# THEORETICAL STUDIES ON SYNTHESIS AND DECAY OF SUPERHEAVY ELEMENTS

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## Introduction

An era of study and synthesis of superheavy elements began with the prediction of the existence of an island of stability of long lived superheavy elements in the vicinity Z=126,N=184 by Myers and Swiatecki in 1966.

Elements having atomic number 104 and above, known as transactinides, are considered as superheavy elements (SHE).

Few atoms of SHE are usually experimentally produced and hence conventional chemical methods cannot be adopted to identify them. Understanding the decay modes and knowing the involved half-lives are, hence, of prime importance to identify the decay chains of superheavy elements, which are the experimental signatures of the formation of superheavy elements in total fusion reaction and fusion-evaporation reactions.

There are two different traditional paths to produce heavy elements known as cold fusion and hot fusion.

## Theory

Concepts of cluster radioactivity and cold valley are used which, in turn, are based on quantum mechanical fragmentation theory taking coulomb & proximity potential as interacting barrier, for our study of superheavy nuclei.

## Result

In our work we calculated cluster decay half-lives of many clusters for 25 isotopes ranging from A=270 to A=318 of Z=118. We found that the clusters $^{4}$He, $^{8}$Be, $^{12}$C, $^{14}$C, $^{18}$O, $^{22}$Ne, $^{28}$Mg are more probable for emission.

By making use of half-lives of different radioactive nuclei, neutron and proton shell closures, mainly in the superheavy region are found out. In the case of neutrons, we detected shell closures at N=166,168, 174,154, 162, 152,172,146, in order of strength, in addition to at N= 184 [1]. In the case of protons, shell closure is found to occur at Z=114. We could note that the doubly magic spherical nuclide $^{298}_{184}114$ could exist and is a good candidate for the centre of island of stability.

Making use of a single isotope, using driving potential curve, we deciphered all the shell closures, neutron as well as proton, from N=2 to N=200 and Z=2 to Z=114, for the first time ever [2].

In our work we calculated α-decay half-lives and fission half-lives for many nuclides belonging to superheavy region and heavy region. These half-lives are in good agreement with experimental values.

The range of isotopes in which α-decay shall occur for each even-even element from Z=118 to Z=98 is found out. All the even-even isotopic chains from $^{270\text{-}318}118$ to $^{230\text{-}278}98$, which comprises a total of 275 nuclide, are considered for the purpose [3].

From the above, making use of difference between α-decay half-life and fission decay half-life values we deduced probable α-decay chains that shall occur for the above Z values. In the case of α-decay chains that do not terminate at Z=98 the procedure is taken forward until the chain reaches at isotope at which α-decay is forbidden due to negative Q-value or at isotope which undergo spontaneous fission. Thus we continued up to Z=76.

These α-decay chain shall help to identify the formation of superheavy elements as well as shed light as to which isotope of each Z value is to be attempted, in an effective manner, to produce. We got chains having various probability to be produced. Isotopes belonging to chains with higher probability of formation are having higher probability (Z value remaining the same) to be produced. Simultaneously, isotopes that can be attempted, in an effective manner, to produce, in the case of each Z value from Z=118 to Z=98 was found out. Almost all of the elements produced so far to which official recognition is granted belong to the mass range that we obtained; and many of the elements belong to the chains that are developed. This shall tempt the experimental scientists to produce other atomic masses belonging to the range that we suggested for each element.

We found that in the case of fission half-lives, maximum values of half-lives are obtained to those isotopes which have got N value such that N-Z=52,for elements with Z=118 to Z≥90. This is in true conformity with the experimental observation that there is long life time for spontaneous fission of elements having N=Z+52 with Z≥90.

We also found that, for elements with atomic number below 90, that is, for elements with Z=88 to Z=78, up to which fission half-life is calculated, fission half-life has got least value for those isotopes which has got N value that satisfies the same condition as above. This is worthy of consideration for experimental verification.

Making use of the information that is gathered from our work, about the range of isotopes where synthesis of Z=118 is probable, sets of reactions according to order of possibility for the production of all isotopes in the relevant range of Z=118 have been developed[4]. In the case of production of $^{294}$118,we suggest the following six reactions.

(1)$^{136}$Xe+$^{(158+x)}$Gd → $^{294}$118+xn

(2)$^{126}$Sn+$^{(168+x)}$Er→ $^{294}$118+xn

(3)$^{86}$Kr+$^{(208+x)}$Pb → $^{294}$118+xn

(4)$^{68}$Ni+$^{(226+x)}$Th→ $^{294}$118+xn

(5)$^{48}$Ca+$^{(246+x)}$Cf → $^{294}$118+xn

(6)$^{34}$Si+$^{(260+x)}$Rf → $^{294}$118+xn

In the above reactions, x=0,1,2,3,4 etc.In the case of analyzing $^{294}$118 , the reactions of the type $^{136}$Xe+$^{158}$Gd →$^{294}$118 {reaction(1)} is obtained. However, in the actual situations due to the dynamical nature of bombardment, few neutrons shall be stripped off. In order to take that into account neutron number of the target is increased by x. However, this small increase in the neutron number will not produce any appreciable change in the coulomb barrier (as the radius of the target changes as the cube root of A),which is an important parameter associated with the reaction.

This shall be of use in the production of various isotopes of Z=118 in the future. The set of reactions developed for the nuclide $^{294}$118 (that has been reported to be produced), contains the reaction that is used for the reported production of $^{294}$118. (Reaction no. 5).

We suggests reaction with nearly equal constituents having most low driving potential minimum between them, as the optimal target-projectile combination for the production of SHEs that are yet to be produced. This, indeed, is a new avenue of production of SHEs and may be termed as more-cold fusion method.

We hope that our work shall pave way for producing newer and newer superheavy elements in the future.

**Reference**

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3 K. Pradeep Kumar, Proceedings of the DAE Symposium on Nuclear Physics, Vizagpatnam, India Vol **56**, 396 (2011).

4 K. Pradeep Kumar, K.P. Santhosh and A. Joseph, Proceedings of the DAE Symposium on Nuclear Physics, Delhi, India Vol **57**, 314 (2012).