Role of surface energy coefficients in cluster decay

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Introduction

Radioactive heavy nuclei reaches stable region by emitting clusters, apart from emitting α particle, which are heavier than α particle and lighter than the lightest fission fragment, a phenomenon named cluster radioactivity. Poenaru and Greiner [1] interpreted the equivalence between the fission model and preformed cluster model, by stating that the preformation probability in fission models can be considered as the penetrability of the prescission part of the barrier. Shi and Swiatecki [2] estimated the half-lives of cluster emission by using a interpolation formula for fused region and a combination of proximity and Coulomb potential for the post-contact region. Proximity potential plays a vital role in deciding the characteristics quantities of a decay. We have analysed the role of nuclear surface energy coefficients in Shi and Swiatecki model in estimating pre-formation probability and half-lives in cluster decay.

Shi and Swiatecki [2] used Coulomb plus proximity potential for the post-touching region and for the pre-touching part they have used power law as given below:

$$V(L) = \frac{Z_1 Z_2 e^2}{R} + V_P - Q, \quad L \geq L_c \quad (1)$$

$$V(L) = a(L - L_0)^x, \quad L_0 \leq L \leq L_c \quad (2)$$

where L indicates the extreme extension of the configuration with L_c corresponds to the contact of the fragments. a and x are calculated using smooth continuity relation between the potentials of pre and post touching regions. V_P is the nuclear proximity potential term given as

$$V_P = 4\pi \overline{R} \gamma b \Phi(\xi). \quad (3)$$

$\Phi(\xi)$ is the universal function of proximity potential and $\overline{R}$ is the mean curvature radius of the reaction partners, characterising the gap. Nuclear surface energy coefficient is given by,

$$\gamma = \gamma_0 \left[1 - k_s \left(\frac{N - Z}{A} \right)^2 \right] MeV fm^{-2}, \quad (4)$$

Here γ_0 and k_s are parametrised by different authors [3]. Half-life is given by

$$T_{1/2} = \frac{\ln 2}{\nu P_0 P} \quad (5)$$

Here ν is assault frequency and P_0 indicates pre-formation probability which is the penetrability for the pre-touching region and P penetrability for the post-touching region; both the penetrabilities are calculated using WKB method.

Results and discussions

We have incorporated, the idea of Poenaru *et al* [1], i.e. considering the penetrability for the pre-touching region as pre-formation probability, in Shi and Swiatecki [2] model for different parametrization of nuclear surface energy coefficients. Shi and Swiatecki does not include preformation probability in his model. Experimentally identified 15 cluster emitters with 221≤A≤242 are considered for study with emitted clusters such as ^{14}C, ^{20}O,^{24}Ne,^{28}Mg and ^{32}Si [4]. Based on the advancements in theory and experiments, the

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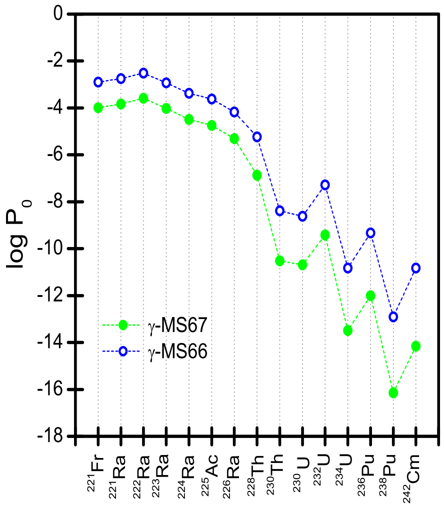

FIG. 1: Calculated $\log P_0$ values for cluster decays of different parent nuclei.

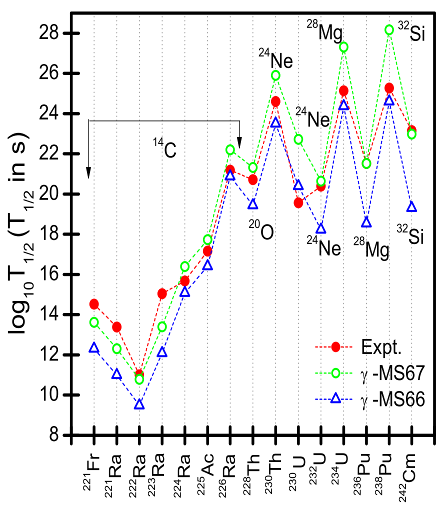

FIG. 2: Experimental and calculated $\log_{10} T_{1/2}$ values for cluster decays of different parent nuclei.

values of γ_0 and k_s of nuclear surface energy coefficients were parametrised. Here we have used two parameter sets $\gamma_0 = 1.01734$ MeV/fm^2, k_s= 1.79 denoted as γ-MS66 and $\gamma_0 = 0.9517$ MeV/fm^2, k_s=1.7828 denoted as γ-MS67 [3]. These values enter the calculation of P_0 in the proximity potential through continuity equation. Shi and Swiatecki employed γ-MS67 in his work. Fig. 1 represents the P_0 values calculated using WKB integral for the use of potential given by Eq. (2) for the use of these two γ's. From the structure of P_0, it is clear that, it decreases as the size of the cluster increases, indicating the size dependence of the P_0 in cluster decay. This structure resembles Fig. 3 of our previous work (Ref. [4]) which is the discrepancy between experimental and calculated half-life assuming P_0 as 1. However magnitude of P_0 differ due to the calculation in the penetrability factor for the post touching region in both the models. Preformation probability values due to use of γ-MS67 are found to be lower than that calculation due to γ-MS66. Half-life is calculated for these 15 parent nuclei for cluster decays using Eq. (5) with P_0 due to both γ's. In Fig. 2 calculated half-lives and experimental half-lives are presented. Solid circle represents the experimental half-lives and open circle and open triangle represent the calculations due to γ-MS67 and γ-MS66 respectively. For the use of γ-MS67, experimental and calculated half-lives coincides for ^{14}C decay from ^{222}Ra, ^{24}Ne decay from ^{232}U. In the case of γ-MS66, better matching between experimental and calculated half-lives are noted, for the emission of ^{14}C from ^{224}Ra, ^{225}Ac and ^{226}Ra and ^{28}Mg from ^{234}U, ^{32}Si from ^{238}Pu.

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