Isotopic analysis of superheavy nucleus Z=114

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Introduction

Asymmetric reactions, involving target and projectile with maximum neutron excess are generally preferred to study the dynamics of superheavy nuclear systems. To attain this, actinide targets (Pu, Cm, and Cf) and ^{48}Ca as the projectile, are capable of producing neutron rich isotopes in the vicinity of the N=184. The N=184 is almost established as a shell closure (Magic) in superheavy region after N=126. Therefore, reactions involving neutron number closer to 184 are supposed to be relatively stable. Following this, the reactions ^{48}Ca+^{242,244}Pu→^{290,292}114* were studied in order to understand the dynamical features of Z=114 isotopes, by taking neutron number closer to N=184. The stability aspect of compound nuclei ^{290,292}114* were investigated at different excitation energies ranging between E^*_{CN} = 34 to 53 MeV. The recent experimental analysis [1] observed a new isotope ^{285}114 via 5n evaporation product from compound nucleus ^{290}114* at relatively higher energy of the order of 50 MeV. Also, the recoil separator TASCA at GSI studied further the reaction ^{244}Pu (^{48}Ca, xn) at excitation energies E^*_{CN} = 36.1-39.5 MeV and E^*_{CN} = 39.8- 43.9 MeV [2] where the modified 3n and 4n cross-sections are reported.

In the present work, the comparative fragmentation behavior of Z=114 isotopes is worked out within the framework of dynamical cluster decay model (DCM) with the inclusion of quadrupole deformations and optimum orientation approach. The calculated cross-sections of ^{290,292}114* are in nice agreement with data of [1, 2]. To calculate the neutron evaporation cross-sections, we have taken proton magic Z=126 and neutron magic N=184 as suggested by [3].

The Model

The dynamical cluster decay model DCM [3, 4] works in terms of the collective coordinates of mass asymmetry $\eta = (A_1 - A_2)/(A_1 + A_2)$; the relative separation R, the multipole deformations $\beta_{\lambda i}$ (λ=2, 3, 4,..), and orientations θ_i (i=1, 2) of two nuclei or fragments (1 and 2 stand, respectively, for heavy and light fragments). Using partial waves, the compound nucleus decay cross-section is given as,

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

with μ as the reduced mass and, ℓ_{max}, the maximum angular momentum, fixed for the light particle cross section $\sigma_{LP} \rightarrow 0$. Here, P_0 is the preformation probability and P is the penetration probability. The Preformation probability accounts for the nuclear structure effects and is calculated by solving the Schrodinger equation in the mass asymmetry (η) coordinate and the penetration probability P is calculated by using WKB approximation.

Calculations and Results

In the decay of ^{290,292}114* superheavy nuclei, the fitting of 3n, 4n and 5n cross-sections is possible only with the inclusion of the deformations, except for 3n-decay of ^{292}114* nucleus. In other words only 3n-decay of ^{292}114* could be fitted using spherical choice of fragmentation and hence the role of deformations are extremely desirable in the decay of ^{290,292}114* superheavy nuclei.

With the inclusion of β_2-deformations within the optimum orientation approach, the decay of compound nuclei ^{290,292}114* formed in the hot fusion reactions ^{48}Ca+^{242,244}Pu is investi-

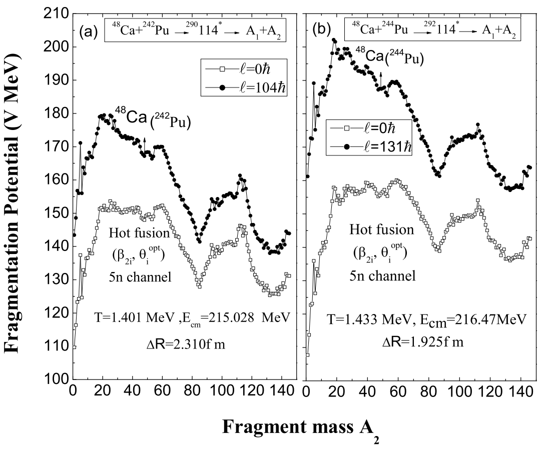

FIG. 1: Fragmentation potentials for $^{290}114^*$ and $^{292}114^*$ as a function of light mass fragment A_2 for neutron-evaporation channel (5n) with β_{2i} deformations and "optimum" orientations θ_i^{opt} at $\ell = 0$ and ℓ_{max} values.

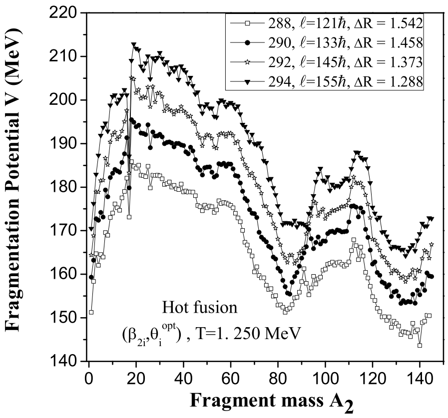

FIG. 2: Fragmentation potential for different isotopes of Z=114 as a function of light mass fragment (A_2) for 3n evaporation channel at $\ell = \ell_{max}$.

gated over a wide range of energies $E^*_{CN} = 34$ to 53 MeV. Firstly, the comparative behavior of fragmentation potential of $^{290}114^*$ and $^{292}114^*$ for 5n decay channel is examined at comparable energies for two extreme values of angular momentum i.e. ℓ=0 and ℓ_{max} values. The 5n decay from $^{290}114^*$ nucleus was recently observed in [1]. Along with this, experimental data is available for 3n, 4n and 5n decay of $^{290,292}114^*$ nuclei in [1, 2] and the same is tested using DCM. However the fragmentation path is shown only for the 5n channel in Fig.1. It is clear that the structure of $V(A_2)$ is nearly similar for $^{290}114^*$ and $^{292}114^*$ decay and is also independent of the ℓ-values. Strong minima are seen for evaporation residues as well as for the fission fragments with of A_2>130 along with heavy mass fragment (HMF) window $80 \leq A_2 \leq 90$. Similar results are seen for 3n and 4n decay channels for both the nuclei.

We have also tested the role of N/Z ratio by adding 2 successive neutrons to different compound nuclei corresponding to Z=114 with A = 288, 290, 292 and 294. The isotopic analysis is done by extrapolating neck-length parameter ΔR values obtained for 3n decay from $^{290}114^*$ and $^{292}114^*$ at T≈1.250 MeV. Broadly speaking the fragmentation paths shown in Fig.2 are quite similar when 2 neutrons are added subsequently in Z=114 and N=174. Although some slight variations are seen in the heavy mass fragment (HMF) and fission region, but the overall fragmentation behavior is independent of isotopic mass. In summary, the decay cross-sections of 3n, 4n and 5n are tested in the energy range $E^*_{CN} = 34$ to 53 MeV using DCM with β_{2i} deformations. It seems that angular momentum and E_{cm} does not influence the fragmentation paths of $^{290}114^*$ and $^{292}114^*$, independent of neutron decay channel. Also changing N/Z ratio doesn't play a significant role in reference to decay of isotopes corresponding to Z=114. The deformation effects are extremely desirable for understanding the dynamics of both the reactions.

References

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