One-proton emission within deformed Yukawa-plus-exponential model

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I. INTRODUCTION

One-proton radioactivity is a phenomenon in which a proton is emitted from a proton rich nuclei. It was first observed in the isomeric state of the nucleus ^{53m}Co by Jackson *et al* and confirmed by Cerny *et al* in 1970 [1]. It usually occurs in the odd-Z nuclei with mass region ranging from $105 \leq$ A ≤ 185 and atomic number ranging from $51 \leq$ Z ≤ 85. Due to advent in the experimental techniques, proton emitters have been identified in the ground as well in the isomeric state. So far, one-proton radioactivity is studied using various theoretical formalism with and without incorporation of deformation. Present study deals with the analysis of one-proton radioactivity using Yukawa-plus-exponential model, with and without incorporation of deformation.

Krappe *et al* [2] has developed the unified nuclear potential by the generalization of nuclear surface energy by taking a double volume integral of the Yukawa folding function. For the present study, it is considered that both parent nucleus and emitted fragment are spheres whereas the daughter nucleus is assumed to be deformed. The potential for the overlapping region with the incorporation of deformation is taken from Ref. [2] and is given as

$$V_{ov}(r) = -E_v + [V(r_t) + E_v]\{s_1\left[\frac{r-r_i}{r_t-r_i}\right]^2 - s_2\left[\frac{r-r_i}{r_t-r_i}\right]^3\}, r_i \leq r \leq r_t \quad (1)$$

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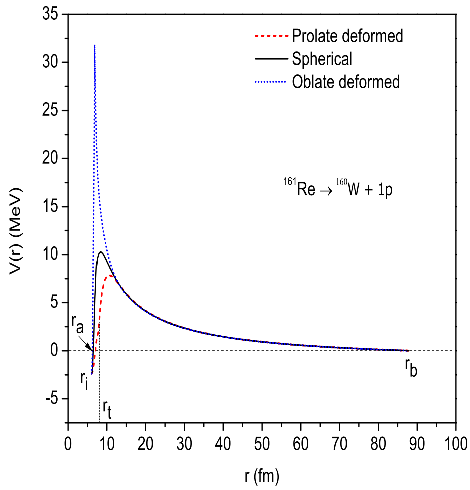

FIG. 1: Comparison of total potential V(r) of $1p$ emitting nucleus ^{161}Re, for spherical (solid line), prolate (dashed line) and oblate (dotted line) configurations.

The potential for the non-overlapping region with the incorporation of deformation in nuclear interaction potential [2] and is given as

$$V_{nov}(r) = V_C(r)+V_n(r)+V_d(r)+V_l(r), \quad r \geq r_t \quad (2)$$

II. RESULTS AND DISCUSSION

Cubic-plus-Coulomb-plus-Yukawa-plus-exponential model (CCYEM) is used to investigate the half-lives of $1p$ emitters of both spherical and deformed configuration. Though there are many experimentally identified $1p$ emitters, for the present study we have considered the $1p$ emitting nucleus ^{161}Re. The nucleus ^{161}Re is having prolate shaped

TABLE I: Calculated logarithmic half-lives of experimentally identified $1p$ emitter ^{161}Re for both spherical and deformed configurations.

Parent Nucleus	l $\hbar$	Q (MeV)	$\log_{10}T_{1/2}^{exp.}$ ($T_{1/2}$ in s)	$\log_{10}T_{1/2}^{sph.}$ ($T_{1/2}$ in s)	$\beta_2^{dau.}$	$\log_{10}T_{1/2}^{def.}$ ($T_{1/2}$ in s)
^{161}Re	0	1.214	-3.432	-3.826	0.128	-4.551
					-0.128	-2.757

daughter nucleus and its angular momentum is found to be zero. Though the nucleus ^{161}Re is having prolate deformed daughter nucleus, we have assumed it to have both negative and zero deformation (i.e., spherical shape), in order to give better explanation of how the area under the potential barrier affects the half-lives of the nucleus, while changing from spherical to deformed configurations.

Total potential for the pre-scission and the post-scission region are calculated for both the cases of spherical and deformed configuration and it is depicted in Fig. 1. Cubic polynomial potential is used for the overlapping region and Coulomb-plus-Yukawa-plus-exponential potential is used for the non-overlapping region. Penetrability is calculated using WKB approximation and the half-lives of the nucleus are listed in Table 1. Probability of penetration in overlapping region is considered as preformation probability and is found to be high for prolate daughter configuration when compared to the oblate daughter configuration. For the positively deformed daughter nucleus, the value of r_t is 7.87 fm, for the spherical case, the value of r_t is found to be 7.36 fm. Whereas for the negatively deformed daughter nucleus, the value of r_t is 6.85 fm. The half-lives of the spherical case is found to be -3.826, whereas for the prolate case, it is found to be -4.551 ($T_{1/2}$ in s). While considering negative deformation, the half-life is found to be -2.757.

While comparing the potential of spherical and deformed configuration, it is found that for the prolate case, the value of r_t is increased, the area under the potential is reduced, and therefore the penetrability increases which in turn reduces the half-life, compared to the spherical case. For the oblate case, the value of r_t is decreased, the area under the potential is increased, and therefore the penetrability decreases which in turn increases the half-life, compared to the spherical case. This shows that $1p$ emission may happen preferably in the prolate deformed configuration when compared with oblate case and a detailed analysis have been done in the study of $2p$ emission of different $2p$ emitters with spherical and deformed configurations [3].

Here, the half-lives calculated for the spherical configuration matches well experimental half-lives, but it is found to have a notable deviation for the deformed cases. Since, no fitting has been attempted to arrive at best matching half-life. A detailed analysis based on all the experimentally available $1p$ emitters will be studied using CCYEM. Better understanding on the effect of deformation in $1p$ emission of experimentally identified nuclei, will lead to prediction of new $1p$ emitters. Detailed analysis of experimentally identified cases will be presented.

References

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