Coupled Channel calculation of fusion cross sections and barrier distribution of deformed-deformed ^{24}Mg + ^{238}U reaction

Nisha Chauhan, S. S. Godre*
Department of Physics, Veer Narmad South Gujarat University, Surat – 395007, India
** email: ssgodre@yahoo.com*

Introduction

It is well known that heavy-ion collisions at energies near the Coulomb barrier are strongly affected by the internal structure of the colliding nuclei [1]. Recent interest in low energy heavy-ion reactions has been focused towards an understanding of the reaction mechanism in the framework of the coupled-channel formalism. The coupling between the relative motion and the internal degrees of freedom such as static deformation, vibration of nuclear surface, zero point motion, rotations of nuclei during collision, etc. results in the splitting of the uncoupled coulomb barrier into distribution of barriers of varying heights.

The role of static deformation (rotational) is of particular interest [2] and the calculations within the coupled channels model may become challenging in most nuclei.

In order to study the role of deformed nuclei in the fusion mechanism, we have calculated the fusion cross section and barrier distribution (BD) for a deformed-deformed ^{24}Mg + ^{238}U system using the code CCFULL [3].

Calculational details

In the present work, the effects of coupling of low lying rotational states of projectile and target nuclei for ^{24}Mg + ^{238}U system is investigated. In particular we have studied the effects of couplings of low lying 2^+ state of ^{24}Mg projectile and ^{238}U target nuclei. The main ingredients needed in the coupled channel calculations are the deformation parameter (β_λ) and the excitation energy (E_λ) of the rotational states. The values of these parameters (β_λ, E_λ) for ^{24}Mg: $\lambda = 2^+$ multipolarity are (0.375, 1.36 MeV) & ^{238}U: $\lambda = 2^+$ multipolarity are (0.286, 0.044 MeV) [4]. We have chosen parameters of the Woods-Saxon form of the nuclear potential for ^{24}Mg + ^{238}U system, V_0 = 200.0 MeV, r_0 = 1.0 fm, a_0 = 0.75 fm. The calculated barrier parameters are V_B = 185.87 MeV, r_B = 10.7 fm, $\hbar\omega$ = 6.25 MeV. Although, there is no experimental data for this system in the literature, this reaction is studied here as involves a light deformed and a heavy-deformed nucleus and helps to understand the effect of low lying rotational states of such system on fusion cross section and barrier distribution (BD).

Results and Discussion

In Fig. (1) and (2), we have plotted the fusion cross section and fusion barrier distribution of ^{24}Mg + ^{238}U fusion reaction respectively as calculated by the code CCFULL with and without coupling.

As seen in figures, the dotted line is the result when the projectile (^{24}Mg) and the target (^{238}U) are assumed to be inert i.e. no excitation level. This result gives a single peaked structure which is at E_{CM} = 131.0 MeV in BD. Then, we consider low-lying 2^+ rotational state of ^{238}U in next calculation. This calculation is denoted by dot-dashed line in figs 1 & 2. In this calculation, we take ^{24}Mg to be inert and the uncoupled single peak splits into two peaks structure. In next calculation, we consider the low-lying 2+ rotational state of ^{24}Mg and target ^{238}U nucleus to be inert. The result of this calculation also gives the two peaked structure which is denoted by dashed line in figs 1 & 2.

Lastly, both the nuclei i.e. the projectile (^{24}Mg) and the target (^{238}U) are assumed to have rotational coupling. The result of this calculation is denoted by solid line. In this calculation, we get the modified structure in the fusion barrier distribution as compared to the previous two cases. In this calculation we get multiple peaked structure i.e. three peaks which are at E_{CM} = 121.0 MeV, 129.0 MeV, 137.0 MeV.

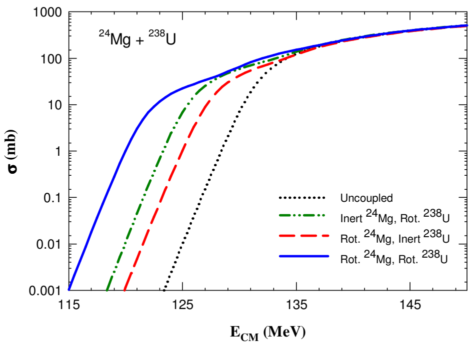

Fig. 1. Fusion cross section of ^{24}Mg + ^{238}U fusion reaction corresponding to various couplings.

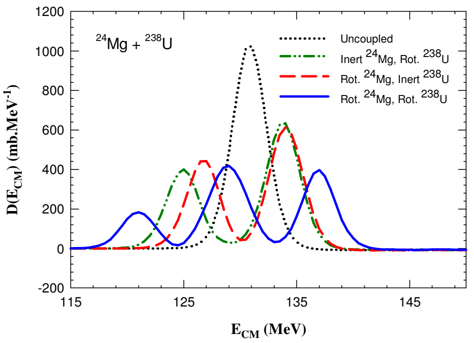

Fig. 2. Fusion barrier distribution of ^{24}Mg + ^{238}U fusion reaction corresponding to various couplings.

It is clear from the fig.-1 that there is substantial enhancement in the fusion cross section when coupling to the 2^+ state of the projectile and the target is taken into account. From the fig.-2 it is found that the barrier height is reduced due to the coupling of various rotational states of the projectile and the target.

Conclusion

We have investigated the effects of the coupling of low lying static deformation i.e. rotational states of the projectile and the target nuclei on the sub-barrier fusion cross-section for ^{24}Mg + ^{238}U fusion reaction through the coupled channel approach by using the code CCFULL. It has been found that the coupling of low lying rotational states with the relative motion of interacting nuclei enhances the sub-barrier fusion cross-section to large extent as compared with the uncoupled barrier calculations. Further, the reduction in barrier height is more pronounced when highly deformed and very low lying state of the projectile and the target is included and is responsible for the large enhancement in fusion cross-section. The enhancement in the fusion cross-section is found to be significantly large in case of highly deformed nucleus having a very low lying rotational state.

Reference

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