# Fusion barriers of Xe-induced reactions to synthesis superheavy elements

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## Introduction

The formation dynamics of SHN in massive fusion and multi nuclei transfer reactions have been main focus. Hence systematic studies are needed to predict the reaction mechanism including optimal projectile-target combinations, while attempting to produce SHN within models. All possible orientations were included by applying the different approach in nuclear fusion transfer process shows great possibilities that there is still untapped potential of superheavy nuclei.

The fusion barrier position and heights of the fusion barrier have a significant role in determining the outcome of a fusion reaction. Bass [1] used a classical potential model to investigate the fusion of heavy nuclei.Swiatecki [2] hypothesized that a specific proximity potential would be required to examine the fusion of superheavy nuclei. Earlier researchers proposed semi-empirical formulae for fusion barrier height and barrier position for $^{48}$Ca induced fusion reactions [3]. Empirical formulae have been proposed for $V_B$ and $R_B$ in the superheavy region [4]. The barrier height and position were effectively used for the prediction of evaporation residue cross sections in the superheavy region [5-11].

Hence, in the present work we have investigated $^{136}$Xe induced fusion reactions to synthesize the super heavy element and proposed empirical formulae for fusion barrier height and position.

## Theoretical frame work:

The interaction of deformed and deformable nuclei is evaluated using the theory explained in literature [12] for the $^{136}$Xe induced fusion reactions. From the available literature it is clear that the reduced fusion barrier $S_B$ depends on Coulomb interaction parameter i.e. $z = \frac{Z_1 Z_2}{\left(A_1^{1/3} + A_2^{1/3}\right)}$. The values obtained from the present work are plotted as a function of Coulomb interaction parameter ($z$). The figure 1 shows a plot of $S_B$ versus $z$. The hallow circle represents value obtained from the present work.

Since, the reduced fusion barrier shows systematic variation, we tried to fit empirical formulae for the same. The suitable equation to fit the selected data is as follows;

$$S_B = \sum_{i=0}^{3} \alpha_i z^i \qquad (1)$$

Here, $\alpha_i$ is the fitting constant and Further, the figure 2 shows a plot of barrier height $V_B$ as a function of $\frac{Z_1 Z_2}{R_B}\left(1 - \frac{1}{R_B}\right)$. The systematic increase in $V_B$ is observed as function of $\frac{Z_1 Z_2}{R_B}\left(1 - \frac{1}{R_B}\right)$. Hence, we tried fit suitable empirical relation for the fusion barrier height for the $^{136}$Xe induced fusion reactions. The parameterized equation for barrier height is as follows;

$$V_B = \sum_{i=0}^{3} \beta_i x^i \qquad (2)$$

Here $\beta_i$ are the fitting constants and $x = \frac{Z_1 Z_2}{R_B}\left(1 - \frac{1}{R_B}\right)$.

Furthermore, we have investigated inverted parabola as a function of Coulomb interaction parameter. Systematic variation is observed with respect to Coulomb interaction parameter. Hence, we have fitted selected suitable equation with larger co-efficient of determination. The fitted empirical relation is as follows;

$$\hbar\omega = \sum_{i=0}^{3} \gamma_i z^i \qquad (3)$$

here $\gamma_i$ is the fitting parameter and $z = \frac{Z_1 Z_2}{\left(A_1^{1/3} + A_2^{1/3}\right)}$.

## Results and Discussions:

We have investigated $^{136}$Xe induced fusion reactions to synthesize the superheavy element in the region $110 \leq Z \leq 126$ using all possible targets with longer half-lives.

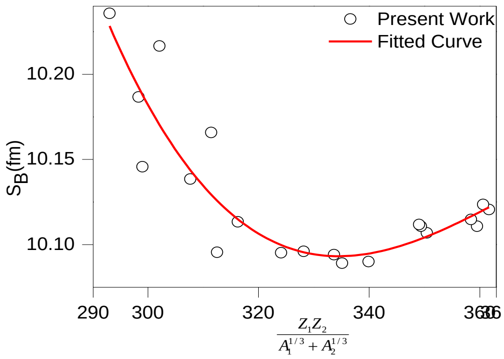


**Fig. 1** A plot of reduced fusion barrier $S_B$ for the $^{136}$Xe induced fusion reactions to synthesize the superheavy element in the region 110≤Z≤126 as function of Coulomb interaction parameter.

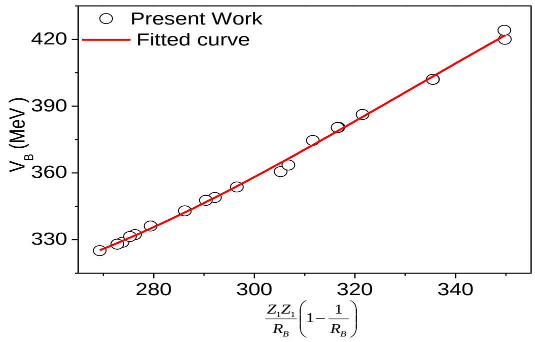


**Fig. 2:** A plot of barrier height $V_B$ as a function of $\frac{Z_1Z_2}{R_B}\left(1-\frac{1}{R_B}\right)$.

Then, we have investigated the reduced fusion barrier, barrier height and inverted parabola for all the projectile-target combinations. The figure 1-3 shows a plot of $S_B$, $V_B$ and $\hbar\omega$ as a function of Coulomb interaction parameter .A plot of inverted parabola $\hbar\omega$ as a function of Coulomb interaction parameter respectively.

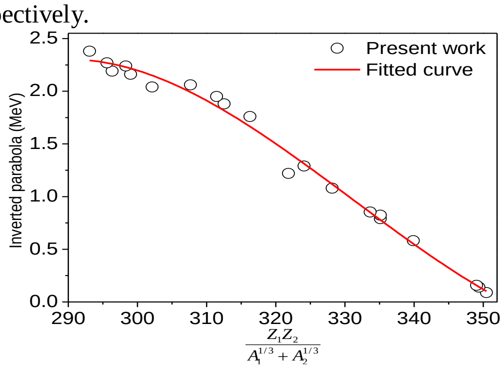


**Fig. 3**: A plot of inverted parabola as function of Coulomb interaction parameter.

In all the figures, hallow circles represents the values obtained from the present work and continuous line shows the value reproduced using proposed formulae. The fitting constants corresponding to these equations were tabulated in table 1.

Table 1:Tabulation of fitting constants.

| | $\alpha$ | β | $\gamma$ |
|---|---|---|---|
| 0 | 2.18591 | 3394.861 | -337.532 |
| 1 | -0.00981 | -26.4614 | 3.16514 |
| 2 | 2.7E-05 | 0.07283 | -0.00971 |
| 3 | -2.5E-08 | -6.5E-05 | 9.78E-06 |

## Conclusions:

In this work, we proposed empirical relation for reduced fusion barrier, barrier height and inverted parabola for the $^{136}$Xe induced fusion reactions to synthesize the superheavy element in the region 110≤Z≤126. These fitting equations can be used to reproduce reduced fusion barrier, barrier height and inverted parabola during the prediction of evaporation residue cross sections particularly for $^{136}$Xe projectiles.

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