Study of deformed Coulomb effects on fusion probabilities with Skyrme's interaction

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Introduction

The study of heavy-ion collisions at low incident energies give us possibility to examine interaction between colliding nuclei in the form of nuclear potential. But, since nuclear potential is very complex, many potentials have been proposed to calculate the nuclear part of the total interaction potential. Out of various proximity based models, the Skyrme energy density formalism [1] takes into account the spin-orbit dependent part which involves the structural effects of the colliding nuclei. It takes into account Skyrme interactions that represent the effective nuclear force valid for low relative momenta cases. As far as Coulomb part of the interaction potential is concerned, a very few efforts have been made to modify it [2]. Our present aim is to study the effect of deformed Coulomb potential on fusion probabilities. The deformation enters the Coulomb potential through the deformation parameter " β_2 ", which describes the collective behavior of a nucleus. This study is carried out using Skyrme Energy Density Formalism (SEDF) by considering Skyrme forces S, SIII, SV and SKa.

Methodology

The nuclear potential V_N(R) is defined as the difference between the energy expectation value E of two colliding nuclei at a finite distance R and at infinity [1, 3]:

$$V_N(R) = E(R) - E(\infty). \quad (1)$$

The energy E at infinity represents the binding energy of a nucleus in isolation. The energy expectation value E is given by

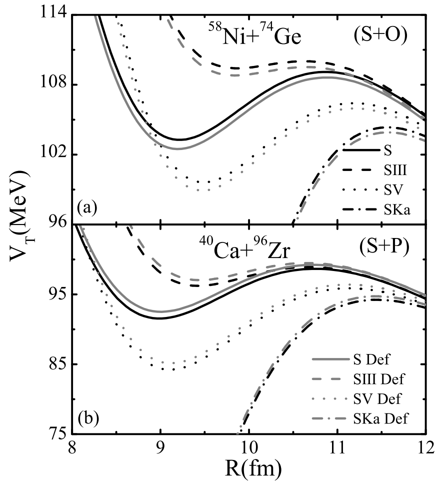

FIG. 1: Total interaction potential V_T (MeV) as a function of internuclear distance R (fm) for the reactions of ^{58}Ni+^{74}Ge and ^{40}Ca+^{96}Zr.

$$E = \int H(\vec{r})d\vec{r}. \quad (2)$$

The barrier formation occurs due to complex interplay between the nuclear and Coulomb potential and the expression for the Coulomb interaction $V_C(R,\theta)$ between two deformed colliding nuclei is given as

$$V_C(R,\theta) = \frac{Z_1Z_2e^2}{R} + \sqrt{\frac{9}{20\pi}}\frac{Z_1Z_2e^2}{R^3}\sum_{i=1}^{2}R_i^2\beta_{2i}P_2(cos\theta_i) + \frac{3}{7\pi}\frac{Z_1Z_2e^2}{R^3}\sum_{i=1}^{2}R_i^2[(\beta_{2i}P_2(cos\theta_i)]^2, \quad (3)$$

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where θ_i is the angle between the radius vector $\overrightarrow{R}$ and the symmetry axis of the *ith* nucleus and R_i being the effective sharp radius of *ith* nucleus.

The cross-section for a complete fusion $\sigma_{fus}(E_{cm})$ is given by:

$$\sigma_{fus} = 10\frac{R_B^2\hbar\omega_0}{2E_{cm}}ln\Big[1+exp\,\{\frac{2\pi}{\hbar\omega_0}(E_{cm}-V_B)\}\Big]. \quad (4)$$

Results and Conclusions

For present study, we calculated fusion cross sections for the reactions of ^{58}Ni+^{74}Ge and ^{40}Ca+^{96}Zr using different Skyrme forces. From Fig. 1, we notice that Skyrme forces S, SIII and SV have switching behavior i.e. they are first attractive and at smaller distances they become repulsive, whereas SKa force remains attractive throughout the distance. We see that the total interaction potential calculated using these forces gets modified by adding deformation to the Coulomb potential. From Fig. 1a, it is noticed that the fusion pocket becomes deeper for the fusion of spherical-oblate (S+O) (grey lines) colliding nuclei than for the spherical-spherical (S+S) (black lines) reaction. On the other hand, in Fig.1b, the fusion pocket becomes shallower for the spherical-prolate (S+P) combination compared to the S+S case.

In Fig. 2a, we notice that there is a slight increase in the fusion probabilities for the S+O nuclei than for the S+S case. Whereas Fig. 2b shows that the fusion probability decreases for S+P colliding nuclei compared to the S+S case. Hence shape of both the nuclei participating in a reaction affects the interaction potential and fusion probabilities at energies below the barrier and adding deformation in Coulomb potential alone can affect fusion probabilities significantly.

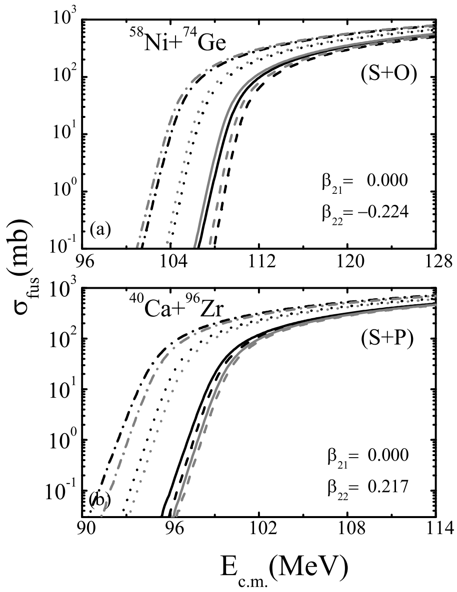

FIG. 2: The fusion cross-section $\sigma_{\rm fus}$ (mb) as a function of centre of mass energy E$_{\rm c.m.}$ (MeV) for the reactions of ^{58}Ni+^{74}Ge and ^{40}Ca+^{96}Zr. Lines have same meaning as in Fig.1. The values of the parameter β_{2i} are taken from Ref. [4].

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