EPJ Web of Conferences **117**, 08028 (2016) DOI: 10.1051/epjconf/201611708028
NN2015

Understanding the effect of channel coupling on fusion of ^{6}Li+^{64}Ni

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Abstract

The effect of inelastic excitation and single particle transfer reactions on fusion have been investigated for the system ^{6}Li+^{64}Ni at near barrier energies. The calculations show that a simultaneous coupling to the inelastic excitation of projectile and target along with positive Q-value 1n- and 1p-stripping channels, describes the experimental CF cross sections reasonably well in the below barrier region.

Exploring the interplay of different reaction channels in the collision of weakly bound systems is a subject of interest, both experimentally and theoretically, over the past several years [1–4].

In a recent work [5], the effect of coupling to inelastic excitations and single particle transfer channels on the back angle quasi-elastic excitation function had been reported for the system ^{6}Li+^{64}Ni. To investigate the effect of these couplings on fusion excitation function, a complementary experimental observable, for ^{6}Li+^{64}Ni is the primary motivation of the present work.

Unlike the heavy targets, for the lower medium mass targets like ^{64}Ni the measured fusion cross sections with weakly bound projectiles provide total fusion (TF) cross sections instead of the cross sections for complete fusion (CF) of the whole projectile. The TF cross section for ^{6}Li+^{64}Ni system includes along with CF cross section the contributions from incomplete

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fusion (ICF) of a fragment of the projectile and particle transfer channels, the channels which populate experimentally indistinguishable residues.

In Ref. [6], we presented the CF cross sections for ^{6}Li+^{64}Ni separated from the measured TF cross sections. The extracted CF cross sections are found to be suppressed by about 13% relative to the one dimensional barrier penetration model (1DBPM) predictions at above barrier energy regime. This is less compared to nearly 30% suppression of the same for heavy targets [7,8]. On the other hand, it is observed that at subbarrier energies the CF cross section is enhanced compared to 1DBPM predictions. A Coupled Reaction Channel (CRC) model calculation has been performed, using the reaction code FRESCO (version FRES 2.9) [9], to investigate the origin of the observed enhancement of fusion cross section in the subbarrier region.

The code estimates the fusion cross sections (σ_{fusion}) from the relation,

$$\sigma_{fusion} = \sigma_{reaction} - \sigma_{outgoing}, \tag{1}$$

where $\sigma_{reaction}$ is the total absorption cross section and $\sigma_{outgoing}$ is the sum of the cross sections of individual direct reaction channels considered.

The direct reaction channels considered in the CRC calculation are the inelastic excitations of the projectile ^{6}Li (3^+, 2.18 MeV) and the target ^{64}Ni (2^+, 1.345 MeV), one neutron stripping to ^{5}Li+^{65}Ni system and one proton stripping to ^{5}He+^{65}Cu system. Altogether four coupling schemes, *viz.*, *CC I*, *CC II*, *CC III* and *CC IV* have been used to systematically understand the effect of coupling of direct reaction channels on fusion reaction. The details of the calculations and different parameters used are given in Ref. [5]

Before introducing the channel coupling, a 1^{st} order DWBA calculation has been performed to obtain the cross sections for the channels at each energy. The fusion cross section at each energy is then estimated from Eq. 1 by summing up the uncoupled channel cross sections to obtain $\sigma_{outgoing}$. The corresponding fusion excitation function is plotted in the Fig. 1 as a dash-dotted line and is labeled by *'NC'*. The excitation function *NC* describes the data nicely at the above barrier region but underpredicts both CF and TF data in the below barrier region.

With only the inelastic couplings switched on in the *CC I* scheme, $\sigma_{outgoing}$ now consists of the inelastic cross sections under coupled conditions and the transfer cross sections in the uncoupled condition. Slight enhancement of cross sections at subbarrier region have been observed, although no significant effect is seen in for the above barrier cross section values.

Coupling of 1n-stripping ($Q_{gg} = 0.435 MeV$) channels along with the inelastic excitations of the projectile and target in the *CC II* coupling scheme,

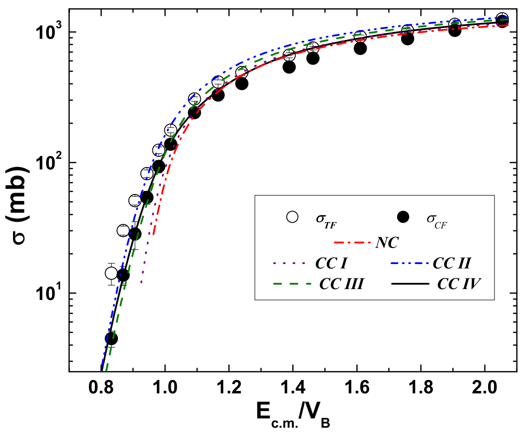

Figure 1: The fusion excitation functions from CRC calculation with different coupling conditions in comparison with the experimental TF and CF excitation functions for system ^{6}Li + ^{64}Ni. The *dashed-dotted* curve represents the excitation function in no coupling condition. The dotted, dashed-double dotted, dashed and solid curves represent the fusion excitation functions from the schemes *CC I*, *CC II*, *CC III* and *CC IV*, respectively.

denoted by dashed-double dot curve in Fig. 1, produces larger enhancement in fusion cross sections at subbarrier energies. Since $\sigma_{outgoing}$ now includes exclusively the contributions of coupled inelastic and 1n-stripping channels, the model fusion cross section matches the measured TF cross section instead of the extracted CF cross section in the low energy regime. The reproduction of TF cross section with this scheme indicates the admixture of 1p-stripping in measured TF cross section. But the model prediction compares well with the predictions of *CC I* and *NC* at above barrier energy range because of the reduced effect of coupling.

On the other hand, in the coupling scheme *CC III*, where 1p-stripping ($Q_{gg} = 3.021 MeV$) channel instead of 1n-stripping is coupled with the inelastic excitations, the model yields the CF cross section. The calculated cross sections marginally underpredict the CF data at subbarrier energies. At higher incident energies, as expected, the fusion cross sections with the scheme *CC III* match the other model predictions. The output from *CC III* scheme is shown by dashed line in Fig. 1.

Finally, it is observed that the coupling scheme $CC\ IV$, which includes the 1n- and 1p-stripping channels as well as the inelastic channels, describes CF data remarkably well at energies below the barrier with marginal increase over the estimates from $CC\ III$ scheme. Again a good matching with the cross section values from other schemes is observed at above barrier region. All the models in this energy regime overpredicts the measured CF cross sections, which is suppressed due to the effect of absorption of flux from the entrance channel through the breakup process, which is not considered in the CRC model.

To summarize, the CRC calculations have been performed to understand the effect of particle transfer channels on fusion excitation functions for the system ^{6}Li + ^{64}Ni. The calculation indicates that the single particle transfer coupling, along with the inelastic excitations, is important in explaining the subbarrier CF enhancement. The above barrier suppression of CF cannot be described by these calculations but the calculated excitation functions describe the TF excitation function quite well in above barrier region.

The authors gratefully acknowledge Professor N. Keeley and Professor A. Moro for their fruitful suggestions and help in carrying out the CRC calculation. Md. Moin Shaikh would like to thank the Council of Scientific & Industrial Research, India for financial support vide File No. 09/489(0084)/2010-EMR-I.

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