally considered to be dominant. The systematic trend, as shown in Fig.1, may also be used for predicting the pre-compound contribution in the nuclei beyond the studied region, except those forming a compound nucleus having closed shell, as a case of CN $^{89}_{39}$Y formed in α+$^{85}_{37}$Rb system. Further details of the analysis and systematics developed will be presented.

The authors are thankful to the Director, VECC, Kolkata for extending all the facilities for carrying out the experiments.

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