Reorientation effect in ^{28}Si+^{120}Sn and ^{28}Si+^{115}In reactions

P. R. Desai[1], S. S. Godre[2*]
[1]*Navyug Science College, Surat – 395009, India*
[2]*Deptartment of Physics, Veer Narmad South Gujarat University, Surat – 395007, India*
** email:ssgodre@yahoo.com*

Introduction

Heavy-ion collisions at energies near the Coulomb barrier are strongly affected by the internal structure of the colliding nuclei [1]. 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 [2-7].

The effect of Coulomb reorientation on fusion cross-sections for ^{24}Mg + ^{208}Pb system has been studied using a *Classical Rigid-Body Dynamics model* (CRBD-model) calculation [6]. It is observed that reorientation of ^{24}Mg, which has prolate deformation (β_2=+0.4), results in suppression of fusion cross-sections [7] as compared to that calculated using a microscopic *Static Barrier Penetration Model* (SBPM) [8] in which all the degrees of freedom including the rotational degrees of freedom are explicitly suppressed. Therefore, spherical+deformed systems in which the lighter nucleus has deformation of approximately the same magnitude as that of ^{24}Mg, but is oblate instead of prolate are studied using CRBD-model. ^{28}Si is such a nucleus with oblate deformation (β_2=-0.4). Two reactions involving this light deformed nucleus, viz, ^{28}Si + ^{120}Sn [4] and ^{28}Si + ^{115}In [5] with heavy spherical partners ^{120}Sn and ^{115}In respectively have been studied experimentally. The study of these systems using CRBD-model calculations is presented here.

Calculational Details

In the CRBD-model, nucleons are assumed to be classical point particles without any intrinsic spin. The two-body NN potential used is a phenomenological soft-core Gaussian potential [9] with a suitable set of potential parameters (V_0 = 900 MeV, C = 1.87 fm and r_0 = 1.13 fm). The individual nuclei used in the collision simulation are first generated using a “STATIC” potential energy minimization procedure [9]. Calculated ground state properties of the nuclei used in the present study are given below:

^{28}Si :β_2=-0.40, BE= -231.23MeV, R_{rms}=2.87fm
^{120}Sn:β_2=+0.07, BE=-1132.88MeV, R_{rms}=4.60fm
^{115}In :β_2=+0.04, BE=-1044.33MeV, R_{rms}=4.55fm.

Details of CRBD-model are given in ref. [6]. The simulation process is initiated by placing the two nuclei along their Rutherford trajectories at the center-of-mass separation of 2500 fm. The colliding nuclei are assumed to be rigid and are allowed to evolve under classical equations of motion for rigid-bodies [6].

For a given initial random orientation of the two nuclei and a given collision energy the barrier parameters for central collisions are (l=0) determined from the ion-ion potential generated from the dynamical simulation. Using the barrier parameters corresponding to the given collision energy and considering a large number of randomly chosen initial orientations, fusion cross-section for this energy is calculated by using the Wong’s formula [10] and averaging over about 500 random initial orientations.

Results and discussion

For ^{28}Si+^{120}Sn system, fusion cross-sections calculated with CRBD-model and SBPM are compared with each other and with the experiment in fig. 1. From this figure it is evident that fusion cross-sections using CRBD-model are enhanced compared to that of SBPM and are found to be in close agreement with the experiment.

The barrier distributions calculated in CRBD-model and SBPM, evaluated with ΔE_{CM}=2 MeV are compared with each other and the experiment in fig. 2. Barrier distribution with SBPM shows a very broad single peak structure while that with CRBD-model shows multiple peak structure which is very much similar to that obtained experimentally. However, the peaks in the barrier distribution for CRBD-model are shifted slightly towards higher energy side indicating a small underestimation as compared to the experiment as seen in fig. 1 also.

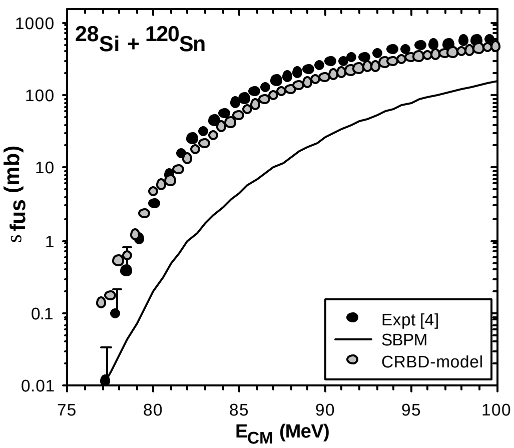

Fig. 1: Fusion cross-sections for ^{28}Si + ^{120}Sn.

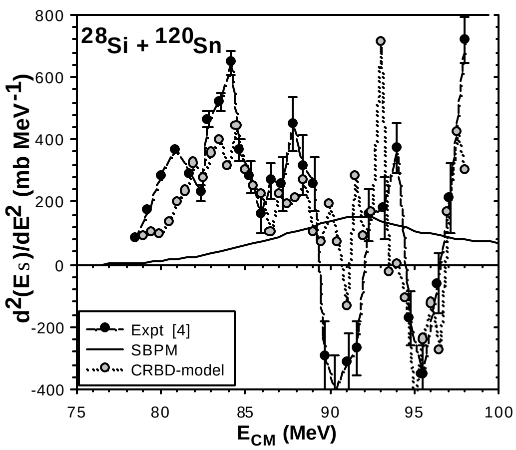

Fig. 2: Barrier distribution for ^{28}Si + ^{120}Sn.

For ^{28}Si+^{115}In system the barrier distribution calculated with CRBD-model and SBPM with ΔE_{CM}=2 MeV are compared with each other in fig. 3. This comparison shows similar behavior as seen for ^{28}Si+^{120}Sn system. From this fig. it is evident that the nature of the barrier distribution for CRBD-model is very similar to that of the experiment [5]. In the case of the experimental barrier distribution there are two peaks while the barrier distribution for CRBD-model also shows two peaks with similar structure but at slightly different locations, clearly indicating the effect of reorientation. Barrier distributions in SBPM calculations for both the systems do show asymmetrical distribution due to deformation but do not show any multiple peak structure as seen in CRBD model calculations due to reorientation effect.

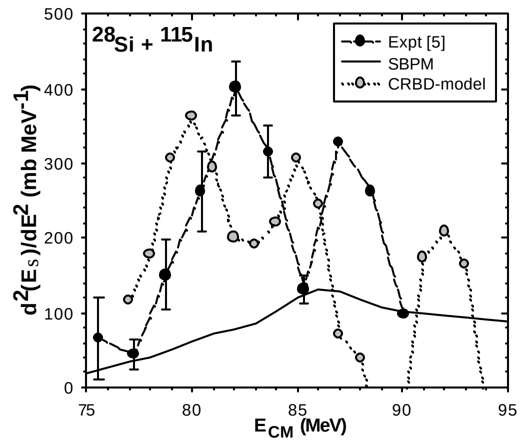

Fig. 3: Barrier distribution for ^{28}Si + ^{115}In.

Both the systems studied here with oblate deformation show fusion enhancement in contrast to a system studied earlier [7] with prolate deformation which showed fusion suppression due to reorientation effect.

References

[1] M. Dasgupta *et al*, Ann. Rev. Nucl. Part. Sci. **48** (1998) 401.
[2] C. Simenel, Ph. Chomaz and G. de France, Phys. Rev. Lett. **93** (2004) 102701.
[3] A. S. Umar and V. E. Oberacker, Phys. Rev. **C 76** (2007) 014614.
[4] L. T. Baby *et al*, Phys. Rev. **C 62** (2000) 014603.
[5] B. K. Nayak *et al*, Phys. Rev. **C 75** (2007) 054615.
[6] P. R. Desai and S. S. Godre, DAE Symp. on Nucl. Phys. (Baroda), **49B** (2006) 419; *ibid* (Roorki), **53** (2008) 479.
[7] S. S. Godre and P. R. Desai, *Proc. Xth Int. Conf. on Nucleus-Nucleus Collisions*, (Beijing) Aug.16-21, 2009.
[8] S. S. Godre, Nucl. Phys. **A734** (2004) E17.
[9] S. S. Godre and Y. R. Waghmare, Phys. Rev. **C 36** (1987) 1632.
[10] C. Y. Wong, Phys. Rev. Lett. **31** (1973) 766.