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Fusion barrier characteristics of actinides

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Abstract

We have studied fusion barrier characteristics of actinide compound nuclei with atomic number range $89 \le Z \le 103$ for all projectile target combinations. After the calculation of fusion barrier heights and positions, we have searched for their parameterization. We have achieved the empirical formula for fusion barrier heights (V_B), positions (R_B), curvature of the inverted parabola ($\hbar\omega$) of actinide compound nuclei with atomic number range $89 \le Z \le 103$ for all projectile target combinations ($6 < A_1 < 127$, $101 < A_2 < 260$, $3 < Z_1 < 51$ and $45 < Z_2 < 100$). This formula is obtained by studying the fusion barrier characteristics of 7205 projectile target combinations. The values produced by the present formula are also compared with experiments. The present pocket formula produces fusion barrier characteristics of actinides with the simple inputs of mass number (A) and atomic number (Z) of projectile-targets.

Keywords: Fusion; Actinides

1. Introduction

Fusion barriers of actinides have its roots in the quest to extend the periodic table. Several parameterizations for fusion barriers are available in the literature. Vaz et al. [1] formulated the semiempirical fusion barriers by analyzing excitation functions for complete fusion. Puri and Gupta [2,3] obtained the semi-empirical relations for fusion barriers based on the Skyrme interaction energy–density model. Sahu and Shastry [4] parameterized the fusion barriers based

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on the effective fusion barrier transmission model. Moustabchir and Royer [5] also developed formulas for the fusion barrier heights and radii. Stefanini et al. [6] studied the fusion barrier of S + Ni systems. Royer and Remaud [7] formulated simple analytical formulae for the various dynamical parameters of the fusion system. Aguiar et al. [8] studied the fusion barriers using the liquid–drop model. Adamian et al. [9] developed a model of competition between fusion and quasifission in reactions with heavy nuclei. Ghodsi and Lari [10] also obtained the analytical expressions for fusion barriers using proximity formalism.

Gupta and Kailas formulated [11] the following semi-empirical formula for fusion barriers $V_B = \frac{-b+(b^2+4mZ)^{1/2}}{2m}$ and $R_B^2 = 2mZ + \frac{b^2}{2} + \frac{b}{2}(b^2+4mZ)^{1/2}$ with A dependent constants $b = (1.498 \pm 0.099)(A_T^{1/3} + A_p^{1/3}) + (1.538 \pm 0.538)$ and $m = \left[-(15.1 \pm 0.8)\left(\frac{A_T+A_p}{A_T A_p}\right)^{1/2} + (0.93 \pm 0.17)\right] \times 10^{-2}$. This formula agrees with experiments within ±4% for the barrier height and within ±8% for the barrier radius. Vaz and Alexander [12] proposed a simple empirical relation for barrier radius ($R_B = a - b log(Z_T Z_P)$) with deviation of 10% with experimental values. Anjos et al. [13] also formulated the empirical relations for fusion barriers of barium with medium nuclei and presented empirical formulae $V_B = 0.152 - 0.00875(A_1^{1/3} + A_2^{1/3})$ and $R_B = 2.25 + 0.035(A_1^{1/3} + A_2^{1/3})$. This formula is having a deviation up to 13% with the experimental values.

Kumari and Puri [14] also presented an empirical formula for fusion barrier heights and positions having projectile/target masses 6 ≤ A ≤ 238. The proposed empirical relations are $V_B^{par} = -1.01 + 0.93 \times \frac{Z_p Z_t}{A_p^{1/3}+A_t^{1/3}} + (4.53 \times 10^{-4}) \times \left(\frac{Z_p Z_t}{A_p^{1/3}+A_t^{1/3}}\right)^2$ and $R_B'^{par} = 3.58 + 0.88 \times \left(A_p^{1/3} + A_t^{1/3}\right)$ with $R_B^{par} = R_B'^{par} + 30 \times \beta_3 + 0.4 \times \left(\frac{N}{Z} - 1\right)$. This agrees well with experiments for low atomic number and for high atomic number, there is a deviation up to 15 MeV and 2 fm for V_B and R_B respectively.

Sahu and Shastry [15] also presented an empirical formula for fusion barrier heights and positions and these are expressed as $R_B = r_0\left(A_1^{1/2} + A_2^{1/2}\right) + 2.72$ fm, $V_B^l = V_B + \frac{\hbar^2}{2\mu}\frac{l(l+1)}{R_B^2}$ with $V_B = \frac{Z_1 Z_2 e^2}{R_B}\left(1 - \frac{a}{R_B}\right)$. Authors [15] tested this formula for Ca + Ti experiments. Gharaei and Sheibani [16] parameterized the fusion barriers in terms of equations $V_B = \delta\left[\frac{1.44 Z_1 Z_2}{R_B^{par}}\left(1 - \frac{\beta}{R_B}\right)\right]$ and $R_B = \alpha exp\left[-\beta(x-2)^\gamma\right] + R_1 + R_2$; these equations are applicable to targets of mass ranges $40 \le A_T \le 233$.

Parameterization of the barrier characteristics for the isotopic systems is one of the interesting subjects of nuclear physics in recent years [17–21]. The study of heavy-ion fusion continues to be an area of intense research. It is useful to have simplified formula/models of the fusion process that can easily be used to calculate its characteristics. From the detail literature survey, it is clear that there is no study on fusion barrier characteristics of actinide nuclei. Fusion is important in the field of actinide region. It is useful to develop a pocket formula for fusion barrier characteristics of nuclei in the actinide region. Hence we have constructed an accurate formula for fusion barrier characteristics.This formula is obtained by studying the fusion barrier characteristics of 7205 projectile target combinations. In the present work, we have studied the fusion barrier characteristics of actinides (89 < Z < 103) and formulated the new empirical formula for fusion barrier height (V_B) and fusion barrier width (R_B).