Influence of entrance channel parameters in compound nucleus formation probability of Nobelium nuclei

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Introduction

Usually, fusion cross section describes the likelihood of atomic nuclei merging, while capture cross section indicates the probability of a nucleus capturing a particle or another nucleus. The compound nucleus formation probability (PCN) in nuclear processes finds its basis in the compound nucleus (CN) model [1]. PCN is investigated and predicted using fusion and capture cross-sections Yanez et al., [2].

Considering the atomic numbers Z=110 - 126, an analysis is conducted, taking into account entrance channel effects, including mass asymmetry, charge asymmetry, isospin asymmetry, non-compound nuclear fission probability, and the Businaro-Gallone mass asymmetry [3]. In the synthesis of superheavy elements, Nobelium has been used in experiments aimed at creating superheavy elements through nuclear fusion reactions. Quasifission and evaporation residue cross sections are examined for Po,Th, and No nuclei synthesis using different projectile-target combinations with the ASM and DNS models [4].

Now the present work involves the variation of PCN with respect to entrance channel parameters by considering the probable projectile target combinations of $^{248\text{-}256}$No, by observing the maximum evaporation residual cross-section. Earlier studies have presented an analysis of PCN evaluations for a range of fusion reactions within the superheavy element region [5-8].

Theory

The compound nucleus formation probability is evaluated as follows;

$$P_{CN} = \frac{\sigma_{fus}}{\sigma_{cap}} \tag{1}$$

Here σ_{fus} is the fusion cross-section and σ_{cap} is the capture cross-section. The fusion cross-section is evaluated as follows;

$$\sigma_{fus}(mb) = \pi R_B^2\left(1 - \frac{V_B}{E_{cm}}\right) \quad \text{for } E_{cm} >> V_B \tag{2}$$

When $E_{cm} << V_B$

$$\sigma_{fus}(mb) = \frac{R_B^2 \hbar\omega}{2E_{cm}} ln\left\{exp\left(\frac{2\pi}{\hbar\omega_0}(E_{cm} - V_B)\right)\right\} \tag{3}$$

Here V_B and E_{cm} are fusion barrier height and center of mass energy. R_B is the fusion barrier position and $\hbar\omega$ is the inverted parabola. Capture cross section [9] is evaluated as follows;

$$\sigma_{cap}(E, l; \alpha_1\alpha_2) = \frac{\lambda^2}{4\pi} P_l^{cap}(E; \alpha_1\alpha_2) \tag{4}$$

Results and Discussions

We have studied fusion and capture cross-section, compound nucleus formation probability of four projectile target combinations such as ^{40}Ca+^{208}Pb→^{248}No,^{48}Ca+^{208}Pb→^{256}No, ^{20}Ne+^{238}U→^{258}No, and ^{208}Pb+^{48}Ca→^{248}No leading to form isotopes of nobelium nuclei $^{248\text{-}256}$No. Figure 1(a-c) shows a plot of fusion cross-section, capture cross-section and compound nucleus formation probability for the fusion reaction of ^{40}Ca+^{208}Pb→^{248}No. Fusion and capture cross-section increases with increase in center of mass energy as seen in figure 1(a-b). However, P_{CN} increases and reaches a maximum value when E_{cm}=194MeV. Further, P_{CN} gradually decreases with increase in energy. Later, we considered P_{CN} at particular E_{cm} at which experimental evaporation residue is found to be maximum.

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Further, we investigated effect of Coulomb interaction parameter $Z_{Coul} = \frac{Z_1 Z_2}{A_1^{1/3} + A_2^{1/3}}$, and fissility parameter (Z^2/A) on P_{CN} for four fusion reactions. Figure 2(a-b) shows a plot of P_{CN} as a function of Coulomb interaction parameter and fissility parameter. From this we have observed that P_{CN} shows systematic variation for both Coulomb interaction parameter and fissility parameter. Hence, the investigated compound nucleus formation probability is more systematic for Coulomb interaction parameter, and fissility parameter. The value of P_{CN} value decreases with increase in Coulomb interaction parameter and fissility parameter. Hence, the present work is helpful in prediction of evaporation residue cross-sections for nobelium isotopes

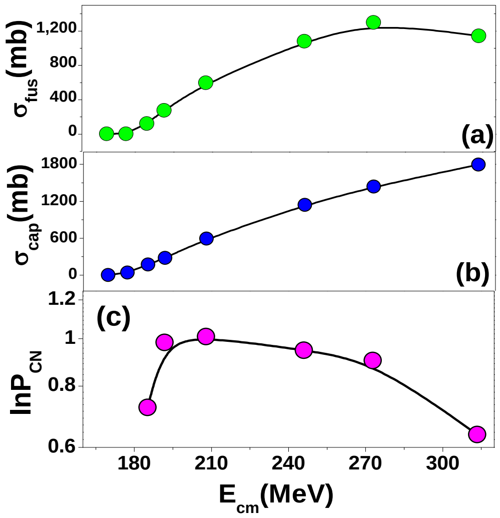

Fig-1 :(a) Variation of fusion cross-section, (b) capture cross-section and (c) P_{CN} with center of mass energy for the fusion reaction of $^{40}Ca+^{208}Pb \rightarrow ^{248}No$.

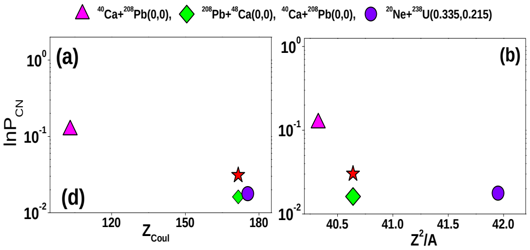

Fig2: Variation of P_{CN} with (a) Coulomb interaction parameter and (b) fissility parameter for $^{40}Ca+^{208}Pb \rightarrow ^{248}No$, $^{48}Ca+^{208}Pb \rightarrow ^{256}No$, $^{20}Ne+^{238}U \rightarrow ^{258}No$, and $^{208}Pb+^{48}Ca \rightarrow ^{248}No$ fusion reactions.

Conclusions

We investigated fusion, capture and compound nucleus formation probability of four fusion reactions leading to form nobelium isotopes. Further, the effect of entrance channel parameter such as Coulomb interaction parameter and fissility parameter. The compound nucleus formation probability shows systematic variation with the studied entrance channel parameters. Hence, the present work is helpful in prediction of evaporation residue cross-sections for nobelium isotopes.

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