Heavy-ion fusion reaction and barrier distribution of $^{16}O +^{120} Sn$ reaction

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Introduction

Fusion reactions at energies near the Coulomb barrier have been interesting to study [1] for the understanding of the nuclear structure effect and and the study is also useful in the formation of super heavy elements (SHE). Of the many factors that have been precisely consider to describe the fusion reactions, the fusion excitation function and barrier distributions have strongly implications [2]. The experimental description of fusion barrier distribution and its comparison with theoretical fusion model calculations have involved a significant advancement in the understanding of fusion process in heavy-ion reactions. The study of fusion barrier distribution allows an extending appreciation of fusion dynamic, since the shape of the barrier distribution can directly be linked to the coupling of channels that are important in conducting the fusion process at energies around the barrier [3].

In the present work the fusion cross-sections and barrier distributions of $^{16}O +^{120} Sn$ are calculated in Classical Molecular Dynamics (CMD-model) model which includes all the degrees of freedom (vibrational, rotational, translational) of the colliding nuclei. Also, calculated fusion cross-sections and barrier distribution are compared with those calculated using Classical Rigid Body Dynamical Model (CRBD-Model) in which rigid body constraints are imposed on the nuclei and only rotational and translational degrees of freedom are taken into account [4] and with microscopic static barrier penetration model (SBPM-model) [5] in which all the degrees of freedom are suppressed explicitly and dynamical effects are neglected.

Calculational Detail

In the present CMD-model calculation, the individual nuclei are generated by "STATIC" method [6] with the phenomenological soft-core Gaussian form of NN-potential,with potential parameter set P4 (V_0 = 1155 MeV, C = 2.07 fm and r_0 = 1.2 fm) are chosen and placed at large initial separation of $R_{in} = 60$ fm in the reaction plane on Rutherford trajecroties. Trajectories of all the nucleons are computed in the centre of mass frame of colliding system by numerically integrating coupled Newton's equation of motion [6].

Fusion cross-sections are calculated from the ion-ion potential obtained dynamically for central collision (b=0) only. The barrier parameters (V_B, R_B, ω_B) for a given initial orientation of the two nuclei and for a given collision energy E_{CM} are noted. Fusion cross-section is calculated from the Wong's formula [7],

$$\sigma(E_{CM}) = [\frac{R_B^2\hbar\omega_B}{2E_{CM}}]ln[1+exp(2\pi\frac{E_{CM}-V_B}{\hbar\omega_l})] \quad (1)$$

using these barrier parameters at the given collision energy E_{CM}.

Fusion barrier distribution can be extracted experimentally [8] from fusion cross-section $\sigma_{fus}(E_{CM})$ by taking second derivative of the product of $E_{CM}\sigma_{fus}(E_{CM})$ with respect to the centre of mass energy E_{CM}, that is,

$$D(E_{CM}) = \frac{d^2(E_{CM}\sigma_{fus})}{dE_{CM}^2} \quad (2)$$

The extracted fusion barrier distribution is found to be very sensitive to the structure of

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the colliding nuclei. Hence, barrier distribution method opens up the possibility of using the heavy-ion fusion reaction to investigate both the static and dynamical properties of the nuclei involved in the collision process [9].

Result and Discussion

Fusion cross- sections calculated in CMD-model for $^{16}O+^{120}Sn$ reaction, in which both lighter and heavy nuclei are spherical, are shown in fig. 1 and are compared with those obtained using CRBD-model and SBPM calculations.

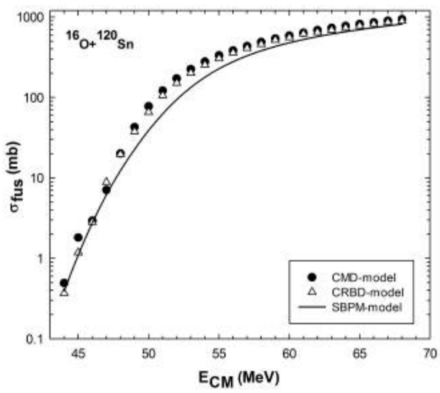

FIG. 1: Fusion cross-sections for $^{16}O+^{120}Sn$ in CMD, CRBD and SBPM-models.

From fig. 1, it can be seen that fusion cross-sections calculated in CMD-model at higher energies are better reproduced and do not show appreciable difference with CRBD and SBPM-model. However, at lower energies CMD-model calculations shows enhancement over CRBD and SBPM-model. In CMD-model at lower energies greater amount of energy from the relative motion is transferred to internal excitations or internal degrees of freedom as compared to that in CRBD-model. It can be concluded that effect of vibrational effect on fusion cross-sections is small at higher energies and become significant at lower energies.

Barrier distribution for $^{16}O+^{120}Sn$ reaction calculated with CMD, CRBD and SBPM-models with $\Delta E_{CM} = 2$ MeV and are compared with each other as shown in fig. 2. The barrier distribution found using SBPM shows a single broad peak structure while that is calculated using CMD-model clearly shows multiple peak structure corresponding to additional vibrational and rotational degree of freedom in CMD-model. Barrier distribution with CRBD-model also shows multiple peak structure. A little modification from the perfect single peak structure in CRBD-model calculation may be due to a small amount of deformation of the colliding nuclei which we chosen for the present study.

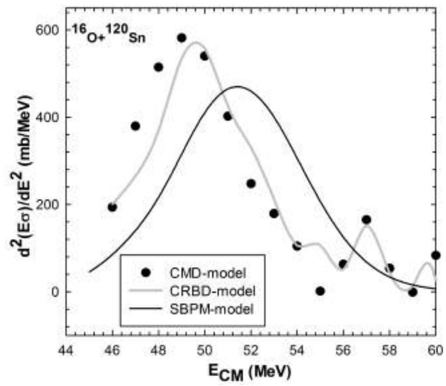

FIG. 2: Barrier distribution for $^{16}O+^{120}Sn$

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