# Alpha decay of Z = 130 element

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## Introduction

The probability of a shallow formation around the nucleus $^{342}126$ stretched towards the larger N may contain relatively long half-lived nuclei of the 128, 130 as well as 127$^{th}$ elements necessarily close to the optimal ratio N/Z. Further, the increasing survival probabilities of SHE from Z = 114 to 118 seem to indicate enhanced shell effects and hence the half-lives. Though the theoretical model identifies island stability of super-heavy elements [1, 2], their half-life extent from minutes up-to years. Generally, the super-heavy nuclei are formed through hot and cold fusion reaction process experimentally. Some of them have been synthesized by cold fusion reaction with Z = 107-112 at GSI, Darmstadt, and RIKEN, Japan [3, 4] and the hot fusion reaction with Z = 113-118 at JINR, Dubna [5, 6]. To find the possible shell or sub-shell closure in the super-heavy region, the study of decay modes have importance to confirm about the shell stability. In this work, we analyze the favorable decay modes for clear representation of nuclei such as alpha decay by using different formulae like Viola-Seaberg, the analytical formula of Royer, Universal curve formula, Universal decay law and compared with the corresponding fission process. The spontaneous fission of super-heavy nuclei with Z =130 within the mass region 310 ≤ A ≤ 330 is studied.

## Theoretical Formalism

The relativistic Lagrangian density for a nucleon-meson system is [7, 8, 9]

$$L = \bar{\psi}(i\partial - M)\psi + \frac{1}{2}\partial_\mu\sigma\partial^\mu\sigma - U(\sigma) - \frac{1}{4}\Omega_{\mu\nu}\Omega^{\mu\nu} + \frac{1}{2}m_\omega^2\omega_\mu\omega^\mu - \frac{1}{4}R_{\mu\nu}R^{\mu\nu} + \frac{1}{2}m_\rho^2\rho_\mu\rho^\mu - \frac{1}{4}F_{\mu\nu}F^{\mu\nu} - g_\sigma\bar{\psi}\sigma\psi - g_\omega\bar{\psi}\omega\psi - g_\rho\bar{\psi}\rho\tau\psi - e\bar{\psi}A\psi$$

Here all the above term have their usual meaning. The Q-value can be calculated from the binding energies of parent nuclei, daughter nuclei and emitted cluster nuclei i.e.

$$Q = M(A,Z) - M(A_1,Z_1) - M(A_2,Z_2)$$

Where $M(A,Z), M(A_1,Z_1), M(A_2,Z_2)$ are the atomic masses of parent, daughter and emitted cluster respectively [10].

The expression for the ∝-decay half life from Viola-Seaborg is given by,

$$log_{10}T_\alpha = \frac{aZ - b}{\sqrt{Q_\alpha}} - (cZ + d) + h_{log}$$

$$h_{log} = 0 \text{ for Z even and N even}$$

$$h_{log} = 1.066 \text{ for Z even and N odd}$$

The analytical formula for the logarithmic alpha decay half-lives have been given by G. Royer,

$$log_{10}T_{1/2}(s) = a_1 + b_1A^{1/6}\sqrt{Z} + \frac{c_1Z}{\sqrt{Q_\alpha}}$$

Where $a_1$ =–25.68, $b_1$ =–1.1423 and $c_1$ =1.5920 are the experimental fitting parameters.

The half life calculations are also calculated by using universal formula for the cluster decay is given as,

$$log_{10}T_{1/2}(s) = -log_{10}P - log_{10}S + [log_{10}(ln2) - log_{10}\upsilon]$$

The universal decay law half-life can be written in the form as,

$$log_{10}T_{1/2} = aZ_eZ_d\sqrt{\frac{A}{Q_e}} + b\sqrt{AZ_eZ_d(A_d^{\frac{1}{3}} + A_e^{1/3})} + c$$

The spontaneous fission half-lives for both e-e nuclei and odd-A nuclei can be expressed as,

$$log_{10}T_{\frac{1}{2}/yr} = c_1 + c_2\left(\frac{Z^2}{A} + k\right) + c_3(\frac{Z^2}{A} + k)^2 + c_4(\frac{Z^2}{A} + k)^3 + (c_5 + \left(\frac{Z^2}{A} + k\right))(c_6(Z - 82)^2 + c_7(N - 126)^2 + c_8(N - Z)) + h$$

Where $c_1$ = 31.196159, $c_2$ = −5.086737, $c_3$ =

−0.0742314, $c_4$ = −0.161829, $c_5$ = 0.0398652, $c_6$ = 0.0585024, $c_7$ = −0.0124953, $c_8$ = 0.108390 and k = −30.444904 and h is the blocking factor, where h=0 for even-even nuclei and h=4.302383 for odd-A nuclei.

**Table – I :** Alpha decay of Z = 130 isotopes

| A | N | Q-value(MeV) | VSS | Royer | Univ. | UDL | SF | Decay Modes |
|---|---|---|---|---|---|---|---|---|
| 310 | 180 | 15.585 | -7.639 | -7.138 | -7.671 | -9.202 | 110.713 | α |
| 311 | 181 | 15.566 | -7.60 | -7.124 | -7.65 | -9.186 | 117.28 | α |
| 312 | 182 | 15.211 | -6.99 | -6.534 | -7.116 | -8.650 | 114.182 | α |
| 313 | 183 | 15.302 | -7.155 | -6.710 | -7.276 | -8.806 | 118.636 | α |
| 314 | 184 | 15.561 | -7.598 | -7.170 | -7.694 | -9.217 | 113.469 | α |
| 315 | 185 | 15.76 | -7.93 | -7.520 | -8.011 | -9.530 | 112.682 | α |
| 316 | 186 | 15.982 | -8.296 | -7.902 | -8.355 | -9.871 | 108.803 | α |
| 317 | 187 | 16.248 | -8.723 | -8.345 | -8.752 | -10.268 | 106.122 | α |
| 318 | 188 | 16.3 | -8.805 | -8.445 | -8.841 | -10.354 | 100.403 | α |
| 319 | 189 | 18.352 | -11.763 | -11.413 | -11.449 | -13.030 | 95.936 | α |
| 320 | 190 | 18.871 | -12.434 | -12.100 | -12.034 | -13.647 | 88.482 | α |
| 321 | 191 | 18.748 | -12.278 | -11.962 | -11.915 | -13.518 | 82.330 | α |
| 322 | 192 | 19.133 | -12.762 | -12.463 | -12.338 | -13.967 | 73.240 | α |
| 323 | 193 | 13.64 | -4.016 | -3.757 | -4.526 | -6.107 | 65.502 | α |
| 324 | 194 | 13.484 | -3.692 | -3.452 | -4.237 | -5.828 | 54.875 | α |
| 325 | 195 | 13.309 | -3.322 | -3.100 | -3.905 | -5.507 | 45.645 | α |
| 326 | 196 | 13.144 | -2.966 | -2.763 | -3.585 | -5.199 | 33.572 | α |
| 327 | 197 | 13.153 | -2.985 | -2.800 | -3.619 | -5.229 | 22.943 | α |
| 328 | 198 | 13.115 | -2.903 | -2.734 | -3.556 | -5.167 | 9.513 | α |
| 329 | 199 | 13.119 | -2.911 | -2.760 | -3.579 | -5.187 | -2.428 | SF |
| 330 | 200 | 12.988 | -2.623 | -2.490 | -3.323 | -4.940 | -17.128 | SF |

## Conclusion

We have analytically evaluated the half-lives and presented absolute plausive decay modes of Z = 130 super-heavy nuclei in Table.1. Our deliberate decay energy $Q_\alpha$ and half-life time $T_\alpha$ are in good agreement with the FRDM calculations. The alpha-decay and SF half-live study of Z = 130 super-heavy nuclei maybe of great exercise for beforehand experimental analysis in the super-heavy region.

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