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The Capping Theory of Chemical Elements and Clusters Based on 4N Series and Skeletal Numbers

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Abstract

The genesis of chemical clusters of the transition and main group elements has been established. The base-line cluster valence electrons has been demarcated with help of capping series. Using the base-line as a reference, the formulas of fragments and clusters were generated. Also a simple general formula for cleating cluster valence electrons for systems ranging from a single skeletal element to hundreds of them was identified. In so doing, the single elements of the periodic table were naturally placed into their respective periods. The concepts of the existence of nuclei in clusters and some having black-holes were deeply rooted. A tentative explanation of some clusters having an octahedral geometry but with low cluster valence electron count was put forward.

Keywords: black-holes, cluster nucleus, baseline, matrix, clan series, family series, genesis, capping electrons, arithmetic progression

1. Introduction

During the analysis and study of the clusters using the 4N series method, it was found that the clusters have three main characteristic series. These are: the one characterized by $\Delta K = \pm 2$, $\Delta n = \pm 1$; the other, $\Delta K = \pm 1$, $\Delta n = 0$; and the last by $\Delta K = \pm 3$, $\Delta = \pm 1$(Kiremire, 2017).The last series corresponds to the correlation scheme that was introduced by Rudolph about 40 years ago(Rudlph, 1976) and still widely directly or indirectly cited(Housecroft and Sharpe,2005). On closer scrutiny, these series also in agreement with Wade-Mingos rules and PSEPT concepts of n+1, n+2 and n+3 rules or n, n-1, n-2, n-3 vertices series(Wade,1971;Mingos, 1972,1984,1991). The series associated with $\Delta K = 3$ has been found useful and hence utilized to broadly classify clusters into [Mx] groups or CLANS. The [Mx] baseline corresponds to the closo series. For instance, [M1] corresponds to $B_1H_1^{2-}$;[M2]→$B_2H_2^{2-}$;[M3]→$B_3H_3^{2-}$;[M4]→ $B_4H_4^{2-}$;[M5]→ $B_5H_5^{2-}$;[M6]→ $B_6H_6^{2-}$;[M7]→ $B_7H_7^{2-}$;[M8] → $B_8H_8^{2-}$;[M9] → $B_9H_9^{2-}$;[M10] → $B_9H_9^{2-}$;[M10]→$B_{10}H_{10}^{2-}$;[M11] → $B_{11}H_{11}^{2-}$;[M12] → $B_{12}H_{12}^{2-}$;and so on. Each of these [Mx] values has a corresponding K(n) parameter and cluster valence electrons component, VE. The objective of this paper is to investigate the origin of the [Mx] series. Do the K(n) which correspond to K(0) parameters possess cluster valence electrons?

2. Results and Discussion

In this section, it is important this stage to compare and contrast the application of the 4N series method of categorizing and structural prediction of clusters with other literature methods by using a few selected examples as illustrations. The analysis of clusters will be done using skeletal numbers which have recently been introduced (Kiremire, 2017a-e). The use of skeletal numbers has been found to be easy, fast and precise and therefore it is better to have them at the begging of the paper for ease of reference and are given in Tables T- and T-2 for main group and transition metals respectively.

Table 1. Skeletal numbers of the Main Group Elements

1	**Li**	**Na**	**K**	**Rb**	**Cs**	**3.5**
2	**Be**	**Mg**	**Ca**	**Sr**	**Ba**	**3**
3	**B**	**Al**	**Ga**	**In**	**Tl**	**2.5**
4	**C**	**Si**	**Ge**	**Sn**	**Pb**	**2**
5	**N**	**P**	**As**	**Sb**	**Bi**	**1.5**
6	**O**	**S**	**Se**	**Te**	**Po**	**1**
7	**F**	**Cl**	**Br**	**I**	**At**	**0.5**
8	**Ne**	**Ar**	**Kr**	**Xe**	**Rn**	**0**

Table 2. Skeletal Numbers of Transition Metals

T-2			
Sc	**Y**	**La**	**7.5**
Ti	**Zr**	**Hf**	**7**
V	**Nb**	**Ta**	**6.5**
Cr	**Mo**	**W**	**6**
Mn	**Tc**	**Re**	**5.5**
Fe	**Ru**	**Os**	**5**
Co	**Rh**	**Ir**	**4.5**
Ni	**Pd**	**Pt**	**4**
Cu	**Ag**	**Au**	**3.5**
Zn	**Cd**	**Hg**	**3**

Comparing and contrasting the 4N series method with other methods

Ex-1: $B_6H_6^{2-}$**:** K =6[2.5]-6[0.5]-2[0.]=11, n=6, K(n)=11(6), S=4n+2, K=2n-1, Kp=C^0C[M6],Ve=4n+2= 4(6)+2 = 26, VF=6[3]+6[1]+2=26. The symbols Ve and VF represents the cluster valence electrons calculated from cluster series formula and cluster molecular formula respectively. The cluster series S=4n+2 belongs to the CLOSO cluster family and [M6] clan of clusters. It has an ideal octahedral geometry as reported in literature(Housecroft & Sharpe, 2005).

Ex-2: B_5H_9: K=5[2.5]-9[0.5]=8, n= 5, K(n) =8(5), S=4n+4→NIDO cluster family; K=2n-2, Kp = C^{-1}C[M6]-the cluster is missing one skeletal element to belong to the CLOSO clan [M6]; Ve= 4n+4 = 4(5)+4 = 24, Ve= 8n-2K =8(5)-2(8)=24,Ve=4+2x+2(n-1) =4+2(6)+2(5-1)=24, VF=5[3]+9=24.

Ex-3: $Os_6(C0)_{18}$:K=6[5]-18=12, K(n)=12(6), S=4n+0, K=2n+0, Kp = C^1C[M5]→the cluster is a MONO-CAPPED trigonal bipyramid. This is as found in literature(Hughes&Wade,2000).The cluster valence content Ve= 14n+0 = 14(6)+0 =84,Ve= 18n-2K = 18(6)-2(12) = 84,Ve=14+2x+12(n-1) =14+2(5)+12(6-1)= 84, VF=6[8]+18[2]=84.

Ex-4: $Os_8(CO)_{22}^{2-}$:K=8[5]-22-1=17,n=8, K(n)=17(8), S=4n-2, K=2n+1, Kp=C^2C[M6] → BI-CAPPED octahedral geometry; Ve=14n-2=14(8)-2=110, Ve=18n-2K=18(8)-2(17)=110, Ve=14+2x+12(n-1)=14+2(6)+12(8-1)=110, VF=8[8]+22[2]+2=110.

Ex-5: $Rh_9(CO)_{19}^{3-}$: K = 9[45]-19-1.5=20, n= 9, K(n) =20(9), S=4n-4,K+2n+2, Kp =C^3C[M6]→TRI-CAPPED octahedral geometry. Ve=14n-4=14(9)-4=122, Ve=18n-2K=18(9)-2(20)=122, Ve=14+2x+12(n-1)=14+2(6)+12(9-1)=122, VF=9[9]+19[2]+3=122. This result is the similar to the one obtained for the cluster F=$Os_9(CO)_{24}^{2-}$: K=9[5]-24-1=20, K(n)=20(9) which is a triply capped octahedraon (Hughes&Wade,2000).

Ex-6 There has been a practice of matching some geometric shapes with cluster valence(Housecroft & Sharpe, 2005). In this way, the observed shape of $Rh_9(CO)_{19}^{3-}$ was matched with Ve=124(Housecroft & Sharpe, 2005). However, according to series, Ve=124=18n-2K=18(9)-2K; 2K =18(9)-124=38, K=19; hence K(n)=19(9), S=4n-2, K=2n+1, Kp=C^2C[M7] predicts an ideal shape is a BI-CAPPED pentagonal bipyramid.

Ex-7. $H_5Re_6(CO)_{24}^{-}$was found to have a structure similar to that of cyclohexane. Its K value is given by :K=6[5.5]-2.5-24-0.5=6,n=6, K(n)=6(6), S=4n+12, K=2n-6, Kp=C^{-5}[M11]→it belongs to the CLUSTER CLAN, [M11] with 5 missing skeletal elements; Ve= 14n+12 = 14(6)+12=98. The hydrocarbon cyclohexane, C_6H_{12}, has K=6[2]-12[0.5]=6,n=6 and K(n) =6(6); therefore it belongs to the same clan and family of clusters. Hence, it is not surprising that it has a similar skeletal shape as the rhenium cluster **(**Housecroft & Sharpe, 2005). In addition, the series method has successfully been applied to the analysis of Zintl ion clusters, the clusters of gold skeletal element, Matryoshka clusters, metalloboranes and others (Kiremire.2016a-b, 2018).

The K(n) Parameter

The K value of a cluster assumes greater meaning when it is associated with its corresponding number of skeletal elements(n). Hence, the concept of K(n) parameter was introduced**.(**Kiremire,2018). Let us consider the [M12] closo cluster. It belongs to the

S=4n+2 series where K=2n-1=2(12)-1=23 and hence K(n) =23(12); VE =8n-2K =8[12]-2[23] =50 for the main group elements, VE =18n-2K = 18(12)-2[23] =170 for transition elements.

What happens when n=0? Do the series still possess some cluster valence electrons when n =0? In the case of [M12], the

K(n) series are: 23(12)→20(11) →17(10) →14(9) →11(8) →8(7)→5(6)→2(5)→-1(4)→-4(3)→-7(2)→-10(1)→-13(0). We can transform these K(n) values into required clusters. Let us use borane clusters as illustrations. The K(n) =23(12) can be changed into series S=4n+2, the digit [4] represents a [BH] building block for borane cluster series, n=12, the digit [2] corresponds to [2H]. Hence the cluster is given by F =[BH](12)+2H =$B_{12}H_{14}[B_{12}H_{12}^{2-}]$. The next K(n) value is 20(11) which belongs to the series S=4n+4. This can be corresponds to the borane F= [BH](11)+4H = $B_{11}H_{15}$. The remaining successive borane clusters are as follows: K(n) =17(10)→$B_{10}H_{16}$; 14(9)→B_9H_{17};11(8)→B_8H_{18};8(7)→B_7H_{19};5(6)→B_6H_{20};2(5)→B_5H_{21};-1(4)→B_4H_{22};-4(3)→B_3H_{23};-7(2)→B_2H_{24};-10(1)→ B_1H_{25};-13(0)→B_0H_{26}=26H. This gives us some very important information that in order to generate the [M12] cluster series, we must have 26H =26e as the BASELINE=2n+2. That is, [M12]→K(n) BASELINE = -13(0)= 26H=26e. We can also derive this value using the KN cluster valence electrons formula as follows; VE =8(0)-2(-13)=26= 26e or 26 H or 13L(ligands) in case of main group elements. In case of transition metals, VE =18(0) -2(-13) = 26 = 26e or 13L (ligands). The beginning is exactly the same as that of the main group elements. We can call the 26 electron component or its equivalent as the genesis of the [M12] cluster series for both the main group and transition metal elements. This value could also have been obtained from the series formulas, S = 4n+26 and S = 14n+26 when all skeletal elements have been de-capped until the [M12] closo fragment has completely been dismantled (n=0). This gives us a very important natural law of clusters.

The genesis principle of clusters: the cluster valence electrons for closo [MX] series is the same for both main group and transtion elements when k(0) is obtained. The objective of this paper is to examine the de-capping cluster family series below the closo baseline.

The difference between the main group elements and transition metal then comes about as a result of the difference in the value of the capping functions of [2e] versus [12e] which is [10e]. Hence, the series for main group elements is S =4n+q while that of transition metals is S = [4+10]n+q = 14n+q. We can also further illustrate using boron, osmium and palladium skeletal elements. If we assume the process occurs step-wise, then we generate the Schemes 1-3.

The capping process from x=0 UP TO THE x=12:-The [M12] closo fragment

$26H \rightarrow [BH^{2+}]H_{26} \rightarrow [BH^{2+}]_2H_{26} \rightarrow [BH^{2+}]_3H_{26} \rightarrow [BH^{2+}]_4H_{26} \rightarrow [BH^{2+}]_5H_{26} \rightarrow [BH^{2+}]_6H_{26}$
$BH^{2+}]_7H_{26} \rightarrow [BH^{2+}]_8H_{26} \rightarrow [BH^{2+}]_9H_{26} \rightarrow [BH^{2+}]_{10}H_{26} \rightarrow [BH^{2+}]_{11}H_{26} \rightarrow [BH^{2+}]_{12}H_{26}$

$[BH^{2+}]_{12}H_{26}$=12B+12H-24H+26H =$B_{12}H_{14}$= $B_{12}H_{12}^{2-}$.

Scheme 1. The capping process for boron clan [M12].

The osmium analogous cluster series:

13L =13CO

$13CO \rightarrow [Os(CO)_2]_1(CO)_{13} \rightarrow [Os(CO)_2]_2(CO)_{13} \rightarrow [Os(CO)_2]_3(CO)_{13} \rightarrow [Os(CO)_2]_4(CO)_{13} \rightarrow [Os(CO)_2]_5(CO)_{13} \rightarrow [Os(CO)_2]_6(CO)_{13} \rightarrow [Os(CO)_2]_7(CO)_{13} \rightarrow [Os(CO)_2]_8(CO)_{13} \rightarrow [Os(CO)_2]_9(CO)_{13} \rightarrow [Os(CO)_2]_{10}(CO)_{13} \rightarrow [Os(CO)_2]_{11}(CO)_{13} \rightarrow [Os(CO)_2]_{12}(CO)_{13} = Os_{12}(CO)_{37}$

Scheme 2. The capping process for osmium carbonyl cluster clan [M12]

The palladium analogous cluster series:

$13CO \rightarrow [Pd(CO)]_1(CO)_{13} \rightarrow [Pd(CO)]_2(CO)_{13} \rightarrow [Pd(CO)]_3(CO)_{13} \rightarrow [Pd(CO)]_4(CO)_{13} \rightarrow [Pd(CO)]_5(CO)_{13} \rightarrow [Pd(CO)]_6(CO)_{13} \rightarrow [Pd(CO)]_7(CO)_{13} \rightarrow [Pd(CO)]_8(CO)_{13} \rightarrow [Pd(CO)]_9(CO)_{13} \rightarrow [Pd(CO)]_{10}(CO)_{13} \rightarrow [Pd(CO)]_{11}(CO)_{13} \rightarrow [Pd(CO)]_{12}(CO)_{13} \rightarrow Pd_{12}(CO)_{25}$

Scheme 3. The capping process for palladium carbonyl clan [M12].

The capping fragments

$[BH]^{2+}$; K=[2.5-0.5]+1=3; VE=2

$[Os(CO)_2]$; K=5-2=3; VE=12

Pd(CO); K=4-1=3; VE=12

The K values of equivalent or isolobal clusters of the [M12] clan series.

$B_{12}H_{12}^{2-}$;K=12[2.5]-6-1=23= [-13+12(3)]=23

$Os_{12}(CO)_{37}$; K=12[5]-37=23=[-13]+ 12(3)]=23

$[Pd_{12}(CO)_{25}$;K=12[4]-25=23= [-13+12(3)]=23

Thus, the K values are the same and K(n) =23(12) is the same.

The K(n) values of the CLOSO clan series [Mx], x=12 to -4 have been tabulated in matrix form for the family series

S=4n+2 to S=4n+16. These are shown in Table3. The corresponding cluster valence electrons are depicted in in matrix form in Tables 4 for the CLAN series [Mx] x=6 to -6 and clusters family series S =4n-12 to S=4n+26 and the [Mx] CLANS, x=2 to -8 and families S=4n-12 to S= 4n+20 respectively.

2.1 Decapping Series

The de-capping series of [M12] clan of clusters show that the starting point is equivalent to 26e,26H or 13 two-electron ligands such as CO or PR_3. Applying this knowledge to the capping process from the beginning for the clan series [M12] for boranes, osmium and palladium we get the hypothetical fragments indicated in schemes 1 to 3 which for boranes gives us the expected $B_{12}H_{12}^{2-}$, osmium, $Os_{12}(CO)_{37}$,and palladium, $Pd_{12}(CO)_{25}$. A selected portion of K(n) de-capping process for [M7] to [M0] is shown in Table 1. The corresponding K values when n=0 are found to be -8 for [M7], -7 for [M6], -6 for [M5], -5 for [M4], -4 for [M3], -3 fo[M2], -2 for[M1] and -1 for [M0]. When these K(0) values are translated into cluster valence electrons are found to be +16e for [M7], +14e for [M6], +12e for [M5],+10e for [M4], +8e for [M3], +6e for[M2], +4e for [M1] and +2e for [M0]. This information is summarized in Scheme 4. It is clear from the sequence of these cluster valence electron values, we can formulate a general equation, for [Mx] clan, The genesis clustr valence electrons are givn by ve= 2x+2 electrons.

2.2 Decapping Electron Series

The discovery of de-capping series of electrons when n=0 for the [Mx] cluster clans, stimulated further investigations. Knowing the fact that the capping or de-capping phenomena involves a set of [12e] at each step, a matrix Table 2 of cluster valence electrons was easily generated by x-cell program. In this discussion, let us keep Table as a reference matrix. Let us regard, the horizontal lines labeled S =4n+q , where q is a variable determinant, as the CLUSTER FAMILIES and the vertical lines as Cluster Clan Families based on [Mx] where [Mx] refers to S=4n+2 [Closo Clan] cluster series, then it becomes easier to analyze the sequence of the capping or de-capping series. For instance, [M6] will mean all the cluster valence electron series in the COLUMN and centered around the cluster valence electrons 86 whose K(n) parameter is 11(6). Then [M5] will refer to the column centered around cluster valence [72] with the corresponding K(n) value of 9(5), [M4]→58,K(n)=7(4), and so on. Thus, the horizontal closo baseline family series, S =4n+2, [Mx] highlighted in blue has x = 6,5,4, 3, 2, 1, 0, -1, -2, -3, -4, -5 and -6. The diagonal baseline cluster valence electron baseline, ve[x] is highligted in red. The diagonal VE[x] sets are, 14[6], 12[5], 10[4], 8[3], 6[2], 4[1], 2[0], 0[-1], -2[-2], -4[-3], -6[--4], -8[-5], and -10[-2]. If this diagonal series is carefully observed, it corresponds to a nice relationship VE =2x+2.

The columns represent capping or de-capping series involving sets of [12e] for each step. These columns represent clan series. The horizontal lines represent another type of capping or de-capping series involving sets of [14e] at each step. These are members of cluster families and the closo family baseline gives the reference for categorizing clusters into clans. All the numbers below and including those on the red diagonal are simply capping/de-caaping series of [12e] electron sets. This concept is summed up in Figure 1. These baseline cluster valence electrons which act the foundation of cluster series are shown in Tables 2 and high-lighted in red. Furthermore, similar information has been extracted and presented in Table 3 for ease of reference. In order to get more information about the de-capping series, the expanded forms of Table 1 were constructed. These are given in Tables 4 for clan series [M2] to [M-8] and Table 5 for [M2] to [M-11].

ABOVE {[Mx], x≥1} CLUSTERS

Consider the step VE[n]: 86[6]→98[7]. This refers to the mono-capped series of octahedral-based nuclear structure. The known clusters include(Hughes&Wade,2000).* $Os_7(CO)_{21}$ and $Re_7(C)(CO)_{21}^{3-}$. The next step will be 110[8]. These are bi-capped octahedral clusters. The examples include, $Re_8(C)(CO)_{24}^{2-}$ and $Os_8(CO)_{22}^{2-}$. The process can go on and on. For instance, the cluster $Pt_6Ni_{38}(CO)_{48}(H)^{5-}$,VE(n)= 542[44], Kp= C^{38}C[M6] has an octahedral nucleus comprising of 6 platinum skeletal elements(Rossi &Zanello,2011) . All these cluster series based upon [M6] nucleus begin with +14e[the genesis] when n=0. Also, the [M1] cluster series begin with +4e. The series include VE[n]=76[6];

$Au_6L_6^{2+}$ and $Rh_6L_6H_{12}^{2+}$; Kp= C^5C[M1]. Other clusters of [M1] clan include, 100[8]: $Au_8L_7^{2+}$, 112[9]: $Au_9L_8^{3+}$, and 136[11]: $Au_{11}L_{10}^{5+}$.

If we analyze Table 2 carefully, some discerning features come out. The demarcation for capping clusters is the Closo Baseline S=4n+2 highlighted in blue. The demarcation for the foundation electrons (Cluster Genesis) from where the skeletal elements start capping is a diagonal highlighted in red.

[M6]→VE[n]: 86[6] →74[5] →62[4] →50[3] →38[2] →26[1] →**14[0]**≡ -6[12]=-72e≡[-6 dozens]

[M5] →VE[n]:72[5] →60[4] →48[3] →36[2] →24[1]→**12[0]**≡-5[12]= -60e≡ [-5 dozens]

[M4] →VE[n]:58[4] →46[3] →34[2] →22[1] →**10[0]**≡-4[12]=-48e≡[-4 dozens]

[M3]→VE[n]:44[3] →32[2] →20[1] →**8[0]**≡-3[12]=-36e≡[-3 dozens]

[M2] →VE[n]: 30[2] →18[1] →**6[0]**≡-2[12]=-24e≡[-2 dozens]

[M1] →VE[n]:16[1] →**4[0]**≡-1[12]=-12e≡ [-1 dozen]

Scheme 4. The genesis of cluster valence electron parameters for [M6] to [M1] clan series

2.3 The [Mx],x≤-1] Clusters:-The Existance of Blackholes in Some Cluster Nuclei

Let us consider the cluster $Pd_{39}(CO)_{23}L_{16}$, VE[n]=468[39], Kp= C^{40}C[M-1]. This means there is ONE capping of 12 skeletal electrons [SEL] in the cluster nucleus. The 39 skeletal elements are capped outside the nucleus making a total of 40 cappings,C^{40}. The 12 electrons in the nucleus may be regarded as the number of electrons needed to stabilize the cluster nucleus so as to allow the addition of skeletal elements to be added on. The CLOSO nucleus electrons of the cluster CNE=14n+2, n= -1, CNE =14[-1]+2 = -12. The ground level capping electrons G_0= [-1+1]L= 0. Hence, the step CNE→G_0: -12e→0e requires an input of 12e [+12e]. The formation of the cluster will therefore require +39 cappings. This corresponds to 39[12] =468e. Since the nucleus requires 12e to be added into it before the skeletal elements can begin to be added on, it has a black-hole.

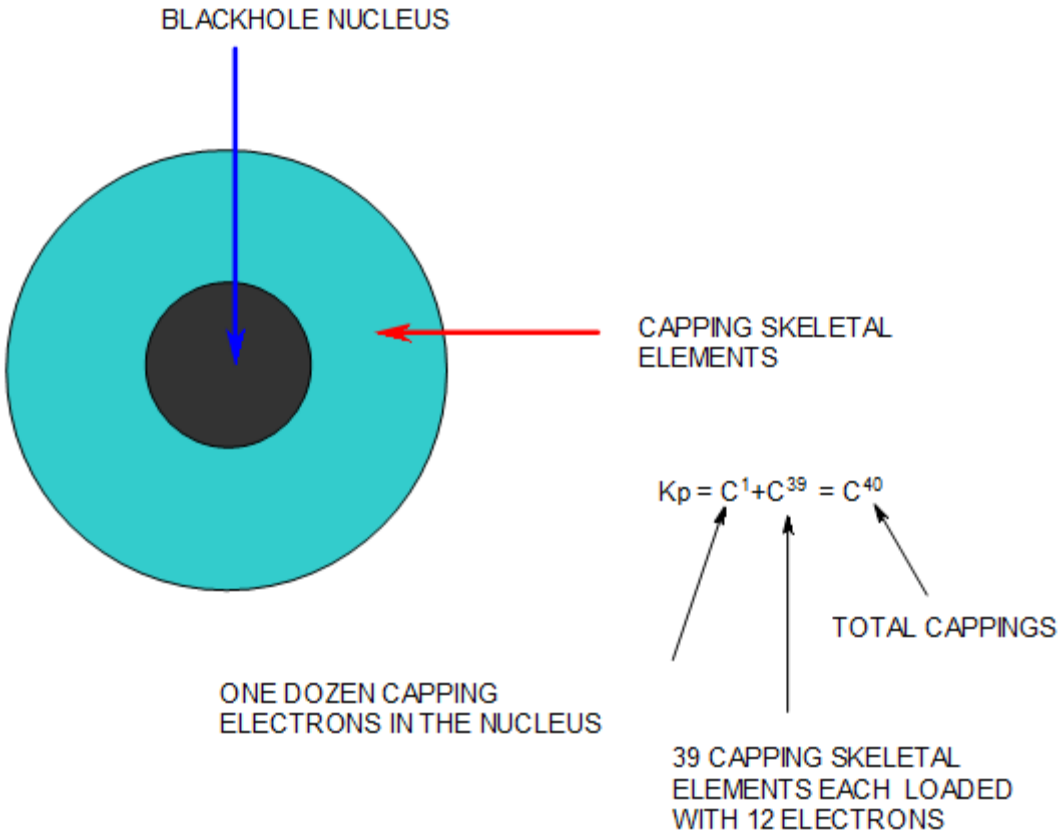


Figure 1. A hypothetical model of a cluster with a black-hole nucleus of $Pd_{39}(CO)_{23}L_{16}$

The above explanation can be applied to other clusters which have negative nuclear indices. A selected sample of these is given in the scheme below and illustrated in Figure*.

2.4 Black Holes

[M-1]→VE[n]: -12[-1]→0[0]≡ 1[+12]= +12e ≡ [+1 dozen]

[M-2]→VE[n]: -26[-2] →-14[-1] →-2[0]≡2[+12]=+24e≡[+2 dozens]

[M-3] →VE[n]: -40[-3] →-28[-2] →-16[-1] →-4[0]≡3[+12] =+36e≡[+3 dozens]

[M-4] →VE[n]:-54[-4] →-42[-3] →-30[-2] →-18[-1] →-6[0]≡4[+12]=+48e≡[+ 4 dozens]

[M-5] →VE[n]:-68[-5] →-56[-4] →-44[-3] →-32[-2] →-20[-1] →-8[0] ≡5[+12] =+60e≡[+5 dozens]

[M-6] →VE[n]: -82[-6] →-70[-5] →-58[-4] →-46[-3] →-34[-2] →-22[-1] →-10[0]≡6[+12]= +72e≡ [+ 6 dozens]

Scheme 5. The genesis of cluster valence electrons of [M-1] to [M-6] clan series

We can regard [M-1] as cluster with a nucleus with a black-hole to be filled 1ith 1 dozen electrons before capping phenomenon commences. For the [M-2] nucleus, 2 dozens, [M-3]→3 dozens,[M-4]→4 dozens, and so on. This concept is illustrated in Figure***. Thus, the black-holes are associated with negative nuclear indices.

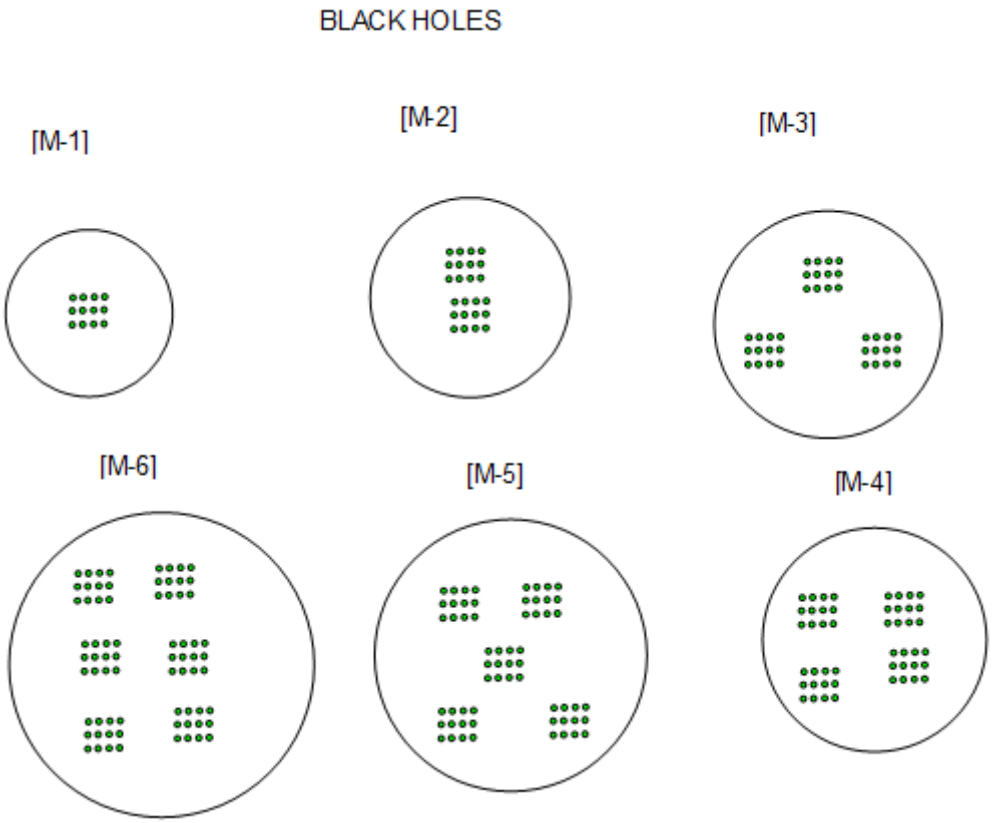


Figure 2. Illustrations of black hole concept in a cluster

Other clusters with black-holes have been analyzed and are presented below.

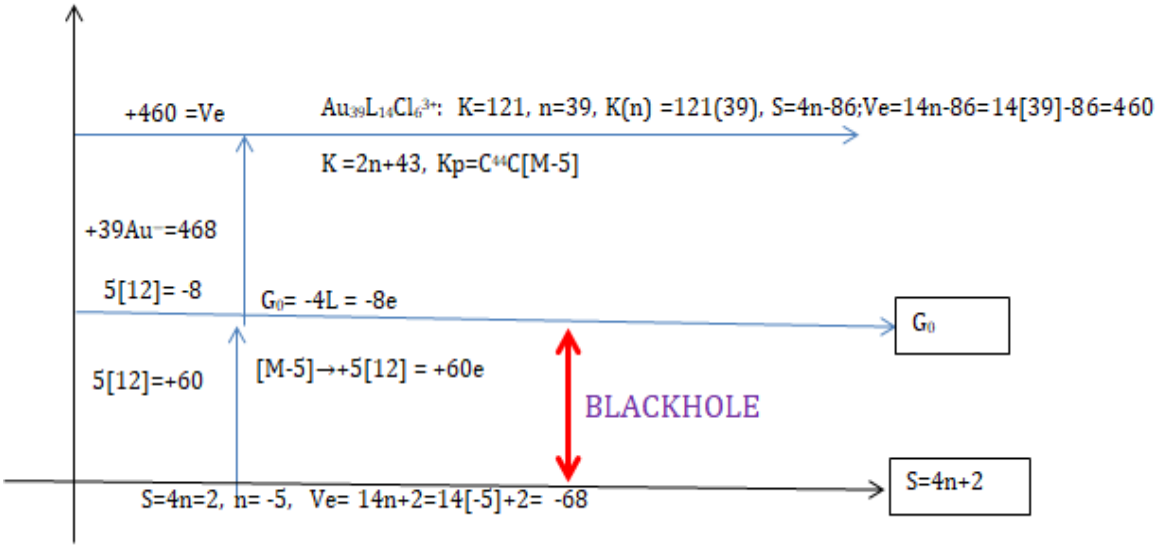


Figure 3. Illustrating the nature of a black-hole in the cluster nucleus

F= n[F_0]+G_0= 39[Au^-]+ [-4L]= $Au_{39}R_{39}$-8R=$Au_{39}R_{31}$=$Au_{39}L_{14}Cl_6^{3+}$

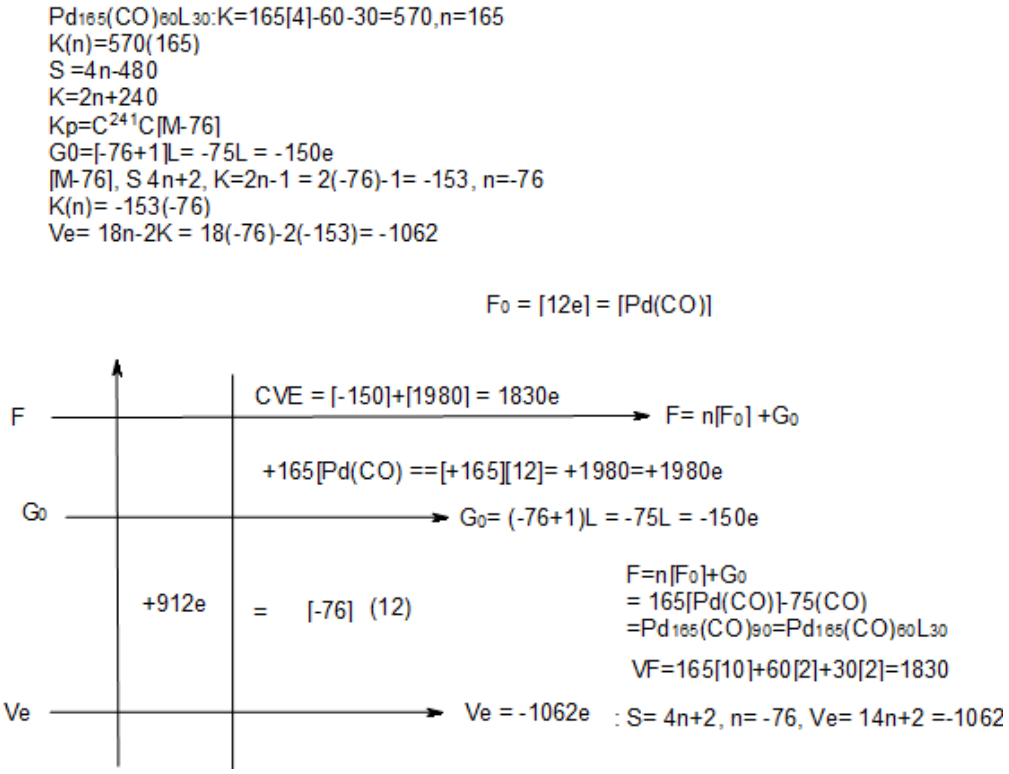


Figure 4. A hypothetical model demonstrating the origin of a black-hole cluster nucleus

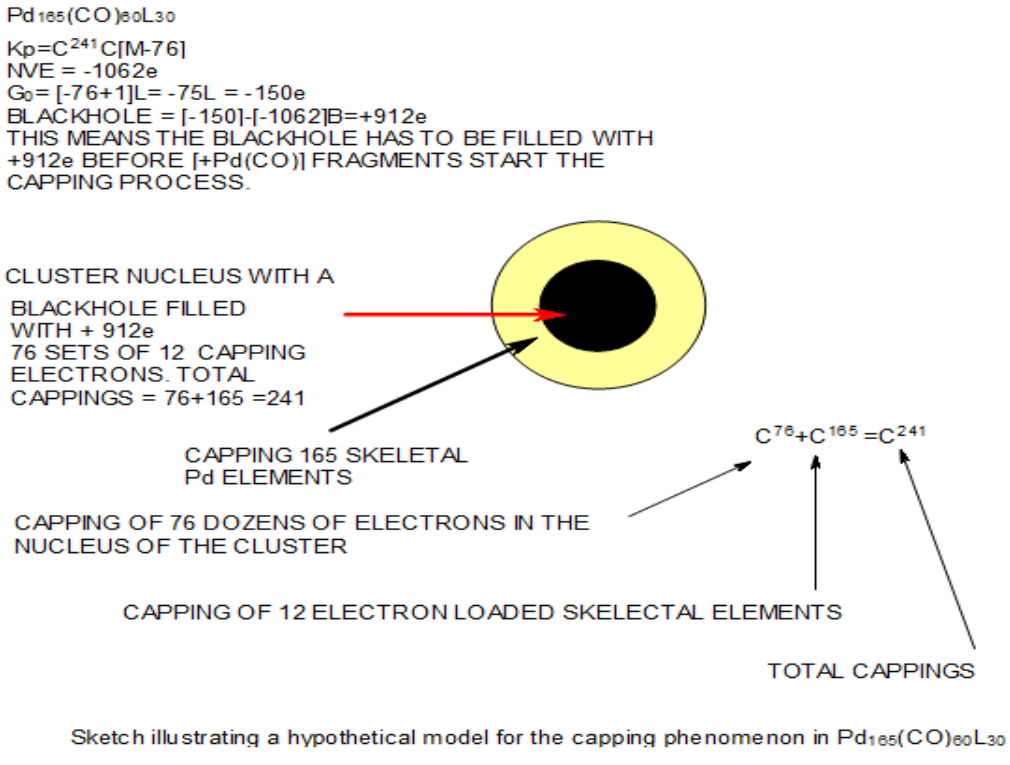


Figure 5. Diagram showing the relationship between the capping electron sets and skeletal elements

Table 3. Selected baseline components of k(n) values for [Mx] series: x =12 TO x= -3

	$C^{0}C[Mx]$	$C^{-1}C[Mx]$	$C^{-2}C[Mx]$	$C^{-3}C[Mx]$	$C^{-4}C[Mx]$	$C^{-5}C[Mx]$	$C^{-6}C[Mx]$	$C^{-7}C[Mx]$
[Mx]	**4n+2**	**4n+4**	**4n+6**	**4n+8**	**4n+10**	**4n+12**	**4n+14**	**4n+16**
12	23(12)	20	17	14	11	8	5	2
11	21(11)	18	15	12	9	6	3	0
10	19(10)	16	13	10	7	4	1	-2
9	17(9)	14	11	8	5	2	-1	-4
8	15(8)	12	9	6	3	0	-3	-6
7	**13(7)**	**10(6)**	**7(5)**	**4(4)**	**1(3)**	**-2(2)**	**-5(1)**	**-8(0)**
6	**11(6)**	**8(5)**	**5(4)**	**2(3)**	**-1(2)**	**-4(1)**	**-7(0)**	**-10(-1)**
5	**9(5)**	**6(4)**	**3(3)**	**0(2)**	**-3(1)**	**-6(0)**	**-9**	**-12**
4	**7(4)**	**4(3)**	**1(2)**	**-2(1)**	**-5(0)**	**-8**	**-11**	**-14**
3	5(3)	2(2)	-1(1)	-4(0)	-7	-10	-13	-16
2	3(2)	0(1)	**-3(0)**	-6	-9	-12	-15	-18
1	1(1)	**-2(0)**	-5	-8	-11	-14	-17	-20
0	**-1(0)**	-4	-7	-10	-13	-16	-19	-22
-1	-3(-1)	-6	-9	-12	-15	-18	-21	-24
-2	-5(-2)	-8	-11	-14	-17	-20	-23	-26
-3	-7(-3)	-10	-13	-16	-19	-22	-25	-28
-4	-9(-4)	-12	-15	-18	-21	-24	-27	-30

Selected baseline cluster valence electrons

K(n)=-8(0): Ve = 18n-2K= 18(0)-2(-8) = +16 ≡**+16e**→[M7]

K(n)=-7(0): Ve= 18n-2K = 18(0)-2(-7) = +14 ≡**+14e**→[M6]

K(n)= -6(0): Ve = 18n-2K = 18(0)-2(-6)= +12 ≡ **+12e**→[M5]

K(n)= -5(0): Ve= 18n-2K = 18(0)-2(-5) =+10 ≡ **+10e**→[M4]

K(n) = -4(0): Ve= 18n-2K = 18(0)-2(-4)= +8 ≡ **+8e**→[M3]

K(n) = -3(0): Ve = 18n-2K = 18(0)-2(-3) = +6 ≡**+6e**→[M2]

K(n) = -2(0): Ve = 18n-2K = 18(0)-2(-2)= +4 ≡ **+4e**→[M1]

K(n) = -1(0): Ve = 18n-2K = 18(0)-2(-1)= +2 ≡ **+2e**→[M0]

For a cluster clan, [Mx], Ve= 2x+2.

Scheme 6. The baseline cluster valence electrons for the [M0] to [M6] clan series

CLUSTER VALENCE ELECTRONS MATRIX FOR DECAPPING SERIES

[T-4]													[Mx]	
x-12	x-11	x-10	x-9	x-8	x-7	x-6	x-5	x-4	x-3	x-2	x-1	x		S
2	16	30	44	58	72	86	100	114	128	142	156	170	13	4n-12
-10	4	18	32	46	60	74	88	102	116	130	144	158	12	4n-10
-22	-8	6	20	34	48	62	76	90	104	118	132	146	11	4n-8
-34	-20	-6	8	22	36	50	64	78	92	106	120	134	10	4n-6
-46	-32	-18	-4	10	24	38	52	66	80	94	108	122	9	4n-4
-58	-44	-30	-16	-2	12	26	40	54	68	82	96	110	8	4n-2
-70	-56	-42	-28	-14	0	14	28	42	56	70	84	98	7	4n+0
-82	-68	-54	-40	-26	-12	2	16	30	44	58	72	86	6	4n+2
-94	-80	-66	-52	-38	-24	-10	4	18	32	46	60	74	5	4n+4
-106	-92	-78	-64	-50	-36	-22	-8	6	20	34	48	62	4	4n+6
-118	-104	-90	-76	-62	-48	-34	-20	-6	8	22	36	50	3	4n+8
-130	-116	-102	-88	-74	-60	-46	-32	-18	-4	10	24	38	2	4n+10
-142	-128	-114	-100	-86	-72	-58	-44	-30	-16	-2	12	26	1	4n+12
-154	-140	-126	-112	-98	-84	-70	-56	-42	-28	-14	0	14	0	4n+14
-166	-152	-138	-124	-110	-96	-82	-68	-54	-40	-26	-12	2	-1	4n+16
-178	-164	-150	-136	-122	-108	-94	-80	-66	-52	-38	-24	-10	-2	4n+18
-190	-176	-162	-148	-134	-120	-106	-92	-78	-64	-50	-36	-22	-3	4n+20
-202	-188	-174	-160	-146	-132	-118	-104	-90	-76	-62	-48	-34	-4	4n+22
-214	-200	-186	-172	-158	-144	-130	-116	-102	-88	-74	-60	-46	-5	4n+24
-226	-212	-198	-184	-170	-156	-142	-128	-114	-100	-86	-72	-58	-6	4n+26
[M-6]	[M-5]	[M-4]	[M-3]	[M-2]	[M-1]	[M0]	[M1]	[M2]	[M3]	[M4]	[M5]	[M6]		

Capping Level

First skeletal Element level

Foundation electrons level

Table 5. The relationship between the nuclearity index and base-line electrons (VE0)

[Mx]	VE0	[Mx]	VE0
20	**42**	-1	**0**
19	**40**	-2	**-2**
18	**38**	-3	**-4**
17	**36**	-4	**-6**
16	**34**	-5	**-8**
15	**32**	-6	**-10**
14	**30**	-7	**-12**
13	**28**	-8	**-14**
12	**26**	-9	**-16**
11	**24**	-10	**-18**
10	**22**	-11	**-20**
9	**20**	-12	**-22**
8	**18**	-13	**-24**
7	**16**	-14	**-26**
6	**14**	-15	**-28**
5	**12**	-16	**-30**
4	**10**	-17	**-32**
3	**8**	-18	**-34**
2	**6**	-19	**-36**
1	**4**	-20	**-38**
0	**2**	-21	**-40**
[Mx]→VE=2x+2			

Table 6. The variation of cluster valence electron content as the nuclearity index varies

x-14	**x-13**	**x-12**	**x-11**	**x-10**	**x-9**	**x-8**	**x-7**	**x-6**	**x-5**	**x-4**	**x**	
-26	**-12**	**2**	**16**	**30**	**44**	**58**	**72**	**86**	**100**	**114**	**13**	**4n-12**
-38	**-24**	**-10**	**4**	**18**	**32**	**46**	**60**	**74**	**88**	**102**	**12**	**4n-10**
-50	**-36**	**-22**	**-8**	**6**	**20**	**34**	**48**	**62**	**76**	**90**	**11**	**4n-8**
-62	**-48**	**-34**	**-20**	**-6**	**8**	**22**	**36**	**50**	**64**	**78**	**10**	**4n-6**
-74	**-60**	**-46**	**-32**	**-18**	**-4**	**10**	**24**	**38**	**52**	**66**	**9**	**4n-4**
-86	**-72**	**-58**	**-44**	**-30**	**-16**	**-2**	**12**	**26**	**40**	**54**	**8**	**4n-2**
-98	**-84**	**-70**	**-56**	**-42**	**-28**	**-14**	**0**	**14**	**28**	**42**	**7**	**4n+0**
-110	**-96**	**-82**	**-68**	**-54**	**-40**	**-26**	**-12**	**2**	**16**	**30**	**6**	**4n+2**
-122	-108	-94	-80	-66	-52	-38	-24	-10	**4**	18	5	4n+4
-134	-120	-106	-92	-78	-64	-50	-36	-22	-8	**6**	4	4n+6
-146	-132	-118	-104	-90	-76	-62	-48	-34	-20	-6	3	4n+8
-158	-144	-130	-116	-102	-88	-74	-60	-46	-32	-18	2	4n+10
-170	-156	-142	-128	-114	-100	-86	-72	-58	-44	-30	1	4n+12
-182	-168	-154	-140	-126	-112	-98	-84	-70	-56	-42	0	4n+14
-194	-180	-166	-152	-138	-124	-110	-96	-82	-68	-54	-1	4n+16
-206	-192	-178	-164	-150	-136	-122	-108	-94	-80	-66	-2	4n+18
-218	-204	-190	-176	-162	-148	-134	-120	-106	-92	-78	-3	4n+20
[M-8]	**[M-7]**	**[M-6]**	**[M-5]**	**[M-4]**	**[M-3]**	**[M-2]**	**[M-1]**	**[M0]**	**[M1]**	**[M2]**		

Table 7. The extension of Table 6 upwards

x-17	x-16	x-15	x-14	x-13	x-12	x-11	x-10	x-9	x-8	x-7	**x-6**	**x-5**	x-4	x	S
76	90	104	118	132	146	160	174	188	202	216	230	244	258	25	4n-36
64	78	92	106	120	134	148	162	176	190	204	218	232	246	24	4n-34
52	66	80	94	108	122	136	150	164	178	192	206	220	234	23	4n-32
40	54	68	82	96	110	124	138	152	166	180	194	208	222	22	4n-30
28	42	56	70	84	98	112	126	140	154	168	182	196	210	21	4n-28
16	30	44	58	72	86	100	114	128	142	156	170	184	198	20	4n-26
4	18	32	46	60	74	88	102	116	130	144	158	172	186	19	4n-24
-8	6	20	34	48	62	76	90	104	118	132	146	160	174	18	4n-22
-20	-6	8	22	36	50	64	78	92	106	120	134	148	162	17	4n-20
-32	**-18**	-4	10	24	38	52	66	80	94	108	122	136	150	16	4n-18
-44	**-30**	**-16**	-2	12	26	40	54	68	82	96	110	124	138	15	4n-16
-56	**-42**	**-28**	**-14**	0	14	28	42	56	70	84	98	112	126	14	4n-14
-68	**-54**	**-40**	**-26**	**-12**	2	16	30	44	58	72	86	100	114	13	4n-12
-80	**-66**	**-52**	**-38**	**-24**	**-10**	4	18	32	46	60	74	88	102	12	4n-10
-92	**-78**	**-64**	**-50**	**-36**	**-22**	**-8**	6	20	34	48	62	76	90	11	4n-8
-104	**-90**	**-76**	**-62**	**-48**	**-34**	**-20**	**-6**	8	22	36	50	64	78	10	4n-6
-116	**-102**	**-88**	**-74**	**-60**	**-46**	**-32**	**-18**	**-4**	10	24	38	52	66	9	4n-4
-128	**-114**	**-100**	**-86**	**-72**	**-58**	**-44**	**-30**	**-16**	**-2**	12	26	40	54	8	4n-2
-140	**-126**	**-112**	**-98**	**-84**	**-70**	**-56**	**-42**	**-28**	**-14**	**0**	14	28	42	7	4n+0
-152	**-138**	**-124**	**-110**	**-96**	**-82**	**-68**	**-54**	**-40**	**-26**	**-12**	**2**	**16**	**30**	6	4n+2
M-11	**M-10**	**M-9**	**M-8**	**M-7**	**M-6**	**M-5**	**M-4**	**M-3**	**M-2**	**M-1**	**M0**	**M1**	**M2**		
132	**120**	**106**	**96**	**84**	**72**	**60**	**48**	**36**	**24**	**12**	2		holes	es	

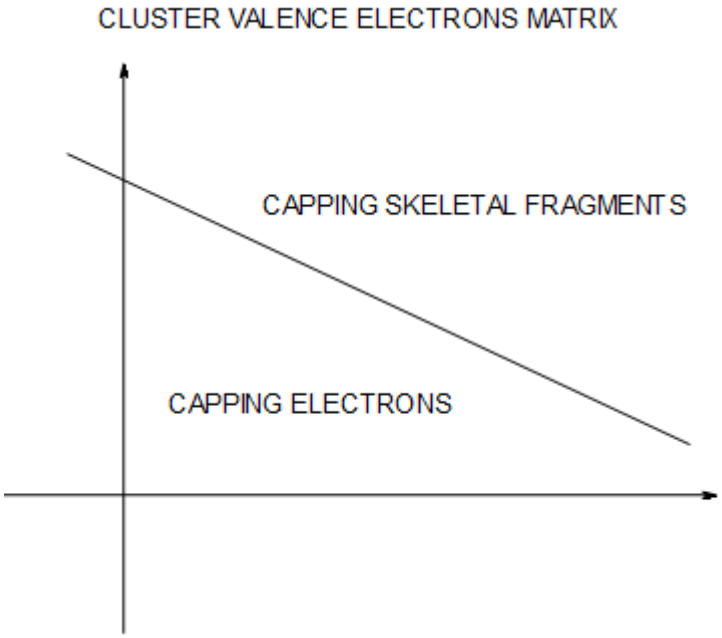


Figure 6. Sketch illustrating the capping concept derived from series

2.5 Applying the Capping Principle of Cluster Genesis to Derive Cluster Formulas

By having the knowledge of the foundation of a given cluster we can derive its molecular or cluster formula. If we define the foundation cluster valence electrons as G_0, and the capping fragment as F_0, and the number of skeletal elements as n, then the cluster or molecular formula F is given by $F=n[F_0]+G_0$. The value of F_0 = 2e (for main group elements) or F_0= 12e for transition metals. By analyzing the series, G_0 is related to [Mx] by G_0 =[x+1]L, where L is a two electron ligand. Hence, by adding appropriate multiples of F_0, a required cluster formula is obtained. The derivation of cluster formulas is illustrated by the following examples 1-22. More examples are provided in Table 7**.

1. $F=B_2H_6$

$K=2[2.5]-6[0.5] = 2$
$K(n)=2(2)$
$S=4n+4$
$K =2n-2$
$Kp = C^{-1}C[M3]$
$G_0 =[3+1]L = 4L = 8H$
$F=n[F_0]+G_0$
$=2[BH^{2+}]+8H =2B+2H-4H+8H =B_2H_6$

2. $F =B_4H_{10}$

$K =4[2.5]-5=5$
$K(n) =5(4)$
$S=4n+6$
$K =2n-3$
$Kp =C^{-2}C[M6]$
$G_O =[6+1]L=7L=14H$
$F = F =n[F_0]+G_0$
$=4[BH^{2+}]+14H=4B+4H-8H+14H =B_4H_{10}$

3. $F= B_5H_9$

$K=5[2.5]-4.5=8$
$K(n)=8(5)$
$S=4n+4$
$K=2n-2$
$Kp=C^{-1}C[M6]$
$G_0 =[6+1]L=7L=14H$
$F =n[F_0]+G_0 =5[BH^{2+}]+14H=5B+5H-10H+14H=B_5H_9$

4. $F =B_6H_{10}$

$K=6[2.5]-5 =10$
$K(n) =10(6)$
$S= 4n+4$
$K=2n-2$
$Kp = C^{-1}C[M7]$
$G_0 =[7+1]=8L =16H$
$F=n[F_0]+G_0= 6[BH^{2+}]+16H=6B+6H-12H+16H=B_6H_{10}$

5. $F= C_2B_7H_{13}$

$K= 2[2]+7[2.5]-6.5 =15$

K(n)=15(9)
S=4n+6
K=2n-3
Kp=$C^{-2}C$[M11]
G_0 =[11+1]L=12L =24H
F=n[F_0]+G_0= 9[BH^{2+}]+24H=9B+9H-18H+24H=B_9H_{15} =$(BH)_2B_7H_{13}$=$C_2B_7H_{13}$

6. F=SB_9H_{11}

K =1[1]+9[2.5]-5.5=18
K(n) =18(10)
S= 4n+4
K=2n-2
Kp =$C^{-1}C$[M11]
G_0 =[11+1]L=12L =24H
F=n[C_0]+G_0= 10[BH^{2+}]+24H=10B+10H-20H+24H=$B_{10}H_{14}$ =$(BH_3)B_9H_{11}$=SB_9H_{11}

7. $B_4H_8Co(Cp)$

K=4[2.5]-4+1[4.5-2.5] =8
K(n) =8(5)
S =4n+4
K =2n-2
Kp = $C^{-1}C$[M6]
G_0 = [6+1]L=7L = 14H
F= n[F_0]+G_0 = 5[BH^{2+}]+14H= 5B+5H-10H+14H =B_5H_9 =$(BH)B_4H_8$= CB_4H_8 =$Co(Cp)B_4H_8$
Co(Cp) ; K =4.5-2.5 = 2≡ [C]

8. F=$B_4H_8Fe(CO)_3$

K= 4[2.5]-4+1[5-3]=8
K(n) =8(5)
S =4n+4
K =2n-2
Kp = $C^{-1}C$[M6]
G_0 = [6+1]L=7L = 14H
F= n[F_0]+G_0 = 5[BH^{2+}]+14H= 5B+5H-10H+14H =B_5H_9 =$(BH)B_4H_8$= CB_4H_8 =$Fe(CO)_3B_4H_8$
$Fe(CO)_3$; K =4.5-2.5 = 2≡ [C]

9. $C_2B_3H_7[Fe(CO)_3]$

K =2L2]+3[2.5]+1[5-3]-3.5=10
K(n) =10(6)
S =4n+4
K=2n-2
Kp=$C^{-1}C$[M7]
G_0= [7+1]L=8L = 16H
F=n[F_0]+G_0 =6[BH^{2+}]+16H =6B+6H-12H+16H =B_6H_{10}=(BH)2(BH)B_3H_7= $C_2[Fe(CO)_3]B_3H_7$; $Fe(CO)_3$ =[C], K=2

10. F= $Os_6(CO)_{18}$

K =6[5]-18 =12
K(n) =12(6)
S =4n+0
K =2n+0
Kp= C^1C[M5]
G_0 = [5+1]L=6L = 6CO
F= n[F_0]+G_0 = 6[$Os(CO)_2$] +6CO= $Os_6(CO)_{18}$

11. F=$Os_7(CO)_{21}$

K=7[5]-21 =14
K(n) =14(7)
S=4n+0
K =2n+0
Kp= C^1C[M6]
G_0 =[6+1]L=7L = 7CO
F=n[F_0]+G_O =7[$Os(CO)_2$]+7CO = $Os_7(CO)_{21}$

12. F= $Os_{17}(CO)_{36}^{2-}$

K = 17[5]-36-1=48
K(n) =48(17)
S = 4n-28
K=2n+14
Kp =$C^{15}C$[M2]
G_0 =[2+1]L= 3L =3CO
F=n[F_0]+G_0 = 17[$Os(CO)_2$]+3CO =$Os_{17}(CO)_{37}$ = $Os_{17}(CO)_{36}^{2-}$

13. F=$Os_{20}(CO)_{40}^{2-}$

K= 20[5]-40-1 =59
K(n)=59(20)
S= 4n-38
K =2n+19
Kp= $C^{20}C$[M0]
G_0 =[0+1]L=1L= 1CO
F =n[F_0]+G_0= 20[$Os(CO)_2$]+1CO =$Os_{20}(CO)_{41}$= $Os_{20}(CO)_{40}^{2-}$

14. F= $Pd_{34}(CO)_{24}L_{12}$

K=34[4]-24-12= 100
K(n) =100(34)

S= 4n-64
K =2n+32
Kp=$C^{33}C$[M1]
G_0 =[1+1]L=2L= 2CO
F=n[F_0]+G_0= 34[Pd(CO)]+2CO = $Pd_{34}(CO)_{36}$ = $Pd_{34}(CO)_{24}L_{12}$

15. F=$Pd_{59}(CO)_{36}L_{14}$

K= 59[4]-36-14 = 186
K(n) = 186(59)
S=4n-136
K =2n+68
Kp= $C^{69}C$[M-10]
G_O= [-10+1]L=-9L = -9CO
F =n[F_0]+G_0 = 59[Pd(CO)]+[-9CO] =$Pd_{59}(CO)_{50}$= $Pd_{59}(CO)_{36}L_{14}$

16. F= $Au_8L_8^{2+}$

K=8[3.5]-8+1=21
K(n)=21(8)
S=4n-10
K =2n+5
Kp = C^6C[M2]
G_0=[2+1]L= 3L
F=n[F_0]+G_0 = 8[Au^-]+3L= 8Au+4L+3L=Au_8L_7 = $Au_8L_8^{2+}$;[8—]=8R=4L

17. F= $Au_9L_8^{3+}$

K = 9[3.5]-8+1.5 =25
K(n)=25(9)
S= 4n-14
K =2n+7
Kp=C^8C[M1]
G_0 =[1+1]L= 2L
F =n[F_0]+G_0 =9[Au—]+2L = 9Au+9R+4R =$Au_9L_{6.5}$ = $Au_9L_8^{3+}$; 2R=1L

18. F=$Au_{39}L_{14}Cl_6^{3+}$

K =39[3.5]-14-3+1.5 =121
K(n)=121(39)
S=4n-86
K=2n+43
Kp=$C^{44}C$[M-5]
G_0 = [-5+1]L=-4L = -8R
F=n[F_0]+G_0= 39[Au^-]+[-8R]= 39Au+39R-8R=$Au_{39}R_{31}$= $Au_{39}L_{14}Cl_6^{3+}$=39Au+28R+6R-3R=$Au_{39}R_{31}$

19. F=$Au_{40}R_{24}$

K = 40[3.5]-12= 128
K(n)=128(40)
S= 4n-96
K =2n+48
Kp= $C^{49}C$[M-9]
G_0=[-9+1]L= -8L = -16R
F=n[F_0]+G_0= 40[Au^-]+[-16R] = 40Au+40R-16R = $Au_{40}R_{24}$

20. F= $Au_{102}R_{44}$

K=102[3.5]-22 =335
K(n)=335(102)
S=4n-262
K=2n+131
Kp = $C^{132}C$[M-30]
G_0 =[-30+1]L= -29L = -58R
F= n[F_0]+G_0 = 102[Au^-]+[-58R]=102Au+102R-58R =$Au_{102}R_{44}$

21. F= C_6H_6

K=6[2]-3=9
K(n)=9(6)
S=4n+6
K=2n-3
Kp= $C^{-2}C$[M8]
G_0 =[8+1]L = 9L =18H
F=n[F_0]+G_0= 6[C^{2+}]+18H=C_6H_6

22. F=N_2H_4

K=2[1.5]-2=1
K(n)=1(2)
S=4n+6
K=2n-3
Kp =$C^{-2}C$[M4]
G_0=[4+1]L = 5L = 10H
F= n[F_0]+G_0 = 2[C^{2+}]+10H=C_2H_6 = $(C+1)_2H_4$=N_2H_4

Scheme 7.Examples illustrating the derivation of cluster formulas applying the genesis principle

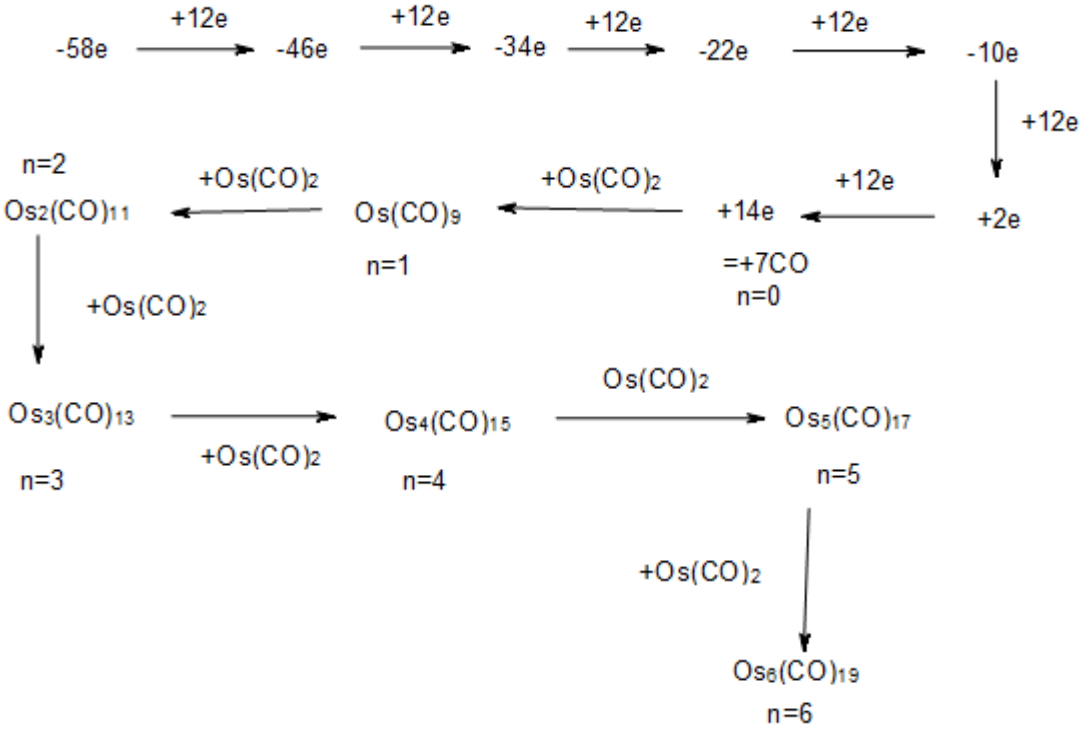
Table 8. Selected examples to show the relationship between cluster valence electrons and the nuclearity index

T-8													
A UNIVERSE OF CAPPING ELECTRONS FOR TANSITION METAL CLUSTERS: DECAPPING SERIES													
S=4n+	2	4	6	8	10	12	14	16	18	20	22	24	26
[Mx]	C^0	C^1	C^2	C^3	C^4	C^5	C^6	C^7	C^8	C^9	C^{10}	C^{11}	C^{12}
12	170	158	146	134	122	110	**98**	86	74	62	50	38	26
11	156	144	132	120	108	**96**	84	72	60	48	36	24	12
10	142	130	118	106	**94**	82	70	58	46	34	22	10	-2
9	128	116	104	**92**	80	68	56	44	32	20	8	-4	-16
8	114	102	**90**	78	66	54	42	30	18	6	-6	-18	-30
7	100	**88**	76	64	52	40	28	16	4	-8	-20	-32	-44
6	**86**	**74**	**62**	**50**	**38**	**26**	**14**	**2**	**-10**	**-22**	**-34**	**-46**	**-58**
5	72	60	48	36	24	12	0	-12	-24	-36	-48	-60	-72
4	58	46	34	22	10	-2	-14	-26	-38	-50	-62	-74	-86
3	44	32	20	8	-4	-16	-28	-40	-52	-64	-76	-88	-100
2	30	18	6	-6	-18	-30	-42	-54	-66	-78	-90	-102	-114
1	16	4	-8	-20	-32	-44	-56	-68	-80	-92	-104	-116	-128
0	2	-10	-22	-34	-46	-58	-70	-82	-94	-106	-118	-130	-142
-1	-12	-24	-36	-48	-60	-72	-84	-96	-108	-120	-132	-144	-156

N6 NUCLEARITY SERIES

BASELINE SERIES

[M6] DECAPPING SERIES



Scheme 8. [M6] Osmum Lower Capping Series

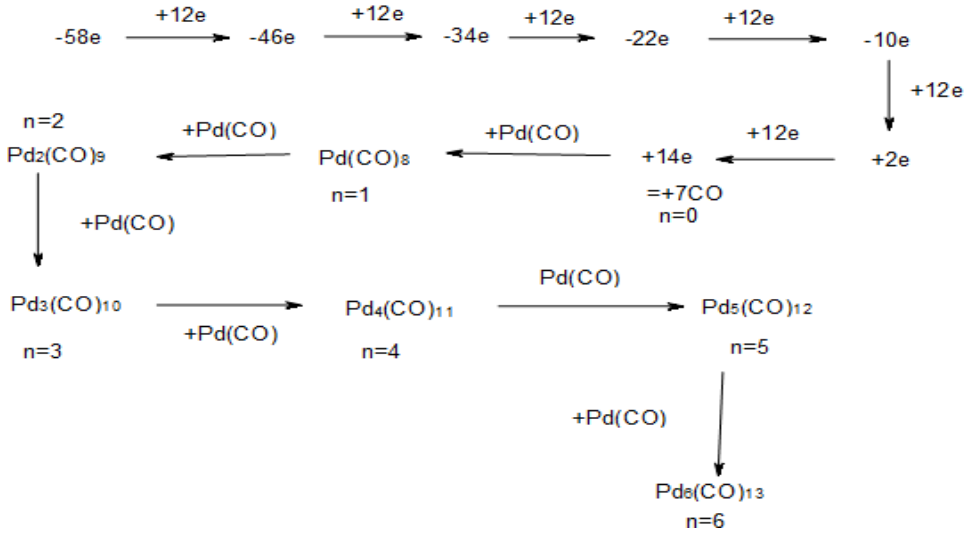
2.6 The Infinite Capping Series

If look at the octahedral CLAN of clusters [M6], K(n) =11(6), Ve = 86, the de-capping series decrease by 12e each step. In terms of K(n) series , the go from 11(6)→8(5) →5(4) →2(3) →-1(2) →-4(1) →-7(0). The K(n) = -7(0) represents +14e. We can regard this as the GENESIS of [M6] CLAN series. From the +14e, the first metallic fragment $[Os(CO)_2]$ commences the addition until the [M6] osmium cluster F=$Os_6(CO)_{19}$ that appears in the form of $Os_6(CO)_{18}^{2-}$ is

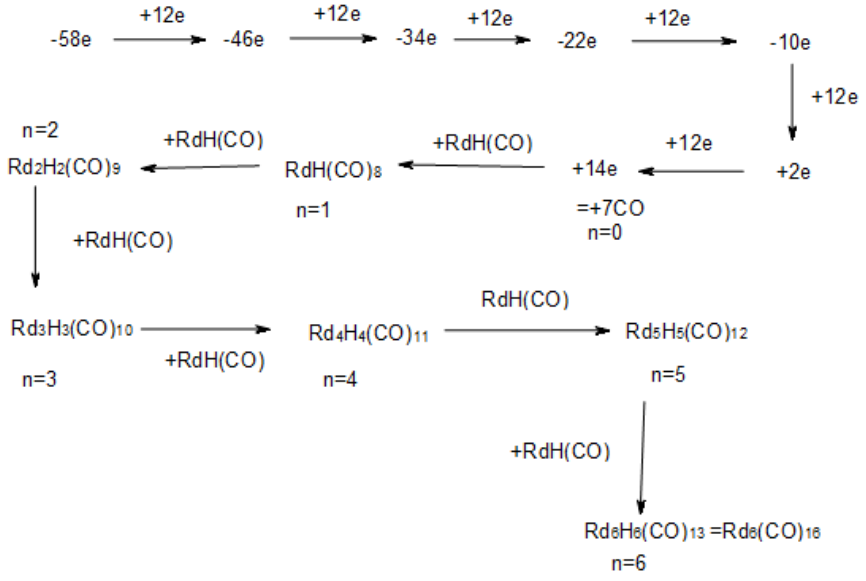
obtained. This process is presented in the scheme**. However, if we look at the capping at a deeper level, we can see that the de-capping series involving a set of 12e is indefinite as indicated by the numbers; 14→2→-10→-22→-34→-46→-58, and so on. When the capping has reached the CLOSO family [M6] represented by F = $Os_6(CO)_{19}$, and moving into the CAPPING direction, the next cluster will be F= $Os_6(CO)_{19}$+$Os(CO)_2$→$Os_7(CO)_{21}$. As we know the cluster $Os_7(CO)_{21}$ is a MONO-CAPPED octahedron.** This process can also go on infinitely. Although this phenomena has been discussed for the [M6] CLAN series, it represents all the [Mx] clans. Some examples for generating selected cluster formulas are given in Schemes 9-13. Using this approach of applying a broad and deep type of clustering, we can view clusters emerging from an infinite universe of capping negative cluster valence electrons to positive cluster valence electrons and finally to skeletal fragment capping electrons all comprising of sets of 12 electrons.

2.7 Derivation of Cluster Formulas

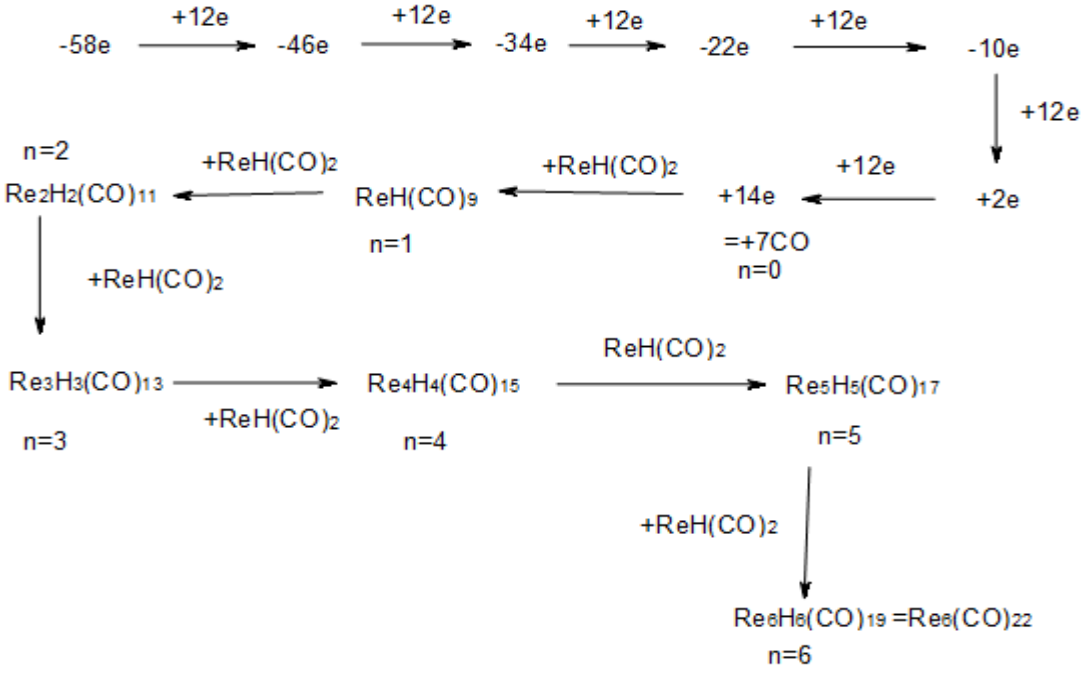
Having determined the starting point, G_0 of a given CLAN series, we can be able to derive required cluster formula or a series of cluster formulas. This is illustrated for a set of selected clusters given in Scheme 14 and since the units of fragments are based on sets of 12 electrons, it is easy to formulate a simple equation to determine the cluster valence electrons VE of any clusters. The examples are given in Table T-9.



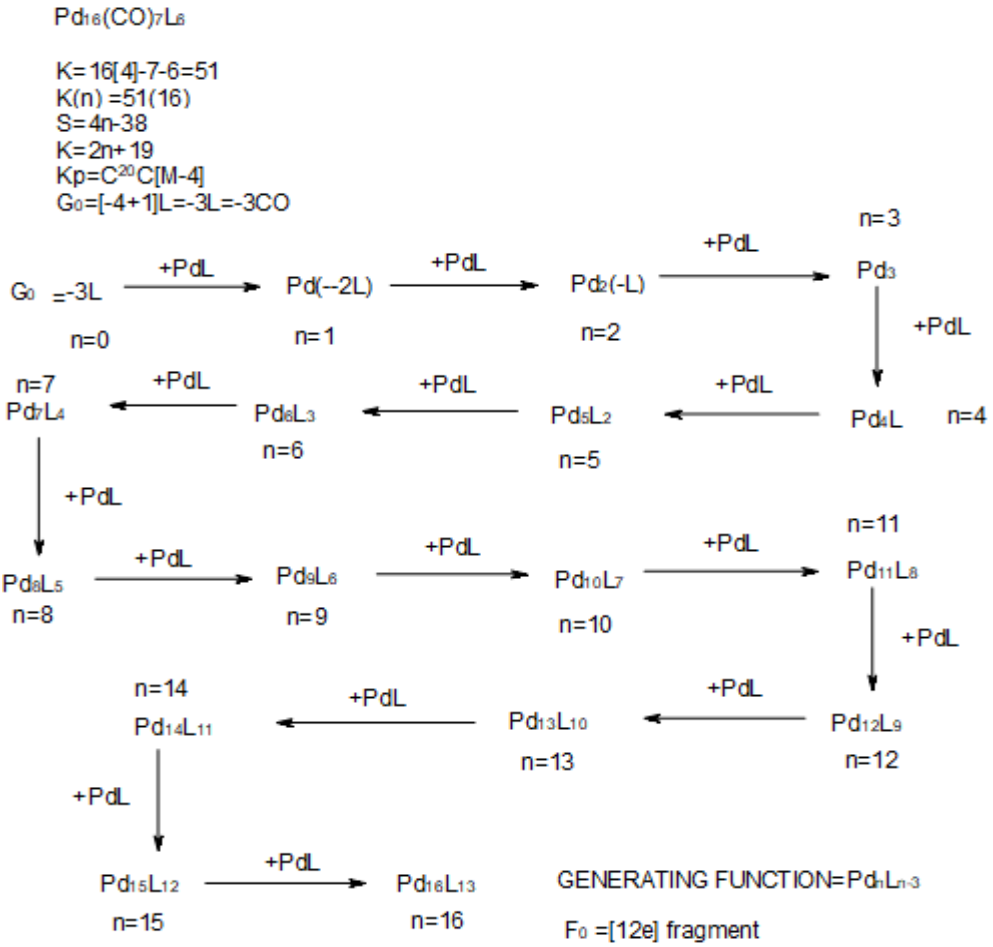
Scheme 9. [M6] Palladium Lower Capping Series



Scheme 10. [M6] Rhodium Lower Capping Series



Scheme 11. [M6] Rhenium Lower Capping Series



Scheme 12. Cluster formula=F=n[F_0]+G_0=16[PdL]-3L=$Pd_{16}L_{13}$ Cluster capping scheme for $Pd_{16}L_{13}$

2.8 Applying the Capping Priciple of Cluster Genesis to Derive Cluster Valence Electrons

We have seen how the capping principle based upon cluster genesis can be used to derive cluster formulas. The same principle can be used to derive cluster valence electrons VE. Firstly, the cluster is categorized into series, S=4n+q using skeletal numbers, Then transform the series formula into a capping formula, Kp= $C^{y}c[Mx]$, where y+x=n and n is the number of skeletal elements in a cluster formula. From the capping formula we can determine the number of GENESIS electrons, VE_0 = 2x+2. The capping fragments valence content [nd](n = number o skeletal elements, d= capping constant of 12 electrons are added on top the base line electrons, VE_0.This is demonstrated in Table T-10.which covers a wide range of more than 150 clusters and elements. What is interesting is that the capping principle based on the genesis of clusters when n=0, ONE SIMPLE FORMULA IS APPLICABLE TO A RANGE OF SKELETAL ELEMENTS FROM 1 TO HUNDREDS OF ATOMS IN MOLECULES AND CLUSTERS.This formula is VE= VE_0+ d[n] where VE= cluster valence electrons, VE_0= cluster valence electrons when n=0 d= 12 for transition elements and 2 for main group elements and n= number of the skeletal elements. The equation is a simple ARITHMETIC PROGRESSION. What is more exciting is that the calculation also places the main group and transition elements into their usual periodic groups of 3 to 18.

Ex -1

$Pd_{59}(CO)_{32}L_{21}$

K =59[4]-32-21=183

K(n)=183(59)

S=4n-130

K=2n+65

$Kp=C^{66}C[M-7]$

G_0=[-7+1]L=-6L

$F=n[F_0]+G_0$ = 59[PdL]+[-6L]=$Pd_{59}L_{53}$=$Pd_{59}(CO)_{53}$= $Pd_{59}(CO)_{32}L_{21}$

Ex-2

$Pd_{69}(CO)_{36}L_{18}$

K=69[4]-36-18=222

K(n)=222(69)

S=4n-168

K=2n+84

$Kp=C^{85}C[M-16]$

G_0=[-16+1]L=-15CO

F=69[Pd(CO)+[-15CO]=$Pd_{69}(CO)_{54}$=$Pd_{69}(CO)_{36}L_{18}$

Ex-3

$Pd_{165}(CO)_{60}L_{30}$

K=165[4]-60-30 =570

K(n)=570(165)

S=4n-480

K=2n+240

$Kp=C^{241}C[M-76]$

G_0=[-76+1]L=-75L

$F=n[F_0]+G_0$ =165[PdL]+[-75L] =$Pd_{165}L_{90}$=$Pd_{165}(CO)60L_{30}$

Scheme 13. The derivation of cluster formulas for selected clusters applying the genesis principle

Table 9. The derivation of cluster valence electrons for selected clusters using the genesis principle

	T-9	K	n	K(n)	S	K	Kp	G_0	VE	VF
1	$Au_{20}L_{10}Cl_4^{2+}$	59	20	59(20)	4n-38	2n+19	$C^{20}C[M0]$	1	242	242
9	$Os_{20}(CO)_{40}^{2-}$	59	20	59(20)	4n-38	2n+19	$C^{20}C[M0]$	1	242	242
2	$Au_{22}L_{12}$	65	22	65(22)	4n-42	2n+21	$C^{22}C[M0]$	1	266	266
3	$Au_{24}L_{10}R_5X_2^{+}$	71	24	71(24)	4n-46	2n+23	$C^{24}C[M0]$	1	290	290
4	$Au_{25}L_{10}R_5^{2+}$	76	25	76(25)	4n-52	2n+26	$C^{27}C[M-2]$	-1	298	298
5	$Au_{38}L_{18}Cl_2^{4+}$	116	38	116(38)	4n-80	2n+40	$C^{41}C[M-3]$	-2	452	452
6	$Au_{39}L_{14}Cl_6^{+}$	120	39	120(39)	4n-84	2n+42	$C^{43}C[M-4]$	-3	462	462
7	$Au_{40}R_{24}$	128	40	128(40)	4n-96	2n+48	$C^{49}C[M-9]$	-8	464	464
8	$Au_{102}R_{44}$	335	102	335(102)	4n-262	2n+131	$C^{132}C[M-30]$	-29	1166	1166
10	$Pd_{39}(CO)_{23}L_{16}$	117	39	117(39)	4n-78	2n+39	$C^{40}C[M-1]$	0	468	468
11	$Pd_{54}(CO)_{40}L_{14}$	162	54	162(54)	4n-108	2n+54	$C^{55}C[M-1]$	0	648	648
12	$Pd_{52}(CO)_{36}L_{14}$	158	52	158(52)	4n-108	2n+54	$C^{55}C[M-3]$	-2	620	620
13	$Pd_{16}(CO)_7L_6$	51	16	51(16)	4n-38	2n+19	$C^{20}C[M-4]$	-3	186	186
14	$Pd_{59}(CO)_{32}L_{21}$	183	59	183(59)	4n-130	2n+65	$C^{66}C[M-7]$	-6	696	696
15	$Pd_{59}(CO)_{36}L_{14}$	186	59	186(59)	4n-136	2n+68	$C^{69}C[M-10]$	-9	690	690
16	$Pd_{69}(CO)_{36}L_{18}$	222	69	222(69)	4n-168	2n+84	$C^{85}C[M-16]$	-15	798	798
17	$Pd_{165}(CO)_{60}L_{30}$	570	165	570(165)	4n-480	2n+240	$C^{241}C[M-76]$	-75	1830	1830

1. $F= n[F_0]+G_0=20[Au^{-}]+1L=Au_{20}R_{20}+2R=Au_{20}R_{22}= Au_{20}L_{11}= Au_{20}L_{10}Cl_4^{2+}$
2. $F= n[F_0]+G_0=22[Au^{-}]+1L= Au_{22}R_{22}+2R=Au_{22}R_{24}= Au_{22}L_{12}$
3. $F= n[F_0]+G_0=24[Au^{-}]+1L= Au_{24}R_{24}+2R=Au_{24}R_{26}= Au_{24}L_{13}= Au_{24}L_{10}R_5X_2^{+}$
4. $F= n[F_0]+G_0=25[Au^{-}]-1L= Au_{25}R_{25}-2R=Au_{25}R_{23}= Au_{25}L_{10}R_5^{2+}$
5. $F= n[F_0]+G_0=38[Au^{-}]-2L= Au_{38}R_{38}-4R=Au_{38}R_{34}= Au_{38}L_{18}Cl_2^{4+}$
6. $F= n[F_0]+G_0=39[Au^{-}]-3L= Au_{39}R_{39}-6R=Au_{38}R_{33}= Au_{39}L_{14}Cl_6^{+}$
7. $F= n[F_0]+G_0=40[Au^{-}]-8L= Au_{40}R_{40}-16R=Au_{40}R_{24}$
8. $F= n[F_0]+G_0=102[Au^{-}]-29L= Au_{102}R_{102}-58R=Au_{102}R_{44}$
9. $F= n[F_0]+G_0=20[Os(CO)_2]+1CO =Os_{20}(CO)_{41}= Os_{20}(CO)_{40}^{2-}$
10. $F= n[F_0]+G_0=39[Pd(CO)]+0=Pd_{39}(CO)_{39}= Pd_{39}(CO)_{23}L_{16}$
11. $F= n[F_0]+G_0=54[Pd(CO)]+0=Pd_{54}(CO)_{54}= Pd_{54}(CO)_{40}L_{14}$
12. $F= n[F_0]+G_0=52[Pd(CO)]-2CO =Pd_{52}(CO)_{50}= Pd_{52}(CO)_{36}L_{14}$
13. $F= n[F_0]+G_0=16[Pd(CO)]-3CO =Pd_{16}(CO)_{13}= Pd_{16}(CO)_7L_6$
14. $F= n[F_0]+G_0=59[Pd(CO)]-6CO =Pd_{59}(CO)_{53}= Pd_{59}(CO)_{32}L_{21}$
15. $F= n[F_0]+G_0=59[Pd(CO)]-9CO =Pd_{59}(CO)_{50}= Pd_{59}(CO)_{36}L_{14}$
16. $F= n[F_0]+G_0=69[Pd(CO)]-15CO =Pd_{69}(CO)_{54}= Pd_{69}(CO)_{36}L_{18}$
17. $F= n[F_0]+G_0=165[Pd(CO)]-75CO =Pd_{165}(CO)_{90}= Pd_{165}(CO)_{60}L_{30}$

Scheme 14. The derivation of cluster formulas of selected clusters using the hypothetical model of cluster genesis principle

Some of the data of clusters was obtained from various sources(Balyekova, et al, 2003; Fehlner & Halet, 2000; Mednikov & Dahl, 2010; Hughes & Wade, 2000).

Table 10.The derivation of cluster valence electrons for selected examples using the genesis principle

	T-10 CLUSTER	K(n)	SERIES	NAME, Kp =$C^yC[Mx]$	[Mx]	* A_1	n	n-1	VE=A_1+12(n-1)	VF
1	$Pd_{165}(CO)_{60}L_{30}$	570(165)	4n-480	$C^{241}CM$-76]	[M-76]	-138	165	164	1830	1830
2	$Au_{102}R_{44}$	335(102)	4n-232	$C^{132}C$[M-30]	[M-30]	-46	102	101	1166	1166
3	$Pd_{69}(CO)_{36}L_{18}$	222(69)	4n-168	$C^{85}C$[M-16]	[M-16]	-18	69	68	798	798
4	$Pd_{59}(CO)_{32}L_{21}$	183(59)	4n-130	$C^{66}C$[M-7]	[M-7]	0	59	58	696	696
5	$Pd_{66}(CO)_{45}L_{16}$	203(66)	4n-142	$C^{72}C$[M-6]	[M-6]	2	66	65	782	782
6	$Pd_{52}(CO)_{36}L_{14}$	158(52)	4n-108	$C^{55}C$[M-3]	[M-3]	8	52	51	620	620
7	$Pd_{54}(CO)_{40}L_{14}$	162(54)	4n-108	$C^{55}C$[M-1]	[M-1]	12	54	53	648	648
8	$Pd_{39}(CO)_{23}L_{16}$	117(39)	4n-78	$C^{40}C$[M-1]	[M-1]	12	39	38	468	468
9	$Pd_3(CO)_3L_4$	5(3)	4n+2	C^0C[M3](closo)	[M3]	20	3	2	44	44
10	$Pd_4(CO)_5L_4$	7(4)	4n+2	C^0C[M4](closo)	[M4]	22	4	3	58	58
11	$Au_{20}L_{10}Cl_4^{2+}$	59(20)	4n-38	$C^{20}C$[M0]	[M0]	14	20	19	242	242
12	$Au_{22}L_{12}$	65(22)	4n-42	$C^{22}C$[M0]	[M0]	14	22	21	266	266
13	$Os_{20}(CO)_{40}^{2-}$	59(20)	4n-38	$C^{20}C$[M0]	[M0]	14	20	19	242	242
14	Au_4L_4	10(4)	4n-4	C^3C[M1]	[M1]	16	4	3	52	52
15	$Au_6L_6^{2+}$	**16(6)**	4n-8	C^5C[M1]	[M1]	16	6	5	76	76
16	$Au_6L_4Cl_2$	**16(6)**	4n-8	C^5C[M1]	[M1]	16	6	5	76	76
17	$Au_8L_7^{2+}$	22(8)	4n-12	C^7C[M1]	[M1]	16	8	7	100	100
18	$Au_9L_8^{3+}$	25(9)	4n-14	C^8C[M1]	[M1]	16	9	8	112	112
19	$Au_{11}L_{10}^{5+}$	31(11)	4n-18	$C^{10}C$[M1]	[M1]	16	11	10	136	136
20	$Pd_{34}(CO)_{24}L_{12}$	100(34)	4n-64	$C^{33}C$[M1]	[M1]	16	34	33	412	412
21	$V(CO)_6^-$	0(1)	4n+4	$C^{-1}C$[M2]	[M2]	18	1	0	18	18
22	$Cr(CO)_6$	0(1)	4n+4	$C^{-1}C$[M2]	[M2]	18	1	0	18	18
23	$Mn(CO)_6^+$	0(1)	4n+4	$C^{-1}C$[M2]	[M2]	18	1	0	18	18
24	$Fe(CO)_5$	0(1)	4n+4	$C^{-1}C$[M2]	[M2]	18	1	0	18	18
25	$Ir(CO)_6^{3+}$	0(1)	4n+4	$C^{-1}C$[M2]	[M2]	18	1	0	18	18
26	$Ni(CO)_4$	0(1)	4n+4	$C^{-1}C$[M2]	[M2]	18	1	0	18	18
27	CH_4	0(1)	4n+4	$C^{-1}C$[M2]	[M2]	18	1	0	18[8]	8
28	PH_3	0(1)	4n+4	$C^{-1}C$[M2]	[M2]	18	1	0	18[8]	8
29	OH_2	0(1)	4n+4	$C^{-1}C$[M2]	[M2]	18	1	0	18[8]	8
30	FH	0(1)	4n+4	$C^{-1}C$[M2]	[M2]	18	1	0	18[8]	8
31	N_2	3(2)	4n+2	C^0C[M2]	[M2]	18	2	1	30[10]	10
32	C_2H_2	3(2)	4n+2	C^0C[M2]	[M2]	18	2	1	30[10]	10
33	$Cr_2(Cp)_2(CO)_4$	3(2)	4n+2	C^0C[M2]	[M2]	18	2	1	30	30
34	$Pd_3(CO)_3L_3$	6(3)	4n+0	C^1C[M2]	[M2]	18	3	2	42	42
35	$(AuL)_2Fe(CO)_4$	6(3)	4n+0	C^1C[M2]	[M2]	18	3	2	42	42
36	$(AuL)_3V(CO)_5$	9(4)	4n-2	C^2C[M2]	[M2]	18	4	3	54	54
37	$(AuL)_3Co(CO)_3$	9(4)	4n-2	C^2C[M2]	[M2]	18	4	3	54	54
38	$Fe_2Ir_2(AuL)(CO)_{12}^+$	12(5)	4n-4	C^3C[M2]	[M2]	18	5	4	66	66
39	$(AuL)_4Re(CO)_4^+$	12(5)	4n-4	C^3C[M2]	[M2]	18	5	4	66	66
40	$Re_5(C)(H)(CO)_{12}^{2-}$	12(5)	4n-4	C^3C[M2]	[M2]	18	5	4	66	66
41	$(AuL)_7Mo(CO)_3^+$	21(8)	4n-10	C^6C[M2]	[M2]	18	8	7	102	102
42	$(AuL)_7Co(CO)_2^{2+}$	21(8)	4n-10	C^6C[M2]	[M2]	18	8	7	102	102
43	$(AuL)_8Pt(CO)^{2+}$	24(9)	4n-12	C^7C[M2]	[M2]	18	9	8	114	114
44	$Au_9L_8^+$	24(9)	4n-12	C^7C[M2]	[M2]	18	9	8	114	114
45	$Os_{17}(CO)_{36}^{2-}$	48(17)	4n-28	$C^{15}C$[M2]	[M2]	18	17	16	210	210
46	$Pd_{35}(CO)_{23}L_{15}$	102(35)	4n-64	$C^{33}C$[M2]	[M2]	18	35	34	426	426
47	$Pd_{37}(CO)_{28}L_{12}$	108(37)	4n-68	$C^{35}C$[M2]	[M2]	18	37	36	450	450
48	B_2H_6	2(2)	4n+4	$C^{-1}C$[M3]	[M3]	20	2	1	32[12]	12
49	$Re_2H_2(CO)_8$	2(2)	4n+4	$C^{-1}C$[M3]	[M3]	20	2	1	32	32
49a	B_4Cl_4	8(4)	4n+0	C^1C[M3]	[M3]	20	4	3	56[16]	16
50	$Re_4H_4(CO)_{12}$	8(4)	4n+0	C^1C[M3]	[M3]	20	4	3	56	56
51	$Os_2(CO)_9$	1(2)	4n+6	$C^{-2}C$[M4]	[M4]	22	2	1	34	34
52	$Re_3H_3(CO)_{10}^{2-}$	4(3)	4n+4	$C^{-1}C$[M4]	[M4]	22	3	2	46	46
53	$B_4H_4^{2-}$	7(4)	4n+2	C^0C[M4]	[M4]	22	4	3	58[18]	18
54	$Pd_6(CO)_4L_7$	13(6)	4n-2	C^2C[M4]	[M4]	22	6	5	82	82
55	$Pt_{19}(CO)_{22}^{4-}$	52(19)	4n-28	$C^{15}C$[M4]	[M4]	22	19	18	238	238
56	$Pd_{16}Ni_4(CO)_{22}L_2^{2-}$	55(20)	4n-30	$C^{16}C$[M4]	[M4]	22	20	19	250	250
56	$(Au)Pd_{22}(CO)_{20}L_8^+$	64(23)	4n-36	$C^{19}C$[M4]	[M4]	22	23	22	286	286
57	$Pd_{23}(CO)_{20}L_8$	64(23)	4n-36	$C^{19}C$[M4]	[M4]	22	23	22	286	286
58	$Au_{39}L_{14}Cl_6^+$	120(39)	4n-84	$C^{43}C$[M4]	[M-4]	6	39	38	462	462
59	$Os_3(CO)_{12}$	3(3)	4n+6	$C^{-2}C$[M5]	[M5]	24	3	2	48	48
60	B_3H_9	3(3)	4n+6	$C^{-2}C$[M5]	[M5]	24	3	2	48[18]	18
61	$Os_4(CO)_{14}$	6(4)	4n+4	$C^{-1}C$[M5]	[M5]	24	4	3	60	60
62	$Os_4H_2(CO)_{12}^{2-}$	6(4)	4n+4	$C^{-1}C$[M5]	[M5]	24	4	3	60	60
63	$Rh_4(CO)_{12}$	6(4)	4n+4	$C^{-1}C$[M5]	[M5]	24	4	3	60	60
64	$Re_4H_4(CO)_{13}^{2-}$	6(4)	4n+4	$C^{-1}C$[M5]	[M5]	24	4	3	60	60
65	B_4H_8	6(4)	4n+4	$C^{-1}C$[M5]	[M5]	24	4	3	60[20]	20
66	CB_4H_6	9(5)	4n+2	C^0C[M5]	[M5]	24	5	4	72[22]	22
67	$B_3C_2H_5$	9(5)	4n+2	C^0C[M5]	[M5]	24	5	4	72[22]	22
68	$Os_5H(CO)_{15}^-$	9(5)	4n+2	C^0C[M5]	[M5]	24	5	4	72	72
69	$Os_6(CO)_{18}$	12(6)	4n+0	C^1C[M5]	[M5]	24	6	5	84	84

70	$Os_{10}(C)(CO)_{24}$	24(10)	4n-8	$C^{5}C[M5]$	[M5]	24	10	9	132	132
71	$Rh_{14}(CO)_{25}^{4-}$	36(14)	4n-16	$C^{9}C[M5]$	[M5]	24	14	13	180	180
72	$Rh_{15}(CO)_{27}^{3-}$	39(15)	4n-18	$C^{10}C[M5]$	[M5]	24	15	14	192	192
73	$Pd_{16}(CO)_{13}L_9$	42(16)	4n-20	$C^{11}C[M5]$	[M5]	24	16	15	204	204
74	$Rh_{17}(CO)_{30}^{3-}$	45(17)	4n-22	$C^{12}C[M5]$	[M5]	24	17	16	216	216
75	$Rh_{22}(CO)_{37}^{4-}$	60(22)	4n-32	$C^{17}C[M5]$	[M5]	24	22	21	276	276
76	$Os_4(CO)_{15}$	5(4)	4n+6	$C^{-2}C[M6]$	[M6]	26	4	3	62	62
77	B_4H_{10}	5(4)	4n+6	$C^{-2}C[M6]$	[M6]	26	4	3	62[22]	22
78	$Os_5H_2(CO)_{16}$	8(5)	4n+4	$C^{-1}C[M6]$	[M6]	26	5	4	74	74
79	$B_4H_8(CoCp)$	8(5)	4n+4	$C^{-1}C[M6]$	[M6]	26	5	4	74[34]	34
80	B_5H_9	8(5)	4n+4	$C^{-1}C[M6]$	[M6]	26	5	4	74[24]	24
81	$B_4H_8Fe(CO)_3$	8(5)	4n+4	$C^{-1}C[M6]$	[M6]	26	5	4	74[34]	34
82	$Os_6(CO)_{18}^{2-}$	11(6)	4n+2	$C^{0}C[M6]$	[M6]	26	6	5	86	86
83	$Rh_5Pt(CO)_{15}^{-}$	11(6)	4n+2	$C^{0}C[M6]$	[M6]	26	6	5	86	86
84	$Re_6C(CO)_{19}^{2-}$	11(6)	4n+2	$C^{0}C[M6]$	[M6]	26	6	5	86	86
85	$B_4C_2H_6$	11(6)	4n+2	$C^{0}C[M6]$	[M6]	26	6	5	86[26]	26
86	$Pd_7(CO)_7L_7$	14(7)	4n+0	$C^{1}C[M6]$	[M6]	26	7	6	98	98
87	$Os_7(CO)_{21}$	14(7)	4n+0	$C^{1}C[M6]$	[M6]	26	7	6	98	98
88	$Rh_7(CO)_{16}^{3-}$	14(7)	4n+0	$C^{1}C[M6]$	[M6]	26	7	6	98	98
89	$Re_7C(CO)_{21}^{3-}$	14(7)	4n+0	$C^{1}C[M6]$	[M6]	26	7	6	98	98
90	$Pd_8(CO)_8L_7$	17(8)	4n-2	$C^{2}C[M6]$	[M6]	26	8	7	110	110
91	$Re_8C(CO)_{24}^{2-}$	17(8)	4n-2	$C^{2}C[M6]$	[M6]	26	8	7	110	110
92	$Os_8(CO)_{22}^{2-}$	17(8)	4n-2	$C^{2}C[M6]$	[M6]	26	8	7	110	110
93	$Os_9H(CO)_{24}^{-}$	20(9)	4n-4	$C^{3}C[M6]$	[M6]	26	9	8	122	122
94	$Rh_9(CO)_{19}^{3-}$	20(9)	4n-4	$C^{3}C[M6]$	[M6]	26	9	8	122	122
95	$Os_{10}(CO)_{26}^{2-}$	23(10)	4n-6	$C^{4}C[M6]$	[M6]	26	10	9	134	134
96	$Rh_{10}(CO)_{21}^{2-}$	23(10)	4n-6	$C^{4}C[M6]$	[M6]	26	10	9	134	134
97	$Os_{10}H_2(C)(CO)_{24}$	23(10)	4n-6	$C^{4}C[M6]$	[M6]	26	10	9	134	134
98	$Rh_{13}(CO)_{24}H_2^{3-}$	32(13)	4n-12	$C^{7}C[M6]$	[M6]	26	13	12	170	170
99	$Pd_{16}Ni_4(CO)_{22}L_4^{2-}$	53(20)	4n-26	$C^{14}C[M6]$	[M6]	26	20	19	254	254
100	$Pd_{23}(CO)_{20}L_{10}$	62(23)	4n-32	$C^{17}C[M6]$	[M6]	26	23	22	290	290
101	$Pt_{24}(CO)_{30}^{2-}$	65(24)	4n-34	$C^{18}C[M6]$	[M6]	26	24	23	302	302
102	$Pd_{29}(CO)_{28}L_7^{2-}$	80(29)	4n-44	$C^{23}C[M6]$	[M6]	26	29	28	362	362
103	$HPd_{30}(CO)_{26}L_{10}^{-}$	83(30)	4n-46	$C^{24}C[M6]$	[M6]	26	30	29	374	374
104	$Au_2Pd_{28}(CO)_{26}L_{10}$	83(30)	4n-46	$C^{24}C[M6]$	[M6]	26	30	29	374	374
105	$Pt_{38}(CO)_{44}^{2-}$	107(38)	4n-62	$C^{32}C[M6]$	[M6]	26	38	37	470	470
106	$Pd_{33}Ni_9(CO)_{41}L_6^{4-}$	119(42)	4n-70	$C^{36}C[M6]$	[M6]	26	42	41	518	518
107	$Pd_8Ni_{36}(CO)_{48}^{6-}$	125(44)	4n-74	$C^{38}C[M6]$	[M6]	26	44	43	542	542
108	$Ni_{35}Pt_9(CO)_{48}^{6-}$	125(44)	4n-74	$C^{38}C[M6]$	[M6]	26	44	43	542	542
109	$Ni_{38}Pt_6(CO)_{48}H^{5-}$	125(44)	4n-74	$C^{38}C[M6]$	[M6]	26	44	43	542	542
109b	B_8Cl_8	16(8)	4n+0	$C^{1}[M7]$	[M7]	28	8	7	42	42
110	$Os_4(CO)_{16}$	4(4)	4n+8	$C^{-3}C[M7]$	[M7]	28	4	3	64	64
111	$Os_5(CO)_{18}$	7(5)	4n+6	$C^{-2}C[M7]$	[M7]	28	5	4	76	76
112	$Rh_5(CO)_{15}^{-}$	7(5)	4n+6	$C^{-2}C[M7]$	[M7]	28	5	4	76	76
113	B_5H_{11}	7(5)	4n+6	$C^{-2}C[M7]$	[M7]	28	5	4	76[26]	26
114	B_6H_{10}	10(6)	4n+4	$C^{-1}C[M7]$	[M7]	28	6	5	88[28]	28
115	$Os_7H_2(CO)_{19}$	15(7)	4n-2	$C^{2}C[M5]$	[M5]	24	7	6	96	96
116	$Os_{10}(C)(CO)_{24}^{4-}$	22(10)	4n-4	$C^{3}C[M7]$	[M7]	28	10	9	136	136
117	$Pd_{10}(CO)_{12}L_6$	22(10)	4n-4	$C^{3}C[M7]$	[M7]	28	10	9	136	136
118	$Rh_{11}(CO)_{23}^{3-}$	25(11)	4n-6	$C^{4}C[M7]$	[M7]	28	11	10	148	148
119	$Pd_9Ni_9(CO)_{17}L_9$	46(18)	4n-20	$C^{11}C[M7]$	[M7]	28	18	17	232	232
120	$Ni_{14}Pt_{10}(CO)_{30}^{4-}$	64(24)	4n-32	$C^{17}C[M7]$	[M7]	28	24	23	304	304
121	$Au_4Pd_{28}(CO)_{22}L_{16}$	88(32)	4n-48	$C^{25}C[M7]$	[M7]	28	32	31	400	400
122	$Au_4Pd_{32}(CO)_{28}L_{14}$	100(36)	4n-56	$C^{29}C[M7]$	[M7]	28	36	35	448	448
123	$Pd_{36}(C)(CO)_{28}L_{14}$	100(36)	4n-56	$C^{29}C[M7]$	[M7]	28	36	35	448	448
124	$Ni_{24}Pt_{14}(CO)_{44}^{4-}$	106(38)	4n-60	$C^{31}C[M7]$	[M7]	28	38	37	472	472
124a	B_9Cl_9	18(9)	4n+0	$C^{1}C[M8]$	[M8]	30	9	8	36	36
125	$Os_5(CO)_{19}$	6(5)	4n+8	$C^{-3}C[M8]$	[M8]	30	5	4	78	78
126	$Os_6(CO)_{21}$	9(6)	4n+6	$C^{-2}C[M8]$	[M8]	30	6	5	90	90
127	CB_5H_{11}	9(6)	4n+6	$C^{-2}C[M8]$	[M8]	30	6	5	90[30]	30
128	B_6H_{12}	9(6)	4n+6	$C^{-2}C[M8]$	[M8]	30	6	5	90[30]	30
129	$B_6C_2H_8$	15(8)	4n+2	$C^{0}C[M8]$	[M8]	30	8	7	114[34]	34
130	$Rh_8C(CO)_{19}$	15(8)	4n+2	$C^{0}C[M8]$	[M8]	30	8	7	114	114
131	B_8H_{12}	14(8)	4n+4	$C^{-1}C[M9]$	[M9]	32	8	7	116[36]	36
132	$Rh_9P(CO)_{21}^{2-}$	16(9)	4n+4	$C^{-1}C[M9]$	[M10]	34	9	8	130	130
133	$B_{10}H_{10}^{2-}$	19(10)	4n+2	$C^{0}C[M10]$	[M10]	34	10	9	142[42]	42
134	$B_{10}H_{14}$	18(10)	4n+4	$C^{-1}C[M11]$	[M11]	36	10	9	144[44]	44
135	SB_9H_{11}	18(10)	4n+4	$C^{-1}C[M11]$	[M11]	36	10	9	144[44]	44

136	$Au_6Ni_{32}(CO)_{44}^{6-}$	102(38)	4n-52	$C^{27}C$[M11]	[M11]	36	38	37	480	480
137	B_8H_{18}	11(8)	4n+10	$C^{-4}C$[M12]	[M12]	38	8	7	122[42]	42
138	$B_9C_2H_{12}^-$	20(11)	4n+4	$C^{-2}C$[M12]	[M12]	38	11	10	158[48]	48
139	$B_{12}H_{12}^{2-}$	23(12)	4n+2	$C^{0}C$[M12]	[M12]	38	12	11	170[50]	50
140	$B_{10}C_2H_{12}$	23(12)	4n+2	$C^{0}C$[M12]	[M12]	38	12	11	170[50]	50
141	Sc	7.5(1)	4n-11	$C^{6.5}C$[M-5.5]	[M-5.5]	3	1	0	3	3
142	Ti	7(1)	4n-10	$C^{6}C$[M-5]	[M-5]	4	1	0	4	4
143	V	6.5(1)	4n-9	$C^{5.5}C$[M-4.5]	[M-4.5]	5	1	0	5	5
144	Cr	6(1)	4n-8	$C^{5}C$[M-4]	[M-4]	6	1	0	6	6
145	Mn	5.5(1)	4n-7	$C^{4.5}C$[M-3.5]	[M-3.5]	7	1	0	7	7
146	Fe	5(1)	4n-6	$C^{4}C$[M-3]	[M-3]	8	1	0	8	8
147	Co	4.5(1)	4n-5	$C^{3.5}C$[M-2.5]	[M-2.5]	9	1	0	9	9
148	Ni	4(1)	4n-4	$C^{3}C$[M-2]	[M-2]	10	1	0	10	10
149	Cu	3.5(1)	4n-3	$C^{2.5}C$[M-1.5]	[M-1.5]	11	1	0	11	11
150	Zn	3(1)	4n-2	$C^{2}C$[M-1]	[M-1]	12	1	0	12	12
151	Li	3.5(1)	4n-3	$C^{2.5}C$[M-1.5]	[M-1.5]	11	1	0	11[1]	1
152	Be	3(1)	4n-2	$C^{2}C$[M-1]	[M-1]	12	1	0	12[2]	2
153	B	2.5(1)	4n-1	$C^{1.5}C$[M-0.5]	[M-0.5]	13	1	0	13[3]	3
154	C	2(1)	4n+0	$C^{1}C$[M0]	[M0]	14	1	0	14[4]	4
155	N	1.5(1)	4n+1	$C^{0.5}C$[M0.5]	[M0.5]	15	1	0	15[5]	5
156	O	1(1)	4n+2	$C^{0}C$[M1]	[M1]	16	1	0	16[6]	6
157	F	0.5(1)	4n+3	$C^{-0.5}C$[M1.5]	[M1.5]	17	1	0	17[7]	7
159	Ne	0(1)	4n+4	$C^{-1}C$[M2]	[M2]	18	1	0	18[8]	8

- IN THE CACULATION OF VE, A_1 VALUE INSTEAD OF A_0 WAS USED, HENCE THE TERM (n-1)

2.9 Arithmetic Progression

When the sequence of the cluster valence electrons are carefully analyzed in line with the capping series, it is found that they follow a simple order of arithmetic progression. Thus,

[Mx]: VE = VE_1+(n-1)d; d= 12, VE_0: depends on [Mx], x=1, VE_0=4, x= 2→6, x=3→8, x=4→10, x=5→10. Thus, VE_0=2x+2; n depends upon the nuclearity of the cluster. When we define the starting point as n=0, then the GENESIS cluster valence electrons are given by VE = VE_0+dn, the d value = 12 for transition metals and 2 for main group elements and the corresponding formulas become VE= VE_0+12n and VE= VE_0+2n.

Examples

Table 11. Derivation of cluster valence electrons of selected clusters using the genesis principle

T-11	CLUSTER	K(n)	SERIES=4n+q	K=2n-½ q	Kp=C^y[Mx]	x	VE_0=2x+2	VE=VE_0+dn	VF
1	$Pd_3(CO)_3L_3$	6(3)	4n+0	2n+0	$C^{1}C$[M2]	2	6	6+12[3]=42	42
2	**$Rh_6(C)(CO)_{15}^{2-}$**	**9(6)**	**4n+6**	**2n-3**	**$C^{-2}C$[M8]**	**8**	**18**	**18+12[6]=90**	**90**
3	**$Rh_6(CO)_{16}$**	**11(6)**	**4n+2**	**2n-1**	**$C^{0}C$[M6]**	**6**	**14**	**14+12[6]=86**	**86**
4	**$Os_6(CO)_{18}$**	**12(6)**	**4n+0**	**2n+0**	**$C^{1}C$[M5]**	**5**	**12**	**12+12[6]=84**	**84**
5	**$Os_6(CO)_{18}^{2-}$**	**11(6)**	**4n+2**	**2n-1**	**$C^{0}C$[M6]**	**6**	**14**	**14+12[6]=86**	**86**
6	**$Rh_6H_{12}L_6^{2+}$**	**16(6)**	**4n-8**	**2n+4**	**$C^{5}C$[M1]**	**1**	**4**	**4+12[6]=76**	**76**
7	**$Mo_6Cl_8L_6^{4+}$**	**28(6)**	**4n-32**	**2n+16**	**$C^{17}C$[M-11]**	**-11**	**-20**	**-20+12[6]=52**	**52**
8	**$Mo_6Cl_{14}^{2-}$**	**28(6)**	**4n-32**	**2n+16**	**$C^{17}C$[M-11]**	**-11**	**-20**	**-20+12[6]=52**	**52**
9	**$Zr_6Cl_{18}(B)^{5-}$**	**29(6)**	**4n-34**	**2n+17**	**$C^{18}C$[M-12]**	**-12**	**-22**	**-22+12[6]=50**	**50**
10	**$Zr_6Cl_{15}(Be)^{3-}$**	**32(6)**	**4n-40**	**2n+20**	**$C^{21}C$[M-15]**	**-15**	**-28**	**-28+12[6]=44**	**44**
11	**$Zr_6Cl_{15}(B)^{2-}$**	**32(6)**	**4n-40**	**2n+20**	**$C^{21}C$[M-15]**	**-15**	**-28**	**-28+12[6]=44**	**44**
12	**$Zr_6Cl_{15}(C)^{-}$**	**32(6)**	**4n-40**	**2n+20**	**$C^{21}C$[M-15]**	**-15**	**-28**	**-28+12[6]=44**	**44**
13	**$Zr_6Cl_{15}(N)$**	**32(6)**	**4n-40**	**2n+20**	**$C^{21}C$[M-15]**	**-15**	**-28**	**-28+12[6]=44**	**44**
14	$Co_9(P)(CO)_{21}^{2-}$	16(9)	4n+4	2n-2	$C^{-1}C$[M10]	10	22	22+12[9]=130	130
15	$Rh_9(CO)_{19}^{3-}$	20(9)	4n-4	2n+2	$C^{3}C$[M6]	6	14	14+12[9]=122	122
16	$Rh_{10}(CO)_{21}^{2-}$	23(10)	4n-6	2n+3	$C^{4}C$[M6]	6	14	14+12[10]=134	134
17	$Ru_6Pd_6(CO)_{24}^{2-}$	29(12)	4n-10	2n+5	$C^{6}C$[M6]	6	14	14+12[12]=158	158
18	$Fe_6Pd_6(H)(CO)_{24}^{3-}$	28(12)	4n-8	2n+4	$C^{5}C$[M7]	7	16	16+12[12]=160	160
19	$Ni_{12}(Ge)(CO)_{22}^{2-}$	23(12)	4n+2	2n-1	$C^{0}C$[M12]	12	26	26+12[12]=170	170
20	$Co_{13}(N)_2(CO)_{24}^{3-}$	28(13)	4n-4	2n+2	$C^{3}C$[M10]	10	22	22+12[13]=178	178
21	$Rh_{13}(CO)_{24}H_5$	32(13)	4n-12	2n+6	$C^{7}C$[M6]	6	14	14+12[13]=1170	170
22	$Rh_{14}(CO)_{26}^{2-}$	36(14)	4n-16	2n+8	$C^{9}C$[M5]	5	12	12+12[14]=180	180
23	$Al_{14}R_6I_6^{2-}$	28(14)	4n+0	2n+0	$C^{1}C$[M13]	13	28	28+2[14]=56	56
24	$Sn_{15}R_6$	27(15)	4n+6	2n-3	$C^{-2}C$[M17]	17	36	36+2[15]=66	66
25	$Pd_{16}(CO)_7L_6$	51(16)	4n-38	2n+19	$C^{20}C$[M-4]	-4	-6	-6+12[16]=186	186
26	$Os_{17}(CO)_{36}^{2-}$	48(17)	4n-28	2n+14	$C^{15}C$[M2]	2	6	6+12[17]=210	210
27	$Ga_{19}R_6^{-}$	44(19)	4n-12	2n+6	$C^{7}C$[M12]	12	26	26+2[19]=64	69
28	$Pt_{19}(CO)_{22}^{4-}$	52(19)	4n-28	2n+14	$C^{15}C$[M4]	4	10	10+12[19]=238	238
29	$Os_{20}(CO)_{40}^{2-}$	59(20)	4n-38	2n+19	$C^{20}C$[M0]	0	2	2+12[20]=242	242
30	$Fe(C_2B_9H_{11})_2^{2-}$	46(23)	4n+0	2n+0	$C^{1}C$[M22]	22	46	46+2[23]+1[10]=102	102
31	$Pt_{24}(CO)_{30}^{2-}$	65(24)	4n-34	2n+17	$C^{18}C$[M6]	6	14	14+12[24]=302	302
32	$Ni_{32}C_6(CO)_{36}^{6-}$	77(32)	4n-26	2n+13	$C^{14}C$[M18]	18	38	38+12[32]=422	422
33	$Ni_{12}As_{21}^{3-}$	78(33)	4n-24	2n+12	$C^{13}C$[M20]	20	42	42+2[33]+12[10]=228	228
34	$Pd_{34}(CO)_{24}L_{12}$	100(34)	4n-64	2n+32	$C^{33}C$[M1]	1	4	4+12[34]=412	412
35	$Pd_{35}(CO)_{23}L_{15}$	102(35)	4n-64	2n+32	$C^{33}C$[M2]	2	6	6+12[35]=426	426

36	$Pt_{38}(CO)_{44}^{2-}$	107(38)	4n-62	2n+31	$C^{32}C[M6]$	6	14	14+12[38]=470	470
37	$Ni_{38}C_6(CO)_{42}^{6-}$	95(38)	4n-38	2n+19	$C^{20}C[M18]$	18	38	38+12[38]=494	494
38	$Pd_{39}CO)_{23}L_{16}$	117(39)	4n-78	2n+39	$C^{40}C[M-1]$	-1	0	0+12[39]=468	468
39	$Pd_{52}(CO)_{36}L_{14}$	158(52)	4n-108	2n+54	$C^{55}C[M-3]$	-3	-4	-4+12[52]=620	620
40	$Pd_{54}(CO)_{40}L_{14}$	162(54)	4n-108	2n+54	$C^{55}C[M-1]$	-1	0	0+12[54]=648	648
41	$Pd_{59}(CO)_{32}L_{21}$	183(59)	4n-130	2n+65	$C^{66}C[M-7]$	-7	-12	-12+12[59]=696	696
42	$Al_{69}R_{18}^{3-}$	162(69)	4n-48	2n+24	$C^{25}C[M44]$	44	90	90+2[69]=228	228
43	$Pd_{69}(CO)_{36}L_{18}$	222(69)	4n-168	2n+84	$C^{85}C[M-16]$	-16	-30	-30+12[69]=798	798
44	$Pd_{165}(CO)_{60}L_{30}$	570(165)	4n-480	2n+240	$C^{241}C[M-76]$	-76	-150	-150+12[165]=1830	1830

2.10 Transforming the Series Into Isomeric Structures

The K(n) and Kp = $C^yC[Mx]$ parameters can be utilized as useful guides to construct isomeric graphical structures. Selected examples of M_6 series are given in Figures7-8. The cluster $Rh_6(C)(CO)_{15}^{2-}$, K(n) = 9(6), S= 4n+6, K=2n-3, Kp= $C^{-2}C[M8]$ from Table T-11 belongs to an ARACHNO family of clusters and the CLAN of cluster series based on [M8] closo baseline. The [M8] has an ideal structure of $B_8H_8^{2-}$, described as a dodecahedron. According to the series, the 6 rhodium skeletal elements will be linked by 9 linkages normally taking up the ideal shape referred to as a trigonal prism as indicated in Figure**. The cluster $Rh_6(CO)_{16}$, K(n) = 11(6), S=4n+2(CLOSO family), Kp = $C^0C[M6]$. The cluster belongs to the CLOSO baseline family of un-capped clusters. It has an ideal octahedral shape. On the other hand, the cluster $Os_6(CO)_{18}$, K(n) = 12(6), S = 4n+0, Kp= $C^1C[M5]$,belongs to mono-capped cluster family and the capping skeletal element is sitting on an ideal trigonal bipyramid shape [M5]. As pointed out already [M5] is expected to have a similar shape as that of $B_5H_5^{2-}$. These shapes are shown in Figure7.

$Rh_6H_{12}L_6^{2+}$, K(n) =16(6), VE= 18n-2K = 18(6)-2(16) = 76 has been described as having an octahedral shape(Housecroft and Sharpe,2005). According to the 4N series approach, it belongs to the series S = 4n-8, Kp= $C^5C[M1]$. This means it is a member of penta-capped cluster series centered on one skeletal element. These clusters belong to the VE[n] series such as 16[1]→28[2] →40[3] →52[4] →64[5] →76[6] →88[7] →100[8] →112[9] →124[10] →136[11] →148[12] and so on. Examples include (Kiremire, 2017f)., 52[4]→Au_4L_4;76[6] →$Au_6L_6^{2+}$;100[8]→$Au_8L_7^{2+}$;112[9] →$Au_9L_8^{3+}$, and so on. The central skeletal element [M1], obeys the S=4n+2 , K=2n-1=2(1)-1=1. According to the series approach, this means the nucleus on its own can be assigned one skeletal linkage out of the total 16 linkages. Therefore the remaining 15 skeletal linkages will be assigned to the skeletal structure which is shown in Figure 8 Indeed the shape appears as the conventional octahedral shape.

There are other clusters that portray the ideal octahedral shape. Among of these include: $Mo_6Cl_8L_6^{4+}$, K(n) = 28(6), S= 4n-32,VE=14n-32=14(6)-32=52, VE=18n-2K= 18(6)-2(28)=52,VE=14+2x+12(n-1)= 14+2(-11)+12(6-1)=52, $VE=VE_0$+dn= 2(-11)+2+12(6)=52, VF=6(6)+8+6(2)-4=52. The above information clearly indicates the cluster obeys the natural laws of the series. We have also found that the negative nuclear index means the capping of electrons in the nucleus in dozen groupings. In this case, there will be 11 dozen electron cappings in the nucleus, C^{11} and hence the capping of the skeletal elements will be C^6 making a total of C^{17} cappings. Does it mean that the 6 caapings identifed by the 4N series, represent the octahedral shape observed? This seems to make sense. According to the 4N series, each capping posses 3 linkages. Therefore the 6 cappings will correspond to 18 linkages. Therefore, we can construct a hypothetical geometry shown in Figure 8.

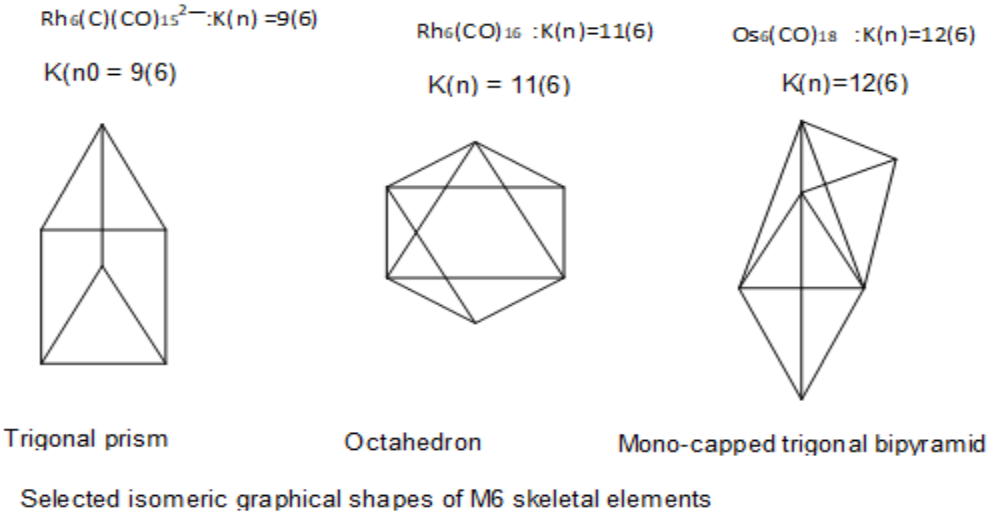
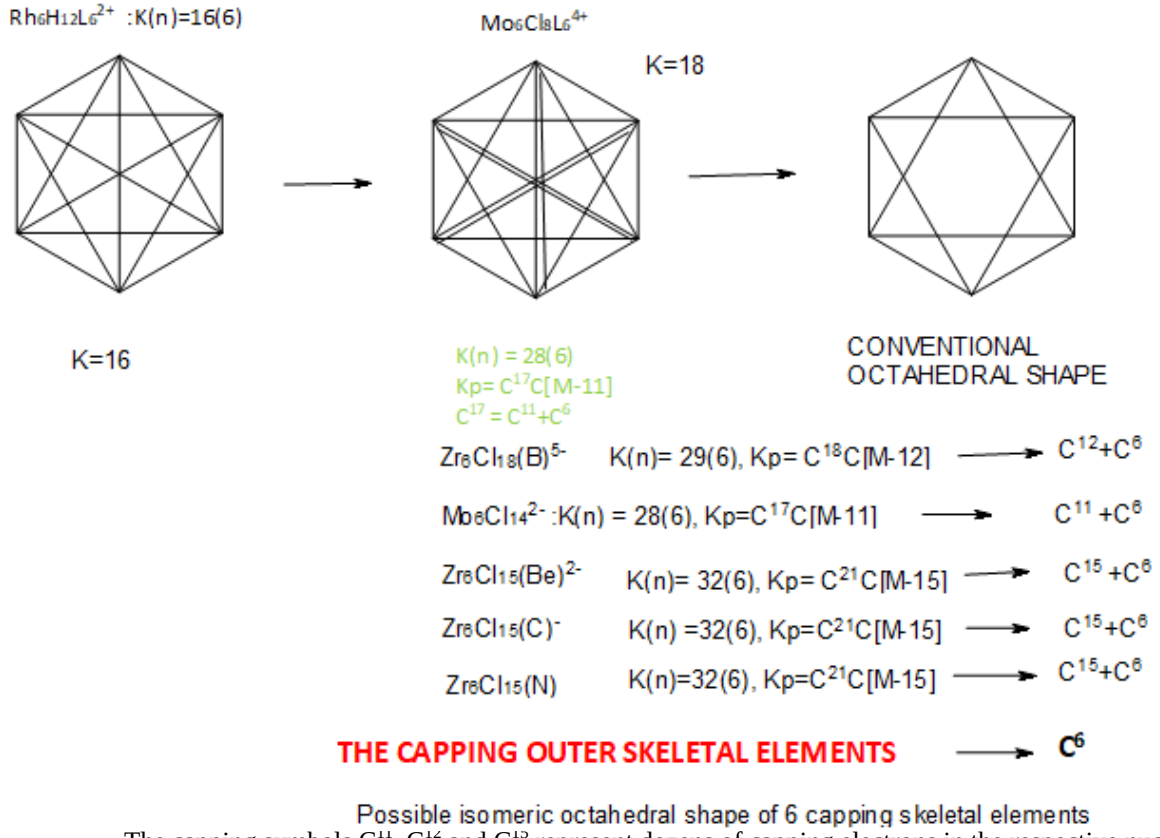


Figure 7. Hypothetical linkage between ideal cluster geometry and cluster numbers



The capping symbols C^{11}, C^{12} and C^{15} represent dozens of capping electrons in the respective nuclei.

Figure 8. Hypothetical possible shapes deduced from the capping principle of selected clusters.

Table 12. The capping series of selected range of clusters

C^{11}	C^{10}	C^{9}	C^{8}	C^{7}	C^{6}	C^{5}	C^{4}	C^{3}	C^{2}	C^{1}	C^{0}	
4n-20	4n-18	4n-16	4n-14	4n-12	4n-10	4n-8	4n-6	4n-4	4n-2	4n+0	4n+2	S/[Mx]
302	290	278	266	254	242	230	218	206	194	182	170	12
288	276	264	252	240	228	216	204	192	180	168	156	11
274	262	250	238	226	214	202	190	178	166	154	142	10
260	248	236	224	212	200	188	176	164	152	140	128	9
246	234	222	210	198	186	174	162	150	138	126	114	8
232	220	208	196	184	172	160	148	136	124	112	100	7
218	**206**	**194**	**182**	**170**	**158**	**146**	**134**	**122**	**110**	**98**	**86**	**6**
204	192	180	168	156	144	132	120	108	96	84	72	5
190	178	166	154	142	130	118	106	94	82	70	58	4
176	164	152	140	128	116	104	92	80	68	56	44	3
162	150	138	126	114	102	90	78	66	54	42	30	2
148	**136**	**124**	**112**	**100**	**88**	**76**	**64**	**52**	**40**	**28**	**16**	**1**
134	122	110	98	86	74	62	50	38	26	14	**2**	0
120	108	96	84	72	60	48	36	24	12	**0**	**-12**	-1
106	94	82	70	58	46	34	22	10	**-2**	**-14**	**-26**	-2
92	80	68	56	44	32	20	8	**-4**	**-16**	**-28**	**-40**	-3
78	66	54	42	30	18	6	**-6**	-18	-30	-42	-54	-4
64	52	40	28	16	4	**-8**	**-20**	-32	-44	-56	-68	-5
50	38	26	14	2	**-10**	**-22**	**-34**	-46	-58	-70	-82	-6
36	24	12	0	**-12**	**-24**	**-36**	**-48**	-60	-72	-84	-96	-7
22	10	-2	**-14**	**-26**	**-38**	**-50**	**-62**	-74	-86	-98	-110	-8
8	-4	**-16**	**-28**	**-40**	**-52**	**-64**	**-76**	-88	-100	-112	-124	-9
-6	**-18**	**-30**	**-42**	**-54**	**-66**	**-78**	**-90**	-102	-114	-126	-138	-10
-20	-32	**-44**	**-56**	**-68**	**-80**	**-92**	**-104**	-116	-128	-140	-152	-11
-34	-46	**-58**	**-70**	**-82**	**-94**	**-106**	**-118**	-130	-142	-154	-166	-12

2.11 Selected Capping Cluster Series

As already discussed, formulas of clusters can easily be derived by applying the genesis principle of starting at n=0. The examples based on [M7], [M6], [M2], and [M1] are given in Scheme 15. More examples of generating fragments and clusters of osmium and palladium are given in Tables T-14 to T-19.

The Derivation of [M7] capping cluster series

K(n) =13(7): K= 13, n=7, Ve= 18n-2K =18[7]-2[13] =**100**; K(n) = -8(0): K= -8, n= 0, Ve=18n-2K = 18(0)-2(-8) = **16**→8CO

The capping fragment is $Os(CO)_2$

8CO[n=0]→$Os(CO)_{10}$[n=1]→$Os_2(CO)_{12}$[n=2]→$Os_3(CO)_{14}$[n=3]→$Os_4(CO)_{16}$[n=4]→$Os_5(CO)_{18}$[n=5]→$Os_6(CO)_{20}$[n=6]

→$Os_7(CO)_{22}$[n=7];[beginning, 8CO ≡ 16e, and, $Os_7(CO)_{22}$ ≡ 7(8)+22(2)=100e]. The numbers form the sequence: **16→28→40→52→64→76→88→100**. Apart from 16, the others represent the corresponding clusters indicated.

$Os_7(CO)_{22}$[n=7]→ $Os_8(CO)_{24}$ [n=8, Ve=112, C^1]→ $Os_9(CO)_{26}$ [n=9, 124, C^2]→ $Os_{10}(CO)_{28}$ [n=10, 136, C^3],….

The Derivation of [M6] capping cluster series

Let us consider going from the beginning n=0 to n = 10. The [12e] capping fragment is[$Os(CO)_2$].

K(n) = 11(6), K =11, n=6; Ve=18n-2K = 18[6]-2[11] =86; and for [M6] series K(n)=-7(0); Ve = 18(0)-2(-7) =14→7CO

De-capping series: 7CO[n=0, Ve=14]→$Os(CO)_9$[n=1,Ve=26]→$Os_2(CO)_{11}$[n=2,Ve=38]→ $Os_3(CO)_{13}$[n=3,Ve=38] $Os_4(CO)_{15}$[n=3,Ve=50] → $Os_5(CO)_{17}$[n=5,Ve=74] → $Os_6(CO)_{19}$[n=6,Ve=86](appears as $Os_6(CO)_{18}^{2-}$).

$Os_6(CO)_{19}$[n=6,Ve=86,C^0]→ $Os_7(CO)_{21}$[n=7,Ve=98,C^1]→ $Os_8(CO)_{23}$[n=8,Ve=110,C^2]→ $Os_9(CO)_{25}$[n=5,Ve=122,C^3]→ $Os_{10}(CO)_{27}$[n=10,Ve=134,C^4],…

The majority of golden clusters belong [M1] or [M2] series. We can apply the same method as used for [M7] and [M6] to generate corresponding series.

The Derivation of [M2] capping cluster series

K(n) = 3(2); Ve=18n-2K = 18(2)-2(3) = 30

K(n)=-3(0); Ve=18(0)-2(-3) = 6 →3CO = 3L (e.g , L=PPh_3)

We can illustrate series using gold skeletal elements. The twelve electron fragment could be AuH = Au^-. 3L[6]→AuL_3^-[18]→$Au_2L_3^{2-}$ =Au_2L_4[30, C^0]→ $Au_3L_4^-$[42,C^1]→ $Au_4L_4^{2-}$= Au_4L_5[54,C^2]→ $Au_5L_5^-$[66,C^3]→ $Au_6L_5^{2-}$=Au_6L_6 [78,C^4]→ $Au_7L_6^-$[90, C^5]→$Au_8L_6^{2-}$=Au_8L_7[102,C^6]→$Au_9L_7^-$→[114,C^7] $Au_{10}L_7^{2-}$= $Au_{10}L_8$126,C^8]→ $Au_{11}L_8^-$[138,C^8]→ $Au_{12}L_8^{2-}$ = $Au_{12}L_9$[150,C^{10}] → $Au_{13}L_9^-$[162,C^{11}]→ $Au_{14}L_9^{2-}$= $Au_{14}L_{10}$[174,C^{12}]

The Derivation of [M1] capping cluster series

K(n) =1(1); Ve = 18n-2K =18[1]-2[1] =16

K(n)= -2(0); Ve= 18n-2K =18(0)-2(-2)=4→2CO=2L

2L[4]→AuL_2^-[16,C^0]$^-$→$Au_2L_2^{2-}$ =Au_2L_3[28, C^1]→ $Au_3L_3^-$[40, C^2]→ → $Au_4L_3^{2-}$ = Au_4L_4[52, C^3]→ → $Au_5L_4^-$[64, C^4] → $Au_6L_4^{2-}$ = Au_6L_5[76, C^5]→ $Au_7L_5^-$[88, C^6]→ $Au_8L_5^{2-}$= Au_8L_6[100, C^7] → $Au_9L_6^-$[112, C^8]→ $Au_{10}L_6^{2-}$= $Au_{10}L_7$[124, C^9]→ $Au_{11}L_7^-$[136, C^{10}]→ $Au_{12}L_7^{2-}$= $Au_{12}L_8$[148, C^{11}]→ $Au_{13}L_8^-$[160, C^{12}]→ $Au_{14}L_8^{2-}$= $Au_{14}L_9$[172, C^{13}]

Scheme 15. More examples illustrating the derivation of cluster formulas using the genesis principle

Table 13. The relationship between the K(N) parameter and cluster valence electron (VE)

T-13														
[M6]	CAP	PIN	G	SER	IES		T10							
K	**-7**	**-4**	**-1**	**2**	**5**	**8**	**11**	**14**	**17**	**20**	**23**	**26**	**29**	**32**
N	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
VE	**14**	**26**	**38**	**50**	**62**	**74**	**86**	**98**	**110**	**122**	**134**	**146**	**158**	**170**
K	**32**	**35**	**38**	**41**	**44**	**47**	**50**	**53**	**56**	**59**	**62**	**65**	**68**	**71**
N	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**
VE	**170**	**182**	**194**	**206**	**218**	**230**	**242**	**254**	**266**	**278**	**290**	**302**	**314**	**326**
K	**71**	**74**	**77**	**80**	**83**	**86**	**89**	**92**	**95**	**98**	**101**	**104**	**107**	**110**
N	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**
VE	**326**	**338**	**350**	**362**	**374**	**386**	**398**	**410**	**422**	**434**	**446**	**458**	**470**	**482**
K	**110**	**113**	**116**	**119**	**122**	**125**	**128**	**131**	**134**	**137**	**140**	**143**	**146**	**149**
N	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	**51**	**52**
VE	**482**	**494**	**506**	**518**	**530**	**542**	**554**	**566**	**578**	**590**	**602**	**614**	**626**	**638**
K	**149**	**152**	**155**	**158**	**161**	**164**	**167**	**170**	**173**	**176**	**179**	**182**	**185**	**188**
N	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**59**	**60**	**61**	**62**	**63**	**64**	**65**
VE	**638**	**650**	**662**	**674**	**686**	**698**	**710**	**722**	**734**	**746**	**758**	**770**	**782**	**794**

Table 14. Generating functions of clan series of clusters based upon the genesis principle

	[M0]	**[M1]**	**[M2]**	**[M3]**	**[M4]**	**[M5]**	**[M6]**
	G_0=0+1=1	G_O=1+1=2	G_O =2+1=3	G_O =3+1=4	G_O =4+1=5	G_O =5+1=6	G_O =6+1=7
	$Os(CO)_2$	$Os(CO)_2$	$Os(CO)_2$	$Os(CO)_2$	$Os(CO)_2$	$Os(CO)_2$	$Os(CO)_2$
	$F=Os_x(CO)_{2x+1}$	$F=Os_x(CO)_{2x+2}$	$F=Os_x(CO)_{2x+3}$	$F=Os_x(CO)_{2x+4}$	$F=Os_x(CO)_{2x+5}$	$F=Os_x(CO)_{2x+6}$	$F=Os_x(CO)_{2x+7}$
X=0	CO	2CO	3CO	4CO	5CO	6CO	7CO
1	$Os(CO)_3$	$Os(CO)_4$	$Os(CO)_5$	$Os(CO)_6$	$Os(CO)_7$	$Os(CO)_8$	$Os(CO)_9$
2	$Os_2(CO)_5$	$Os_2(CO)_6$	$Os_2(CO)_7$	$Os_2(CO)_8$	**$Os_2(CO)_9$**	**$Os_2(CO)_{10}$**	$Os_2(CO)_{11}$
3	$Os_3(CO)_7$	$Os_3(CO)_8$	$Os_3(CO)_9$	$Os_3(CO)_{10}$	**$Os_3(CO)_{11}$**	**$Os_3(CO)_{12}$**	$Os_3(CO)_{13}$
4	$Os_4(CO)_9$	$Os_4(CO)_{10}$	$Os_4(CO)_{11}$	$Os_4(CO)_{12}$	$Os_4(CO)_{13}$	**$Os_4(CO)_{14}$**	$Os_4(CO)_{15}$
5	$Os_5(CO)_{11}$	$Os_5(CO)_{12}$	$Os_5(CO)_{13}$	$Os_5(CO)_{14}$	$Os_5(CO)_{15}$	**$Os_5(CO)_{16}$**	$Os_5(CO)_{17}$
6	$Os_6(CO)_{13}$	$Os_6(CO)_{14}$	$Os_6(CO)_{15}$	$Os_6(CO)_{16}$	$Os_6(CO)_{17}$	**$Os_6(CO)_{18}$**	**$Os_6(CO)_{19}$**
7	$Os_7(CO)_{15}$	$Os_7(CO)_{16}$	$Os_7(CO)_{17}$	$Os_7(CO)_{18}$	$Os_7(CO)_{19}$	$Os_7(CO)_{20}$	$Os_7(CO)_{21}$
8	$Os_8(CO)_{17}$	$Os_8(CO)_{18}$	$Os_8(CO)_{19}$	$Os_8(CO)_{20}$	$Os_8(CO)_{21}$	$Os_8(CO)_{22}$	**$Os_8(CO)_{23}$**
9	$Os_9(CO)_{19}$	$Os_9(CO)_{20}$	$Os_9(CO)_{21}$	$Os_9(CO)_{22}$	**$Os_9(CO)_{23}$**	$Os_9(CO)_{24}$	$Os_9(CO)_{25}$
10	$Os_{10}(CO)_{21}$	$Os_{10}(CO)_{22}$	$Os_{10}(CO)_{23}$	$Os_{10}(CO)_{24}$	$Os_{10}(CO)_{25}$	$Os_{10}(CO)_{26}$	**$Os_{10}(CO)_{27}$**
11	$Os_{11}(CO)_{23}$	$Os_{11}(CO)_{24}$	$Os_{11}(CO)_{25}$	$Os_{11}(CO)_{26}$	$Os_{11}(CO)_{27}$	$Os_{11}(CO)_{28}$	$Os_{11}(CO)_{29}$
12	$Os_{12}(CO)_{25}$	$Os_{12}(CO)_{26}$	$Os_{12}(CO)_{27}$	$Os_{12}(CO)_{28}$	$Os_{12}(CO)_{29}$	$Os_{12}(CO)_{30}$	$Os_{12}(CO)_{31}$
13	$Os_{13}(CO)_{27}$	$Os_{13}(CO)_{28}$	$Os_{13}(CO)_{29}$	$Os_{13}(CO)_{30}$	$Os_{13}(CO)_{31}$	$Os_{13}(CO)_{32}$	$Os_{13}(CO)_{33}$
14	$Os_{14}(CO)_{29}$	$Os_{14}(CO)_{30}$	$Os_{14}(CO)_{31}$	$Os_{14}(CO)_{32}$	$Os_{14}(CO)_{33}$	$Os_{14}(CO)_{34}$	$Os_{14}(CO)_{35}$
15	$Os_{15}(CO)_{31}$	$Os_{15}(CO)_{32}$	$Os_{15}(CO)_{33}$	$Os_{15}(CO)_{34}$	$Os_{15}(CO)_{35}$	$Os_{15}(CO)_{36}$	$Os_{15}(CO)_{37}$
16	$Os_{16}(CO)_{33}$	$Os_{16}(CO)_{34}$	$Os_{16}(CO)_{35}$	$Os_{16}(CO)_{36}$	$Os_{16}(CO)_{37}$	$Os_{16}(CO)_{38}$	$Os_{16}(CO)_{39}$
17	$Os_{17}(CO)_{35}$	$Os_{17}(CO)_{36}$	$Os_{17}(CO)_{37}$	$Os_{17}(CO)_{38}$	$Os_{17}(CO)_{39}$	$Os_{17}(CO)_{40}$	$Os_{17}(CO)_{41}$
18	$Os_{18}(CO)_{37}$	$Os_{18}(CO)_{38}$	$Os_{18}(CO)_{39}$	$Os_{18}(CO)_{40}$	$Os_{18}(CO)_{41}$	$Os_{18}(CO)_{42}$	$Os_{18}(CO)_{43}$
19	$Os_{19}(CO)_{39}$	$Os_{19}(CO)_{40}$	$Os_{19}(CO)_{41}$	$Os_{19}(CO)_{42}$	$Os_{19}(CO)_{43}$	$Os_{19}(CO)_{44}$	$Os_{19}(CO)_{45}$
20	**$Os_{20}(CO)_{41}$**	$Os_{20}(CO)_{42}$	$Os_{20}(CO)_{43}$	$Os_{20}(CO)_{44}$	$Os_{20}(CO)_{45}$	$Os_{20}(CO)_{46}$	$Os_{20}(CO)_{47}$
21	$Os_{21}(CO)_{43}$	$Os_{21}(CO)_{44}$	$Os_{21}(CO)_{45}$	$Os_{21}(CO)_{46}$	$Os_{21}(CO)_{47}$	$Os_{21}(CO)_{48}$	$Os_{21}(CO)_{49}$
22	$Os_{22}(CO)_{45}$	$Os_{22}(CO)_{46}$	$Os_{22}(CO)_{47}$	$Os_{22}(CO)_{48}$	$Os_{22}(CO)_{49}$	$Os_{22}(CO)_{50}$	$Os_{22}(CO)_{51}$
23	$Os_{23}(CO)_{47}$	$Os_{23}(CO)_{48}$	$Os_{23}(CO)_{49}$	$Os_{23}(CO)_{50}$	$Os_{23}(CO)_{51}$	$Os_{23}(CO)_{52}$	$Os_{23}(CO)_{53}$
24	$Os_{24}(CO)_{49}$	$Os_{24}(CO)_{50}$	$Os_{24}(CO)_{51}$	$Os_{24}(CO)_{52}$	$Os_{24}(CO)_{53}$	$Os_{24}(CO)_{54}$	$Os_{24}(CO)_{55}$
25	$Os_{25}(CO)_{51}$	$Os_{25}(CO)_{52}$	$Os_{25}(CO)_{53}$	$Os_{25}(CO)_{54}$	$Os_{25}(CO)_{55}$	$Os_{25}(CO)_{56}$	$Os_{25}(CO)_{57}$
26	$Os_{26}(CO)_{53}$	$Os_{26}(CO)_{54}$	$Os_{26}(CO)_{55}$	$Os_{26}(CO)_{56}$	$Os_{26}(CO)_{57}$	$Os_{26}(CO)_{58}$	$Os_{26}(CO)_{59}$
27	$Os_{27}(CO)_{55}$	$Os_{27}(CO)_{56}$	$Os_{27}(CO)_{57}$	$Os_{27}(CO)_{58}$	$Os_{27}(CO)_{59}$	$Os_{27}(CO)_{60}$	$Os_{27}(CO)_{61}$
28	$Os_{28}(CO)_{57}$	$Os_{28}(CO)_{58}$	$Os_{28}(CO)_{59}$	$Os_{28}(CO)_{60}$	$Os_{28}(CO)_{61}$	$Os_{28}(CO)_{62}$	$Os_{28}(CO)_{63}$
29	$Os_{29}(CO)_{59}$	$Os_{29}(CO)_{60}$	$Os_{29}(CO)_{61}$	$Os_{29}(CO)_{62}$	$Os_{29}(CO)_{63}$	$Os_{29}(CO)_{64}$	$Os_{29}(CO)_{65}$
30	$Os_{30}(CO)_{61}$	$Os_{30}(CO)_{62}$	$Os_{30}(CO)_{63}$	$Os_{30}(CO)_{64}$	$Os_{30}(CO)_{65}$	$Os_{30}(CO)_{66}$	$Os_{30}(CO)_{67}$
31	$Os_{31}(CO)_{63}$	$Os_{31}(CO)_{64}$	$Os_{31}(CO)_{65}$	$Os_{31}(CO)_{66}$	$Os_{31}(CO)_{67}$	$Os_{31}(CO)_{68}$	$Os_{31}(CO)_{69}$
32	$Os_{32}(CO)_{65}$	$Os_{32}(CO)_{66}$	$Os_{32}(CO)_{67}$	$Os_{32}(CO)_{68}$	$Os_{32}(CO)_{69}$	$Os_{32}(CO)_{70}$	$Os_{32}(CO)_{71}$
33	$Os_{33}(CO)_{67}$	$Os_{33}(CO)_{68}$	$Os_{33}(CO)_{69}$	$Os_{33}(CO)_{70}$	$Os_{33}(CO)_{71}$	$Os_{33}(CO)_{72}$	$Os_{33}(CO)_{73}$
34	$Os_{34}(CO)_{69}$	$Os_{34}(CO)_{70}$	$Os_{34}(CO)_{71}$	$Os_{34}(CO)_{72}$	$Os_{34}(CO)_{73}$	$Os_{34}(CO)_{74}$	$Os_{34}(CO)_{75}$
35	$Os_{35}(CO)_{71}$	$Os_{35}(CO)_{72}$	$Os_{35}(CO)_{73}$	$Os_{35}(CO)_{74}$	$Os_{35}(CO)_{75}$	$Os_{35}(CO)_{76}$	$Os_{35}(CO)_{77}$
36	$Os_{36}(CO)_{73}$	$Os_{36}(CO)_{74}$	$Os_{36}(CO)_{75}$	$Os_{36}(CO)_{76}$	$Os_{36}(CO)_{77}$	$Os_{36}(CO)_{78}$	$Os_{36}(CO)_{79}$
37	$Os_{37}(CO)_{75}$	$Os_{37}(CO)_{76}$	$Os_{37}(CO)_{77}$	$Os_{37}(CO)_{78}$	$Os_{37}(CO)_{79}$	$Os_{37}(CO)_{80}$	$Os_{37}(CO)_{81}$
38	$Os_{38}(CO)_{77}$	$Os_{38}(CO)_{78}$	$Os_{38}(CO)_{79}$	$Os_{38}(CO)_{80}$	$Os_{38}(CO)_{81}$	$Os_{38}(CO)_{82}$	$Os_{38}(CO)_{83}$
39	$Os_{39}(CO)_{79}$	$Os_{39}(CO)_{80}$	$Os_{39}(CO)_{81}$	$Os_{39}(CO)_{82}$	$Os_{39}(CO)_{83}$	$Os_{39}(CO)_{84}$	$Os_{39}(CO)_{85}$
40	$Os_{40}(CO)_{81}$	$Os_{40}(CO)_{82}$	$Os_{40}(CO)_{83}$	$Os_{40}(CO)_{84}$	$Os_{40}(CO)_{85}$	$Os_{40}(CO)_{86}$	$Os_{40}(CO)_{87}$

Table 15. Continuation of Table 14

T15	**[M6]**	**[M7]**	**[M8]**	**[M9]**	**[M10]**
	G_O =6+1=7	G_O =7+1=8	G_O =8+1=9	G_O =9+1=10	G_O =10+1=11
	$Os(CO)_2$	$Os(CO)_2$	$Os(CO)_2$	$Os(CO)_2$	$Os(CO)_2$
	$F=Os_x(CO)_{2x+7}$	$F=Os_x(CO)_{2x+8}$	$F=Os_x(CO)_{2x+9}$	$F=Os_x(CO)_{2x+10}$	$F=Os_x(CO)_{2x+11}$
X=0	7CO	8CO	9CO	10CO	11CO
1	$Os(CO)_9$	$Os(CO)_{10}$	$Os(CO)_{11}$	$Os(CO)_{12}$	$Os(CO)_{13}$
2	$Os_2(CO)_{11}$	$Os_2(CO)_{12}$	$Os_2(CO)_{13}$	$Os_2(CO)_{14}$	$Os_2(CO)_{15}$
3	$Os_3(CO)_{13}$	$Os_3(CO)_{14}$	$Os_3(CO)_{15}$	$Os_3(CO)_{16}$	$Os_3(CO)_{17}$
4	**$Os_4(CO)_{15}$**	**$Os_4(CO)_{16}$**	$Os_4(CO)_{17}$	$Os_4(CO)_{18}$	$Os_4(CO)_{19}$
5	**$Os_5(CO)_{17}$**	**$Os_5(CO)_{18}$**	**$Os_5(CO)_{19}$**	$Os_5(CO)_{20}$	$Os_5(CO)_{21}$
6	$Os_6(CO)_{19}$	**$Os_6(CO)_{20}$**	**$Os_6(CO)_{21}$**	$Os_6(CO)_{22}$	$Os_6(CO)_{23}$
7	**$Os_7(CO)_{21}$**	**$Os_7(CO)_{22}$**	**$Os_7(CO)_{23}$**	$Os_7(CO)_{24}$	$Os_7(CO)_{25}$
8	$Os_8(CO)_{23}$	$Os_8(CO)_{24}$	$Os_8(CO)_{25}$	$Os_8(CO)_{26}$	$Os_8(CO)_{27}$
9	$Os_9(CO)_{25}$	$Os_9(CO)_{26}$	**$Os_9(CO)_{27}$**	$Os_9(CO)_{28}$	$Os_9(CO)_{29}$
10	$Os_{10}(CO)_{27}$	$Os_{10}(CO)_{28}$	$Os_{10}(CO)_{29}$	$Os_{10}(CO)_{30}$	$Os_{10}(CO)_{31}$
11	$Os_{11}(CO)_{29}$	$Os_{11}(CO)_{30}$	$Os_{11}(CO)_{31}$	$Os_{11}(CO)_{32}$	$Os_{11}(CO)_{33}$
12	$Os_{12}(CO)_{31}$	$Os_{12}(CO)_{32}$	$Os_{12}(CO)_{33}$	$Os_{12}(CO)_{34}$	$Os_{12}(CO)_{35}$
13	$Os_{13}(CO)_{33}$	$Os_{13}(CO)_{34}$	$Os_{13}(CO)_{35}$	$Os_{13}(CO)_{36}$	$Os_{13}(CO)_{37}$
14	$Os_{14}(CO)_{35}$	$Os_{14}(CO)_{36}$	$Os_{14}(CO)_{37}$	$Os_{14}(CO)_{38}$	$Os_{14}(CO)_{39}$
15	$Os_{15}(CO)_{37}$	$Os_{15}(CO)_{38}$	$Os_{15}(CO)_{39}$	$Os_{15}(CO)_{40}$	$Os_{15}(CO)_{41}$
16	$Os_{16}(CO)_{39}$	$Os_{16}(CO)_{40}$	$Os_{16}(CO)_{41}$	$Os_{16}(CO)_{42}$	$Os_{16}(CO)_{43}$
17	$Os_{17}(CO)_{41}$	$Os_{17}(CO)_{42}$	$Os_{17}(CO)_{43}$	$Os_{17}(CO)_{44}$	$Os_{17}(CO)_{45}$
18	$Os_{18}(CO)_{43}$	$Os_{18}(CO)_{44}$	$Os_{18}(CO)_{45}$	$Os_{18}(CO)_{46}$	$Os_{18}(CO)_{47}$
19	$Os_{19}(CO)_{45}$	$Os_{19}(CO)_{46}$	$Os_{19}(CO)_{47}$	$Os_{19}(CO)_{48}$	$Os_{19}(CO)_{49}$
20	$Os_{20}(CO)_{47}$	$Os_{20}(CO)_{48}$	$Os_{20}(CO)_{49}$	$Os_{20}(CO)_{50}$	$Os_{20}(CO)_{51}$
21	$Os_{21}(CO)_{49}$	$Os_{21}(CO)_{50}$	$Os_{21}(CO)_{51}$	$Os_{21}(CO)_{52}$	$Os_{21}(CO)_{53}$
22	$Os_{22}(CO)_{51}$	$Os_{22}(CO)_{52}$	$Os_{22}(CO)_{53}$	$Os_{22}(CO)_{54}$	$Os_{22}(CO)_{55}$
23	$Os_{23}(CO)_{53}$	$Os_{23}(CO)_{54}$	$Os_{23}(CO)_{55}$	$Os_{23}(CO)_{56}$	$Os_{23}(CO)_{57}$
24	$Os_{24}(CO)_{55}$	$Os_{24}(CO)_{56}$	$Os_{24}(CO)_{57}$	$Os_{24}(CO)_{58}$	$Os_{24}(CO)_{59}$
25	$Os_{25}(CO)_{57}$	$Os_{25}(CO)_{58}$	$Os_{25}(CO)_{59}$	$Os_{25}(CO)_{60}$	$Os_{25}(CO)_{61}$
26	$Os_{26}(CO)_{59}$	$Os_{26}(CO)_{60}$	$Os_{26}(CO)_{61}$	$Os_{26}(CO)_{62}$	$Os_{26}(CO)_{63}$
27	$Os_{27}(CO)_{61}$	$Os_{27}(CO)_{62}$	$Os_{27}(CO)_{63}$	$Os_{27}(CO)_{64}$	$Os_{27}(CO)_{65}$
28	$Os_{28}(CO)_{63}$	$Os_{28}(CO)_{64}$	$Os_{28}(CO)_{65}$	$Os_{28}(CO)_{66}$	$Os_{28}(CO)_{67}$
29	$Os_{29}(CO)_{65}$	$Os_{29}(CO)_{66}$	$Os_{29}(CO)_{67}$	$Os_{29}(CO)_{68}$	$Os_{29}(CO)_{69}$
30	$Os_{30}(CO)_{67}$	$Os_{30}(CO)_{68}$	$Os_{30}(CO)_{69}$	$Os_{30}(CO)_{70}$	$Os_{30}(CO)_{71}$
31	$Os_{31}(CO)_{69}$	$Os_{31}(CO)_{70}$	$Os_{31}(CO)_{71}$	$Os_{31}(CO)_{72}$	$Os_{31}(CO)_{73}$
32	$Os_{32}(CO)_{71}$	$Os_{32}(CO)_{72}$	$Os_{32}(CO)_{73}$	$Os_{32}(CO)_{74}$	$Os_{32}(CO)_{75}$
33	$Os_{33}(CO)_{73}$	$Os_{33}(CO)_{74}$	$Os_{33}(CO)_{75}$	$Os_{33}(CO)_{76}$	$Os_{33}(CO)_{77}$
34	$Os_{34}(CO)_{75}$	$Os_{34}(CO)_{76}$	$Os_{34}(CO)_{77}$	$Os_{34}(CO)_{78}$	$Os_{34}(CO)_{79}$
35	$Os_{35}(CO)_{77}$	$Os_{35}(CO)_{78}$	$Os_{35}(CO)_{79}$	$Os_{35}(CO)_{80}$	$Os_{35}(CO)_{81}$
36	$Os_{36}(CO)_{79}$	$Os_{36}(CO)_{80}$	$Os_{36}(CO)_{81}$	$Os_{36}(CO)_{82}$	$Os_{36}(CO)_{83}$
37	$Os_{37}(CO)_{81}$	$Os_{37}(CO)_{82}$	$Os_{37}(CO)_{83}$	$Os_{37}(CO)_{84}$	$Os_{37}(CO)_{85}$
38	$Os_{38}(CO)_{83}$	$Os_{38}(CO)_{84}$	$Os_{38}(CO)_{85}$	$Os_{38}(CO)_{86}$	$Os_{38}(CO)_{87}$
39	$Os_{39}(CO)_{85}$	$Os_{39}(CO)_{86}$	$Os_{39}(CO)_{87}$	$Os_{39}(CO)_{88}$	$Os_{39}(CO)_{89}$
40	$Os_{40}(CO)_{87}$	$Os_{40}(CO)_{88}$	$Os_{40}(CO)_{89}$	$Os_{40}(CO)_{90}$	$Os_{40}(CO)_{91}$

Table 16. Generating of clan series of palladium cluster carbonyls

	[M0]	[M1]	[M2]	[M3]	[M4]	[M5]	[M6]
	G_O =0+1=1	G_O =1+1=2	G_O =2+1=3	G_O =3+1=4	G_O =4+1=5	G_O =5+1=6	G_O =6+1=7
	Pd(CO)	Pd(CO)	Pd(CO)	Pd(CO)	Pd(CO)	Pd(CO)	Pd(CO)
	$F=Pd_x(CO)_{x+1}$	$F=Pd_x(CO)_{x+2}$	$F=Pd_x(CO)_{x+3}$	$F=Pd_x(CO)_{x+4}$	$F=Pd_x(CO)_{x+5}$	$F=Pd_x(CO)_{x+6}$	$F=Pd_x(CO)_{x+7}$
0	CO	2CO	3CO	4CO	5CO	6CO	7CO
1	$Pd(CO)_2$	$Pd(CO)_3$	$Pd(CO)_4$	$Pd(CO)_5$	$Pd(CO)_6$	$Pd(CO)_7$	$Pd(CO)_8$
2	$Pd_2(CO)_3$	$Pd_2(CO)_4$	$Pd_2(CO)_5$	$Pd_2(CO)_6$	$Pd_2(CO)_7$	$Pd_2(CO)_8$	$Pd_2(CO)_9$
3	$Pd_3(CO)_4$	$Pd_3(CO)_5$	**$Pd_3(CO)_6$**	$Pd_3(CO)_7$	$Pd_3(CO)_8$	$Pd_3(CO)_9$	$Pd_3(CO)_{10}$
4	$Pd_4(CO)_5$	$Pd_4(CO)_6$	**$Pd_4(CO)_7$**	$Pd_4(CO)_8$	$Pd_4(CO)_9$	$Pd_4(CO)_{10}$	$Pd_4(CO)_{11}$
5	$Pd_5(CO)_6$	$Pd_5(CO)_7$	$Pd_5(CO)_8$	$Pd_5(CO)_9$	$Pd_5(CO)_{10}$	$Pd_5(CO)_{11}$	$Pd_5(CO)_{12}$
6	$Pd_6(CO)_7$	**$Pd_6(CO)_8$**	$Pd_6(CO)_9$	$Pd_6(CO)_{10}$	$Pd_6(CO)_{11}$	$Pd_6(CO)_{12}$	**$Pd_6(CO)_{13}$**
7	$Pd_7(CO)_8$	$Pd_7(CO)_9$	**$Pd_7(CO)_{10}$**	$Pd_7(CO)_{11}$	$Pd_7(CO)_{12}$	$Pd_7(CO)_{13}$	**$Pd_7(CO)_{14}$**
8	**$Pd_8(CO)_9$**	**$Pd_8(CO)_{10}$**	**$Pd_8(CO)_{11}$**	**$Pd_8(CO)_{12}$**	$Pd_8(CO)_{13}$	**$Pd_8(CO)_{14}$**	$Pd_8(CO)_{15}$
9	$Pd_9(CO)_{10}$	**$Pd_9(CO)_{11}$**	**$Pd_9(CO)_{12}$**	$Pd_9(CO)_{13}$	$Pd_9(CO)_{14}$	$Pd_9(CO)_{15}$	**$Pd_9(CO)_{16}$**
10	$Pd_{10}(CO)_{11}$	**$Pd_{10}(CO)_{12}$**	**$Pd_{10}(CO)_{13}$**	$Pd_{10}(CO)_{14}$	$Pd_{10}(CO)_{15}$	$Pd_{10}(CO)_{16}$	$Pd_{10}(CO)_{17}$
11	$Pd_{11}(CO)_{12}$	$Pd_{11}(CO)_{12}$	**$Pd_{11}(CO)_{14}$**	$Pd_{11}(CO)_{15}$	**$Pd_{11}(CO)_{16}$**	$Pd_{11}(CO)_{17}$	$Pd_{11}(CO)_{18}$
12	$Pd_{12}(CO)_{13}$	$Pd_{12}(CO)_{13}$	$Pd_{12}(CO)_{15}$	$Pd_{12}(CO)_{16}$	$Pd_{12}(CO)_{17}$	$Pd_{12}(CO)_{18}$	$Pd_{12}(CO)_{19}$
13	$Pd_{13}(CO)_{14}$	$Pd_{13}(CO)_{15}$	**$Pd_{13}(CO)_{16}$**	$Pd_{13}(CO)_{17}$	$Pd_{13}(CO)_{18}$	$Pd_{13}(CO)_{19}$	$Pd_{13}(CO)_{20}$
14	$Pd_{14}(CO)_{15}$	$Pd_{14}(CO)_{16}$	$Pd_{14}(CO)_{17}$	$Pd_{14}(CO)_{18}$	$Pd_{14}(CO)_{19}$	**$Pd_{14}(CO)_{20}$**	$Pd_{14}(CO)_{21}$
15	$Pd_{15}(CO)_{16}$	$Pd_{15}(CO)_{17}$	$Pd_{15}(CO)_{18}$	$Pd_{15}(CO)_{19}$	$Pd_{15}(CO)_{20}$	**$Pd_{15}(CO)_{21}$**	$Pd_{15}(CO)_{22}$
16	$Pd_{16}(CO)_{17}$	$Pd_{16}(CO)_{18}$	$Pd_{16}(CO)_{19}$	$Pd_{16}(CO)_{20}$	$Pd_{16}(CO)_{21}$	**$Pd_{16}(CO)_{22}$**	$Pd_{16}(CO)_{23}$
17	$Pd_{17}(CO)_{18}$	$Pd_{17}(CO)_{19}$	**$Pd_{17}(CO)_{20}$**	$Pd_{17}(CO)_{21}$	$Pd_{17}(CO)_{22}$	**$Pd_{17}(CO)_{23}$**	$Pd_{17}(CO)_{24}$
18	$Pd_{18}(CO)_{19}$	$Pd_{18}(CO)_{20}$	$Pd_{18}(CO)_{21}$	$Pd_{18}(CO)_{22}$	$Pd_{18}(CO)_{23}$	$Pd_{18}(CO)_{24}$	$Pd_{18}(CO)_{25}$
19	$Pd_{19}(CO)_{20}$	$Pd_{19}(CO)_{21}$	$Pd_{19}(CO)_{22}$	$Pd_{19}(CO)_{23}$	$Pd_{19}(CO)_{24}$	$Pd_{19}(CO)_{25}$	$Pd_{19}(CO)_{26}$
20	$Pd_{20}(CO)_{21}$	$Pd_{20}(CO)_{22}$	$Pd_{20}(CO)_{23}$	$Pd_{20}(CO)_{24}$	$Pd_{20}(CO)_{25}$	$Pd_{20}(CO)_{26}$	$Pd_{20}(CO)_{27}$
	0	1	2	3	4	5	6
21	$Pd_{21}(CO)_{22}$	$Pd_{21}(CO)_{23}$	$Pd_{21}(CO)_{24}$	$Pd_{21}(CO)_{25}$	$Pd_{21}(CO)_{26}$	$Pd_{21}(CO)_{27}$	$Pd_{21}(CO)_{28}$
22	$Pd_{22}(CO)_{23}$	$Pd_{22}(CO)_{24}$	$Pd_{22}(CO)_{25}$	$Pd_{22}(CO)_{26}$	$Pd_{22}(CO)_{27}$	$Pd_{22}(CO)_{28}$	$Pd_{22}(CO)_{29}$
23	$Pd_{23}(CO)_{24}$	$Pd_{23}(CO)_{25}$	$Pd_{23}(CO)_{26}$	$Pd_{23}(CO)_{27}$	**$Pd_{23}(CO)_{28}$**	$Pd_{23}(CO)_{29}$	$Pd_{23}(CO)_{30}$
24	$Pd_{24}(CO)_{25}$	$Pd_{24}(CO)_{26}$	$Pd_{24}(CO)_{27}$	$Pd_{24}(CO)_{28}$	$Pd_{24}(CO)_{29}$	$Pd_{24}(CO)_{30}$	$Pd_{24}(CO)_{31}$
25	$Pd_{25}(CO)_{26}$	$Pd_{25}(CO)_{27}$	$Pd_{25}(CO)_{28}$	$Pd_{25}(CO)_{29}$	$Pd_{25}(CO)_{30}$	$Pd_{25}(CO)_{31}$	$Pd_{25}(CO)_{32}$
26	$Pd_{26}(CO)_{27}$	$Pd_{26}(CO)_{28}$	$Pd_{26}(CO)_{29}$	$Pd_{26}(CO)_{30}$	$Pd_{26}(CO)_{31}$	$Pd_{26}(CO)_{32}$	$Pd_{26}(CO)_{33}$
27	$Pd_{27}(CO)_{28}$	$Pd_{27}(CO)_{29}$	$Pd_{27}(CO)_{30}$	$Pd_{27}(CO)_{31}$	$Pd_{27}(CO)_{32}$	$Pd_{27}(CO)_{33}$	$Pd_{27}(CO)_{34}$
28	$Pd_{28}(CO)_{29}$	$Pd_{28}(CO)_{30}$	$Pd_{28}(CO)_{31}$	$Pd_{28}(CO)_{32}$	$Pd_{28}(CO)_{33}$	$Pd_{28}(CO)_{34}$	$Pd_{28}(CO)_{35}$
29	$Pd_{29}(CO)_{30}$	$Pd_{29}(CO)_{31}$	$Pd_{29}(CO)_{32}$	$Pd_{29}(CO)_{33}$	$Pd_{29}(CO)_{34}$	$Pd_{29}(CO)_{35}$	$Pd_{29}(CO)_{36}$
30	$Pd_{30}(CO)_{31}$	$Pd_{30}(CO)_{32}$	$Pd_{30}(CO)_{33}$	$Pd_{30}(CO)_{34}$	$Pd_{30}(CO)_{35}$	**$Pd_{30}(CO)_{36}$**	$Pd_{30}(CO)_{37}$
31	$Pd_{31}(CO)_{32}$	$Pd_{31}(CO)_{33}$	$Pd_{31}(CO)_{34}$	$Pd_{31}(CO)_{35}$	$Pd_{31}(CO)_{36}$	$Pd_{31}(CO)_{37}$	$Pd_{31}(CO)_{38}$
32	$Pd_{32}(CO)_{33}$	$Pd_{32}(CO)_{34}$	**$Pd_{32}(CO)_{35}$**	**$Pd_{32}(CO)_{36}$**	$Pd_{32}(CO)_{37}$	$Pd_{32}(CO)_{38}$	$Pd_{32}(CO)_{39}$
33	$Pd_{33}(CO)_{34}$	$Pd_{33}(CO)_{35}$	$Pd_{33}(CO)_{36}$	$Pd_{33}(CO)_{37}$	$Pd_{33}(CO)_{38}$	$Pd_{33}(CO)_{39}$	$Pd_{33}(CO)_{40}$
34	$Pd_{34}(CO)_{35}$	**$Pd_{34}(CO)_{36}$**	$Pd_{34}(CO)_{37}$	$Pd_{34}(CO)_{38}$	$Pd_{34}(CO)_{39}$	$Pd_{34}(CO)_{40}$	$Pd_{34}(CO)_{41}$
35	$Pd_{35}(CO)_{36}$	$Pd_{35}(CO)_{37}$	**$Pd_{35}(CO)_{38}$**	$Pd_{35}(CO)_{39}$	$Pd_{35}(CO)_{40}$	$Pd_{35}(CO)_{41}$	$Pd_{35}(CO)_{42}$
36	$Pd_{36}(CO)_{37}$	$Pd_{36}(CO)_{38}$	$Pd_{36}(CO)_{39}$	$Pd_{36}(CO)_{40}$	$Pd_{36}(CO)_{41}$	**$Pd_{36}(CO)_{42}$**	$Pd_{36}(CO)_{43}$
37	$Pd_{37}(CO)_{38}$	$Pd_{37}(CO)_{39}$	**$Pd_{37}(CO)_{40}$**	$Pd_{37}(CO)_{41}$	$Pd_{37}(CO)_{42}$	$Pd_{37}(CO)_{43}$	$Pd_{37}(CO)_{44}$
38	$Pd_{38}(CO)_{39}$	**$Pd_{38}(CO)_{40}$**	$Pd_{38}(CO)_{41}$	$Pd_{38}(CO)_{42}$	$Pd_{38}(CO)_{43}$	$Pd_{38}(CO)_{44}$	$Pd_{38}(CO)_{45}$
39	$Pd_{39}(CO)_{40}$	$Pd_{39}(CO)_{41}$	$Pd_{39}(CO)_{42}$	$Pd_{39}(CO)_{43}$	$Pd_{39}(CO)_{44}$	$Pd_{39}(CO)_{45}$	$Pd_{39}(CO)_{46}$
40	$Pd_{40}(CO)_{41}$	$Pd_{40}(CO)_{42}$	$Pd_{40}(CO)_{43}$	$Pd_{40}(CO)_{44}$	$Pd_{40}(CO)_{45}$	$Pd_{40}(CO)_{46}$	$Pd_{40}(CO)_{47}$

Table 17. Generating functions of clan series of palladium continued

	[M6]	**[M7]**	**[M8]**	**[M9]**	**[M10]**	**[M11]**	**[M12]**
	G_O =6+1=7	G_O =7+1=8	G_O =8+1=9	G_O =9+1=10	G_O =10+1=11	G_O =11+1=12	G_O =13
	Pd(CO)	Pd(CO)	Pd(CO)	Pd(CO)	Pd(CO)	Pd(CO)	Pd(CO)
	$F=Pd_x(CO)_{x+7}$	$F=Pd_x(CO)_{x+8}$	$F=Pd_x(CO)_{x+9}$	$F=Pd_x(CO)_{x+10}$	$F=Pd_x(CO)_{x+11}$	$F=Pd_x(CO)_{x+12}$	$F=Pd_x(CO)_{x+13}$
0	7CO	8CO	9CO	10CO	11CO	12CO	13CO
1	$Pd(CO)_8$	$Pd(CO)_9$	$Pd(CO)_{10}$	$Pd(CO)_{11}$	$Pd(CO)_{12}$	$Pd(CO)_{13}$	$Pd(CO)_{14}$
2	$Pd_2(CO)_9$	$Pd_2(CO)_{10}$	$Pd_2(CO)_{11}$	$Pd_2(CO)_{12}$	$Pd_2(CO)_{13}$	$Pd_2(CO)_{14}$	$Pd_2(CO)_{15}$
3	$Pd_3(CO)_{10}$	$Pd_3(CO)_{11}$	$Pd_3(CO)_{12}$	$Pd_3(CO)_{13}$	$Pd_3(CO)_{14}$	$Pd_3(CO)_{15}$	$Pd_3(CO)_{16}$
4	$Pd_4(CO)_{11}$	$Pd_4(CO)_{12}$	$Pd_4(CO)_{13}$	$Pd_4(CO)_{14}$	$Pd_4(CO)_{15}$	$Pd_4(CO)_{16}$	$Pd_4(CO)_{17}$
5	$Pd_5(CO)_{12}$	$Pd_5(CO)_{13}$	$Pd_5(CO)_{14}$	$Pd_5(CO)_{15}$	$Pd_5(CO)_{16}$	$Pd_5(CO)_{17}$	$Pd_5(CO)_{18}$
6	$Pd_6(CO)_{13}$	$Pd_6(CO)_{14}$	$Pd_6(CO)_{15}$	$Pd_6(CO)_{16}$	$Pd_6(CO)_{17}$	$Pd_6(CO)_{18}$	$Pd_6(CO)_{19}$
7	$Pd_7(CO)_{14}$	$Pd_7(CO)_{15}$	$Pd_7(CO)_{16}$	$Pd_7(CO)_{17}$	$Pd_7(CO)_{18}$	$Pd_7(CO)_{19}$	$Pd_7(CO)_{20}$
8	$Pd_8(CO)_{15}$	$Pd_8(CO)_{16}$	$Pd_8(CO)_{17}$	$Pd_8(CO)_{18}$	$Pd_8(CO)_{19}$	$Pd_8(CO)_{20}$	$Pd_8(CO)_{21}$
9	$Pd_9(CO)_{16}$	$Pd_9(CO)_{17}$	$Pd_9(CO)_{18}$	$Pd_9(CO)_{19}$	$Pd_9(CO)_{20}$	$Pd_9(CO)_{21}$	$Pd_9(CO)_{22}$
10	**$Pd_{10}(CO)_{17}$**	**$Pd_{10}(CO)_{18}$**	$Pd_{10}(CO)_{19}$	$Pd_{10}(CO)_{20}$	$Pd_{10}(CO)_{21}$	$Pd_{10}(CO)_{22}$	$Pd_{10}(CO)_{23}$
11	$Pd_{11}(CO)_{18}$	**$Pd_{11}(CO)_{19}$**	$Pd_{11}(CO)_{20}$	$Pd_{11}(CO)_{21}$	$Pd_{11}(CO)_{22}$	$Pd_{11}(CO)_{23}$	$Pd_{11}(CO)_{24}$
12	$Pd_{12}(CO)_{19}$	**$Pd_{12}(CO)_{20}$**	$Pd_{12}(CO)_{21}$	**$Pd_{12}(CO)_{22}$**	$Pd_{12}(CO)_{23}$	**$Pd_{12}(CO)_{24}$**	**$Pd_{12}(CO)_{25}$**
13	$Pd_{13}(CO)_{20}$	$Pd_{13}(CO)_{21}$	$Pd_{13}(CO)_{22}$	$Pd_{13}(CO)_{23}$	$Pd_{13}(CO)_{24}$	$Pd_{13}(CO)_{25}$	$Pd_{13}(CO)_{26}$
14	$Pd_{14}(CO)_{21}$	$Pd_{14}(CO)_{22}$	$Pd_{14}(CO)_{23}$	$Pd_{14}(CO)_{24}$	$Pd_{14}(CO)_{25}$	$Pd_{14}(CO)_{25}$	$Pd_{14}(CO)_{27}$
15	$Pd_{15}(CO)_{22}$	$Pd_{15}(CO)_{23}$	$Pd_{15}(CO)_{24}$	$Pd_{15}(CO)_{25}$	$Pd_{15}(CO)_{26}$	$Pd_{15}(CO)_{27}$	$Pd_{15}(CO)_{28}$
16	$Pd_{16}(CO)_{23}$	$Pd_{16}(CO)_{24}$	$Pd_{16}(CO)_{25}$	$Pd_{16}(CO)_{26}$	$Pd_{16}(CO)_{27}$	$Pd_{16}(CO)_{28}$	$Pd_{16}(CO)_{29}$
17	$Pd_{17}(CO)_{24}$	$Pd_{17}(CO)_{25}$	$Pd_{17}(CO)_{26}$	**$Pd_{17}(CO)_{27}$**	$Pd_{17}(CO)_{28}$	$Pd_{17}(CO)_{29}$	$Pd_{17}(CO)_{30}$
18	$Pd_{18}(CO)_{25}$	$Pd_{18}(CO)_{26}$	$Pd_{18}(CO)_{27}$	$Pd_{18}(CO)_{28}$	$Pd_{18}(CO)_{29}$	$Pd_{18}(CO)_{30}$	$Pd_{18}(CO)_{31}$
19	$Pd_{19}(CO)_{26}$	$Pd_{19}(CO)_{27}$	$Pd_{19}(CO)_{28}$	$Pd_{19}(CO)_{29}$	$Pd_{19}(CO)_{30}$	$Pd_{19}(CO)_{31}$	$Pd_{19}(CO)_{32}$
	6	7	8	9	10	11	12
20	$Pd_{20}(CO)_{27}$	$Pd_{20}(CO)_{28}$	$Pd_{20}(CO)_{29}$	$Pd_{20}(CO)_{30}$	$Pd_{20}(CO)_{31}$	$Pd_{20}(CO)_{32}$	$Pd_{20}(CO)_{33}$
21	$Pd_{21}(CO)_{28}$	$Pd_{21}(CO)_{29}$	$Pd_{21}(CO)_{30}$	$Pd_{21}(CO)_{31}$	$Pd_{21}(CO)_{32}$	$Pd_{21}(CO)_{33}$	$Pd_{21}(CO)_{34}$
22	$Pd_{22}(CO)_{29}$	$Pd_{22}(CO)_{30}$	$Pd_{22}(CO)_{31}$	$Pd_{22}(CO)_{32}$	$Pd_{22}(CO)_{33}$	$Pd_{22}(CO)_{34}$	$Pd_{22}(CO)_{35}$
23	**$Pd_{23}(CO)_{30}$**	$Pd_{23}(CO)_{31}$	**$Pd_{23}(CO)_{32}$**	$Pd_{23}(CO)_{33}$	$Pd_{23}(CO)_{34}$	$Pd_{23}(CO)_{35}$	$Pd_{23}(CO)_{36}$
24	$Pd_{24}(CO)_{31}$	$Pd_{24}(CO)_{32}$	$Pd_{24}(CO)_{33}$	$Pd_{24}(CO)_{34}$	$Pd_{24}(CO)_{35}$	$Pd_{24}(CO)_{36}$	$Pd_{24}(CO)_{37}$
25	$Pd_{25}(CO)_{32}$	$Pd_{25}(CO)_{33}$	$Pd_{25}(CO)_{34}$	$Pd_{25}(CO)_{35}$	$Pd_{25}(CO)_{36}$	$Pd_{25}(CO)_{37}$	$Pd_{25}(CO)_{38}$
26	$Pd_{26}(CO)_{33}$	$Pd_{26}(CO)_{34}$	$Pd_{26}(CO)_{35}$	$Pd_{26}(CO)_{36}$	$Pd_{26}(CO)_{37}$	$Pd_{26}(CO)_{38}$	$Pd_{26}(CO)_{39}$
27	$Pd_{27}(CO)_{34}$	$Pd_{27}(CO)_{35}$	$Pd_{27}(CO)_{36}$	$Pd_{27}(CO)_{37}$	$Pd_{27}(CO)_{38}$	$Pd_{27}(CO)_{39}$	$Pd_{27}(CO)_{40}$
28	$Pd_{28}(CO)_{35}$	$Pd_{28}(CO)_{36}$	$Pd_{28}(CO)_{37}$	$Pd_{28}(CO)_{38}$	$Pd_{28}(CO)_{39}$	$Pd_{28}(CO)_{40}$	$Pd_{28}(CO)_{41}$
29	**$Pd_{29}(CO)_{36}$**	$Pd_{29}(CO)_{37}$	$Pd_{29}(CO)_{38}$	$Pd_{29}(CO)_{39}$	$Pd_{29}(CO)_{40}$	$Pd_{29}(CO)_{41}$	$Pd_{29}(CO)_{42}$
30	**$Pd_{30}(CO)_{37}$**	$Pd_{30}(CO)_{38}$	$Pd_{30}(CO)_{39}$	$Pd_{30}(CO)_{40}$	$Pd_{30}(CO)_{41}$	$Pd_{30}(CO)_{42}$	$Pd_{30}(CO)_{43}$
31	$Pd_{31}(CO)_{38}$	$Pd_{31}(CO)_{39}$	$Pd_{31}(CO)_{40}$	$Pd_{31}(CO)_{41}$	$Pd_{31}(CO)_{42}$	$Pd_{31}(CO)_{43}$	$Pd_{31}(CO)_{44}$
32	$Pd_{32}(CO)_{39}$	$Pd_{32}(CO)_{40}$	$Pd_{32}(CO)_{41}$	$Pd_{32}(CO)_{42}$	$Pd_{32}(CO)_{43}$	$Pd_{32}(CO)_{44}$	$Pd_{32}(CO)_{45}$
33	$Pd_{33}(CO)_{40}$	$Pd_{33}(CO)_{41}$	$Pd_{33}(CO)_{42}$	$Pd_{33}(CO)_{43}$	$Pd_{33}(CO)_{44}$	$Pd_{33}(CO)_{45}$	$Pd_{33}(CO)_{46}$
34	$Pd_{34}(CO)_{41}$	$Pd_{34}(CO)_{42}$	$Pd_{34}(CO)_{43}$	$Pd_{34}(CO)_{44}$	$Pd_{34}(CO)_{45}$	$Pd_{34}(CO)_{46}$	$Pd_{34}(CO)_{47}$
35	$Pd_{35}(CO)_{42}$	$Pd_{35}(CO)_{43}$	$Pd_{35}(CO)_{44}$	$Pd_{35}(CO)_{45}$	$Pd_{35}(CO)_{46}$	$Pd_{35}(CO)_{47}$	$Pd_{35}(CO)_{48}$
36	$Pd_{36}(CO)_{43}$	$Pd_{36}(CO)_{44}$	$Pd_{36}(CO)_{45}$	$Pd_{36}(CO)_{46}$	$Pd_{36}(CO)_{47}$	$Pd_{36}(CO)_{48}$	$Pd_{36}(CO)_{49}$
37	$Pd_{37}(CO)_{44}$	$Pd_{37}(CO)_{45}$	$Pd_{37}(CO)_{46}$	$Pd_{37}(CO)_{47}$	$Pd_{37}(CO)_{48}$	$Pd_{37}(CO)_{49}$	$Pd_{37}(CO)_{50}$
38	$Pd_{38}(CO)_{45}$	$Pd_{38}(CO)_{46}$	$Pd_{38}(CO)_{47}$	$Pd_{38}(CO)_{48}$	$Pd_{38}(CO)_{49}$	$Pd_{38}(CO)_{50}$	$Pd_{38}(CO)_{51}$
39	$Pd_{39}(CO)_{46}$	$Pd_{39}(CO)_{47}$	$Pd_{39}(CO)_{48}$	$Pd_{39}(CO)_{49}$	$Pd_{39}(CO)_{50}$	$Pd_{39}(CO)_{51}$	$Pd_{39}(CO)_{52}$
40	$Pd_{40}(CO)_{47}$	$Pd_{40}(CO)_{48}$	$Pd_{40}(CO)_{49}$	$Pd_{40}(CO)_{50}$	$Pd_{40}(CO)_{51}$	$Pd_{40}(CO)_{52}$	$Pd_{40}(CO)_{53}$
41	$Pd_{41}(CO)_{48}$	$Pd_{41}(CO)_{49}$	$Pd_{40}(CO)_{50}$	$Pd_{40}(CO)_{51}$	$Pd_{40}(CO)_{52}$	$Pd_{40}(CO)_{53}$	$Pd_{40}(CO)_{54}$
	6	7	8	9	10	11	12
42	**$Pd_{42}(CO)_{49}$**	$Pd_{42}(CO)_{50}$	$Pd_{40}(CO)_{51}$	$Pd_{40}(CO)_{52}$	$Pd_{40}(CO)_{53}$	$Pd_{40}(CO)_{54}$	$Pd_{40}(CO)_{55}$
43	$Pd_{43}(CO)_{50}$	$Pd_{43}(CO)_{51}$	$Pd_{43}(CO)_{52}$	$Pd_{43}(CO)_{53}$	$Pd_{43}(CO)_{54}$	$Pd_{43}(CO)_{55}$	$Pd_{43}(CO)_{56}$
44	$Pd_{44}(CO)_{51}$	$Pd_{44}(CO)_{52}$	$Pd_{44}(CO)_{53}$	$Pd_{44}(CO)_{54}$	$Pd_{44}(CO)_{55}$	$Pd_{44}(CO)_{56}$	$Pd_{44}(CO)_{57}$
45	$Pd_{45}(CO)_{52}$	$Pd_{45}(CO)_{53}$	$Pd_{45}(CO)_{54}$	$Pd_{45}(CO)_{55}$	$Pd_{45}(CO)_{56}$	$Pd_{45}(CO)_{57}$	$Pd_{45}(CO)_{58}$
46	$Pd_{46}(CO)_{53}$	$Pd_{46}(CO)_{54}$	$Pd_{46}(CO)_{55}$	$Pd_{46}(CO)_{56}$	**$Pd_{46}(CO)_{57}$**	$Pd_{46}(CO)_{58}$	$Pd_{46}(CO)_{59}$
47	$Pd_{47}(CO)_{54}$	$Pd_{47}(CO)_{55}$	$Pd_{47}(CO)_{56}$	$Pd_{47}(CO)_{57}$	$Pd_{47}(CO)_{58}$	$Pd_{47}(CO)_{59}$	$Pd_{47}(CO)_{60}$
48	$Pd_{48}(CO)_{55}$	$Pd_{48}(CO)_{56}$	$Pd_{48}(CO)_{57}$	$Pd_{48}(CO)_{58}$	$Pd_{48}(CO)_{59}$	$Pd_{48}(CO)_{60}$	$Pd_{48}(CO)_{61}$
49	$Pd_{49}(CO)_{56}$	$Pd_{49}(CO)_{57}$	$Pd_{49}(CO)_{58}$	$Pd_{49}(CO)_{59}$	$Pd_{49}(CO)_{60}$	$Pd_{49}(CO)_{61}$	$Pd_{49}(CO)_{62}$
50	$Pd_{50}(CO)_{57}$	$Pd_{50}(CO)_{58}$	$Pd_{50}(CO)_{59}$	$Pd_{50}(CO)_{60}$	$Pd_{50}(CO)_{61}$	$Pd_{50}(CO)_{62}$	$Pd_{50}(CO)_{62}$
	6	7	8	9	10	11	12

Table 18. Generating functions of clans series of palladium clusters

	[M-4]	[M-3]	[M-2]	[M-1]	[M0]
	G_O =-4+1= -3	G_O =-3+1= -2	G_O =-2+1= -1	G_O =-1+1=0	G_O =0+1=1
	Pd(CO)	Pd(CO)	Pd(CO)	Pd(CO)	Pd(CO)
	$F=Pd_x(CO)_{x-3}$	$F=Pd_x(CO)_{x-2}$	$F=Pd_x(CO)_{x-1}$	$F=Pd_x(CO)_{x+0}$	$F=Pd_x(CO)_{x+1}$
0	-3CO	-2CO	-CO	0	CO
1	Pd-2CO	Pd-CO	Pd	Pd(CO)	$Pd(CO)_2$
2	Pd_2-CO	Pd_2	$Pd_2(CO)_1$	$Pd_2(CO)_2$	$Pd_2(CO)_3$
3	Pd_3	$Pd_3(CO)_1$	$Pd_3(CO)_2$	$Pd_3(CO)_3$	$Pd_3(CO)_4$
4	$Pd_4(CO)_1$	$Pd_4(CO)_2$	$Pd_4(CO)_3$	$Pd_4(CO)_4$	$Pd_4(CO)_5$
5	$Pd_5(CO)_2$	$Pd_5(CO)_3$	$Pd_5(CO)_4$	$Pd_5(CO)_5$	$Pd_5(CO)_6$
6	$Pd_6(CO)_3$	$Pd_6(CO)_4$	$Pd_6(CO)_5$	$Pd_6(CO)_6$	$Pd_6(CO)_7$
7	$Pd_7(CO)_4$	$Pd_7(CO)_5$	$Pd_7(CO)_6$	$Pd_7(CO)_7$	$Pd_7(CO)_8$
8	$Pd_8(CO)_5$	$Pd_8(CO)_6$	$Pd_8(CO)_7$	$Pd_8(CO)_8$	$Pd_8(CO)_9$
9	$Pd_9(CO)_6$	$Pd_9(CO)_7$	$Pd_9(CO)_8$	$Pd_9(CO)_9$	$Pd_9(CO)_{10}$
10	$Pd_{10}(CO)_7$	$Pd_{10}(CO)_8$	$Pd_{10}(CO)_9$	$Pd_{10}(CO)_{10}$	$Pd_{10}(CO)_{11}$
11	$Pd_{11}(CO)_8$	$Pd_{11}(CO)_9$	$Pd_{11}(CO)_{10}$	$Pd_{11}(CO)_{11}$	$Pd_{11}(CO)_{12}$
12	$Pd_{12}(CO)_9$	$Pd_{12}(CO)_{10}$	$Pd_{12}(CO)_{11}$	$Pd_{12}(CO)_{12}$	$Pd_{12}(CO)_{13}$
13	$Pd_{13}(CO)_{10}$	$Pd_{13}(CO)_{11}$	$Pd_{13}(CO)_{12}$	$Pd_{13}(CO)_{13}$	$Pd_{13}(CO)_{14}$
14	$Pd_{14}(CO)_{11}$	$Pd_{14}(CO)_{12}$	$Pd_{14}(CO)_{13}$	$Pd_{14}(CO)_{14}$	$Pd_{14}(CO)_{15}$
15	$Pd_{215}(CO)_{12}$	$Pd_{215}(CO)_{13}$	$Pd_{215}(CO)_{14}$	$Pd_{215}(CO)_{15}$	$Pd_{15}(CO)_{16}$
16	**$Pd_{16}(CO)_{13}$**	$Pd_{16}(CO)_{14}$	$Pd_{16}(CO)_{15}$	$Pd_{16}(CO)_{16}$	$Pd_{16}(CO)_{17}$
17	$Pd_{17}(CO)_{14}$	$Pd_{17}(CO)_{15}$	$Pd_{17}(CO)_{16}$	$Pd_{17}(CO)_{17}$	$Pd_{17}(CO)_{18}$
18	$Pd_{18}(CO)_{15}$	$Pd_{18}(CO)_{16}$	$Pd_{18}(CO)_{17}$	$Pd_{18}(CO)_{18}$	$Pd_{18}(CO)_{19}$
19	$Pd_{19}(CO)_{16}$	$Pd_{19}(CO)_{17}$	$Pd_{19}(CO)_{18}$	$Pd_{19}(CO)_{19}$	$Pd_{19}(CO)_{20}$
20	$Pd_{20}(CO)_{17}$	$Pd_{20}(CO)_{18}$	$Pd_{20}(CO)_{19}$	$Pd_{20}(CO)_{20}$	$Pd_{20}(CO)_{21}$
21	$Pd_{21}(CO)_{18}$	$Pd_{21}(CO)_{19}$	$Pd_{21}(CO)_{20}$	$Pd_{21}(CO)_{21}$	$Pd_{21}(CO)_{22}$
22	$Pd_{22}(CO)_{19}$	$Pd_{22}(CO)_{20}$	$Pd_{22}(CO)_{21}$	$Pd_{22}(CO)_{22}$	$Pd_{22}(CO)_{23}$
23	$Pd_{23}(CO)_{20}$	$Pd_{23}(CO)_{21}$	$Pd_{23}(CO)_{22}$	$Pd_{23}(CO)_{23}$	$Pd_{23}(CO)_{24}$
24	$Pd_{24}(CO)_{21}$	$Pd_{24}(CO)_{22}$	$Pd_{24}(CO)_{23}$	$Pd_{24}(CO)_{24}$	$Pd_{24}(CO)_{25}$
25	$Pd_{25}(CO)_{22}$	$Pd_{25}(CO)_{23}$	$Pd_{25}(CO)_{24}$	$Pd_{25}(CO)_{25}$	$Pd_{25}(CO)_{26}$
26	$Pd_{26}(CO)_{23}$	$Pd_{26}(CO)_{24}$	$Pd_{26}(CO)_{25}$	$Pd_{26}(CO)_{26}$	$Pd_{26}(CO)_{27}$
27	$Pd_{27}(CO)_{24}$	$Pd_{27}(CO)_{25}$	$Pd_{27}(CO)_{26}$	$Pd_{27}(CO)_{27}$	$Pd_{27}(CO)_{28}$
28	$Pd_{28}(CO)_{25}$	$Pd_{28}(CO)_{26}$	$Pd_{28}(CO)_{27}$	$Pd_{28}(CO)_{28}$	$Pd_{28}(CO)_{29}$
29	$Pd_{29}(CO)_{26}$	$Pd_{29}(CO)_{27}$	$Pd_{29}(CO)_{28}$	$Pd_{29}(CO)_{29}$	$Pd_{29}(CO)_{30}$
30	$Pd_{30}(CO)_{27}$	$Pd_{30}(CO)_{28}$	$Pd_{30}(CO)_{29}$	$Pd_{30}(CO)_{30}$	$Pd_{30}(CO)_{31}$
31	$Pd_{31}(CO)_{28}$	$Pd_{31}(CO)_{29}$	$Pd_{31}(CO)_{30}$	$Pd_{31}(CO)_{31}$	$Pd_{31}(CO)_{32}$
32	$Pd_{32}(CO)_{29}$	$Pd_{32}(CO)_{30}$	$Pd_{32}(CO)_{31}$	$Pd_{32}(CO)_{32}$	$Pd_{32}(CO)_{33}$
33	$Pd_{33}(CO)_{30}$	$Pd_{33}(CO)_{31}$	$Pd_{33}(CO)_{32}$	$Pd_{33}(CO)_{33}$	$Pd_{33}(CO)_{34}$
34	$Pd_{34}(CO)_{31}$	$Pd_{34}(CO)_{32}$	$Pd_{34}(CO)_{33}$	$Pd_{34}(CO)_{34}$	$Pd_{34}(CO)_{35}$
35	$Pd_{35}(CO)_{32}$	$Pd_{35}(CO)_{33}$	$Pd_{35}(CO)_{34}$	$Pd_{35}(CO)_{35}$	$Pd_{35}(CO)_{36}$
36	$Pd_{36}(CO)_{33}$	$Pd_{36}(CO)_{34}$	$Pd_{36}(CO)_{35}$	$Pd_{36}(CO)_{36}$	$Pd_{36}(CO)_{37}$
37	$Pd_{37}(CO)_{34}$	$Pd_{37}(CO)_{35}$	$Pd_{37}(CO)_{36}$	$Pd_{37}(CO)_{37}$	$Pd_{37}(CO)_{38}$
38	$Pd_{38}(CO)_{35}$	$Pd_{38}(CO)_{36}$	$Pd_{38}(CO)_{37}$	$Pd_{38}(CO)_{38}$	$Pd_{38}(CO)_{39}$
39	$Pd_{39}(CO)_{36}$	$Pd_{39}(CO)_{37}$	$Pd_{39}(CO)_{38}$	**$Pd_{39}(CO)_{39}$**	$Pd_{39}(CO)_{40}$
40	$Pd_{40}(CO)_{37}$	$Pd_{40}(CO)_{38}$	$Pd_{40}(CO)_{39}$	$Pd_{40}(CO)_{40}$	$Pd_{40}(CO)_{41}$
	-4	-3	-2	-1	0

Table 19. Generating functions of palladium clan series

T19	[M-8]	[M-7]	[M-6]	[M-5]	[M-4]	[M-3]
	n=-8+1= -7	n=-7+1= -6	n=-6+1= -5	n=-5+1= -4	n=-4+1= -3	n=-3+1= -2
	Pd(CO)	Pd(CO)	Pd(CO)	Pd(CO)	Pd(CO)	Pd(CO)
	$F=Pd_x(CO)_{x-7}$	$F=Pd_x(CO)_{x-6}$	$F=Pd_x(CO)_{x-5}$	$F=Pd_x(CO)_{x-4}$	$F=Pd_x(CO)_{x-3}$	$F=Pd_x(CO)_{x-2}$
0	-7CO	-6CO	-5CO	-4CO	-3CO	-2CO
1	Pd-6CO	Pd-5CO	Pd-4CO	Pd-3CO	Pd-2CO	Pd-CO
2	Pd_2-5CO	Pd_2-4CO	Pd_2-3CO	Pd_2-2CO	Pd_2-CO	Pd_2
3	Pd_3-4CO	Pd_3-3CO	Pd_3-2CO	Pd_3-CO	Pd_3	$Pd_3(CO)_1$
4	Pd_4-3CO	Pd_4-2CO	Pd_4-CO	Pd_4	$Pd_4(CO)_1$	$Pd_4(CO)_2$
5	Pd_5-2CO	Pd_5-CO	Pd_5	$Pd_5(CO)_1$	$Pd_5(CO)_2$	$Pd_5(CO)_3$
6	Pd_6-1CO	Pd_6	$Pd_6(CO)_1$	$Pd_6(CO)_2$	$Pd_6(CO)_3$	$Pd_6(CO)_4$
7	Pd_7	$Pd_7(CO)_1$	$Pd_7(CO)_2$	$Pd_7(CO)_3$	$Pd_7(CO)_4$	$Pd_7(CO)_5$
8	$Pd_8(CO)_1$	$Pd_8(CO)_2$	$Pd_8(CO)_3$	$Pd_8(CO)_4$	$Pd_8(CO)_5$	$Pd_8(CO)_6$
9	$Pd_9(CO)_2$	$Pd_9(CO)_3$	$Pd_9(CO)_4$	$Pd_9(CO)_5$	$Pd_9(CO)_6$	$Pd_9(CO)_7$
10	$Pd_{10}(CO)_3$	$Pd_{10}(CO)_4$	$Pd_{10}(CO)_5$	$Pd_{10}(CO)_6$	$Pd_{10}(CO)_7$	$Pd_{10}(CO)_8$
11	$Pd_{11}(CO)_4$	$Pd_{11}(CO)_5$	$Pd_{11}(CO)_6$	$Pd_{11}(CO)_7$	$Pd_{11}(CO)_8$	$Pd_{11}(CO)_9$
12	$Pd_{12}(CO)_5$	$Pd_{12}(CO)_6$	$Pd_{12}(CO)_7$	$Pd_{12}(CO)_8$	$Pd_{12}(CO)_9$	$Pd_{12}(CO)_{10}$
13	$Pd_{13}(CO)_6$	$Pd_{13}(CO)_7$	$Pd_{13}(CO)_8$	$Pd_{13}(CO)_9$	$Pd_{13}(CO)_{10}$	$Pd_{13}(CO)_{11}$
14	$Pd_{14}(CO)_7$	$Pd_{14}(CO)_8$	$Pd_{14}(CO)_9$	$Pd_{14}(CO)_{10}$	$Pd_{14}(CO)_{11}$	$Pd_{14}(CO)_{12}$
15	$Pd_{215}(CO)_8$	$Pd_{215}(CO)_9$	$Pd_{215}(CO)_{10}$	$Pd_{215}(CO)_{11}$	$Pd_{215}(CO)_{12}$	$Pd_{215}(CO)_{13}$
16	$Pd_{16}(CO)_9$	$Pd_{16}(CO)_{10}$	$Pd_{16}(CO)_{11}$	$Pd_{16}(CO)_{12}$	$Pd_{16}(CO)_{13}$	$Pd_{16}(CO)_{14}$
17	$Pd_{17}(CO)_{10}$	$Pd_{17}(CO)_{11}$	$Pd_{17}(CO)_{12}$	$Pd_{17}(CO)_{13}$	$Pd_{17}(CO)_{14}$	$Pd_{17}(CO)_{15}$
18	$Pd_{18}(CO)_{11}$	$Pd_{18}(CO)_{12}$	$Pd_{18}(CO)_{13}$	$Pd_{18}(CO)_{14}$	$Pd_{18}(CO)_{15}$	$Pd_{18}(CO)_{16}$
19	$Pd_{19}(CO)_{12}$	$Pd_{19}(CO)_{13}$	$Pd_{19}(CO)_{14}$	$Pd_{19}(CO)_{15}$	$Pd_{19}(CO)_{16}$	$Pd_{19}(CO)_{17}$
20	$Pd_{20}(CO)_{13}$	$Pd_{20}(CO)_{14}$	$Pd_{20}(CO)_{15}$	$Pd_{20}(CO)_{16}$	$Pd_{20}(CO)_{17}$	$Pd_{20}(CO)_{18}$
21	$Pd_{21}(CO)_{14}$	$Pd_{21}(CO)_{16}$	$Pd_{21}(CO)_{17}$	$Pd_{21}(CO)_{18}$	$Pd_{21}(CO)_{19}$	$Pd_{21}(CO)_{10}$
22	$Pd_{22}(CO)_{15}$	$Pd_{22}(CO)_{17}$	$Pd_{22}(CO)_{18}$	$Pd_{22}(CO)_{19}$	$Pd_{22}(CO)_{20}$	$Pd_{22}(CO)_{21}$
23	$Pd_{23}(CO)_{16}$	$Pd_{23}(CO)_{18}$	$Pd_{23}(CO)_{19}$	$Pd_{23}(CO)_{20}$	$Pd_{23}(CO)_{21}$	$Pd_{23}(CO)_{22}$
24	$Pd_{24}(CO)_{17}$	$Pd_{24}(CO)_{19}$	$Pd_{24}(CO)_{20}$	$Pd_{24}(CO)_{21}$	$Pd_{24}(CO)_{22}$	$Pd_{24}(CO)_{23}$
25	$Pd_{25}(CO)_{18}$	$Pd_{25}(CO)_{20}$	$Pd_{25}(CO)_{21}$	$Pd_{25}(CO)_{22}$	$Pd_{25}(CO)_{23}$	$Pd_{25}(CO)_{24}$
26	$Pd_{26}(CO)_{19}$	$Pd_{26}(CO)_{21}$	$Pd_{26}(CO)_{22}$	$Pd_{26}(CO)_{23}$	$Pd_{26}(CO)_{24}$	$Pd_{26}(CO)_{25}$
27	$Pd_{27}(CO)_{20}$	$Pd_{27}(CO)_{22}$	$Pd_{27}(CO)_{23}$	$Pd_{27}(CO)_{24}$	$Pd_{27}(CO)_{24}$	$Pd_{27}(CO)_{25}$
28	$Pd_{28}(CO)_{21}$	$Pd_{28}(CO)_{23}$	$Pd_{28}(CO)_{24}$	$Pd_{28}(CO)_{25}$	$Pd_{28}(CO)_{25}$	$Pd_{28}(CO)_{26}$
29	$Pd_{29}(CO)_{22}$	$Pd_{29}(CO)_{24}$	$Pd_{29}(CO)_{25}$	$Pd_{29}(CO)_{26}$	$Pd_{29}(CO)_{26}$	$Pd_{29}(CO)_{27}$
30	$Pd_{30}(CO)_{23}$	$Pd_{30}(CO)_{25}$	$Pd_{30}(CO)_{26}$	$Pd_{30}(CO)_{27}$	$Pd_{30}(CO)_{27}$	$Pd_{30}(CO)_{28}$
31	$Pd_{31}(CO)_{24}$	$Pd_{31}(CO)_{26}$	$Pd_{31}(CO)_{27}$	$Pd_{31}(CO)_{28}$	$Pd_{31}(CO)_{28}$	$Pd_{31}(CO)_{29}$
32	$Pd_{32}(CO)_{25}$	$Pd_{32}(CO)_{27}$	$Pd_{32}(CO)_{28}$	$Pd_{32}(CO)_{29}$	$Pd_{32}(CO)_{29}$	$Pd_{32}(CO)_{30}$
33	$Pd_{33}(CO)_{26}$	$Pd_{33}(CO)_{28}$	$Pd_{33}(CO)_{29}$	$Pd_{33}(CO)_{30}$	$Pd_{33}(CO)_{30}$	$Pd_{33}(CO)_{31}$
34	$Pd_{34}(CO)_{27}$	$Pd_{34}(CO)_{29}$	$Pd_{34}(CO)_{30}$	$Pd_{34}(CO)_{31}$	$Pd_{34}(CO)_{31}$	$Pd_{34}(CO)_{32}$
35	$Pd_{35}(CO)_{28}$	$Pd_{35}(CO)_{30}$	$Pd_{35}(CO)_{31}$	$Pd_{35}(CO)_{32}$	$Pd_{35}(CO)_{32}$	$Pd_{35}(CO)_{33}$
36	$Pd_{36}(CO)_{29}$	$Pd_{36}(CO)_{31}$	$Pd_{36}(CO)_{32}$	$Pd_{36}(CO)_{33}$	$Pd_{36}(CO)_{33}$	$Pd_{36}(CO)_{34}$
37	$Pd_{37}(CO)_{30}$	$Pd_{37}(CO)_{32}$	$Pd_{37}(CO)_{33}$	$Pd_{37}(CO)_{34}$	$Pd_{37}(CO)_{34}$	$Pd_{37}(CO)_{35}$
38	**$Pd_{38}(CO)_{31}$**	$Pd_{38}(CO)_{33}$	$Pd_{38}(CO)_{34}$	$Pd_{38}(CO)_{35}$	$Pd_{38}(CO)_{35}$	$Pd_{38}(CO)_{36}$
39	$Pd_{39}(CO)_{32}$	$Pd_{39}(CO)_{34}$	$Pd_{39}(CO)_{35}$	$Pd_{39}(CO)_{36}$	$Pd_{39}(CO)_{36}$	$Pd_{39}(CO)_{37}$
40	$Pd_{40}(CO)_{33}$	$Pd_{40}(CO)_{35}$	$Pd_{40}(CO)_{36}$	$Pd_{40}(CO)_{37}$	$Pd_{40}(CO)_{37}$	$Pd_{40}(CO)_{38}$

3. Conclusion

The de-capping series were investigated using the K(n) series. As a consequence, the base-line(genesis) of clusters was demarcated. The cluster valence electron pairs when n=0 based on the capping symbol, Kp= $C^yC[Mx]$ is given by G_0= [x+1]L where L is a two electron-pair ligand, or the number of cluster valence electrons VE_0= 2x+2. An equation for generating required cluster formula was established as $F=nF_0+G_0$ where n = number of skeletal elements, and F_0 = a skeletal fragment with a 12 electron content. Also a cluster valence electrons equation was developed and is given by $VE=VE_0+dn$ where d= 12 for transition elements and 2 for main group elements. The difference of 10 originates from the existence of 14N and 4N series. The clarity of a black-hole concept was established. A tentative explanation as to why clusters such as $Mo_6Cl_{14}^{2-}$ portray an octahedral shape was made by applying the black-hole concept. When the matrix table of capping cluster valence electrons is carefully examined, the capping process extends indefinitely with capping skeletal elements on one end and on the other, it also ends with capping dozen sets of electrons indefinitely. Clearly, the universe of possible range of chemical clusters is very, very wide. Since cluster valence electron VE calculated from the several different equations derived from the series are precisely the same as those calculated directly from the cluster formula VF, it means that the 4N series approach of analyzing clusters including the capping principle is quite credible.

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