Pre-compound emission in $^{12}C+^{169}Tm$, $^{16}O+^{169}Tm$ and $^{16}O+^{159}Tb$ systems at low excitation energies

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During last few decades the pre-compound emission (PCN) and compound nucleus (CN) emission in light ion reactions has been well studied but in heavy ion reactions it needs to be further explored particularly for those associated with emission prior to the establishment of equilibrated CN. The particles which are emitted before the formation of CN are referred to pre-compound particles and reaction mechanism is known as PCN process.

Furthermore, the mechanism of PCN, particularly in heavy ion reactions at low excitation energies where compound nucleus CN process dominates, has regenerated interest, since it is expected to occur generally at moderate excitation energies[1, 2]. Following are the experimental characteristics of PCN process; (i) the presence of a larger number of high-energy particles as compared to the spectrum predicted by the statistical model, (ii) forward-peaked angular distribution of the emitted particles, (iii) observation of smaller recoil range/linear momentum of the evaporation residues left over emission of PC particles as compared to CN particles, (iv) observation of lower value of the spin with PCN process as compared to CN process, (v) slowly decreasing tails of the excitation functions etc.,

Information about the PCN process in heavy ion reactions may be obtained by measuring anyone of the above experimental characteristics. In the present work, a more direct method, based on the measurement of angular momentum involved in the PCN and CN processes has been discussed. Since emitted PCN particles takes away a significant part of angular momentum as compared to CN particles, the angular momentum associated with the PCN products is relatively smaller than that associated with the CN process. Therefore, in PCN reactions, the residues are populated at relatively lower spin states as compared to those of the residues populated via CN process. As such, the measurements of the momentum involved during the interaction may provide a promising tool for the characterization of the PCN and CN processes.

In order to determine the angular momentum involved in the PCN and CN processes, the experiment based on particle-gamma coincidence technique has been performed for measuring the population of spin states during de-excitation of reaction residues. In the present work, the spin-distributions of the reactions $^{169}Tm(^{12}C,2n)^{179}Re$, $^{169}Tm(^{12}C,pn)^{179}W$ and $^{169}Tm(^{12}C,p2n)^{178}W$ at $\approx$68 MeV have been measured using Gamma Detector Array (GDA) alongwith Charged Particle Detector Array (CPDA). Multiparameter, particle-γ-coincidence data are recorded in list mode, which includes different gating conditions such as particle(s)/α detected in backward (B), forward (F), and sideways (S) angles. Singles data are also collected to identify xn channels.

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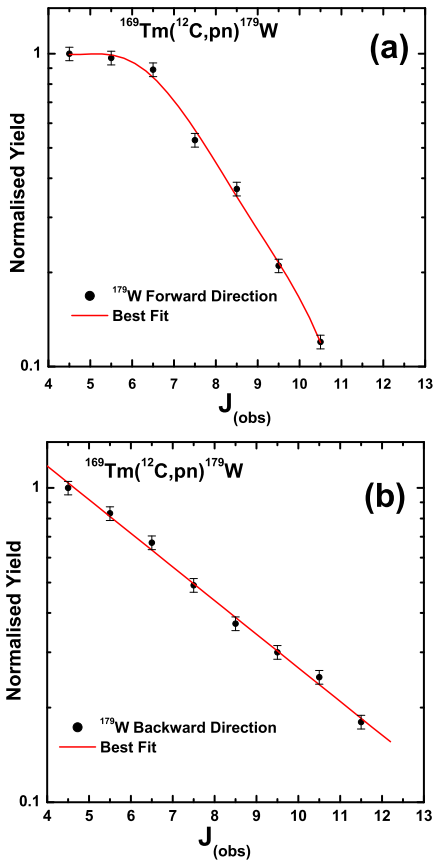

FIG. 1: The experimentally measured spin distributions for reactions ^{169}Tm(^{2}C,pn)^{179}W in forward and backward directions. The curve and line in this figure guide the eye as a best fit to the experimentally normalized yield of spin distributions of PCN and CN processes.

The reaction residues have been identified from their characteristic prompt γ-transition lines. The values of relative production yields of the residues (observed area under the peak of the experimentally measured prompt gamma lines with proper detector efficiency correction) have been plotted as a function of observed spin J_{obs} corresponding to prompt gamma-transitions[3]. The relative yield has been normalized with minimum observed spin (J_{obs}^{min}) at highest yield (Y_{obs}^{max}).

As a representative case the experimentally measured SDs obtained from prompt γ-rays recorded in forward and backward directions for the reaction ^{169}Tm(^{12}C,pn)^{179}W are shown in Fig 1 (a) and 1(b) at 68 MeV, respectively. As can be seen from this figure, the measured SDs and hence its decay pattern for this reaction obtained in the forward and backward directions are distinctly different from each other indicating widely different reaction mechanisms involved. It may be pointed out the entirely different shapes of SDs in forward and backward directions indicate that the two processes are quite different in nature.

As such, it is concluded that distinctly different SDs give a direct evidence of the PCN emission process. The measurements of SDs for ^{12}C+^{169}Tm system are consistent with measurements of excitation functions, recoil range distributions and SDs carried out for ^{16}O+^{169}Tm and ^{16}O+^{159}Tb systems[1, 2]. Thus, the results of the measurements of the SDs further supplement the conclusions drawn from the earlier measurements. Further details will be presented.

The authors are thankful to the Director, IUAC, New Delhi for extending all the facilities for carrying out the experiments. MKS thanks to the Council of Scientific and Industrial Research (CSIR), New Delhi, India vide the project number 03(1361)16/EMR-11 for financial support.

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