Investigation of 1n- and 2n-transfer in ^{7}Li+^{115}In reaction around the Coulomb barrier

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Introduction

In recent years, numerous theoretical and experimental studies have focused on investigating the reaction mechanisms of weakly bound nuclei, such as ^{6,7}Li, with particular emphasis on elastic scattering, breakup, transfer, and fusion [1]. The enhanced cross sections in these reactions are often attributed to incomplete fusion (ICF), while direct transfer processes are overlooked. Although these two processes are hard to separate experimentally, transfer and ICF are viewed as distinct processes theoretically.

Multi-nucleon transfer (MNT) reactions are gaining attention as a promising method for producing neutron-rich heavy nuclei. However, due to its complexity, our understanding of the reaction mechanism is still limited. Single nucleon transfer offers valuable insights into shell structure, while two-nucleon transfer reactions are especially useful for studying pairing correlations [2, 3]. Transfer reactions have also been used to measure nuclear matrix elements of neutrinoless double β decay [4]. The presence of multi-step transfers involving sequential transfer, inelastic excitations before or after the transfer, and other factors, in addition to the typically dominant direct transfer, complicates the reaction mechanism. The complexity of the reaction mechanism increases significantly with the number of transferred nucleons. MNT reactions are effectively described by the coupled reaction channel (CRC) formalism, as it enables the inclusion of all possible channels in heavy-ion-induced reactions.

Theoretical analysis

The experiment was performed at the BARC-TIFR Pelletron facility in Mumbai, India, where ^{7}Li-ion beam was allowed to incident on In targets (0.4 mg/cm^{2} thick) backed by Al foils of thickness 1.6 mg/cm^{2} arranged in a stack. Al foil served the purpose of an energy degrader and a catcher for recoils. After irradiation, the residues populated in target and catcher foils were detected using γ-spectroscopy, and cross sections were calculated.

In this study, we have analyzed the measured cross sections of residues ^{116m}In and ^{117}In in ^{7}Li-induced reaction on ^{115}In within 20-45 MeV energy range using codes: FRESCO [5] and EMPIRE-3.2.3 [6].

For $1n$-transfer, the calculations utilized a double-folding São Paulo Potential (SPP) [7] for both the real and imaginary components of the optical potential ($U(R) = (N_r + iN_i)V^{SP}(R)$). In the entrance channel, the strength coefficients for the real and imaginary potentials have been set to $N_r = N_i = 0.6$ to account for flux loss due to dissipative and breakup channels, as well as the repulsive nature of the real part of the breakup polarization potential. The SPP has been applied to the real and imaginary components with strength coefficients $N_r = 1.0$ and $N_i = 0.78$ in the exit channel. The post potential form, including full complex remnant terms and non-orthogonality corrections, is incorporated into the calculations. A Woods-Saxon form factor with a radius of $1.27A^{1/3}$ fm and a diffuseness of 0.65 fm has been used for both the lighter and heavier nuclei. A spin-orbit component is also included.

For $2n$-transfer, the extreme cluster approach has been utilized. In this method, transition potential acts on the relative mo-

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tion between the correlated nucleon pair and the core, treating the nucleon pair as a single quasi-particle. The initial and final bound state wave functions for the di-neutron system have been generated using a Woods-Saxon potential with a radius of $1.30A^{1/3}$ fm and a diffuseness of 0.65 fm. The potential depth was adjusted to match the two-neutron separation energy. The post form of the interaction potential, which includes the full complex remnant term and non-orthogonality correction, has been used for finite range transfer calculations. The SPP with a strength coefficient of 0.6 is used as the optical potential for the real and imaginary components in the entrance channel. The imaginary component of SPP is scaled by a factor of 0.78 in the exit channel. The spin-orbit interaction term is also included in the computations.

Results and discussion

Fig. 1 presents a comparison between theoretical results and the experimental data. The solid black line represents the CRC calculations using the SPP potential, while the dotted black line represents the EMPIRE calculations using the EGSM level density. $^{116}_{g.s}\mathrm{In}(1^+)$, $^{116}_{0.127}\mathrm{In}(5^+)$, $^{116}_{0.223}\mathrm{In}(4^+)$, $^{116}_{0.273}\mathrm{In}(2^+)$, and $^{116}_{0.313}\mathrm{In}(4^+)$ states of ^{116}In and $^{117}_{g.s}\mathrm{In}(4.5^+)$, $^{117}_{0.315}\mathrm{In}(0.5^-)$, $^{117}_{0.589}\mathrm{In}(1.5^-)$, and $^{117}_{0.660}\mathrm{In}(1.5^+)$ states of ^{117}In have been included. It is evident from the figure that the EMPIRE calculations with EGSM level density significantly underpredict the experimental data for both residues. This suggests that other mechanisms, such as nucleon transfer or ICF, likely contribute to the production of these residues, in addition to equilibrium and PEQ particle emissions.

The CRC calculations using the SPP potential grossly agree with the experimental data for ^{116m}In, indicating that this residue is predominantly produced through one-neutron transfer. However, for ^{117}In, the CRC calculations underpredict the experimental data, suggesting that ICF may play a significant role in its production. The ongoing analysis of the production of ^{117}In via two-neutron transfer is in progress, and more details on this will be presented at the conference.

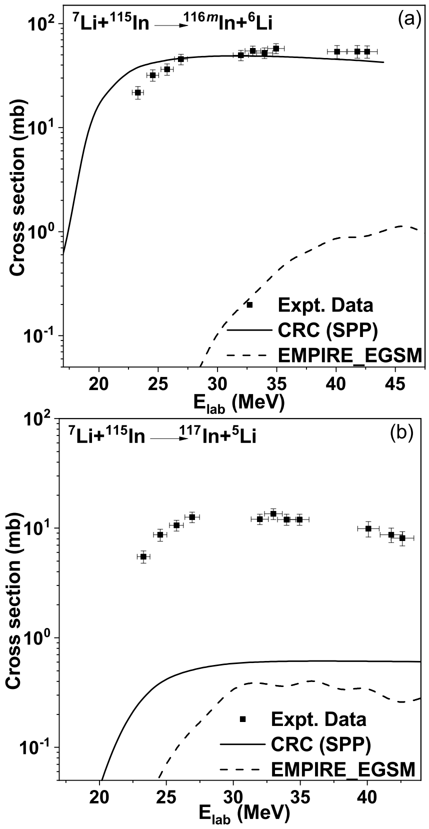

FIG. 1: Comparison of experimental excitation functions of (a) ^{116m}In and (b) ^{117}In with theoretical predictions from FRESCO and EMPIRE.

Acknowledgments

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