Influence of 2n transfer channels on sub-barrier fusion

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Introduction

Extensive work has been performed in the last few decades to examine sub-barrier fusion dynamics, where the influence of inclusion of nuclear surface vibrations and shape deformations of reactants has been well accounted, but the effect of coupling of transfer channels still needs to be explored [1, 2]. In our recent work [3], it has been shown that the influence of coupling of positive Q-value neutron transfer channels (PQNT) depend on structure of reacting nuclei. Specifically a significant enhancement in sub-barrier fusion was observed for the systems having one of the interacting nuclei as spherical or less deformed while negligible enhancement has been found for the systems where both the colliding nuclei were deformed. In ref [3] oblate deformed projectile with prolate deformed targets were considered. Therefore, in the present contribution we have analysed the fusion reactions induced by prolate deformed projectile ^{32}S on targets ^{64}Ni (spherical) and ^{154}Sm (prolate deformed) within the coupled channel (CC) formalism [4] to investigate the influence of shape and structure of colliding nuclei on fusion enhancement caused by PQNT coupling in sub-barrier energy region.

Coupled Channel Calculations

To examine the influence of coupling of excited states and neutron transfer channels coupled channel (CC) calculations have been carried out for fusion reactions ^{32}S + ^{64}Ni and ^{32}S + ^{154}Sm using code CCFULL [4] . Nuclear potential parameters , energy and deformation parameters of inelastic states of colliding partners are the main ingredients needed to carry out these calculations. Here, we have used Akyuj-Winther parameterization scheme[5] to obtain the parameters of the woods-saxon potential and the set of values obtained for potential depth (V_0), range (r_0) and diffuseness (a_0)are listed in table I. Also, the energies and deformation parameters for excited states of fusing partners taken from ref [6, 7] and are tabulated in table II.

TABLE I: Geometrical parameters of Akyuj-Winther (AW) potential (V_0, r_0, a_0) used in calculations

Systems	V_0(MeV)	a_0(MeV)	r_0(fm)
$^{32}S + ^{64}Ni$	64.702	0.652	1.172
$^{32}S + ^{154}Sm$	74.559	0.678	1.179

TABLE II: Excited states(λ^π) along with excitation energies(E_λ)and the corresponding deformation parameters(β_λ)used in coupled channel calculations.

Nucleus	λ^π	E_λ(MeV)	β_λ
^{32}S	2^+	3.290	0.168
^{64}Ni	2^+	1.34	3.56
	3^-	0.179	0.15
^{154}Sm	2^+	0.081	0.267
	4^+	0.341	0.07

Results and Discussion

The calculated fusion excitation functions for reactions ^{32}S + ^{64}Ni and ^{32}S + ^{154}Sm along with corresponding experimental data are shown in figure 1 and figure 2 respectively. As observed from figures that the results of 1D-BPM calculations lag behind the experimental data for both the systems in the sub-barrier region. Therefore target and projectile excitations were included in the coupling scheme. For system ^{32}S + ^{64}Ni, incorporation of coupling of target vibrational states 2^+,3^- enhanced the fusion cross sections (with respect to no coupling calculations (1D-BPM calculations)) but still the obtained cross sections fails to predict the experimental results. However, the inclusion of vibrational state (2^+) of projectile brought noticeable increment in cross sections although calculations could not reproduce the data. Nevertheless, the inclusion of coupling to 2n transfer channel(Q-value=3.564 MeV) was produced additional enhancement in fusion cross sections at sub-barrier energies which in turn reproduced the experimental fusion excitation function in this energy domain. Now, for system ^{32}S + ^{154}Sm as observed in figure 2 coupling of 2^+ rotational states of target enhanced the fusion cross section significantly but still experimental results remain quite far from the calculations in the sub-barrier region. Further coupling of vibrational state (2^+) of projectile and rotational state 4^+ of target incremented the fusion cross section but

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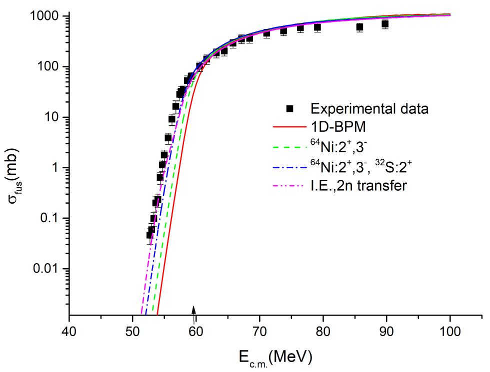

FIG. 1: Calculated fusion excitation function for ^{32}S + ^{64}Ni system with coupling of excited states of colliding nuclei and neutron transfer channel(denoted by lines). Experimental data (denoted by symbols) has been taken from ref [8].

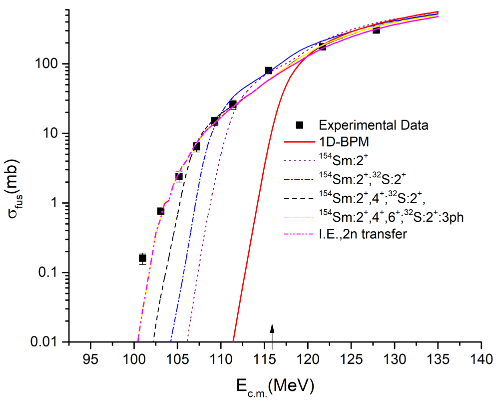

FIG. 2: Calculated fusion excitation function for ^{32}S + ^{154}Sm system with coupling of excited states of colliding nuclei and neutron transfer channel(denoted by lines). Experimental data (denoted by symbols) has been taken from ref[9].

couldn't remove the gap between the data and predictions. So multi-phonon excitations of vibrational state of projectile (three-phonon coupling of 2^+ state) and 6^+ rotational state of target were incorporated in the calculations which consequently explain the data quite well in the entire energy region. Furthermore 2n transfer channel (Q-value=6.22 MeV) was also included but negligible effect of coupling of transfer channel has been observed for this system.

Conclusion

CC calculations has been performed for reactions induced by prolate deformed projectile ^{32}S on spherical (^{64}Ni) and prolate deformed (^{154}Sm) targets. Coupling of excited states of reactants produced enhancement in sub-barrier region for both the systems. Consideration of contribution of 2n transfer channel in ^{32}S + ^{64}Ni reaction explain the experimental results in whole energy region but inspite of having positive Q-value for neutron transfer negligible effect of coupling of transfer channel has been found for ^{32}S + ^{154}Sm system which signify that system having spherical nuclei as one of the interacting partners show significant enhancement due to coupling of transfer channel. Whereas for reactions consisting of deformed nuclei as the interacting partners show negligible contributions. It is useful to mention here that similar results were obtained in our previous work with oblate projectile so it is concluded that shape of colliding partners has no influence on contribution of PQNT coupling.

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