# Study of alpha decay of Superheavy Elements

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## Introduction

Currently nuclear physics is passing through an exciting period of time when one after another new super heavy elements (SHE) are being discovered. These super heavy elements were supposed to undergo spontaneous fission but instead of undergoing fission, each of these elements emits a characteristic $\alpha$ decay chain, a decay process that was first introduced by Gamow and by Condon and Gurney in the 1920s as a quantum tunneling effect. So, by identifying a particular $\alpha$ decay chain one can identify a particular super heavy element. The observed decay mode is mainly the $\alpha$ emission. Alpha Decay is the most prominent tool to investigate the super heavy nuclei [1]. In experiments one usually measures the decay energies and decay times, while the goal of theory is to predict the decay properties of SHE. In 1965 Myers and Swiatecki added the shell corrections to liquid drop model and in 1969 Nilsson et al. predicted that the longest fission half-life centre rather symmetrical around the nucleon numbers Z=114, N=184 [2-5]. Such theoretical predictions of long lived super heavy nuclei prompted for a world wide search for such nuclei in nature. Theoretical calculations were performed to predict the absolute alpha decay width, to extract nuclear structure information, and to pursue a microscopic understanding of the alpha decay phenomenon. Recent microscopic calculations predicts long- lived super heavy elements in a variety of shapes, including spherical, axial and triaxial configurations. Many authors proposed that in super heavy mass region the proton numbers 114,120,126 and the neutrons numbers 162,172,184 are the shell closures. In this work, by using Preformed Cluster Model (PCM) the half lives of super heavy elements have been determined and compared with the other existing theoretical results to test the extent of validity of the formalism.

## The preformed cluster decay model

The Half –lifetime according to PCM is given by

$$T_{1/2}=\ln2/\lambda$$

Where,

$$\lambda=P_0\nu_0P \qquad (1)$$

Here $\nu_0$ is the impinging frequency with which the cluster hits the barrier, P is the penetration probability that gives the probability of penetration of the barrier by the fragment and $P_0$ is the preformation probability of the cluster giving the probability of the formation of the cluster within the mother nucleus.

For calculating $P_0$ and P the dynamical collective coordinate of mass asymmetry $\eta = (A_1-A_2)/(A_1+A_2)$ and relative separation R between the two fragments, is considered via the stationary Schrödinger equation

$$H(\eta, R)\,\psi_n(\eta, R) = E_n\,\psi_n(\eta, R) \qquad (2)$$

In Principle, the two coordinates are coupled, but in view of the defining equation (1), the Schrödinger equation (2) is solved in the decoupled approximation of $\eta$ and R-motions. Only the ground state (n=0) solution is relevant for the cluster decay to occur in the ground state of the daughter nucleus. Then, for $\eta$ motion, the properly normalized fractional cluster preformation probability is

$$P_0(A_2) = |\psi(n)|2\sqrt{B_{\eta\eta}(\eta)}\,2/A, \qquad (3)$$

Details of this model can be found in ref [6]

## Results and discussions

The PCM Based calculations have been made by using the Audi and Wapstra tables of binding energies of 1995 and whenever some values was not present in this table it was taken from the 1995 theoretical binding energies. In table1 we calculate for the alpha decay the half life times for a large number of super heavy elements, though there exist many more [7], which are expected to long enough to detect after the synthesis in the present day experiment set up. We investigate here the magicity (spherical and /or deformed) in superheavy mass region. Any stability against spontaneous fission in this region is due to extra binding resulting from the shell effect which essentially increases the alpha

**Table 1**: TABLE FOR ALPHA DECAY IN VARIOUS ISOTOPES

| Z | N | A | $P_0$ | $LOGP_0$ | LOGP | Q | Log $T_{1/2}$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | PCM | VSS | DDM3Y | VS |
| 104 | 170 | 274 | 4.48E-11 | -10.3487 | -24.924 | 6.186 | 13.762 | 9.21 | 8.75 | 9.35 |
| 104 | 174 | 278 | 7.89E-12 | -11.1029 | -30.277 | 5.216 | 19.908 | 14.80 | 14.31 | 15.00 |
| 104 | 178 | 282 | 4.15E-12 | -11.382 | -31.853 | 4.976 | 21.775 | 17.88 | 17.34 | 18.13 |
| 104 | 182 | 286 | 2.74E-12 | -11.5622 | -33.958 | 4.686 | 24.075 | 23.21 | 22.65 | 23.57 |
| 104 | 186 | 290 | 2.41E-12 | -11.618 | -28.725 | 5.446 | 18.868 | 14.67 | 14.01 | 14.88 |
| 106 | 172 | 278 | 1.92E-10 | -9.7167 | -22.117 | 7.006 | 10.297 | 7.92 | 7.49 | 8.03 |
| 106 | 176 | 282 | 9.94E-12 | -11.0026 | -27.164 | 5.896 | 16.67 | 12.58 | 12.09 | 12.74 |
| 106 | 180 | 286 | 4.75E-12 | -11.3233 | -29.103 | 5.546 | 18.945 | 15.61 | 15.06 | 15.85 |
| 106 | 184 | 290 | 3.1E-12 | -11.5086 | -29.609 | 5.456 | 19.642 | 18.45 | 17.87 | 18.71 |
| 106 | 188 | 294 | 2.08E-12 | -11.6816 | -33.354 | 4.896 | 23.586 | 12.86 | 12.21 | 13.03 |
| 108 | 174 | 282 | 5.15E-11 | -10.2882 | -24.213 | 6.676 | 12.978 | 7.13 | 6.72 | 7.17 |
| 108 | 178 | 286 | 1.97E-11 | -10.7055 | -23.856 | 6.746 | 13.038 | 8.59 | 8.11 | 8.69 |
| 108 | 182 | 290 | 5.27E-12 | -11.2782 | -26.949 | 6.086 | 16.728 | 12.74 | 12.20 | 12.92 |
| 108 | 186 | 294 | 5.98E-12 | -11.2233 | -23.502 | 6.806 | 13.204 | 7.35 | 6.78 | 7.43 |
| 110 | 176 | 286 | 9.98E-11 | -10.0009 | -21.224 | 7.606 | 9.6748 | 5.38 | 5.00 | 5.40 |
| 110 | 180 | 290 | 1.39E-11 | -10.857 | -24.381 | 6.796 | 13.715 | 8.08 | 7.64 | 8.11 |
| 110 | 184 | 294 | 7.56E-12 | -11.1215 | -23.685 | 6.946 | 13.281 | 9.67 | 9.15 | 9.73 |
| 110 | 188 | 298 | 8.22E-12 | -11.0851 | -20.611 | 7.736 | 10.149 | 6.08 | 5.54 | 6.12 |
| 112 | 176 | 288 | 4.78E-10 | -9.32057 | -19.424 | 8.346 | 7.1761 | 2.44 | 2.14 | 2.35 |
| 112 | 180 | 292 | 3.31E-11 | -10.4802 | -22.229 | 7.506 | 11.165 | 5.57 | 5.20 | 5.56 |
| 112 | 184 | 296 | 1.51E-11 | -10.821 | -21.478 | 7.696 | 10.752 | 6.27 | 5.83 | 6.26 |
| 112 | 188 | 300 | 1.95E-11 | -10.71 | -19.323 | 8.326 | 8.4711 | 3.65 | 3.19 | 3.59 |
| 114 | 176 | 290 | 8.67E-10 | -9.06198 | -19.58 | 8.496 | 7.0707 | .02 | -.17 | -.16 |
| 114 | 180 | 294 | 1.70E-10 | -9.76955 | -19.164 | 8.616 | 7.3607 | 2.84 | 2.55 | 2.73 |
| 114 | 184 | 298 | 9.01E-11 | -10.0453 | -18.246 | 8.916 | 6.7135 | 2.98 | 2.63 | 2.84 |
| 116 | 168 | 284 | 1.44E-06 | -5.48416 | -13.244 | 11.606 | -2.5569 | -6.19 | -6.04 | -6.57 |
| 116 | 172 | 288 | 2.15E-07 | -6.66756 | -13.661 | 11.316 | -1.3062 | -3.18 | -3.18 | -3.48 |
| 116 | 176 | 292 | 7.14E-08 | -7.71463 | -14.477 | 10.826 | 0.000129 | -1.99 | -2.09 | -2.26 |
| 116 | 180 | 296 | 1.70E-08 | -7.76955 | -13.907 | 11.106 | 0.049925 | -.99 | -1.15 | -1.25 |
| 116 | 184 | 300 | 8.98E-09 | -8.04672 | -13.333 | 11.406 | -0.25042 | -1.02 | -1.23 | -1.26 |
| 118 | 174 | 292 | 1.06E-06 | -5.97469 | -12.379 | 12.366 | -3.2984 | -4.23 | -4.15 | -4.61 |
| 118 | 178 | 296 | 2.74E-07 | -6.56225 | -12.435 | 12.286 | -2.6515 | -3.79 | -3.77 | -4.15 |
| 118 | 182 | 300 | 5.94E-08 | -7.22621 | -11.792 | 12.716 | -2.6355 | -3.56 | -3.61 | -3.91 |
| 120 | 176 | 296 | 1.47E-06 | -5.83268 | -11.013 | 13.686 | -4.8261 | -6.03 | -5.84 | -6.51 |
| 120 | 180 | 300 | 1.61E-06 | -5.79317 | -11.284 | 13.396 | -4.5876 | -5.42 | -5.31 | -5.87 |

half lives for nuclei with Z<114 and N< 184 and decreases those of nuclei with Z>114 and N>184.We Compare here our results with the existed models and found the shell closures at Z=114 and at N=184. Calculations are given in Table I.

## References

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