Role of shell corrections in the decay of medium and heavy mass compound nuclei

Manjot Kaur, Sarbjeet Kaur,* Amandeep Singh, and BirBikram Singh†
Department of Physics, Sri Guru Granth Sahib World University, Fatehgarh Sahib- 140406, PUNJAB

Introduction

The binding energy of an atomic nucleus which binds the nucleons inside the nucleus, was first formulated in Weizsäcker's semi-empirical mass formula based on the liquid drop generalization. Later on studies show that in addition to liquid drop energy, experimental binding energy contains the microscopic shell correction part, as defined by Strutinsky renormalization procedure [1]. The empirical formula that gives the shell corrections was developed by Myers and Swiatecki [2].

The nuclear shell corrections plays important role in the process of cluster radioactivity as explored by the quantum mechanical fragmentation theory. Earlier studies shows that shell corrections play a crucial role in the collective clusterization process for the decay of radioactive nuclei [3]. Also, the effect of shell corrections on beta decay stable isobars have been studied [4]. It is observed that shell corrections significantly enhance the stability of beta decay stable isobar. The role of shell corrections on collective potential energy surface in light mass region for the decay of ^{20}Ne has been investigated within the dynamical cluster-decay model (DCM) [5]. It is observed that in light mass region the shell corrections do play a significant role at T = 0 MeV and T = 1.59 MeV but vanishes at higher temperature [6]. Now we intend to further explore their role in the decay of medium and heavy mass compound nuclei (CN) at T = 1.5 MeV. In present work, the role of shell corrections, on the fragmentation potential or collective potential energy surface in the decay of medium and heavy mass CN, respectively, $^{124}Ce^*$ and $^{246}Bk^*$, have been elucidated. It is relevant to mention here that the decay of these CN have been studied earlier [7, 8], within DCM, with the effects of shell corrections included.

Methodology

The fragmentation potential ($V_R(\eta$,T)) within DCM is given as

$$V_R(\eta, T) = B_i + V_c + +V_p + +V_l \quad (1)$$

i.e. it is sum of Coulomb (V_c), proximity (V_p), centrifugal potential (V_l) all being temperature (T) dependent and B_i are the T dependent binding energies of two nuclei and defined within Strutinsky renormalization procedure [1] as below

$$B_i(T) = V_{LDM}(T) + \delta U \exp(\frac{-T^2}{T_0^2}) \quad (2)$$

where V_{LDM} is the liquid drop energy [9] and δU are the empirical shell corrections [2], of the binding energies. Based upon the semi-empirical mass formula of Seeger [10], the T dependent V_{LDM} part is taken from Davidson et al. [9], as

$$V_{LDM}(A,Z) = \alpha A + \beta A^{\frac{2}{3}} + \left(\gamma - \frac{\eta}{A^{\frac{1}{3}}}\right) \left(\frac{I^2 + 2 \mid I \mid}{A}\right) + \frac{Z^2}{R_0 A^{\frac{1}{3}}} \left(1 - \frac{0.7636}{Z^{\frac{2}{3}}} - \frac{2.29}{[R_0 A^{\frac{1}{3}}]^2}\right) + \delta \frac{f(Z,A)}{A^{\frac{3}{4}}} \quad (3)$$

where above terms represent volume, surface, asymmetry, Coulomb and pairing energies, respectively and I = a_a(Z - N). Also,respectively,for even-even, even-odd and odd-odd nuclei, f(Z, A) = (-1,0,1). In the

*Electronic address: sarbjeetsangha13@gmail.com
†Electronic address: birbikram.singh@gmail.com

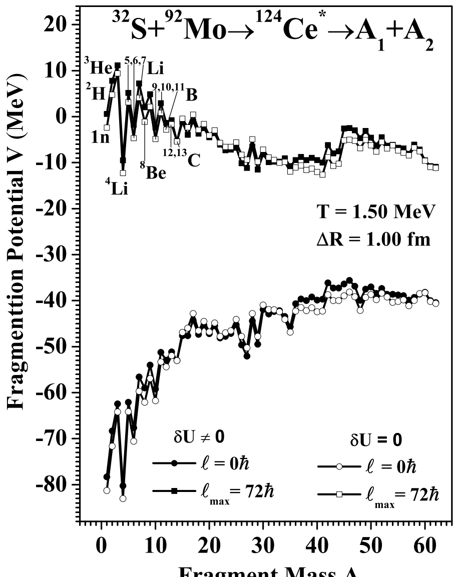

FIG. 1: Fragmentation potential V (MeV) for the decay of medium mass compound nucleus $^{124}Ce^{*}$ at T = 1.50 MeV with the choice of δU = 0 and δU $\neq$ 0 i.e. with and without inclusion of shell corrections.

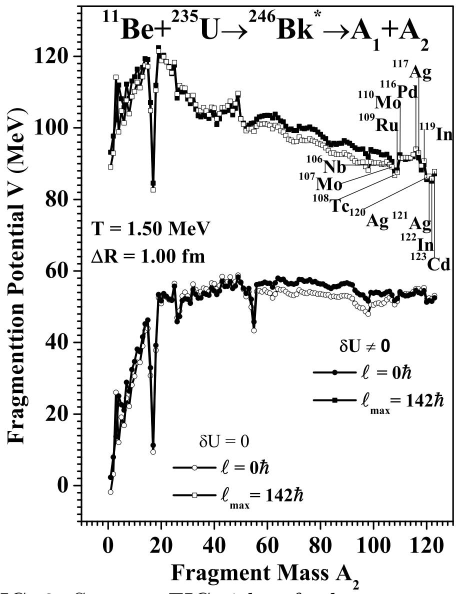

FIG. 2: Same as FIG. 1 but for heavy mass compound nucleus $^{246}Bk^{*}$.

present work, the role of shell corrections on the fragmentation potential (given by eq. 1) is studied by taking δU $\neq$ 0 and δU = 0 in eq.(2).

Calculations and Discussions

The Fig. 1 and 2 shows the calculated fragmentation potential V (MeV) as a function of light fragment mass A_2 for the decay of CN $^{124}Ce^{*}$ and $^{246}Bk^{*}$ illustrated for $\ell = 0$ and ℓ_{max} for inclusion (δU $\neq$ 0) and non-inclusion (δU = 0) of shell corrections. From Fig. 1 we note that at both the ℓ-values there is very small change, with the inclusion and non-inclusion of shell corrections, in the value of V (MeV) for medium mass compound $^{124}Ce^{*}$. However, the change becomes noticeable, particularly, for heavy mass fragments in the decay of heavy mass compound nucleus $^{246}Bk^{*}$ (Fig. 2). Moreover, for compound nucleus $^{246}Bk^{*}$, at both the ℓ-Values, symmetric mass fragments show little change only. These result may further affect the decay properties of these nuclear systems, within DCM. The investigation of the role of shell corrections in medium and heavy mass region at lower temperature T < 1.50 MeV will be of further interest.

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