Effects of different couplings on the barrier distributions for ^{28}Si+^{232}Th, ^{238}U

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Introduction

According to single barrier penetration model, the projectile has to overcome the coulomb barrier for fusion to occur. When the couplings to static and dynamic deformation of interacting nuclei are taken into account, the single coulomb barrier splits into a distribution of discrete barriers called barrier distribution. So, the barrier distributions may be used to get structural information of the interacting nuclei. N. Rowley et al. [1] has demonstrated that the representation of the barrier distribution could be obtained by taking the second derivative of the product $E_{c.m}\sigma_{c.m}$, w.r.t. $E_{c.m}$. The advantage of doing this is that it is much easier to see the effects of different couplings in the barrier distribution than in an excitation function, though same information is carried in both. Many people has done this type of work with ^{28}Si as projectile [2-4]. Some of them has taken the rotational excitation in ^{28}Si to reproduce the experimental data and others included the vibrational states of ^{28}Si for the same purpose but for different system. It is also interesting to study the barrier distribution of super-heavy elements. A program has been started to measure the barrier distribution of heavy elements through ^{28}Si+^{232}Th, ^{238}U. Here, we have given exploratory calculations for ^{28}Si+^{232}Th, ^{238}U with different couplings.

Calculations details

The theoretical fusion cross section has been obtained by the coupled-channel calculations using the CCFULL code [5]. It uses the ingoing-wave boundary condition inside the Coulomb barrier to account for fusion, along with the isocentrifugal approximation, which works well for heavy ions. The nuclear potential in the entrance channel is defined by parameters V_0, R_0 and A_0; where V_0 is the depth parameter of the Woods-Saxon potential, R_0 is the radius parameter, and A_0 is the surface diffuseness parameter. These parameters are selected, such a way that without coupling barrier distribution should give the peak at energy equal to the average of the BASS barrier and the Ackyuz-Winther barrier. From calculated cross sections with finite energy intervals, the second derivative of Eσ has been obtained using a point difference formula. At energy $(E_1 + 2E_2 + E_3)/4$, it is given by

$$\frac{d^2(E\sigma)}{dE^2} = \left(\frac{(E\sigma)_3 - (E\sigma)_2}{E_3 - E_2} - \frac{(E\sigma)_2 - (E\sigma)_1}{E_2 - E_1}\right)\left(\frac{1}{E_3 - E_1}\right) \tag{1}$$

where $(E\sigma)_i$ are evaluated at energies E_i.

Results and discussion

The deformation parameters and E(4^+)/E(2^+) value for target and projectile are given in the table 1. The nucleus with E(4^+)/E(2^+)=3.3 is considered as rotor whereas if this value is 2.0, then it will act as vibrator during the interaction. So, the rotational coupling for both the targets are considered in the coupled-channel calculations. But for ^{28}Si, the value E(4^+)/E(2^+) is mid-way between that for the rotor and vibrator. So, it may either act as rotor or vibrator. The barrier distributions for coupling involving the different states of target are shown in Fig. 1. As the number of target states included in the coupling are increased, the number of peaks in the low energy side get increased. The rotational and vibrational coupling of ^{28}Si in addition to the different states of target are compared separately in

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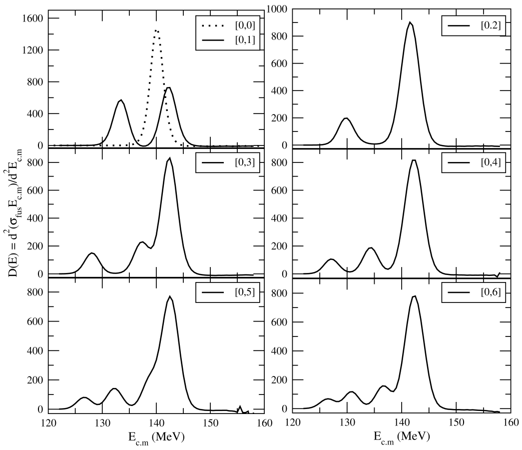

FIG. 1: Barrier distributions for ^{28}Si+^{232}Th with coupling of different states of ^{232}Th.

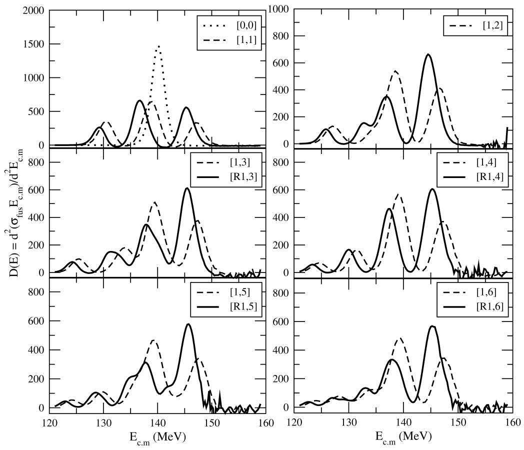

FIG. 2: Barrier distributions for ^{28}Si+^{232}Th with coupling of single vibrational (dashed lines) and rotational state (solid lines) of ^{28}Si in addition to different states of ^{232}Th.

Fig. 2. The shape of distribution is almost same for two types of coupling but the higher barrier is contributing more in the rotational case with a small shift in energy. In Fig. 3., the distributions are compared for β_2, of ^{28}Si, as positive and negative with its rotational coupling. In one case, the highest value peak is at low energy and for other case it is reverse. It means for oblate ^{28}Si, the higher barrier is contributing more and for prolate, the lower barrier has major contribution to fusion. This may be used to get information about the oblate and prolate shape of ^{28}Si during the interaction. Same type of trends in the distributions has been observed for other system, i.e. ^{28}Si+^{238}U. Detailed calculations will be shown in the poster. The experiment to get the experimental barrier distributions for these systems has been proposed at IUAC, New Delhi. The author is very grateful to Dr. N. Rowley for his guidance.

TABLE I: Deformation parameters:

	β_2	β_4	$E(4^+)/E(2^+)$
^{28}Si	0.407	0.100	2.59
^{232}Th	0.260	0.119	3.33
^{238}U	0.253	0.051	3.30

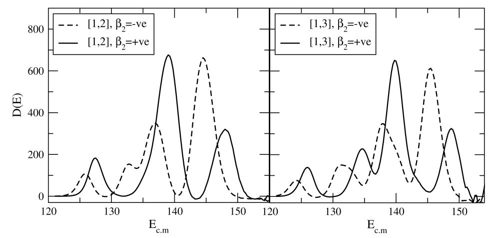

FIG. 3: Barrier distributions taking ^{28}Si as oblate (dashed lines) and prolate (solid lines). The notation $[n_p, n_t]$ gives the number of states of projectile and target included in the coupled channel calculation.

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