Study of fusion hindrance via cold configuration within SIII Skyrme force

Shivani Jain,* Raj Kumar, and Manoj K. Sharma
School of Physics and Materials Science,
Thapar Institute of Engineering and Technology, Patiala - 147004, INDIA

Introduction

The nuclear density is used as an input to calculate the ion-ion interaction potential within the extended Thomas-Fermi approach of Skyrme Energy Density Formalism. In heavy-ion collisions, the addition of Coulomb potential (V_C) and nuclear potential (V_N) gives rise to the fusion barrier characteristics (barrier height V_B, barrier position R_B and barrier curvature $\hbar\omega_B$), which serve as crucial input to govern the fusion cross-sections of nuclear reactions at the below, near and above barrier energies.

The fusion barrier characteristics get influenced by various parameters, such as deformations, orientations, angular momentum, excitation energy etc., which are used to describe the nuclear properties. At the optimized orientations, the highest barrier height and smallest interaction radius obtained for hot or compact configuration. On the other hand, cold or elongated configuration shows lowest barrier height and largest radius [1]. In the present work, the effect of hot and cold optimum orientations has been investigated on the density distribution of colliding nuclei and the corresponding influence on the fusion cross-sections is duly analyzed.

In the present work, the fusion cross-sections are calculated using the extended ℓ-summed Wong model [2] for ^{64}Ni+^{100}Mo and ^{16}O+^{148}Sm reactions, which are forming same compound nucleus, i.e. ^{164}Yb*. In [3], it has been mentioned that, the fusion excitation function of the compound nucleus ^{164}Yb* formed via different incoming channels show fusion hindrance for SIII Skyrme force. The present work is focused on the addressal of fusion cross-sections in reference to the experimental data [4, 5] by considering the spherical approach as well as optimum orientations ('hot' and 'cold' configurations) for the use of SIII Skyrme force.

1. Methodology

The fusion barrier height is defined as the combination of the Coulomb potential V_C and attractive nuclear proximity potential V_N, at the barrier position $R = R_B$, and reads as

$$V_B = V_C(R_B, Z_i, \beta_{2i}, \theta_i) + V_N(R_B, A_i, \beta_{2i}, \theta_i), \quad (1)$$

where β_{2i} is the static quadruple deformation and i=1, 2 for projectile and target, respectively. In the above expression, the V_C for the deformed and oriented nuclei is referred from Ref.[1]. The Energy density formalism (EDF) [3] is employed to estimate nuclear potential. To calculate the nuclear density, the two-parameter Fermi density function is used

$$\rho_i(z_i) = \rho_{0i}\left[1 + \exp\left(\frac{z_i - R_{0i}}{a_i}\right)\right]^{-1}, -\infty \le z \le \infty. \quad (2)$$

The fusion cross-sections are calculated by using extended ℓ-summed Wong model [3]

$$\sigma(E_{c.m.}) = \frac{\pi}{k^2}\sum_{\ell=0}^{\ell_{max}}(2\ell+1)\left[1 + \exp\left(\frac{2\pi(V_B^\ell - E_{c.m.})}{\hbar\omega_\ell}\right)\right]^{-1}, \quad (3)$$

2. Results and discussions

In the work of [3], the fusion cross-sections have been calculated for ^{164}Yb* compound nucleus, formed via two different incoming channels i.e. ^{64}Ni+^{100}Mo and ^{16}O+^{148}Sm, within the framework of extended ℓ-summed Wong

*Electronic address: jain.shivani04@gmail.com

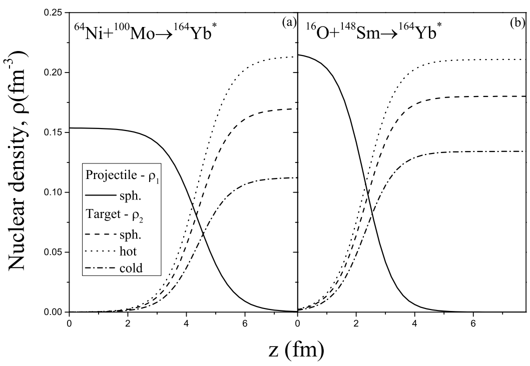

FIG. 1: The nuclear density distribution of colliding nuclei for spherical, hot and cold configurations of (a) ^{64}Ni+^{100}Mo and (b) ^{16}O+^{148}Sm reactions.

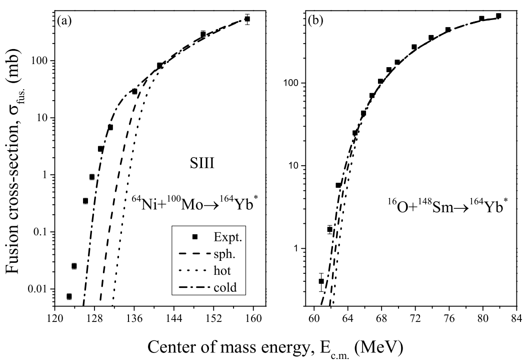

FIG. 2: The fusion cross-sections as a function of center of mass energy ($E_{c.m.}$) for spherical, hot and cold configurations of (a) ^{64}Ni+^{100}Mo and (b) ^{16}O+^{148}Sm reactions [4, 5].

model, where the calculated fusion cross-sections for the hot configuration of showed fusion hindrance for the use of SIII Skyrme force. The present work shows the effect of cold (elongated) configuration, with respect to the hot and spherical configurations, in terms of the nuclear density and fusion cross-sections. Panels (a) and (b) of Fig.1 present the nuclear density distribution of colliding nuclei, where projectiles (^{64}Ni and ^{16}O) are spherical and targets (^{100}Mo and ^{148}Sm) are deformed. It has been observed that, the nuclear densities calculated using cold (elongated) configuration show overlapping at earlier stage of interaction, which in turn, give lower barrier height than the spherical and hot configurations. Subsequently, there is an enhancement in the fusion cross-sections due to lower barrier height for the elongated configuration, as shown in the panels (a) and (b) of Fig.2. In other words, it can be said that using SIII Skyrme force, the fusion cross-sections are improved significantly when hot (compact) configuration is replaced with cold (elongated) case. It may be noted that the present work us mainly constrained to the two parameter Fermi density function. So, it would be interesting to analyze the role of deformations and optimum orientations for the use of the three parameter Fermi and Gaussian density functions for a set of deformed colliding partners.

3. Acknowledgments

The financial support from DAE, Govt. of India, sanction no. 58/14/12/2019-BRNS and UGC-DAE Consortium for Scientific Research, File No. UGC-DAE-CSR-KC/CRS/19/NP09/0920 are gratefully acknowledged.

References

[1] R. K. Gupta *et.al.*, J. Phys. G: Nuc. Part. Phys. **31**, 631-644 (2005).
[2] C. Y. Wong, Phys. Rev. Lett. **31**, 766-769 (1973); R. K. Gupta *et.al.*, Phys. Rev. C **80**, 034618 (2009).
[3] D. Jain *et.al.*, Eur. Phys. J. A **50**, 155 (2014).
[4] C. L. Jiang *et.al.*, Phya. Rev. C **71**, 044613 (2005).
[5] J. R. Leigh *et.al.*, Phys. Rev. C **52**, 3151 (1995).