Compactness based suitability of the target-projectile combinations for the synthesis of $^{310}_{126}X^{184}$

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Introduction

For deformed nuclei the interaction potential is a function of orientation angles and for a particular combination of the orientation angles the barrier height is maximum and interaction radius is minimum, called compact configuration. The fusion cross-section of the colliding nuclei in compact configuration is relatively higher than those of other configurations [1–3]. For the compact configuration, due to the maximum fission barrier height there is an increased evaporation residue cross-section. Thus, the knowledge of compactness for a given pair of target-projectile is important for the synthesis of a stable/cool compound nucleus.

In a recent work of [4], the fission-fragments combinations around different cold valleys in the potential energy surface of $^{310}_{126}\mathrm{X}^{184}$ system in hot optimum orientations beyond Ca-valley has been suggested as suitable target-projectile combinations for the synthesis of $^{310}_{126}\mathrm{X}^{184}$ superheavy element. For the nuclei having higher multiple deformations the hot optimum/compact configuration changes, depending on the magnitude of the deformation [5]. The target-projectile combinations suggested around Zr, Sn, Ba and Pb valleys are having the conditions (i) $P_0 > 10^{-12}$ and (ii) fission barrier of magnitude 10 to 13 MeV. In addition to above mentioned conditions, the condition of compactness must also be satisfied to obtain high fusion probability.

In this work, we have investigated further the suitability of the colliding partners for the synthesis of $^{310}_{126}\mathrm{X}^{184}$ on the basis of their compactness.

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Methodology

The interaction potential between the two deformed and oriented nuclei in a plane is

$$V(R) = V_P(R, A_i, \beta_{\lambda i}, \theta_i) + V_C(R, Z_i, \beta_{\lambda i}, \theta_i) \quad (1)$$

where θ_i; (i= 1, 2) are the orientation angles and $\beta_{\lambda i}$, $\lambda = 2, 3, 4$ are quadrupole, octupole and hexadecupole deformations respectively of colliding nuclei, V_P is the nuclear proximity potential [6] given as

$$V_P(R, A_i, \beta_{\lambda i}, \theta_i) = 4\pi\overline{R}\gamma b\phi(s_o) \quad (2)$$

where $\overline{R}$ is the mean curvature radius of two nuclei and V_C is Coulomb potential [7] given as

$$V_C = \frac{Z_1Z_2}{R_i}e^2 + \sum_{\lambda,i=1,2}\frac{3Z_1Z_2e^2}{2\lambda+1}\frac{R_i^\lambda(\alpha_i)}{R^{\lambda+1}} \times Y_\lambda^{(0)}(\theta_i)\{\beta_{\lambda i} + \frac{4}{7}\beta_{\lambda,i}^2Y_\lambda^0(\theta_i)\} \quad (3)$$

The compact configuration is obtained by varying the orientations of the nuclei by taking angular step of 0.1 ° so that the potential barrier is maximum and interaction radius is minimum.

Calculations and results

The compact configurations has been obtained for the target-projectile (T-P) combinations suggested in ref. [4] i.e. around Zr, Sn, Ba and Pb valleys and is tabulated in Table I. From the table I, it is clear that most of the combinations are spherical + prolate and correspond to non-equatorial compact (nec) around Zr, Sn and Ba valleys and equatorial compact (ec) around Pb valley. There are two combinations of prolate + prolate shapes

TABLE I: The valleys, T-P combinations, shapes, compact orientations (θ_{ci}) and corresponding configurations: ec, nec, near bbc, nbbc.

Valley	T-P combinations	Shapes	θ_{ci}		config.
			θ_{c1}	θ_{c2}	
Zr	^{91}Y+^{219}Fr	s-p$^+$	s	60.6^0	nec
	^{92}Zr+^{218}Rn	s-p$^+$	s	59.2^0	nec
	^{93}Zr+^{217}Rn	p-p$^+$	90^0	58.7^0	nbbc
Sn	^{122}Sn+^{188}Os	s-p$^-$	s	86.4^0	nec
	^{123}Sn+^{187}Os	s-p$^-$	s	86.5^0	nec
	^{124}Sn+^{186}Os	s-p$^-$	s	86.4^0	nec
Ba	^{135}Cs+^{175}Lu	s-p$^-$	s	86.1^0	nec
	^{136}Ba+^{174}Yb	p-p$^-$	90^0	85.0^0	near bbc
	^{137}Cs+^{173}Lu	s-p$^-$	s	85.1^0	nec
	^{138}Ba+^{172}Yb	s-p$^-$	s	85.1^0	nec
	^{139}La+^{171}Tm	s-p$^-$	s	84.1^0	nec
	^{140}Ce+^{170}Er	s-p$^-$	s	83.6^0	nec
Pb	^{103}Ru+^{207}Pb	p$^+$-s	89.8^0	s	ec
	^{104}Ru+^{206}Pb	p$^+$-s	89.8^0	s	ec
	^{105}Rh+^{205}Tl	p$^+$-s	89.7^0	s	ec

and shows not belly-to-belly (nbbc) and near belly-to-belly (near bbc) compact configurations.

For the relative compactness of the colliding partners around Sn, Ba, Pb and Zr cold valleys, we have studied the variation of barrier height and interaction radius with hexadecapole deformation β_4 as shown in Fig.1 (a) and (b), respectively. It is found that the interaction barrier is highest for Ba valley followed by Sn, Pb and Zr valleys and the corresponding interaction radius is smallest for Ba valley followed by Sn and Pb valley in ascending order, except for Zr-valley for which it descends. The exceptional behaviour is found to be due to the presence of negative β_3-values. If we exclude β_3-values in our calculations then we find that the interaction radius for the combination around Zr-valley increases. The fragment combinations around Zr-valley are relatively more compact, but due to relatively lower barrier height and fission barrier [4], can not be preferred. Next, we

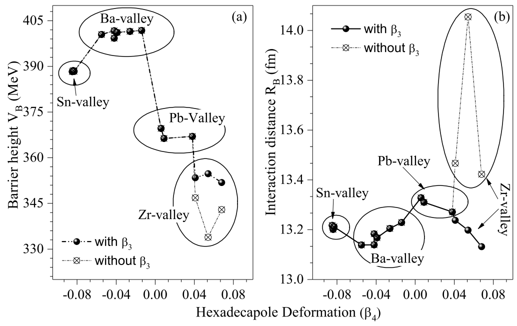

FIG. 1: Variation of interaction (a) barrier height and (b) radius with hexadecapole deformation β_4 for the fragment combination around Sn, Ba, Pb and Zr valleys.

have Pb-valley where the interaction radius is more (or lesser compact configuration due to positive β_4-values) than Sn and Ba valleys. The fragment combinations around Sn and Ba valleys, being negative β_4-deformed, are having most compact configurations and hence are suitable for the synthesis of $^{310}_{126}X^{184}$. Our calculations further validate the T-P combinations suggested in ref. [4].

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