# One and two proton radioactivity of Lanthanum

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## Introduction

The nuclei that have $Q_{p/2p} > 0$ and are above the proton drip line have proton instability as well as exotic decay modes. Understanding proton decay is essential for studying nuclear structure. The binding energy of protons above the drip line drops progressively, implying one-proton and two-proton decay. The most stable superheavies are expected to be located near the β-stability line, which is unreachable by fusion reactions with stable beams. The literature studies shows the competition between different decay modes [1-8]. Within generalized liquid drop model, Cui et al., predicted two proton radioactivity of ground state nuclei [9]. Zhou et al., investigated recent progress in two-proton decay [10]. Many theoretical models and semi-empirical relations have been used to explore proton-decay half-lives [11-12]. Earlier researchers [13-14] investigated different decay modes of superheavy nuclei. Hence, in the present work we examined one and two proton-decay half-lives of lanthanum.

### Theoretical Frame work

The reaction of nuclear one proton decay can be written as ;

$$^{A}_{Z}(X)_N \rightarrow ^{A-1}_{Z-1}(Y)_N + ^{1}_{1}(H) + Q_P \quad (1)$$

Similarly, for two proton-decay, the nuclear reaction can be written as;

$$^{A}_{Z}(X)_N \rightarrow ^{A-2}_{Z-2}(Y)_N + 2^{1}_{1}(H) + Q_{2P} \quad (2)$$

where $Q_{P/2P}$ is the amount of energy released during one and two proton decay. The one and two proton decay half-lives are defined as;

$$T_{1/2} = \frac{\ln 2}{\nu\, PP_0} \quad (3)$$

where symbols with usual notations. The assault frequency term in half-lives is evaluated as follows;

$$\nu = \frac{41}{hA^{1/3}} MeV \quad (4)$$

and penetration probability is evaluated using WKB approximation as follows;

$$P = \exp\left[-\frac{2}{\hbar}\int_{Rin}^{Rout}\sqrt{2\mu(V - Q_{P/2P})}dr\right] \quad (5)$$

where μ is reduced mass, $R_{in}$ and $R_{out}$ are the inner and outer turning points [5]. $V$ is the total interaction potential.

### Results and Discussions:

The one and two proton decay half-lives are investigated in the isotopes of Lanthanum using CPPM with harmonic oscillator frequency. The one and two proton radioactivity is energetically feasible only if Q-value of the reaction is positive. The recent mass excess values [15] were taken to evaluate Q-values.

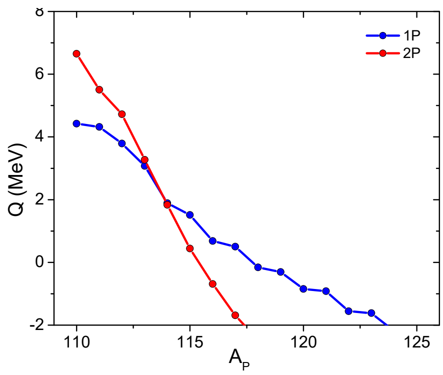


**Fig 1:** A plot of one and two proton-decay energies as function of mass number of parent nuclei for the lanthanum nuclei.

The figure 1 shows a plot of Q-values as a function of mass number of parent nuclei. The Q-values are +ve for $^{110-117}$La and $^{110-115}$La for one and two proton radioactivity respectively. It is also noticed that the Q-values decreases with increase in mass number of parent nuclei.

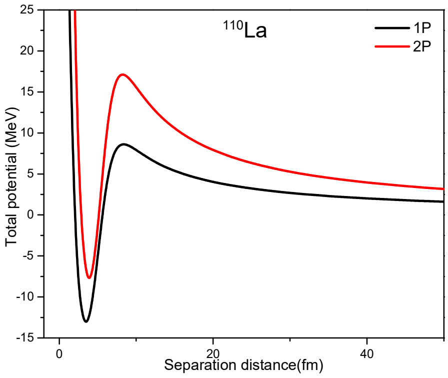


**Fig 2:** A plot of driving potential as a function of separation distance for both one and two proton radioactivity for $^{110}$La nuclei.

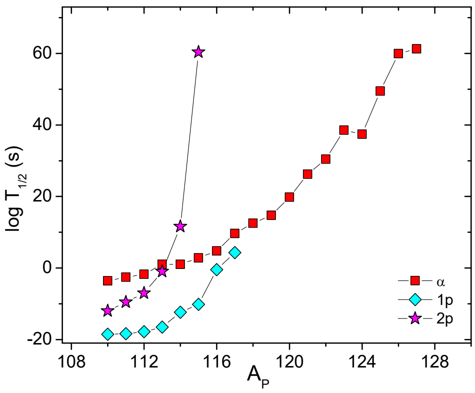


**Fig 3:** A comparison of one, two and alpha decay half-lives as a function of mass number of parent nuclei of Lanthanum.

Figure 2 shows a plot of driving potential as a function of separation distance for $^{110}$La nuclei. The potential well is deep in case of one-proton radioactivity when compared to two-proton radioactivity. The turning points are evaluated using the boundary conditions [5] and the corresponding Q-values are 4.421MeV and 6.625MeV for one and two proton radioactivity respectively.

Further, we have compared one and two proton radioactivity half-lives with that of alpha and beta decay half-lives. However, it is noticed that the Q-values of beta decay are not energetically feasible. Hence, we have compared only with the alpha decay half-lives. From the comparison it is noticed that the one-proton radioactivity is having shorter half-lives when compared to two-proton radioactivity and alpha-decay. Hence, the Lanthanum nuclei with mass number $^{110\text{-}117}$La undergoes one-proton radioactivity only.

**Conclusions:**

We have investigated one and two proton radioactivity for lanthanum nuclei. The one proton radioactivity is feasible in the mass number range $^{110\text{-}117}$La and two-proton radioactivity in case of $^{110\text{-}115}$La nuclei. The one and two proton radioactivity half - lives of lanthanum are compared with the alpha-decay half-lives. The Lanthanum nuclei with mass number $^{110\text{-}117}$La undergoes one-proton radioactivity. Hence, these results may find its importance in the field of new proton emitters.

## References


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