Energy dependence of fusion barrier parameters due to Coulomb reorientation effect in ^{24}Mg+^{208}Pb system

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Introduction

For nuclei with significant static deformation the reorientation of the deformed nucleus under the influence of the torque produced by the long-range Coulomb force plays a key role in sub-barrier collisions [1-5]. This is especially important in the case of collisions with energies near fusion barrier where the interaction time between the two nuclei is sufficiently large to cause reorientation of the colliding nuclei which is expected to be crucial in determining the approach state of the two nuclei for fusion.

It is shown in ref. [4] that for ^{24}Mg + ^{208}Pb system which is light-deformed and heavy-spherical system, the fusion cross-sections get significantly modified due to Coulomb reorientation of the deformed ^{24}Mg nucleus at collision energies close to the barrier as compared to microscopic *Static Barrier Penetration Model* (SBPM) calculation [5] in which all the dynamical effects are completely neglected.

Details of dynamics of the Coulomb reorientation in ^{24}Mg+^{208}Pb system have been studied using a *Classical Rigid-Body Dynamics Model* (CRBD-model) [6]. Orientation of the deformed nucleus is specified using Euler angles (α, β, γ) defined relative to the reaction plane [7]. In ref. [6] it has been reported that due to the Coulomb reorientation of the deformed ^{24}Mg nucleus, modification in the isotropy of initial orientation takes place. It is also shown that the extent of reorientation of the deformed nucleus depends not only on the initial orientation of the axis of symmetry of the deformed nucleus but it also depends strongly on the collision energy.

In the present paper the dependence of barrier parameters on collision energy and initial orientation is presented.

Calculational details

In CRBD-model the nuclei are assumed to be rigid. The two nuclei are allowed to evolve from initial separation of 2500 fm after they are brought along their Rutherford trajectories. The translational and rotational evolution of the two nuclei is determined by numerically solving the rigid-body equations of motion. Details of the CRBD-model are given in ref. [4].

Results & Discussions

Because of the dynamical effect of reorientation, the barrier parameters, particularly the barrier-height are found to depend on the initial orientation and the collision energy. Ion-ion potential near the barrier top for ^{24}Mg + ^{208}Pb system calculated for different E*cm*, but with the same arbitrary initial orientation in each case, is shown in fig. 1. It can be seen from fig. 1 that the barrier-height (V_B) and the barrier radius (R_B) depend on the incident energy E*cm*. The barrier height is increasing and the barrier radius is decreasing as E*cm* is reduced from 250 MeV to 120 MeV for this random orientation.

It is reported in ref. [6] that, reorientation is negligible if the initial orientation is perpendicular. Ion-ion potential near the barrier top for different collision energies but the same initially perpendicular orientation corresponding to initial angle $\beta_0 = 270^\circ$, $\alpha_0 = \gamma_0 = 0^\circ$ is shown in fig. 2.

It can be seen from the fig. 2 that the ion-ion potentials and the values of V_B and R_B for this orientation in fig. 2 do not show much variation which is unlike as seen in the case of a particular random orientation in fig. 1. Further The SBPM calculation in fig. 2 does not show a well defined barrier with a pocket, but it is nevertheless close to the CRBD potential for $E_{c.m.}$=250 MeV.

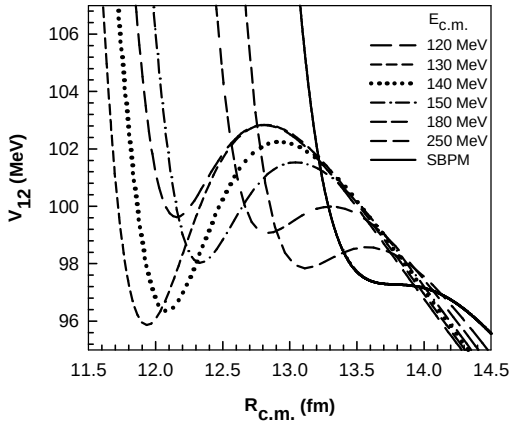

Fig. 1 Ion-ion potential for the ^{24}Mg + ^{208}Pb reaction for different collision energies $E_{c.m.}$ but the same arbitrary initial orientation in CRBD calculation. SBPM calculation for this orientation is also shown.

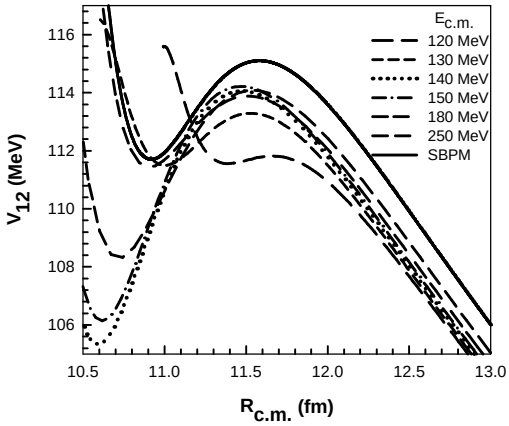

Fig. 2 Ion-ion potential for the ^{24}Mg + ^{208}Pb reaction for different collision energies $E_{c.m.}$ but initial orientation of^{24}Mg corresponding to β_0 = 270, $\alpha_0 = \gamma_0 = 0^\circ$. SBPM calculation for this orientation is also shown.

Since nuclei with the same deformation, structure, and NN-potential are used in both the SBPM and CRBD calculations, the CRBD calculation is expected to approach the SBPM calculation for the same initial orientation at higher energies because of the lack of reorientation. Corresponding ion-ion potentials calculated in SBPM are also shown in fig. 1 and fig. 2 respectively as thick lines. The SBPM calculations in fig. 1 and fig. 2 are close to the corresponding CRBD potentials for E*cm*=250 MeV.

Thus we find that the barrier parameters depend not only on the initial orientation but on the collision energy also and the CRBD calculations approach the SBPM calculations at higher collision energies.

References

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