Study of Charged Particles and Neutrons Emitted from a Completely Symmetric Fusion-Evaporation Reaction at Various Excitation Energies

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Introduction

The compound nuclear processes with $E \leq 5\ MeV/A$ are dominated by compound nuclear processes. In various recent mass-symmetric reaction studies, the particle spectra evaporated from the Fusion-evaporation reaction show the influence of deformation on α and proton spectra [1–4]. The statistical model with the inclusion of dynamical effects have been necessary in some of the studies to explain the experimental spectra [5]. In order to inquire more about this discrepancy and understand the dynamics of a mass-symmetric reaction, we have populated ^{48}Ti + ^{48}Ti at various energies. The dynamics of the reaction is studied by observing inclusive as well as exclusive charged particle spectra.

Experimental Details

The experiment was performed using the NAND chamber at IUAC. ^{48}Ti pulsed beam was accelerated at energies of 130 MeV, 140 MeV and 150 MeV using 15 UD pelletron accelerator. The beam was accelerated on 500 $\mu g/cm^2$ ^{48}Ti target to study the neutrons and charged particles emitted from a completely symmetric reaction. For the experiment, 16 in-plane neutron detectors from the NAND array were utilized to get the neutron spectra at angles of 18°, 36°, 54°, 72°, 90°, 108°, 126°, 144°, 162°, 198°, 216°, 234°, 252°, 270°, 288° and 342°. BC501A organic scintillators used for neutron spectroscopy were at a distance of 175 cm from the target ladder. $CsI(Tl)$ detector array placed at a distance of 16.2 cm inside the NAND chamber had an angular coverage of $\approx 46° - 114°$. These detectors were used to study the light charged particle spectra emitted from the reaction. The evaporation residues were obained with the help of two MWPCs having an active area of $2'' \times 4''$ each, placed at left and right direction, respectively with respect to the beam. These detectors were kept at a distacne of 50 cm from the target ladder, and provided an angular coverage of $4° - 17.5°$.

Results and Discussions

The inclusive as well as exclusive measurements for charged particles and neutrons have been carried out at various energies. The experimental results at 150 MeV have been shown in Fig. 1 and Fig. 2. For the neutron spectra, the exclusive measurements are taken by gating with the ERs obtained from MWPC detector placed at forward angles. The neutron spectra at various angles are represented in Fig 1. The CASCADE model calculations have been performed using level density parameter as $a = A/8$ and $r = 1.25\ fm$. They fit the experimental spectra well. Also, the calibrated alpha particle spectra obtained form the $CsI(Tl)$ detector at some of the angles has been shown in Fig. 2. The spectra are fitted using the default value of deformation parameters for this case, and rest of the values are same as considered to fit the neutron spectra at most of the angles. While it is observed at some forward angles, the experimental spectra do not fit at higher. The level density parameter if changed to $a = A/9$ might fit the spectra in those cases, which suggests that α

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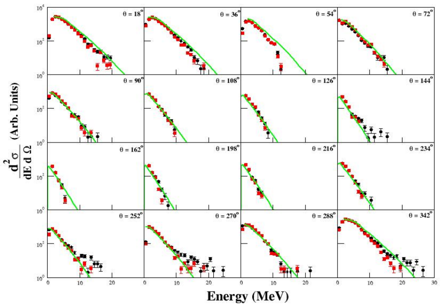

FIG. 1: Neutron spectra for ^{48}Ti + ^{48}Ti system at 150 MeV. The figure shows inclusive (black circles), exclusive (red diamonds) and CASCADE model calculations (green solid line) with default parameters (refer to text for more information).

are emitted from a higher temperature compound nuclie in such cases. In order to get

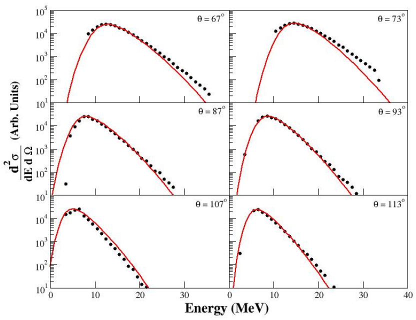

FIG. 2: Alpha particle spectra for ^{48}Ti + ^{48}Ti system at 150 MeV. Black circles show the experimental spectra, and red solid line represents CASCADE model calculations with default parameters (refer to text for more information).

more insight into the observations, dynamical HICOL model calculations were performed (Fig. 3) and maximum possible value of angular momentum comes out to be 37$\hbar$. From CASCADE calculations, the maximum possible value of angular momentum is 34$\hbar$, which is same as obtained from the HICOL model calculations. The formation time of the system, from HICOL calculations is 5.43 $\times$ 10^{-21} *sec*, while the decay time (from PACE calculations) is 6.40 $\times$ 10^{-21} *sec*. As the decay time and the formation time are approximately same, so we do not see any influence of fusion hindrance effect at this energy.

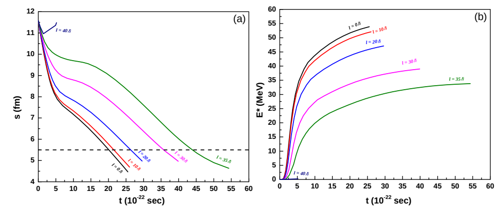

FIG. 3: HICOl model calculations for ^{48}Ti + ^{48}Ti system at 150 MeV showing (a) The evolution of nuclie by observing change in fusing distance s with time and (b) the evolution of excitation energy with time for different angular momentum values.

Conclusion

Hence, we conclude that dynamical effects do not influence the formation of compound nucleus at this excitation energy (E* = 64 MeV), and the emitted particles can be well explained using the statistical model calculations only, with adjustment of level density parameter at some of the angles for emitted α-particles. These observations counter previous well documented studies where discrepancy is observed in the particle spectra at similar excitation energies [3, 6]. Further experiments at higher energies for this system need to be conducted to investigate the energy where influence of dynamical effect sets in, if any.

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