Evaporation residue cross-sections of ^{249}Bk+^{48}Ca→^{297}117* reaction

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Introduction

Synthesis of superheavy nuclei is an important research area in nuclear physics and the question of new magic numbers, the island of stability, and related aspects like the static deformations and orientations of reaction partners have been studied quite extensively in recent times. An equally important question is the decay of compound nucleus so formed. Experimentally, a large amount of data is recently made available on both the fusion and fusion-fission processes. For fission-less decays, the fusion cross-section is given by the fusion-evaporation residue cross-section alone.

The production of a superheavy nucleus (Z≥ 103) is generally associated with the strong (microscopic) shell closure effects of nuclei which compensate the large Coulomb repulsive interaction. The macro-microscopic model predicts the magic proton shell closure in superheavy region at Z=114, whereas the same for microscopic Hartee-Fock-Bogoliubov and the relativistic mean field (RMF) theories are given at Z=120 or 126. The neutron magicity is predicted to be at N=184 in a majority of these calculations, though some RMF calculations favor N=172. A recent work on the dynamical cluster-decay model (DCM) [1], used here, shows the Z=126, N=184 as the best possible choice for the proton, neutron magic pair in the superheavy region.

In the present work, we have used the DCM [1, 2] for studying the decay of ^{297}117* nucleus formed in ^{249}Bk+^{48}Ca reaction where the neutron evaporation residue cross-sections σ_{3n} and σ_{4n} have been measured, respectively, at compound nucleus excitation energies E^*_{CN}=35.3 MeV and =39.3 MeV [3]. Precisely, only 3n cross-sections are measured at E^*_{CN}=35.3 MeV and only 4n cross-sections at 39.3 MeV. Also, some theoretical estimates are available for 2n decay, but the contribution of the 2n cross-sections is quite small in data, as the reaction used is apparently a hot fusion reaction. Static quadrupole deformations and optimum orientations of the target, projectile and decaying fragments are also included here, since these are known to play a significant role in the formation and decay of nuclear systems [4]. Thus, the 2n, 3n and 4n cross-sections are calculated in reference to the available data [3], taking Z=126 and N=184 as the possible magic numbers in the use of DCM where static deformations and orientations of the fragments are also included [1, 2].

The Model

The dynamical cluster-decay model (DCM) is a two-step model. The first step is the quantum mechanical preformation probability P_0 of the decay products (cluster and daughter) formed in mother nucleus, and the second step is the penetration P of the cluster through the interaction barrier. Both of these quantities, P_0 and P, are calculated, respectively, for the fragmentation and scattering potentials, where the effects of deformations and orientations of fragments are included. The decay cross-section is then defined 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 particles cross-section $\sigma_{LP}\rightarrow 0$ at $\ell=\ell_{max}$. The energy transfer during the process of tunnelling the interaction barrier can be re-

TABLE I: DCM calculated σ_{3n} and σ_{4n} cross-sections compared with experimental data.

E^*_{CN} (MeV)	ΔR (fm)	σ_{ER} (pb)		
			DCM	Expt.
35.3±2.1	1.565	3n	0.504	0.5
39.3±2.1	2.305	4n	1.02	1.3
	0.883	^{4}He	0.304	-

lated as follows:

$$E^*_{CN} = E_{c.m.} + Q_{in} = Q_{out} + TKE(T) + TXE(T) \quad (2)$$

with the compound nucleus excitation energy E^*_{CN} related to temperature T (in MeV) as $E^*_{CN} = \frac{A}{11}T^2 - T$. All the quantiies in Eq. (2) have their ususal well known meanings.

Calculations and Results

Figure 1 shows the fragmentation potential for the reaction ^{249}Bk+^{48}Ca→^{297}117* → $A_1 + A_2$, at two extreme angular momentum values ℓ=0 and ℓ_{max}, with deformation effects included up to quadrupole deformation β_2 and optimum orientations. The fragmentation path is shown nearly independent of the ℓ value, particularly for heavier fragments.

First, we tried to fit the 3n and 4n ER cross-sections of ^{297}117*, using the spherical fragmentations in DCM. But, the measured 3n and 4n ER cross-section could not be achieved for any value of neck length parameter ΔR, the only parameter of the model, which called for to include the possible role of deformations and orientations of incoming nuclei and outgoing fragments. Including multipole deformations up to quadrupole deformation β_2, together with "optimum" orientations $\theta^{optimum}$, the DCM calculated 3n ER cross-section σ_{3n} finds a nice comparison with the experimental data but the 4n cross-section σ_{4n} is underestimated by ∼25%, which indicates the possibility that some other competing process, like the ^{4}He decay, is contributing towards the 4n-decay cross-sections. This result is born out as we compare our calculated 3n and 4n, together with ^{4}He, cross-sections with experimental data in Table I.

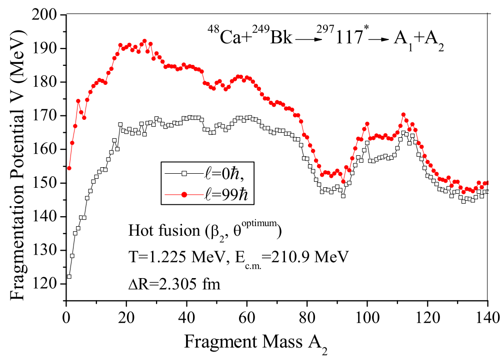

FIG. 1: Fragmentation potential as a function of the light fragment mass for ^{297}117* nucleus, with deformation and orientation effects included.

In summary, 3n and 4n ER cross-sections data, respectively, at E^*_{CN}=35.3 and 39.3 MeV in the raction ^{249}Bk+^{48}Ca→^{297}117* are studied by using the DCM. The intersting result is that the angular momentum does not seem to influence the fragmentation path in this reaction, and that the deformations and orientations effects of both the reacting partners and decay fragments are extremely desirable. Some component of ^{4}He also seems to contribute towards the 4n ER cross-section.

References

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