Quasifission barrier of $^{296}120$

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Introduction

Recent advancements in the theoretical and experimental studies of superheavy nuclei have provided profound insights into their intricate structures, stability, and decay characteristics [1]. The domain of superheavy elements (SHE) remains at the cutting edge of nuclear physics, propelling forward both experimental endeavors and theoretical explorations [2]. This research focuses on evaluating the properties of superheavy elements using various covariant density functionals, uncovering the nuanced impact of the N=172 neutron shell closure and the diverse predictions surrounding the stability at N=184 [3].

Investigations into the synthesis of element 120 have shown potential, albeit with inconclusive outcomes [4]. Efforts to produce superheavy elements 119 and 120 through fusion-evaporation reactions have so far been unsuccessful, with no detections reported. These results are analyzed within the framework of theoretical models that predict fission-barrier heights [5,6].

Theoretical research has delved into the quasifission barrier associated with element 120 [7]. Despite extensive experimental attempts to synthesize this superheavy element, the production has been hindered by fission events occurring at each stage of the process. The quasifission mechanism, which unfolds on a zeptosecond timescale prior to full nuclear fusion, continues to be a significant obstacle in the creation of superheavy elements [8].

Studies on the quasifission barriers of elements ranging from Z = 104 to Z = 126 indicate that entrance channel parameters play a crucial role in the formation of compound nuclei [9]. The theoretical calculation of the quasifission barrier (B_{qf}) is a complex and understudied area, particularly for the isotope $^{296}120$. This gap in the literature drives our investigation into the quasifission barriers of $^{296}120$ and the development of an empirical formula for B_{qf}.

Theory

With a dinuclear model, the quasifission barrier expressed as [10].

$$B_{qf} = V(R_b, Z, A, \beta, \ell, \alpha) - V(R_m, Z, A, \beta, \ell, \alpha) \quad (1)$$

Where is angular momentum, β_2 is the quadrapole deformation parameter and V is the nucleus nucleus potential is expressed as

$$V(R, Z, A, \beta, \ell, \alpha) = V_C + V_N + V_{rot} \quad (2)$$

Where V_C is the Coulomb potential, V_N is the nuclear potential and V_{rot} rotational potential are explained in the [10,11].

Results and Discussions

We systematically evaluated all feasible projectile and target combinations to synthesize superheavy element 120. After careful consideration, we selected eight reactions involving projectiles and targets with longer half-lives, which are crucial for successful synthesis. The quasifission barrier (B_{qf}) for these reactions was calculated as outlined in the theory section.

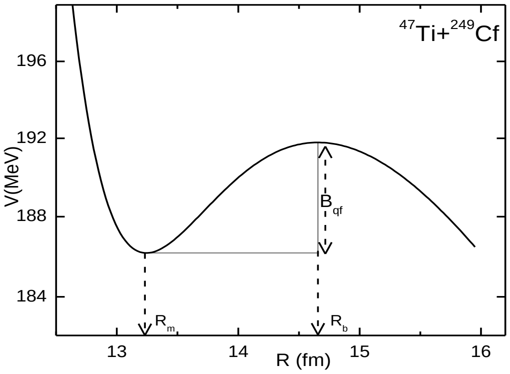

Fig. 1 A plot of nucleus-nucleus interaction potential using DNS approach for the fusion reaction of $^{47}Ti+^{249}Cf$.

For the ^{47}Ti + ^{249}Cf reaction, we analyzed the interaction potential as a function of the separation distance, depicted in Fig. 1. As

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*Corresponding author: [$]*damodarkolar@gmail.com*, ^ *manjunathhc@rediffmail.com* illustrated, R_m and R_b denote the separation distances where the potential reaches its minimum and maximum values, respectively. The difference in potential between these two points defines the quasifission barrier, B_{qf}.

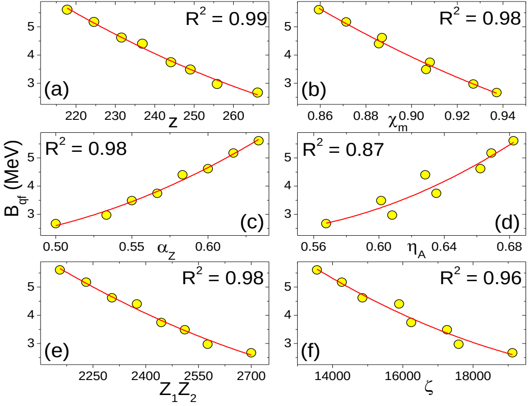

Fig. 2 Variation of quasifission barrier (B_{qf}) for (a) Coulomb interaction parameter, (b) mean fissility, (c) charge asymmetry, (d) mass asymmetry, (d) product of charge and (e) zeta .

Figure 2 (a-f) shows the variation of B_{qf} as a function of entrance channel parameters for the fusion reactions listed in Table 1. The B_{qf} decreases with increasing Coulomb interaction, mean fissility, the product of charges, and the zeta parameter, while it increases with charge asymmetry and mass asymmetry. Among all these variations, the Coulomb interaction parameter exhibits the most systematic trend for B_{qf}, with the highest coefficient of determination, R^2=0.99. Leveraging this strong correlation, we derived a fitting equation for B_{qf} as a function of the Coulomb interaction parameter, expressed as:

$$B_{qf} = 3.41 \times 10^{-4} z^2 - 0.2283z + 39.2458 \quad (3)$$

We then compared the Bqf values obtained from both theoretical calculations and the proposed semi-empirical formula, as shown in Table 1. The close agreement between the values from the formula and theoretical predictions demonstrates the accuracy and reliability of the proposed empirical equation.

Conclusion

In this study, we analyzed eight fusion reactions to synthesize the superheavy element ^{296}120, selecting projectile and target combinations with higher half-lives for optimal results. Among these, the ^{47}Ti + ^{249}Cf reaction exhibited the highest quasifission barrier (B_{qf}) of 5.61 MeV. Our investigation into entrance channel parameters revealed that the Coulomb interaction parameter provided the most systematic correlation with B_{qf}. Leveraging this, we developed a semi-empirical formula that allows for the straightforward calculation of B_{qf} using the charge and mass numbers of the projectile and target. This work offers a valuable tool for predicting quasifission barriers in future fusion reactions and provides critical insights for the synthesis of superheavy element 120.

Table 1: Fusion reactions and comparison of quasifission barrier from theoretical and present formula.

Reaction	B_{qf} (MeV)	
	Theo.	Empr.
^{47}Ti(stable)+^{249}Cf(351 y)	5.61	5.65
^{49}V(330 d)+^{247}Bk(1380 y)	5.18	5.12
^{50}Cr(stable)+^{246}Cm(4760 y)	4.61	4.61
^{55}Mn(stable)+^{241}Am(432.2 y)	4.41	4.25
^{54}Fe(stable)+^{242}Pu(3.75×10^5 y)	3.74	3.78
^{59}Co(stable)+^{237}Np(2.14×10^6 y)	3.49	3.48
^{58}Ni(stable)+^{238}U(4.47×10^6 y)	2.97	3.09
^{64}Zn(stable)+^{232}Th(1.4×10^{10} y	2.67	2.57

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