Alpha and proton decay of ^{166}Ir

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Introduction

The process in which a nucleus disintegrates by emitting a proton is known as proton decay. Above the proton drip line, the nuclei with positive Q values are proton unstable. Nuclear surface energy coefficient of proximity potential plays a vital role in deciding the preformation probability of alpha and clusters [1]. Further it decides the accuracy of half-lives. It motivates to study the branching aspect of a medium nuclei ^{166}Ir for proton and alpha decay.

In the present work fission model [1] with Coulomb, proximity and centrifugal potential for post touching region and a simple power law for pre touching region is used, which is given below:

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

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

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 [2]. Here we have used five parameter sets γ_0 and k_s denoted as γ-RR84, γ-MS67, γ-PD03b, γ-PD03a and γ-BW91 [2]. These values enter the calculation of P_{ov} through continuity equation. Half-life is given by

$$T_{1/2} = \frac{\ln 2}{\nu P_{ov} P_{nov}} \quad (5)$$

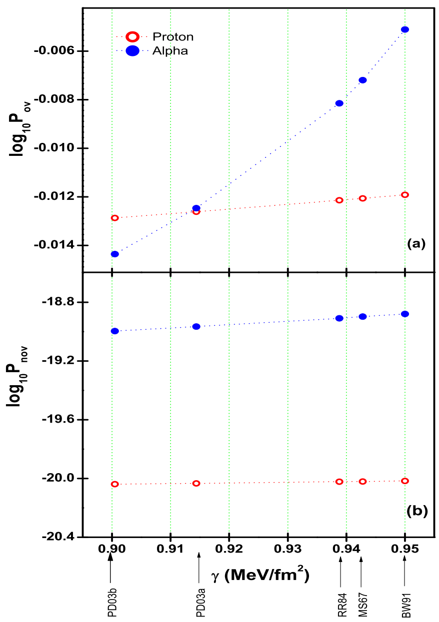

FIG. 1: Calculated $\log_{10} P_{ov}$ and $\log_{10} P_{nov}$ values for proton and alpha decay of ^{166}Ir using different γs.

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Here ν is assault frequency and P_{ov} indicates pre-formation probability which is the penetrability for the pre-touching region and P_{nov} penetrability for the post-touching region; both the penetrabilities are calculated using WKB method.

Results and discussion

The experimental Q_p value for proton decay of ^{166}Ir is 1.168 MeV. For ℓ=2$\hbar$, the experimental half-life of proton emission is 150 ms and the calculated best matching half-life is 72 ms, for the use of γ-PD03b. For ground state alpha decay ℓ=0$\hbar$, Q_α value calculated using masses from [3] is 6.722 MeV. The experimental half-life is 11.3 ms, whereas the calculated best matching half-life is 50.6 ms for the use of γ-PD03b. For both decays, as γ increases half-life decreases. Figure 1(a) and 1(b) respectively shows the variation of $\log_{10}P_{ov}$ and $\log_{10}P_{nov}$ with respect to γ's of ^{166}Ir with open circle for proton decay and solid circle for alpha decay. For overlapping region, $\log_{10}P_{ov}$ for alpha decay increases steeply as γ increases from 0.9 to 0.95, whereas in proton decay, $\log_{10}P_{ov}$ values do not vary much. Preformation probability for alpha decay is greater than proton decay for the use of γ-RR84, γ-MS67, and γ-BW91. For the use of γ-PD03a, both are equal. For the use of γ-PD03b, $\log_{10}P_{ov}$ is less for alpha decay than for proton decay.

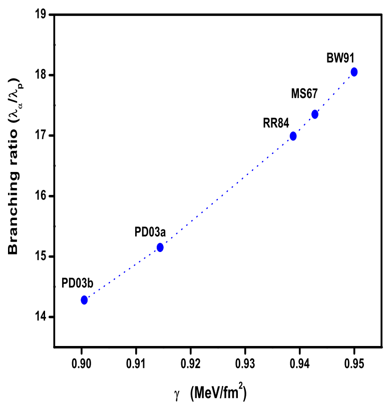

FIG. 2: Branching ratio of alpha emission with respect to proton emission for ^{166}Ir.

For non-overlapping region, P_{nov} value for alpha emission is of the order of 10^{-19} whereas for proton decay, it is of the order of 10^{-21} for the use of all the five γ's. Eventhough ^{166}Ir is a proton emitter as predicted in [4], alpha decay is the preferred mode than proton decay, as indicated by the values of preformation probability in pre-touching region for the use of γ-RR84, γ-MS67, γ-BW91 and penetration probability in the post touching region for all the γ's. Percentage branching of ^{166}Ir is 7.3% and 92.7% respectively for proton decay and alpha decay [3]. This is confirmed by the present results for the use of different γ's.

Though preformation probability plays a vital role in deciding accuracy of half-life, in cluster and alpha decay of heavy nuclei, penetration probability has a dominant role in deciding the preference than preformation probability, in proton and alpha decay. But in the case of ^{166}Ir, alpha decay preference is confirmed by preformation probability values also. Figure 2 presents the branching ratio for alpha decay with respect to proton decay of ^{166}Ir. Branching ratio increases for increase in γ, indicates preference for alpha decay than proton decay for the use of all five γ's. Similar variation of P_{ov} and P_{nov} for the use of five γ's is noted for ^{167}Ir also. The present results confirm one of our previous work [5].

References

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