Fusion barriers of ^{115}Sn induced fusion reactions to synthesis Superheavy elements 119 and 120.

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Introduction

Nuclear fusion reactions are very useful in the production of superheavy elements. The study of nuclear dynamics in the fusion process involves the total interaction potential between the colliding nuclei, which is the sum of the repulsive Coulomb potential, attractive nuclear potential and centrifugal potential. At energies near the barrier, quantum mechanical effects come into play. As a result, fusion barrier height plays a significant role in determining the outcome of a fusion reaction. Bass [1] investigated the fusion of heavy nuclei with a classical potential model. Swiatecki [2] anticipated that a specific proximity potential is required to examine the fusion of superheavy nuclei. Gupta and Kailas [3] formulated a semi-empirical formula for fusion barriers. Vaz and Alexander [4] proposed an empirical relation for barrier radius with deviation of 10% with experimental values. The study of heavy-ion fusion continues to be an area of intense research[6-11]. It is useful to have simplified formulas of the fusion process that can easily be used to calculate its characteristics. From a detail literature survey, there is a need to investigate fusion barrier characteristics of ^{115}Sn induced fusion reactions. Hence, in the present work, we proposed an empirical relation for the fusion barriers of ^{115}Sn-induced fusion reactions in the superheavy nuclei region. Further we have also predicted fusion characteristics of ^{115}Sn induced fusion reactions to synthesis SHE, Z=119, and 120.

Theoretical Frame work

The potential for ^{115}Sn induced fusion reaction is evaluated as follows,

$$V(R) = V_N(R) + V_C(R) + \frac{\ell(\ell+1)}{2\mu R^2} \qquad (1)$$

Here $V_N(R)$, $V_C(R)$, and $\ell(\ell+1)/2\mu R^2$ are the nuclear interaction, Coulomb, and centrifugal potential. The fusion barrier characteristics are evaluated using boundary conditions as explained in the literature [5]. The fitted equations for ^{115}Sn induced fusion barrier characteristics are as follows;

$$R_B(fm) = 10.879 + 0.115 \times (A_1^{1/3} + A_2^{1/3}) \qquad (2)$$

$$V_B^{Par}(MeV) = 1.4057 + \left[\frac{Z_1 Z_2}{R_B}\left(1 - \frac{1}{R_B}\right)\right] + 5.4746 \qquad (3)$$

$$\hbar\omega(MeV) = -3.34\times10^{-7} \times \left[\frac{Z_1 Z_2}{(A_1^{1/3} + A_2^{1/3})}\right]^3 + 1.39\times10^{-4} \times \left[\frac{Z_1 Z_2}{(A_1^{1/3} + A_2^{1/3})}\right]^3 - 2.37\times10^{-2} \times \left[\frac{Z_1 Z_2}{(A_1^{1/3} + A_2^{1/3})}\right] + 5.67 \qquad (4)$$

Where Z_i and A_i are the atomic and mass number of projectile and target nuclei respectively.

Results and Discussions

The total potential is evaluated using equation (1). The fusion barrier characteristics were evaluated using boundary equations as explained in literature [5]. Once the fusion barrier characteristics were evaluated, then we fitted suitable equations for the same and it is represented by equations (2) to (4). Further, the variation of fusion barrier height (V_B), fusion barrier radius (R_B) and inverted parabola ($\hbar\omega$) with the mass asymmetry parameter $\eta=(A_1-A_2)/(A_1+A_2)$ for the projectile ^{115}Sn+$^{169-170}$Tm (Z=119) and ^{115}Sn+$^{168,170-174,176}$Yb (Z=120) is predicted in figure 1. From the figure it is found that V_B decreases whereas R_B and $\hbar\omega$ increases with η for both the projectiles. These effects collectively enhance the probability of achieving fusion, making it a crucial factor in the

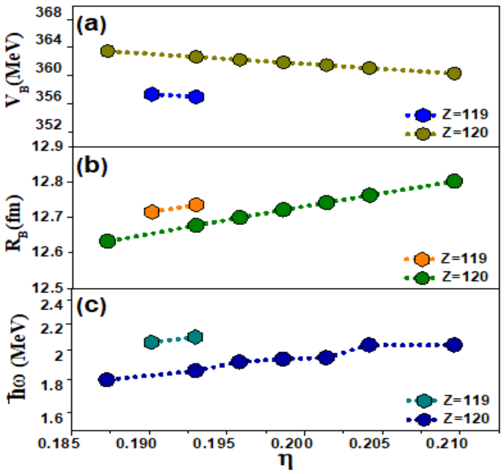

Fig 1: A plot of V_B,R_B and $\hbar\omega$ as function of mass assymmetry (η) for the fusion reaction of ^{115}Sn+$^{169-170}$Tm (Z=119) and ^{115}Sn+$^{168,170-174,176}$Yb (Z=120).

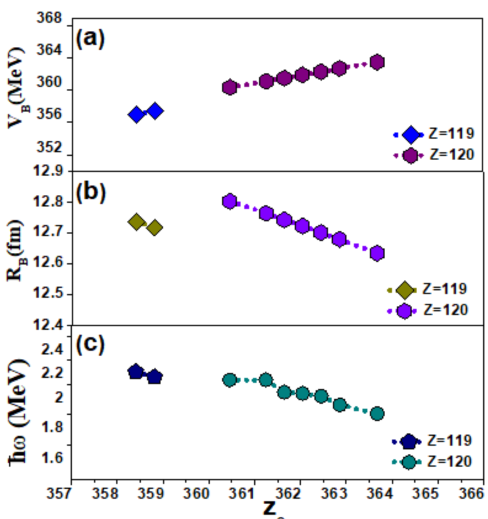

Fig. 2 A plot of V_B,R_B and $\hbar\omega$ as function of Coulomb interaction parameter (z_c) for the fusion reaction of ^{115}Sn+$^{169-170}$Tm (Z=119) and ^{115}Sn+$^{168,170-174,176}$Yb (Z=120).

design and execution of experiments aimed at synthesizing new superheavy elements. The variation of V_B, R_B and $\hbar\omega$ with the Coulomb interaction parameter $Z_c=(Z_1Z_2)/(A_1^{1/3}+A_2^{1/3})$ for the projectiles ^{115}Sn-induced fusion reactions are predicted in figure 2. It is found that V_B increases whereas R_B and $\hbar\omega$ decreases with Zc for both the projectiles. The Coulomb interaction parameter significantly influences the fusion barrier height, radius, and shape in the synthesis of superheavy elements.

Conclusions:

We investigated the fusion barrier characteristics of ^{115}Sn-induced fusion reactions. The targets such as $^{69-170}$Tm and $^{168,170-174,176}$Yb has been selected for the formation of compound nuclei leading to form Z=119 and 120. A empirical formula for fusion barrier characteristics of ^{115}Sn-induced fusion reactions have been proposed as a function of atomic and mass numbers of projectile and target nuclei respectively. This empirical approach provides a better understanding of the barrier heights and other fusion properties essential for optimizing reaction conditions to successfully synthesize elements Z=119 and Z=120.

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