Fusion of ^{11}B in Mo: Residual cross section measurement

Yasir Arafat and Moumita Maiti*
Department of Physics, Indian Institute of Technology Roorkee, Roorkee – 247667, Uttarakhand, India

Introduction

The study of heavy-ion (HI) fusion has been extensively investigated in recent decades due to the technological advancements of accelerators. The HI reaction may lead to a variety of nuclear reaction processes such as complete fusion (CF), incomplete fusion (ICF), pre-equilibrium (PEQ) emission, fusion-fission, quasifission, and transfer reactions [1, 2]. The strength of these processes is yet to be understood below 10 MeV/A energy [3, 4], while the complete fusion process is found to dominate in this energy region. In central collisions such as CF, the projectile transfers its total angular momentum to the target within the limit of $0 < l \leq l_{crit}$, while in the pheripheral collisions and ICF process, partial angular momentum transfer occurs with $l \geq l_{crit}$. Thus, exploration of heavy-ion fusion processes is required to understand the dynamics of nuclear reactions around and above the Coulomb barrier. In order to understand the reaction mechanisms, we measured residual cross-sections in ^{11}B+Mo reaction with the 31–63 MeV energy range.

Experiment

The experiment was performed at the BARC-TIFR Pelletron facility in Mumbai. The stacks of Mo foils of thickness ≈ 2.6–2.7 mg/cm^2 backed by Al foils of thickness ≈ 1.6 mg/cm^2 were irradiated by ^{11}B beam within the energy range 31–63 MeV. Al backing foils served the purpose of energy degrader and the catcher for residue. The Stopping and Range of Ions in Matter (SRIM) code was employed to determine the energy degradation in each foil. The efficiency and energy calibration of the HPGe detectors were performed using a standard ^{152}Eu and ^{60}Co γ-ray source. The irradiated target-catcher foils were assayed offline using pre-calibrated HPGe detectors, and residues were identified from their characteristic γ-rays and decay curves. The residual cross-sections were estimated using the activation formula [5], taking care of all the sources of errors.

Results and discussion

The residues ^{103,104,106m}Ag, ^{100,101}Pd, ^{100}Rh, ^{97}Ru, and ^{96}Tc were populated in ^{11}B+Mo reaction via xn, pxn, αxn, αpxn, and $2\alpha xn$ channels, respectively. However, in this abstract, the ^{103}Ag and ^{100}Pd populated via xn and pxn channels have been discussed in details. The measured cross-sections are compared with the theoretical predictions from PACE4 and EMPIRE3.2.2. PACE4 is based on Hauser-Fashbach (HF) formalism and only deals with the equilibrium (EQ) process. In PACE computations, the fusion cross-section is estimated using the Bass model. The Fermi gas level density with level density parameter $a = A/K$, where A is the mass number of compound nuclei, and K is a free parameter, with $K = 10$, has been used. EMPIRE considers all three major nuclear processes–direct reactions, PEQ emission, and EQ process. EMPIRE is also based on HF formalism but incorporates the phenomenological exciton model (EM) for PEQ emission of particles and the coupled-channel (CC) approach and distorted-wave Born approximation (DWBA) for direct reactions. The simplified coupled channel code (CCFUS) determines the fusion cross-section in EMPIRE estimations. We have used EMPIRE with EGSM (Enhanced Generalized Superfluid Model) level density and the mean free path parameter 1.5 in the exciton model for PEQ emission. The measured cross-sections of ^{103}Ag and ^{100}Pd are compared with the theoretical predictions

*Electronic address: moumita.maiti@ph.iitr.ac.in

from PACE and EMPIRE, as shown in Fig. 1 and Fig. 2.

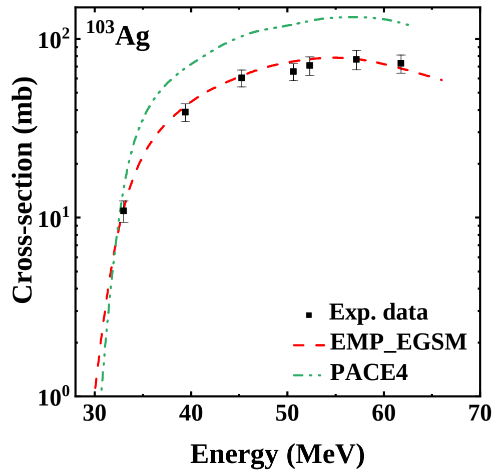

FIG. 1: Comparison of measured excitation function with theoretical predictions for ^{103}Ag populated via xn channel.

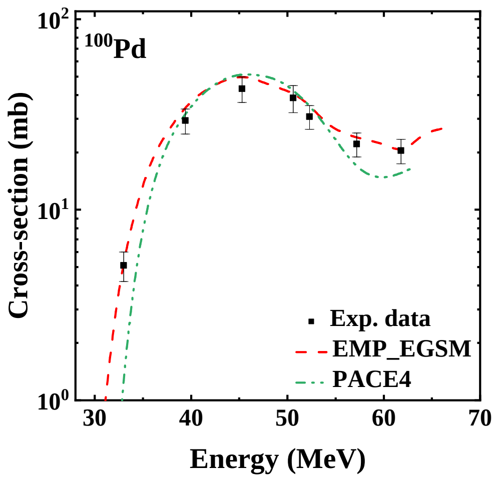

FIG. 2: Comparison of measured excitation function with theoretical predictions for ^{100}Pd populated via pxn channel.

xn channel: The measured data of ^{103}Ag agree well with EMPIRE throughout the energy range, as shown in Fig. 1. However, PACE overpredicts the measured data in the energy range above 33 MeV.

pxn channel: EMPIRE predicts the experimental data satisfactorily for the residue ^{100}Pd as shown in Fig. 2. However, PACE accurately predicts the measured data in the energy range 39.4–52.3 MeV but underpredicts below 39.4 MeV and above 52.3 MeV. PACE ensures the production of ^{100}Pd through the equilibrium mechanism in the energy range 39.4–52.3 MeV.

Besides the above residues, the measured excitation functions in all xn and pxn channels are reproduced by EMPIRE with EGSM calculations, while PACE fails to reproduce those. Thus, the formation of the residues via xn and pxn channels can be assumed through EQ and PEQ processes. To further confirm the contribution of PEQ, we stopped the PEQ channels in EMPIRE estimations, and it was seen that the measured data is fairly reproduced within this energy range. Thus, it can be concluded that the xn and pxn channel residues are produced only through the EQ process. The discrepancy in PACE and EMPIRE estimations may be due to the role of the method of fusion cross-section calculation for the reaction ^{11}B+Mo. The detailed analysis of the data and its interpretation in the framework of theoretical model codes is in progress.

Acknowledgments

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