Fusion-fission of compound nuclei $^{244-247}$Cm* formed in low energy heavy ion collisions of $^{12-15}$C projectiles with target ^{232}Th

BirBikram Singh[1],* Manpreet Kaur[1,2],† Navjot Kaur[3,1], and Manoj K. Sharma[4]
[1]*Department of Physics, Pondicherry University, Puducherry 605014*
[2]*Department of Physics, S.G.G.S. World University, Fatehgarh Sahib, Punjab 140407*
[3]*Department of Physics, Akal University, Talwandi Sabo, Punjab 151302 and*
[4]*Department of Physics and Materials Science, T.I.E.T, Patiala, Punjab 147004*

Introduction

The excited and rotating compound nucleus emit gamma rays, light particles, intermediate mass fragments and fusion-fission (FF) fragments with any one of them being a dominant mode depending upon the excitation energy, entrance channel, deformations or orientations of target/ projectile and mass of the compound nucleus. In the present work, the reactions involving FF of compound nuclei (CN) $^{244-247}$Cm* formed in low energy heavy ion collisions of $^{12-15}$C projectiles with actinide target ^{232}Th have been investigated, at $E_{c.m.}\sim$ 69 MeV, within dynamical cluster-decay model (DCM) [1, 2]. We have probed the effects of transition from a paired to an unpaired valence neutron on the FF fragments ($A = (A_{CN}/2)\pm 20$) cross sections σ_{FF} in the decay of CN $^{244-247}$Cm*. Here, the subsequent decays of the CN and hence the effects of multichance fission are not explored.

The dynamics of these reactions is explored via fragmentation potential and preformation probability (P_0) of the fragments. The variation of summed up preformation probability, of FF fragments, ΣP_0 ($\ell = 0$ $\hbar$ to ℓ_{max}) is explored, for different CN, as a function of fragment mass no. (A) as well as angular momentum (ℓ). With spherical considerations, neck length parameter (ΔR) is taken 0 fm, to calculate the normalized values of σ_{FF}. The DCM calculated σ_{FF}, for the choice of deformed and oriented (compact) nuclei with the fitted ΔR values, are also compared with the experimental data [3] for all the four CN under study. The dynamical collective clusterisation process in the form of preformed fragments, before subsequent tunneling of the potential barrier, used in DCM seems an effective tool to predict the mass distribution of decay products of compound systems produced in low energy heavy ion collisions [1]. Earlier, the DCM calculated results for the reactions ^{12,15}C + ^{232}Th and ^{13,14}C + ^{232}Th [2], respectively, explored the effect of halo configuration of projectile (^{15}C) and the barrier penetrability P on the reaction dynamics. These studies explicitly established the role of P_0, carrying relevant structure information. Moreover, it is shown that in the binary decay of the CN under study FF dominate the evaporation residue or light particle decay process having negligible contribution.

Methodology

The DCM [1, 2], worked out in terms of collective co-ordinates of mass (and charge) asymmetries, for ℓ-partial waves, gives the compound nucleus decay cross-section as

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

where, $\mu = [A_1A_2/(A_1 + A_2)]m$ is the reduced mass, with m as the nucleon mass and ℓ_{max} is the maximum angular momentum. P is penetrability across the interaction barrier (of the preformed fragments), calculated using the WKB tunneling process.

Results and Discussions

We find that the potential energy surface of FF fragments have the nuclear structure

*Electronic address: birbikram.singh@pondiuni.ac.in;drbirbikramsingh@gmail.com
†Electronic address: manpreetphysics95@gmail.com

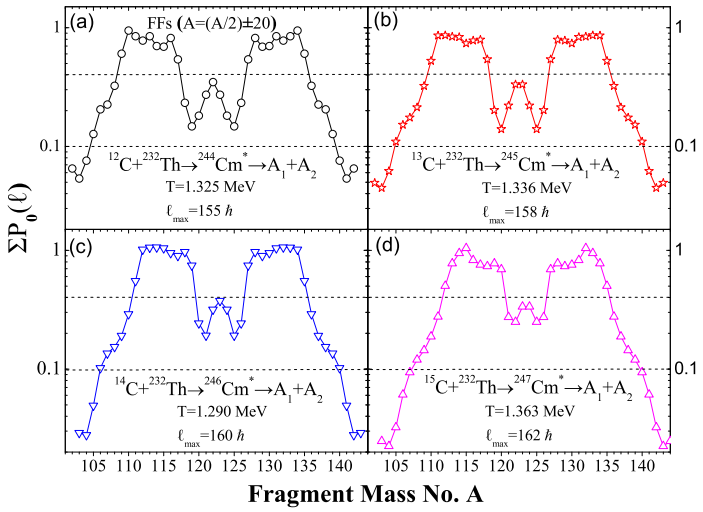

FIG. 1: The ΣP_0 vs A for CN (a) ^{244}Cm* (b) ^{245}Cm* (c) ^{246}Cm* (d) ^{247}Cm*.

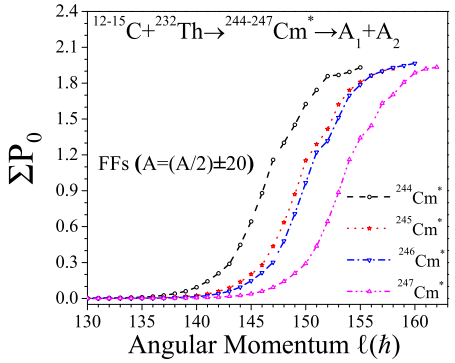

FIG. 2: The ΣP_0 of the FF fragments in the decay of CN $^{244-247}$Cm*.

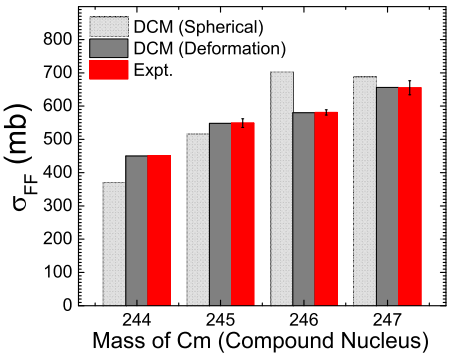

FIG. 3: The DCM calculated σ_{FF} in comparison with the experimental data [3].

effects, subsequently reflected in the P_0 profile, in the FF dynamics with increasing mass of CN. It is quite evident in fig.1(a-d), which presents the ΣP_0 as a function of fragment mass no. A for CN (a) ^{244}Cm* (b) ^{245}Cm* (c) ^{246}Cm* (d) ^{247}Cm*. We see that the ΣP_0 of the FF fragments evolves with increasing mass of CN. It clearly shows the steady increase in the ΣP_0 value of symmetric and near symmetric fragments A = (A_{CN}/2)±3, with increase in the projectile/ compound nucleus mass.

Fig. 2, shows the variation of ΣP_0 as a function of ℓ-values. It explores the role of angular momentum in the decay dynamics of CN under study. The ΣP_0 curve shift to higher ℓ-values for ^{13}C induced reaction in comparison to the one induced by ^{12}C, respectively, having unpaired and paired neutron. Hence, depicting more probable interaction of ^{13}C with the ^{232}Th target. While a very small shift from ^{13}C to ^{14}C induced reactions can be attributed to the magic neutron number N=8/ unpaired neutron in case of ^{14}C. Again, significant increase in the ℓ-values for ^{15}C induced reactions mark the role of unpaired neutron. Quite interestingly, this observation is well supported by the experimental data [3] presented in fig. 3 in comparison with the DCM calculated results for both the choices of spherical and deformed nuclei. The comparison betters with the deformation and orientation effects included.

References

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