Dependence of reorientation on collision energy and moment of inertia in deformed+spherical systems

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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].

The effect of Coulomb reorientation on fusion cross-sections for deformed+spherical ^{24}Mg + ^{208}Pb system has been studied using a *Classical Rigid-Body Dynamics model* (CRBD-model) calculation [4]. It is shown in ref. [4] that for ^{24}Mg + ^{208}Pb 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 the dynamics of the Coulomb reorientation in ^{24}Mg + ^{208}Pb system in CRBD-model and the collision energy dependence of the reorientation are presented. Dependence of reorientation on moment of inertia of the deformed nucleus is also discussed by considering ^{16}O+^{154}Sm and ^{16}O+^{238}U systems.

Calculational details

Details of the CRBD-model are given in ref. [4]. Orientation of the deformed nucleus is specified using Euler angles (α,β,γ) defined relative to the reaction plane [7]. The two nuclei evolve along their respective trajectories and the extent of reorientation (Δβ) is given by,

$$\Delta\beta = \beta_f - \beta_0 \qquad (1)$$

where β_f is the final angle made by the symmetry axis of the deformed nucleus with the line joining the two nuclei and β_0 is the initial angle at initial separation $R_{c.m.}$= 2500 fm.

Results and discussion

^{24}Mg + ^{208}Pb system

To investigate the dependence of the extent of reorientation Δβ on initial orientation and energy, collision simulations are carried out for different collision energies viz. $E_{c.m.}$ = 115 MeV, 130 MeV and 250 MeV for different initial orientation angles β_0 from 0° to 360° keeping $\alpha_0 = \gamma_0 = 0°$ in each case. Since the barrier top occurs at different values of R_B for different initial orientations and collision energies, the extent of reorientation Δβ for every value of initial angle β_0 and all the energies are noted at a common distance $R_{c.m.}$ =12.7 fm which is very close to the barrier top.

The extent of reorientation Δβ as a function of initial angle β_0 is shown in fig. 1(a) which shows that maximum reorientation takes place for the minimum energy considered here, $E_{c.m.}$= 115 MeV, while minimum reorientation takes place for the maximum energy 250 MeV. Further, Δβ is different for different initial angles β_0. Therefore, the extent of reorientation Δβ not only depends on the initial orientation angle β_0 but it also depends on the collision energy, unlike as reported in similar TDHF calculations [1,2].

The number of trajectories which arrive at $R_{c.m.}$= 12.7 fm making an angle β_f is also counted. This gives the angular distribution of the angle β_f near the barrier top, N(β_f), and is shown in the fig. 1(b). From Fig. 1(b) it can be seen that for $E_{c.m.}$ = 115 MeV the number of trajectories that arrive at a distance close to the barrier top is maximum when β_f = 90° and 270° corresponding to "*perpendicular collisions*" and it becomes minimum when β_f = 0° and 180° corresponding to "*parallel collisions*".

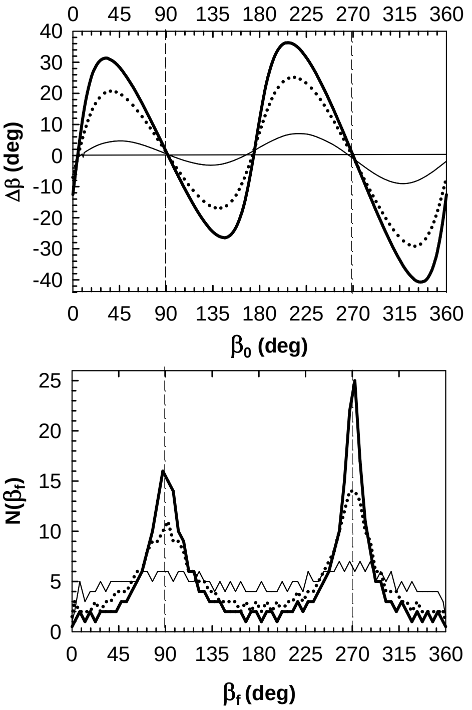

Fig. 1 (a) Extent of reorientation $\Delta\beta$ for different initial orientations β_0; (b) The number of trajectories $N(\beta_f)$ with angle β_f for ^{24}Mg +^{208}Pb collision for $E_{c.m.}$ = 115 MeV (thick solid line), $E_{c.m.}$= 130 MeV (dotted line) and $E_{c.m.}$ = 250 MeV (thin solid line).

On the other hand, for $E_{c.m.}$ = 250 MeV it is found that the angular distribution $N(\beta_f)$ is nearly uniform which indicates that there is little preference for any particular angle due to negligible reorientation at higher energies and the isotropy in the distribution of initial orientation angle β_0 is approximately maintained for the angle β_f also.

These preferential orientations result in modification of the initial isotropy of the distribution of the orientations of the deformed nucleus and hence in the calculation of fusion cross-sections also when orientation average is taken as is reported in ref. [4].

^{16}O+^{154}Sm and ^{16}O + ^{238}U systems

To study the dependence of reorientation on moment of inertia we have chosen two other spherical+deformed systems with heavier deformed nuclei viz. ^{16}O+^{154}Sm and ^{16}O+^{238}U systems. The extent of reorientation noted for both the systems at distances close to the barrier is shown in fig.2. The collision energy for ^{16}O+^{154}Sm system is 70 MeV and that for ^{16}O+^{238}U system is 90 MeV in the fig. 2.

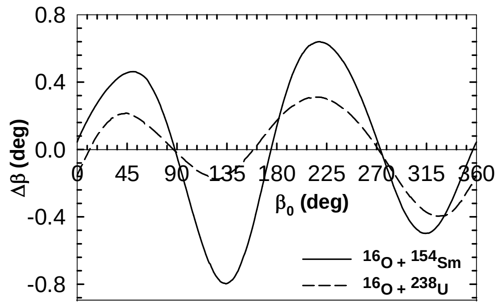

Fig 2 Extent of reorientation $\Delta\beta$ for different initial orientations β_0 for heavy deformed nuclei.

It is obvious from fig.2 that the maximum extent of reorientation ($\Delta\beta$) is less for ^{238}U as compared to ^{154}Sm because moment of inertia of ^{238}U is larger. Further, on comparing with fig.1(a), we find that $\Delta\beta$ for ^{24}Mg is maximum since its moment of inertia is least among the systems that are considered.

Thus we find that the extent of reorientation of a deformed nucleus in a deformed+spherical system resulting from long range Coulomb torque not only depends on the initial orientations but also on the collision energy and further it also depends on the moment of inertia of the deformed partner.

References

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