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# STUDY OF α-DECAY AND CLUSTER DECAY OF SUPERHEAVY ELEMENTS Z=120

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## ABSTRACT

*We have analyzed the different-decay chains of Z=120 element observed recently, by using the Preformed cluster model which is based on the Quantum Mechanical Fragmentation Theory. Not only the α-decay characteristics have been studied but also the cluster decay calculation being studied first time. The α-decay characteristics gives the information about the nuclear structure, and compared the results with the experimental data of Dubna and the Generalized Liquid Drop Model (GLDM).The PCM calculations are in good agreement with the observed data.The superheavy elements are expected to show extra stability at the shell closures. On this basis some α-decay chains are studied, we have found the most stable nuclei at Z=112, N=161,163; Z=114, N=171,178,179; and at Z=124, N=194. Also, the possibility of heavy cluster emissions with respect to α-decays* $^{301}$*120 α-decay chain is studied. The calculated cluster decays show the large stability at the* $^{289}$*114 parents against* $^{10}$*Be decay giving Z=114, N=175 proton and neutron number respectively. Another possibility of* $^{14}$*C and* $^{34}$*Si cluster decay of the parent* $^{301}$*120 gives Z=114, N=173 and Z=106, N=161 daughter nucleus respectively.* $^{49}$*Ca is the most probable emitted cluster from the same parent giving Z=100, N=152 daughter nucleus.*

***Keywords:** **superheavy nuclei, Fragmentation, α-decay, Cluster decay, Preformed Cluster, model (PCM) of Gupta and Collaborators, Preformation probability.***

## I. INTRODUCTION

In the past two decades, the synthesis of superheavy elements and their decay lifetime measurements have been two major goals of nuclear physics. This field has gotten new impetus by recent synthesis of several heavy elements and their subsequent reconfirmations [3, 8, 6, 7, 5] with the advent of radioactive ion beam facilities it is now believed that ultimately it would be possible to reach the center of the island of superheavy elements. In this scenario, the study of decay properties of superheavy elements, primarily by α-emissions has become an important domain of intense research. Discoveries of new superheavy elements have also provided a testing ground for many theoretical formalism. It has been shown that half-life calculations in the WKB framework, it was shown that the generalized liquid drop model including the proximity effects could reasonably estimates the experimental data on superheavy nuclei when the experimental Q-values were used. In the recent experiments designed to synthesize the element 115 in the 243Am +$^{48}$Ca reaction at Dubna in Russia, three similar decay chains consisting five consecutive α- decays and another different decay chain of four consecutive α-decays are detected, and the decay properties of these synthesized nuclei are claimed to be consistent with consecutive α-decays originating from the parent isotopes of new element 115, $^{288}115$ and $^{287}115$, respectively. The RMF calculation has been carried out using the model Lagrangian density with nonlinear terms. It has been observed in this calculation that the isotopes of the element 115 are very deformed. For the measured α-decay energies of the newly produced isotopes, one can estimate half-lives for allowed transitions and compare them with experimental values under the Geiger-Nuttall treatment using the formula by Viola and Seaborg. Parameters are obtained from fits to the $T_a$ versus $Q_a$ values of 65 known even-even nuclei with $Z > 82$ and $N > 126$. The ratio between the experimental $T_{expt}$ and $T_{cal}$ half-lives define the hindrance factors caused by odd numbers of protons and or neutrons in the newly synthesized nuclei. The measured $T_{exp}$ values closely reproduce the calculated ones for the first two nuclei of these chains: thus the element 115 and element 113 isotopes have rather low hindrance factors, if any, for α-decay. The next magic numbers beyond the doubly magic nucleus $^{208}Pb$ is a long standing question in the nuclear structure physics. A number of theoretical calculations [12] -[20] have been made in the late 1960's for the existence of long lived superheavy nuclei and about the next magic numbers and all of them predict Z=114, 124, 164 for protons and N=184, 196, 236, 318 for neutrons as magic numbers. Recently, some models [21, 22, 23] on the basis of Strutinsky approach, have found Z=114 more stable, whereas Hartree-Fock calculation based models [24, 25] predict the highest stability at proton number Z=120,124, 126. The macro-microscopic calculations predict spherical shell closures at Z=114 and N=184. In the relativistic mean field calculations Rutz predicted Z=120 and N=172 as the next magic shells in the spherical RMF theory, meanwhile Patra predicted Z=120 and N=184 in the axially deformed RMF theory as the next possible magic numbers for superheavy elements. In the Skyrme Hartree-Fock calculations with parameters sets of SKI3 and SKI4 the most pronounced shell effects at Z=120 and N=184 are obtained, while in the Hartree-Fock-Bouglibove calculations with the finite range Gogny force one predicts Z=120, 126 and N= 172, 184 as the possible proton shell closures. Very recently Tappa applied the new effective field theory to analyze the isotopic and isotonic chains of superheavy nuclei and searched next shell closures. They predicted Z=120 and N=172 and Z=120 and N=258 as possible spherical doubly magic super heavy nuclei. As mentioned above, the most theoretical studies predicted Z=120 as a possible magic number of proton in superheavy nuclei. Actually, the key role of the shell stability of nuclei at Z=120 was first pointed out by Gupta et al. Recently Gupta et al used the Quantum Mechanical Fragmentation theory to describe the interaction potential for some target-projectile combinations of the elements as shown: $^{136}Xe+^{166}Dy\rightarrow^{302}120^*$,$^{94}Sr+^{208}Pb\rightarrow^{302}120$,$^{50}Ca+^{252}\rightarrow$ $^{302}120$. The results obtained in the QMFT illustrated that the interaction potential can provide the information of the synthesis of superheavy nuclei at Z=120 in the fusion reaction. They predicted $^{94}Sr+^{208}Pb$ as a best cold fusion reaction for producing $^{302}120$ nucleus. During the last two decades evidences has been confirmed experimentally connected to superheavy elements. The advancement in the accelerator technology has opened the door to synthesizing the new superheavy elements. The Z=107-112 [26] superheavy elements are synthesized successfully using the lead and bismuth targets in the cold fusion reactions. Since, elements Z=114 [27, 28] and 116 [29], identified by hot fusion reactions. The hot fusion reactions are based on heavy actinide targets from Th to Cf with very light C to S projectile. These heaviest iso..topes decay predominantly by groups of α particles (or α chains) as expected theoretically [30, 31]. The minimum excitation energy is obtained using the $^{48}Ca$ beam in the hot fusion reactions. A possibility of $^{50}$Ca has shown a better beam in [32] for the formation of superheavy nuclei by cold fusion, since $^{50}$Ca is a radioactive nucleus.

In this work we have investigated the stability of superheavy nuclei by analyzing the various α-decay chains. Not only the α-decays but most probable heavy cluster also looked in this process. For this calculation we have used the preformed cluster model of gupta and collaborators [33, 34, 35, 36, 37, 38]. The results of our calculations, compared with recent works, are presented in here.

## II. CALCULATIONS

### The α-decay chain in superheavy nuclei

In this calculation we have pay more attention to the stability of superheavy elements, particularly, the effects of spherical or deformed shells. Large half-lives or stability of superheavy nuclei being considered due to the shell closure effects either they are proton number or neutrons. We have study some α-decay chains $^{289,291,297,301,303,305,309,311}$120 and $^{320,326}$128, notice in the figure (1, 2) the maxima of the half-lives in the α-decay chains $^{289,291,297}$120, connected to the (Z=112, N=161), (Z=112, N=163), and (Z=114, N=171) appears for the ground state configurations of these nuclei.

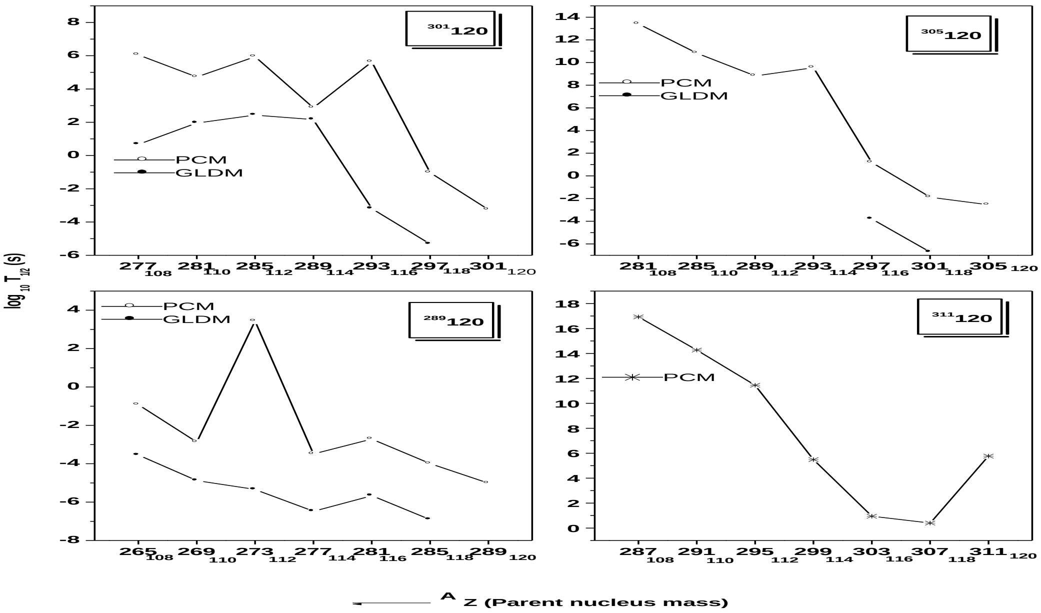

**Figure1: The calculated $\alpha$ -decay half-lives based on the preformed cluster model, are compared with available data of the GLDM model, and plotted as a function of the parent nucleus mass for various $\alpha$ -decay chains.**

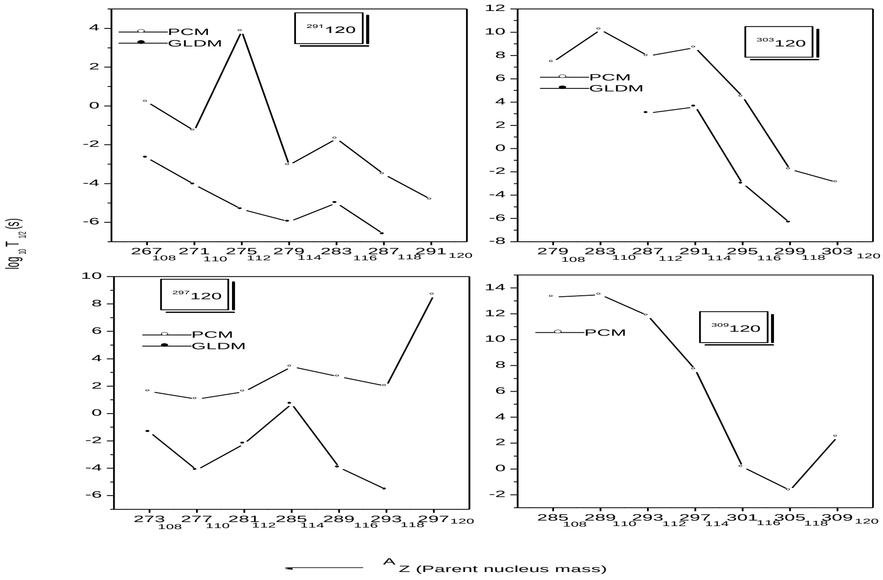

**Figure 2: The same as for fig.1.but for different $\alpha$ -decay chains.**

The maximum stability of neutron numbers at (N=161, N=163) are identified close to the N=162 which is a deformed magic number [162]. Similarly, the element (Z=114, N=171) is found more stable against α-decay. Since (Z=114, N=184) predicted magic numbers, both for proton and neutron. After scanning a wide range of superheavy nuclei [24] N=172 magicity is predicted with Z=120[9] proton number. From the figure (3, 4), the alpha decay energy Q_ are plotted against the charge number. In the $^{289,291,297}120$ _-decay chains the shell closure effects are clearly visible and reflects the strength of the shell closure at (Z=112, N=161, 163) and (Z=114, N=171).

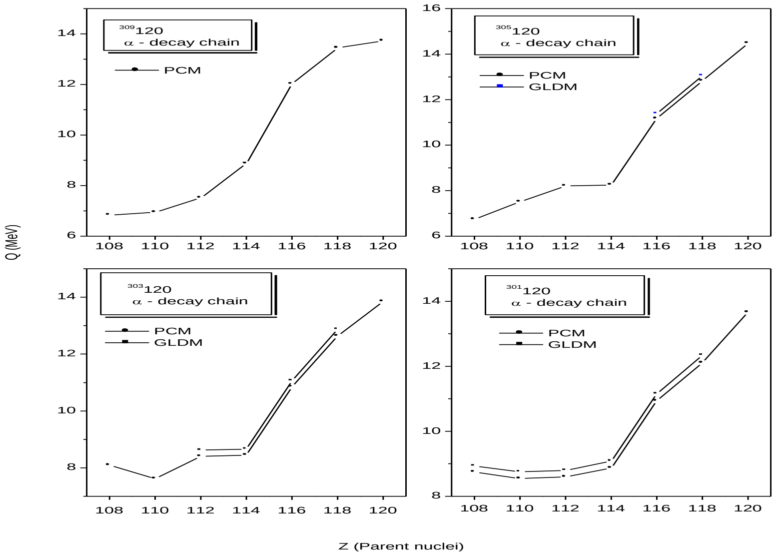

**Figure 3: The calculated Q-values on the basis of PCM compared with GLDM, plotted as a function of charge number for various $\alpha$ -decay chains.**

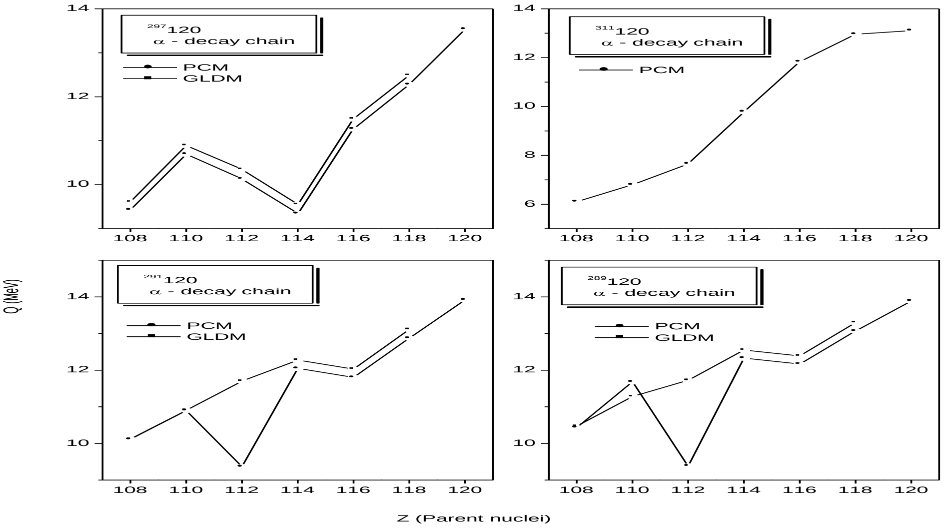

**Figure 4: the same as for fig.3, but for different $\alpha$ -decay chains.**

A very interesting point has been noticed in the study of these α-decay chains that the Q-values are almost same at Z=120 with different neutron numbers, since a considerable difference has been noticed at Z=108 for the same. We have found in all the α-decay chains that for a fixed number of protons Z=114, the α-decay half-lives are maximum around the N~178 relative to other neutron numbers. Not only the stability but a sharp change also in the α-decay half-lives has been noticed in these $^{297,301,303,305}$120 α-decay chains at Z=114 within the range of neutron numbers from N=171-179. The maximum α-decay half-lives occurs at (Z=114, N=179). The calculated Q-values and α-decay half-lives are compared with recent calculations [163] based on the generalized liquid drop model (GLDM). The results of both the calculations PCM and GLDM shows the similar trends. From the figure (5),

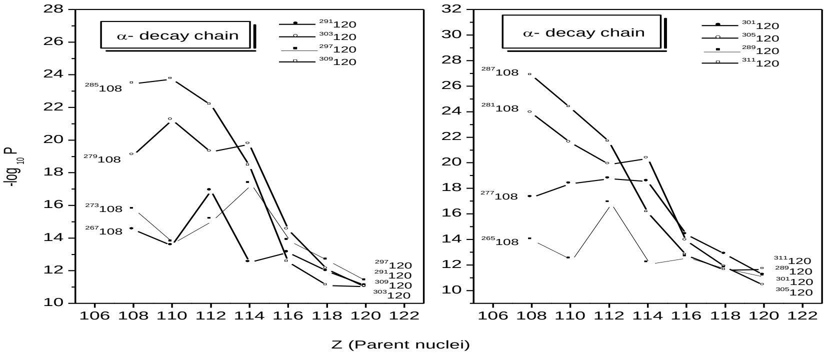

**Figure.5: The Calculated penetrability P on the basis of PCM, plotted as a function of the parent charge number for various $\alpha$ -decay chains**

Interested enough that the penetration probabilities of all the α-decay chains are almost same of the order $10^{-12}$ at Z=120, but it changes towards the lower atomic number rapidly. In this fig.5 element $^{305}$120 have the maximum penetration probability than the $^{311}$120 element. Which means (Z=120, N=185) have more decay probability against the α-particle than the (Z=120, N=191) nucleus. Hence (Z=120, N=191) is more stable nucleus than the (Z=120, N=185). The fig. 6 shows the pre-formation probabilities of α-particles,

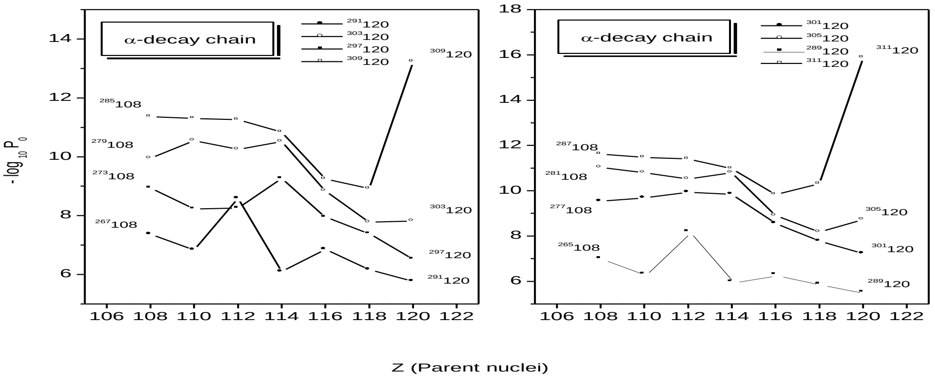

**Figure 6: The calculated preformation probability using the PCM model, plotted as a function of the parent charge number for various $\alpha$ -decay chains.**

It is clear that the 289120 α-decay chain parents have largest preformation probabilities compare to other α-decay chain parents. It also noticed that the preformation probability for the $^{305}120$ is larger compared to the $^{311}120$ nucleus in many order.

## III. POSSIBLE CLUSTER DECAY FROM $^{301}$120 DECAY CHAIN

Figure (9, 10) shows the results of our calculation for heavy cluster decays.

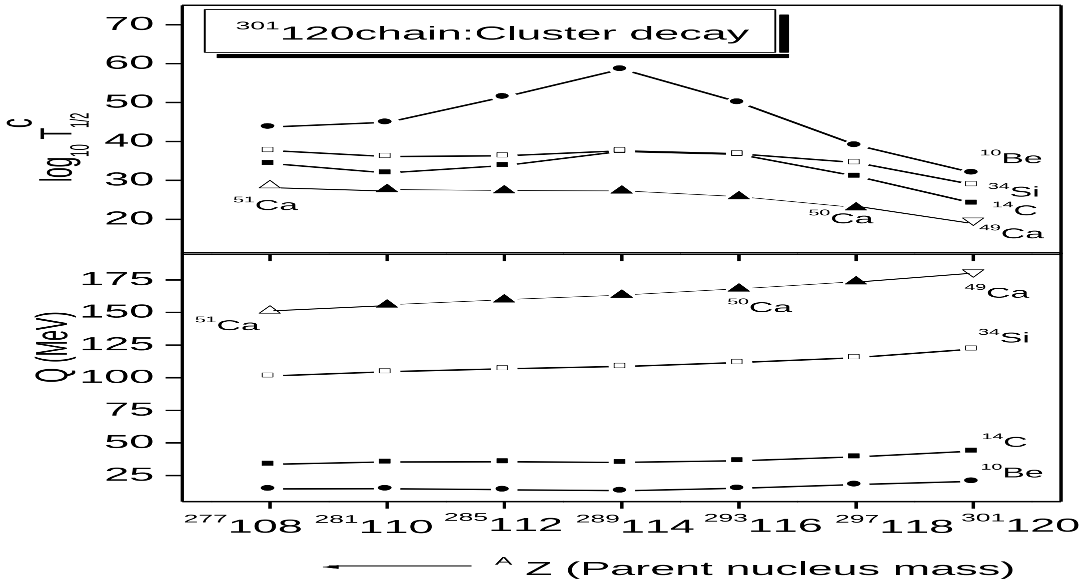

**Figure 9: The calculated decay half-lives and the Q-values on the basis of PCM for some cluster decays of the parents of $\alpha$ -decay chain for the $^{301}120$ plotted as a function of the parent nucleus mass.**

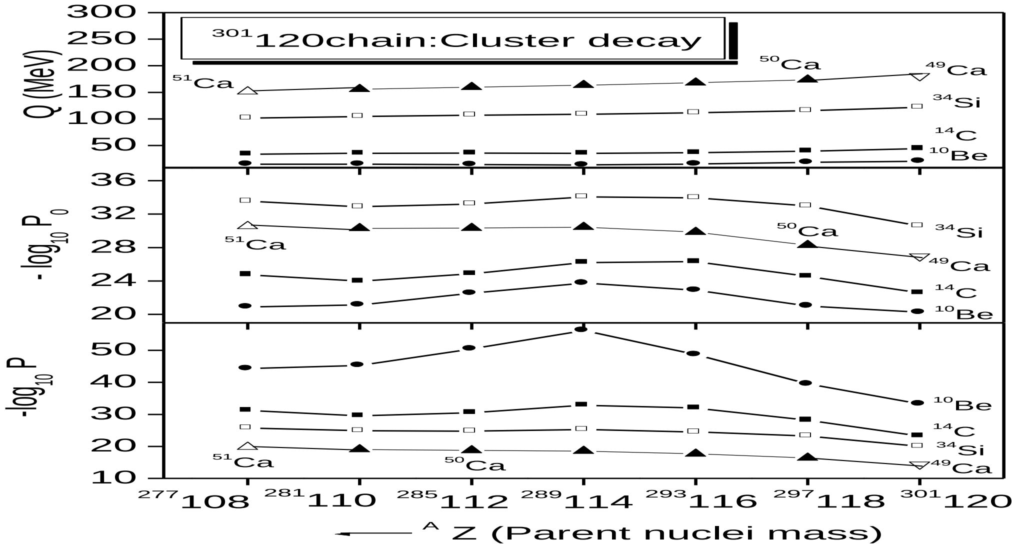

**Figure 10: The PCM calculated Q-values, penetrability P and preformation factors $P_0$ for some cluster decays of the parents of $\alpha$ -decay chain for $^{301}120$, plotted as a function of the parent nucleus mass.**

We have found that $^{10}$Be is the most probable cluster because its have smaller penetration probability P and larger pre-formation probability $P_0$ in all the parents. For the $^{10}$Be, the $\log T_{1/2}$ is much larger compare to other clusters, so that all parents are stable against $^{10}$Be decay. The Q-values are plotted against the mass number, of all the possible clusters. It is clearly seen that the behavior of Q-values are completely independent from the mass number. There is another interesting feature appear in this cluster decay calculation, the maximum half-life of the parent Z=114, A=289 against the $^{10}$Be cluster decay. Clearly shell stabilizing effects appears in the considered decay. So, (Z=114, N=175) nucleus are observed most stable in cluster radioactivity studies. The decay of $^{10}$Be of parent $^{301}$120 give the daughter (Z=116, N=175) $^{291}$116 nucleus. The next excitement of this study is the decay of $^{14}$C and $^{34}$Si of the parent $^{301}$120. The cluster $^{14}$C gives daughter (Z=114, N=173) and for the cluster $^{34}$Si gives the (Z=106, N=161), a deformed magic nucleus $^{267}$106. Since, $^{34}$Si have lowest pre-formation probability in all the cases the clusters, $^{49-51}$Ca shows more decay probability compare to others. The decay of $^{49}$Ca from $^{301}$120 gives the (Z=100, N=152) deformed daughter [44].

**Table 1:** The calculated α-decay half lives and other characteristics for ground state decay of superheavy nuclei in various α-decay chains, based on PCM, compare with GLDM calculations. Binding energies are taken from the Audi-Wapstra & Moller et.al, (2003), data table. [10,11]

| | **PCM** | | | | **GLDM** | |
|---|---|---|---|---|---|---|
| **Parent** | **$Q_\alpha$ (MeV)** | **$P_o$** | **P** | **$\text{Log}_{10}T^{\alpha}_{1/2}$ (a)** | **$Q_\alpha$ *(MeV)** | **$\text{Log}_{10}$ $T^{\alpha}_{1/2}$ (a)** |
| $^{311}$120 | 13.106 | $1.77*10^{-16}$ | $2.14*10^{-12}$ | 5.766 | | |
| $^{307}$118 | 12.956 | $3.4*10^{-11}$ | $7.9*10^{-25}$ | 0.397 | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| $^{303}116$ | 11.836 | $1.54* 10^{-10}$ | $1.7* 10^{-13}$ | 0.945 | | |
| $^{299}114$ | 9.786 | $1.07* 10^{-11}$ | $7.7* 10^{-17}$ | 5.480 | | |
| $^{295}112$ | 7.656 | $4.28* 10^{-12}$ | $2.37*10^{-22}$ | 11.447 | | |
| $^{291}110$ | 6.796 | $3.48* 10^{-12}$ | $4.6* 10^{-25}$ | 14.270 | | |
| $^{287}108$ | 6.806 | $2.47* 10^{-12}$ | $1.49*10^{-27}$ | 16.931 | | |
| $^{309}120$ | 13.726 | $7.27* 10^{-14}$ | $9.62*10^{-12}$ | 2.489 | | |
| $^{305}118$ | 13.446 | $1.21* 10^{-9}$ | $8.12*10^{-12}$ | -1.658 | | |
| $^{301}116$ | 12.016 | $5.75* 10^{-10}$ | $2.85*10^{-13}$ | 0.144 | | |
| $^{297}114$ | 8.866 | $1.486*10^{-11}$ | $3.71* 10^{-19}$ | 7.681 | | |
| $^{293}112$ | 7.516 | $5.92* 10^{-12}$ | $6.86*10^{-23}$ | 11.867 | | |
| $^{289}110$ | 6.946 | $5.29* 10^{-12}$ | $1.90*10^{-24}$ | 13.468 | | |
| $^{285}108$ | 6.836 | $4.386*10^{-12}$ | $3.45*10^{-24}$ | 13.292 | | |
| $^{305}120$ | 14.476 | $1.83* 10^{-9}$ | $4.005*10^{-11}$ | -2.547 | | |
| $^{301}118$ | 12.826 | $1.15*10^{-8}$ | $1.45*10^{-12}$ | -1.877 | 13.05 | -6.72 |
| $^{297}116$ | 11.166 | $1.24*10^{-9}$ | $1.21*10^{-14}$ | 1.191 | 11.38 | -3.80 |
| $^{293}114$ | 8.246 | $1.66*10^{-11}$ | $4.65* 10^{-21}$ | 9.549 | | |
| $^{289}112$ | 8.206 | $3.01* 10^{-11}$ | $1.36*10^{-20}$ | 8.820 | | |
| $^{285}110$ | 7.506 | $1.64* 10^{-11}$ | $2.539*10^{-22}$ | 10.832 | | |
| $^{281}108$ | 6.746 | $9.27*10^{-12}$ | $1.27*10^{-24}$ | 13.402. | | |
| $^{303}120$ | 13.846 | $1.67* 10^{-8}$ | $1.02*10^{-11}$ | -2.905 | | |
| $^{299}118$ | 12.636 | $1.68*10^{-8}$ | $7.90*10^{-13}$ | -1.778 | 12.87 | -6.37 |
| $^{295}116$ | 10.846 | $2.74*10^{-12}$ | $3.11*10^{-15}$ | 4.447 | 11.06 | -3.00 |
| $^{291}114$ | 8.946 | $3.08*10^{-11}$ | $1.83*10^{-20}$ | 8.678 | 8.66 | 3.59 |
| $^{287}112$ | 8.406 | $5.66* 10^{-11}$ | $5.24*10^{-20}$ | 7.956 | 8.62 | 3.03 |
| $^{283}110$ | 7.616 | $2.79*10^{-11}$ | $5.87*10^{-22}$ | 10.233 | | |
| $^{279}108$ | 8.096 | $1.14*10^{-10}$ | $8.60*10^{-20}$ | 7.441 | | |
| $^{301}120$ | 13.666 | $6.07* 10^{-8}$ | $6.32*10^{-12}$ | -3.254 | | |
| $^{297}118$ | 12.106 | $1.68*10^{-8}$ | $1.43*10^{-13}$ | -1.027 | 12.34 | -5.32 |
| $^{293}116$ | 8.887 | $1.67*10^{-9}$ | $9.25*10^{-20}$ | 5.630 | 11.15 | -3.19 |
| $^{289}114$ | 9.908 | $3.25*10^{-8}$ | $1.02*10^{-16}$ | 2.872 | 9.08 | 2.16 |
| $^{285}112$ | 8.734 | $7.03* 10^{-10}$ | $4.26*10^{-19}$ | 5.942 | 8.80 | 2.43 |
| $^{281}110$ | 8.959 | $8.87*10^{-10}$ | $5.52*10^{-18}$ | 4.722 | 8.75 | 1.95 |
| $^{277}108$ | 8.401 | $3.84*10^{-10}$ | $6.12*10^{-19}$ | 6.053 | 8.93 | 0.67 |
| $^{297}120$ | 9.002 | $4.27* 10^{-11}$ | $1.32*10^{-20}$ | 8.666 | | |
| $^{293}118$ | 12.301 | $9.73*10^{-12}$ | $2.34*10^{-13}$ | 1.991 | 12.49 | -5.56 |
| $^{289}116$ | 11.701 | $6.99*10^{-12}$ | $6.57*10^{-14}$ | 2.696 | 11.50 | -3.94 |
| $^{285}114$ | 11.001 | $8.13*10^{-12}$ | $1.10*10^{-14}$ | 3.415 | 9.55 | 0.71 |

| | | | | | | |
|---|---|---|---|---|---|---|
| $^{281}$112 | 10.281 | 4.55* $10^{-9}$ | 1.35*$10^{-15}$ | 1.593 | 10.35 | -2.20 |
| $^{277}$110 | 10.301 | 6.11*$10^{-9}$ | 3.55*$10^{-15}$ | 1.042 | 10.89 | -4.13 |
| $^{273}$108 | 9.901 | 3.90*$10^{-9}$ | 1.55*$10^{-15}$ | 1.604 | 9.61 | -1.36 |
| $^{291}$120 | 13.916 | 1.73* $10^{-6}$ | 8.32*$10^{-12}$ | -4.832 | | |
| $^{287}$118 | 12.876 | 6.87*$10^{-7}$ | 1.04*$10^{-12}$ | -3.521 | 13.11 | -6.65 |
| $^{283}$116 | 11.866 | 1.40*$10^{-7}$ | 7.70*$10^{-14}$ | -1.680 | 12.03 | -5.01 |
| $^{279}$114 | 12.046 | 7.98*$10^{-9}$ | 3.17*$10^{-13}$ | -3.057 | 12.27 | -5.97 |
| $^{275}$112 | 9.38 | 2.63* $10^{-9}$ | 1.34*$10^{-17}$ | 3.850 | 11.70 | -5.33 |
| $^{271}$110 | 10.871 | 1.69*$10^{-7}$ | 2.59*$10^{-14}$ | -1.277 | 10.90 | -4.05 |
| $^{267}$108 | 10.121 | 4.71*$10^{-8}$ | 3.16*$10^{-15}$ | 0.204 | 10.12 | -2.64 |
| $^{289}$120 | 13.886 | 2.99* $10^{-6}$ | 7.27*$10^{-12}$ | -5.017 | | |
| $^{285}$118 | 13.066 | 1.29*$10^{-6}$ | 1.63*$10^{-12}$ | -3.995 | 13.30 | -6.91 |
| $^{281}$116 | 12.166 | 4.98*$10^{-7}$ | 2.29*$10^{-13}$ | -2.713 | 12.39 | -5.67 |
| $^{277}$114 | 12.326 | 1.02*$10^{-6}$ | 6.62*$10^{-13}$ | -3.492 | 12.55 | -6.48 |
| $^{273}$112 | 9.403 | 6.52* $10^{-9}$ | 1.41*$10^{-17}$ | 3.430 | 11.72 | -5.34 |
| $^{269}$110 | 11.586 | 6.71*$10^{-7}$ | 2.46*$10^{-13}$ | -2.870 | 11.28 | -4.88 |
| $^{265}$108 | 10.587 | 1.10*$10^{-7}$ | 1.78*$10^{-14}$ | -0.927 | 10.47 | -3.55 |

## IV. SUMMARY OF OUR RESULTS

We have studied some α-decay chains of the superheavy nuclei $^{311,309,305,303}$120, $^{301,297,291,289}$120 and $^{320,326}$128. The calculation are completed using the preformed cluster decay model of Gupta and collaborators [33, 34, 35, 36, 37, 38], based on the Quantum Mechanical Fragmentation Theory (QMFT). The calculated half lives and the Q-values are compared with the recent calculation based on Generalized Liquid Drop Model (GLDM). Comparison shows the same trends in both the calculations. The maximum pre-formation probability of the order $10^{-6}$ has been found for the parents of the $^{289}$120 α-decay chain. We conclude that the stability of the superheavy nuclei based on their half-lives and Q-value are found for the nuclei at (Z=112, N=161,163), (Z=114, N=171,178,179) or at (Z=124, N=194). Cluster decays are also studied for the $^{301}$120 α-decay chain. The shell stabilizing effects appears in $^{10}$Be decay of the parent $^{289}$114 nucleus. A good indication seen in the cluster radioactivity calculation, decay of $^{34}$Si from parent $^{301}$120, gives a deformed magic daughter (Z=106, N=161), and $^{49}$Ca from the same parent gives (Z=100, N=152).

## REFERENCES

[1] M.A. Stoyer, Nature 442, 876 (2006); also reference therein.
[2] S. Hofmann et al., Nucl. Phys. A 734, 93 (2004).
[3] H. Hofman and G. M¨unzenberg, rev. Mod. Phys.72, 733 (2000).
[4] D. Ackermann, Nucl. Phys. A 787, 353C (2007).

[5] Yu. Ts. Oganessian et al., Phys. Rev. C. 74,044602 (2006); and reference therin.

[6] Yu. Ts. Oganessian et al., Phys. Rev. C70, 064609 (2004); Phys. Rev. C 71, 029902 (E)(2005).

[7] K. Morita et al., J. Physics. Soc. Jpn. 73, 2593 (2004).

[8] Yu. Ts. Oganessian et al., Phys. Rev. C69, R021601 (2004).

[9] C Samanta, P Roy Chowdhruy and D N Basu, Nuclear Physics A 789, 142-154 2007).

[10] G. Audi and A. H. Wapstra, Nucl. Phys. A595,4 (2003).

[11] P. M¨oller, J. R. Nix, W. D. Myers and W. J. Swiatecki, At. Data Nucl. Data Tables 59, 185 (2003).

[12] W D Myers and W J Sewiatecki, Nucl. Phys. A81, 1 (1966).

[13] A Sobiczewski, F A Gareev, and B N Kalinkin, Phys. Lett. 22, 500 (1966).

[14] H Meldner, Ark. Fys. 36, 593 (1967).

[15] S G Nilsson et al., Nucl. Phys. A115, 545(1968).

[16] U Mosel, and W Greiner, Z. Phys. 222, 261(1969).

[17] J Grumann, U Mosel, B Frink, and W Greiner, Z. Phys. 228, 371(1969).

[18] S G Nilsson, C F Tsang, A Sobiczewski, Z Szymanski, S Wyeech, C Gustafsson, I L Lamm, P M¨oller, and B Nilsson, Nucl. Phys. A131, 1(1969).

[19] E O Fiset and J R Nix, Nucl. Phys. A193, 647(1972).

[20] J Randrup, S E Larsson, P M¨oller, A Sobiczewski, and A Lukasiak, Phys. Scr. 10A, 60(1974).

[21] A Sobiczewski, Phys. of Particles and Nuclei 25, 295-311(1994).

[22] R Smolanczuk, J Skalski, and A Sobiczewski, Phys. Rev. C52, 1871-1880(1995).

[23] P M¨oller, and J R Nix, J. Phys. G: Nucl. Part. Phys. 20, 1681-1747(1994).

[24] K Rutz, M Bender, T B¨urvenich, T Schilling, P G Reinhard, J A Maruhn and W greiner, Phys. Rev. C56, 238-243(1997).

[25] S Cwiok, J Dobaczewski, P H Heenen, PMagierski, and W Nazarewicz, Nucl. Phys. A611, 211-246(1996).

[26] S Hofmann, Rep. Prog. Phys. 61, 639(1998).

[27] Y T Oganessian et al., Phys. Rev. Lett. 83, 3154(1999).

[28] Y T Oganessian et al., Phys. Rev. C62, 041604(R)(2000).

[30] S Cwiok, and A Sobiczewski, Z. Phys. A342, 203(1992).

[31] R Smolanczuk, Phys. Rev. C56, 812(1997).

[32] Sushil Kumar, M Balasubramanium, R K Gupta, G M¨unzenberg, and W Scheid, J Phys. G: Nucl. Part. Phys. 29, 625-639(2003).

[33] S.S. Malik and R.K. Gupta, Phys. Rev. C 39 (1989) 1992.

[34] R.K. Gupta, W. Scheid, and W. Greiner, J. Phys. G 17 (1991) 1731.

[35] S. Kumar and R.K. Gupta, Phys. Rev. C 49 (1994) 1922.

[36] R.K. Gupta and W. Greiner, Int. J. Mod. Phys. E 3 (1994, Supp.) 335.

[37] R.K. Gupta, in Heavy Elements and Related New Phenomena, Eds. W. Greiner and R.K. Gupta, World Scientific, Singapore, 1999, Vol. II, p. 730.

[38] R.K. Gupta, Phys. Rev. C 21 (1980) 1278.

[39] R.K. Gupta, C. Pˆarvulescu, A. Sˇandulescu and W. Greiner, Z. Physik A283 (1977) 217.
[40] R.K. Gupta, Proc. 5th Int. Conf. on Nuclear Reaction Mechanisms, Varenna 1988, p.416.
[41] R.K. Gupta, ibid [148], Vol. II, p. 730.
[42] S Hofmann, and G M¨unzenberg, Rev. Mod. Phys. 72, 733(2000).
[43] G Royer, J Phys. G: Nucl. Part. Phys. 26, 1149(2000).
[44] Yu A Lazarev et al., Phys. Rev. C54, 620(1996).