Comparative Study of Double Alpha Emission and ^{8}Be Cluster Decay in Superheavy Nuclei

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Introduction

Double alpha decay (2α) is when certain nuclides have the ability to undergo nuclear decay and release two alpha particles at the same time. There has been a notable increase in scholarly interest in double alpha decay, as evidenced by numerous studies published in recent years [1, 2]. While single alpha decay has already been extensively studied. The dynamics of double alpha decay offer deeper insights into nuclear structure and decay mechanisms, particularly for superheavy elements.

In the present work, we have compared the half-lives of double α-decay and ^{8}Be cluster decay from various super heavy parent nuclei.

In nuclear physics, the decay of superheavy elements (SHEs) presents a rich field for exploring exotic and rare decay modes due to their large atomic numbers and complex nuclear structures. There are numerous studies [3] supporting the existence of an island of stability in the region of Z=118-126, so, we have selected these superheavy elements as the primary focus of our study.

The model

The interacting potential barrier for a parent nucleus exhibiting exotic decay is given by

$$V = Z_1 Z_2 e^2 / r + V_p(z) + \frac{\hbar^2 l(l+1)}{2\mu r^2} \quad \text{for } Z > 0 \qquad (1)$$

Here Z_1 and Z_2 are the atomic numbers of daughter and emitted cluster; 'r' is the distance between fragment centers, l the angular momentum, μ the reduced mass and Vp is the proximity potential.

The barrier penetrably P is given as:

$$P = \exp\{-\frac{2}{\hbar}\int_a^b \sqrt{2\mu(V-Q)}dz\} \qquad (2)$$

The turning points 'a' and 'b' are given by $V(a) = V(b) = Q$, where Q is the energy released. Q values for 2α and Be are 4.849 Mev and 4.941 Mev respectively which is taken from[4].

The half-life time is given by

$$T_{1/2} = \ln 2/\nu P. \qquad (3)$$

Where, ν = 2Ev/h, represent the number of assaults on the barrier per second and E_v, the empirical zero point vibration energy.

Results and Discussions

In the present work we have carried out the comparison of half-life of double alpha and ^{8}Be from superheavy elements Z=118,120,122, and 124.

Table 1 illustrates the variation in half-lives for double alpha decay and ^{8}Be emission across different parent nuclei.

Zp	**Np**	**log $_{10}$ T $_{½}$ (s)**	
		^{8}Be	**2α**
118	158	6.71826	6.54704
	160	7.26181	7.08782
120	162	7.30008	7.12838
	164	10.6067	10.4196
122	166	11.0867	10.9000
	168	10.3159	10.1325
124	170	8.82779	8.65353
	172	9.64065	9.46248

Table 1 Comparison of log $_{10}$ T $_{½}$ of 2α and ^{8}Be from various superheavy parent nuclei.

To estimate the half-life values for 2α and ^{8}Be emission, we used CPPM [5], a powerful tool for the study of heavy cluster radioactivity.

Theoretical $T_{1/2}$ estimations are calculated for the most prospective candidates. And the calculated $T_{1/2}$ values are plotted against the neutron number of parent in figures 1 and 2.

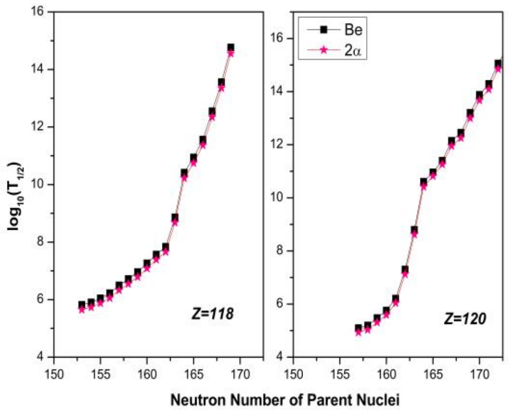

Fig. 1 Plot of log $_{10}$ T $_{1/2}$ versus neutron number of the parent nuclei from Z=118 and 120 for the decay of 2α and ^{8}Be.

From the plot, it is observed that half- lives of 2α and ^{8}Be nuclei emissions from the selected superheavy parent nuclei are less than or equal to 10^{15}s, which indicates that these decays are measurable with the presently available experimental techniques.

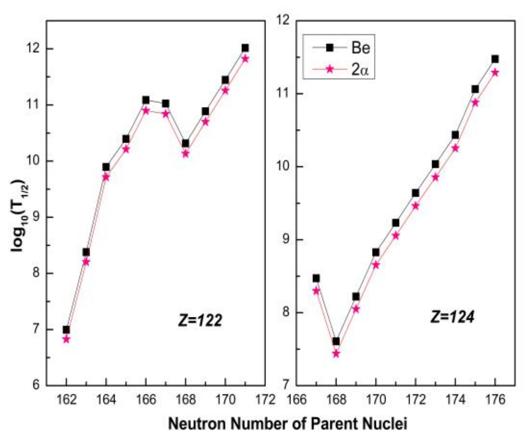

Fig. 2 Plot of log $_{10}$ T $_{1/2}$ versus neutron number of the parent nuclei from Z=122 and 124 for the decay of 2α and Be.

Also, it is clear that the half-lives of the double α-decay are smaller than that for the emission of ^{8}Be cluster. Which reveals that 2*α* emission is more probable than ^{8}Be emission, and ^{8}Be emission does not occur due to its highly unstable nature.

From fig. 2, we can observe the dip in the half-lives at the parent neutron number N~168. That indicates the shell closure of daughter nuclei at N~164 that leads to stability of these nuclei.

Neutron shell closure at N=164 is already predicted in the earlier works [6]. So, our observations confirm the earlier predictions.

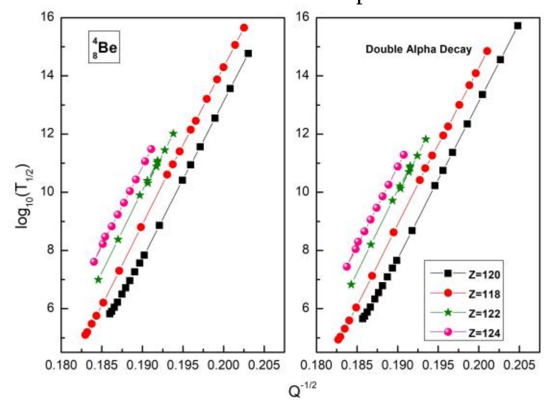

Fig. 3 GN plot of log $_{10}$ T $_{1/2}$ vs. $Q^{-1/2}$ for the emission of 2α and ^{8}Be from various SH isotopes.

From fig. 3, we can see that the addition of proximity potential does not make any notable variation in the linear behavior of the Geiger–Nuttall plots. Hence GN law is also applicable to double alpha decay.

This study provides a comprehensive comparison of double alpha and beryllium emission in superheavy nuclei. Our findings indicate that double alpha decay is the most favored decay mode.

Also, double alpha decay has shed light on the complex processes that govern the stability and decay of superheavy elements in the selected range.

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