Theoretical investigation of fusion cross sections of ^{256}No nucleus using Skyrme energy density formalism

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Introduction

The quest for the heaviest element in the nuclear landscape has yielded many surprises and enhanced the understanding of nuclear reactions which further attributed to play a crucial role in the synthesis of new elements and the corresponding isotopes. Persistent theoretical and experimental efforts have been made to investigate various fusion reactions and their subsequent decay mechanisms. The study of fusion reactions induced by low-energy heavy ions is crucial for exploring several key aspects of nuclear synthesis, including the extension of the Periodic Table and related mechanisms. A precise understanding of the nuclear potential resulting from the interaction between colliding heavy ions is essential for understanding the complex dynamics governing the fusion process [1].

The low-energy heavy-ion induced reactions serve as a useful tool to interpret the correlation between the nuclear structure and reaction dynamics. The objective of present analysis is to find the fusion cross-sections for the ^{40}Ca + ^{208}Pb reaction forming $^{256}No^*$ compound nucleus [2] using the nuclear potential extracted from the Skyrme energy density formalism [3]. Here the capture cross-sections are calculated within the ℓ-summed Wong model [4]. The probability of formation of compound nucleus (P_{CN}) is determined using the energy dependent function [5].

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Methodology

The extended ℓ-summed Wong Model: The capture cross-section between two nuclei can be calculated by using ℓ-summed Wong model [4] in terms of angular momentum ℓ partial waves as [6]:

$$\sigma_{capt(E_{c.m.})} = \frac{\pi}{k^2} \sum_{\ell=0}^{\ell_{max}} (2\ell+1) P_\ell(E_{c.m.}), \quad (1)$$

Further, the nuclear potential based on Skyrme energy density formalism (SEDF) is used with SIII parameters set [3].

Probability of Compound nucleus formation P_{CN}:
Probability of completely fused compound system after the capture stage is referred as the Probability of compound nucleus formation (P_{CN}). Here, the energy dependence of fusion probability can be calculated as [5]

$$P_{CN} = \frac{P_0^{'}}{1 + exp\left(\frac{V_B^* - E^*}{\Delta}\right)}. \quad (2)$$

The probability of a compound nucleus formation decreases with an increase in the atomic mass, particularly for Superheavy region. Thus, the fusion cross-sections is expressed as:

$$\sigma_{fus} = \sigma_{capt} P_{CN}. \quad (3)$$

Results and Discussions

In the synthesis of superheavy elements, the fusion of a heavy ion projectile with a heavy target (higher $Z_1 Z_2$ product) results in an increased Coulomb barrier, thereby

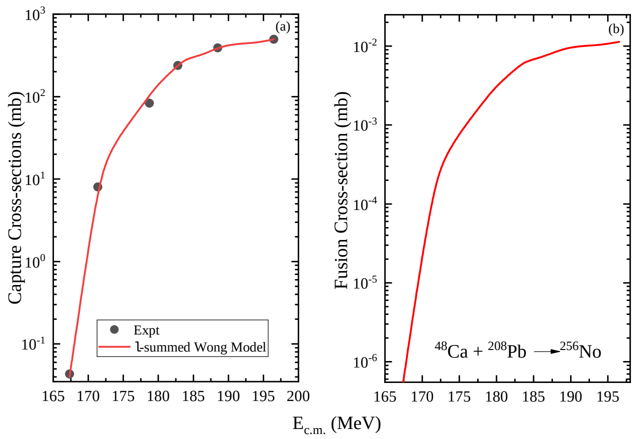

FIG. 1: (a) The capture cross-section plotted as a function of centre of mass energy $E_{c.m.}$ using the ℓ-summed Wong model and (b). Predicted fusion cross-section σ_{fus} (mb) as a function of center-of-mass energy $E_{c.m.}$. Experimental data is taken from the Ref. [2].

decreasing the probability of formation of a superheavy nucleus. In the capture process, the projectile must possess sufficient energy to overcome the barrier generated by the combined effects of the repulsive Coulomb potential, centrifugal potential, and attractive nuclear interaction potential. Key parameters such as the barrier height, barrier position, and barrier frequency, derived from the total barrier formed by these potentials, are utilized in calculating the capture cross-sections. In this work, we have calculated the capture cross-sections for the ^{40}Ca + ^{208}Pb reaction forming $^{256}No^{*}$ compound nucleus at different centre of mass energies $E_{c.m.}$ around and above the Coulomb barrier using the SIII parameters set. Fig.1 (a) show that the calculated capture cross-sections find nice agreement with the experimental data.

The probability of compound nucleus formation (P_{CN}), represents the probability of achieving a fully fused compound system after the initial capture stage. In case of superheavy mass region, the formation of the compound nucleus is a critical factor as it finds the competition from other non compound nucleus (nCN) channels such as quasi fission.

The fusion cross-sections for a superheavy nucleus are obtained using the expression in Eq. (3). Fig.1 (b) represents predicted fusion cross section (σ_{fus}) as a function of $E_{c.m.}$ for the ^{40}Ca + ^{208}Pb reaction forming $^{256}No^{*}$ compound nucleus. With the inclusion of P_{CN} with σ_{capt} one can observe the scaling down by an order of 5.

We are in the process to find the ER cross-sections of the chosen reaction and intend to present competing decay dynamics by the time of symposium.

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