Theoretical study of decay of ^{296}Lv* formed in ^{48}Ca + ^{248}Cm fusion reaction by using SkM* Skyrme Force

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Introduction

During the past three decades, a significant extension of the nuclear chart at its upper end has been achieved through the synthesis of new elements with proton numbers up to Z =118. [1] The elements having Z≥104 in the periodic table are generally known as superheavy elements (SHEs). The experimental study of these elements is very difficult and huge efforts are currently spent in this field of nuclear physics research.[2]Also, the description of these heaviest nuclei is a challenge to nuclear theory since it requires the extrapolation of model parameters, which are usually adjusted to explain the observed properties of stable nuclei, towards an unknown region. It is therefore no surprise that still no firm consensus has been reached concerning the location of the next proton and neutron shell closures above doubly magic ^{208}Pb.[3]

In the present work, we have studied the excitation functions (EFs) for the production of ^{296}Lv*(Z=116) compound nucleus formed in the hot fusion reaction ^{48}Ca + ^{248}Cm [4] and have calculated evaporation residue cross-sections σ_{3n-4n} of the decay of ^{296}Lv*, at an excitation energy of compound nucleus $E^* = 30.6$ to 38.6 MeV, based on the dynamical cluster-decay model (DCM) [5–7], including quadrupole deformations β_{2i} and hot-optimum orientations θ_i. The calculations are done using Skyrme SkM* [5] force and the so obtained results have been compared with the experimental data taken from Ref. [4]. The DCM reproduced the measured data on fusion evaporation residue (ER) nicely within a single parameter ΔR fitting.

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Methodology

The nucleus-nucleus interaction potential in SEDF, based on ETF method, is defined as

$$V_N(R) = E(R) - E(\infty) = \int H(\vec{r})d\vec{r} - \left[\int H_1(\vec{r})d\vec{r} + \int H_2(\vec{r})d\vec{r}\right] \quad (1)$$

where H is the Skyrme Hamiltonian density, a function of nuclear, kinetic, and spin-orbit energy densities, the latter two themselves being the functions of the nuclear density, written in terms of the Skyrme force parameters, obtained by fitting to ground-state properties of various nuclei.

The radius vectors for axially symmetric deformed nuclei are

$$R_i(\alpha_i, T) = R_{0i}(T)\left[1 + \sum_\lambda \beta_{\lambda i} Y_\lambda^{(0)}(\alpha_i)\right], \quad (2)$$

with T-dependent equivalent spherical nuclear radii $R_{0i}(T) = R_{0i}(T = 0)(1 + 0.0007T^2)$ [8] for the nuclear proximity pocket formula, and $R_{0i}(T) = R_{0i}(T = 0)(1 + 0.0005T^2)$ [9] for SEDF, where $R_{0i}(T = 0) = [1.28A_i^{1/3} - 0.76 + 0.8A_i^{-1/3}]$.

Finally, the compound nucleus temperature T (in MeV) is given by

$$E^* = E_{c.m.} + Q_{in} = (A/10)\,T^2 - T. \quad (3)$$

Adding to V_N, the Coulomb and angular momentum ℓ-dependent potentials V_C and V_ℓ, we get the total interaction potential $V(R, \ell)$, characterized by barrier height V_B^ℓ, position R_B^ℓ and curvature $\hbar\omega_\ell$, each being ℓ-dependent.

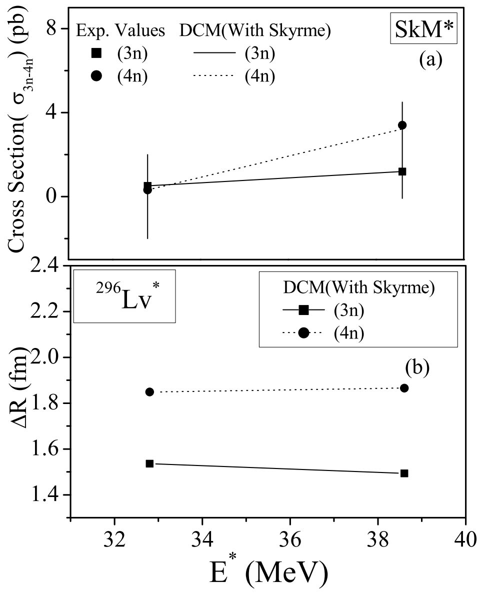

FIG. 1: (a) represents the excitation functions for the individual 3n and 4n evaporation channels for the fusion reactions ^{248}Cm(^{48}Ca,3n-4n)^{292,293}Lv* using the Skyrme force SkM*.The experimental data is taken from Ref.[4], and the solid and dotted lines represent our calculations on DCM for the best fitted ΔR values is shown in Fig1(b).

The compound nucleus decay/ fragment formation cross sections are calculated within the DCM, given as

$$\sigma = \frac{\pi}{k^2}\sum_{\ell=0}^{\ell_{max}}(2\ell+1)P_0P; \qquad k=\sqrt{\frac{2\mu E_{c.m.}}{\hbar^2}} \tag{4}$$

where P_0 is preformation probability referring to mass asymmetry η $[=(A_1-A_2)/(A_1+A_2)]$ motion and P, the penetrability, to R motion. For complete details of the model DCM, see references [5–7].

Calculations and Results

The dynamical cluster-decay model (DCM), with effects of deformations of the incoming nuclei or outgoing fragments and their compact-orientation degrees of freedom included, is used to calculate the evaporation residue excitation functions of equatorial compact ($\theta_c = 90^0$ for ^{296}Lv*) hot fusion reaction ^{48}Ca + ^{248}Cm. We have compared our calculated results with the experimental 3n and 4n evaporation channel cross-sections using the SkM* Skyrme Force as shown in Fig.1(a) and we have observed that the ΔR is larger for 4n emission than 3n emission implied that 4n emission takes place earlier than 3n emission from the CN ^{296}Lv*. The best fitted neck-length parameter ΔR as a function of E^* for 3n and 4n evaporation channel cross section of ^{296}Lv* represented in Fig.1(b). Our calculated results coincides with the experimental data indicating that the DCM successfully explains the experimental results.

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