Alpha and heavy cluster radioactivity of superheavy nuclei
$100 \leq Z \leq 120$

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Abstract. Using Cubic plus Yukawa plus Exponential (CYE) model, half lives of alpha decay and heavy cluster radioactivity of Superheavy nuclei have been systematically investigated for even-even, even-odd, odd-even and odd-odd nuclei with $100 \leq Z \leq 120$. We have done our calculations by considering the Coulomb, centrifugal and Yukawa plus exponential potentials as an interacting barrier for separated fragments and the cubic potential for the overlapping region. The predicted half life time values by including deformation effects on parent and parent cluster have been compared with the Analytical Super Asymmetric Fission (ASAF) model of D.N.Poenaru et.al. In this work, we have compared the half life time values of alpha and heavy cluster radioactivity of Super heavy nuclei leading to $^{208}$Pb. This study suggests that heavy-cluster radioactivity may be comparable to or even dominant over $\alpha$ decay for some of the isotopes with $Z \geq 118$. Furthermore, branching ratio calculations have been performed to find out the probable cluster emitters. The predictions for cluster emitters are in agreement with CPPM model by Santhosh et. al., and Wentzel-Kramers-Brillouin (WKB) method by A.Soylu et. al. We hope that this study will help in future measurements on $\alpha$-decay and cluster radioactivity half-lives of SHN.

1. Introduction

The study of Superheavy nuclei (SHN) has become a most interesting topic in the field of nuclear physics both experimentally [1-5] as well as theoretically [6 -14]. In the past few years, new Superheavy elements (SHEs) up to $Z = 118$ were synthesized in fusion reactions with the subsequent emission of neutrons and $\gamma$ rays [3]. Two different experimental approaches, cold fusion (with one evaporated neutron) and hot fusion (with three or four evaporated neutrons), were used to synthesis SHN [5].

The formation of Superheavy nuclei may undergo different types of decay modes such as alpha decay, cluster radioactivity, spontaneous fission and ternary fission. In 1986, Becquerel [15] discovered radioactivity of Uranium. Rutherford and Geiger [16] studied nuclear charge and nature of alpha particle. Flerov and Petrakh [17], discovered the spontaneous fission of $^{238}$U. Sandulescu et al. [18] studied the cluster decay of $^{134}$C from SHN. Poenaru et al., [19] studied alpha decay half lives of Superheavy nuclei. Poenaru et al. [20] used the analytical super asymmetric fission model (ASAFM)
to calculated the alpha and cluster radioactive decay half lives of heavy and superheavy nuclei. Poenaru et.al., [21] studied half lives and branching ratios of Z=104-124. Poenaru et.al., [22, 23] studied half lives of alpha decay and cluster radioactivity of SHN and observed that alpha decay is the most prominent decay mode in SHN. Poenaru and Gherghescu [24, 12] studied cluster radioactivity of Superheavy nuclei using ASAF, UNIV and alpha decay ASAF, UNIV, semFIS and AKRA. Poenaru et.al. [25] studied the spontaneous fission half lives of the SHN 286Fl using asymmetry center shell model. Xu et al. [26] investigated the half-lives and branching ratios of alpha decay and spontaneous fission in the heavy and Super heavy nuclei Z ≥ 90. Staszczak et al. [27] studied the competition between different decay modes in superheavy nuclei with 108 ≤ Z ≤ 126. Using a unified fission model and Royer’s analytical formula, Bao et al. [28] evaluated alpha decay half lives of superheavy nuclei and compared with that of the available experimental values. Ni et al. [29] proposed a semiempirical formula for alpha decay and cluster radioactivity. Manjunatha and Sridhar [30] predicted most suitable projectile – target combination in the synthesis of Z=117. Manjunatha et.al., studied the half lives of spontaneous fission, ternary fission and cluster decay of Superheavy nuclei Z=126, 124 [31, 32] and compared with that of alpha decay half lives. Zhang et.al.[33] systematically investigated the probable cluster radioactivity of SHN Z=118, 119 & 120.

The study of the structure, decay modes, and decay half-lives of Super heavy nuclei is of great importance for future studies. Superheavy nuclei may decay through different decay modes such as, alpha decay, cluster radioactivity and spontaneous fission. Alpha decay is one of the dominant decay modes of the Super heavy nuclei and the alpha decay half-life is crucial for the synthesis and study of Super heavy nuclei. A Survey of literature reveals that half lives of different cluster decay modes have been studied using different models such as Analytical Super Asymmetric Fission Model (ASAFM) [22], Unified description (UD) formula [34], the Universal curve for alpha and cluster radioactive decay [35], Universal decay law (UDL) [36], the Horoi formula [37] and Cubic plus Yukawa plus Exponential model (CYEM) [38-48].

In our earlier work, we have compared the alpha decay, cluster decay and Spontaneous fission decay properties of different isotopes of Superheavy nuclei 126307, 318-320, 322-326 using our Cubic plus Yukawa plus Exponential model without considering the deformation effects [49]. Also we have studied the alpha decay properties of 126317-319, 325, 330, 331 using Cubic plus Yukawa plus Exponential model by including both parent and daughter deformations [50]. Alpha decay half lives of various isotopes of Superheavy elements with Z=122 and Z=124 for different Q values have been studied [51, 52]. Alpha and Spontaneous fission decay properties of various isotopes of SHE Z=125 for different Q values have been studied by using CYEM with parent deformation [53]. We have also studied the alpha decay and different cluster radioactive decay such as 8Be, 12C, 16O, 30,32Si, 48Ca, 66,68Ni, 72,74,76Zn, 75,77,79Ga, 80Ge, 81,83As, 84Se, 85Br, 86Kr, 87,89Rb, 90Sr, 89,93,96Y, 94,96Zr, 97,99,103Nb and 98,100,102Mo of 208118, 206120 and 208122 using Cubic plus Yukawa plus Exponential Model (CYEM) by including both parent & daughter deformation (WPD) and parent & cluster deformation (WPC) effects [54]. In this work, we have studied the heavy cluster radioactivity half life time values of Superheavy nuclei for set of some even-even, even-odd and odd-odd emitted clusters. And also studied the competition between alpha decay and cluster radioactivity of Superheavy nuclei leading to 208Pb and the branching ratio calculations have been done. These computed values are used for the prediction of prominent decay modes in SHN and the results are compared with the results of ASAF [12], WKB [55] and CPPM [11].

The overview of the paper is as follows: A detailed description of our CYEM is given in section II. The results and discussions of alpha and cluster decay properties of SHN are presented in section III and the last section summarizes our entire work.
2. CUBIC PLUS YUKAWA PLUS EXPONENTIAL (CYE) MODEL:

In this work, to study the properties of Superheavy elements we have used a realistic model [39] called as CYE model. The zero-point vibration energy is explicitly included without violating the conservation of energy and the inertial mass coefficient dependent on the centre of mass distance.

The half life time of the system is calculated by using the relation,

\[ T = \frac{1.433 \times 10^{-21}}{E_v} [1 + \exp(K)] \]  

(1)

Where

\[ K = \frac{2}{\hbar} \int_{r_a}^{r_f} [2B_r(r) V(r)]^{1/2} dr + \frac{2}{\hbar} \int_{r_f}^{r_b} [2B_r(r) V(r)]^{1/2} dr \]  

(2)

Here, \( r_a \) and \( r_b \) are the two appropriate zeros of the integrand.

POTENTIAL FOR THE POST-SCISSION REGION

In this work, the parent and the daughter nucleus are treated as spheroid. If the daughter nucleus has a deformation, say quadrupole deformation only, while the emitted nucleus is spherical and if the Q value of the reaction is taken as the origin, then the potential for the post-sciission is given by,

\[ V(r) = V_c(r) + V_n(r) - V_{df}(r) - Q \quad \text{if} \quad r \geq r_i \]  

(3)

Here,

- \( V_c(r) \) is the coulomb potential between a spheroidal daughter and spherical emitted fragment as in Ref. [56].
- \( V_n(r) \) is the nuclear interaction energy due to finite range effects Krappe et.al. [57].
- \( V_{df}(r) \) is the change in the nuclear interaction energy due to quadrupole deformation (\( \beta_2 \)) of the daughter nucleus as in Ref. [57].

For a prolate spheroid daughter nucleus with longer axis along the fission direction, Pik-Pichak [56] obtained

\[ V_c(r) = \frac{3}{2} \frac{Z_1 Z_2 e^3}{\gamma r} \left[ \frac{1 + \gamma}{2} \ln \frac{\gamma + 1}{\gamma - 1} + \gamma \right] \]  

(4)

and for an oblate spheroid daughter with shorter axis along the fission direction

\[ V_c(r) = \frac{3}{2} \frac{Z_1 Z_2 e^3}{\gamma r} \left[ \gamma (1 + \gamma^2) \arctan \gamma^{-1} - \gamma^2 \right] \]  

(5)

Here

\[ \gamma = \frac{r}{\sqrt{(a_z^2 - b_z^2)^3}} \]

Here \( a_2 \) and \( b_2 \) are the semi-major and minor axes of the spheroidal daughter nucleus respectively.

If the nuclei have spheroid shape, the radius vector \( R(\theta) \) making an angle \( \theta \) with the axis of symmetry locating sharp surface of a deformed nuclei is given by ref [57].
\[ R(\theta) = R_0 \left[ 1 + \sum_{n=0}^{\infty} \sum_{m=-n}^{n} \beta_{nm} Y_{nm}(\theta) \right] \] (6)

Here \( R_0 \) is the radius of the equivalent spherical nucleus.

The Change in the nuclear interaction energy due to the quadrupole deformation \( \beta_2 \) [41] of the daughter nucleus is given by

\[ V_d = \frac{4R_0^4 \beta_2}{a r_0^2} \left( \frac{5}{4\pi} \right)^{1/2} \]

### POTENTIAL FOR THE PRE-SCISSION REGION

The shape of the potential barrier in the overlapping region which connects the ground state and the contact point is approximated by a third order polynomial in \( r \) suggested by Nix [58] having the form,

\[ V(r) = -E_v + \left[ V(r_i) + E_v \right] \left\{ s_1 \left[ \frac{r}{r_i} \right]^2 - s_2 \left[ \frac{r}{r_i} \right]^3 \right\} ; \quad r_i \leq r \leq r_t \] (7)

Where \( r_i \) is the distance between the centre of mass of two portions of the daughter and the emitted nuclei in the spheroidal parent nucleus.

If we consider spheroid deformation \( \beta_2 \), then

\[ R(\theta) = R_0 \left[ 1 + \beta_2 \left( \frac{5}{4\pi} \right)^{1/2} \left( \frac{5}{8} \cos^2 \theta - \frac{1}{2} \right) \right] \] (8)

and if the Nilsson’s hexadecapole deformation \( \beta_4 \) is also included in the deformation, then eq. (6) becomes

\[ R(\theta) = R_0 \left[ 1 + \beta_2 \left( \frac{5}{4\pi} \right)^{1/2} \left( \frac{5}{8} \cos^2 \theta - \frac{1}{2} \right) + \beta_4 \left( \frac{5}{4\pi} \right)^{2/3} (35 \cos^4 \theta - 30 \cos^2 \theta + 3) \right] \] (9)

For calculating the zero point vibration energy \( E_v \), we choose [59]

\[ E_v = \frac{\hbar}{2} \left( \frac{\omega_i^4}{(C_1 + C_2)} \right) \]

\( C_1 \) and \( C_2 \) are the central radii of the fragments given by [60],

\[ C_i = 1.18 \ A_i^{1/4} - 0.48 \quad (i = 1, 2) \]

and reduced mass,

\[ \mu = \frac{m_1 m_2}{m_1 + m_2} \]
Table 1. Comparison of Cluster radioactivities of even-even emitters from SHN using CYEM with ASAFM

| Parent nuclei | Daughter nuclei | Emitted cluster | $Q_c$ (MeV) | Log $T_c$ (s) |
|---------------|----------------|-----------------|-------------|---------------|
|               |                |                 | CYEM        | ASAFM         |
|               |                |                 | WOD         | WP            | WPC           |
| $^{252}$Fm    | $^{204}$Hg     | $^{48}$Ca       | 145.85      | 24.19         | 21.59         | 20.838        | 23.63         |
| $^{278}$Ds    | $^{208}$Pb     | $^{72}$Ni       | 216.64      | 20.48         | 18.23         | 22.681        | 16.76         |
| $^{282}$Cn    | $^{208}$Pb     | $^{74}$Zn       | 223.06      | 19.20         | 16.66         | 22.105        | 15.21         |
| $^{284}$Cn    | $^{208}$Pb     | $^{76}$Zn       | 245.52      | 13.93         | 12.32         | 5.375         | 9.29          |
| $^{284}$Fl    | $^{208}$Pb     | $^{78}$Ge       | 245.30      | 13.33         | 12.16         | 1.850         | 8.91          |
| $^{286}$Fl    | $^{208}$Pb     | $^{80}$Ge       | 264.41      | 12.80         | 11.69         | -3.084        | 6.71          |
| $^{288}$Fl    | $^{208}$Pb     | $^{80}$Ge       | 264.72      | 12.06         | 10.68         | 10.48         | 42.839        | 6.18          |
| $^{290}$Fl    | $^{208}$Pb     | $^{82}$Ge       | 263.89      | 10.91         | 11.33         | 11.33         | 21.328        | 5.30          |
| $^{294}$Fl    | $^{212}$Pb     | $^{82}$Ge       | 258.17      | 18.06         | 18.20         | 25.584        | 10.81         |
| $^{294}$Lv    | $^{208}$Pb     | $^{84}$Se       | 284.64      | 7.15          | 8.45          | 14.389        | 0.55          |
| $^{294}$Og    | $^{208}$Pb     | $^{86}$Kr       | 303.81      | 6.15          | 5.45          | 20.674        | -2.45         |
| $^{300}$120   | $^{208}$Pb     | $^{92}$Sr       | 321.36      | 4.58          | 4.52          | -6.583        | -5.73         |
| $^{302}$120   | $^{208}$Pb     | $^{94}$Sr       | 320.04      | 5.16          | 4.70          | -21.795       | -5.26         |

Table 2. Comparison of Cluster radioactivities of even-odd emitters from SHN using CYEM with ASAFM

| Parent nuclei | Daughter nuclei | Emitted cluster | $Q_c$ (MeV) | Log $T_c$ (s) |
|---------------|----------------|-----------------|-------------|---------------|
|               |                |                 | CYEM        | ASAFM         |
|               |                |                 | WOD         | WP            | WPC           |
| $^{265}$Rf    | $^{210}$Pb     | $^{55}$Ti       | 165.27      | 26.83         | 22.94         | 18.72         | 26.71         |
| $^{267}$Rf    | $^{208}$Hg     | $^{61}$Cr       | 175.93      | 29.88         | 25.53         | 18.46         | 28.83         |
| $^{269}$Sg    | $^{205}$Hg     | $^{64}$Fe       | 195.84      | 26.67         | 22.54         | 22.42         | 24.94         |
| $^{271}$Sg    | $^{206}$Hg     | $^{65}$Fe       | 195.65      | 26.49         | 22.07         | 23.34         | 24.86         |
| $^{273}$Hs    | $^{207}$Hg     | $^{68}$Ni       | 216.27      | 22.52         | 18.01         | 20.69         | 20.25         |
| $^{275}$Hs    | $^{207}$Hg     | $^{70}$Ni       | 216.20      | 21.97         | 17.73         | 21.54         | 19.97         |
| $^{277}$Hs    | $^{206}$Hg     | $^{71}$Ni       | 216.04      | 21.64         | 18.51         | 21.94         | 19.76         |
| $^{279}$Ds    | $^{208}$Pb     | $^{71}$Ni       | 225.09      | 17.30         | 15.08         | 20.58         | 15.77         |
| $^{281}$Ds    | $^{209}$Pb     | $^{72}$Ni       | 223.55      | 18.86         | 17.06         | 21.67         | 17.05         |
| $^{281}$Cn    | $^{207}$Pb     | $^{74}$Zn       | 245.18      | 14.71         | 13.61         | 6.58          | 12.15         |
| $^{283}$Cn    | $^{207}$Pb     | $^{76}$Zn       | 244.79      | 14.38         | 13.10         | 3.54          | 12.00         |
| $^{285}$Cn    | $^{208}$Pb     | $^{77}$Zn       | 244.08      | 14.67         | 12.87         | 7.83          | 12.26         |
| $^{287}$Fl    | $^{207}$Pb     | $^{80}$Ge       | 264.49      | 11.37         | 10.40         | 1.34          | 8.04          |
| $^{289}$Fl    | $^{208}$Pb     | $^{81}$Ge       | 263.78      | 11.56         | 11.88         | 4.47          | 8.22          |
| $^{291}$Lv    | $^{207}$Pb     | $^{84}$Se       | 284.42      | 7.90          | 6.52          | 12.99         | 3.58          |
| $^{293}$Lv    | $^{208}$Pb     | $^{85}$Se       | 283.13      | 8.90          | 8.82          | -0.21         | 4.34          |
| $^{295}$Og    | $^{209}$Pb     | $^{87}$Kr       | 303.06      | 6.58          | 7.35          | 14.89         | 0.50          |
| $^{299}$120   | $^{208}$Pb     | $^{91}$Sr       | 321.48      | 5.11          | 5.57          | 24.64         | -2.70         |
| $^{301}$120   | $^{208}$Pb     | $^{93}$Sr       | 320.58      | 5.03          | 5.06          | -22.12        | -3.86         |
Table 3. Comparison of Cluster radioactivities of odd-even & odd-odd emitters from SHN using CYEM with ASAM

| Parent nuclei | Daughter nuclei | Emitted cluster | $Q_c$ (MeV) | Log $T_c$ (s) | CYEM | ASAFM |
|---------------|----------------|-----------------|-------------|--------------|------|-------|
| $^{253}$Es    | $^{207}$Tl     | $^{40}$Ar       | 129.54      | 24.71        | 22.05| 16.78| 25.87|
| $^{277}$Hs    | $^{206}$Th     | $^{71}$Ar       | 216.04      | -47.95       | -45.72| -28.59| 19.76|
| $^{277}$Hg    | $^{206}$Hg     | $^{71}$Ni       | 225.98      | 7.12         | 4.97 | 13.00| 15.24|
| $^{287}$Nh    | $^{208}$Pb     | $^{77}$Ga       | 254.02      | 12.98        | 12.47| 5.96 | 8.97 |
| $^{297}$119   | $^{208}$Pb     | $^{81}$Rb       | 311.65      | 6.81         | 7.77 | 5.47 | -1.71|
| $^{299}$119   | $^{208}$Pb     | $^{81}$Rb       | 310.63      | 6.99         | 7.30 | -4.93| -1.52|
| $^{278}$Bh    | $^{205}$Au     | $^{77}$Ni       | 211.19      | 23.76        | 21.56| 24.80| 22.73|
| $^{282}$Mt    | $^{211}$Pb     | $^{71}$Co       | 208.28      | 27.30        | 24.83| 24.35| 25.44|
| $^{286}$Rg    | $^{208}$Pb     | $^{75}$Cu       | 230.34      | 20.75        | 18.85| 20.95| 18.88|
| $^{290}$Nh    | $^{209}$Pb     | $^{81}$Ga       | 251.27      | 15.88        | 15.12| 22.35| 13.45|
| $^{300}$119   | $^{208}$Pb     | $^{92}$Rb       | 309.74      | 7.70         | 7.61 | -21.94| 1.56 |

Figures 1-3: Comparison of the calculated CR half lives of even-even, even-odd and odd-even & odd-odd clusters from SHN by with & without deformation with ASAFM.
3. Results and discussions:

In this work, we have calculated the heavy cluster radioactivity half lives of some of the isotopes of heavy mass nuclei using Cubic plus Yukawa plus Exponential Model (CYEM) without including deformation (WOD), with including parent deformation (WP) only and parent, cluster deformation(WPC) effects for the case of even-even, even-odd, odd-even and odd-odd. The comparison of heavy cluster radioactivity half lives using CYEM and the other theoretical values are given in Table 1-3. In this table, the first & second columns indicate the parent nuclei and the emitted clusters. The third column denotes the energy released during the emission of heavy cluster radioactivity. The Q values for the decay were taken from ref. [11] in which they were calculated using WS4 mass table [61]. The next four columns give the calculated cluster radioactivity half lives of SHN using ASAFM and CYE model. The half lives of all the heavy cluster emissions shown in Tables 1-3 are less than $10^{30}$s. So These clusters may be detected through the experiments.

Next, we have compared the competition between alpha decay and cluster radioactive decay half lives of some of the isotopes of Superheavy nuclei leading to $^{208}$Pb using our CYE model for e-e, e-o, o-e & o-o in Tables 4-7. The predicted values are compared with the other values of ASAF model of Poenaru et.al, CPPM of Santhosh et. al, and WKB method of Soylu et.al. To gain a better insight into the competition between alpha decay and cluster radioactive decay, we calculated the branching ratio $b_c$ of cluster decay relative to the corresponding alpha decay as

$$
\text{Log}_{10}(b_c) = \text{Log}_{10}(\lambda_c/\lambda_a) = \text{Log}_{10}(T_a/T_c)
$$

where $\lambda_c$ and $\lambda_a$ are the decay constants for cluster and alpha emission, $T_c$ and $T_a$ are the half-lives for cluster and alpha emission respectively. Ratio values ($\text{log}_{10} b$) have been calculated as

$$
\text{log}_{10}[T_a(s)]-\text{log}_{10}[T_c(s)].
$$

We have plotted logarithmic half lives for the emission of heavy clusters from a set of isotopes of Superheavy nuclei using the CYE model as a function of the energy released during the emission. Figures 1-3 shows the comparison of cluster radioactivity of Superheavy nuclei for the case of even-even, even-odd, odd-even and odd-odd using the CYE model with the other theoretical values of ASAF. From this figure, it is seen that these values are in agreement with each other. Figures 4-7 shows the decimal logarithm of $b_c$ for the most probable emitted clusters versus the neutron number N of parent nuclei by using the WKB, CYEM, CPPM and UDL. From this figure we observed that $\text{Log}_{10} b_c < 0$, which means that the alpha decay half lives are much shorter than the cluster radioactivity half lives which shows that the alpha decay is the dominant decay mode.
### Table 4. Comparison of alpha and CR decay half lives for even-even clusters from SHN using CYEM with the other theoretical model values.

| Parent  | Q_α (MeV) | Cluster | Q_α (MeV) | Log T_α (s) CYEM | Log T_α (s) WKB | Log T_α (s) CPPM |
|---------|-----------|---------|-----------|------------------|-----------------|-----------------|
| Q_α     |           |         |           | CYEM             | WKB             | CPPM            |
|         |           |         |           |                  |                 |                 |
| 235Fm   | 6.452     | 50Ar    | 125.322   | 8.98            | 7.875           | 6.338           |
| 236Fm   | 5.746     | 52Ar    | 117.703   | 12.85           | 11.644          | 9.853           |
| 238Ra   | 8.427     | 54Ti    | 169.713   | 2.41            | 1.526           | 0.494           |
| 236Rf   | 8.427     | 54Ti    | 169.713   | 2.41            | 1.526           | 0.494           |
| 238Sg   | 8.562     | 58Cr    | 187.005   | 2.70            | 1.801           | 0.782           |
| 236Sg   | 8.089     | 60Cr    | 184.492   | 4.40            | 3.433           | 2.294           |
| 239Hs   | 9.131     | 62Fe    | 205.344   | 1.53            | 0.672           | -0.232          |
| 237Hs   | 9.578     | 64Fe    | 204.680   | 0.10            | -0.695          | -1.504          |
| 237Hs   | 9.517     | 66Fe    | 204.000   | 0.25            | -0.551          | -1.375          |
| 238Ds   | 10.892    | 66Ni    | 225.766   | -2.81           | -3.470          | -4.031          |
| 238Ds   | 10.868    | 68Ni    | 226.562   | -2.78           | -3.445          | -4.012          |
| 238Ds   | 10.226    | 70Ni    | 225.893   | -1.12           | -1.864          | -2.554          |
| 239Ds   | 9.410     | 72Ni    | 224.634   | 1.26            | 0.406           | -0.457          |
| 238Ds   | 8.511     | 74Ni    | 222.909   | 4.28            | 3.309           | 2.231           |
| 238Ds   | 7.862     | 76Ni    | 220.495   | 6.77            | 5.718           | 4.466           |
| 238Ds   | 7.745     | 78Ni    | 218.010   | 7.25            | 6.159           | 4.873           |
| 238Cn   | 10.089    | 74Zn    | 244.875   | -0.11           | -0.910          | -1.636          |
| 238Cn   | 9.514     | 76Zn    | 244.548   | 1.61            | 0.768           | -0.088          |
| 239Cn   | 9.010     | 78Zn    | 243.250   | 3.26            | 2.326           | 1.351           |
| 239Cn   | 9.081     | 80Zn    | 241.562   | 2.99            | 2.061           | 1.102           |
| 239Cn   | 8.950     | 82Zn    | 237.248   | 3.75            | 2.796           | 1.780           |
| 238Fl   | 9.936     | 76Ge    | 263.339   | 1.08            | 0.221           | -0.557          |
| 238Fl   | 9.614     | 78Ge    | 263.655   | 2.03            | 1.139           | 0.288           |
| 239Fl   | 9.491     | 80Ge    | 262.971   | 2.39            | 1.483           | 0.603           |
| 239Fl   | 8.924     | 82Ge    | 259.488   | 4.27            | 3.292           | 2.274           |
| 239Fl   | 8.685     | 84Ge    | 255.184   | 5.10            | 4.093           | 3.013           |
| 239Fl   | 9.533     | 86Ge    | 249.904   | 5.64            | 4.609           | 3.488           |
| 240Lv   | 11.052    | 82Se    | 282.590   | -1.38           | -2.128          | -2.688          |
| 240Lv   | 11.096    | 84Se    | 283.645   | -1.53           | -2.268          | -2.821          |
| 240Lv   | 10.635    | 86Se    | 281.394   | -0.33           | -1.129          | -1.776          |
| 240Lv   | 10.865    | 88Se    | 278.668   | -0.99           | -1.755          | -2.357          |
| 240Lv   | 10.743    | 90Se    | 274.664   | -0.70           | -1.474          | -2.101          |
| 240Og   | 12.167    | 86Kr    | 302.857   | -3.48           | -4.125          | -4.484          |
| 240Og   | 11.722    | 88Kr    | 301.778   | -2.47           | -3.168          | -3.611          |
| 240Og   | 12.153    | 90Kr    | 300.304   | -3.52           | -4.157          | -4.523          |
| 240Og   | 11.928    | 92Kr    | 297.665   | -3.03           | -3.696          | -4.104          |
| 240Og   | 12.014    | 94Kr    | 241.426   | -3.27           | -3.917          | -4.310          |
| 240Og   | 13.096    | 96Kr    | 292.723   | -5.65           | -6.162          | -6.365          |
| 240Og   | 12.455    | 98Kr    | 289.570   | -4.33           | -4.919          | -5.236          |
| 240Og   | 11.180    | 100Kr   | 285.311   | -1.32           | -2.068          | -2.622          |
| 240Og   | 13.312    | 88Sr    | 321.274   | -5.34           | -5.875          | -6.035          |
| 240Og   | 12.977    | 90Sr    | 321.277   | -4.68           | -5.258          | -5.479          |
| 240Og   | 13.290    | 92Sr    | 320.816   | -5.36           | -5.896          | -6.063          |
| 240Og   | 12.862    | 94Sr    | 319.646   | -4.51           | -5.092          | -5.336          |
| 240Og   | 12.736    | 96Sr    | 317.102   | -4.27           | -4.868          | -5.137          |
Table 5. Comparison of alpha and CR decay half lives for even-odd from SHN using CYEM with the other theoretical model values.

| Parent | Q_α (MeV) | Cluster | Q_c (MeV) | Log T_α (s) CYEM | Log T_α (s) WKB | Log T_α (s) CPPM | Log T_c (s) CYEM | Log T_c (s) WKB | Log T_c (s) CPPM |
|--------|------------|---------|-----------|----------------|----------------|----------------|----------------|----------------|----------------|
| ^{264}\text{Rf} | 8.691 | ^{53}\text{Ti} | 169.729 | 1.52 | 0.894 | -0.298 | 21.43 | 14.159 | 22.502 |
| ^{267}\text{Sg} | 8.269 | ^{59}\text{Cr} | 185.130 | 3.74 | 3.020 | 1.706 | 24.45 | 15.165 | 23.200 |
| ^{270}\text{Ds} | 6.834 | ^{71}\text{Ni} | 224.814 | -0.02 | -0.590 | -1.583 | 17.67 | 7.838 | 16.019 |
| ^{271}\text{Ds} | 8.956 | ^{75}\text{Ni} | 223.404 | 2.73 | 2.035 | 0.246 | 19.01 | 9.099 | 16.579 |
| ^{273}\text{Ds} | 8.142 | ^{75}\text{Ni} | 221.424 | 5.66 | 4.865 | 3.468 | 21.30 | 10.940 | 17.642 |
| ^{275}\text{Cn} | 9.203 | ^{77}\text{Zn} | 243.548 | 2.63 | 1.939 | 0.789 | 15.45 | 5.183 | 12.526 |
| ^{277}\text{Cn} | 9.036 | ^{79}\text{Zn} | 242.147 | 3.16 | 2.447 | 1.255 | 16.71 | 6.342 | 13.055 |
| ^{279}\text{Cn} | 9.021 | ^{81}\text{Zn} | 239.146 | 3.17 | 2.463 | 1.267 | 20.42 | 9.046 | 14.969 |
| ^{281}\text{Fl} | 9.241 | ^{83}\text{Gr} | 261.074 | 3.20 | 2.479 | 1.317 | 14.61 | 3.536 | 9.499 |
| ^{283}\text{Fl} | 8.579 | ^{85}\text{Gr} | 252.092 | 5.48 | 4.679 | 3.349 | 26.25 | 11.611 | 15.911 |
| ^{285}\text{Lv} | 10.763 | ^{87}\text{Se} | 282.194 | -0.67 | -1.225 | -2.066 | 10.32 | -0.934 | 4.216 |
| ^{287}\text{Lv} | 10.744 | ^{87}\text{Se} | 279.642 | -0.65 | -1.207 | -2.054 | 13.05 | 1.066 | 5.750 |
| ^{289}\text{Lv} | 10.207 | ^{89}\text{Se} | 276.303 | -0.85 | -1.401 | -2.237 | 16.98 | 3.822 | 7.996 |
| ^{291}\text{Og} | 11.872 | ^{89}\text{Kr} | 302.099 | -2.22 | -3.270 | -3.906 | 7.99 | -4.194 | -0.563 |
| ^{293}\text{Og} | 12.074 | ^{91}\text{Kr} | 300.635 | -3.32 | -3.749 | -4.349 | 8.87 | -3.218 | -0.047 |
| ^{295}\text{Og} | 12.017 | ^{91}\text{Kr} | 298.540 | -3.22 | -3.655 | -4.268 | 10.81 | -1.692 | 1.125 |
| ^{297}\text{Og} | 13.113 | ^{95}\text{Kr} | 321.105 | -4.95 | -5.287 | -5.705 | 7.18 | -6.642 | -5.028 |
| ^{301}\text{Og} | 13.036 | ^{97}\text{Sr} | 319.729 | -4.86 | -5.199 | -5.634 | 6.33 | -6.060 | -5.833 |
| ^{303}\text{Og} | 12.783 | ^{97}\text{Sr} | 312.098 | -4.35 | -4.726 | -5.207 | 7.55 | -4.994 | -5.056 |
| ^{305}\text{Og} | 11.001 | ^{101}\text{Sr} | 305.805 | -0.22 | -0.809 | -1.634 | 21.18 | 4.286 | 3.266 |
Table 6. Comparison of alpha and CR decay half lives for odd-even from SHN using CYEM with the other theoretical model values.

| Parent | $Q_α$ (MeV) | Cluster | $Q_α$ (MeV) | Log $T_α$ (s) CYEM | Log $T_α$ (s) WKB | Log $T_α$ (s) CPPM | Log $T_c$ (s) CYEM | Log $T_c$ (s) WKB | Log $T_c$ (s) CPPM |
|--------|-------------|---------|-------------|--------------------|------------------|------------------|--------------------|------------------|------------------|
| $^{288}$Rg | 9.300 | $^{60}$Cu | $^{233}$677 | 1.97 | 1.540 | 0.187 | 17.33 | 7.225 | 14.754 |
| $^{288}$Rg | 8.660 | $^{60}$Cu | $^{232}$94 | 4.12 | 3.608 | 2.101 | 18.59 | 8.420 | 15.284 |
| $^{288}$Rg | 8.415 | $^{60}$Cu | $^{230}$240 | 4.99 | 4.446 | 2.876 | 20.91 | 10.284 | 16.403 |
| $^{288}$Rg | 8.405 | $^{60}$Cu | $^{226}$923 | 4.99 | 4.450 | 2.876 | 25.28 | 13.454 | 18.638 |
| $^{288}$Nh | 9.460 | $^{60}$Ga | $^{253}$288 | 2.17 | 1.728 | 0.394 | 14.53 | 3.880 | 10.932 |
| $^{288}$Nh | 9.317 | $^{60}$Ga | $^{252}$620 | 2.60 | 2.141 | 0.773 | 14.91 | 4.510 | 10.985 |
| $^{290}$Nh | 9.132 | $^{62}$Ga | $^{250}$069 | 3.18 | 2.702 | 1.289 | 17.57 | 6.514 | 12.323 |
| $^{290}$Mc | 10.363 | $^{60}$As | $^{271}$927 | 0.17 | -0.195 | -1.344 | 14.01 | 1.622 | 8.150 |
| $^{292}$Mc | 9.902 | $^{64}$As | $^{271}$325 | 1.45 | 1.038 | -0.214 | 12.89 | 1.778 | 7.204 |
| $^{292}$Mc | 9.668 | $^{64}$As | $^{268}$083 | 2.15 | 1.702 | 0.896 | 16.73 | 4.479 | 9.325 |
| $^{290}$Mc | 9.579 | $^{68}$As | $^{263}$985 | 2.40 | 1.942 | 0.614 | 21.96 | 8.064 | 12.202 |
| $^{290}$Ts | 11.346 | $^{66}$Br | $^{291}$744 | -1.85 | -2.122 | -3.088 | 9.69 | -2.004 | 2.288 |
| $^{290}$Ts | 11.473 | $^{68}$Br | $^{289}$937 | -2.20 | -2.455 | -3.97 | 11.25 | -0.694 | 3.138 |
| $^{292}$Ts | 11.490 | $^{68}$Br | $^{287}$164 | -2.28 | -2.526 | -3.467 | 14.33 | 1.483 | 4.903 |
| $^{300}$Ts | 11.521 | $^{62}$Br | $^{283}$855 | -2.39 | -2.630 | -3.566 | 18.18 | 4.198 | 7.149 |
| $^{299}$119 | 12.684 | $^{92}$Rb | $^{310}$410 | -4.38 | -4.511 | -5.239 | 8.00 | -4.465 | -2.513 |
| $^{300}$119 | 12.543 | $^{92}$Rb | $^{308}$963 | -4.10 | -4.253 | -5.007 | 8.88 | -3.522 | -1.995 |
| $^{302}$119 | 12.398 | $^{92}$Rb | $^{306}$661 | -3.81 | -3.981 | -4.763 | 11.01 | -1.844 | -0.559 |
| $^{304}$119 | 12.902 | $^{92}$Rb | $^{304}$176 | -4.94 | -5.039 | -5.733 | 13.81 | 0.029 | 1.044 |
| $^{306}$119 | 13.173 | $^{92}$Rb | $^{302}$910 | -5.53 | -5.595 | -6.243 | 14.75 | 0.874 | 1.459 |
| $^{308}$119 | 12.032 | $^{102}$Rb | $^{300}$89 | -3.08 | -3.283 | -4.135 | 17.97 | 3.023 | 3.301 |
| $^{310}$119 | 10.855 | $^{102}$Rb | $^{296}$174 | -0.13 | -0.494 | -1.567 | 23.10 | 6.409 | 6.328 |
Table 7. Comparison of alpha and CR decay half lives for odd-odd from SHN using CYEM with the other theoretical model values.

| Parent | $Q_\alpha$ (MeV) | Cluster | $Q_\gamma$ (MeV) | Log $T_\alpha$ (s) | Log $T_\gamma$ (s) |
|--------|------------------|---------|-----------------|-------------------|-------------------|
|        |                  |         |                 | CYEM | WKB | CPPM | CYEM | WKB | CPPM |
| $^{271}$Mt | 9.785 | $^{65}$Co | 214.549 | -0.11 | -0.682 | -1.673 | 21.69 | 1.931 | 19.646 |
| $^{272}$Mt | 10.190 | $^{65}$Co | 214.761 | -1.30 | -1.814 | -2.726 | 20.70 | 9.844 | 18.940 |
| $^{273}$Mt | 9.109 | $^{71}$Co | 221.969 | 1.85 | 1.195 | 0.050 | 22.79 | 12.467 | 19.560 |
| $^{281}$Mt | 8.230 | $^{77}$Co | 209.782 | 4.93 | 4.156 | 2.795 | 25.47 | 14.631 | 20.853 |
| $^{283}$Mt | 7.526 | $^{75}$Co | 206.545 | 7.78 | 6.911 | 5.853 | 29.80 | 17.961 | 23.099 |
| $^{285}$Rg | 9.730 | $^{77}$Cu | 234.400 | 0.64 | 0.035 | -0.988 | 16.69 | 6.370 | 14.474 |
| $^{289}$Rg | 8.998 | $^{77}$Cu | 233.416 | 2.95 | 2.251 | 1.062 | 17.33 | 7.181 | 14.661 |
| $^{291}$Rg | 2.431 | $^{77}$Cu | 231.826 | 4.95 | 4.170 | 2.839 | 19.23 | 8.772 | 15.543 |
| $^{293}$Rg | 8.415 | $^{79}$Cu | 229.607 | 4.97 | 4.196 | 2.859 | 21.57 | 10.611 | 16.647 |
| $^{281}$Nh | 10.372 | $^{75}$Ga | 253.410 | -0.51 | -1.067 | -1.967 | 15.76 | 3.751 | 11.839 |
| $^{283}$Nh | 9.778 | $^{77}$Ga | 253.692 | 1.19 | 0.556 | -0.471 | 14.41 | 3.359 | 10.936 |
| $^{287}$Nh | 9.315 | $^{79}$Ga | 253.215 | 2.62 | 1.929 | 0.796 | 14.18 | 3.635 | 10.652 |
| $^{291}$Nh | 9.292 | $^{81}$Ga | 252.029 | 2.66 | 1.970 | 0.829 | 15.07 | 4.552 | 10.981 |
| $^{293}$Nh | 8.220 | $^{83}$Ga | 248.075 | 4.04 | 3.290 | 2.050 | 20.13 | 8.073 | 13.702 |
| $^{287}$Mc | 10.467 | $^{79}$As | 271.643 | -0.11 | -0.693 | -1.586 | 14.95 | 1.720 | 8.744 |
| $^{291}$Mc | 10.263 | $^{81}$As | 272.794 | 0.43 | -0.172 | -1.109 | 12.30 | 0.547 | 7.045 |
| $^{293}$Mc | 10.162 | $^{83}$As | 272.931 | 0.69 | 0.077 | -0.884 | 11.05 | 0.237 | 6.159 |
| $^{297}$Mc | 9.684 | $^{85}$As | 270.046 | 2.11 | 1.436 | 0.368 | 14.25 | 2.579 | 7.964 |
| $^{299}$Mc | 9.695 | $^{87}$As | 266.570 | 2.04 | 1.370 | 0.304 | 18.56 | 5.528 | 10.299 |
| $^{293}$Mc | 9.564 | $^{89}$As | 261.857 | 2.43 | 1.738 | 0.640 | 24.70 | 9.748 | 13.719 |
| $^{297}$Ts | 11.591 | $^{85}$Br | 292.841 | -2.44 | -2.916 | -3.600 | 8.64 | -3.046 | 1.689 |
| $^{301}$Ts | 11.266 | $^{87}$Br | 291.182 | -1.67 | -2.180 | -2.927 | 9.94 | -1.876 | 2.387 |
| $^{297}$Ts | 11.589 | $^{89}$Br | 289.153 | -2.51 | -2.974 | -3.662 | 11.88 | -0.367 | 3.461 |
| $^{301}$Ts | 11.430 | $^{91}$Br | 285.884 | -2.15 | -2.635 | -3.354 | 15.73 | 2.265 | 5.689 |
| $^{305}$Ts | 11.584 | $^{93}$Br | 282.208 | -2.56 | -3.025 | -3.717 | 20.12 | 5.263 | 8.187 |
| $^{291}$Rb | 12.394 | $^{89}$Rb | 311.079 | -3.72 | -4.129 | -4.673 | 7.67 | -5.122 | -2.702 |
| $^{295}$Rb | 12.735 | $^{91}$Rb | 310.194 | -4.50 | -4.863 | -5.349 | 7.66 | -4.649 | -2.809 |
| $^{301}$Rb | 12.398 | $^{93}$Rb | 308.297 | -3.80 | -4.200 | -4.747 | 9.26 | -3.328 | -1.786 |
| $^{305}$Rb | 12.389 | $^{95}$Rb | 305.374 | -3.81 | -4.212 | -4.762 | 12.49 | -1.109 | 0.289 |
| $^{309}$Rb | 13.398 | $^{97}$Rb | 303.888 | -5.97 | -6.237 | -6.611 | 13.73 | -0.083 | 0.909 |
| $^{301}$Rb | 12.753 | $^{99}$Rb | 302.050 | -4.68 | -5.023 | -5.510 | 15.59 | 1.266 | 1.897 |
| $^{305}$Rb | 11.342 | $^{101}$Rb | 298.500 | -1.40 | -1.931 | -2.681 | 12.07 | 4.179 | 4.526 |
Table 8. Comparison of branching ratios of the probable cluster emitters from SHN using CYEM with the other theoretical model values.

| Parent | Cluster | WKB   | CPPM  | CYEM  |
|--------|---------|-------|-------|-------|
| 288Fl  | 80Ge    | -0.143| -8.057| -10.19|
| 290Fl  | 82Ge    | -0.224| -7.602| -9.86 |
| 291Mc  | 83As    | -0.160| -7.043| -10.36|
| 293Ts  | 85Br    | 0.130 | -5.289| -11.08|
| 294Ts  | 86Br    | -0.118| -5.376| -11.54|
| 295Ts  | 87Br    | -0.304| -5.314| -11.61|
| 292Lv  | 84Se    | 0.017 | -6.109| -10.24|
| 293Lv  | 85Se    | -0.291| -6.283| -10.99|
| 294Lv  | 86Se    | -0.556| -6.321| -11.3 |
| 294Og  | 86Kr    | 0.795 | -3.649| -11.03|
| 295Og  | 87Kr    | 0.924 | -3.344| -10.81|
| 296Og  | 88Kr    | 1.102 | -2.883| -10.29|
| 297Og  | 89Kr    | -0.531| -4.302| -12.19|
| 297119 | 89Rb    | 0.993 | -1.971| -11.39|
| 298119 | 90Rb    | -0.046| -2.726| -12.38|
| 299119 | 91Rb    | -0.214| -2.540| -12.16|
| 300119 | 92Rb    | -0.731| -3.012| -12.98|
| 30119  | 93Rb    | -0.872| -2.961| -13.06|
| 300120 | 88Sr    | 0.995 | -1.380| -13.03|
| 297120 | 89Sr    | 1.355 | -0.677| -12.13|
| 298120 | 90Sr    | 1.874 | 0.338 | -10.80|
| 300120 | 92Sr    | 1.132 | 0.506 | -10.73|
| 301120 | 93Sr    | 0.861 | 0.199 | -11.19|
| 302120 | 94Sr    | 1.258 | 1.077 | -10.21|
| 303120 | 95Sr    | 0.268 | -0.151| -11.90|
| 304120 | 96Sr    | -0.341| -0.694| -12.74|
| 310120 | 103Sr   | -1.206| -1.003| -14.48|
4. Conclusion

In this work, we have calculated the heavy cluster radioactivity half lives of some of the set of isotopes of Superheavy nuclei using Cubic plus Yukawa plus Exponential Model in two sphere approximations and also including parent deformation and parent cluster deformations. The computed values are compared with the ASAF model of Poenaru et.al. Then we have studied the comparison between alpha decay and cluster radioactivity half lives of Superheavy nuclei leading to $^{208}$Pb using our CYE model. These values are compared with the other theoretical values. To investigate the dominant decay modes of the Super heavy nuclei, we have calculated the branching ratio values also. From the results it is found that alpha decay half lives are smaller than that of cluster radioactivity and it is confirmed that alpha decay is the most dominant decay mode for SHN. Finally, the parent nuclei emit probable clusters when the daughter nuclei are close to doubly magic $^{208}$Pb. As all the predicted half-lives are below $10^{30}$s and are within the experimentally measurable range, we hope that our present predictions would be helpful for future studies in this field.

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