Competition between Coulomb fission, fission and capture cross sections for $^{54}Fe+^{245}Pu$ reaction

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Introduction

Heavy ion fusion encounters several challenges in compound nucleus formation, including Coulomb barriers, energy-dependent fusion cross-sections, shell effects, fragmentation, angular momentum redistribution, competing fission channels, and optimization of evaporation residue yields. Coulomb fission cross-section in superheavy element synthesis represents the probability of fission occurring due to the repulsive Coulomb interaction between the colliding projectile and target nuclei. This strong repulsion between heavy, positively charged nuclei can cause the system to break apart before full fusion into a compound nucleus occurs.

The fission cross-section is crucial in the formation of superheavy elements (SHEs), as it influences the likelihood of successful fusion and the stability of the resulting nucleus. High fission cross-sections during synthesis can cause the compound nucleus to break apart prematurely, preventing the formation of SHEs[1-2]. In fusion reactions forming heavier compound nuclei, fission increasingly dominates as a de-excitation pathway [3].

Earlier researches aimed to determine optimal conditions for synthesizing superheavy elements, including the choice of projectile-target pairs, beam energies, and reaction pathways. By analyzing fission barriers, fusion probabilities, and nucleus stability, these models are crucial for guiding experimental efforts to discover new superheavy elements [5-8].

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We investigated the Coulomb fission cross-sections, fission cross-sections and capture cross sections for the $^{54}Fe+^{245}Pu$ fusion reaction aimed at synthesizing superheavyelement with Z = 120. To calculate the Coulomb fission cross-sections, we applied an extended trapezoidal integration method. Coulomb fission is crucial in heavy-ion collision experiments and in analyzing the decay processes of highly charged nuclei. The Coulomb fission cross section (σ^{CF}) quantifies the probability of the fission process occurring.

Theory

The N(E) of virtual photons as function of E using Weizsacker-Williams method [4] is expressed as;

$$N(E) = \int_{b_{\min}}^{\infty} N(E,b) 2\pi b db \qquad (1)$$

Where b_{min} is the impact parameter.
Coulomb fission cross section is written as

$$\sigma_A^{CF} = \int_{b_{\min}}^{\infty} 2\pi b db \int_{E_{\min}}^{E_{\max}} N_B(E,b) \sigma_A^{\gamma f}(E) dE \qquad (2)$$

Capture cross section is expressed as follows;

$$\sigma^{Capture} = \frac{\pi}{k^2} \sum_{\ell=0}^{\infty} (2\ell+1) T(E,\ell) \qquad (3)$$

Results and discussions

We investigated Coulomb fission cross-sections of fusion reactions such as $^{54}Fe+^{2454}Pu$. The Coulomb fission cross-sections were calculated using a simple extended trapezoidal integration approach. The Coulomb fission cross-sections were evaluated as represented in the theory section.

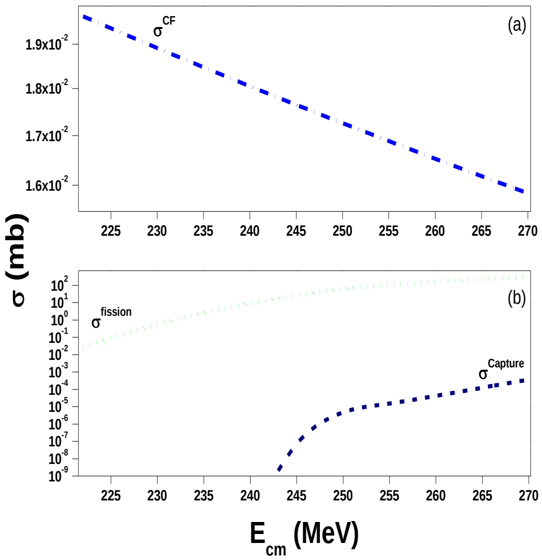

Fig. 1: Variation of Coulomb fission cross-section (σ^{CF}), capture cross-section ($\sigma^{Capture}$) and fission cross-section ($\sigma^{fission}$) as function of centre of mass energy (E_{cm}).

Figure-1 shows a plot of σ^{CF}, $\sigma^{Capture}$and $\sigma^{fission}$ as a function of center of mass energy E_{cm}. As E_{cm} increases, Coulomb fission cross-section decreases as in figure 1(a), the capture cross section increases as a function of center of mass energy E_{cm}represented by short dots in green colour of figure 1(b), the fusion cross-section increases and reaches almost constant when E_{cm} is greater than 270MeV represented by short dash in figure 1(b).

From this comparison, it is observed that the evaluated Coulomb fission cross-sections, fission cross-section and capture cross-section were about 79.9515mb, 0.000014728mb and 5.8173mb respectively.

Conclusions:

We studied Coulomb fission cross-sections, fission cross-section and capture cross-section of the $^{54}Fe+^{245}Pu$ reaction in an attempt to synthesize the superheavy element Z = 120. The Coulomb fission cross-sections were calculated using an extended trapezoidal integration method, yielding values of approximately79.9515 mb for Coulomb fission0.000014728mb for fission and 5.8173mb for capture cross section. This detailed analysis of the cross-sections provides insight into the synthesis of superheavy element Z = 120, though further investigations are necessary to validate these predicted values.

References:

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