Decay of ^{124}Ce* using Skyrme Energy Density Formalism within the Dynamical Cluster-decay Model

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Introduction

Recently [1], the decay of proton-rich nucleus ^{124}Ce* formed in ^{32}S+^{92}Mo reaction has been studied at an incident center-of-mass energy $E_{c.m.}$=111.29 MeV (equivalently, the laboratory energy 150 MeV) within the dynamical cluster-decay model (DCM) of Gupta and collaborators [2] using, for nuclear proximity potential, the pocket formula of Blocki *et al.*. The relative population of α-nucleus clusters like ^{8}Be, ^{12}C, etc., was studied *w.r.t.* the non-α nucleus clusters like ^{6}Be, ^{10}C, etc., in the decay of compound nucleus (CN) ^{124}Ce*. For this system, the relative cross-sections of various evaporation residues (ERs; A≤4, Z≤2) and intermmediate mass fragments (IMFs; 5≤A≤10, 3≤Z≤6) are observed *w.r.t.* ^{4}Li [3]. In DCM, we have fitted the two ERs (2p and 3p) and two IMFs (^{5}Li and ^{6}Be) cross-sections, in order to predict the behavior of the relative cross-sections of ^{7}B, ^{8}Be, ^{9}B, ^{10}C, and ^{12}C, etc., clusters at a fixed temperature T=2.297 MeV, referring to the experimental beam-energy. Neck-length ΔR is the only parameter of the model, whose value remains within ∼2 fm, the range of validity of proximity potential used here. For the best fitted ΔR's upto A_2=6 , the relative populations of ^{6}Be and ^{8}Be, and that of ^{10}C and ^{12}C are analyzed, showing thereby that the compound nucleus ^{124}Ce* decays preferentially via A=4n, α-nucleus clusters as compared to A≠4n, non-α nucleus clusters, similar to what was predicted for ground-state (T=0) decays [4].

Here, we have extended this study to the use of various other nuclear potentials derived from Skyrme Energy Density Formalism based on Semiclassical extended Thomas Fermi method under Frozen density approximation using SIII and GSKI forces with effects of deformations and orientations included.

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Dynamical cluster-decay model

In the CN model, the CN formation probability P_{CN}=1 for complete fusion, and it decays by emitting multiple light particles, the ER, and fusion-fission (ff) fragments (including IMFs). However, non-compound nucleus (nCN) decays (P_{CN} <1), like quasi-fission (qf), etc., also contribute to fusion process such that the total cross-section is

$$\begin{aligned} \sigma_{fusion} &= \sigma_{ER} + \sigma_{ff} + \sigma_{nCN} \\ &= \sigma_{CN} + \sigma_{nCN}. \end{aligned} \qquad (1)$$

Then, P_{CN} is defined [1, 5] as the ratio of CN formation cross-section σ_{CN} and the total fusion cross-section σ_{fusion} which includes the nCN component σ_{nCN}:

$$P_{CN} = \frac{\sigma_{CN}}{\sigma_{fusion}} = 1 - \frac{\sigma_{nCN}}{\sigma_{fusion}} \qquad (2)$$

For the reaction under study, P_{CN} ≈1 since the data is at above-barrier energy [1].

In DCM, the decay of hot and rotating CN is worked out in terms of the decoupled relative separation R and mass asymmetry η [$=(A_1-A_2)/(A_1+A_2)$] coordinates, defining the CN decay cross-section as

$$\sigma = \frac{\pi}{k^2}\sum_{\ell=0}^{\ell_{max}}(2\ell+1)P_0P; \qquad k=\sqrt{\frac{2\mu E_{c.m.}}{\hbar^2}} \qquad (3)$$

Here, P_0 is the preformation probability, referring to η-motion and P, the penetrability, to R-motion. μ is the reduced mass and ℓ_{max} is the maximum angular momentum, defined for the ER cross-section σ_{ER} →0. In

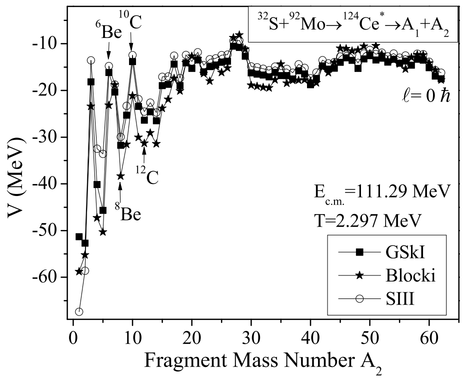

FIG. 1: Mass fragmentation potential $V(A_2)$, minimized in charge fragmentation coordinate η_Z, for the decay of ^{124}Ce* at $E_{c.m.}$=111.29 MeV for various Skyrme forces at ℓ=0 $\hbar$.

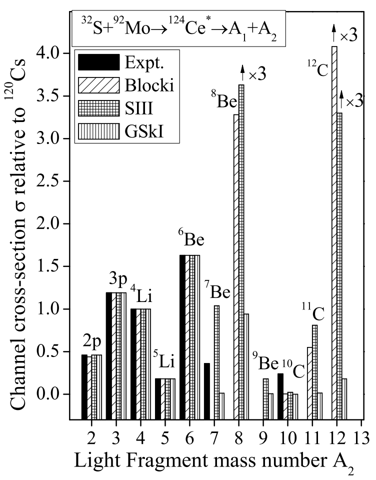

FIG. 2: DCM calculated relative cross-sections σ(Channel)/σ(^{120}Cs), for various Skyrme forces, in the decay of $^{124}Ce^*$, compared with the experimental data [3] at $E_{c.m.}$=111.29 MeV.

DCM, the structure effects of the CN are introduced through proformation probabilities P_0 of the fragments, given by the solution of stationary Schrödinger equation in η, and P is the WKB penetrability of the preformed fragments. The only parameter of the model is the neck-length parameter ΔR, defined by the first turning point of the WKB integral, as $R_a = R_1 + R_2 + \Delta R$.

Calculations and Results

Fig.1 shows the calculated fragmentation potential as a function of fragment mass for SIII, GSkI and proximity potential, for the decay of CN ^{124}Ce* at $E_{c.m.}$=111.29 MeV (E_{Lab}=150 MeV or T=2.297 MeV), illustrated for ℓ=0, using the best fitted ΔR-values upto ^{6}Be. Note that in Fig. 1, we have replaced the binding energy of the energetically most favored fragment, *i.e.*, the fragment having minimum value of binding energy, with the binding energy of fragment of interest from experiment's point of view. Interestingly, similar to proximity potential, for the skyrme forces SIII and GSkI, the α-nucleus clusters ^{8}Be, ^{12}C, etc., occur at deeper minima as compared to non-α nucleus nucleus clusters ^{6}Be, ^{10}C, etc., establishing that the α-nucleus clusters are energetically more preferred.

Fig.2 shows our DCM calculated cross-sections, for various forces compared with experimental data [3]. Note that, ^{8}Be and ^{12}C decays are not observed in the experiment. For the best fitted ER cross-sections up to A_2=6, ^{8}Be and ^{12}C are shown to be relatively more populated than ^{6}Be and ^{10}C for the force SIII, similar to that for the proximity pocket formula. However, the same is not true for the GSkI force, emphasizing that, similar to that for the pocket formula, also for some Skyrme forces (SIII compared to GSkI) the α-nucleus structures are preferred over the non-α-nuclei.

Acknowledgments

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