Fusion dynamics studies using Coupled Channel Calculations for the ^{32}S+^{100,102,104}Ru Reactions

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Introduction

Fusion cross-sections around the barrier are observed to have been influenced by various degrees of freedom of the interacting nuclei. They include low energy surface vibrations and static deformation shapes of the fusing nuclei. These lead to the modification of the single barrier into multiple potential barriers which causes the enhancement at sub-barrier region[1]. Coupled channel calculations have well established the role of various couplings in heavy ion fusion mechanism. These calculations have being carried out using many theoretical codes including CCFULL [3]. In this report, the coupled channel calculations were performed for ^{32}S+^{100,102,104}Ru systems using CCFULL code and the influence of hexadecapole deformation for the projectile and target nuclei has been checked. Experimental data were taken from pengo et al., [2]. The aim of this work is to provide a insight understanding about the interplay between the fusion dynamics and the underlying nuclear structure of the colliding partners.

Theoretical Calculations

In the present calculations, fusion excitation functions were compared with the theoretically obtained One Dimensional Barrier Penetration Model(1DBPM) in order to understand the fusion enhancements by including the low lying vibrational excitations for projectile and target nuclei. As shown in Fig.1, lowest quadrupole (2+) and octupole (3-) excitations in the target nuclei as well as the quadrupole excitation in the projectile are included in the coupling scheme for all the reactions. The single 2+ state of the projectile was found to be negligible for all the cases. The low-lying inelastic excitation states of 2+ and 3- of the target nuclei and 2+ state of the projectile enhanced the sub-barrier cross sections, but failed to reproduce the experimental data. The multiphonon and mutual excitations of the 2 + and 3- states were also included eventually in the calculations. The effect of state 2 + (two phonons) and 3-(single phonon) of the target and 2+ (single phonon) for the projectile underestimated the fusion cross sections in the sub-barrier energy region for all three reactions but is significant for above barrier energies. To overcome this limitation the contribution of two phonon excitation of the 2+ state for both target and projectile nuclei reproduced the experimental data for both ^{32}S+^{100,102}Ru reactions but not for ^{32}S+^{104}Ru system. For that, collective excitations comprising the inelastic couplings of single-phonon (3-) and double-phonon (2+) vibrational states of target and single phonon(2+) of the projectile respectively were included which reasonably matched the experimental data. Here, the combined effect of the both projectile and target inelastic states were included in the calculations.

To check the influence of quadrupole and hexadecapole deformation of the systematic target nuclei in the fusion of ^{32}S+^{100,102,104}Ru reactions, we have performed the coupled channel calculations with different coupling schemes. For the same system, semi-empirical coupled-channel calculations using the NRV code [4] was performed in the Ref.[2]. However, in the NRV code either rotational or vibrational channel coupling has to be considered simultaneously for both target and projectile in a reaction. But in the CCFULL code, rotational or vibrational channel cou-

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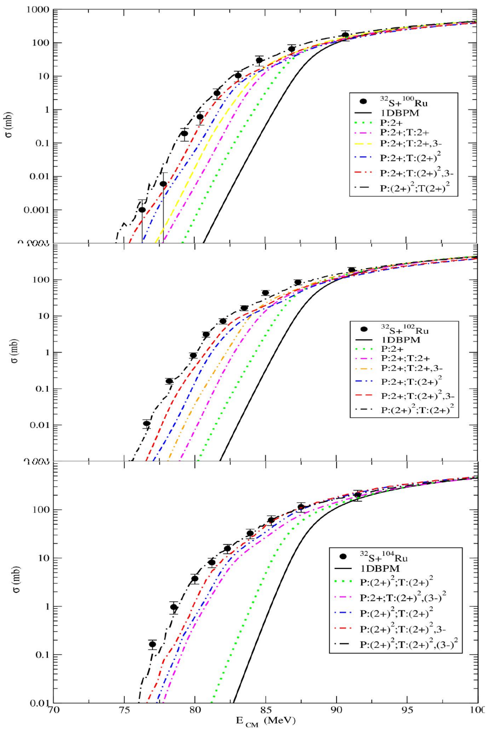

FIG. 1: Experimental fusion excitation functions for the ^{32}S+^{100,102,104}Ru reactions along with the predictions of 1DBPM calculations using CC-FULL code.

pling can be considered independently for the fusing partners. In the present Coupled Channel calculations, the rotational coupling have been considered for both projectile and target nuclei as shown in Fig.2.

Interestingly we noticed that a good fit to the experimental barrier distribution for ^{32}S+^{100,102,104}Ru systems were obtained using the hexadecapole deformation. Thus, we conclude that the rotational excitation of the both projectile and target with its quadrupole and hexadecapole effect plays a significant role in the fusion mechanism for all the three systems, respectively. The inclusion of low-lying inelastic excitation seems to give a nice explanation to the experimental data. The barrier distributions obtained from the coupled channels calculations without and with the coupling scheme is shown in Fig.2.

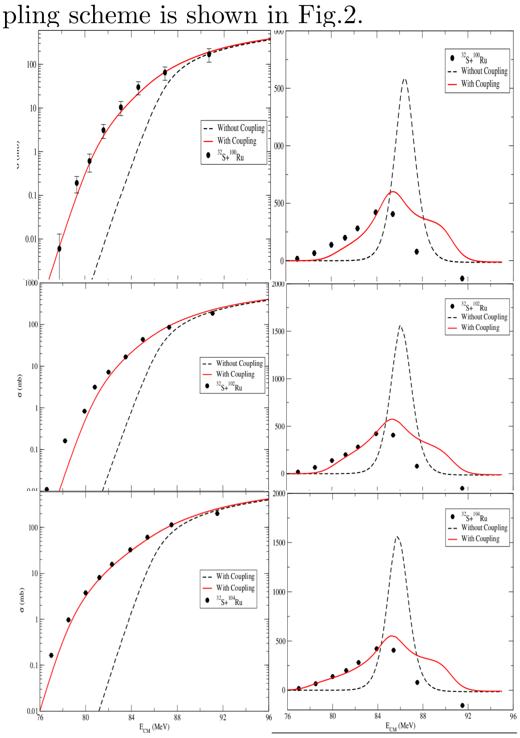

FIG. 2: Results of coupled channels calculations for the fusion barrier distribution of ^{32}S+^{100,102,104}Ru reactions without (dashed line) and with coupling scheme (solid line). Filled circles represent the experimental data

References

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