STUDIES ON SELECTED MONO- AND TETRANUCLEAR GROUP 8 CARBONYL COMPOUNDS

by

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ABSTRACT

The compounds $M(CO)_4L$ (M=Fe,Ru,Os, L=EPh_3, E=P,As,Sb, L=PMe_3, $P(OCH_2)_3CMe$; M=Ru,Os, L=$SbMe_3$) have been synthesized from L and $M(CO)_5$. In $Ru(CO)_4AsPh_3$ and $Ru(CO)_4SbMe_3$, crystal structures revealed the unique ligand is in an axial position of the trigonal-bipyramidal coordination sphere, whereas, in $Os(CO)_4SbPh_3$, $SbPh_3$ is in an equatorial site. Infrared spectroscopy showed the presence of both axial and equatorial isomers in solution for many of the complexes; interconversion is rapid on the ^{13}C NMR time scale. The tendency to give the less common equatorial isomer is Ru>Os>>Fe, Sb>As>P, Ph>Me, and $P(OCH_2)_3CMe$>PMe_3,PPh_3. The ordering of the group 15 elements is rationalized in terms of their σ-donor rather than π-acceptor ability (π bonding may be important in determining the other trends). This is the first time an axial-equatorial switchover has been observed in a closely related series of five-coordinate compounds.

The clusters $Os_4(CO)_nPMe_3$ (n=15, 14, 13) have been synthesized and their crystal structures determined. This series constitutes the first example where a 64 electron cluster displays sequential ligand loss to a 62 and then to a 60 electron species. The $Os_4(CO)_{15}PMe_3$ (1) cluster is the first reported with an unsupported donor-acceptor metal-metal bond. In $Os_4(CO)_{14}PMe_3$ (2) the Os_4 skeleton is a planar rhomboid with two long and two short Os-Os bonds. This asymmetry is discussed in terms of a novel bonding model using three-centre-two-electron bonds. The structure of 2 is compared to that of $(\mu\text{-H})_2\text{Os}_4(\text{CO})_{13}\text{PMe}_3$ (3) which has also been synthesized and characterized. Although 3 is isoelectronic with 2, it has an Os_4 butterfly structure with a dihedral angle of 113°. The $\text{Os}_4(\text{CO})_{13}\text{PMe}_3$ (4) compound is the only reported group 8 tetrahedral cluster with 14 two-electron donor ligands.

The fluxional properties of the clusters have been investigated by variable temperature ^{13}C NMR spectroscopy. In solution 1 undergoes CO ligand exchange probably via several different processes. In contrast to 3 which is rigid, 2 exhibits remarkable nonrigidity which is accounted for by an unusual dynamic rearrangement of the metal skeleton. Cluster 4 is highly fluxional even at -120 °C.

This unique group of molecules will be of interest to chemists investigating structural and fluxional properties of clusters.

DEDICATION

For Nicole, for whom there has never been enough time.

QUOTATION

"Concern for man himself and his fate must always form the chief interest of all technical endeavors, concern for the great unsolved problems of the organization of labor and the distribution of goods--in order that the creations of our mind shall be a blessing and not a curse to mankind. Never forget this in the midst of your diagrams and equations."

Albert Einstein

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I have been particulary appreciative of the unusual competence of the technicians M. Tracy and M. K. Yang who obtained the NMR spectra and chemical analyses, respectively.

My mother, who provided needed funds and made purchase of a reliable vehicle possible, is also deeply appreciated.

To my friends, Jan and Dave and Joyce and Dennis, thank you for babysitting and for being there.

And lastly, I would like to thank the working people of Canada whose taxes have made it possible for NSERC to support me financially.

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PART A

AXIAL-EQUATORIAL ISOMERISM IN COMPLEXES $M(CO)_4L$

(M=Fe, Ru, Os; L=GROUP 15 LIGAND)

CHAPTER 1

INTRODUCTION

1.1 Overview

Five-coordinate, transition metal complexes of the type ML_5 (M=transition metal, L=two electron donor ligand) exist in two ideal geometries, the trigonal bipyramid (TBP) and the square pyramid. In either geometry, a monosubstituted complex ML_4L' may take one of two isomeric forms. In a square pyramid, the unique ligand L' may appear at either an apical or basal position. In a TBP either axially or equatorially substituted geometries are possible (see Figure A.1.1). Most organometallic complexes of d^8 metals adopt a trigonal bipyramidal configuration and the site preference of the unique ligand in this form has been the subject of considerable theoretical and experimental interest. Several models describing the inherent

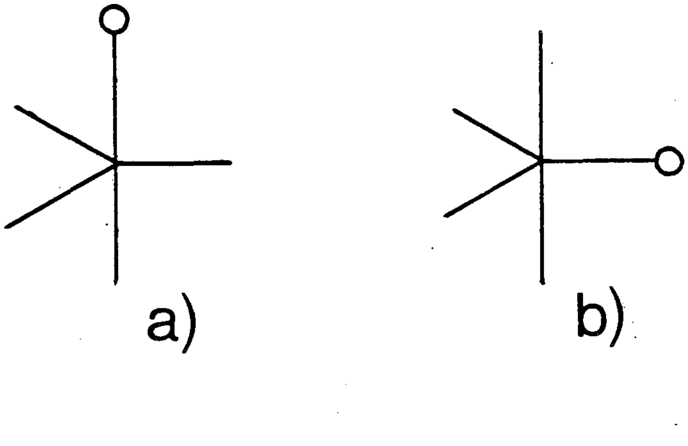

Figure A.1.1. Trigonal Bipyramidal Geometry. The unique ligand is in the a)axial and b)equatorial site.

differences of the M-L bonds in ML_5 have also been proposed.[1,2,3] Interest has been expressed not only in the stable molecules[4,5,6,7,8] but also in intermediates of dissociative reactions of octahedral complexes[9] as well as of associative reactions of tetrahedral complexes.[10]

Nonrigidity involving axial-equatorial exchange has been observed for many TBP ML_4L' complexes, and the Berry psuedorotation mechanism has often been proposed as the exchange mechanism.[11] Both theoretical[12,13] and experimental[14] studies indicate the barrier to nonrigidity is low so that which isomer is adopted by a given complex can be attributed to thermodynamic rather than kinetic constraints. Infrared spectroscopy reveals which isomer predominates in solution; an axial $M(CO)_4L$ complex typically has three bands in the carbonyl stretching region while an equatorial $M(CO)_4L$ complex has four.[15] The short time scale of this technique (10^{-11}s)[16] allows detection of both isomeric forms if they are present in solution.

A theme common to many studies is that a ligand possessing better π-acceptor properties is more likely to be found in the equatorial site.[17] Indeed, a search of the literature revealed numerous examples of strong π-acceptors such as CO, PF_3 or NO in the equatorial position of a TBP (see Table A.1.1, page 15). However, in most cases the unique ligand, a weak π-acceptor was found in the axial site. Also, the large majority of the known complexes contained a first row transition metal as the central atom. Other (theoretical) studies indicated that the σ-donor ability[1,18] or the steric requirements[2] of the unique ligand might also be important in determining the site preference.

As the following literature survey illustrates there was little experimental evidence to support or refute these ideas. Also there was almost no discussion as to whether the period of the transition metal row could influence ligand site preference.

1.2 Literature Survey

1.2.1 Theoretical Papers

Without doubt, the most significant theoretical work on transition metal pentacoordination to appear in recent years is that of Rossi and Hoffmann.[1] As their work is so germane to this study, the appropriate sections are summarized here in some detail.

The authors cautioned that the extended Hückel calculations on which their model is based do not take into account steric or electrostatic effects. It might also be added that the calculations were performed on ML_5 species where M was a third row transition metal (Pt). What effect changing M to a first or second row metal might have had on their conclusions was not discussed.

The consideration of the electronic effects began with a molecular orbital interaction diagram (reproduced in Figure A.1.2). for a trigonal bipyramidal ML_5 species assuming π bonding ligands are absent. The low lying e', a_2" and a_1' orbitals can be viewed as filled by ligand electrons; their nature is such that for d^0 systems the axial bonds are weaker than the equatorial ones. As metal d electrons are added the e" orbitals are filled first. Since this set is rigorously non-bonding, there is no effect on bond strength. The next orbitals to be filled, the e' set are weakly metal-equatorial antibonding. The antibonding nature arises from mixing of not

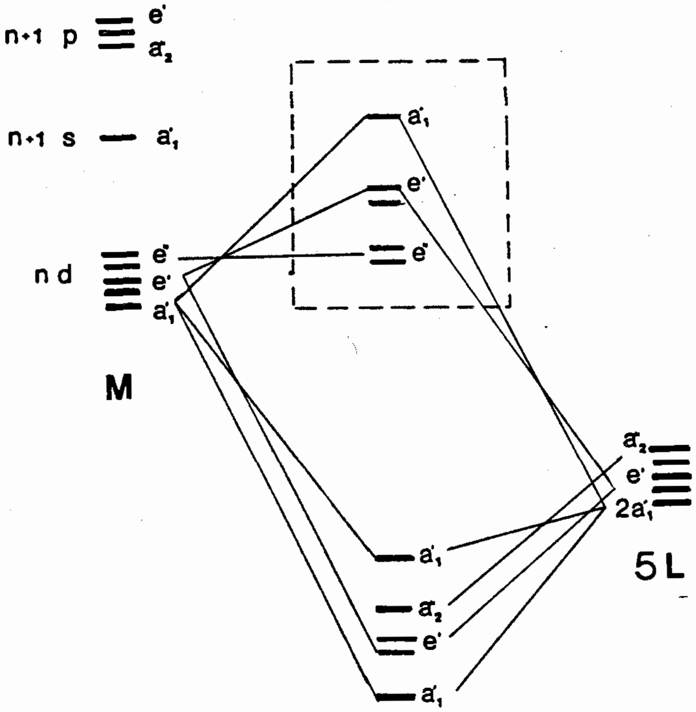

Figure A.1.2. Molecular Orbital Interaction Diagram for ML_5 Complexes. The interactions shown here are for σ interactions only, π-bonding interactions are considered subsequently. (After Rossi and Hoffmann.[1])

only ligand σ and metal nd orbitals but metal (n+1)p orbitals as well. The (n+1)p orbital mixing has the effect of hybridizing the orbitals away from the ligands thus weakening the antibonding interaction and stabilizing the orbital. Nevertheless, addition of metal d electrons to this e' set results in weakening of the metal-equatorial ligand bonds to the extent that for the cases where the central metal has d^6-d^8

configuration, they are calculated to be weaker than the metal-axial ligand bonds. The last orbital to be filled, having a_1', symmetry, is strongly metal-axial ligand antibonding so that in a d^{10} complex, the axial bonds are once again predicted to be weaker, (see Figure A.1.3).

It is assumed that a strong σ-donor would take up the position where it would form the most stable, lowest energy bond. That is, strong σ-donor ligands are more likely to be found at equatorial sites in complexes in which the central metal has d^0-d^4 and d^{10} electronic configuration and at axial sites if the central metal has d^6-d^8 electronic configuration. Conversely, weak σ-donors are more likely found in an equatorial site in a complex having a central metal of d^6 to d^8 configuration.

Consideration of the effects of π bonding on the site preference of the ligands takes into account the change of symmetry of the molecule, and therefore of the orbitals, that results from substitution of only one ligand. A normal two electron donor, π-acceptor ligand, has two low-lying unoccupied orbitals of π symmetry. If the ligand occupies an axial site the molecular symmetry is changed from D_{3h} to C_{3v} and the π-acceptor orbitals on the ligand transform as e_x and e_y. If the ligand is equatorial the complex has C_{2v} symmetry and the ligand π orbitals transform as b_1 and b_2. In this case these orbitals line up parallel and perpendicular to the original 3-fold axis of the trigonal bipyramid, repectively. The

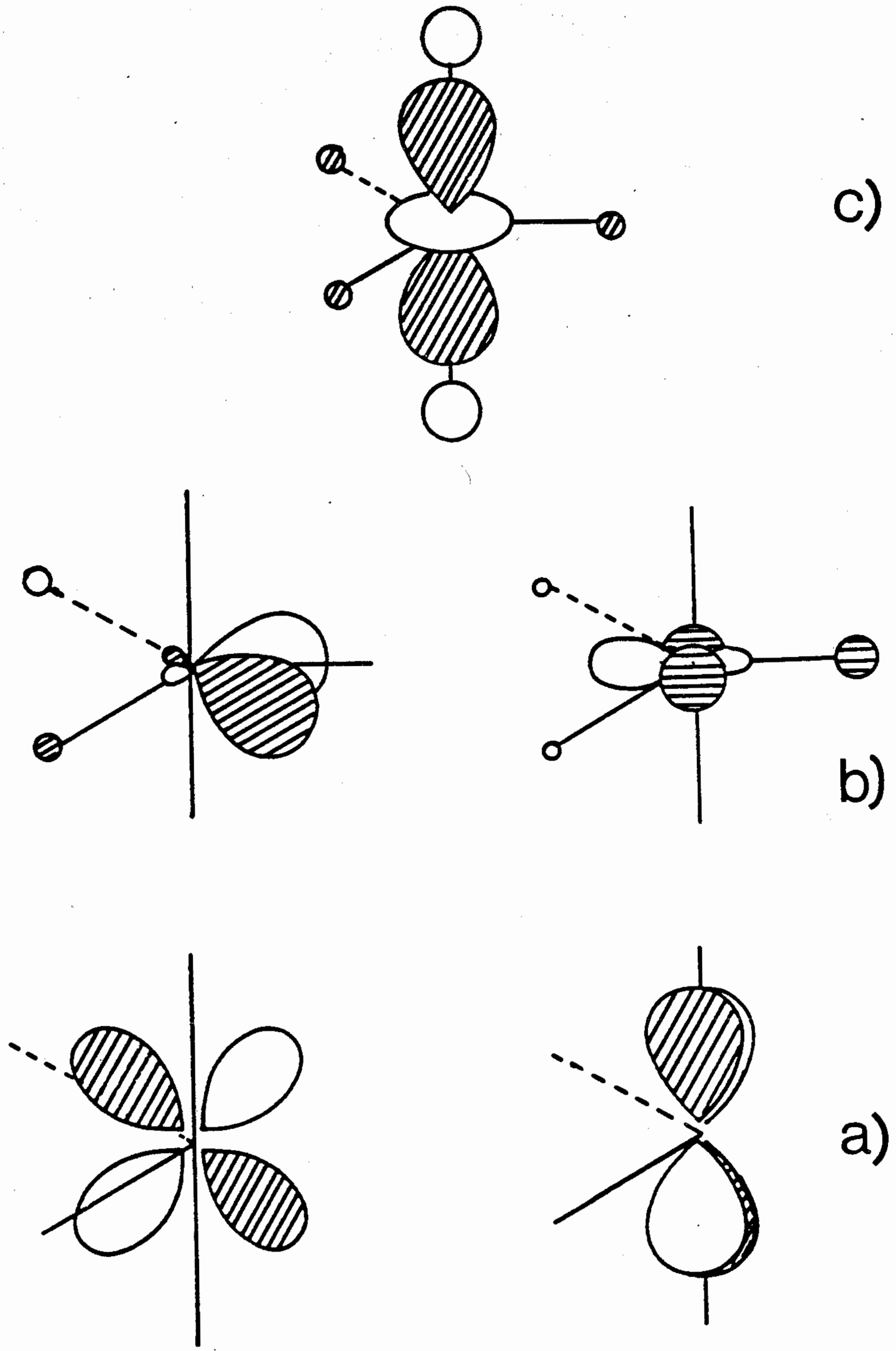

Figure A.1.3. Molecular Orbitals Filled by d Electrons of $M(CO)_5$ Complexes. The e'' orbitals shown in a) are filled first, then the e' orbitals shown in b) and finally the a_1' orbital shown in c). (After Rossi and Hoffmann.[1])

orbitals of the ML_4 framework also transform differently with the change of molecular point group. From a consideration of the π interactions of the unique ligand orbitals and ML_4 framework metal d orbitals that are allowed by symmetry, Rossi and Hoffmann concluded that the equatorial perpendicular interaction is stronger than the equatorial parallel interaction which is about equal to the axial interaction. These features are displayed in the MO diagram, given in Figure A.1.4. It was concluded that when the central metal has d^8 electronic configuration a π-acceptor ligand will favour an equatorial site.

Prediction of the site preference of a real ligand must take into account both σ and π bonding. For example conclusions drawn regarding d^8 $M(CO)_4L$ complexes must attempt an evaluation of the relative importance of these factors since CO and many other common ligands are poor σ-donors (preferring equatorial sites) and good π-acceptors (also preferring equatorial sites). Any ligand which is both a poorer σ-donor and a better π-acceptor than CO would be predicted to occupy an equatorial site. But if only one of these conditions is satisfied the situation is less clear. For example, what would be the site preference of a very poor σ-donor ligand in the presence of very good π-acceptor ligands, i.e., are σ or π effects dominant? The crystal structures analyzed by the authors showed longer equatorial bonds for ML_5 d^8 systems (i.e. dominance of the σ effect). However there were no consistent trends for the ML_4L'

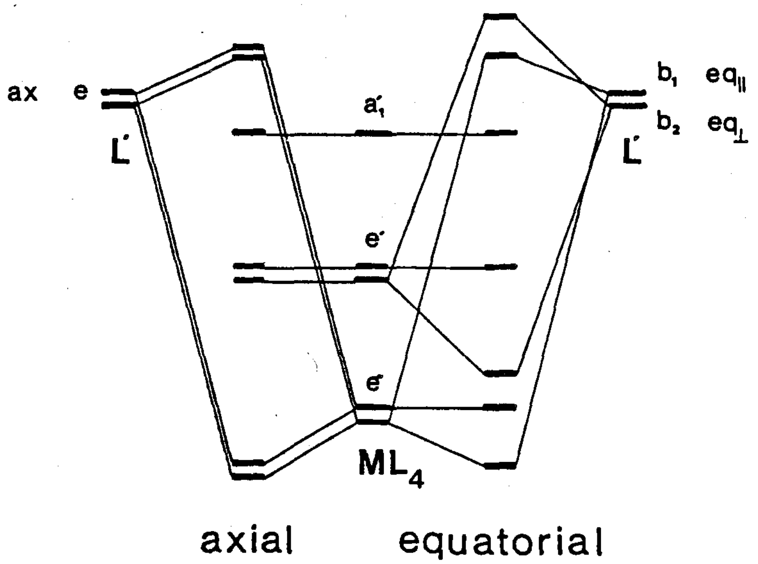

Figure A.1.4. Molecular Orbital Diagram for π-Interactions of an ML$_4$ Fragment with a π-accectopr Ligand. (After Rossi and Hoffmann.[1])

systems with d^8 configurations.

In summary, the work of Rossi and Hoffmann indicates that a weak σ-donor, or a strong π-acceptor ligand will occupy an equatorial site in the d^8 case; conversely a strong σ-donor, or weak π-acceptor will prefer the axial site. The prediction of the site preference of any particular ligand rests on a evaluation of the relative importance of these two types of bonding.

Another theoretical paper on pentacoordination is that of Burdett[18] who considered the angular overlap of the metal d and ligand σ orbitals only. He concluded that for a low-spin d^8 configuration the stronger σ-donor will prefer the axial position, and also that "within the d orbital manifold the axial bond strength was greater that the equatorial." Since there was no consideration of the effect of π bonding on site preference the author readily admitted "our scheme is not the whole story."

Shustorovich has written a number of papers based on perturbation theory, on substitution effects of the σ bonded components in molecules of various geometries.[3,19,20] He concluded that for d^8 metals, the axial site is favoured for a strong σ-donor. Once again, the effect of π bonding was not considered.

Since the question of site preference of the ligands cannot be separated from the inherently unequal nature of the axial and equatorial bonds of a TBP complex, several MO calculations on $Fe(CO)_5$ and closely related molecules are also of interest.[12,13,21,22] The results underscore the difficulties of theoretical studies on pentacoordinate molecules. That is, the energy differences of the various conformations are small, and subject to error. The axial bonds of $Fe(CO)_5$ have been calculated to be weaker,[21] stronger but much longer,[13] and marginally longer[22] than the equatorial bonds. Experimental lengths as determined in an electron diffraction study are 1.807(6)Å for the $Fe-C_{ax}$ distance and 1.827(6)Å for the $Fe-C_{eq}$

distance.[23] The most recent calculations[12] (using an SCF method) show that a subtle change in the assumed 3d energy level brings the caculated lengths for the axial and equatorial Fe-C bonds (1.82Å and 1.83Å respectively) into close correspondence with the experimental values. This results from both a decrease in the p_x and p_y contribution to equatorial Fe-C bonds and an increased d_{z^2} bonding contribution to the a_1' orbital. Thus the symmetry overlap model of Rossi and Hoffmann in which the d orbitals make their main contribution to the e" and e' orbitals is only valid as a first approximation and the d orbital contribution to the lower lying bonding orbitals must also be taken into account for more precise predictions.

Unfortunately even this improved picture of the bonding in $Fe(CO)_5$ does not provide a satisfactory explanation as to why a weak σ-donor ligand, such as $SbPh_3$ should be in an axial position in $Fe(CO)_4SbPh_3$[24] but in an equatorial site in $Ru(CO)_4SbPh_3$.[6] Actually, $Fe(CO)_4SbPh_3$ would be predicted to exist as the equatorial isomer on the basis of this model, since the equatorial bonds have the weaker σ component.

The situation with regard to steric factors is complicated since it is unclear whether axial or equatorial sites are more sterically hindered. Lichtenberger and Brown[14] have shown that for symmetric ER_3 ligands (the type used in this study) the equatorial position is more crowded. Thus ligands with large cone angles should prefer the axial position. Keiter[25] and Cowley[26] have pointed out that for large asymmetric ligands such as $PPh(PPh_2)_2$ and $P_2(2,4,6,t\text{-}Bu_3C_6H_2)_2$ steric strain is actually eased in the equatorial position.

Favas and Kepert have developed more subtle steric reasoning based on a mathematical summation of all possible ligand-ligand interactions.[2] They base their calculations on the ratio (R) of the effective bond length of the unique ligand to that of the other four ligands. The effective bond length is the distance from the metal atom to a theoretical point location of the bonding electron pair. When the one effective bond length associated with the unique ligand is shorter that the other four (e.g., R=0.8) the equatorial isomer is predicted to be stable. However, when R=1.2 the axial isomer is predicted. The crossover from the equatorial to axial form occurs at about R=1.00. For very low or high values of R the predicted stereochemistry approaches an apically substitued square pyramid or a capped tetrahedron, respectively. The R values were calculated for a number of different geometries, described in terms of the OC-M-CO and OC-M-L angles, and the results presented graphically. Thus if the structure of a complex is known its R value can be read off the appropriate graph.

Unfortunately nearly all the examples of $M(CO)_4L$ type compounds cited by Favas and Kepert are axially substituted and have R values $\simeq$1.00. For example, the authors calculated the R value for $Fe(CO)_4L$ compounds to be $\simeq$1.00 and thus explained the low barrier to axial-equatorial rearrangement found in ^{13}C NMR studies.[27] However, this does little to predict the axial substitution of the cited examples. Nor can it explain the change in site preference for the $SbPh_3$ ligand when iron is replaced by ruthenium in $M(CO)_4SbPh_3$ (M=Fe,Ru).

In eq-$Mn(CO)_4NO$[28] there is no significant distortion of the equatorial carbonyls and again an R value of ≃1.0 would be predicted. This is in contradiction to the statement of Favais and Kepert that the known geometry of this compound (equatorial substitution) implies "greater replusion (lower R values) from the nitrosyl ligand than from the other four unidentate ligands."[2]

In summary, it can be said that not enough work has been done to build up a sizeable set of self-consistent R values and in most cases, the R values are calculated from the structure, rather than the structure predicted on the basis of known R values. This has led to some contradictory results. The work of these authors is rarely cited by other workers in the field suggesting their method has not gained wide acceptance.

1.2.2 Experimental Studies

Table A.1.1 lists 46 known d^8 transition metal complexes of the type $M(CO)_4L$. Analysis of these data and the related literature points out that both experimental confirmation and a wide understanding of the theoretical predictions summarized above are lacking. Most of the complexes are of a first row transition metal and the unique ligand, a relatively poor π-acceptor, occupies an axial position. While this is

Table A.1.1. Previously Known $M(CO)_4L$ Derivatives.

Compound	Substitution Site	Ref.
$[Mn(CO)_4PPh_3]^-$	axial[a]	29
$Mn(CO)_4NO$	equatorial[a]	28
$[Fe(CO)_4CN]^-$	axial[a]	8
$Fe(CO)_4L$ (L=PPh_3, $AsPh_3$, $SbPh_3$, PPh_2Me, $PPhMe_2$, $P(C_6H_{11})_3$ $P(n\text{-}Bu)_3$, $P(OPh)_3$, $P(OEt)_3$, $P(OMe)_3$)	axial	30
$Fe(CO)_4L$ (L=PPh_3, CNMe, CNEt, CNPh, $CNBu^t$)	axial	31
$Fe(CO)_4P\{(N(SiMe_3)_2\}\{C(SiMe_3)_2\}$	equatorial	32
$Fe(CO)_4SbMe_3$, $Fe(CO)_4AsMe_3$	axial[a]	33
$Fe(CO)_4L$ (L=PEt_3, $Ph_2P(CH_2)_2PPh_2$, C_2H_5NC)	axial	34
$Fe(CO)_4L$ (L=C_5H_5N, $C_5H_4N_2$)	axial	35
$Fe(CO)_4PCl_3$	mixture	36
$Fe(CO)_4PF_3$	mixture	37
$Fe(CO)_4L$ L=$PF_2[(OC)(CF_3)_2CN]$	mixture	7
L=$PF[(OC)(CF_3)_2CN]_2$	mostly equatorial	
L=$P[(OC)(CF_3)_2CN]_3$	equatorial	
L=$PF_2OCNC_2(CF_3)_4O$	mixture	
$Fe(CO)_4P(NMe_2)_3$	axial[a]	38
$Fe(CO)_4(\eta^1\text{-}PPh_2CH_2CH_2PPh_2)$	axial[a]	25
$Fe(CO)_4SC_3Ph_2$	axial	2
$[Fe(CO)_4SnR_2]^{2-}$	axial	39

$Ru(CO)_4L$ ($L=PPh_3$, $PMePh_2$, PBu_3)	axial	40
$Ru(CO)_4P(OCH_3)_3$	axial[a]	41
$Ru(CO)_4SbPh_3$	equatorial[a]	6
$Ru(CO)_4PF_3$	mixture[b]	42
$Os(CO)_4PPh_3$	axial	43
$Co(CO)_4SiR_3$ ($R=H$, F, Cl)	axial[a]	14,44
$Co(CO)_4GeCl_3$	axial	2
$Co(CO)_4AuPPh_3$	axial	2

[a] Solid state crystal structure determined by X-ray crystallography.

[b] Very poorly characterized.

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consistent with the theories outlined above it can only be taken as partial confirmation of them as there are so few equatorial isomers. Also very little attempt has been made to discuss both the π and σ properties of the unique ligands. Indeed, π bonding arguments alone have been used by a number of authors to explain site preference.[8,29,38] Several other studies dealt with other aspects of the chemistry of $M(CO)_4L$ complexes rather than the observed geometry.[30,31,33,34,44]

Reasoning based on π-bonding alone or in conjuction with steric factors was also used in a few cases where equatorial isomers were found.[7,45] In these examples, $Fe(CO)_4P[(OC)(CF_3)_2CN]_3$ and $Fe(CO)_4PF_3$, the unusually high values of the carbonyl stretching frequencies were consistent with the unique ligand having exceptional π-acceptor ability.

Steric arguments alone were used to explain why the unique ligand in both $Fe(CO)_4P_2(2,4,6,t\text{-}Bu_3C_6H_2)_2$[26] and $Fe(CO)_4P\{N(SiMe_3)_2\}\{C(SiMe_3)_2\}$[32] adopts an equatorial position. In both cases the ligand is large and asymmetric.

The compound eq-$Mn(CO)_4NO$ is the subject of some controversy in the literature; the original authors[28] suggested the data were not consistent with NO being a better π-acceptor than CO while later workers[8] claimed the opposite.

A few authors did note that the relative σ-donor/π-acceptor ratio of the ligands is important in determining the geometry.[25,35] However in no case was there any attempt to rate the relative importance of these factors separately.

The situation for the nine listed compounds of the second and third row metals is no better. Of these, seven are axially substituted, and no explanation was given for the site preference.[40,41,43] Of the remaining two, $Ru(CO)_4PF_3$ probably exists as a mixture of isomers in solution but it was very poorly characterized.[42] The other complex, $Ru(CO)_4SbPh_3$, was shown to exist as the equatorial form in the solid state, but the authors were unable to rationalize that obervation.[6] It will be shown later that their interpretation of the solution infrared spectrum of this compound was incorrect.

In summary, it can be said that the preference of strong π-acceptor ligands to occupy equatorial sites while weak π-acceptors are found in axial positions is widely accepted and illustrated by numerous examples. The role of σ bonding in influencing site preference is well documented in the theoretical literature but rarely cited in papers concerned with synthetic chemistry. Little effort has been made to rank the relative importance of the two types of bonding, i.e. to predict the site preference of a weak σ-donor in the presence of strong π-acceptors. The possibility of first, second, or third row transition metals having different tendencies to give equatorial or axial isomers has received little attention.

1.3 Project Description

It was decided to undertake a study of the site preference of the unique ligand in d^8 transition metal complexes of the iron triad of the type $M(CO)_4L$ (M=Fe,Ru,Os; L=group 15 ligand). These complexes seemed a suitable target group since they exist as TBP's and from the one study on $Ru(CO)_4SbPh_3$ were expected to exhibit axial-equatorial isomerism.

Interest in this project was stimulated by the knowledge that relatively few second and third row TBP complexes were known, and few of these were equatorially substituted. The structure of $Ru(CO)_4SbPh_3$ was of special interest since it contained a second row transition metal and the unique ligand (not known as a strong π acid) was equatorial.[6] In the Fe analogue it was axial.[24] Convenient synthetic routes to $Ru(CO)_5$ and $Os(CO)_5$ had been developed in this laboratory[46] and it was thought that this would allow facile synthesis of $Ru(CO)_4L$ and $Os(CO)_4L$ derivatives. It was hoped that new equatorial isomers could be synthesized and that this would lead to a better understanding of the question of site preference in general. The existence of eq-$Ru(CO)_4SbPh_3$ suggested that attempts to synthesize $Os(CO)_4SbPh_3$ might be a useful starting point. As the work proceeded it became apparent that compounds of the type $M(CO)_4L$ (M=Fe, Ru, Os; L=ER_3, E=P, As, Sb; R=Ph, Me; L=$P(OCH_2)_3CMe$) would be synthetically accessible and this would allow a systematic study of the influence of both the ligand and the central metal on the site preference.

CHAPTER 2

RESULTS

Several derivatives of the type $M(CO)_4L$ (M=Fe,Ru,Os; L=group 15 ligand) have been prepared.[47] The ruthenium trimethylphosphine derivative, $Ru(CO)_4PMe_3$, was prepared by the action of PMe_3 on $Ru_3(CO)_{12}$ at 120 °C under 75 atmospheres of CO, a method used previously for $Ru(CO)_4P(OMe_3)$.[41] The osmium analogue was synthesized in a similar manner only under more forcing conditions (280 °C, 200 atm CO). All other derivatives were prepared in hexane from $M(CO)_5$ and the appropriate ligand. With $Ru(CO)_5$ the reaction proceeded at a convenient rate at room temperature whereas for $Os(CO)_5$ temperatures of 80 °C or above were necessary. This illustrates the greater lability of carbonyls when bonded to the second row transition metal, a property previously observed with this group of metals in $M(CO)_4(SiCl_3)_2$ derivatives.[48] For osmium, and to a lesser extent, ruthenium, there were competing reactions in the formation of the $M(CO)_4L$ complexes which gave $M_3(CO)_{12}$ and other clusters. The poor yields of $Os(CO)_4L$ were marginally improved by carrying out the reactions under carbon monoxide. The colour of the complexes ranged from the orange $Ru(CO)_4SbPh_3$ to the white $M(CO)_4PMe_3$ species. They could be handled in air for short periods but decomposed upon prolonged exposure.

2.1 Structural Studies

The structures of ax-$Ru(CO)_4AsPh_3$, ax-$Ru(CO)_4SbMe_3$ and eq-$Os(CO)_4SbPh_3$ were determined by conventional X-ray diffraction techniques. Views of each molecule showing the thermal ellispoids and the atomic numbering scheme for each are given in Figures A.2.1, A.2.2 and A.2.3 respectively; selected bond lengths and angles are given in Tables A.2.1, A.2.2 and A.2.3. Although the structure was not determined, the compound $Os(CO)_4AsPh_3$ was found to be isostructural with $Ru(CO)_4AsPh_3$. It can be seen that of the compounds studied here, $Ru(CO)_4AsPh_3$, $Os(CO)_4AsPh_3$ and $Ru(CO)_4SbMe_3$ adopt the axial form in the solid state while only $Os(CO)_4SbPh_3$ (as determined in this study) and $Ru(CO)_4SbPh_3$ (as determined by Forbes and coworkers[6]) adopt the equatorial form. This represents the first occasion where a site preference switchover for a closely related series of five-coordinate complexes has been observed. The reasons for this will be discussed subsequently, however there are several other points of interest about the structures which are considered now.

The Os-Sb bond length of 2.612(2)Å[49] appears to be the first reported in the literature for a molecular compound. It may be compared with the Os-Sb bond lengths in $OsSb_2$ (2.639(3)Å and 2.644(4)Å),[50] and the Ru-Sb distance of 2.623(4)Å in $Ru(CO)_4SbPh_3$.[6,51] The Ru-Sb distance of 2.619(1)Å found for $Ru(CO)_4SbMe_3$ may likewise be compared to these lengths. The

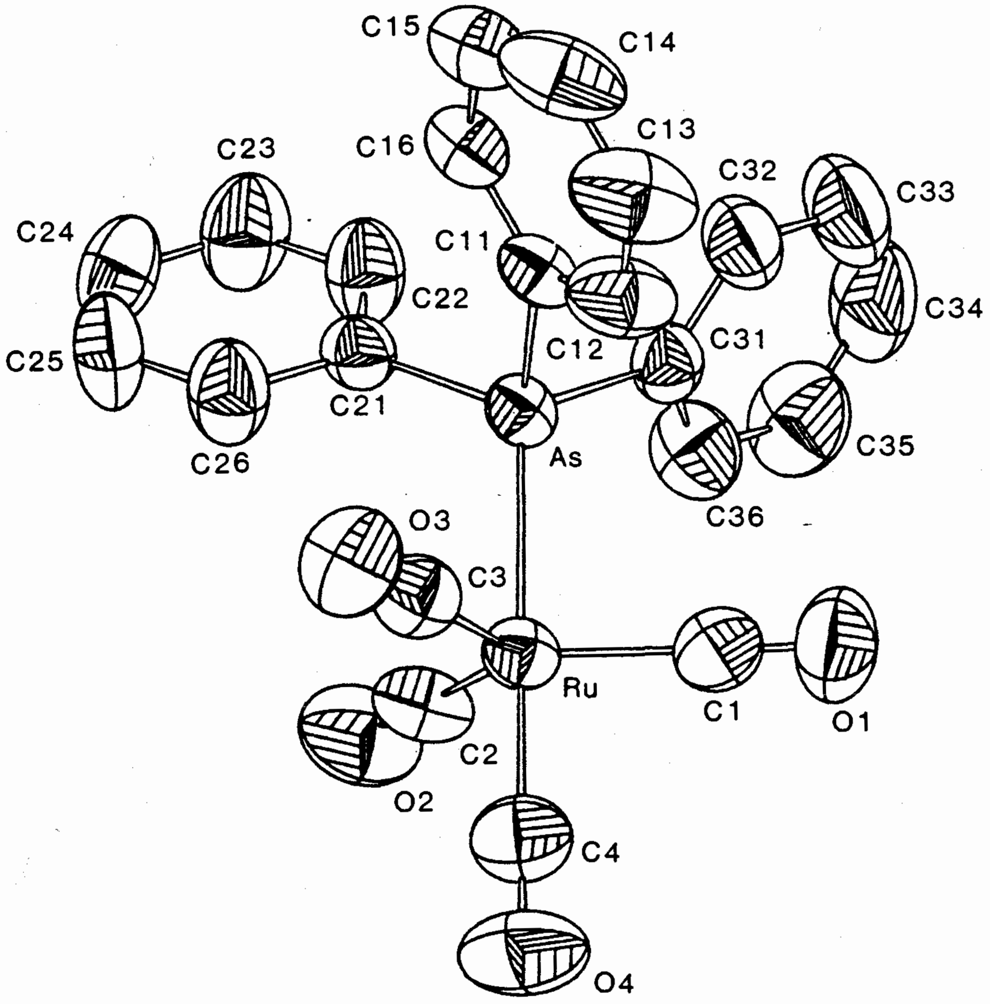


Figure A.2.1. Thermal Ellipsoid Diagram for $Ru(CO)_4AsPh_3$

Table A.2.1 Selected Molecular Dimensions for $Ru(CO)_4AsPh_3$.

a)Bond Lengths

Atoms	Length (Å)	Corrected Length (Å)
Ru-As	2.461(1)	2.507^a
Ru-C(1)	1.918(5)	1.930^b
Ru-C(2)	1.915(5)	1.921^b
Ru-C(3)	1.921(5)	1.932^b
Ru-C(4)	1.890(5)	1.906^b
C(1)-O(1)	1.140(7)	1.153^c
C(2)-O(2)	1.147(6)	1.160^c
C(3)-O(3)	1.132(7)	1.146^c
C(4)-O(4)	1.153(6)	1.168^c
As-C(11)	1.938(5)	
As-C(21)	1.932(5)	
As-C(31)	1.925(5)	

b)Bond Angles

Bond	Angle (°)	Bond	Angle (°)
C(1)-Ru-C(2)	117.9(2)	O(2)-C(2)-Ru	178.6(4)
C(1)-Ru-C(3)	118.5(2)	O(3)-C(3)-Ru	178.1(5)
C(1)-Ru-C(4)	92.5(2)	O(4)-C(4)-Ru	179.2(5)
C(2)-Ru-C(3)	123.4(2)	C(11)-As-C(21)	103.1(2)
C(2)-Ru-C(4)	90.0(2)	C(11)-As-C(31)	103.0(2)
C(3)-Ru-C(4)	91.5(2)	C(21)-As-C(31)	103.3(2)
As-Ru-C(1)	89.0(1)	C_{Ph}-As-C_{Ph}^{d}	103.1
As-Ru-C(2)	89.1(1)	Ru-As-C(11)	115.4(1)

As-Ru-C(3)	88.0(1)	Ru-As-C(21)	115.1(1)
As-Ru-C(4)	178.5(2)	Ru-As-C(31)	115.2(1)
O(1)-C(1)-Ru	177.9(5)	Ru-As-C_{Ph}[d]	115.2

c)Torsion Angles

Bonds	Angle (°)
C(11)-As-Ru-C(3)	34.24
C(21)-As-Ru-C(2)	37.67
C(31)-As-Ru-C(1)	35.57

[a] Atoms assumed to move independently.

[b] Second atom assumed to ride on the first.

[c] Both atoms assumed to ride on Ru.

[d] Mean value.

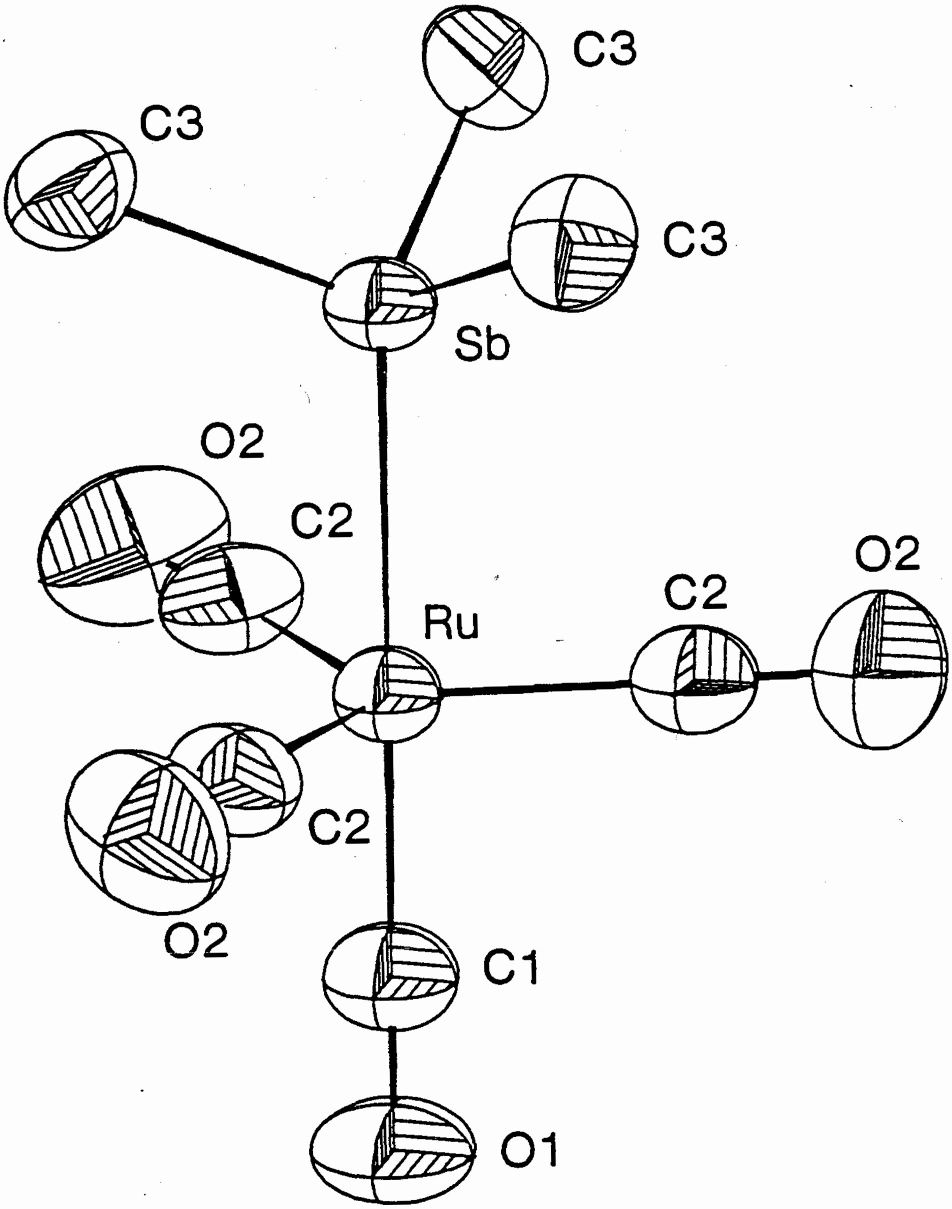


Figure A.2.2. Thermal Ellipsoid Diagram for $Ru(CO)_4SbMe_3$

Table A.2.2. Selected Molecular Dimensions for $Ru(CO)_4SbMe_3$

a)Bond Lengths

Atoms	Length (Å)	Corrected Length (Å)
Ru-Sb	2.6187(9)	2.6578[a]
Ru-C(1)	1.89(2)	1.90[b]
Ru-C(2)	1.92(1)	1.94[b]
Sb-C(3)	2.140(7)	
C(1)-O(1)	1.16(2)	1.17[c]
C(2)-C(2)	1.13(1)	1.15[c]

b)Bond Angles

Bond	Angle (°)
C(1)-Ru-C(2)	91.9(2)
C(2)-Ru-C(2)	119.9(3)
Ru-Sb-C(1)	180.0(-)
Ru-Sb-C(3)	115.7(2)
C(3)-Sb-C(3)	102.6(3)
Ru-C(2)-O(2)	178.3(9)

[a] Atoms assumed to move independently.

[b] Second assumed to ride on first atom.

[c] Both atoms assumed to ride on Ru.

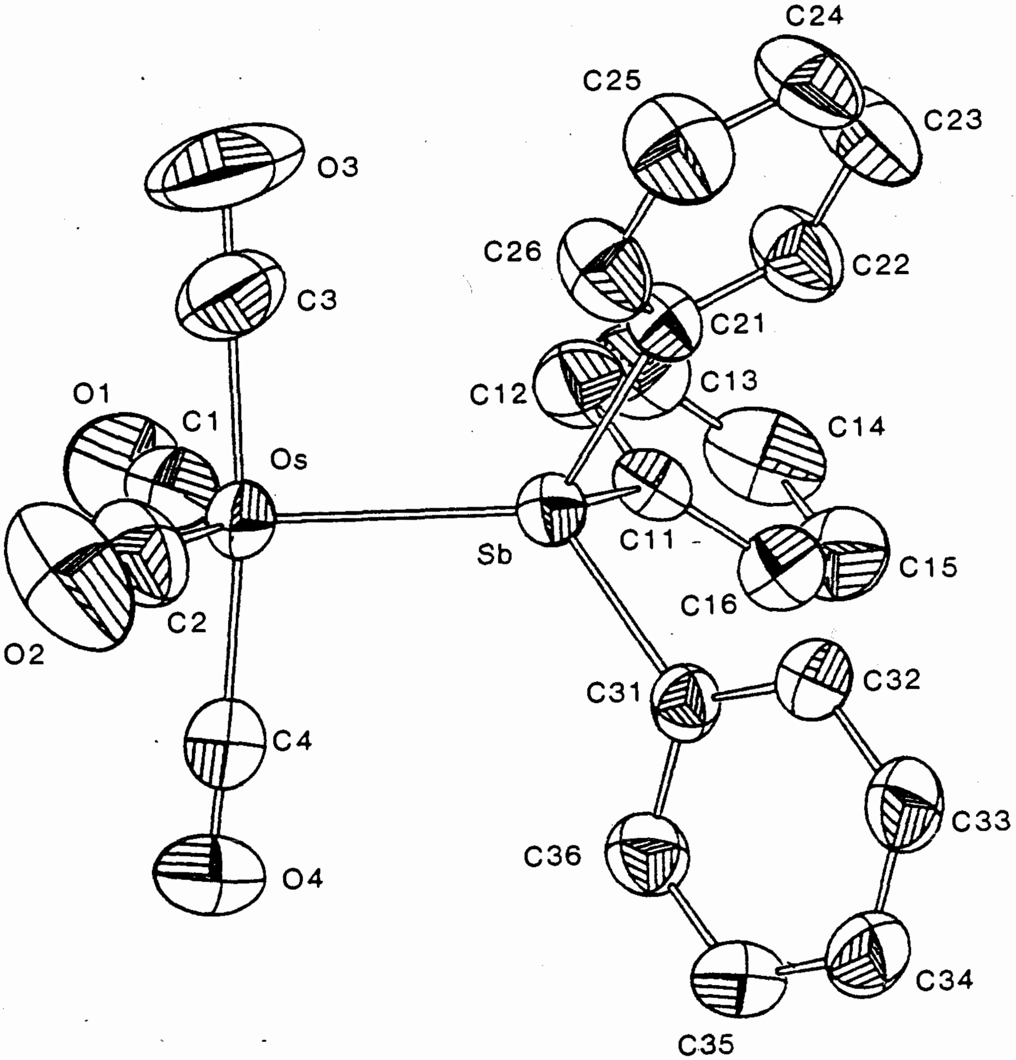


Figure A.2.3. Thermal Ellipsoid Diagram for $Os(CO)_4SbPh_3$.

Table A.2.3. Selected Molecular Dimensions for $Os(CO)_4SbPh_3$.

a) Bond Lengths

Atoms	Length (Å)	Corrected Length (Å)
Os-Sb	2.612(2)	2.649[a]
Os-C(1)	1.926(5)	1.934[b]
Os-C(2)	1.911(7)	1.933[b]
Os-C(3)	1.952(6)	1.980[b]
Os-C(4)	1.939(6)	1.945[b]
C(1)-O(1)	1.134(7)	1.148[c]
C(2)-O(2)	1.148(8)	1.164[c]
C(3)-O(3)	1.117(8)	1.138[c]
C(4)-O(4)	1.134(7)	1.150[c]
Sb-C(11)	2.131(5)	
Sb-C(21)	2.136(5)	
Sb-C(31)	2.124(5)	

b) Bond Angles

Bond	Angle (°)	Bond	Angle (°)
C(1)-Os-C(2)	136.4(3)	O(2)-C(2)-Os	175.6(6)
C(1)-Os-C(3)	90.7(3)	O(3)-C(3)-Os	178.6(8)
C(1)-Os-C(4)	88.8(2)	O(4)-C(4)-Os	177.1(5)
C(2)-Os-C(3)	88.6(3)	C(11)-Sb-Os	114.0(1)
C(2)-Os-C(4)	87.6(3)	C(21)-Sb-Os	118.4(1)
C(3)-Os-C(4)	173.8(3)	C(31)-Sb-Os	121.2(1)
Sb-Os-C(1)	107.0(2)	C_{Ph}-Sb-Os[d]	117.9
Sb-Os-C(2)	116.6(2)	C(11)-Sb-C(21)	100.1(2)

Sb-Os-C(3)	90.7(2)	C(11)-Sb-C(31)	99.0(2)
Sb-Os-C(4)	95.4(2)	C(21)-Sb-C(31)	100.5(2)
O(1)-C(1)-Os	176.9(5)	C_{Ph}-Sb-C_{Ph}[d]	99.9

c)Torsion Angles

Bonds	Angle (°)
C(21)-Sb-Os-C(3)	22.97
C(31)-Sb-Os-C(4)	31.03

[a] Atoms assumed to move independently.

[b] Second atom assumed to ride on the first.

[c] Both atoms assumed to ride on Ru.

[d] Mean value.

Ru-As bond length of 2.461Å is somewhat longer than the Ru-As bond lengths in the literature which are in the range 2.401(3)-2.445(2)Å.[52,53] However, the literature values are for bidentate arsenic ligands in cluster compounds so that it would be unwise to attach any significance to the differences. The C(1)-Os-Sb angle (107.0(2)°) in eq-Os(CO)$_4$SbPh$_3$ is significantly smaller than the C(2)-Os-Sb angle (116.6(2)°). This difference is difficult to rationalize. A similar inequality of seemingly equivalent angles was also present in Co(PPh$_2$Me)$_2$Cl$_2$NO.[54]

There has been considerable discussion[8,28,29,38] regarding differences in M-C$_{eq}$ and M-C$_{ax}$ bonds in Fe(CO)$_4$L and similar complexes. When L=phosphine the bonds are shortened as compared to those of the parent pentacarbonyl[23] with greater contraction of the

Table A.2.4. M-C Distances in $Fe(CO)_5$ and $M(CO)_4L$ Compounds

Compound	$M-C_{eq}$(Å)[a]	$M-C_{ax}$ (Å)	Ref.
$Fe(CO)_5$[b]	1.827(6)	1.807(6)	23
$Fe(CO)_5$[c]	1.795(20)	1.795(20)	55
$Fe(CO)_4PPh_3$	1.795(2)	1.795(2)	29
$Fe(CO)_4P(NMe_2)_3$	1.787(5)	1.793(6)	38
$Fe(CO)_4SbPh_3$	1.787(4)	1.765(4)	24
$Fe(CO)_4Sb(Bu^t)_3$	1.794(7)	1.748(8)	56
$[Fe(CO)_4CN]^-$	1.768(8)	1.723(8)	8
$Ru(CO)_4AsPh_3$	1.918(5)	1.909(5)	this work
$Ru(CO)_4SbMe_3$	1.92(1)	1.89(2)	this work
$Ru(CO)_4SbPh_3$	1.932(6)	1.929(6)[a]	6
$Os(CO)_4SbPh_3$	1.919(6)	1.946(6)[a]	this work

[a] Mean value

[b] Electron diffraction study

[c] X-ray diffraction study

$Fe-C_{eq}$ bonds as compared to the $Fe-C_{ax}$ bond (see Table A.2.4). The normal explanation for these observations is that replacement of the strongly π-accepting CO by a poorer π-bonding ligand reduces competition for the metal π electron density so that the other CO ligands, particularly the equatorial ones, may form stronger Fe-C π bonds. This can be seen in the structures of $Fe(CO)_4PPh_3$ and $Fe(CO)_4P(NMe_2)_3$ both of which have nearly equal $Fe-C_{eq}$ and $Fe-C_{ax}$ bond lengths. When the ligand is $SbPh_3$,

$Sb(t\text{-}Bu)_3$ or CN^-, the overall shortening of the Fe-C bonds can be seen, but the axial and equatorial bonds are significantly different. Presumably any directional π bonding effect causing shortening of $Fe\text{-}C_{eq}$ bonds is accompanied by a reduced trans influence of the unique ligand causing shortening of the $Fe\text{-}C_{ax}$ bond as well. For the compounds studied here comparisons with the parent carbonyls cannot be made since the structures of $Ru(CO)_5$ and $Os(CO)_5$ are not known. In the compounds $Ru(CO)_4AsPh_3$ and $Ru(CO)_4SbMe_3$ the mean $M\text{-}C_{eq}$ length is longer than the $M\text{-}C_{ax}$ length, while in $Os(CO)_4SbPh_3$ the opposite is true. However, in these compounds and in eq-$Ru(CO)_4SbPh_3$ and in $Fe(CO)_4PPh_3$ noted above, the distances are not significantly different. In light of this, and the fact that the X-ray structure of $Fe(CO)_5$ had large estimated standard deviations and showed nearly equal $Fe\text{-}C_{eq}$ and $Fe\text{-}C_{ax}$ lengths[55] which were shorter than the distances found in the electron diffraction study, it seems hazardous to draw any firm conclusions on this question.

Finally it should be noted that although the distortion from TBP geometry in the equatorially substituted complexes is significant, assignment of square pyramid geometry would not be appropriate. According to criteria developed by Holmes,[57] $Os(CO)_4SbPh_3$ has an axial angle, θ_{15}, of 173.8°, and an equatorial angle, θ_{24}, of 136.4° and a dihedral angle, δ_{24}, of 36.6° (see Figure A.2.4). This places the complex considerably more than half-way along a Berry type coordinate along which the

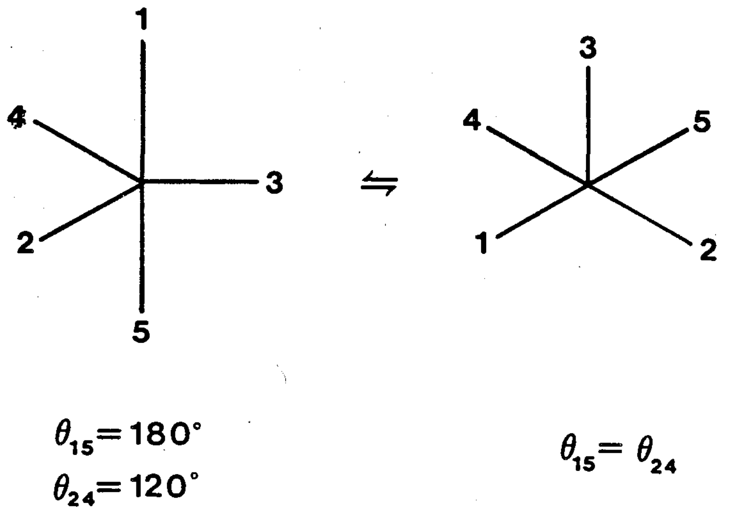


Figure A.2.4. Definition of Structural Angles for Five Coordinate Compounds. The angle δ_{24} is that between the normals of the 1,2,4 and 2,4,5 planes. (After Holmes.[57])

δ_{24} angles varies smoothly from 0° for a square pyramid to 53.1° for an ideal trigonal bipyramid.

2.2 Infrared Studies

Solution infrared spectra in the carbonyl stretching region are illustrated in Figures A.2.5, A.2.6 and A.2.7 and summarized in Table A.2.5. The assignment of peaks to either the axial or equatorial isomer was done on the following basis. When only three carbonyl stretches were present these were assigned to the axial isomer, in accord with the characteristic pattern for $M(CO)_4L$ complexes of C_{3v} symmetry.[15,58] Similar peaks in solutions of compounds displaying more than three carbonyl stretches were also assigned to the axial isomer with the additional peaks being assigned to the equatorial isomer. No absorptions were assigned to possible isomers adopting a square pyramid geometry since few d^8 complexes of this type are known and theoretical predictions have been made to suggest this form is unlikely.[59] Futhermore, in the solid state $M(CO)_4SbPh_3$ (M=Ru,Os) adopt the equatorial form; it is just these species which show the most intense absorptions of the second isomer in solution. The maximum number of peaks assigned to the equatorial isomer in any solution was three although four infrared active CO stretches are expected for an $M(CO)_4L$ molecule displaying C_{2v} symmetry. It is thought that, since the infrared spectrum of no solution indicated the presence of the equatorial isomer to the exclusion of the axial isomer, the unobserved peak, or peaks, of the equatorial form were degenerate with those due to the axial molecule. The solid state infrared spectra of both eq-$Ru(CO)_4SbPh_3$ and

Table A.2.5. Infrared, ^{13}C NMR and Melting Point Data for $M(CO)_4L$ Compounds.

Compound	ν(CO)cm^{-1} [a]						^{13}C NMR[b] (ppm)	m. p. °C[c]
	eq[d]	ax[e]	eq	ax	eq	ax		
$Fe(CO)_4PMe_3$		2051		1978		1937	214.2(20.8)	
$Fe(CO)_4P(OCH_2)_3CMe$		2070		1997		1970	212.2(25.5)	
$Fe(CO)_4PPh_3$		2052		1979		1947	209.0(18.7)	
$Fe(CO)_4AsPh_3$		2051		1977		1947	213.7	
$Fe(CO)_4SbPh_3$		2048		1976		1946	212.7	
$Ru(CO)_4PMe_3$		2061		1985		1947	205.3(2.4)	84-86
$Ru(CO)_4P(OCH_2)_3CMe$	2093	2076	2014	2006		1976	203.3(10.5)	95
$Ru(CO)_4PPh_3$		2062		1988		1955	204.6(3.5)	
$Ru(CO)_4AsPh_3$	2079	2061	1999	1986		1958	204.7	168
$Ru(CO)_4SbMe_3$	2071	2060	1988	1988	1965	1952	203.4	67-71
$Ru(CO)_4SbPh_3$	2078	2060	1999	1987	1967		207.4	
$Os(CO)_4PMe_3$		2061		1980		1939	189.9(4.5)	-
$Os(CO)_4P(OCH_2)_3CMe$	2092	2076	2009	2001		1967	186.7(12.5)	-
$Os(CO)_4PPh_3$		2061		1983		1946	189.4(6.0)	
$Os(CO)_4AsPh_3$	2077	2061	1991	1981		1947	188.7	152-154
$Os(CO)_4SbMe_3$	2069	2058		1977	1955	1942	188.2	103-104
$Os(CO)_4SbPh_3$	2076	2060	1992	1978	1957	1950	190.1	104
$Ru(CO)_4SbPh_3$[f]	2078		1997		1980, 1949			
$Os(CO)_4SbPh_3$[f]	2076		1987		1973, 1937			

[a] All solution spectra recorded in hexane.

[b] Spectra recorded at room temperature in CD_2Cl_2/CH_2Cl_2 (1:5) or CD_2Cl_2 soln.; J_{PC} (Hz) in parenthesis.

[c] New compounds only.

[d] Equatorial isomer.

[e] Axial isomer.

[f] Solid state spectrum in KBr disk.

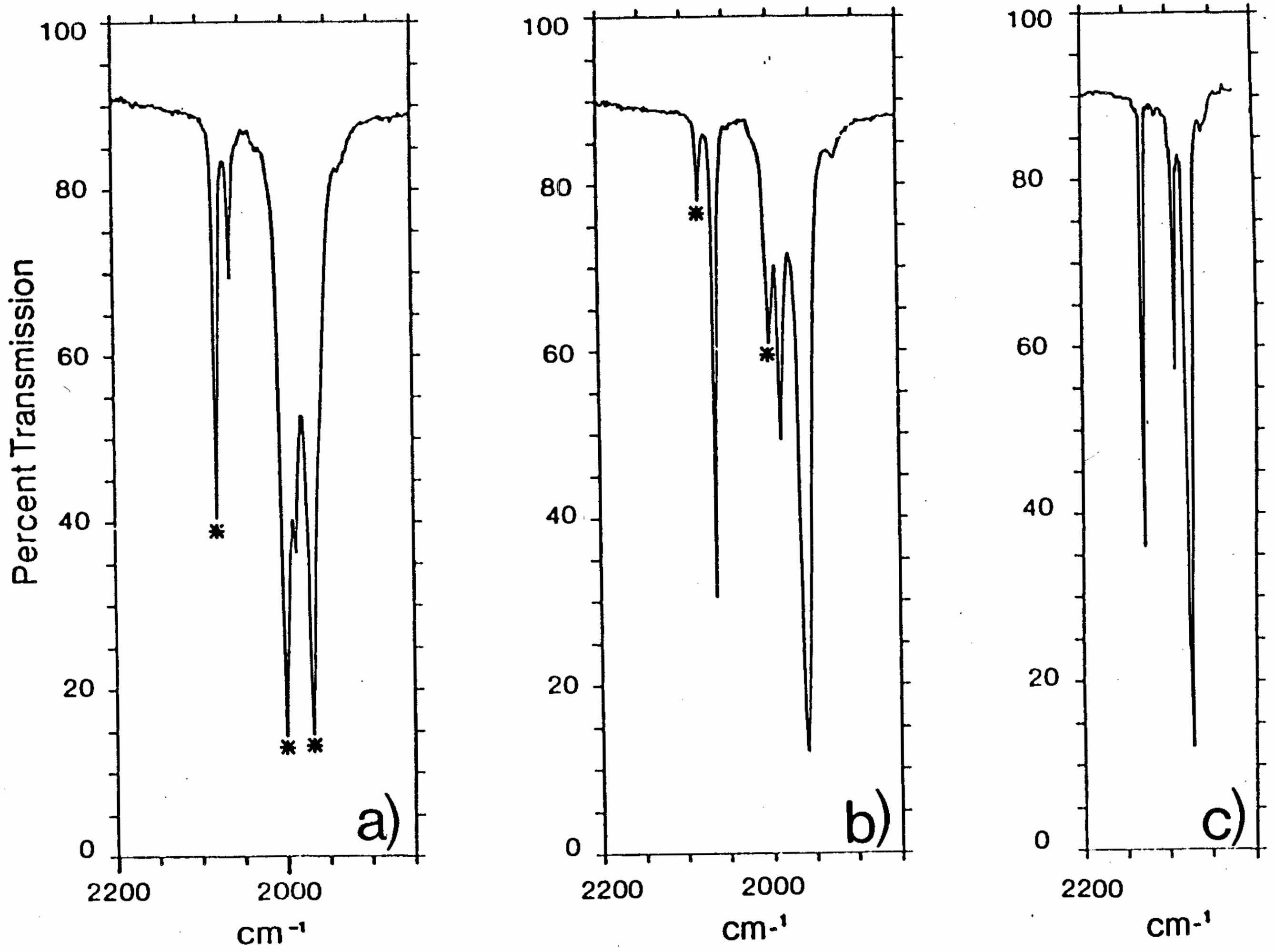


Figure A.2.5. Solution Infrared Spectra of a)$Ru(CO)_4SbPh_3$, b)$Ru(CO)_4AsPh_3$ and c)$Ru(CO)_4PPh_3$. Bands due to the equatorial isomer are marked with an asterisk. The wavenumber scale of spectrum c) is reduced by a factor of two compared to that of a) and b).

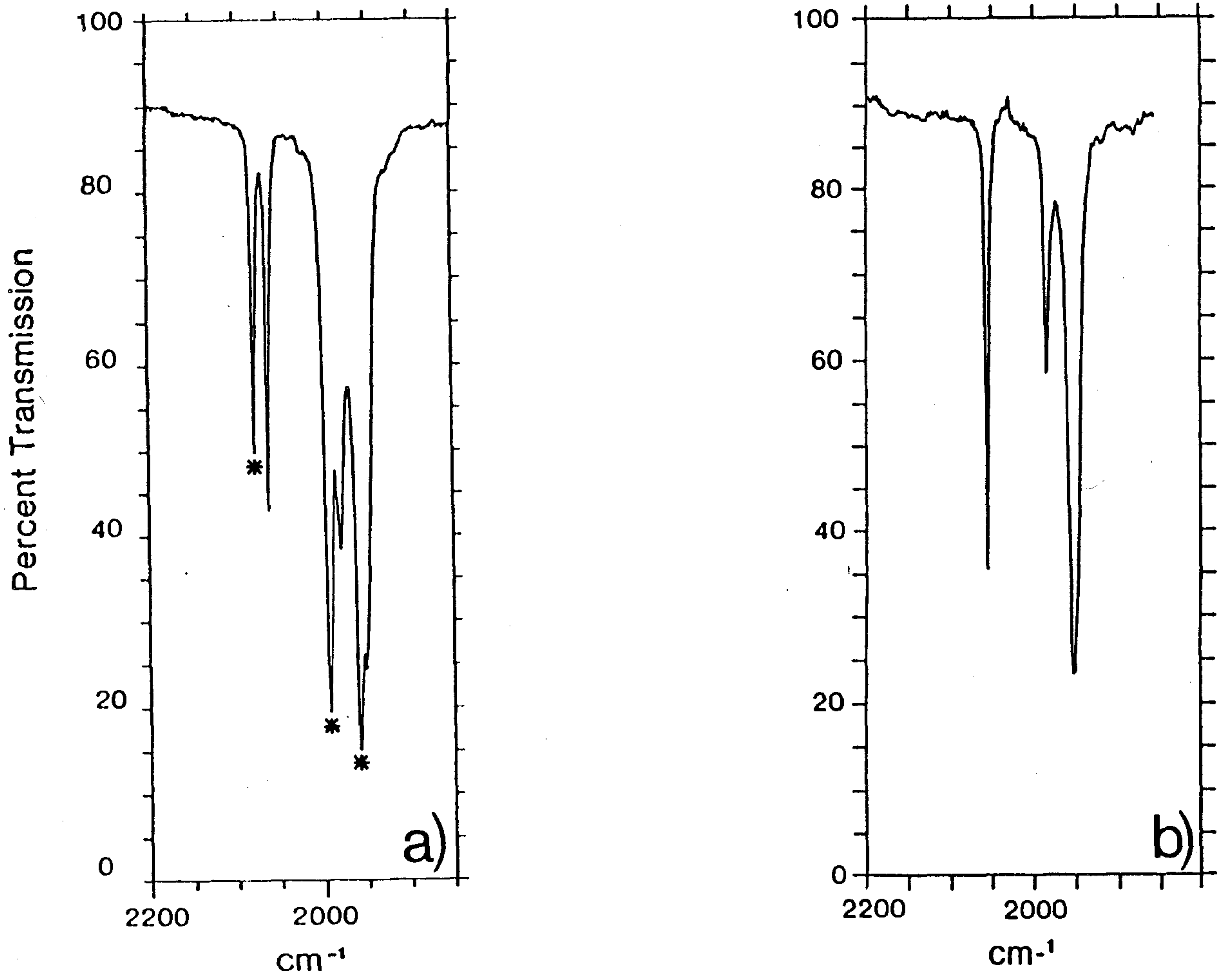


Figure A.2.6. Solution Infrared Spectra of a)$Os(CO)_4SbPh_3$ and b)$Fe(CO)_4SbPh_3$. Bands due to the equatorial isomer are marked with an asterisk.

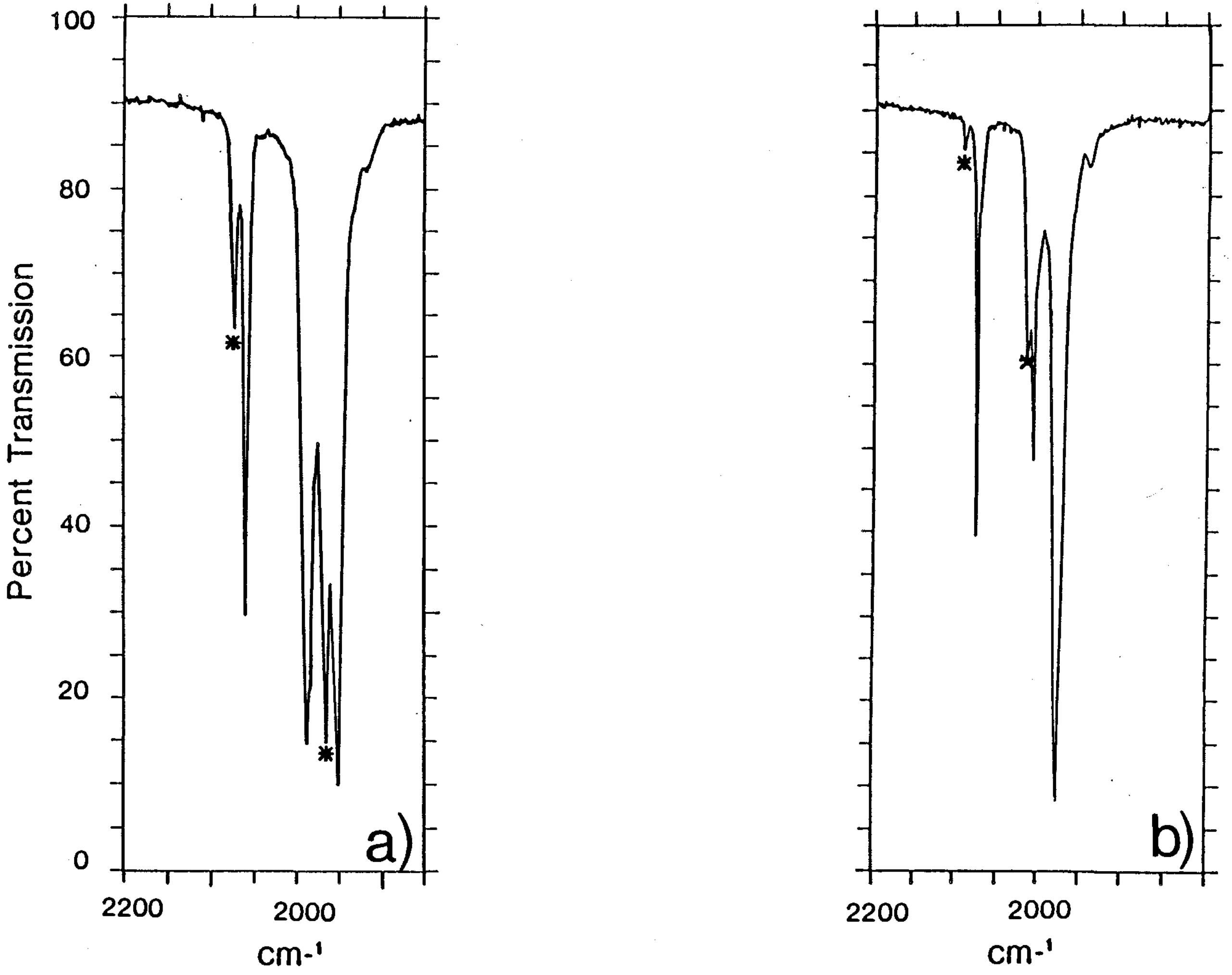


Figure A.2.7. Solution Infrared Spectra of a)$Ru(CO)_4SbMe_3$ and b)$Ru(CO)_4P(OCH_2)_3CMe$. Bands due to the equatorial isomer are marked with an asterisk.

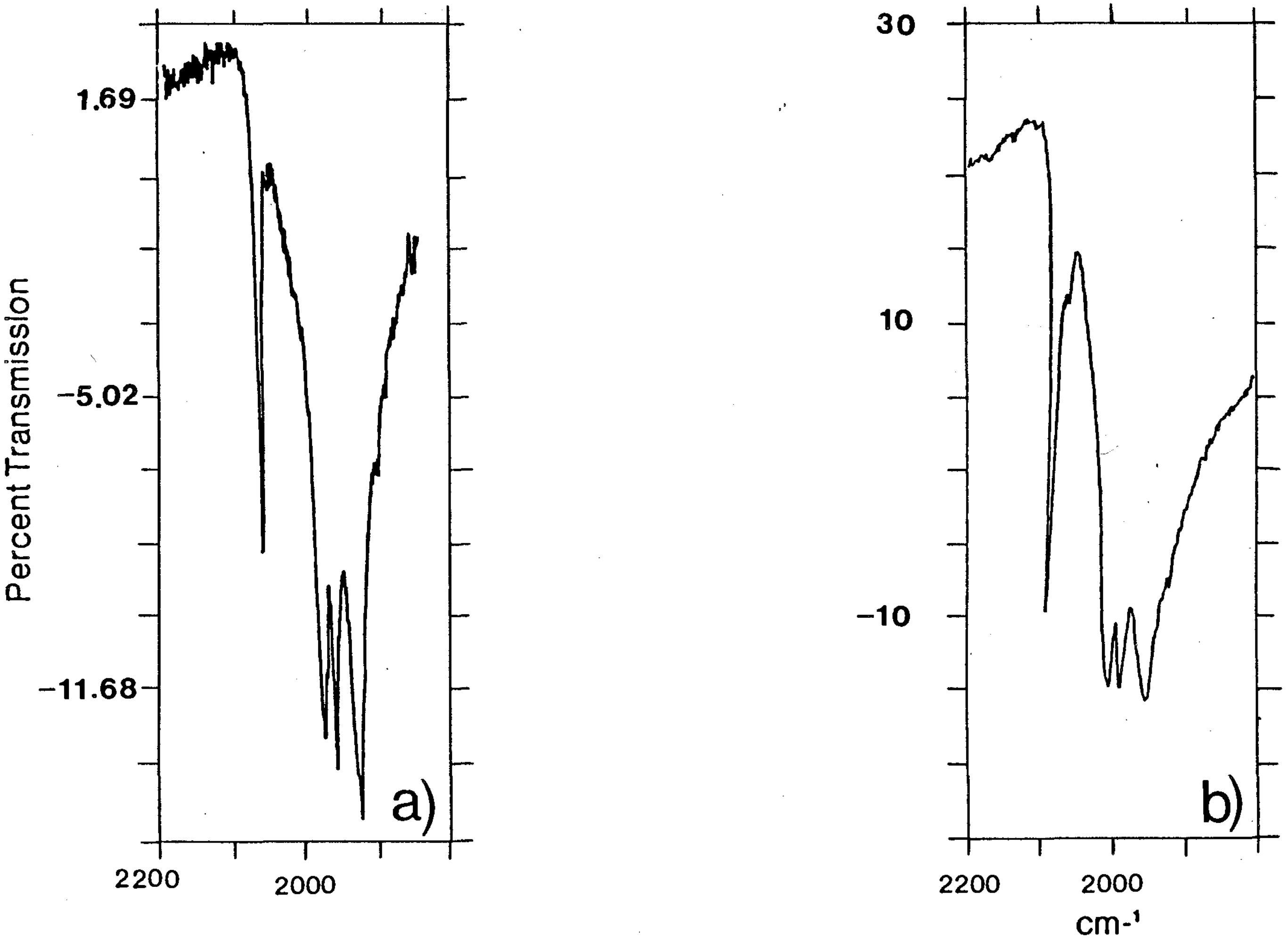


Figure A.2.8. Solid State Infrared Spectra of a)$Ru(CO)_4SbPh_3$ and b)$Os(CO)_4SbPh_3$.

eq-$Os(CO)_4SbPh_3$ did display four bands (Figure A.2.8.) These solid state spectra confirm that the structures determined by X-ray diffraction were representative of the bulk solid state structure and were not the chance result of single crystal analysis.

The short time scale[16] of infrared spectroscopy allowed the existence of two isomers in solution to be displayed for all the Ru and Os derivatives except when L was PMe_3, see Table A.2.5. It was hoped that low temperature studies using the method of Hartman and co-workers[60] would reveal a shift in the equilibrium of the two isomers and hence allow the calculation of thermodynamic parameters. Accordingly the area of the absorbance peaks of $Ru(CO)_4SbPh_3$ at 2078 cm^{-1}(ax) and 2060 cm^{-1}(eq) were measured at temperatures ranging from ambient to -90 °C. Similar attempts were made for $Os(CO)_4SbPh_3$ and $Ru(CO)_4SbMe_3$ but no linear relationship between the band areas could be detected and this avenue of investigation was abandoned.

2.3 NMR Studies

While the solution infrared spectra clearly displayed the presence of two isomers in solution for many of the $M(CO)_4L$ complexes, the ^{13}C NMR spectra revealed only a single resonance in all cases, except that ^{31}P coupling was observed when the complex contained a phosphorus donor ligand. (The J_{P-C} values are noted in brackets in Table A.2.5.) The indication is clearly that not only are the axial and equatorial carbonyls exchanging rapidly in each isomer but also the isomeric forms must be rapidly interconverting. This would be the expected result if the exchange occurred by the Berry pseudorotation (BPR) mechanism.[11] Such a mechanism has been previously proposed many times to account for the nonrigidity of five coordinate molecules.[45,61] It seems likely to be occurring in the complexes studied here because the equatorial isomer can be detected for many of the species. If a BPR mechanism were operative the free energy change upon rearrangement could be represented as in Figure A.2.9. It would be expected that the energy difference between the equatorially substituted molecule (3) and the axial isomer (1 and 5) would be reflected in the ratio of isomers displayed in the infrared spectra. Where the ax/eq ratio is nearly one, the energy level of the equatorial form would be nearly equal to that of the axial form (case A). When only the axial form can be detected in solution the energy difference would be large, (case B) i.e., the equatorial form is best considered as an intermediate. Slowed exchange would be expected if the initial activation barrier were large (cases C and D), or if the equatorial isomer were highly unfavoured (case E).

Whereas it was previously noted that $Fe(CO)_4PPh_3$[62] and several other $Fe(CO)_4L$[7] complexes showed no signs of slowed exchange at low temperatures it was hoped that this would not be

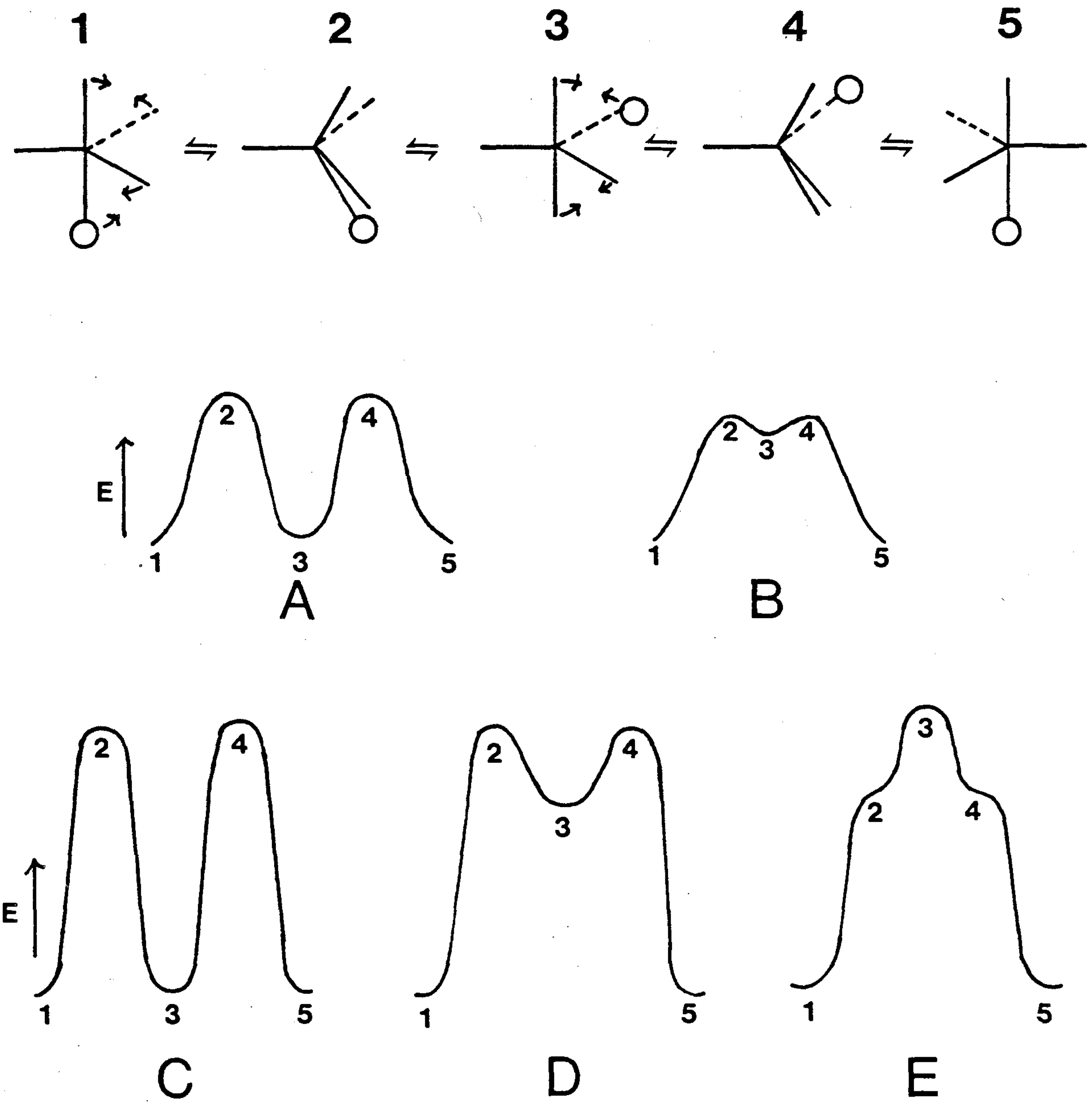


Figure A.2.9. Berry Pseudorotation Mechanism and Some Possible Reaction Coordinates. (After Lichtenberger and Brown,[14]) the case for the Ru and Os derivatives. Much higher barriers to nonrigidity had been observed for an octahedral system of $M(CO)_4(EMe_3)_2$ (E=Si,Ge,Sn,Pb) complexes when M=Ru or Os than when M=Fe.[63] In this case both cis and trans isomers could be detected in the ^{13}C NMR spectra indicating a reaction diagram as in C would be applicable. A variable temperature ^{13}C NMR study on a series of ax-$Co(CO)_4EX_3$ (E=C,Si,Ge,Sn,Pb; X=F,Cl,CH_3,$CH_2C_6H_5$,C_6H_5) derivatives found slow exchange at low temperatures.[14] Coalescence temperatures varying from −10 °C to <−160 °C were observed. (In this case only the axial form was detected in the low temperature limit so that the diagrams D or E might apply.) It was found that higher barriers to non-rigidity were associated with smaller group 14 donor atoms. For example, $Co(CO)_4CF_3$ had a coalescence temperature of −10 °C.

The solution ^{13}C NMR spectra of $Ru(CO)_4P(OCH_2)_3CMe_3$, $Ru(CO)_4SbPh_3$ and $Os(CO)_4SbPh_3$ were studied to very low temperatures (−100 °C, −110 °C, and −100 °C respectively), but in all cases the carbonyl resonance remained a sharp singlet or doublet, (the ^{13}CO signal for $Ru(CO)_4P(OCH_2)_3CMe$ is coupled to P). Therefore kinetic parameters for axial-equatorial exchange could not be obtained. Valuable mechanistic information could have been obtained had the exchange been slowed on the NMR time scale because the Berry pseudorotation mechanism predicts simultaneous collapse of the signals of each isomer. This has yet to be observed for any system.

CHAPTER 3

DISCUSSION

It can be seen from Figures A.2.1 to A.2.3, A.2.5 to A.2.7 and Table A.2.5 that the tendency to give equatorial isomer is $Ph_3Sb>Ph_3As>Ph_3P$ and Ru>Os>>Fe. Also, as far as the substituents on the ligand are concerned, $(OCH_2)_3CMe$ must be considered the most likely to give an equatorial isomer since it alone displays the existence of that form in solution when attached to phosphorus. The ordering for the ligand substituents is then $SbPh_3>SbMe_3$ (As ligands would probably display similar behaviour) and $P(OCH_2)_3CMe>PPh_3,PMe_3$. The site preference switchover from axial to equatorial isomers in the solid state occurs for M=Ru, Os when the unique ligand is $SbPh_3$. It was found that it was exactly those compounds which displayed the most intense solution IR bands for the equatorial isomer that adopted this form in the solid state.

It is clear that the tendency to give equatorial isomer depends both on the nature of the ligand and on the central metal. Each of these factors is discussed below, in terms of both steric and electronic (σ and π bonding) considerations.

3.1 Steric Considerations

It seems fairly easy to discount steric factors as the cause of the observed switchover of the solid state configurations and of the variation of the axial/equatorial isomer ratio in solution. As mentioned earlier, Lichtenberger and Brown[14] have shown that ER_3 type ligands are more sterically crowded in the equatorial position than in the axial position, even though only two close encounters with CO groups at 90° are expected for the unique ligand when it is in an equatorial position. The reason is the inability of the three R groups to adopt a fully staggered conformation with respect to the two CO ligands. This is illustrated in the Newman projections in Figure A.3.1. We also find that the closest non-bonded contacts do indeed occur in the equatorial compound $Os(CO)_4SbPh_3$, (C(1)•••H(12)=3.09Å). Furthermore, calculations on a model of eq-$Os(CO)_4AsPh_3$ using coordinates from ax-$Ru(CO)_4AsPh_3$ and eq-$Os(CO)_4SbPh_3$ indicate two contacts between the group 15 ligand and carbonyls that are slightly less than the sum of the van der Waals radii for the atoms involved (C(1)•••H(12)=2.79Å; C(4)•••H(36)=2.83Å).[64] Within ax-$Ru(CO)_4AsPh_3$ the comparable contacts are at this sum (C(3)•••H(26)=3.16Å.) (The closest nonbonded contacts between the hydrogens and oxygens were O(1)•••H(32)=3.02Å for ax-$Ru(CO)_4AsPh_3$ and O(1)•••H(12)=3.04Å for eq-$Os(CO)_4SbPh_3$.)

Given that the equatorial site is more sterically crowded it is to be expected that a ligand having a larger cone angle would be more likely to occupy the axial position. In the case of $Ru(CO)_4SbR_3$ (R=Me, Ph) the reverse is found. When R=Me (estimated cone angle=118°) the compound crystallizes as the

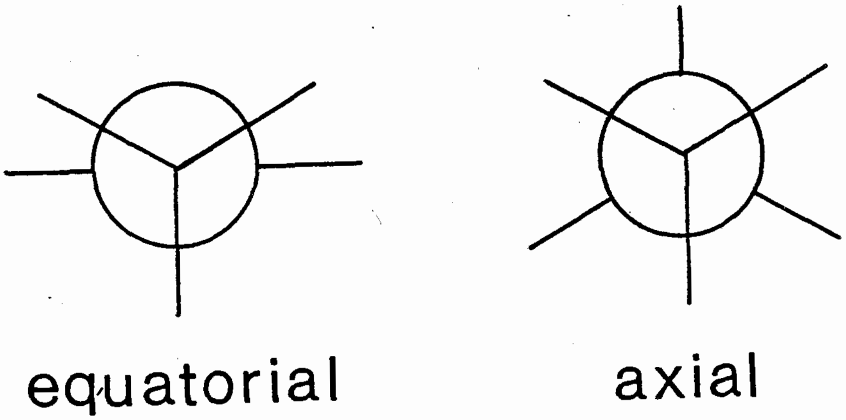


Figure A.3.1. Newman Projections for $M(CO)_4ER_3$ Compounds (After Lichtenberger and Brown.[14])

axial isomer whereas when R=Ph (estimated cone angle=145°) the equatorial isomer is observed. (The cone angles of these ligands were considered to be equal to the corresponding phosphorus analogues.[65]) The solution IR spectra are consistent with there being more axial isomer in solution for R=Me than for R=Ph. Large ligands are known to occupy both equatorial sites, as in $Fe(CO)_4P[OC(CF_3)_2CN]_3$,[7] and axial sites as in $Fe(CO)_4[P(t\text{-}Bu)_3]$.[66] In the former case the cone angle is at least 160° while in the latter it is 182°.[65] Ligands with small cone angles are also found in both sites. The compound $Fe(CO)_4P(OMe)_3$ exists entirely in the axial form, while a statistical distribution of isomers is found for $Fe(CO)_4PF_3$.[67] The cone angles are 107° for $P(OMe_3)$[66] and 104° for PF_3.[67] Also different site preferences are found for ligands which have approximately the same cone angle; i.e. PPh_3 and $AsPh_3$ prefer the axial site in $M(CO)_5L$ (M=Fe, Ru, Os) while $SbPh_3$ occupies an equatorial position in both $Ru(CO)_4SbPh_3$ and $Os(CO)_4SbPh_3$ in the solid state. The cone angle in all three cases is 145°.[68] We conclude that arguments based on the steric requirements of the ligands may be discounted as an explanation for axial-equatorial isomerism regardless of whether the axial or equatorial site is considered the more crowded.

As far as the central metal is concerned, it would be expected that iron (having the smallest covalent radius of the three metals) would be most affected by steric factors. And while it is true that all the iron compounds studied here displayed only the axial isomer in solution, the examples of other workers cited above show this is not always the case.

A more subtle steric argument based on calculating a minimum total repulsion energy summed over all the M-L bonds is the subject of the review by Favas and Kepert[2] noted in the introduction. It will be remembered that they base their calculations on the ratio (R) of the effective bond lengths of the unique ligand to the other four ligands and that for $M(CO)_4L$ complexes the distortion of the C-M-C bond angles was calculated for different R values and the results were presented in graphical form. Thus the theoretical R values can be deduced if the structure is known. In ax-$Ru(CO)_4AsPh_3$ and ax-$Ru(CO)_4SbMe_3$ there is only a slight bending of the equatorial carbonyls toward the non-carbonyl ligand. This would be in accord with $R \simeq 1.00$ and no clear prediction of site preference. For the compounds eq-$Ru(CO)_4SbPh_3$ and eq-$Os(CO)_4SbPh_3$ the bending of the carbonyl ligands is quite pronounced and would lead to a predicted R value of $\simeq 0.85$ in accord with the site preference found. However this R value is intuitively very unsatisfying in that it would be expected that the M-C bonding electrons would be closer to the metal nucleus than the M-Sb bonding electrons, leading to an R value >1.0. The distortion of the equatorial bond angles from the ideal 120° could then be seen as the result of the greater replusion between the electrons in the M-C bonds (which also have a large, diffuse, π component) than between these electrons and those in the M-Sb bond.

One final point is that it appears highly unlikely that crystal packing forces contribute to the switchover of isomeric forms in the solid state. If this were the case the close correlation with the solution infrared spectra would not be expected. Furthermore, the four species studied here, $M(CO)_4AsPh_3$ and $M(CO)_4SbPh_3$ (M=Ru,Os), as well as $Fe(CO)_4EPh_3$ E=P[29] and Sb[24] crystallize in the same space group ($P\bar{1}$), regardless of the isomeric form adopted. Packing forces may be the determining factor in the compound $Fe(CO)_4PPh(PPh_2)_2$ which crystallizes as the equatorial isomer but displays only an axial carbonyl stretching pattern in solution.[69]

3.2 Electronic Properties of the Ligands

It is generally recognized[70,71] that while the π-acceptor properties of the group 15 ligands do not vary appreciably on descending the group, the σ-donor ability decreases in the order $PR_3>AsR_3>SbR_3$.[71,72] Since some of the conclusions of this work are based on this premise it is worth exploring it in some detail.

It has been established that the carbonyl stretching frequencies of closely related species of the type $M(CO)_xL$ increase with increasing π-acceptor properties of L but do not vary as much with the σ-donor properties.[73] From Table A.2.5 it can be seen that the CO stretching frequencies of $M(CO)_4EPh_3$ (E=P,As,Sb) for the axial isomer are all very similar indicating no appreciable variation of the π-acidity of the ligands. This is consistent with earlier studies wherein it was taken to indicate near equality of the π-acceptor qualities of these ligands.[74,75]

Considerable experimental evidence[68,76,77,78] has been presented to show that the donor strength of group 15 ligands follows the order $PR_3>AsR_3>SbR_3$. A quantitive understanding of the relative σ-donor strength of the ligands studied here can be gained from an analysis of the heats of formation of a number of LBX_3 adducts. Mente and Mills[76] found ΔH values of -68.6,

-46.2 and -26.8 kcal/mol for the reaction of BCl_3 with Me_3P, Me_3As and Me_3Sb respectively. Values for BH_3 were closely related at -79.9 and -49.6 kcal/mol for Me_3P and Me_3As. (The reaction between Me_3Sb and BH_3 was anomalous.) Other investigators[79] have found the ΔH of $OCBH_3$ to be -25.1 kcal/mol; a value approximately equal to that expected for Me_3SbBH_3. Since no π interaction is expected between the group 15 donor atom and the B atom we may take these measurements as an indication of donor strength. Because of the weaker inductive effect of the phenyl group compared th the methyl group, the $SbPh_3$ ligand would be expected to be a weaker donor than $SbMe_3$ and hence a weaker donor than CO. This would explain why a switchover of site preference in the solid state occurs when the unique ligand is changed from $SbMe_3$ to $SbPh_3$. A rough estimate of the magnitude of the change of donor strength that occurs when Ph groups are substituted for Me groups can be seen from the values of the ΔH values found for the reaction of ER_3 ligands with trans $[CH_3L'_2(THF)Pt][PF_6]$ $(L'=P(CH_3)_2(C_6H_5))$.[68] The values for PMe_3 and PPh_3 were -26.2 and -19.5 kcal/mol respectively while those for $AsMe_3$ and $AsPh_3$ were -15.4 and -12.8 kcal/mol. (The value for $SbPh_3$ was -6.1 kcal/mol, no value was recorded for $SbMe_3$.) Any strengthening of the π component in the L-Pt bond in the compounds studied above would offset the trend displayed. The fact that the trend so clearly exists must be taken as an indication of the weakening donor strength.

A more recent study[80] based on ^{13}C chemical shifts in NMR spectra concluded that the ordering of the donor/acceptor ratio of these ligands is $SbR_3>PR_3>AsR_3$. However, this conclusion must be viewed with some caution since it is based only on the correlation between the ^{13}C NMR chemical shift (δCO) in $LNi(CO)_3$ complexes and the relative donor/acceptor character of L. The ordering is as above only when R=Ph, and differs when R=Me. From the ^{13}C NMR data obtained in this study (Table A.2.5) an order of $AsPh_3>SbPh_3>PPh_3$ is indicated, based on the $Fe(CO)_4L$ complexes which exist only in the axial form. Yet other orderings are possible if the data of Buchner and Schenk[81] are used. It seems that while such methods may be valid when applied to P donor ligands, they cannot be extended to other group 15 ligands. In 1965 it was noted[82] that ^{13}C chemical shifts of transition metal complexes were poorly understood. This comment was reiterated in 1974[83] and still seems valid in 1986.

A structural study of $Cr(CO)_5EPh_3$ (E=P, As, Sb, Bi) complexes concluded from decreasing C-E-C angles and relatively shortened M-E bond lengths that the M-E bonds had more s character on descending the group.[84] From these results it was concluded that the bond order increased on going to the element lower in the group. (The distortion of the group 15 ligand from tetrahedral geometry can also be seen in the crystal structures determined here and by others.[6,43]) The explanation that the E-C bonds have enhanced p-character while the M-E bonds have enhanced s-character is well accepted. It has been pointed out, however, that increased s character of the lone pair of such ligands makes it <u>less</u> available for bonding.[81] Futhermore, a recent theoretical study[85] indicated the lone pair on PF_3 was less diffuse and had more s character than that of PMe_3. It is well known that PF_3 is less basic that PMe_3.

While it is generally accepted that a shorter bond indicates a stronger bond it should be remembered that the Cr-E bonds of the heavier analogues are only shortened relative to the covalent radii of the donor atom. This would be the expected result of the lone pair having more s character and does not necessarily indicate increased bond order. Such an effect might be expected to be quite large when the donor atom is Sb or Bi since their covalent radii are considerably larger than that of P. The variation of bond length can thus be explained (at least in part) by the more compact nature of the orbital having the greater s character. Other workers have found that shorter bonds do not necessarily mean stronger bonds. Bryan and Kuchowski[86] concluded that Me_3PBH_3 was a more stable adduct that F_3PBH_3 even though the latter molecule had a significantly shorter P-B bond. Similarly, in $PtCl_2(PEt_3)(PF_3)$ the Pt-PEt_3 bond length (2.272(3)Å) was longer than the Pt-PF_3 length (2.141(3)Å) even though the Pt-PF_3 bond was thought to have lower intrinsic strength that the Pt-PEt_3 bond.[87]

We conclude that it is the σ-donor strength of most of the ligands studied here that determines their site preference in

$M(CO)_4L$ complexes, i.e., the stronger σ-donors prefer the axial position while the weaker σ-donors favour the equatorial site <u>even in the presence of strong π-acceptor ligands (such as CO).</u> This is in accord with the theoretical studies discussed in the introduction but at variance with the usual explanation that it is the π-acceptor properties of the ligand that determines the site preference.

The commonly held view that good π-acceptor ligands prefer the equatorial site, is not disputed. However, if it were the determining factor in the molecules studied here it would be reflected in higher CO stretching frequencies for the axial isomers of those complexes with a significant amount of equatorial isomer in solution. As noted earlier the CO stretching frequencies of all the $M(CO)_4EPh_3$ (E=P, As, Sb) complexes (axial isomer) are all very similar. Only for $M(CO)_4P(OCH_2)_3CMe$ (M=Fe, Ru, Os) are the bands due to the axial isomer shifted to higher frequencies and in this case the occurrence of some equatorial isomer for M=Ru and Os may be rationalized accordingly, using π bonding arguments. The same can be said for other examples of $M(CO)_4L$ compounds reported in the literature which have a large fraction of equatorial isomer in solution such as $M(CO)_4PF_3$ (M=Fe[26], Ru[41]) and $Fe(CO)_4P[OC(CF_3)_2CN]_3$[7]. That the carbonyl stretching frequencies of $M(CO)_4SbPh_3$ complexes do not occur at high frequencies indicates that $SbPh_3$ is not a better π-acceptor than CO; therefore π bonding arguments cannot be used to explain why

$Ru(CO)_4SbPh_3$ and $Os(CO)_4SbPh_3$ exist predominantly as the equatorial form.

3.3 Influence of the Central Metal

As was stated earlier the tendency of the transition metals to give the equatorial isomer was Ru>Os>>Fe. In fact, there was no example for the group 15 ligands studied here of a $Fe(CO)_4L$ derivative which gave detectable amounts of the equatorial isomer in solution. This trend is difficult to rationalize especially for the ruthenium and osmium complexes where the energy differences between the two isomers were small. Several possible explanations were considered and are now discussed. Unfortunately they do not account for the observations.

1)According to simple MO theory, ligand orbitals which are closest in energy to the symmetry matched metal orbitals form the strongest bonds. The ligand σ-donor orbitals are necessarily lower in energy than those of the metal while the opposite is true for the π orbitals. The increased energy of the valence metal orbitals on going from Fe, to Ru and/or Os should lead to stronger π bonds and weaker σ bonds. The energy levels of the valence orbitals are about equal for Ru and Os since the effect of increased atomic number is offset by the lanthanide contraction. Thus any ligand should have a greater tendency to occupy the equatorial position in ruthenium and osmium complexes. However this effect should be approximately the same for CO as for the other ligand, so that no difference is site preference should result when the central metal is changed.

The available evidence suggests that the amount of π bonding to the CO ligands follows the order Fe-CO>Os-CO>Ru-CO, that is, the infrared CO stretching frequencies in complexes studied here and in the parent carbonyls follow the order, Ru-CO>Os-CO>Fe-CO. Also $Ru(CO)_5$ was the least stable of the three pentacarbonyls.[46] However, the differences in the infrared stretching frequencies are not great, and it is difficult to understand why the same order would not also be true for $M-ER_3$ bonds. In that case there would be no change in the difference between the M-CO and $M-ER_3$ bond strengths as M varied.

2)Other factors which have been used to explain differences in M-L bonding as the metal is replaced by heavier members of the triad are atomic size,[88] the lanthanide contraction[89] and relativity effects.[90] Each of these explain trends in M-L bonding as M is varied. But once again, a difference between M-CO and $M-ER_3$ bonding cannot be easily rationalized.

3)Arguments based on the hardness and softness of metals and ligands[91] might lead to the conclusion that the soft $SbPh_3$ ligand should form stronger bonds to ruthenium and osmium than to iron. This in turn would lead to the prediction that there would be less of the equatorial form for the $M(CO)_4SbPh_3$

complexes of the heavier metals, contrary to what is observed.

4)A careful study of the M-Sb-C_{Ph} and C_{Ph}-Sb-C_{Ph} bond angles for the three compounds $M(CO)_4SbPh_3$ (M=Fe, Ru, Os) revealed that all the M-Sb-C_{Ph} angles are enlarged from the tetrahedral angle of 109.5° and follow the order Ru≥Os>Fe for M. Consequently all the C_{Ph}-Sb-C_{Ph} are reduced from the tetrahedral angle and follow the order Fe>Os≥Ru (see Table A.3.1.) In accord with the above discussion, this may be taken to mean that all the M-Sb bonds have enhanced s character while the Sb-C_{Ph} bonds have enhanced p character. The s character of the M-Sb bond would follow the order Ru-Sb>Os-Sb>Fe-Sb. The logical extension of the statement that increased s character of the lone pair on ER_3 ligands makes them less available for bonding,[81] leads to the conclusion that M-ER_3 σ bonds with greater s character are weaker would be consistent with the observed trend for the site preference. This line of reasoning is weak however, in that it only correlates two sets of observations and explains neither. Also, it would lead one to predict that the Ru-Sb-C_{Me} and Ru-As-C_{Ph} angles of $Ru(CO)_4SbMe_3$ and $Ru(CO)_4AsPh_3$ would be larger than the Fe-Sb-C_{Ph} angle in $Fe(CO)_4SbPh_3$. As can be seen from Table A.3.1 they are smaller.

It is concluded that a deeper understanding of the influence of the central metal on the site preference of a unique group 15 ligand awaits more detailed molecular orbital calculations. Simple symmetry overlap arguments do not suffice. Quite subtle yet significant differences could be expected from varying the

Table A.3.1. Ligand Bond Angles for $M(CO)_4ER_3$ Complexes.

Compound	$M-E-C_{ph}$ Angle (°)[a]	$C_{ph}-E-C_{ph}$ Angle (°)[a]	Ref.
$Fe(CO)_4SbPh_3$	116.0-116.8	101.6-102.0	24
$Ru(CO)_4SbPh_3$	113.8-121.7	98.7-99.9	6
$Os(CO)_4SbPh_3$	114.0-121.2	99.0-100.5	this work
$Ru(CO)_4SbMe_3$	115.7(2)	102.6(3)	this work
$Ru(CO)_4AsPh_3$	115.1-115.4	103.0-103.3	this work

[a] Range where appropriate.

MO approach. This has been discussed by Blyholder and Springs in their study on $Fe(CO)_5$.[12]

3.4 Summary

It has been previously predicted that better π-acceptors and weaker σ-donor ligands have a greater tendency to occupy the equatorial site in a d^8 transition metal TBP complex of the type ML_4L'.[1] Since good π-acceptor ligands are usually poor σ-donors and vice versa, changes in site preference have been difficult to attribute unambiguously to either the σ or π properties of the unique ligand. In many synthetic papers the site preferences were discussed only in terms of the π bonding ability of the unique ligand.[17]

The majority of known complexes of the type ML_4L' were of first row transition metals wherein the unique ligand occupied an axial position. A few other examples existed which had a very strong π-acceptor ligand in the equatorial site. That the carbonyl stretching frequencies of these complexes were shifted to higher wave numbers was consistent with unusual π bonding ability of the ligands (i.e., PF_3 and $P[OC(CF_3)_2CN]_3$ in the iron tetracarbonyl compounds.)

The complex $Ru(CO)_4SbPh_3$ was, therefore, unusual and interesting in that it contained both a second row transition metal and a unique ligand ($SbPh_3$), not known as an exceptional π acid, in an equatorial position. This anomaly was the main impetus for the present study.

The new and known complexes synthesized and characterized here were all of the type $M(CO)_4L$ (M=Fe, Ru, Os; L=group 15 ligand). This has allowed a systematic study of the influence of the central metal, the group 15 donor atom, and the ligand substituents on the site preference. Axial-equatorial isomerism was observed for a number of these complexes. The solution and solid state CO stretching frequencies and the crystal structures are all consistent with the tendency to give the equatorial isomer as Sb>As>P, Ph>Me, $P(OCH_2)_3CMe>PPh_3,PMe_3$ and Ru>Os>>Fe. The switchover to the equatorial form in the solid state occurred between $Ru(CO)_4AsPh_3$ and $Ru(CO)_4SbPh_3$, and $Ru(CO)_4SbMe_3$ and $Ru(CO)_4SbPh_3$. The osmium analogues displayed similar behaviour.

Group 15 ligands with the same substituents are similar in size[68] and in their π bonding properties,[70,71] but their basicity decreases markedly on descending the period.[70,75,76,77,78] The observed site preference trend for the group 15 ligands with the same substituents has, therefore, been rationalized on the basis that weaker σ-donor ligands prefer the equatorial site even in the presence of strong π-acceptors such as CO. The same explanation was used with regard to EMe_3 and EPh_3 ligands since the Me group is known to increase the σ basicity of any ligand to which it is attached. Reasoning based on π bonding is more relevant when applied to the $P(OCH_2)_3CMe$ ligand. The $M(CO)_4P(OCH_2)_3CMe$ (M=Ru, Os) complexes were the only ones with a phosphorus ligand to exhibit a detectable amount of the equatorial isomer in solution. It was noted that the CO stretching frequencies of these complexes were shifted to considerably higher wavenumbers compared to those found for $M(CO)_4PMe_3$. It thus seems reasonable that existence of a small amount of equatorial isomer when the unique ligand was $P(OCH_2)_3CMe$ ligand may be rationalized in terms of the good π bonding ability of that ligand. However, it should be remembered that this phosphite ligand is also expected to be a weak σ-donor.

The influence of the central metal on the ligand site preference is certainly one of the most interesting and unexpected findings of this study. Unfortunately, it has been difficult to account for the observation in terms of σ bonding, variation in valence orbital energies, or any other possible explanation. Arguments based on π bonding can be made in view of the lability of CO ligands attached to Ru and the CO stretching frequencies of Ru-CO>Os-CO>Fe-CO. But this rationalization is weak at best because it does not predict a different change in the nature of the M-CO bond as compared to the M-ER_3 bond.

Steric factors have been discussed and ruled out as a major contribution for the complexes studied here. They are probably important in other cases where the steric requirement of the unique ligand is extreme, e.g. in $Fe(CO)_4P\{N(SiMe_3)_2\}\{C(SiMe_3)_2\}$[32] and $Fe(CO)_4P_2(2,4,6,t\text{-}Bu_3C_6H_2)_2$.[26]

The ^{13}C NMR spectra displayed only one signal for each compound studied. This is indicative of rapid axial-equatorial exchange and rapid equilibrium between the isomers. The Berry psuedoratation mechanism accounts for both observations. Low temperature studies indicated the barrier to rearrangement is low.

3.5 Future Directions

It is felt that the insight into the factors determining site perference in TBP derivatives of d^8 transition metals has been considerably enhanced by this study. However the nature of the influence of the central metal is still poorly understood. Structural characterization of $Ru(CO)_5$ and/or $Os(CO)_5$ would allow detailed MO calculations to be carried out on these molecules. This might point out interesting differences between their electronic structures which could help account for the changes in molecular geometry that occur when Ru or Os is substituted for Fe in the $M(CO)_4L$ complexes studied here.

Another approach would be to investigate whether the metals of other triads influence the geometry of ML_4L' complexes in a similar way. Numerous complexes of the type $Co(CO)_4XR_3$ (X=group 14 atom; R=alkyl, aryl, H) are known. However, the rhodium and iridium analogues are unknown. Synthesis and characterization of such complexes might prove extremely interesting because axial-equatorial exchange in $Co(CO)_4EX_3$ complexes can be slowed down on the ^{13}C NMR time-scale.[14]

CHAPTER 4

EXPERIMENTAL PROCEDURES

4.1 Materials and Instrumentation

Unless otherwise stated, manipulations of starting materials and products were carried out under a nitrogen atmosphere with use of standard Schlenk techniques. Reactions under moderate CO pressure were carried out in a 200-mL general-purpose bomb from Parr Instrument Co. Hexane was refluxed over potassium and THF over potassium benzophenone ketyl; both were distilled and stored under nitrogen before use. The pentacarbonyls of ruthenium and osmium were prepared by literature methods;[46] $Fe(CO)_5$ was commercially available. The group 15 ligand, $P(OCH_2)_3CMe$, was synthesized by the method of Heitsch and Verkade[92] by Mr. R. F. Alex; it was sublimed before use. Other ligands were commercially available. The iron complexes $Fe(CO)_4L$ were prepared by literature[34] methods or minor variations thereof. The method previously used to prepare $Ru(CO)_4P(OMe)_3$ from $Ru_3(CO)_{12}$ was used for $Ru(CO)_4PMe_3$.[41]

Infrared spectra were obtained with a Perkin-Elmer 983 spectrophotometer; NMR spectra with a Bruker 400-MHz instrument and mass spectra with a Hewlett Packard 5985 GC-MS system with an ionization voltage of 70eV. Microanalysis were performed by Mr. M. K. Yang of the Microanalytical Laboratory of Simon Fraser University. Analytical and mass spectral data for new compounds are given in Table A.4.1; infrared, ^{13}C NMR and melting point data in Table A.2.5. Yields were calculated by comparing the weight of product (pure by infrared spectroscopy) to that expected for 100% yield.

Solutions of $Ru(CO)_5$ and $Os(CO)_5$ were handled with extreme caution in view of the well known toxic properties of $Fe(CO)_5$. The ligands PMe_3 and $SbMe_3$ were handled in the inert atmosphere of a dry box since they ignite spontaneously in air.

Because of the nature of the preparations of $Ru(CO)_5$ and $Os(CO)_5$, the concentrations of the hexane solutions of these compounds could only be determined approximately. For most preparations described below the concentration of $Ru(CO)_5$ in hexane was $\simeq 2\times10^{-3}$M, for $Os(CO)_5$ it was $\simeq 7\times10^{-3}$ M. Typical reactions using these starting materials involved 25mL of solution.

4.2 <u>Synthesis Methods</u>

4.2.1 Preparation of $Ru(CO)_4P(OCH_2)_3CMe$

A solution of $Ru(CO)_5$ and a slight excess of $P(OCH_2)_3CMe$ was stirred in the dark at room temperature for 18 h during which time a pale yellow precipitate formed. The mother liquor was then removed and the precipitate washed with hexane (3x5mL). The precipitate was recrystallized from a large volume of hexane to give the product as pale yellow needles. The yield was 43%.

Table A.4.1. Analytical and Mass Spectral Data for New $M(CO)_4L$ Derivatives.

Compound	%Calcd.		%Found		Mass Spectrum[a]
	C	H	C	H	
$Ru(CO)_4P(OCH_2)_3CMe$	29.92	2.51	29.95	2.50	362 (P^+)
$Ru(CO)_4PMe_3$	29.07	3.14	29.01	3.16	290 (P^+)
$Ru(CO)_4AsPh_3$	50.89	2.91	50.92	2.89	dec.
$Ru(CO)_4SbMe_3$	22.13	2.39	22.19	2.19	382 (P^+)
$Os(CO)_4P(OCH_2)_3CMe$	24.15	2.01	23.99	1.90	452 (P^+)
$Os(CO)_4PMe_3$	22.22	2.40	22.25	2.40	380 (P^+)
$Os(CO)_4AsPh_3$	43.43	2.48	43.51	2.57	610 (P^+)
$Os(CO)_4SbMe_3$	17.91	1.92	17.89	1.93	470 (P^+)
$Os(CO)_4SbPh_3$	40.32	2.31	40.43	2.58	656 (P^+)

[a] Most intense peak of parent ion envelope; in all cases the parent ion agreed with that simulated by computer.

4.2.2 Preparation of $Ru(CO)_4EPh_3$ (E=P,As,Sb)

A hexane solution of $Ru(CO)_5$ with an approximate two-fold molar excess of the ligand was stirred under CO pressure (25 atm) at room temperature for 18 h. After this period the gas was released and the solvent removed on the vacuum line to leave a yellow-orange powder. Recrystallization of the powder twice from hexane gave the pure $Ru(CO)_4EPh_3$ product. The yield was 41% for $Ru(CO)_4AsPh_3$ and 39% for $Ru(CO)_4SbPh_3$. The arsenic derivative was thermally unstable and slowly decomposed when stored at room temperature. Preparation of $Ru(CO)_4PPh_3$ from $Ru(CO)_5$ and PPh_3 has been reported previously.[43]

4.2.3 Preparation of $Ru(CO)_4SbMe_3$

A solution of $Ru(CO)_5$ in hexane was placed in a Carius tube. The tube was cooled to -196 °C and evacuated; the solution was degassed with one freeze-thaw cycle. With the vessel at room temperature an approximately equimolar quantity of $SbMe_3$ was added and the tube pressurized with CO (2 atm). The solution was then stirred in the dark at room temperature for 5 h. After this period the gases were released, the solution transferred to a Schlenk tube and evaporated to dryness at 0 °C. The pure, pale yellow product was obtained by sublimation (static atmosphere, <0.02 mm) to a cold-water probe. The yield was 41%.

4.2.4 Preparation of $Os(CO)_4PMe_3$

METHOD 1. The compound was prepared in excellent yield by the reaction of equimolar quantities of PMe_3 and $Os(CO)_5$ in hexane at 120 °C under CO pressure (40 atm) for 16 h. The white compound was purified by sublimation at 35 °C, <0.02mm, to a probe at -78 °C.

METHOD 2. This derivative was also prepared (in excellent yield) by heating $Os_3(CO)_{12}$ and PMe_3 (1:3 molar ratio) in hexane at 280 °C under CO (200 atm) for 48 h. The compound was isolated as in Method 1. (This reaction was first carried out by Dr. P. Rushman.)

4.2.5 Preparation of $Os(CO)_4SbMe_3$

Approximately equimolar quantities of $Os(CO)_5$ and $SbMe_3$ in hexane solution were heated at 80 °C under CO (33 atm) for 16 h. After the reaction vessel had been cooled and the CO released, the solution was transferred to a Schlenk tube and evaporated to dryness on the vacuum line. The pure, pale yellow $Os(CO)_4SbMe_3$ (11% yield) was isolated by sublimation from the residue onto a cold water probe at static vacuum (<0.02 mm).

4.2.6 Preparation of $Os(CO)_4EPh_3$ (E=As, Sb)

Approximately equimolar quantities of $Os(CO)_5$ and EPh_3 in hexane were heated at 90 °C under CO (25 atm). The resulting solution was evacuated to dryness. This procedure removed unreacted $Os(CO)_5$ as well as solvent. The remaining solid was dissolved in a minimum of hexane and chromatographed on a silica gel column (20 x 2.5 cm), with an eluent of hexane:THF (11:1). (Although occasional exposure of the solutions to air appeared not to affect the chromatography, the other conditions were found to be critical to the successful isolation of the desired product.) During the chromatography three bands formed, the first two were yellow, and the third very pale yellow to almost colourless. The first and third bands, $Os_3(CO)_{12}$ and $Os_3(CO)_{11}EPh_3$ respectively, were discarded. The second band was the product, $Os(CO)_4EPh_3$, which was recrystallized from hexane to give pale yellow crystals . The yield was 15% for $Os(CO)SbPh_3$ and 7% for $Os(CO)AsPh_3$. The triphenylphosphine analogue, $Os(CO)_4PPh_3$, was prepared similarly, in much better yield.[43]

4.3 Crystal Structure Determinations

4.3.1 $Ru(CO)_4AsPh_3$ and $Os(CO)_4SbPh_3$

Details are given here for the crystallographic analysis of $Ru(CO)_4AsPh_3$ with the differences for $Os(CO)_4SbPh_3$ noted in parentheses.

Pale yellow, plate-like crystals suitable for X-ray analysis were grown from hexane. Oscillation, Weissenberg and precession photographs were taken with Cu K radiation. These indicated the space group to be $P\bar{1}$ or $P1$ and gave approximate cell dimensions. The space group was subsequently determined to be $P\bar{1}$ by the structure solution. Accurate cell dimensions were determined by a least-squares refinement of 24 (22) reflections in the range $2\theta=16.2-25.4°$ (30.9-42.4°) on a Picker FACS-I four circle automated diffractometer which employed graphite monochromated Mo K_α radiation, $\lambda=0.71069$ Å.

Details of the data collection are given in Table A.4.2, other crystallographic data in Table A.4.3. The data were collected at 20±1 °C. Stationary-crystal stationary-counter background counts for 10% of the scan time were taken at each side of the scan. Peak-profile analysis was performed on all reflections to derive the intensity, I, and the associated error, $\sigma(I)$.[93] Two standards were measured after every 70

Table A.4.2. Diffractometer Collection and Refinement Parameters for $M(CO)_4L$ Compounds.

	$Ru(CO)_4AsPh_3$	$Os(CO)_4SbPh_3$	$Ru(CO)_4SbMe_3$
scan method	ω-2θ	ω-2θ	ω-2θ
scan range, 2θ, deg	3.5-40.0	3.5-40.0	3.0-50.0
scan width, 2θ, deg	1.40	1.20	1.30
scan rate, 2θ, deg/min	2	3	1.3-6.6
collection range	±h, +k, ±l	±h, +k, ±l	±h, +k, +l
transmission coefficient range	0.594-0.932	0.365-0.644	0.913-1.000[a]
unique reflections	2018	3754	582
observed reflections ($I>2.3\sigma$)	1650	3115	523
variables	253	298	39
R_1[b]	0.0203	0.0192	0.0233
R_2[c]	0.0213	0.0205	0.0295
gof	1.0463	1.3989	0.9806
largest shift[d]	0.15	0.36	0.00

[a] Empirical absorption correction, see text.

[b] $R_1=\Sigma||F_o|-|F_c||/\Sigma|F_o|$

[c] $R_2=[\Sigma\omega(|F_o|-|F_c|)^2/\Sigma\omega|F_o|^2]^{1/2}$

[d] Largest shift/error in the final cycle of refinement.

reflections; they gave no indication of decomposition. The data were corrected for Lorentz and polarization effects and an analytical absorption correction[94] was also applied.

The structures were solved by Patterson and Fourier methods. All non-hydrogen atoms were located from successive electron density difference maps. The final refinement was by block-diagonal least-squares methods with anisotropic parameters for all non-hydrogen atoms. Hydrogen atoms were included at calculated (or previously refined) positions. Unit weights were used throughout for both structures. There were no significant trends in the average $\Sigma\omega||F_o|-|F_c||^2$ as a function of $|F_o|$ and $\sin\theta/\lambda$ in the final error analysis. Atomic scattering factors including anomalous dispersion for non-hydrogen atoms were taken from reference 95.[95] ORTEP views, with 50% thermal ellipsoids, of $Ru(CO)_4AsPh_3$ and $Os(CO)_4SbPh_3$ are given in Figures A.2.1 and A.2.3 respectively; these also give the labelling scheme employed for each molecule. Final coordinates for all atoms of both molecules, anisotropic thermal parameters for the non-hydrogen atoms, thermal parameters for the hydrogen atoms and structure factors are listed in the appendix. Selected bond lengths and angles for $Ru(CO)_4AsPh_3$ are given in Table A.2.1; for $Os(CO)_4SbPh_3$ in Table A.2.3. The computer programs used were those developed by Larson and Gabe.[96]

4.3.2 $Os(CO)_4AsPh_3$

Space group and approximate cell dimensions were determined as for $Ru(CO)_4AsPh_3$. Accurate cell dimensions were obtained in a manner similar to that used for $Ru(CO)_4SbMe_3$; the 2θ scan range was 16.2-25.4° for 25 accurately centred reflections. The standard deviations of the cell dimensions were slightly higher than desirable for data collection; an examination of the peak profiles also indicated the crystal was not of sufficiently high quality for a structure determination. Cell dimensions (see Table A.4.3) and the space group revealed the compound is isostructural with $Ru(CO)_4AsPh_3$.

4.3.3 $Ru(CO)_4SbMe_3$

Pale yellow crystals suitable for X-ray analysis were obtained by slow sublimation in a sealed, evacuated tube. Weisenberg photographs (Cu, λ=1.5418 Å) were used to assign the space group as R3 or R$\bar{3}$. The compound was then assumed to be isostructural with $Fe(CO)_4SbMe_3$[33] (space group R3) and the cell dimensions of this compound were used as a first approximation for the ruthenium analogue. Accurate cell dimensions were determined by least-squares refinement of 25 accurately centred reflections (2θ=20-25°, Mo $K_{\alpha 1}$ λ=0.7093 Å). Crystal data are given in Table A.4.2. Diffraction data were collected at 20±1 °C. on an Enraf-Nonius CAD4-F diffractometer using a graphite monochromator. Background measurements were made by extending the scan range by 25% at each side of the scan. Measurement of two standard reflections every hour showed no significant

Table A.4.3. Crystallographic Data for $Ru(CO)_4AsPh_3$, $Os(CO)_4SbPh_3$, $Ru(CO)_4SbMe_3$ and $Os(CO)_4AsPh_3$.

	$Ru(CO)_4AsPh_3$	$Os(CO)_4SbPh_3$	$Ru(CO)_4SbMe_3$	$Os(CO)_4AsPh_3$
formula wt.	519.4	655.3	380.0	608.4
space group	$P\bar{1}$	$P\bar{1}$	R3	$P\bar{1}$
crystal system	triclinic	triclinic	hexagonal	triclinic
a, Å	10.605(3)	11.123(2)	10.378(1)	10.633(6)
b, Å	11.068(4)	11.284(4)	-	11.029(7)
c, Å	9.979(3)	12.714(4)	9.632(1)	9.979(6)
α, deg	113.57(3)	129.29(2)	90	113.43(5)
β, deg	93.14(3)	102.35(2)		93.24(5)
γ, deg	91.47(3)	102.45(2)	120	91.60(5)
Volume, $Å^3$	1070.6	1068.5	898.3	1070.3
Z	2	2	3	2
d_{calcd}, g/cm^3	1.611	2.037	2.057	
d_{found}, g/cm^3	1.50	1.99	2.10	
μ (Mo K_α), cm^{-1}	22.70	71.81	33.99	
crystal size, mm	0.24x0.22x0.030	0.076x0.11x0.22	0.61x0.37x0.14	

crystal decay, instability in the detection chain or variation in generator output. Lorentz polarization and a semi-empirical absorption[97] corrections were applied.

The non-hydrogen positional parameters from $Fe(CO)_4SbMe_3$[33] were employed as the initial model. Refinement proceeded quickly by full matrix least-squares methods with anisotropic temperature factors used in the final cycles. Hydrogen atoms were not included in the calculations. When inverse coordinates were employed the residual R_1 dropped from 0.0248 to 0.0233 therefore they were used for subsequent refinement. The weighting scheme $\omega=[\sigma^2(F)+0.0006F^2]^{-1}$ was shown to be correct on the basis of trends in $\omega\Delta^2$ as a function of $|F_o|$ and $\sin\theta/\lambda$. The 1,-1,0 reflection was omitted from the refinement because it was judged to suffer from extinction (final $KF_o=229.43$, $F_c=260.88$). Details of the data collection and final refinement parameters are given in Table A.4.2. Atomic scattering factors which included anomalous dispersion were taken from reference 95. An ORTEP view, with the atomic labelling scheme, of $Ru(CO)_4SbMe_3$ is shown in Figure A.2.2. Selected bond lengths and angles are given in Table A.2.2. Final atomic coordinates, anisotropic thermal parameters and structure factor listings are listed in the appendix. The computer programs in this determination were from, "The Vax 750/780 Crystal Structure System".[98]

PART B

SYNTHESIS, STRUCTURE AND CHARACTERIZATION OF $Os_4(CO)_nPMe_3$ (n=15, 14, 13) AND $(\mu\text{-}H)_2Os_4(CO)_{13}PMe_3$

CHAPTER 1

INTRODUCTION

1.1 Theoretical Approaches

Chemists remain interested in transition metal clusters even though previously hoped for industrial catalytic applications have been slow in coming. The continued fascination stems from the large number of bonding modes, structures, fluxional processes and reactivities that clusters exhibit which present a challenge to both the theoretician and the experimentalist. The group 8 metals have proven a particularly fruitful area of study; over a thousand clusters are known with nuclearities ranging from three to ten[99] and geometries from chains[100] to very compact deltahedra.[101] Of special interest to this study are Group 8 tetranuclear clusters; these exhibit spiked triangle,[102] tetrahedral,[103], butterfly,[104] planar rhomboidal[105] and other[101,106] geometries, see Figure B.1.1.

Several different approaches are used to rationalize or predict these structural variations but the discussion here will be limited to those most frequently encountered: the Effective Atomic Number (EAN) or 18-Electron Rule, Polyhedral Skeletal Electron Pair Theory (PSEPT), the isolobal analogy and some specific molecular orbital treatments. The first of these, the well known[70,107] EAN or 18-Electron Rule is often used to explain the structures of mono-, di- and trinuclear transition

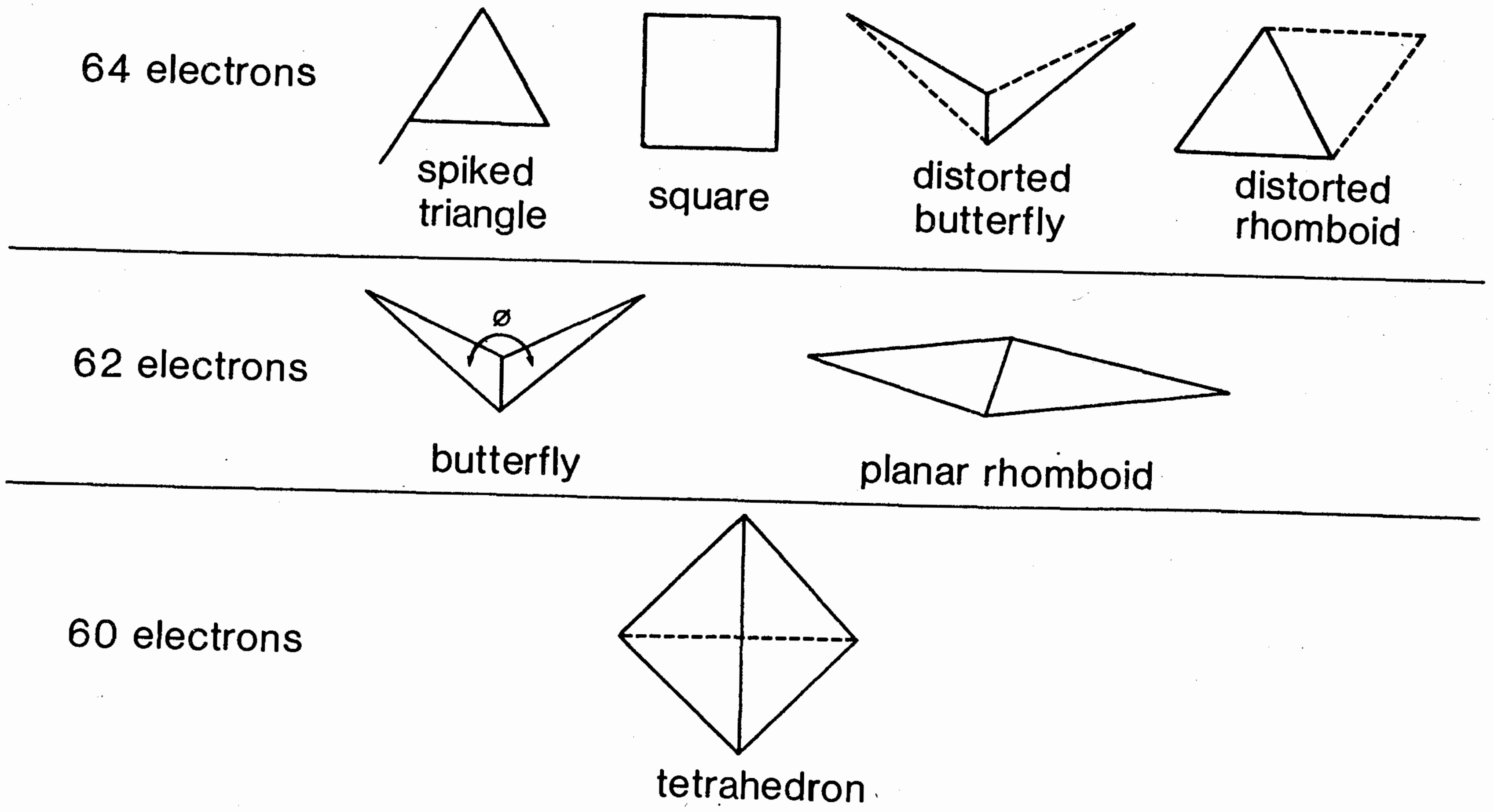


Figure B.1.1. Geometries of Tetranuclear Group 8 Clusters.

metal complexes containing π-acceptor ligands. According to this approach valence electrons are assigned to the metal atoms, each of which is considered separately. Since a transition metal atom has nine valence orbitals, a stable structure is predicted only if a total of 18 electrons can be assigned to <u>each</u> metal atom. If there are not enough electrons available from the metal atom d orbitals and from the ligands then metal-metal bonding occurs. These bonds usually contribute one electron to each metal atom involved. For tetranuclear complexes the predicted number of cluster metal-metal bonds is given by the formula: nb=(72-ne)/2, where nb is the number of metal-metal bonds and ne is the number of electrons assignable to the complex from the ligands, charge and metal valence electrons. Thus a 64 electron tetranuclear complex is expected to have four metal-metal bonds and a square or spiked triangle geometry. The predicted number of bonds (and shapes) for 62 and 60 electron complexes are five (butterfly) and six (tetrahedron) respectively.

Churchill and Hollander used the 18-Electron Rule to explain the geometry of $HOs_3Re(CO)_{15}$, which has a planar rhomboidal structure.[108] The two $Os(CO)_4$ moieties were viewed as 16 electron fragments needing two metal-metal bonds each and they thus bridge the $HOs(CO)_3$ and $Re(CO)_4$ fragments. The latter two fragments are 15 electron species needing three metal-metal bonds and hence the extra bond between them (see Figure B.1.2). The total number of valence electrons associated with the cluster is 62.

Adams and co-workers also used the 18-Electron Rule in their discussion of the tetrahedral molecule $Os_4(CO)_{12}(\mu_3\text{-}S)$.[109] Each $Os(CO)_3$ fragment was seen as having 14 electrons; an additional three are obtained from the three metal-metal bonds in which each osmium atom partakes. The sulphur ligand donates four electrons to the cluster, thus each osmium atom obtains an 18 electron configuration. The total number of electrons is 60 so that a tetrahedral structure is predicted, in agreement with experiment. However, it is difficult to understand on the basis of localized two-center, two-electron bonds how a μ_3-S ligand, capping one face of a tetrahedron can contribute one electron to each of <u>four</u> osmium atoms.

A similar difficulty exists in describing the bonding in $Os_5(CO)_{12}(\mu_3\text{-}S)_2$ which has a butterfly structure. Each osmium atom obtains an eighteen electron configuration only if each μ_3-S ligand contributes three electrons to the cluster. This is in contradiction to the normal description of sulphur as a four electron donor. Adams and Yang view the sulphur ligands as contributing four electrons and refer to the cluster as 'electron rich'.[110] That is, it has 64 electrons but five metal-metal interactions. The authors believe the extra electrons cause weakening (and lengthening) of two of the Os-Os bonds which are consequently very reactive. It is difficult to view these elongated bonds as normal two-center-two-electron bonds.

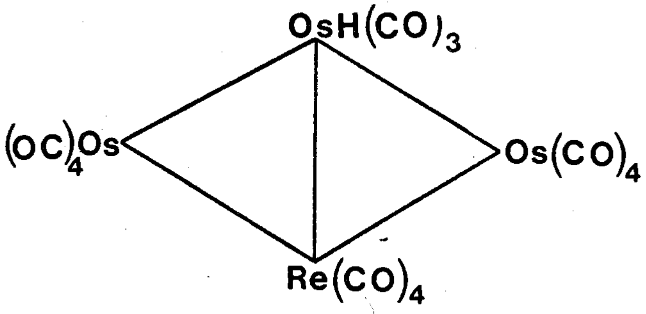


Figure B.1.2. Geometry of $HOs_3Re(CO)_{15}$.

A large number of cluster compounds, particularly those of high nuclearity, cannot be adequately described using only the 18-Electron Rule and simple two-center-two-electron bonds. The tetrahedral cluster $H_4Re_4(CO)_{12}$ is electron deficient and is more appropriately described as having four, four-center Re_3H bonds.[111] Each of the clusters, $Rh_6(CO)_{16}$, $[Co_6(CO)_{14}]^{4-}$, and $H_2Ru_6(CO)_{18}$ has two electrons too many to be accomodated by twelve two-center-two-electron bonds is its octahedral core.[112] A more suitable approach for these and other clusters is based on molecular orbital calculations which can be applied to transition metal clusters in a simplified version, namely the Polyhedral Skeletal Electron Pair Theory (PSEPT).

This theory was developed and applied to transition metal clusters almost simultaneously by Wade[113] and by Mingos.[114] According to these early versions of PSEPT each metal contributes three atomic orbitals to the bonding molecular orbitals of the cluster. A cluster containing n metal atoms therefore has 3n atomic orbitals from which the cluster molecular orbitals can be formed. It is considered that one orbital from each vertex atom, that is n orbitals, point toward the center of the cluster to form one strongly bonding and n-1 non-bonding or antibonding molecular orbitals. The remaining 2n orbitals are dispersed radially and combine to form n bonding and n antibonding orbitals. The result is n+1 bonding molecular orbitals.

The number of electrons donated by a vertex varies with the metal and number and type of ligands. For group 8 metals, $M(CO)_3$ vertices contribute two electrons and $M(CO)_4$ vertices, four electrons. Bridging carbonyl ligands contribute two electrons and bridging or terminal hydrides one electron to cluster bonding. PSEPT predicts that when n+1 electron pairs are available to fill the n+1 bonding orbitals a stable compact deltahedron with n vertices i.e., a 'closo' structure, results. If n+2 electron pairs are present the appropriate deltahedron has n+1 vertices, one of which is unoccupied. This results in a more open structure, designated 'nido' which has one vertex missing. Thus an M_5 cluster with 7 electron pairs such as $Fe_5(CO)_{15}C$ is expected to, and does, adopt a square pyramidal geometry, i.e., an octahedron with one vertex missing.[115] This may be compared to $Os_5(CO)_{16}$ which has 6 electron pairs (n+1) and a trigonal bipyramid (closo) geometry.[116] Complexes with n+3 electron pairs exhibit even more open 'arachno' geometries which are based on deltahedra with two vertices missing. For example, in $H_3Os_4(CO)_{12}I$ which has seven electron pairs, the osmium atoms display a butterfly arrangement which is considered as an octahedron with two cis vertices missing.[117] A rarely used extension of this theory designates complexes with n+4 electron pairs as 'hypho' structures; deltahedra with three vertices missing.

Despite the advantage of PSEPT that it shifts the focus of attention from the individual metal atoms to the cluster as a whole, application of the theory to tetranuclear clusters is problematic. The view that the tetrahedral geometries of $[H_3Ru_4(CO)_{12}]^-$,[118] $H_2FeRu_2Os(CO)_{13}$,[119] and $Os_4(\mu_3\text{-NCH})(CO)_{12}$,[120] (for example), which have six skeletal electron pairs apiece, are trigonal bipyramids with one vertex missing has been described as 'artifical'.[121] Certainly the idea that spiked triangles such as $H_2Os_4(CO)_{15}$ or $H_3Os_4Br(CO)_{13}$[102] which contain 8 skeletal pairs are hypho pentagonal bipyramids, is of little use. Mingos attempted to deal with part of the problem by defining an 'electron precise' cluster as one having the same number of bonding pairs as M-M vectors. This definition was then applied to tetrahedral clusters with six electron pairs.[114] Confusion is still evident, however, in that he later referred to such clusters as 'closo' structures.[122]

Another weakness of this theory is the rule that each metal atom makes available three atomic orbitals for cluster bonding regardless of the number of terminal ligands bonded to it. Later calculations have shown that, in many cases, an $Os(CO)_4$ fragment contributes only two orbitals to cluster bonding.[122]

Recent modifications of PSEPT have made some attempt to deal with these issues. Johnson and Benfield,[107] for example, suggested that an $M(CO)_4$ (M=Fe, Ru, Os) fragment contributes two electrons and two atomic orbitals to cluster bonding. This concept is intuitively satisfying where the $Os(CO)_4$ fragment is found in an edge bridging position as in $H_2Os_5(CO)_{16}$,[123] but less so where the $Os(CO)_4$ fragment is more highly coordinated. For example, $Os_5(CO)_{16}$, which was cited in the paper, has an $Os(CO)_4$ fragment with a total connectivity of eight, but this was not discussed at all.

A far more comprehensive discussion is that of Evans and Mingos.[122] Their paper on the extension of PSEPT to nonconical fragments decribed the application of extended Hückel molecular orbital (EHMO) calculations to carbonyl clusters containing $Os(CO)_4$ and T-shaped $Os(CO)_3$ vertices. Specific calculations were performed for several tetranuclear configurations that bear a close relationship to those studied here. The authors showed that the isoelectronic C_{2v} $[Os(CO)_4]^{2+}$ and T-shaped $Os(CO)_3$ fragments are also isolobal, i.e., they have frontier orbitals of similar, but not identical, energy and shape. The $Os(CO)_4$ fragment is similar to the $[Os(CO)_4]^{2+}$ fragment but has two more electrons. The frontier orbitals a_1 and b_2, hybrid s-z and hybrid xy respectively, are illustrated in Figure B.1.3., which shows that the order of the orbitals differs for the two fragments. The nature of the frontier orbitals also differs in that the b_2 orbital in $Os(CO)_3$ is calculated to be 17% metal in character while in $Os(CO)_4$ it is 53%. This led the authors to predict that T-shaped $Os(CO)_3$ fragments are "likely to be less effective in cluster bonding" and also "distorted from planar geometry in order that the overlap with the a_1 orbital be maximized". On the other hand, the $Os(CO)_4$ fragments were calculated to have the correct symmetry and bonding characteristics to form planar systems. As an illustration, the authors performed calculations on the hypothetical planar cluster, $[Os_4(CO)_{16}]^{2+}$ while the planar structures, $HOs_3Re(CO)_{15}$ and $[Re_4(CO)_{16}]^{2-}$ were cited as known examples. Taken together these two concepts mean that 62 electron clusters with $M(CO)_3$ groups at the hinges are more likely to be butterflies while those with $M(CO)_4$ groups may be planar. It should also be noted that a cluster containing an excess of electrons for a closo polyhedron and having an $M(CO)_4$ vertex is more likey to adopt an edge-bridged rather than a nido or arachno structure, as in $H_2Os_5(CO)_{16}$, cited above.

The authors considered polyhedra wherein the electron count for a closo structure was not exceeded and were led to several conclusions. First, $Os(CO)_4$ fragments are likely to maintain their C_{2v} symmetry since deformation to C_{4v} is calculated to require 2.6eV. Second, the a_1 orbital of the $M(CO)_4$ is only 28% localized on the metal meaning it is largely CO π^* in character.

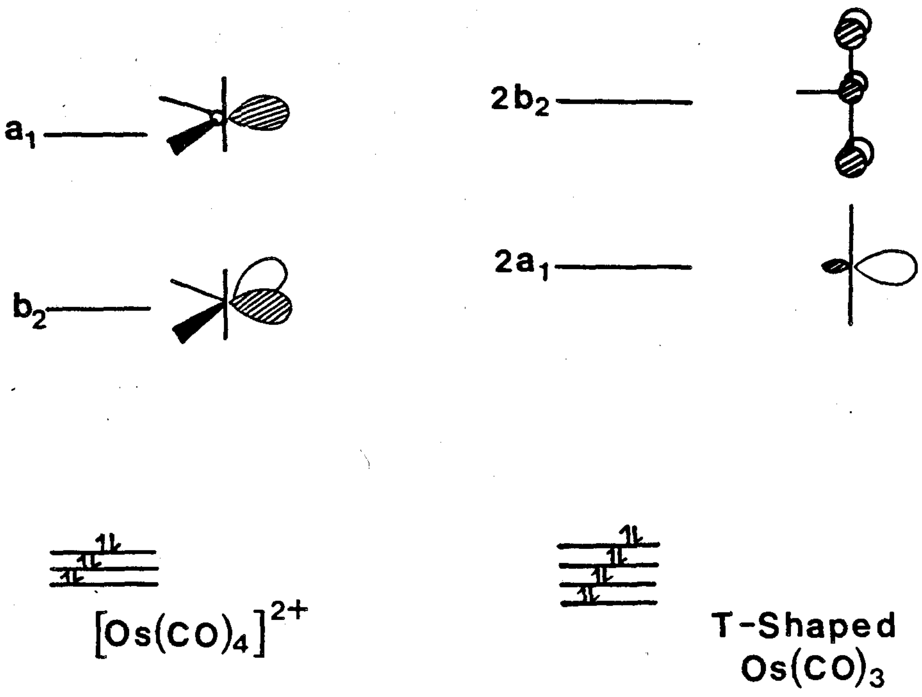
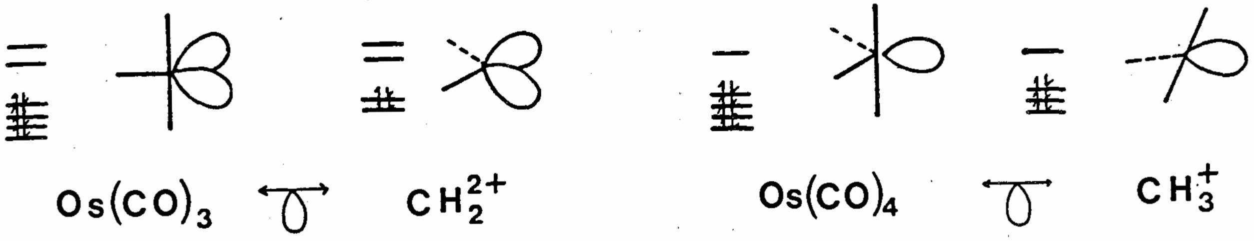


Figure B.1.3. Frontier Orbitals for $[M(CO)_4]^{2+}$ and $M(CO)_3$. (After Evans and Mingos.[122])

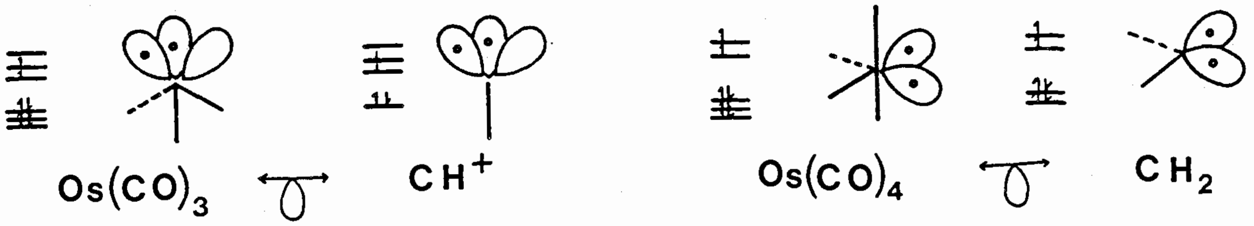
In order to make up for a deficiency of electron density, the carbonyl ligands were predicted to take part in semi-bridging interactions with other metal atoms. Specific overlap population calculations for a tetrahedral cluster with one $Os(CO)_4$ group gave 0.23 and 0.25 for M'-C overlap, depending on the conformer. Finally the authors predicted that even with additional metal-metal bonding arising from weak interaction of the cluster with the $M(CO)_4$ b_1 orbital, an $M(CO)_4$ fragment will be less effective in a nonplanar cluster enviroment than a conical $M(CO)_3$ fragment. That being the case, bonds involving $Os(CO)_4$ fragments are expected to be longer than those involving only conical $Os(CO)_3$ fragments. The authors go so far as to predict that closed polyhedra with more than one $M(CO)_4$ vertex are "unlikely to be stable."

Although PSEPT is widely used to rationalize the structures of many medium-sized clusters, other approaches have also been employed. Hoffmann used EHMO calculations to develop an isolobal analogy betweed transition metal and organic fragments.[124] According to this analogy the number of electrons and orbitals a transition metal fragment has available depends on the coordination number of the transition metal. An $Os(CO)_4$, fragment, for example, can be isolobal to several different organic fragments depending on whether the osmium atom is 5, 6 or 7 coordinate, as in Figure B.1.4. This method has limited predictive powers but it does have flexibility and is therefore useful in rationalizing structures after the fact.

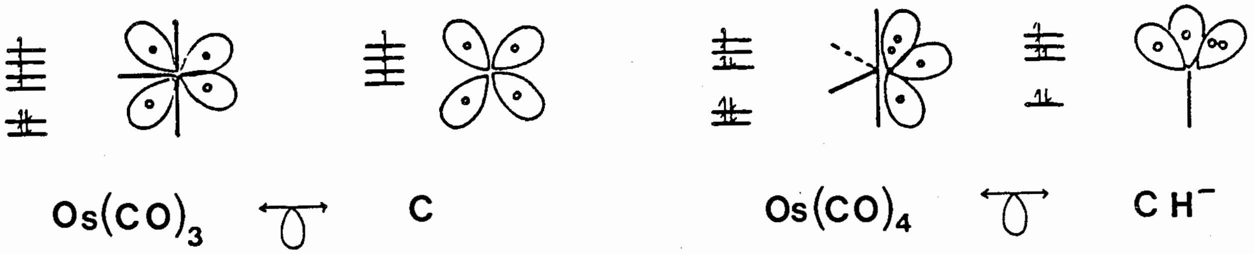
Lauher also used extended Hückel calculations on bare metal clusters to investigate their bonding.[125] The four metal atoms of a tetranuclear cluster contribute nine orbitals each and generate 36 molecular orbitals. According to Lauher, six of these orbitals are antibonding in molecules of T_d symmetry, thus 30 orbitals are bonding and 60 valence electrons are necessary for a stable structure to be formed. Changing the symmetry to C_{2v} (butterfly geometry) results in one antibonding orbital being lowered in energy so that 62 cluster valence electrons are necessary. Square (D_{4h}) symmetry is shown to require 64 electrons. No calculations were performed for a spiked triangle. While these conclusions are consistent with those of



5 coordinate



6 coordinate



7 coordinate

Figure B.1.4.The Isolobal Analogy as Applied to $Os(CO)_4$ and $Os(CO)_3$ Fragments. The '$\overset{\longleftrightarrow}{\text{O}}$' character means 'is isolobal with'. (After Hoffmann.[124])

PSEPT and the 18-Electron Rule, it can be seen that this method cannot take into account any possible localized or unequal metal-metal bonds.

In an alternative scheme relating the electron count to structure, Teo emphasized the number of vertices, faces and 'missing' antibonding orbitals a cluster possesses.[126,127] The conclusions drawn regarding tetranuclear clusters are similar to those described above i.e., a four vertex, four face cluster (tetrahedron) needs 60 cluster electrons, and reduction of the number of faces (i.e., changing to butterfly or planar geometry) requires additional electrons. Like Lauher, Teo was concerned only with the total number of valence electrons of a cluster and not with the influence the ligands attached to a particular vertex have on localized bonding. Nor did he make any attempt to account for the variation in the structures of 62 or 64 electron species.

As can be seen there are several different approaches to understanding the structure and bonding in tetranuclear clusters, all of which give similar predictions. That is, tetranuclear clusters containing 60 valence electrons should be tetrahedra, while those containing 62 electrons should be butterflies or planar rhomboidal structures. To our knowledge no author has dealt extensively with 64 electron clusters, but it is accepted that only four metal-metal interactions are expected for these species.[125] That these general predictions are valid can be seen from the examples cited in Tables B.1.1, B.1.2 and B.1.3. The most notable exceptions are 64 electron clusters which can be not only squares and spiked triangles, but distorted butterflies as well. There are also a few examples in the literature of 60 electron butterflies such as $[Fe_4(CO)_{12}CCO_2Me]^-$ [128] and $Os_4(CO)_{12}(C_2H_2)$[129] but they are not relevant to this study.

Table B.1.1. Group 8 Tetrahedral Clusters with 60 Valence Electrons.

Compound	Comments	Ref.
$[Fe_4(CO)_{13}]^{2-}$	has one μ_3-CO ligand and three three weakly semi-bridging CO's	103
$H_2FeRu_3(CO)_{13}$	three terminal CO's on each Ru, two terminal CO's on Fe, two asymmetric CO bridges on Fe-Ru bonds	130
$[FeRu_3(CO)_{12}NO]^-$	NO is terminal on Fe, three CO's are μ_2	131
$H_2FeRu_2Os(CO)_{13}$ $H_2FeRuOs_2(CO)_{13}$	isomeric forms in solution, NMR evidence that metal framework undergoes minor reorganization in solution at temperatures above -45 °C	119
$[HFeOs_3(CO)_{13}]^-$	two CO's bridge Fe and Os bonds, H bridges Os-Os bond	132
$H_2FeOs_3(CO)_{13}$	two bridging CO's on Fe-Os bonds	132
$H_2Ru_4(CO)_{13}$	H's probably bridge long Ru-Ru bonds	133
$[H_3Ru_4(CO)_{12}]^-$	two isomers in solid state, rapid isomerism of H positions in solution	118, 134
$[H_2Ru_4(CO)_{12}]^{2-}$	NMR evidence for CO bridges at $\simeq$-80 °C	135
$H_4Ru_4(CO)_{12}$	H's probably bridge long Ru-Ru bonds	136
$H_4Ru_4(CO)_{10}PPh_3$	long Ru-Ru bonds bridged by H's	137
$[HOs_4(CO)_{13}]^-$	has a bridging CO which is rare for Os clusters	138
$[H_2Os_4(CO)_{12}I]^-$	I is terminal	139

$H_3Os_4(CO)_{11}NO$	NO is terminal, long Os-Os bonds and displacement of CO groups indicate position of bridging H's	140
$HOs_4AuPEt_3(CO)_{13}$	one bridging CO, $AuPEt_3$ group is μ_2	141
$H_3Os_4AuPEt_3(CO)_{13}$	no bridging CO, $AuPEt_3$ group is μ_2	141
$Os_4NCH_3(CO)_{13}$	NCH_3 caps one face and is 4 e donor	120
$H_3Os_4(CO)_{11}C_6H_9$	cyclohexene ring σ-bonded to one Os and π-bonded to another	142
$H_3Os_4(CO)_{11}CHCHPh$	H's located by neutron diffraction, one H bridges short Os-Os bond	143
$H_4Os_4(CO)_{11}P(OMe)_3$	the H's bridge long Os-Os bonds	144
$H_4Os_4(CO)_{11}NCMe$	as for $H_4Os_4(CO)_{11}P(OMe)_3$	145
$H_2Os_4(CO)_{12}CHCH_2Ph$	$CHCH_2Ph$ is μ_2 only, 2 e donor	146

Table B.1.2. Group 8 Butterfly Structures.

Compound	Comments	Ref.
$[HFe_4(CO)_{12}]^-$	one π-CO, H bridges the hinge, ϕ=117°, converts to tetrahedron with all terminal CO's when warmed.	147,148
$[Fe_4C(CO)_{12}]^{2-}$	^{13}C NMR evidence for butterfly structure	149
$[Fe_4N(CO)_{12}]^-$	N is μ_4 to Fe's, Fe-N-Fe unit almost linear, ϕ=78.2°	150
$HFe_4N(CO)_{12}$	N is μ_4 to Fe's, Fe-N-Fe unit almost linear, ϕ=101°	151
$Fe_4N(CO)_{11}NO$	spectroscopic evidence only for butterfly structure	150
$[HFe_4(CO)_{12}C]^-$	C is μ_4, ϕ=104°	152
$HFe_4(CO)_{12}(\eta^2\text{-}COCH_3)$	η^2-$COCH_3$ group is 5 e donor	152
$HFe_4(\eta^2\text{-}CH)(CO)_{12}$	in η^2-CH group the C is μ_4 to all Fe's, the H is μ_2 between C and one Fe, ϕ=110.6°	153
$Fe_4AuPEt_3(CO)_{12}COCH_3$	as for $HFe_4(CO)_{12}(\eta^2\text{-}COCH_3)$	154
$[Fe_4(CO)_{13}A]^-$ A=$AuEt_3$, $AuPh_3$, $HgCH_3$	two isomers as for $[HFe_4(CO)_{13}]^-$, in tetrahedral form A is μ_3 on a face	154,155
$Ru_4(CO)_{13}PPh$	μ_3PPh group bridges both wing tips and one hinge Ru ϕ=111.24°	156
$[Ru_4(CO)_{13}Cl]^-$	Cl bridges wing tips, ϕ=91.0°	157
$H_3Ru_4N(CO)_{11}$	one H bridges hinge, other two H's bridge hinge-wing tips, N is μ_4 to Ru's, ϕ=108.6(108.2)°[b]	158
$HRu_4N(CO)_{12-x}[P(OMe)_3]_x$ x=1,2,3	N is μ_4 to Ru's, ϕ not given[a]	159

$Os_4(CO)_{13}S$	S is μ_3 to one closed triangular face, i.e., no bridge across wing tips or hinge, nearly flat, ϕ=170.0(176.5)°[b]	160
$[Os_4(CO)_{12}N]^-$	isostructural with $[Fe_4(CO)_{12}N]^-$ ϕ=105.4°	158
$H_3Os_4(CO)_{12}I$	I bridges the wing tips, H's located by neutron diffraction, ϕ not given[a]	117
$H_3Os_4(CO)_{12}NO$	NO bridges the wing tips, ϕ not given[a]	159
$[H_3Os_4(CO)_{12}(NCMe)_2]^+$	one H bridges the hinge, no bridge across the wing tips, ϕ=112.2(1)°	104
$H_3Os_4(CO)_{12}OH$	OH is 3 e donor, OH bridges the wing tips, ϕ=92.5°	161
$H_3Os_4(CO)_{12}OPO_3H$	wing tips bridged be OPO_3H, ϕ=92.5(92.2)°[b]	161
$[H_4Os_4(CO)_{12}OH]^+$	hinge not bridged, OH bridges wing tips, ϕ=82.3°	161

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[a] Where the dihedral angle, ϕ, is noted as 'not given' the crystal structure diagram clearly indicated a butterfly structure.

[b] Two molecules in the asymmetric unit.

Table B.1.3. Tetranuclear Group 8 Clusters with 64 Valence Electrons.

Compound	Comment	Ref.
$Fe_4(CO)_{11}(NEt)(ONEt)$	square, NEt is μ_4, ONEt is μ_4	162
$Fe_4(CO)_{12}(PR)_2$ $Fe_4(CO)_{11}P(OMe)_3(PR)_2$ $Fe_4(CO)_{10}(P(OMe)_3)_2(PR)_2$	square, PR ligands are μ_4, first two easily lose CO	106
$FeRu_3(CO)_{13}(PPh_2)_2$	distorted planar rhomboid, all Ru-Ru bonds elongated, pheripheral Ru-Ru bonds bridged by PPh_2 ligands	163
$Ru_4(CO)_{13}(C{\equiv}CBu^t)(PPh)_2$	nearly planar rhomboid, ϕ=176.93°	164
$Ru_4(CO)_8(PPh_2)_2(C{\equiv}CBu^t)_2(PPh_2C{\equiv}CBu^t)$	butterfly, ϕ=167.04°	164
$Ru_4(CO)_{10}(PPh_2)(C{=}CHPr^i)(OH)$	butterfly, ϕ=141.49°	164
$Ru_4(CO)_{10}(OEt)(PPh_2)(C{\equiv}CHPr^i)$	butterfly, ϕ=143.69°	165
$H_2Os_4(CO)_{15}$, $H_3Os_4Br(CO)_{13}$	spiked triangles, all Os-Os bonds normal covalent bonds	102
$Os_4(CO)_{12}(CS)S$	distorted square or butterfly unit not bonded across the hinge, the S is μ_3, it caps one face, CS on other side of the framework	166
$Os_4(CO)_{12}S_2$	butterfly, S ligands are μ_3 and bridge both wing tips and one hinge atom apiece, two weak metal-metal interactions	110
$Os_4(CO)_{12}Se_2$	see comments for $Os_4(CO)_{12}S_2$, can be described as nido pentagonal bipyramid	167

1.2 Project Description

The study here described began as an attempt to synthesize a cluster containing an unsupported, donor-acceptor metal-metal bond. In such a bond one metal is considered as donating two electrons to the other metal in order that both metals achieve an 18-electron count. In most organometallic complexes with metal-metal bonds the bond is considered as a normal covalent bond, i.e., each metal contributes one electron to the bond. Bridged donor-acceptor metal-metal bonds had been proposed several times[168] but alternate electron counting schemes could be applied to many of the examples. Several dimeric compounds synthesized in our laboratory had metal-metal bonds that could be unambiguously assigned as donor-acceptor bonds,[169,170,171] but until this study no cluster containing an unsupported donor-acceptor metal-metal bond had been synthesized. It was thought that the synthesis of cluster compounds with one or more such bonds could provide a systematic route to larger clusters. Rational routes to high nuclearity clusters are known[172] but these are rare; for example, many large osmium clusters are still obtained, in poor yields, by pyrolysis of $Os_3(CO)_{12}$ or its derivatives.[99,173,174] The mechanisms of these building up reactions are still not well understood.

Until the present work, there was no reported fully characterized example of a 64 electron cluster displaying sequential ligand loss to give a 62 and then a 60 electron species.[102,175] Here we report just such a series of compounds in the synthesis and characterization of the three clusters $Os_4(CO)_nPMe_3$ (n=15, 14, 13). The 62 electron butterfly structure $(\mu\text{-}H)_2Os_4(CO)_{13}PMe_3$ has also been synthesized and characterized. All four clusters have gross frameworks in accord with the theories outlined in the previous discussion. However, each has unique and interesting aspects not predicted by theory. The fluxional properties of these molecules were also investigated by variable temperature ^{13}C NMR spectroscopy. For two of the compounds novel exchange mechanisms are proposed. We believe the mechanism put forward for $Os_4(CO)_{14}PMe_3$ has not been previously proposed.

CHAPTER 2

RESULTS AND DISCUSSION

The reaction of $Os_3(CO)_{11}MeCN$ with $Os(CO)_4PMe_3$ proceeded at a convenient rate in hexane at 60 °C to produce $Os_4(CO)_{15}PMe_3$, a brilliant orange compound. Subsequent structural studies revealed it to be a spiked triangle in which $Os(CO)_4PMe_3$, an 18 electron moiety acts as a two electron donor to the $Os_3(CO)_{11}$ species.[176]

This initial success led to a similar attempt with $H_2Os_3(CO)_{10}$ and $Os(CO)_4PMe_3$. The unsaturated cluster $H_2Os_3(CO)_{10}$ was known to be very reactive and many ligand addition reactions with it had been reported.[177] Surprisingly, the product of this reaction was not $H_2Os_4(CO)_{14}PMe_3$ but rather $Os_4(CO)_{15}PMe_3$ as before. Indeed, the reaction in hexane was complete at room temperature in one hour. A 57% yield could be obtained if excess $Os(CO)_4PMe_3$ was present.

A further attempt to obtain a new cluster with a donor-acceptor bond was made by adding Me_3NO to $Os_4(CO)_{15}PMe_3$ in CH_2Cl_2 in the presence of $Os(CO)_4PMe_3$. It was hoped that substitution of a CO ligand by an $Os(CO)_4PMe_3$ would occur producing a doubly spiked triangle, $Os_5(CO)_{18}(PMe_3)_2$. Instead, simple CO ligand loss occurred and the product was $Os_4(CO)_{14}PMe_3$. This compound has the interesting property that it appears deep red in CH_2Cl_2 solution and distinctly green in hexane. Novel features were displayed in the variable temperature ^{13}C NMR spectra of this compound so the structure was determined by X-ray analysis.

Results of mass spectra of both these compounds showed the most abundant peak in the highest mass envelope to be at 1202 m^+/e, i.e., $[P-2CO]^+$ and $[P-CO]^+$ respectively suggesting the compound $Os_4(CO)_{13}PMe_3$ might be synthetically accessible. Indeed, this deep burgundy compound was obtained in 34% yield when a hexane solution of $Os_4(CO)_{14}PMe_3$ was heated at 90 °C for 24 h.

During the investigation of the reaction of $H_2Os_3(CO)_{10}$ and $Os(CO)_4PMe_3$ it was noted that addition of Me_3NO to the reaction mixture produced several products. Isolation of bright red $H_2Os_4(CO)_{13}PMe_3$ was possible using chromatographic techniques. Although this complex is isoelectronic with $Os_4(CO)_{14}PMe_3$ its structure and fluxional properties are quite different.

These differences along with other aspects of the chemistry of these four tetranuclear osmium clusters are the basis of this discussion.

2.1 $Os_4(CO)_{15}PMe_3$

2.1.1 Structure and Bonding

The structure of $Os_4(CO)_{15}PMe_3$ (1) as determined by X-ray crystallography shows there are two molecules in the asymmetric unit but the differences between them are not chemically significant (see Figure B.2.1 and Table B.2.1). The metal atom framework of 1 is best described as a 'spiked triangle' in which the 18 electron moiety $Os(CO)_4PMe_3$ donates two electrons to the $Os_3(CO)_{11}$ fragment. There are no unusual bond lengths or angles; all carbonyl ligands are terminal and the the closest non-bonded Os-C contact is Os(12)••C(113) at 3.32(3)Å. This is consistent with the IR solution spectrum in CH_2Cl_2 which exhibits only terminal carbonyl stretches (see Table B.3.2 page 146). According to the 18-Electron Rule each osmium atom has its required complement of 18 electrons.

Similar spiked triangle structures have been observed for $(\mu\text{-}H)Os_3Re(CO)_{15}NCMe$[175] and $(\mu\text{-}H)HOs_4(CO)_{15}$[102], but this is the first example containing a dative, or donor-acceptor, metal-metal bond. The dative metal-metal bond in 1 has no supporting metal-metal bonds nor is there evidence of even weak interaction between the Os(11) (or Os(21)) carbonyl ligands and Os(12) (or Os(22)).

While this type of unsupported dative bond is previously unknown for cluster compounds it has been reported for a number of dimeric complexes synthesized in this laboratory.[169,170,171]

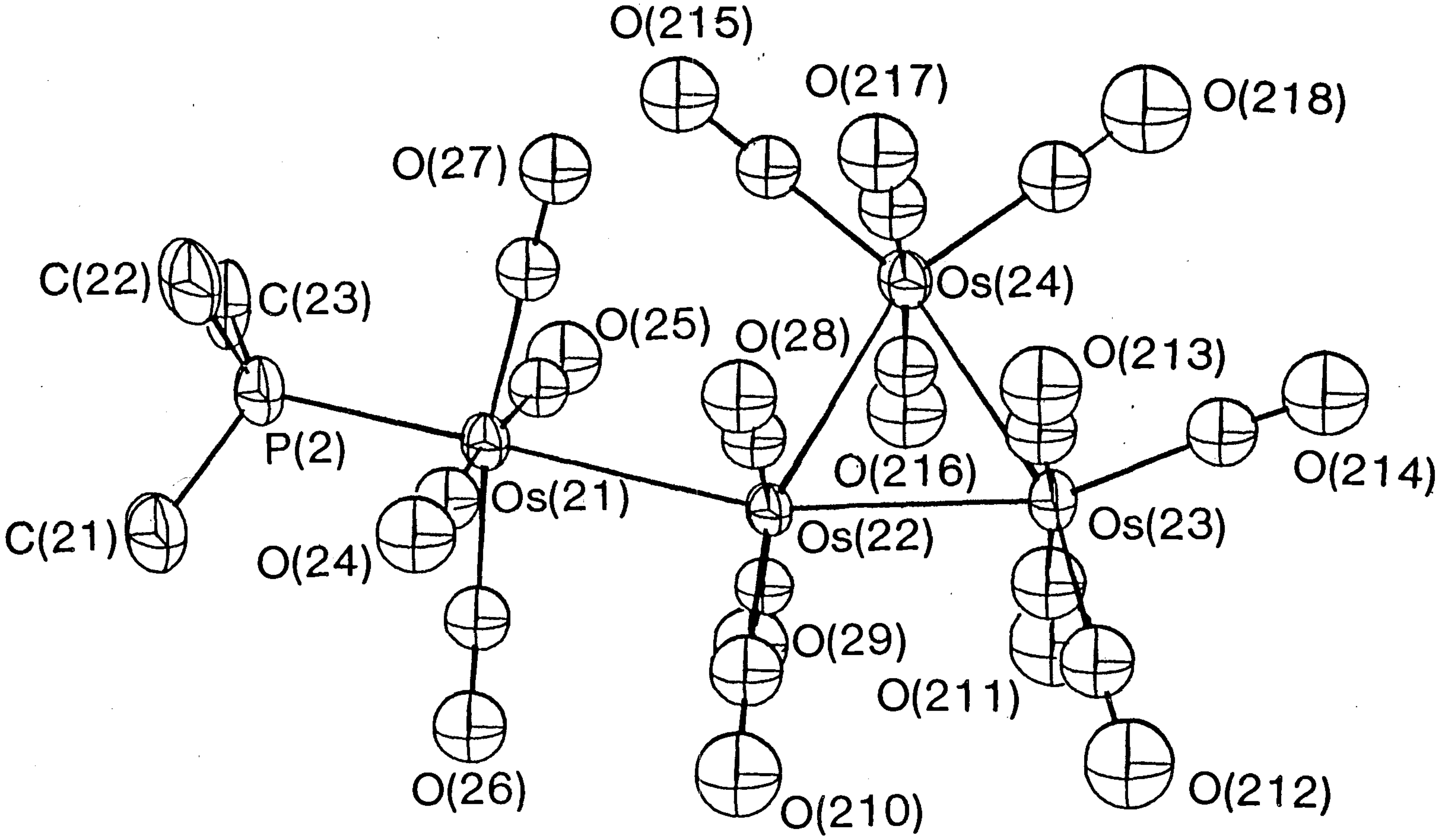


Figure B.2.1. Thermal Ellipsoid Diagram for $Os_4(CO)_{15}PMe_3$.

Table B.2.1. Selected Molecular Dimensions for $Os_4(CO)_{15}PMe_3$

a)Bond Lengths--Molecule 1.

Atoms	Bond Length (Å)	Atoms	Bond Length (Å)
Os(11)-Os(12)	2.939(1)	Os(14)-C(118)	1.91(2)
Os(11)-P(1)	2.354(5)	P(1)-C(11)	1.83(2)
Os(11)-C(14)	1.92(2)	P(1)-C(12)	1.79(2)
Os(11)-C(15)	1.92(2)	P(1)-C(13)	1.83(2)
Os(11)-C(16)	1.92(2)	C(14)-O(14)	1.15(2)
Os(11)-C(17)	1.91(2)	C(15)-O(15)	1.16(2)
Os(12)-Os(13)	2.849(1)	C(16)-O(16)	1.15(2)
Os(12)-Os(14)	2.923(1)	C(17)-O(17)	1.15(2)
Os(12)-C(18)	1.91(2)	C(18)-O(18)	1.16(2)
Os(12)-C(19)	1.89(2)	C(19)-O(19)	1.17(2)
Os(12)-C(110)	1.81(2)	C(110)-O(110)	1.18(2)
Os(13)-Os(14)	2.894(1)	C(111)-O(111)	1.13(2)
Os(13)-C(111)	1.93(2)	C(112)-O(112)	1.17(3)
Os(13)-C(112)	1.85(2)	C(113)-O(113)	1.15(2)
Os(13)-C(113)	1.92(2)	C(114)-O(114)	1.19(3)
Os(13)-C(114)	1.84(2)	C(115)-O(115)	1.14(2)
Os(14)-C(115)	1.89(2)	C(116)-O(116)	1.16(3)
Os(14)-C(116)	1.87(2)	C(117)-O(117)	1.15(3)
Os(14)-C(117)	1.88(2)	C(118)-O(118)	1.16(2)

b)Bond Angles--Molecule 1.

Bonds	Angle (°)	Bonds	Angle (°)
Os(11)-Os(12)-Os(13)	165.32(3)	Os(14)-Os(12)-C(110)	157.3(6)
Os(13)-Os(12)-Os(14)	60.17(3)	C(18)-Os(12)-C(19)	173.1(8)
Os(12)-Os(13)-Os(14)	61.19(3)	Os(14)-Os(13)-C(112)	157.4(7)
Os(12)-Os(14)-Os(13)	58.64(3)	Os(14)-Os(13)-C(114)	99.7(7)
Os(12)-Os(11)-P(1)	174.0(1)	C(111)-Os(13)-C(113)	175.6(9)
Os(12)-Os(11)-C(14)	88.3(6)	Os(13)-Os(14)-C(115)	162.5(6)
Os(12)-Os(11)-C(15)	84.1(6)	Os(12)-Os(14)-C(118)	89.2(6)
Os(12)-Os(11)-C(16)	88.0(5)	C(116)-Os(14)-C(117)	91.8(9)
Os(12)-Os(11)-C(17)	84.9(5)	Os(11)-P(1)-C(11)	113.4(7)
C(14)-Os(11)-C(15)	171.3(8)	Os(11)-P(1)-C(12)	114.3(7)
C(16)-Os(11)-C(17)	172.8(8)	Os(11)-P(1)-C(13)	114.9(7)

c)Bond Lengths--Molecule 2.

Atoms	Bond Length (Å)	Atoms	Bond Length (Å)
Os(21)-Os(22)	2.937(1)	Os(24)-C(218)	1.88(2)
Os(21)-P(2)	2.355(5)	P(2)-C(21)	1.81(2)
Os(21)-C(24)	1.94(2)	P(2)-C(22)	1.79(2)
Os(21)-C(25)	1.93(2)	P(2)-C(23)	1.82(2)
Os(21)-C(26)	1.93(2)	C(24)-O(24)	1.13(2)
Os(21)-C(27)	1.94(2)	C(25)-O(25)	1.14(2)
Os(22)-Os(23)	2.855(1)	C(26)-O(26)	1.16(2)
Os(22)-Os(24)	2.930(1)	C(27)-O(27)	1.13(2)
Os(22)-C(28)	1.93(2)	C(28)-O(28)	1.13(2)
Os(22)-C(29)	1.90(2)	C(29)-O(29)	1.17(2)

Os(22)-C(210)	1.83(2)	C(210)-O(210)	1.17(2)
Os(23)-Os(24)	2.894(1)	C(211)-O(211)	1.16(2)
Os(23)-C(211)	1.91(2)	C(212)-O(212)	1.18(2)
Os(23)-C(212)	1.84(2)	C(213)-O(213)	1.15(2)
Os(23)-C(213)	1.92(2)	C(214)-O(214)	1.14(2)
Os(23)-C(214)	1.90(2)	C(215)-O(215)	1.18(2)
Os(24)-C(215)	1.85(2)	C(216)-O(216)	1.17(2)
Os(24)-C(216)	1.92(2)	C(217)-O(217)	1.14(2)
Os(24)-C(217)	1.91(2)	C(218)-O(218)	1.17(2)

d)Bond Angles--Molecule 2.

Bonds	Angle (°)	Bond	Angle (°)
Os(21)-Os(22)-Os(23)	163.05(3)	Os(24)-Os(22)-C(210)	159.3(6)
Os(23)-Os(22)-Os(24)	60.02(2)	C(28)-Os(22)-C(29)	173.8(7)
Os(22)-Os(23)-Os(24)	61.28(3)	Os(24)-Os(23)-C(212)	163.2(6)
Os(22)-Os(24)-Os(23)	58.70(2)	Os(22)-Os(23)-C(214)	156.9(6)
Os(22)-Os(21)-P(2)	177.3(1)	C(211)-Os(23)-C(213)	173.9(8)
Os(22)-Os(21)-C(24)	90.6(5)	Os(23)-Os(24)-C(215)	162.8(6)
Os(22)-Os(21)-C(25)	84.5(5)	Os(22)-Os(24)-C(218)	154.6(6)
Os(22)-Os(21)-C(26)	82.21(6)	C(216)-Os(24)-C(217)	174.5(8)
Os(22)-Os(21)-C(27)	87.0(5)	Os(21)-P(2)-C(21)	113.6(7)
C(24)-Os(21)-C(25)	175.1(7)	Os(21)-P(2)-C(22)	113.4(7)
C(26)-Os(21)-C(27)	169.2(7)	Os(21)-P(2)-C(23)	114.4(6)

Invesigation of the structure, reactivity, and fluxional properties of these compounds has established the following:

1)Dative metal-metal bonds are slightly longer than normal covalent bonds between the same metals.

2)The $Os(CO)_4PMe_3$ complex is a weak donor ligand, comparable in strength to CO.

3)These complexes are either sparingly soluble or insoluble in hexane but all dissolve readily in CH_2Cl_2. This is probably a consequence of the polar nature of the donor-acceptor bond.

4)Compounds with donor-acceptor bonds are fluxional; they exhibit intramolecular carbonyl exchange. A mechanism consistent with the variable temperature ^{13}C NMR spectra is bridge-terminal carbonyl exchange across the dative bond.

Complex 1 exhibits all the above characteristics. From Figure B.2.2 which shows the Os-Os bond lengths in Å within each of the two independent molecules it can be seen that the

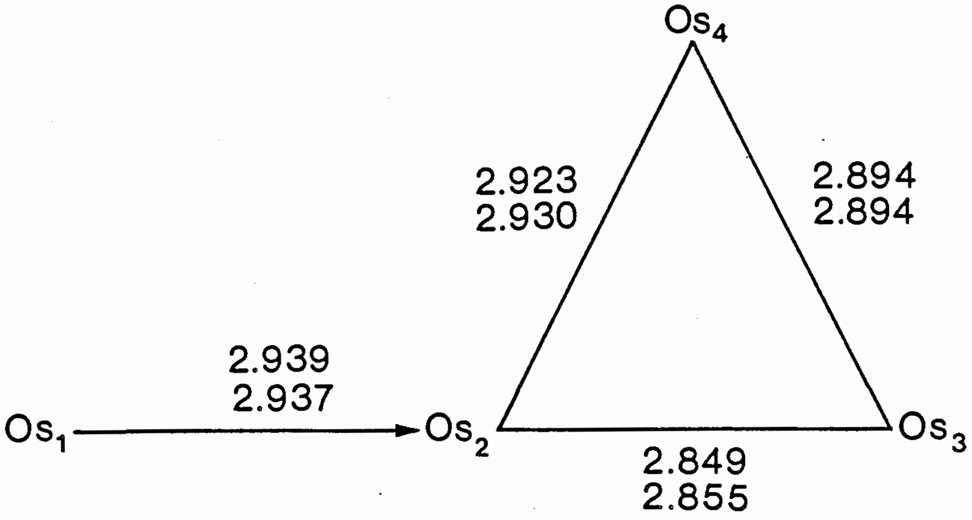


Figure B.2.2. Os-Os Bond Lengths in $Os_4(CO)_{15}PMe_3$. There are two independent molecules in the asymmetric unit.

donor-acceptor bond in each molecule is ≈0.06Å longer than the average Os-Os bond length of 2.877Å in $Os_3(CO)_{12}$.[178] (The standard deviation in each length is 0.001Å). While unbridged Os-Os bond lengths in osmium clusters vary, they rarely exceed 2.91Å, especially when the osmium atoms are six-coordinate.[179]

The Os(12)-Os(13) (or Os(22)-Os(23)) bond which is trans to the dative metal-metal bond is short compared to those in $Os_3(CO)_{12}$, indicating $Os(CO)_4PMe_3$ is a weak donor ligand.[180] It is known that strong σ-donors lengthen the M-L bond in the position trans to the donor ligand in monomeric complexes[181] and Adams has extended this idea in his proposal that the trans influence of ligands affects the length of metal-metal bonds in osmium clusters.[180] It was observed that the Os-Os bonds trans to PMe_2Ph and CS were 2.856(1)Å and 2.830(2)Å in $Os_3(\mu_3\text{-}S)(CO)_8L$ complexes compared to a length of 2.814(1)Å when L=CO. It follows that a comparatively short Os-Os bond indicates the ligand in the trans position is a weak σ-donor.

The Os(13)-Os(14) (or Os(23)-Os(24)) bond is of comparable length to those in $Os_3(CO)_{12}$, while the bond cis to the dative bond, Os(12)-Os(14) (or Os(22)-Os(24)), is somewhat lengthened. This may be a result of the shortening of the Os(12)-Os(13) (or Os(22)-Os(23)) bond. This type of reciprocal relationship between bond lengths was suggested in regard to $Os_3(\mu_3\text{-}S)_2(CO)_8PMe_2Ph$ by Adams and coworkers who speculated that the weakening of one bond is accompanied by a decrease in metal-metal overlap.[180] This in turn permits increased overlap between one of the atoms involved in the weak bond and a third metal atom. Presumably the reverse is equally reasonable, i.e., strengthening of one bond, with increased orbital overlap could lead to a longer neighbouring bond.

Further evidence that $Os(CO)_4PMe_3$ is a weak donor ligand comes from thermal decomposition and ligand substitution studies. When a solution of 1 was stirred overnight at room temperature (25 °C) it decomposed. Both $Os_3(CO)_{12}$ and $Os_3(CO)_{11}PMe_3$ were identified as decomposition products by IR spectroscopy.[182] (Decomposition of 1 during synthesis was avoided by carrying out the reaction in hexane, in which 1 precipitates.) Reaction of 1 with PPh_3 in solution quickly produced $Os_3(CO)_{11}PPh_3$ and $Os(CO)_4PMe_3$.

We have described the bonding in 1 as that of a triangular cluster having one unusual ligand, $Os(CO)_4PMe_3$. However, 1 may also be considered a tetranuclear cluster with 64 electrons that is predicted to have four metal-metal bonds. Both a spiked triangle and a square fulfill this requirement and both configurations are known. As mentioned in the introduction, there are also a number of 64 electron butterfly structures; these have two or three elongated metal-metal bonds.

Neither the 18-Electron Rule nor PSEPT is useful in predicting the specific geometry of a particular 64 electron compound. An alternative proposal is that the bridging characteristics of the ligands strongly influence the geometry of the metal atom framework.[102] For example, the square clusters cited in Table B.1.1 and elsewhere[183,184] all have two face bridging ligands, perhaps this μ_4 bonding is able to overcome diagonal interactions that could produce strain in square complexes. Butterfly clusters which have 64 electrons also have ligands that are edge or face bridging and may consequently prevent the complete rupture of metal-metal bonds. The known spiked triangles have ligands which do not constrain the structure in this way even though some have bridging hydrides or halogens. It therefore seems that the spiked triangle is the preferred, or lowest energy configuration and other geometries are adopted when there are ligands present that prevent the molecule from opening up to the fullest extent possible.

2.1.2 *Fluxional Properties of* $Os_4(CO)_{15}PMe_3$

The ^{13}C NMR spectrum at -67 °C of a ^{13}CO enriched sample of 1 is consistent with the solid state structure. It has five resonances of relative intensity one at δ=183.9, 180.1, 173.0, 171.6 and 171.0 ppm; three resonances of relative intensity two at δ=198.4, 187.7 and 184.0 ppm; and one resonance of relative intensity four at δ=181.6 ppm (see Figure B.2.3). The resonance at δ=181.6 ppm is assigned to the carbonyl groups on the $Os(CO)_4PMe_3$ ligand which rotates about the Os(11)-Os(12) (or Os(21)-Os(22)) axis in solution; those of relative intensity one and two are assigned to the equatorial and axial carbonyls respectively of the $Os_3(CO)_{11}$ fragment. When the solution was warmed to -26 °C two axial signals and two equatorial signals

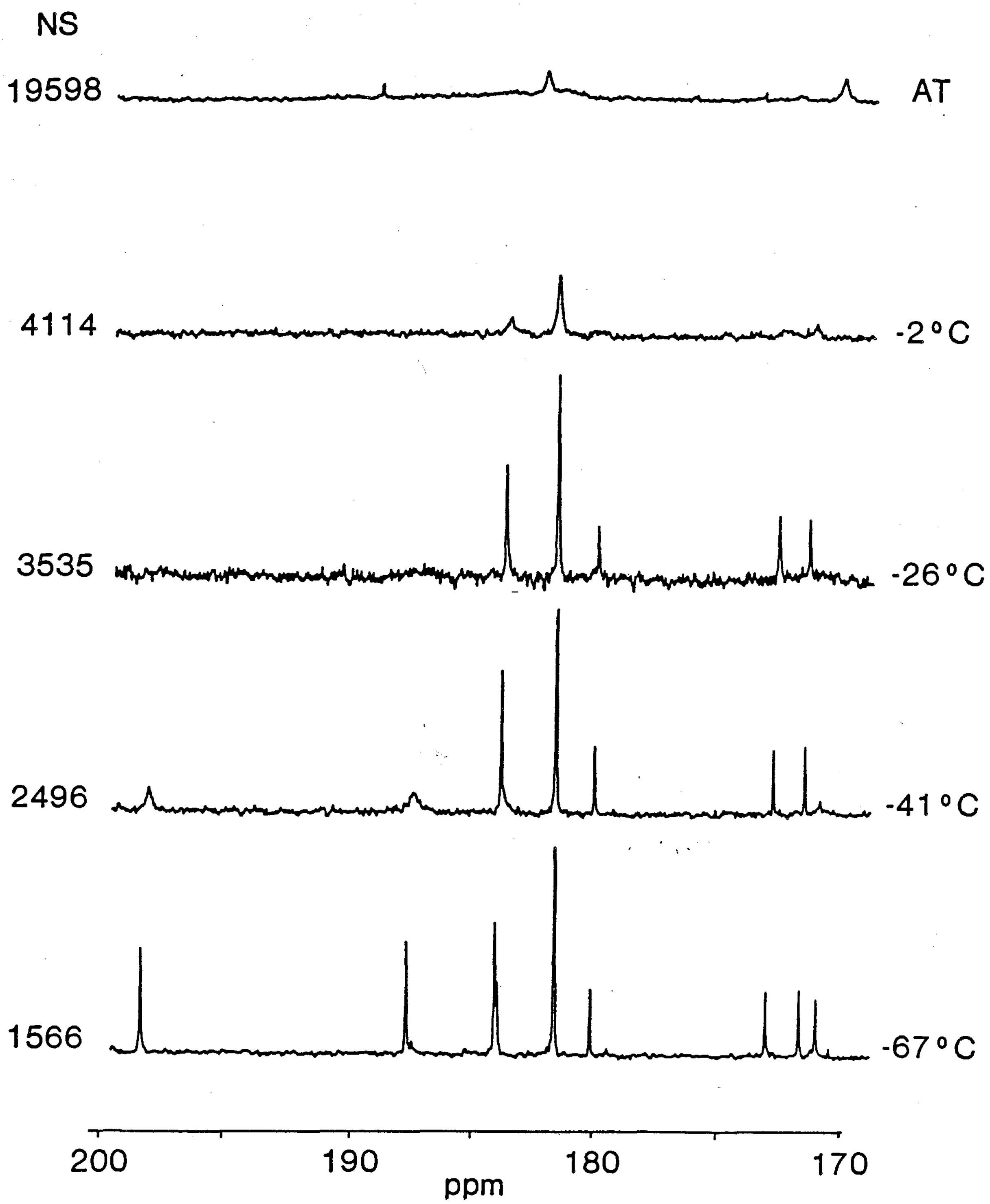
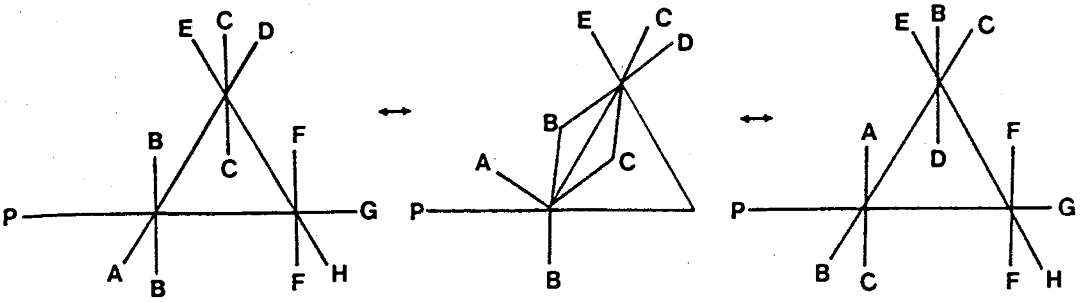


Figure B.2.3. Variable Temperature ^{13}C NMR Spectra of $Os_4(CO)_{15}PMe_3$. 'NS' means 'number of scans'.

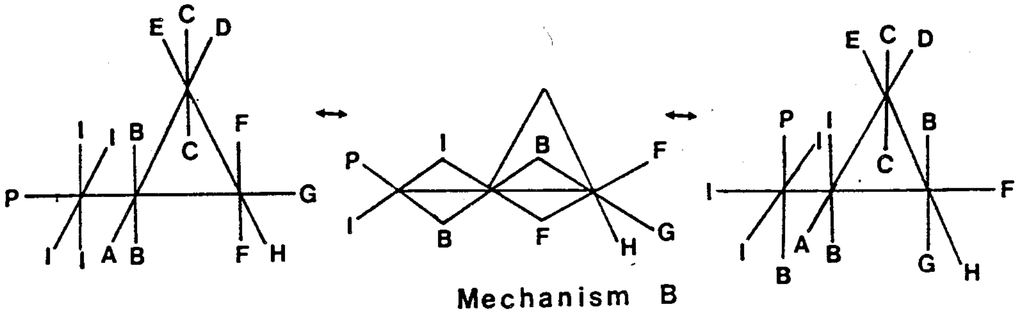
broadened and collapsed into the baseline. Further warming resulted in collapse of the remaining signals. At ambient temperature (20 °C) the only peaks present in the spectrum were the very weak signals due to the decomposition products $Os(CO)_4PMe_3$ and $Os_3(CO)_{12}$. Decomposition was more extensive on further warming and precluded investigation of the ^{13}C NMR spectrum of 1 at a higher temperature. Apart from the decomposition, the collapse process was reversible.

Mechanistic proposals which account for these observations are as follows:

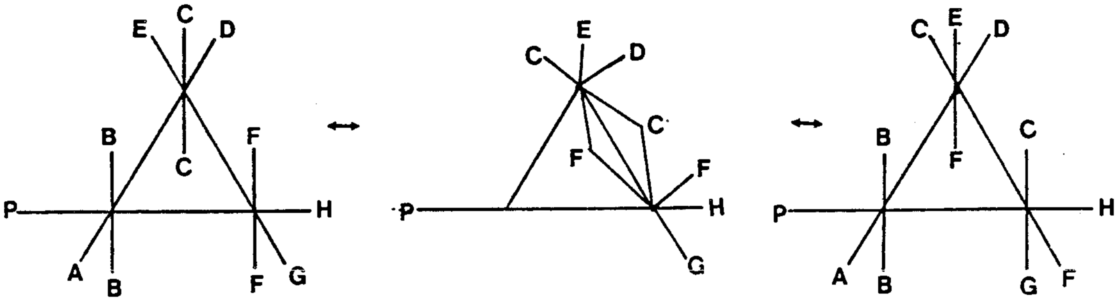
1)At temperatures between -67 °C and -26 °C the process A shown in Figure B.2.4 occurs. In the intermediate, two carbonyls bridge the Os-Os bond cis to the $Os(CO)_4PMe_3$ ligand. Bridge-terminal exchange causes collapse of carbonyl signals A, B, C and D. This mechanism has been proposed for $Os_3(CO)_{11}L$ ($L=PEt_3$[185], $P(OMe_3)$[186]). It appears that the extra electron density on the osmium atom donated from L, or left there because of weak back-bonding, facilitates carbonyl exchange with the osmium atom cis to the $L \longrightarrow Os$ bond. Ligand exchange along the trans Os-Os bond might also be expected, but would this bring L into an axial position, which appears to an energetically unfavourable process. Investigations in this laboratory of the ^{13}C NMR spectra of $Os_3(CO)_{11}P(OMe)_3$ have confirmed that at -10 °C there is only one sharp equatorial carbonyl signal, all others are broadened (see Figure B.2.5).[186] This observation is accounted for if bridge-terminal exchange does not take place



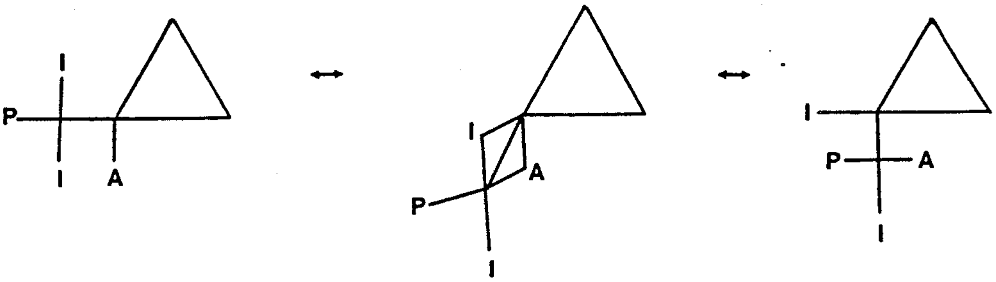
Mechanism A



Mechanism B



Mechanism C



Mechanism D

Figure B.2.4. Fluxional Processes of $Os_4(CO)_{15}PMe_3$.

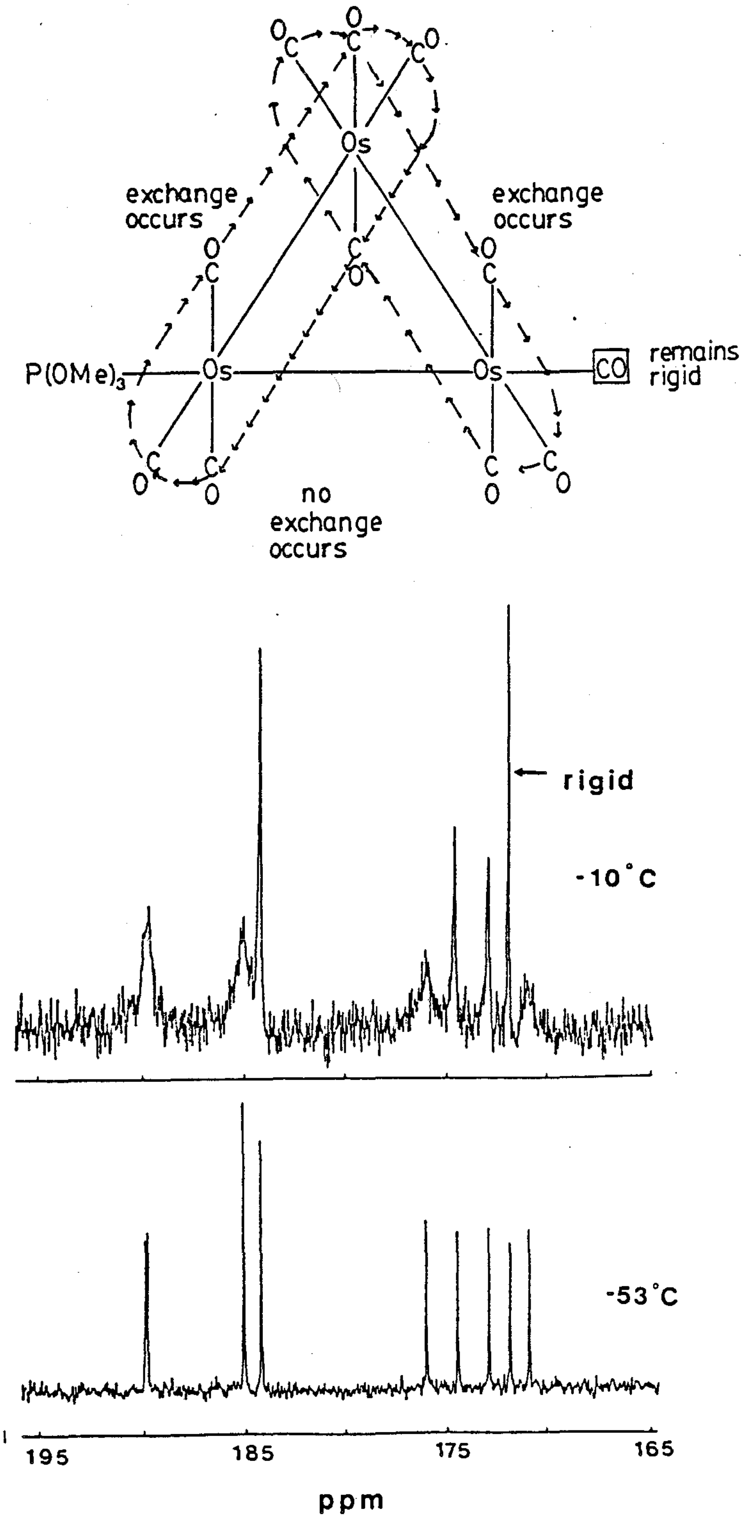


Figure B.2.5. Fluxional Processes and ^{13}C NMR Spectrum of $Os_3(CO)_{11}P(OMe)_3$.

along the Os-Os bond trans to $P(OMe)_3$ but does occur along the other two Os-Os bonds. Such processes always leave the $P(OMe)_3$ ligand in an equatorial position. Therefore the CO ligand in the trans three bond position to $P(OMe)_3$ also does not exchange with, or become equivalent to, any other CO group, and the peak assigned to it does not broaden.

2)At temperatures above -26 °C, two processes, B and C, illustrated in Figure B.2.4 occur. The first, B, involves simultaneous bridge terminal exchange across the dative Os-Os bond and across the Os-Os bond trans to the dative bond. Such a mechanism accounts for the collapse of signals due to carbonyl ligands B, F, G and I. In order to account for collapse of the other signals mechanism C is proposed. That this exchange occurs more slowly than A is consistent with the observations made for $Os_3(CO)_{11}P(OMe)_3$.

An alternative mechanism which accounts for the spectra observed at -26 °C and at 0 °C is exchange across the dative Os-Os bond involving carbonyls A and I and a change of position of the $Os(CO)_4PMe_3$ group (mechanism D in Figure B.2.4). However, when 1 was prepared from $Os_3(CO)_{11}MeCN$ and ^{13}CO enriched $Os(CO)_4PMe_3$ the ^{13}C NMR spectrum revealed that the ^{13}C label was equally distributed over all carbonyl sites within the molecule. This cannot occur unless mechanism C is also operative. Without a high temperature limiting spectrum it is not possible to distinguish between the A,B,C and A,C,D possibilities.

It is interesting to note that both B and D mechanisms give rise to a second isomer of 1 with the PMe_3 ligand in an axial position. There are a number of weak peaks in the ^{13}C NMR spectrum of 1 taken at -67 °C, suggesting that such an isomer is present. The ^{13}C NMR spectra of two other compounds which have donor-acceptor metal-metal bonds, $(Me_3P_x(CO)_{5-x}OsW(CO)_5$ (x=1,2), also indicated the presence of two isomers in solution.[169,187]

2.2 $Os_4(CO)_{14}PMe_3$

2.2.1 Structure and Bonding

According to the bonding models discussed in the introduction, a 62 electron tetranuclear complex such as $Os_4(CO)_{14}PMe_3$ (2) is expected to adopt a butterfly arrangement of metal atoms. Such a geometry accomodates five nearly equal metal-metal bonds and allows variation of the dihedral angle between the metal atom triangles depending upon the number and bonding characteristics of the ligands. The crystal structure of 2 revealed it is not a butterfly. Rather, as can be seen from Figure B.2.6 and Table B.2.2, molecules of 2 are very nearly planar in the solid state; the dihedral angle between the planes Os(1)-Os(2)-Os(3) and Os(1)-Os(3)-Os(4) is 177.10(3)°. The solution ^{13}C NMR spectrum at low temperature (see Figure B.2.10, page 115) exhibits four signals of relative intensity two which are assigned to the four different pairs of axial carbonyl ligands. The axial carbonyls on any given osmium atom can be equivalent only if the molecule is planar. It is

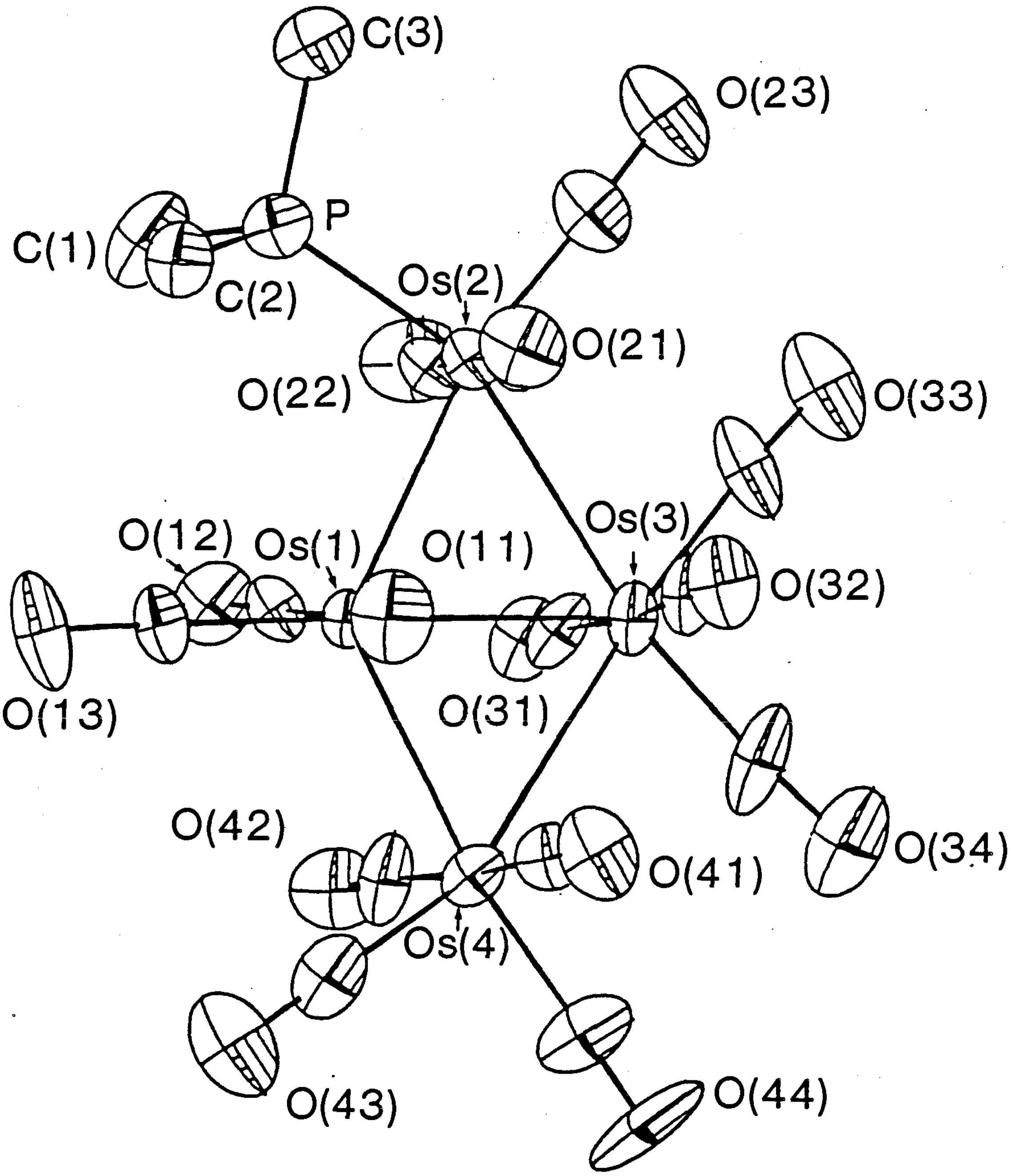


Figure B.2.6. Thermal Ellipsoid Diagram for $Os_4(CO)_{14}PMe_3$.

Table B.2.2 Selected Molecular Dimensions for $Os_4(CO)_{14}PMe_3$.

a)Bond Lengths

Atoms	Bond Length (Å)	Atoms	Bond Length (Å)
Os(1)-Os(2)	2.779(2)	Os(4)-C(44)	1.93(2)
Os(1)-Os(3)	2.935(2)	P(1)-C(1)	1.79(2)
Os(1)-Os(4)	2.784(2)	P(1)-C(2)	1.78(2)
Os(2)-Os(3)	3.013(2)	P(1)-C(3)	1.80(3)
Os(3)-Os(4)	2.982(2)	C(11)-O(11)	1.13(3)
Os(2)-P(1)	2.320(6)	C(12)-O(12)	1.16(3)
Os(1)-C(11)	1.92(2)	C(13)-O(13)	1.16(2)
Os(1)-C(12)	1.88(2)	C(21)-O(21)	1.14(2)
Os(1)-C(13)	1.86(2)	C(22)-O(22)	1.12(3)
Os(2)-C(21)	1.95(2)	C(23)-O(23)	1.16(3)
Os(2)-C(22)	1.92(2)	C(31)-O(31)	1.13(3)
Os(2)-C(23)	1.89(2)	C(32)-O(32)	1.08(3)
Os(3)-C(31)	1.93(2)	C(33)-O(33)	1.14(3)
Os(3)-C(32)	2.02(2)	C(34)-O(34)	1.18(3)
Os(3)-C(33)	1.88(2)	C(41)-O(41)	1.13(3)
Os(3)-C(34)	1.87(2)	C(42)-O(42)	1.14(3)
Os(4)-C(41)	1.97(3)	C(43)-O(43)	1.19(3)
Os(4)-C(42)	1.93(3)	C(44)-O(44)	1.12(3)
Os(4)-C(43)	1.82(3)		

b)Bond Angles

Bonds	Angle (°)	Bonds	Angle (°)
Os(2)-Os(1)-Os(3)	63.57(3)	Os(1)-Os(2)-P(1)	97.7(2)
Os(2)-Os(1)-Os(4)	126.28(5)	Os(1)-Os(2)-C(23)	165.7(7)
Os(3)-Os(1)-Os(4)	62.79(3)	Os(2)-Os(3)-C(33)	74.1(8)
Os(1)-Os(2)-Os(3)	60.74(5)	Os(2)-Os(3)-C(34)	170.9(8)
Os(2)-Os(3)-Os(1)	55.69(3)	Os(3)-Os(4)-C(43)	155.5(7)
Os(2)-Os(3)-Os(4)	111.76(5)	Os(1)-Os(4)-C(44)	168.0(8)
Os(1)-Os(3)-Os(4)	56.12(3)	Os(4)-Os(1)-C(13)	116.0(7)
Os(3)-Os(4)-Os(1)	61.09(4)	Os(2)-Os(1)-C(13)	117.7(7)
C(11)-Os(1)-C(12)	170.0(8)	Os(2)-P(1)-C(1)	114.8(9)
C(21)-Os(2)-C(22)	177.8(8)	Os(2)-P(1)-C(2)	117.0(7)
C(31)-Os(3)-C(32)	172.4(8)	Os(2)-P(1)-C(3)	114.0(8)
C(41)-Os(4)-C(42)	174.2(9)		

concluded that 2 is planar from a chemical point of view and the small deviation of the dihedral angle from 180° arises from solid state effects. This structure exists despite the presence of a T-shaped $Os(CO)_3$ fragment, in conflict with the prediction of Evans and Mingos discussed earlier.[122]

We believe the planar geometry is related to the lack of bridging ligands. There is no indication in the crystal structure of any weakly semi-bridging interaction between a carbonyl ligand and a neighbouring non-bonded Os atom. The closest non-bonded Os-C contact is Os(2)···C(33) at 3.08(2)Å. Furthermore, the solution infrared spectrum displayed only terminal carbonyl stretches, see Table B.3.2. Because 2 is isoelectronic with $(\mu\text{-H})_2Os_4(CO)_{13}PMe_3$ (3), a butterfly with two bridging ligands, further discussion of this point is postponed until the structure of 3 has been described.

Another interesting aspect of the structure of 2 is its asymmetry. The fifteen terminal ligands are not evenly distributed among the four osmium atoms; one of the hinge atoms, Os(1), has only three carbonyl ligands while each of the other three metal atoms has four ligands apiece. Contrary to the prediction of Evans and Mingos, the peripheral bonds involving the T-shaped $Os(CO)_3$ fragment are much shorter than the other Os-Os vectors. The Os(1)-Os(2), Os(1)-Os(4) distances are 2.779(2)Å and 2.784(2)Å respectively, while the other two peripheral bonds are very long; i.e., Os(2)-Os(3)=3.013(2)Å and Os(3)-Os(4)=2.982(2)Å. The short diagonal Os(1)-Os(3) vector is of more typical length, 2.935(2)Å. These values can be compared to the average Os-Os distance in $Os_3(CO)_{12}$ i.e., 2.877(3)Å.[178] Both $Os_3(CO)_{12}$ and 2 are planar clusters and three of the four vertices in 2, like those in $Os_3(CO)_{12}$, have four terminal ligands.

In order to account for the long and short bonds in 2 and ensure that each osmium atom obeys the 18-Electron Rule we propose the bonding model illustrated in Figure B.2.7. It has a single bond between the $Os(CO)_3$ fragment and each of the other three vertices. In addition there are two three-centre-two-electron bonds, each encompassing the wing tips

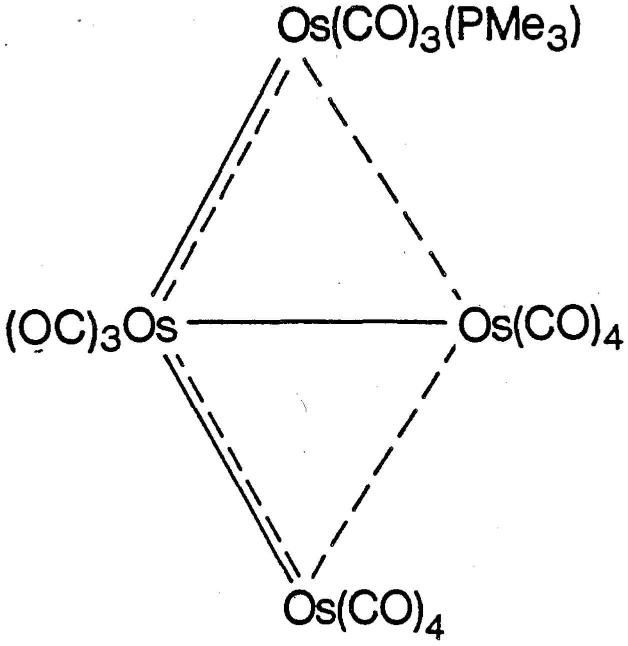


Figure B.2.7. Bonding Model for $Os_4(CO)_{14}PMe_3$.

and one hinge vertex. The short Os-Os vectors are thereby assigned a bond order of 1.5 and the long Os-Os vectors an order of 0.5, while the hinge vertices are connected by a normal single bond.

We would be interested to see if detailed molecular orbital calculations would support or refute this proposed bonding model, as simpler approaches have not proven helpful. For example we have attempted to apply PSEPT to **2**, but the results are unsatisfactory. If, in accord with the view of Evans and Mingos, the T-shaped $Os(CO)_3$ fragments donates two orbitals and no electrons to cluster bonding while the C_{2v} OsL_4 fragments donate two orbitals and one electron pair, there are only three bonding interactions. This is shown in the scheme developed for

$[Os_4(CO)_{16}]^{2+}$ (Figure B.2.8) a hypothetical molecule isoelectronic with **2**.[122] Three bonds hardly seems enough to hold so stable a tetranuclear species together. Also, the $[Os_4(CO)_{16}]^{2+}$ molecule is not predicted to be asymmetric, no localized bonding is anticipated.

A rather liberal application of the isolobal analogy[124] with the T-shaped $Os(CO)_3$ fragment deemed to provide three orbitals and two electrons in a manner similar to a conical $Os(CO)_3$ fragment (see page 83) does result in a structure with five bonding interactions including a dative covalent bond across the hinge (see Figure B.2.9). The model also satisfies the 18-Electron Rule for all the osmium atoms but all the bonds are normal single bonds. Like PSEPT, this model fails to predict the observed asymmetry in **2**.

2.2.2 Fluxional Properties

A ^{13}CO enriched sample of 2 in $CHFCl_2/CD_2Cl_2$ solution at -115 °C exhibited a ^{13}C NMR spectrum in the carbonyl region consistent with the structure found in the solid state, i.e., four resonances of relative intensity two (at δ=211.9, 202.0 (J_{P-C}=8.6Hz), 192.5 and 171.9 ppm), assigned to the axial carbonyls; and six resonances of relative intensity one (at δ=192.2, 176.9, 174.7, 172.7, 171.0 and 166.4 ppm) assigned to equatorial carbonyls, see Figure B.2.10. The axial signal at δ=202.0 ppm can be assigned to the carbonyls bonded to Os(2) by virtue of the carbon-phosphorus coupling, but no phosphorus

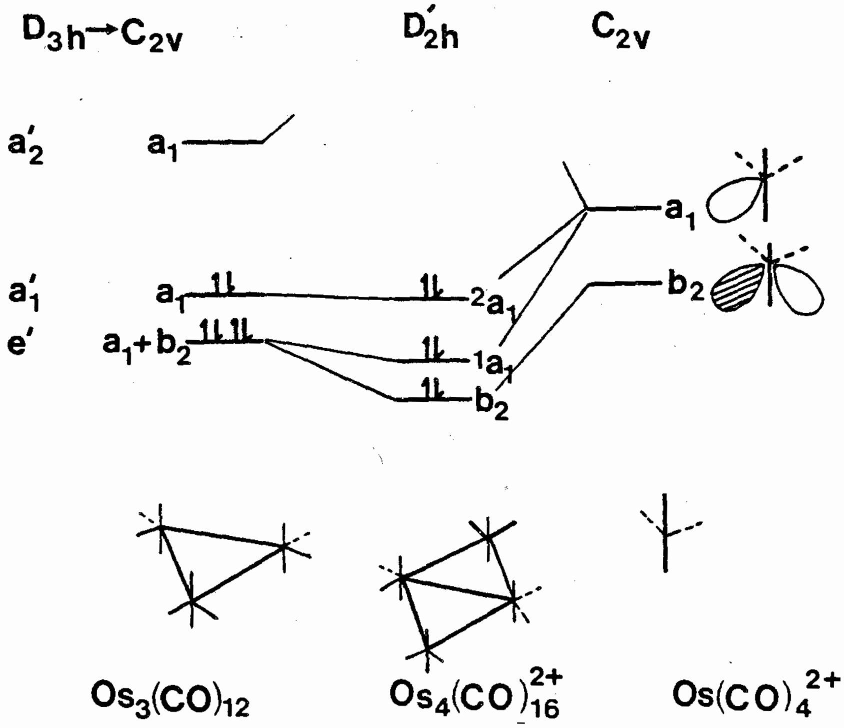


Figure B.2.8. Molecular Orbital Diagram for [$Os_4(CO)_{16}$]$^{2+}$. (After Evans and Mingos[123])

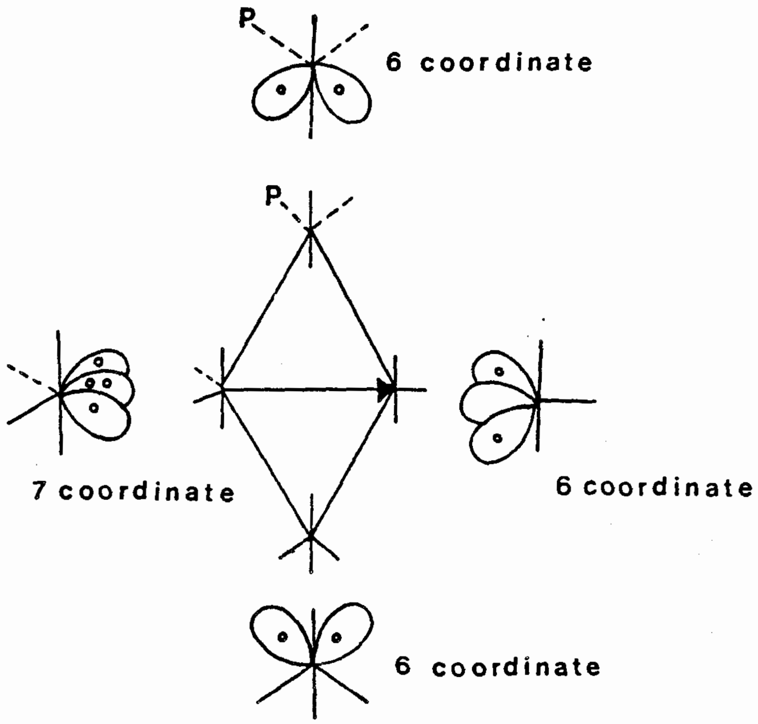


Figure B.2.9. Application of the Isolobal Analogy to $Os_4(CO)_{14}PMe_3$.

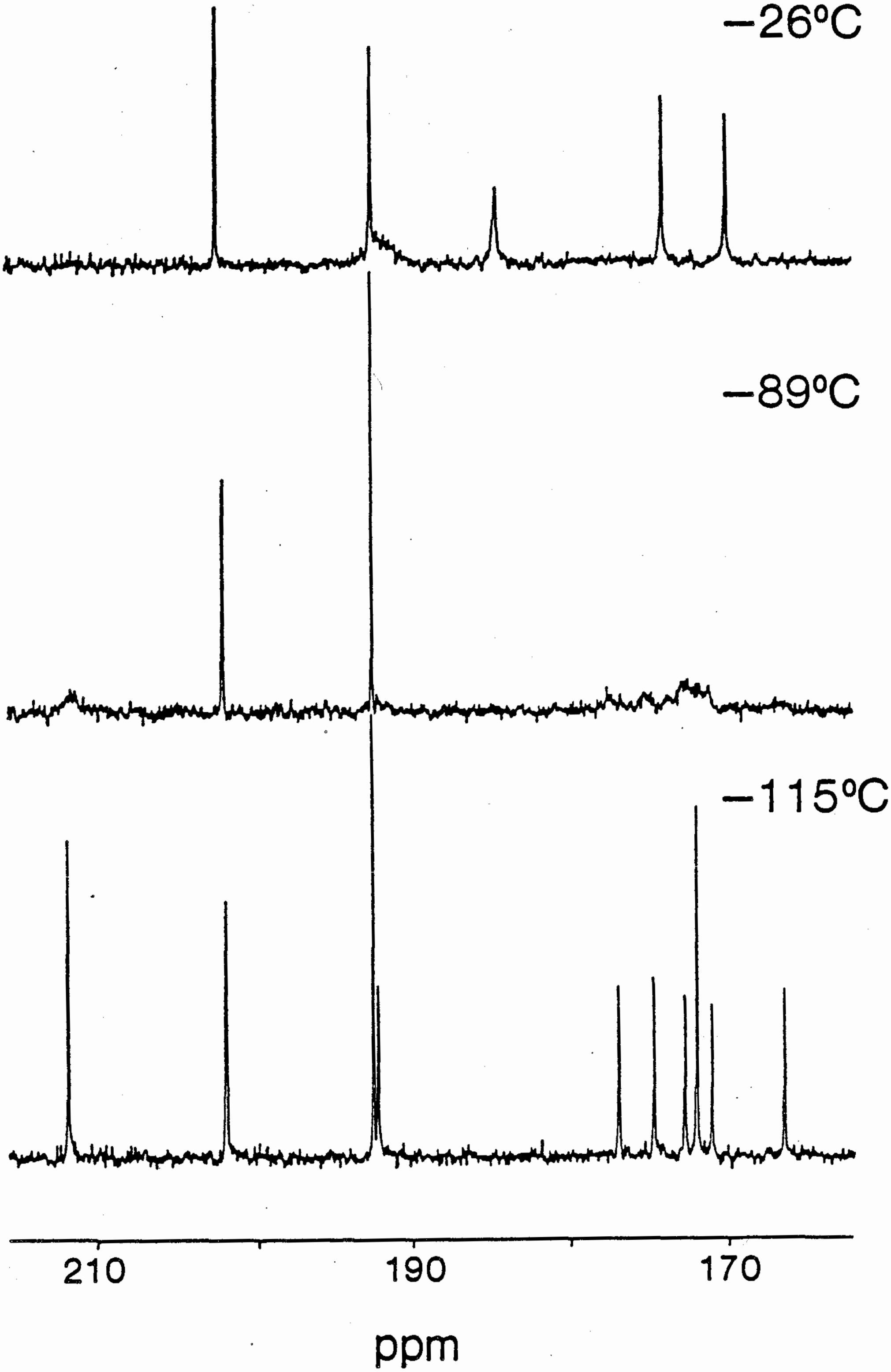


Figure B.2.10. ^{13}C NMR Spectra of $Os_4(CO)_{14}PMe_3$.

coupling was observed for any of the equatorial resonances. This lack of equatorial carbon-phosphorus coupling has been noted for other osmium clusters.[185,186]

When the solution was warmed to -87 °C, eight of the signals broadened and collapsed into the baseline; the two remaining signals were due to axial carbonyls including those bonded to Os(2). The spectrum obtained with the sample at -26 °C has three additional peaks at δ=183.6, 173.1 and 169.0 ppm, as well as a broad resonance just upfield of the signal at δ=191.6 ppm.[188] These four signals are at the average value of the chemical shifts of the original signals taken in pairs. The broad signal at approximately δ=190 ppm arises from the coalescence of the two axial peaks, while the other three new peaks come from the pair-wise collapse of the original six equatorial signals.

Various fluxional mechanisms have been proposed for osmium clusters,[101,189] but none of these can explain the variable temperature ^{13}C NMR spectra of 2. For example, three-fold twist and bridge-terminal carbonyl exchange mechanisms cause axial and equatorial signals to average. A simple merry-go-round rearrangement (as in step I of Mechanism B, Figure B.2.11) produces a second isomer of 2 with the PMe_3 ligand trans to the $Os(CO)_3$ fragment rather than to an $Os(CO)_4$ fragment. There is no evidence for such a second isomer in the spectrum at -115 °C. Furthermore, this mechanism would not cause pair-wise coalescence of the original signals, rather signals would appear at values averaging those assignable to the individual isomers. Mechanism A, shown in Figure B.2.11, correctly accounts for the observed spectra, it predicts the following exchanges: C(13) with C(23), C(33) with C(43), C(34) with C(44), and C(31),C(32) with C(41), C(42). The axial carbons of Os(1) {C(11), C(12)} and Os(2) {C(21),C(22)} remain unaffected by the process. The double bond between Os(1) and Os(2) in the intermediate is proposed in order to fulfill the requirements of the 18-Electron Rule for both Os atoms. Similar configurations have been reported elsewhere.[190] It is probable that the extreme weakness of the Os(2)-Os(3) bond lowers the activation barrier to non-rigidity and allows exchange to continue at temperatures down to approximately -100 °C. It would be interesting to see what effect substitution of the PMe_3 with weaker σ-donors might have on the exchange rate.

This novel 'windshield wiper' mechanism involves a significant rearrangement of the metal skeleton. Skeletal reorganization has been previously proposed for metal clusters but was either unspecified[191,192] or included only subtle changes in bond lengths.[193] A recent study has concluded, however, that Pt-Os bond breaking and making probably occurs in $PtOs_3(CO)_9(PMe_2Ph)_2(\mu_3\text{-}S)_2$.[194] Recently, Johnson has suggested that such mechanisms are more common than previously thought.[195]

Because the mechanism A is so unusual, an exhausive search was made for other explanations of the ^{13}C NMR spectra, but only one emerged. Mechanism B (Figure B.2.11) shows a two step

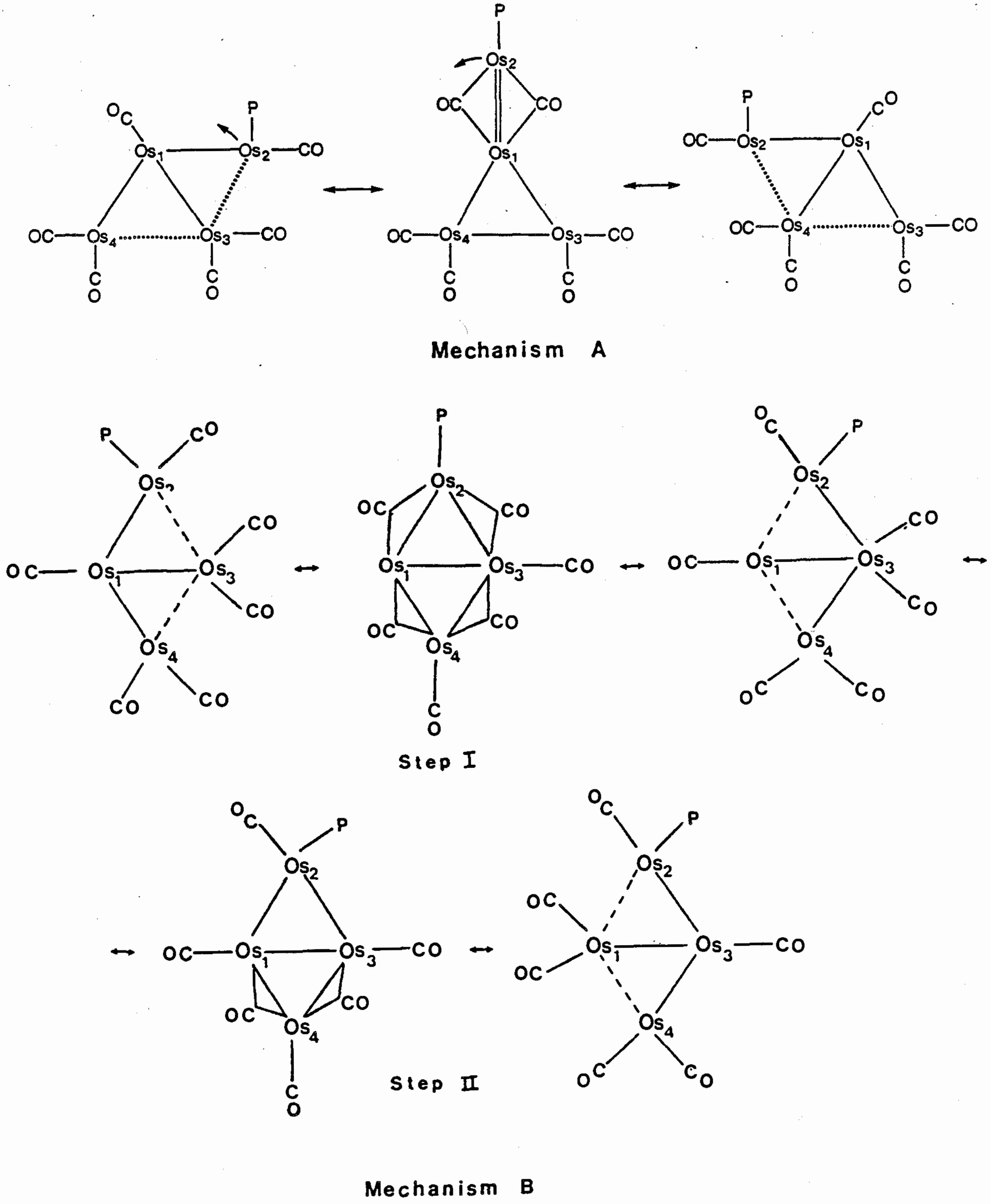


Figure B.2.11. Fluxional Mechanisms for $Os_4(CO)_{14}PMe_3$. (Axial carbonyls have been omitted for clarity.)

merry-go-round rearrangement wherein only equatorial carbonyls take part in bridging but the axial carbons C(11), C(12) exchange with C(31), C(32) by virtue of the change in the number of ligands on Os(1) and Os(3). Equatorial carbonyl signal averaging predicted by this mechanism is C(13) with C(23), C(34) with C(44), and C(33) with C(43). This scheme is consistent with the observed spectra but is thought unlikely to be correct for the following reasons:

1)The mechanism has two steps, each of which must occur at the same rate, otherwise signal averaging would occur between the structure found in the solid state and the intermediate II. It is unlikely that step I which involves four bridging carbonyls would occur at the same speed as step II which involves only two.

2)The mechanism involves carbonyls bridging the extremely long Os(2)-Os(3) and Os(3)-Os(4) bonds.

3)The intermediates of both steps do not obey the 18-Electron Rule.

4)If such merry-go-round mechanisms have low activation barriers, one would be expected to operate in $Os_3(CO)_{11}PEt_3$ but this is not observed.[185]

The ^{13}C spectrum of 2 with the sample at 0 °C showed the peaks at δ=201.6, 183.6, 173.1 and 169.0 ppm had broadened. An attempt was made to investigate the second fluxional process operating at higher temperatures but a spectrum for the fast exchange limit could not be obtained as the sample underwent some sort of reaction (perhaps with the solvent). A sharp peak at δ=189.9 ppm appeared in the room temperature spectrum which was assigned to the decomposition product $Os(CO)_4PMe_3$.

2.3 $(\mu\text{-}H)_2Os_4(CO)_{13}PMe_3$

2.3.1 Structure and Bonding

Like 2, $(\mu\text{-}H)_2Os_4(CO)_{13}PMe_3$ (3) is a 62 electron species, but the X-ray structure determination revealed it has a butterfly framework with a dihedral angle of 112.74(3)° between the Os_3 triangles (Figure B.2.12 and Table B.2.3.) The PMe_3 group is attached to one of the wing-tips, Os(2), and all the carbonyl ligands are terminal. The closest non-bonded Os-C contact is Os(2)•••O(12) 3.17Å.

As a consequence of the bend at the hinge the terminal ligands at the wing-tips are forced into close contact. In 3 the affected carbonyl ligands are skewed to alleviate the resulting non-bonded interactions, (Figure B.2.12.) The dihedral angle between the Os(2)-Os(4)-C(41) and Os(4)-Os(2)-C(21) planes is 51.1(9)° and the C(21)•••C(41) distance is 2.87(2)Å. This distance is considered a 'close contact' since the van der Waals radius of carbon, if taken as half the interplanar distance in graphite, is 1.67Å.[196]

The hydride ligands in 3 were not located in the X-ray diffraction investigation, however, the ^1H NMR spectrum had two signals in the bridging hydride region, a doublet of doublets at

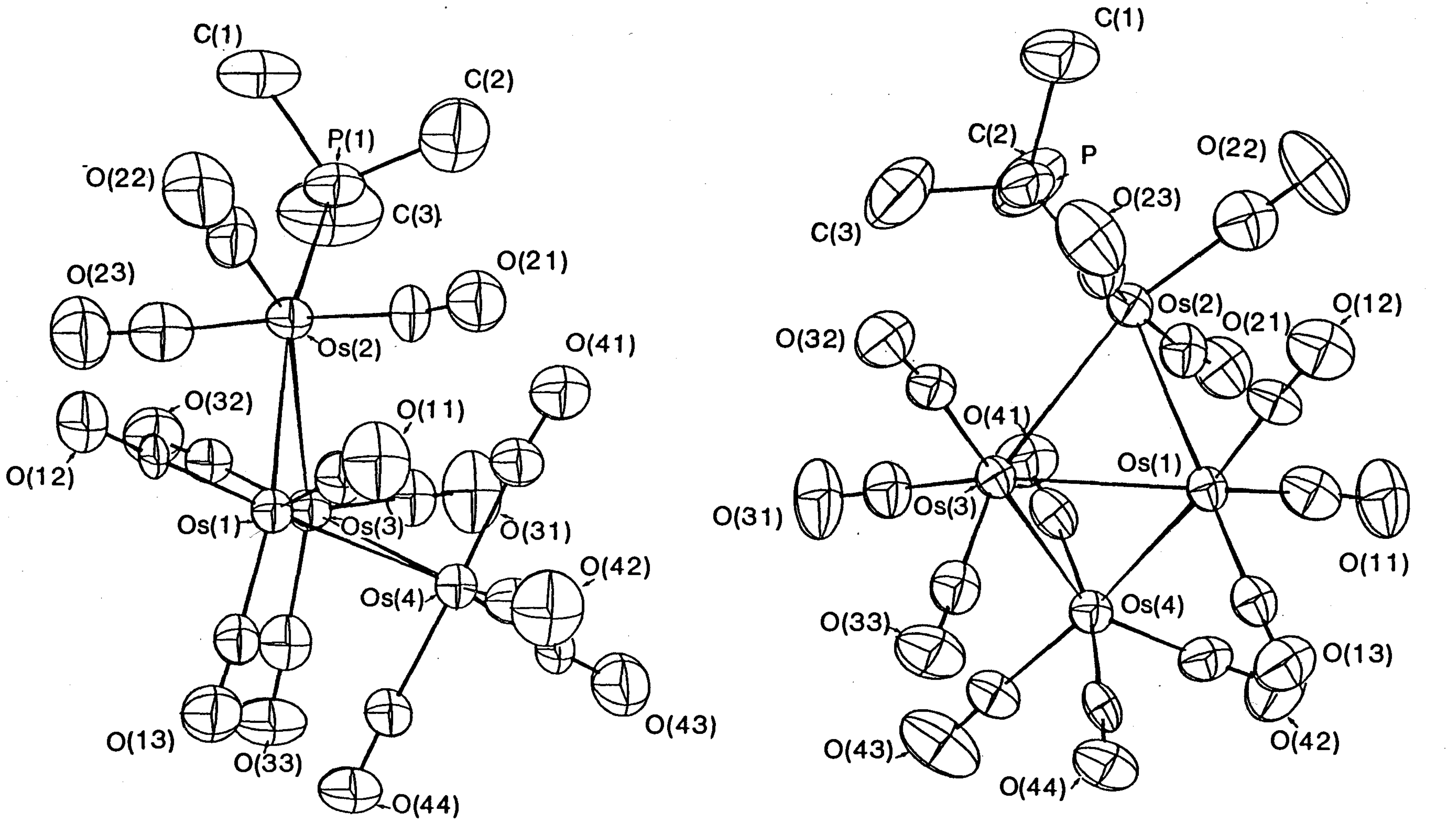


Figure B.2.12. Thermal Ellipsoid Diagrams for $(\mu\text{-H})_2Os_4(CO)_{13}PMe_3$.

Table B.2.3. Selected Molecular Dimensions for $(\mu\text{-H})_2Os_4(CO)_{13}PMe_3$

a)Bond Lengths

Bond	Length (Å)	Bond	Length (Å)
Os(1)-Os(2)	2.868(1)	Os(4)-C(43)	1.90(2)
Os(1)-Os(3)	2.886(1)	Os(4)-C(44)	1.94(2)
Os(1)-Os(4)	2.939(1)	P(1)-C(1)	1.82(2)
Os(2)-Os(3)	3.115(1)	P(1)-C(2)	1.79(3)
Os(3)-Os(4)	2.850(1)	P(1)-C(3)	1.80(3)
Os(2)-P(1)	2.342(4)	C(11)-O(11)	1.17(3)
Os(1)-C(11)	1.86(2)	C(12)-O(12)	1.15(2)
Os(1)-C(12)	1.87(1)	C(13)-O(13)	1.12(2)
Os(1)-C(13)	1.91(2)	C(21)-O(21)	1.14(2)
Os(2)-C(21)	1.94(2)	C(22)-O(22)	1.13(3)
Os(2)-C(22)	1.93(2)	C(23)-O(23)	1.16(2)
Os(2)-C(23)	1.91(2)	C(31)-O(31)	1.15(2)
Os(3)-C(31)	1.89(2)	C(32)-O(32)	1.13(2)
Os(3)-C(32)	1.93(2)	C(33)-O(33)	1.13(3)
Os(3)-C(33)	1.89(2)	C(41)-O(41)	1.15(2)
Os(4)-C(41)	1.92(2)	C(42)-O(42)	1.15(2)
Os(4)-C(42)	1.89(2)	C(43)-O(43)	1.13(2)
		C(44)-O(44)	1.16(2)

b)Bond Angles (°)

Bond	Angle (°)	Bond	Angle (°)
Os(2)-Os(1)-Os(3)	65.56(2)	Os(2)-Os(1)-C(13)	170.1(5)
Os(2)-Os(1)-Os(4)	94.86(3)	Os(1)-Os(2)-C(22)	100.6(5)
Os(3)-Os(1)-Os(4)	58.59(3)	Os(3)-Os(2)-P(1)	106.4(1)
Os(1)-Os(2)-Os(3)	57.48(2)	Os(2)-Os(3)-C(31)	110.1(6)
Os(2)-Os(3)-Os(1)	56.96(2)	Os(2)-Os(3)-C(32)	89.4(5)
Os(2)-Os(3)-Os(4)	91.50(3)	Os(2)-Os(3)-C(33)	158.8(6)
Os(1)-Os(3)-Os(4)	61.64(3)	Os(3)-Os(4)-C(43)	107.8(5)
Os(3)-Os(4)-Os(1)	59.77(2)	Os(1)-Os(4)-C(42)	91.9(5)
C(21)-Os(2)-C(23)	169.1(7)	Os(2)-P(1)-C(1)	113.3(9)
C(41)-Os(4)-C(44)	168.4(7)	Os(2)-P(1)-C(2)	114.6(7)
Os(2)-Os(1)-C(11)	93.7(6)	Os(2)-P(1)-C(3)	116.2(8)
Os(2)-Os(1)-C(12)	81.0(5)		

δ=-20.4 ppm, H_A, (J_{H-H}=1.23Hz and J_{P-H}=10.2 Hz) and an unresolved doublet at δ=-18.3 ppm, H_B. The small J_{P-H} value is consistent with H_A bridging the Os(2)-Os(3) vector, i.e., cis to the PMe_3 ligand. Trans J_{P-H} values are of the order of 150 Hz.[197,198,199] Consistent with this positioning is the Os(2)-Os(3) distance which is extremely long, 3.115(1)Å. Long Os-Os vectors have been previously associated with $Os(\mu\text{-}H)Os$ configurations as in $H_2Os_3(CO)_{11}$ which has an H-bridged Os-Os vector of 2.9886(9)Å.[179] Other long Os-Os vectors that are H-bridged have been noted for the butterfly clusters $H_3Os_4(CO)_{12}(NCMe)_2$ in which the bridged Os-Os distances are

3.130(2)Å, 3.145(2)Å and 2.937(2)Å,[104] and $H_3Os_4(CO)_{12}I$ in which the bridged Os-Os distances are 3.055(1)Å and 2.927(2)Å[117]

The location of the second bridging hydrogen cannot be determined unambiguously. There are no other Os-Os vectors which, by being conspicuously long, would indicate the presence of an Os(μ-H)Os linkage. Since the two hydrogens are coupled H_B probably bridges either the Os(1)-Os(3) or the Os(3)-Os(4) vector. The Os(1)-Os(3) distance is significantly longer, i.e., 2.886(1)Å cf. 2.850(1)Å, and therefore this position is favoured, i.e., H_B bridges the hinge. It should be noted however, that the Os-Os distance assigned to this Os(μ-H)Os grouping is very short. Further evidence in support of the positioning of this hydride is presented in the section on the ^{13}C NMR spectra of this complex.

The position of bridging hydride ligands can sometimes be inferred from the distortion of M-M-CO angles cis to the hydride bridge.[178] For this compound, however, it was thought that such distortion could be a result of the skewing of the CO(21) and CO(41) ligands noted earlier. If this were the case the displacement of the CO ligands could not be relied upon to indicate the position of the hydride ligands.

Comparison of the isolectronic structures 2 and 3 leads to the question of why 2 is planar but 3 is bent, or more generally, 'What determines the dihedral angle of such compounds?' As indicated earlier, we believe the answer lies in

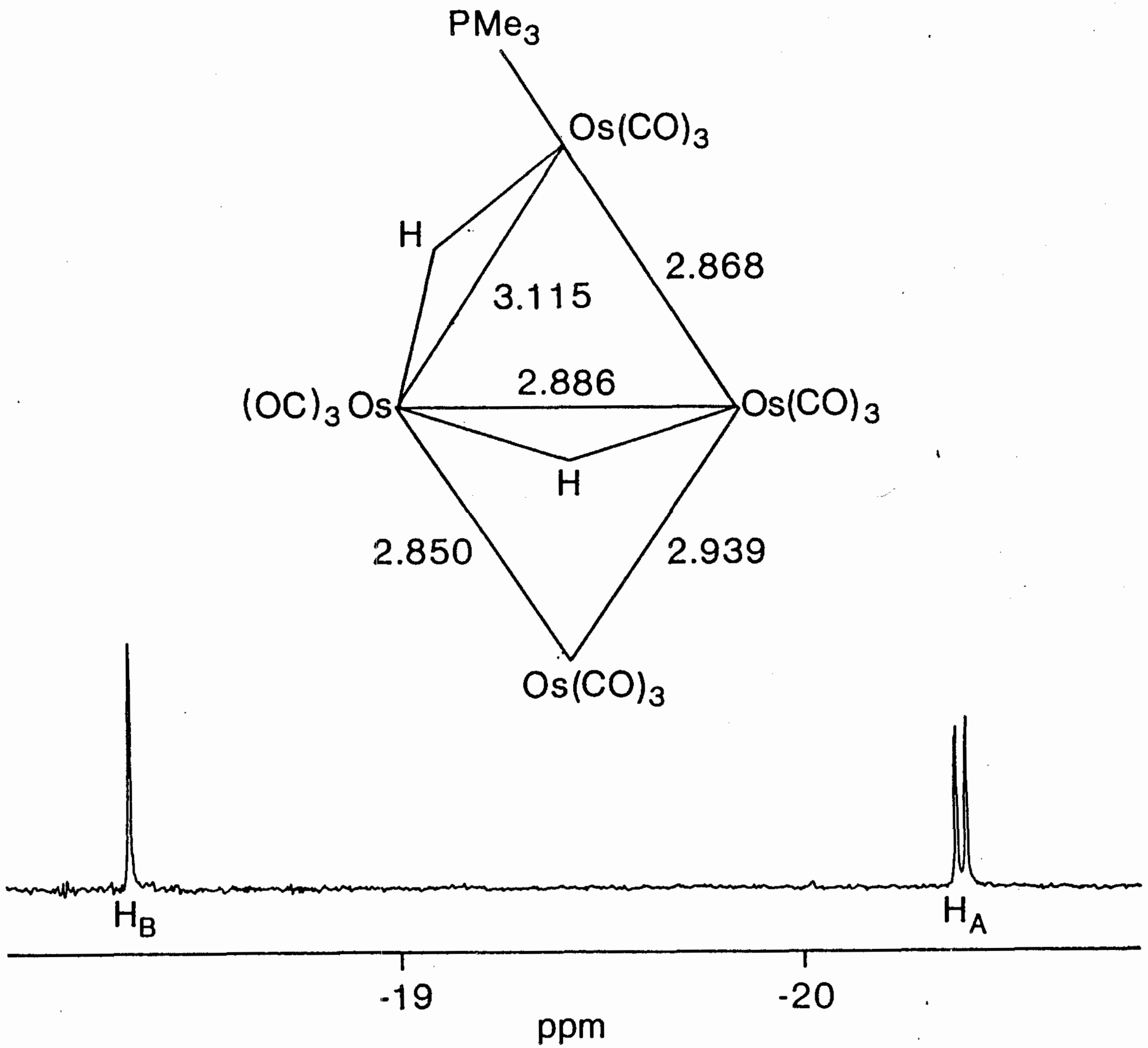


Figure B.2.13. ^1H NMR Spectrum and Hydride Ligand Positions for $(\mu\text{-}H)_2Os_4(CO)_{13}PMe_3$.

the presence and position of bridging ligands. Two other flat 62 electron clusters are known, $ReOs_3H(CO)_{15}$ and $[Re_4(CO)_{16}]^{2-}$; both lack bridging ligands.[108,200] The same is true for the larger planar structures $Os_5(CO)_{19}$[201] and $Os_5(CO)_{17}[P(OMe)_3]_4$.[202] On the other hand the twenty-three butterfly clusters listed in Table B.1.2 all have a bridging ligand across the hinge, across the wing-tips, or both. Some flat 62 or 64 electron structures with bridging ligands are known, but these bridges are either on a face or along a peripheral edge.

It is easy to understand that the wing-tips must be drawn closer together when bridged, otherwise the distance between them would be too long for bonding with the bridging ligand to take place. The Os(2)-Os(4) distance in 2, for example, is 4.962(3)Å, while typical wing-tip spans in $[Os_4(CO)_{12}(\mu_4\text{-}N)]^-$ and $[(\mu\text{-}H)_4Os_4(CO)_{12}(\mu\text{-}OH)]^+$ are 3.903Å[158] and 3.537Å,[161] respectively. Bending at the hinge allows the wing-tip osmiums to maintain pseudo-octahedral geometry in that the bridge atom-wing-tip osmium-terminal carbonyl angle is close to 180°. Such angles in $(\mu\text{-}H)_3Os_4I(CO)_{13}$ and $[(\mu\text{-}H)_4Os_4(CO)_{12}OH]^+$ are 172.5(1)° and 174.2(4)° respectively.[117,161] (The geometry is only pseudo-octahedral because the angles of the osmium triangles must be approximately 60°.)

Similar maintenance of nearly octahedral geometry occurs for the hinge osmium atoms if they are bridged by a hydride ligand, as is often the case. Such M-μH-M' configurations are often

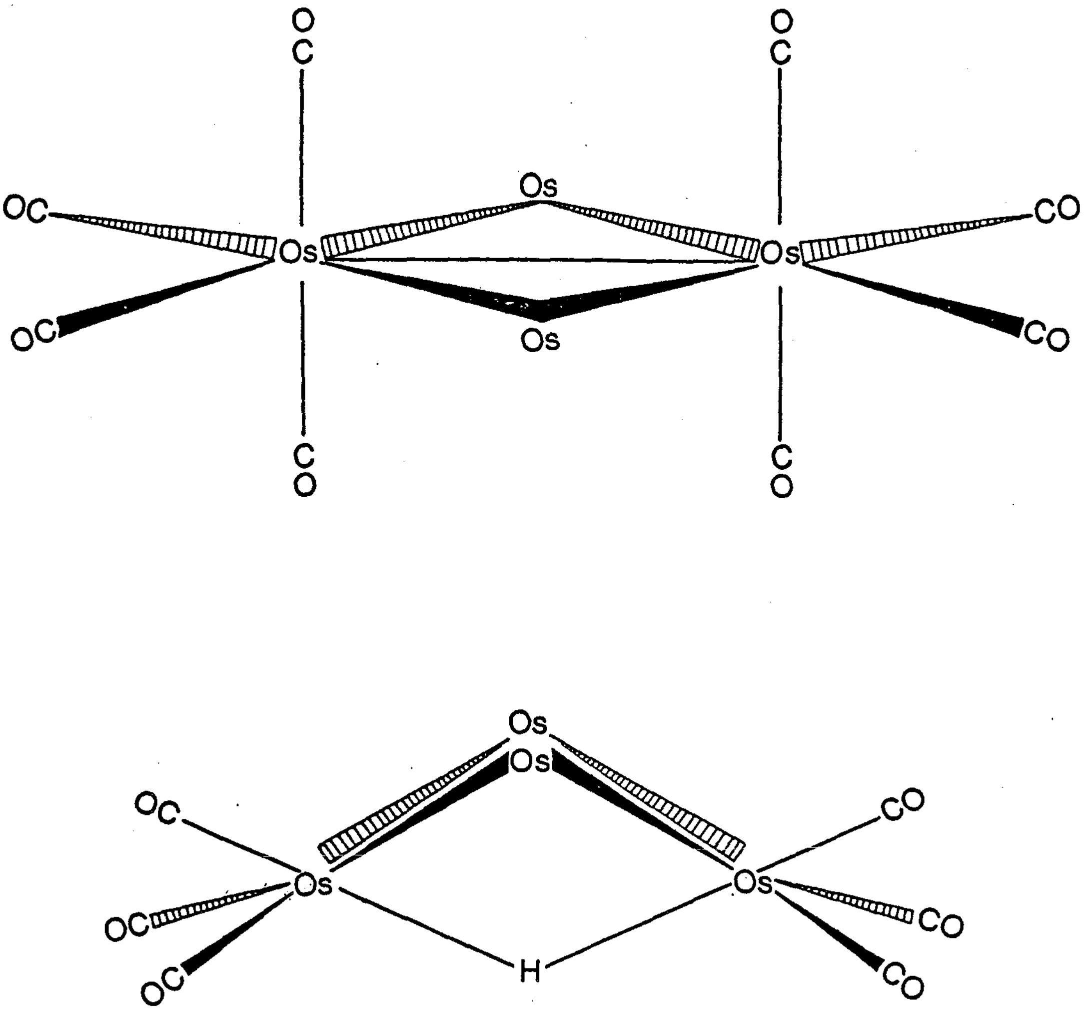


Figure B.2.14. Octahedral Geometry of the Hinge Vertices of Butterfly Structures.

represented as three-centre-two-electron bonds with little or no direct metal-metal interaction.[203,204] Octahedral geometry can be maintained at the hinge vertices if the terminal ligands are bonded trans and cis to the bridging hydride. Only by bending can a butterfly achieve this, otherwise the terminal ligands must make very small angles with each other or the peripheral M-M vectors. In $(\mu\text{-H})_3Os_4I(CO)_{13}$, the hydride ligands were located by neutron diffraction, and the H(2)-Os(2)-C(22) i.e., $\mu\text{-H-M-CO}_{trans}$ angle is 172.5(1)°.[117] The octahedral geometry must be energetically favoured otherwise the bending of the Os_4 framework in 3 would be prevented by the steric interaction between C(21) and C(41), noted earlier.

We conclude that it is the wing-tip or hinge bridging ligands that force the metal framework to adopt a butterfly geometry; if neither is present the molecule will be flat. The electronic and steric properties of the hinge or wing-tip bridge ligands may determine the exact dihedral angle. In this regard, it is interesting to note that the cluster cation $[(\mu\text{-H})_3Os_4(CO)_{12}(NCMe)_2]^+$ which has a similar structure to 3 in that the hinge is hydrogen bridged but the wing-tips are not connected, has a dihedral angle of 112.2°, very close to that of 3.[104]

2.3.2 ^{13}C NMR Studies

Unlike the other complexes in this study, 3 does not appear to undergo rapid ligand exchange at temperatures close to ambient. A $^{13}C\{^1H\}$ NMR spectrum run on a ^{13}CO enriched sample of 3 held at 0 °C revealed thirteen sharp resonances, as expected from the solid state structure (Figure B.2.15). It is possible that the bridging hydrogens block the carbonyl ligand exchange. The peaks of low intensity at $\delta=190.3$ and $\delta=188.0$ ppm can be assigned to the pseudo-axial carbonyls on Os(2), consistent with previous assignments of low field signals to axial carbonyls in planar osmium clusters.[102,185,186] The low intensity of these signals is due to unresolved coupling to the phosphorus atom. The low field signals at $\delta=191.3$ and 186.7 ppm were tentatively assigned to the pseudo-axial carbonyls on Os(4), but the origin of the other peaks could not be unambiguously determined.

In order to help determine the position of the bridging hydrogens, gated and selectively hydrogen decoupled ^{13}C NMR spectra were obtained on 3 with the sample at 0 °C. The gated spectrum showed that the three carbon peaks at $\delta=175.5$, 174.4 and 171.4 ppm exhibited coupling to hydrogen. The peak at $\delta=176.8$ ppm was reduced in intensity from that in the $^{13}C\{^1H\}$ spectrum of 3. Selective decoupling of H_A at -20.4 ppm gave a singlet signal at $\delta=174.4$ ppm, while the signal at $\delta=176.8$ ppm sharpened marginally. The same procedure applied to H_B at -18.3 ppm resulted in singlets for the $\delta=175.5$ and 171.4 ppm

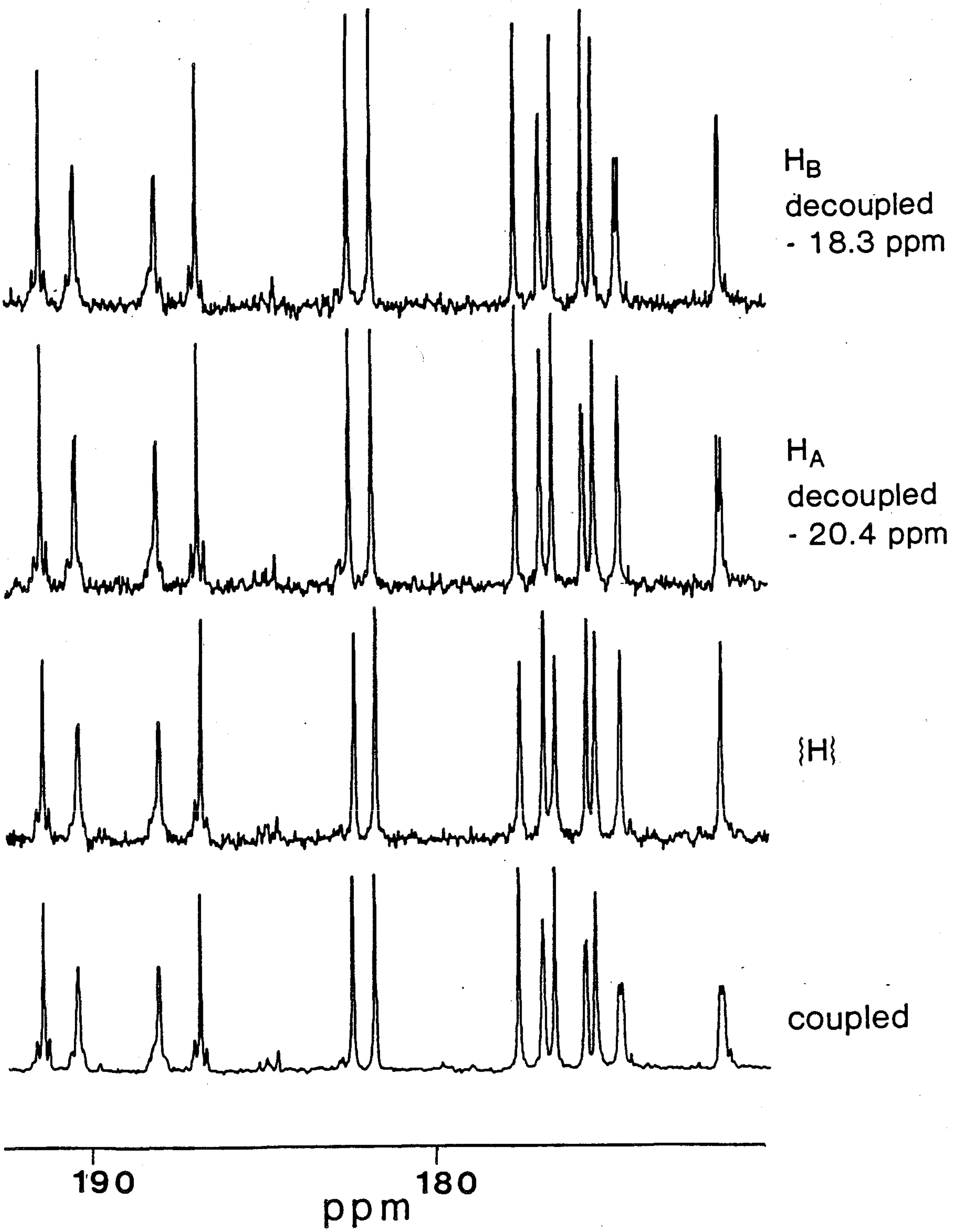


Figure B.2.15. ^{13}C NMR Spectra for $(\mu\text{-H})_2Os_4(CO)_{13}PMe_3$

resonances, see Figure B.2.15. The data are consistent with the presence of the bridging hydrides along the Os(2)-Os(3) (H_A) and Os(1)-Os(3) (H_B) vectors, except that the weakness of the coupling of H_A to one of the carbonyl signals is not explained. Placement of H_A along the Os(1)-Os(2) vector would explain why it shows strong coupling to only one carbonyl but then it would be expected to exhibit strong trans coupling to the phosphorus atom, which is not observed.

An alternative position of H_B, i.e., along the Os(3)-Os(4) vector, is also in accord with with the observed H-C couplings, but this location is not consistent with the length of the Os(3)-Os(4) vector which is only 2.850(1)Å. Placement of H_B along the much longer Os(1)-Os(4) vector (2.939(1)Å) is ruled out because the two hydrogen signals are coupled in the ^1H NMR spectrum.

2.4 $Os_4(CO)_{13}PMe_3$

2.4.1 Structure and Bonding

The major stimulus for investigating the structure of $Os_4(CO)_{13}PMe_3$ (4) was the desire to examine the validity of the scheme of structural changes that occur with sequential ligand loss. It can be seen, however, from Figure B.2.16 and Table B.2.4 that this complex has several interesting aspects in its own right. As expected, the metal atom framework consists of a tetrahedron, but the vertices are more unusual: one $Os(CO)_3PMe_3$

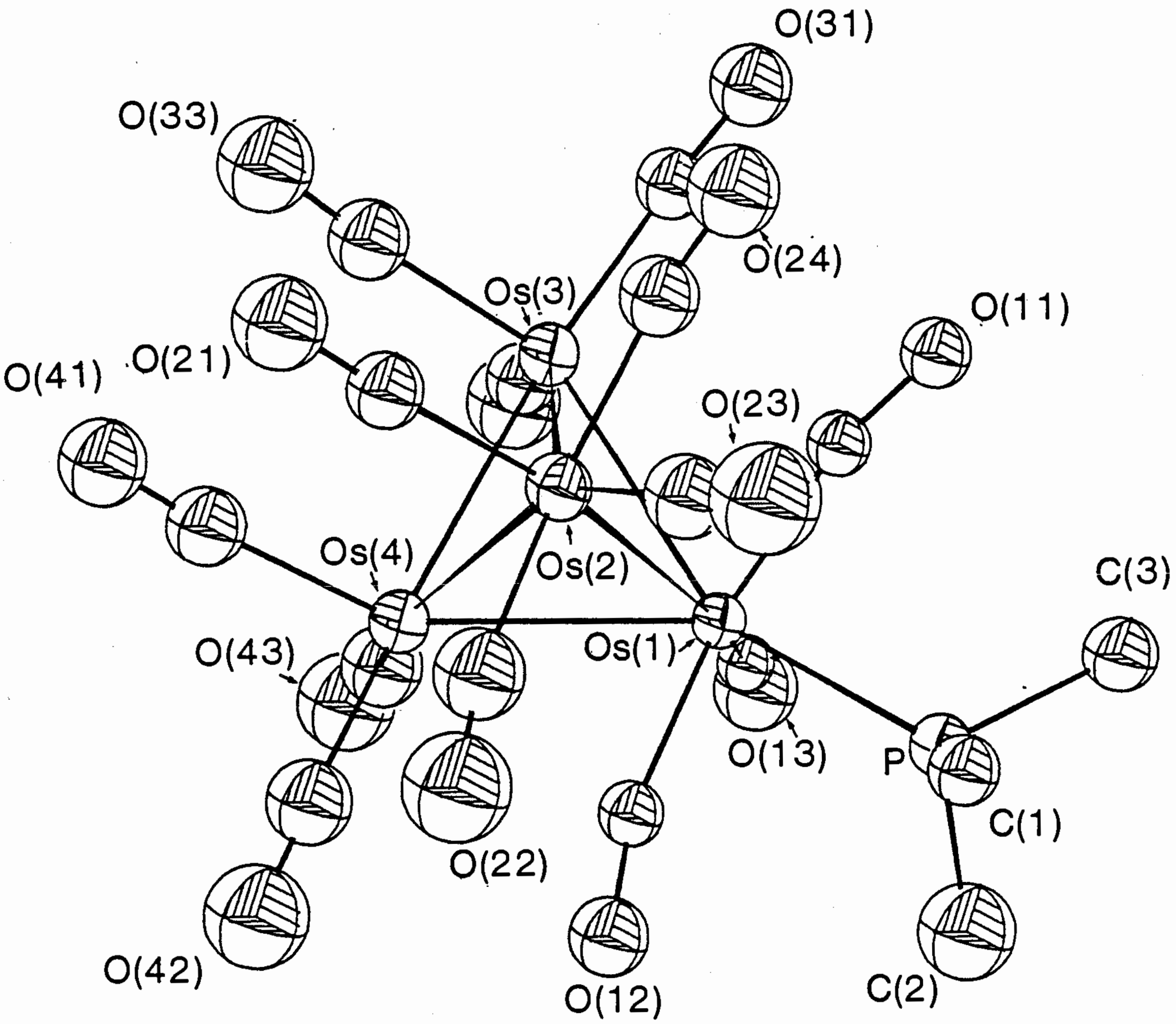


Figure B.2.16. Thermal Ellipsoid Diagram for $Os_4(CO)_{13}PMe_3$.

Table B.2.4. Selected Molecular Dimensions for $Os_4(CO)_{13}PMe_3$.

a)Bond Lengths.

Atoms	Bond Length (Å)	Atoms	Bond Length (Å)
Os(1)-Os(2)	2.861(2)	Os(4)-C(42)	1.88(3)
Os(1)-Os(3)	2.831(1)	Os(4)-C(43)	1.89(3)
Os(1)-Os(4)	2.842(1)	P(1)-C(1)	1.73(3)
Os(2)-Os(3)	2.857(2)	P(1)-C(2)	1.83(3)
Os(2)-Os(4)	2.869(1)	P(1)-C(3)	1.85(3)
Os(3)-Os(4)	2.765(1)	C(11)-O(11)	1.18(3)
Os(1)-P(1)	2.361(6)	C(12)-O(12)	1.15(3)
Os(1)-C(11)	1.91(2)	C(13)-O(13)	1.20(3)
Os(1)-C(12)	1.92(3)	C(21)-O(21)	1.17(4)
Os(1)-C(13)	1.87(2)	C(22)-O(22)	1.17(5)
Os(2)-C(21)	1.90(3)	C(23)-O(23)	1.13(4)
Os(2)-C(22)	1.87(4)	C(24)-O(24)	1.17(4)
Os(2)-C(23)	1.92(3)	C(31)-O(31)	1.15(3)
Os(2)-C(24)	1.94(3)	C(32)-O(32)	1.17(4)
Os(3)-C(31)	1.89(3)	C(33)-O(33)	1.12(4)
Os(3)-C(32)	1.85(3)	C(41)-O(41)	1.07(4)
Os(3)-C(33)	1.90(3)	C(42)-O(42)	1.18(4)
Os(4)-C(41)	1.90(3)	C(43)-O(43)	1.16(4)

b)Weak Interactions

Atoms	Distance Å
Os(3)--C(11)	2.73(2)
Os(3)--C(24)	2.57(3)
Os(4)--C(12)	2.68(2)
Os(4)--C(22)	2.80(4)

c)Bond Angles

Bonds	Angle (°)	Bonds	Angle (°)
Os(2)-Os(1)-Os(3)	60.24(4)	Os(4)-Os(2)-C(21)	94.4(8)
Os(2)-Os(1)-Os(4)	60.41(4)	Os(4)-Os(2)-C(22)	69(1)
Os(3)-Os(1)-Os(4)	58.34(3)	Os(3)-Os(2)-C(24)	61.2(9)
Os(1)-Os(2)-Os(3)	59.35(4)	Os(1)-Os(2)-C(23)	108(1)
Os(1)-Os(2)-Os(4)	59.45(4)	Os(4)-Os(1)-C(12)	65.3(7)
Os(3)-Os(2)-Os(4)	57.75(4)	Os(2)-Os(3)-C(32)	148.3(8)
Os(1)-Os(3)-Os(2)	60.41(4)	Os(4)-Os(3)-C(33)	92.1(9)
Os(1)-Os(3)-Os(4)	61.02(3)	Os(1)-Os(3)-C(31)	112.5(8)
Os(2)-Os(3)-Os(4)	61.35(4)	Os(2)-Os(4)-C(43)	150(1)
Os(1)-Os(4)-Os(2)	60.14(4)	Os(3)-Os(4)-C(41)	93.7(9)
Os(1)-Os(4)-Os(3)	60.64(3)	Os(1)-Os(4)-C(42)	115(1)
Os(2)-Os(4)-Os(3)	60.90(4)	Os(1)-P(1)-C(1)	117(1)
Os(2)-Os(1)-P(1)	111.8(2)	Os(1)-P(1)-C(2)	113(1)
Os(3)-Os(1)-C(11)	66.9(7)	Os(1)-P(1)-C(3)	115(1)
Os(2)-Os(1)-C(13)	152.4(7)		

fragment, one $Os(CO)_4$ fragment and two $Os(CO)_3$ fragments. This appears to be the first recorded example of a closed polyhedron having two vertices with four terminal two-electron donor ligands. In contrast to the prediction of Mingos and Evans[122] neither steric nor electronic effects appear to make this compound unstable. It can be stored under N_2, at room temperature, for several months without decomposition. Indeed, the other compounds **1** and **2** showed loss of CO under the ionization conditions of mass spectroscopy while **4** did not, indicating it may be the most stable of the three. Complex **4** has the highest melting point of the series, 183 °C (see Table B.2.5.) Further evidence of stability comes from the Os-Os bond lengths. The shortest Os-Os bond [Os(3)-Os(4), 2.765(1)Å] is between the two $Os(CO)_3$ fragments, while the other five bonds are all within 0.02Å of their mean value of 2.852Å. Churchill has pointed out that such values should be compared to similar unbridged bond lengths in other tetrahedra.[205] The complex $H_2Os_3Co(CO)_{16}(\eta^5\text{-}C_5H_5)$[205] for example, has an unbridged Os-Os bond between two $Os(CO)_3$ fragments, of 2.778(1)A°, similar to the Os(3)-Os(4) bond length determined here. The cluster $[H_2Os_4(CO)_{12}]^{2-}$ has unbridged Os-Os bonds of 2.797(2), 2.811(2), 2.792(2) and 2.792(2)Å,[206] while those in $[HOs_4(CO)_{13}]^-$ are 2.817(2), 2.807(2), 2.773(2) and 2.774(2)Å.[138] The unique inequivalent unbridged Os-Os distance in the neutral complex $H_2Os_4(CO)_{11}CNMe$ is 2.822(1)Å.[145] The bonds involving the $Os(CO)_4$ and $Os(CO)_3PMe_3$ fragments in **4** are significantlty longer than any of these lengths, perhaps reflecting their diminished cluster bonding capacity, relative to that of an $Os(CO)_3$ fragment. However, the differences are not so great as to imply any of the Os-Os bonds in **4** are particularly weak. The crystallographically inequivalent bonds in $Os_5(CO)_{16}$ which involve the $Os(CO)_4$ fragment are significantly longer at 2.889(3)Å and 2.866(4)Å.[116] One might predict the Os(1)-Os(2) bond in **4** to be especially lengthened since both osmium atoms have four ligands, but it is not particularly long at 2.861(2)Å.

In agreement with Mingos and Evans' calculations,[122] the OsL_4 fragments maintain nearly C_{2v} symmetry and there exists evidence for weakly semi-bridging interactions between four of the carbon atoms bonded to Os(1) and Os(2) and neighbouring osmium atoms [Os(3)···C(11)=2.73(2)Å, Os(3)···C(24)=2.57(3)Å, Os(4)···C(12)=2.68(2)Å and Os(4)···C(22)=2.80(4)Å; the corresponding Os-C-O angles are listed in Table B.2.4.] These semi-bridging interactions, however weak, add to the overall stability of the complex. As Mingos noted, such interactions have been previously observed in $Os_5(CO)_{16}$,[116] $(\mu\text{-H})_2Ru_4(CO)_{13}$[133] and $(\mu\text{-H})_2FeRu_3(CO)_{13}$.[130] It is of interest that other similar structures such as $[(\mu\text{-H})Os_4(CO)_{13}]^-$[138] and $(\mu\text{-H})_2FeOs_3(CO)_{13}$[207] have fully bridging CO ligands rather than $M(CO)_4$ vertices, but the reasons for such variation in structure are not understood.

It can be seen that PSEPT in its more sophisticated form is applicable to this complex, in spite of the fact that its ability to exist was questioned. Predictions regarding the symmetry of OsL_4 vertices, their weakly semi-bridging interactions and the relative strength of the metal framework bonds are all in accord with the results determined here.[122] While a bonding scheme of the osmium carbonyl cluster $Os_4(CO)_{14}$, which would be analogous to 4 was not developed by Mingos and Evans, there can be little doubt such calculations would result in the prediction of six cluster bonding orbitals containing twelve electrons.

We have used the isolobal analogy to develop a simple localized bonding picture for 4.[124] According to this approach, the $Os(CO)_3$ fragments, which have a total coordination of six, contribute three orbitals containing two electrons to the cluster, while the other two fragments, $Os(CO)_4$ and $Os(CO)_3PMe_3$, which are seven coordinate contribute three orbitals containing four electrons. Thus the resonance structures shown in Figure B.2.16 may be proposed for 4, in which each osmium atom achieves an 18 electron configuration. The model shows donor-acceptor bonds from the vertices having four ligands to those having three. The expectation that these bonds would be slightly longer than normal covalent bonds is in accord with the lengths determined here. The electron density built up on Os(3) and Os(4) is relieved by the semi-bridging action of the carbonyl ligands.

The main difference between this approach and PSEPT is the assumption that the frontier orbitals are almost degenerate rather that separated by an energy gap large enough to maintain the electrons in pairs. This difference is minor especially in view of the fact that the EHMO method, on which both the isolobal analogy and PSEPT are based, is well known to be subject to error regarding the computed energy levels of the orbitals. Hence, there is no strong reason to prefer one model over the other.

2.4.2 Fluxional Properties

Variable temperature ^{13}C NMR spectra revealed that the barrier to internuclear carbonyl exchange is very low in **4**. The room temperature spectrum had only one resonance, a sharp singlet at δ=181.1 ppm. This signal shifted slightly upfield as the sample was cooled; at -125 °C, the lowest temperature

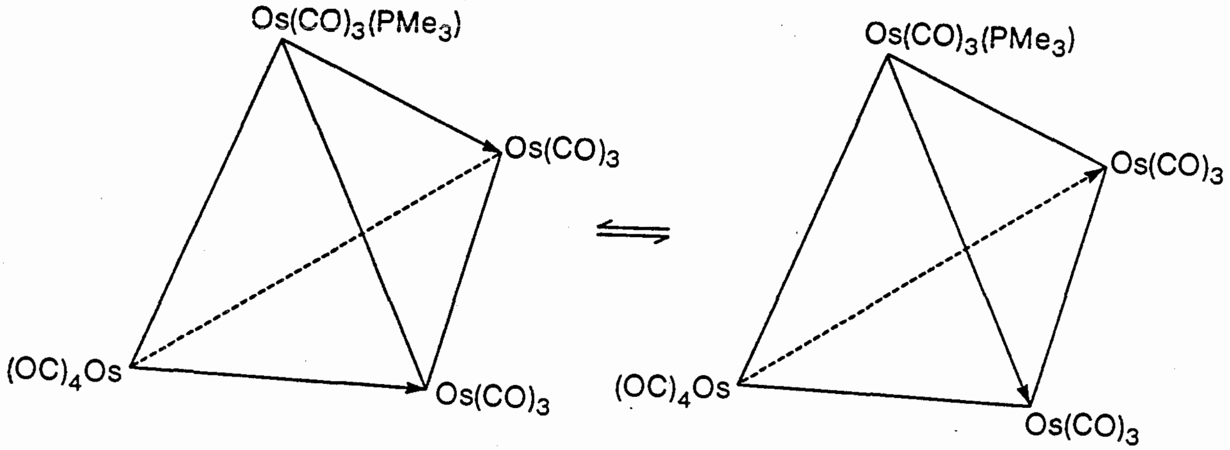


Figure B.2.17. Possible Resonance Structures for $Os_4(CO)_{13}PMe_3$.

attained, the peak was at δ=179 ppm, and was considerably broadened (Figure B.2.17). These data are consistent with rapid exchange of all carbonyl ligands on the four osmium atoms probably via a bridge-terminal mechanism. Local exchange at separate vertices is not ruled out, but must occur in conjunction with internuclear exchange if the existence of only one carbonyl signal is to be explained. It is probable that the weak semi-bridging interactions between non-bonded Os and C atoms facilitate bridge-terminal carbonyl exchange.

When the sample was cooled to -91 °C, two other small peaks at δ=202.0 and 195.2 ppm appeared in the spectrum. The spectrum obtained with the sample at -125 °C had a total of ten additional peaks, all of which were attributable to complex **2**. Compound **4** is almost certainly not reverting back to **2** at this temperature. Rather it is probable that the two complexes were both present in solution because they were not completely separated during synthesis. Pure samples of **4** were obtained by chromatography on a silica gel column, a procedure which required that the column eluent be monitored by IR spectroscopy because the bands due to **2** and **4** overlapped somewhat. This was very difficult with samples that had been enriched with ^{13}CO because of the large number of CO stretches. The reason that the signals due to **2** did not appear in the higher temperature ^{13}C spectrum is that this complex was present in only trace amounts in the sample. The presence of sharp resonances due to **2** in the spectrum taken with the sample at -125 °C confirms that

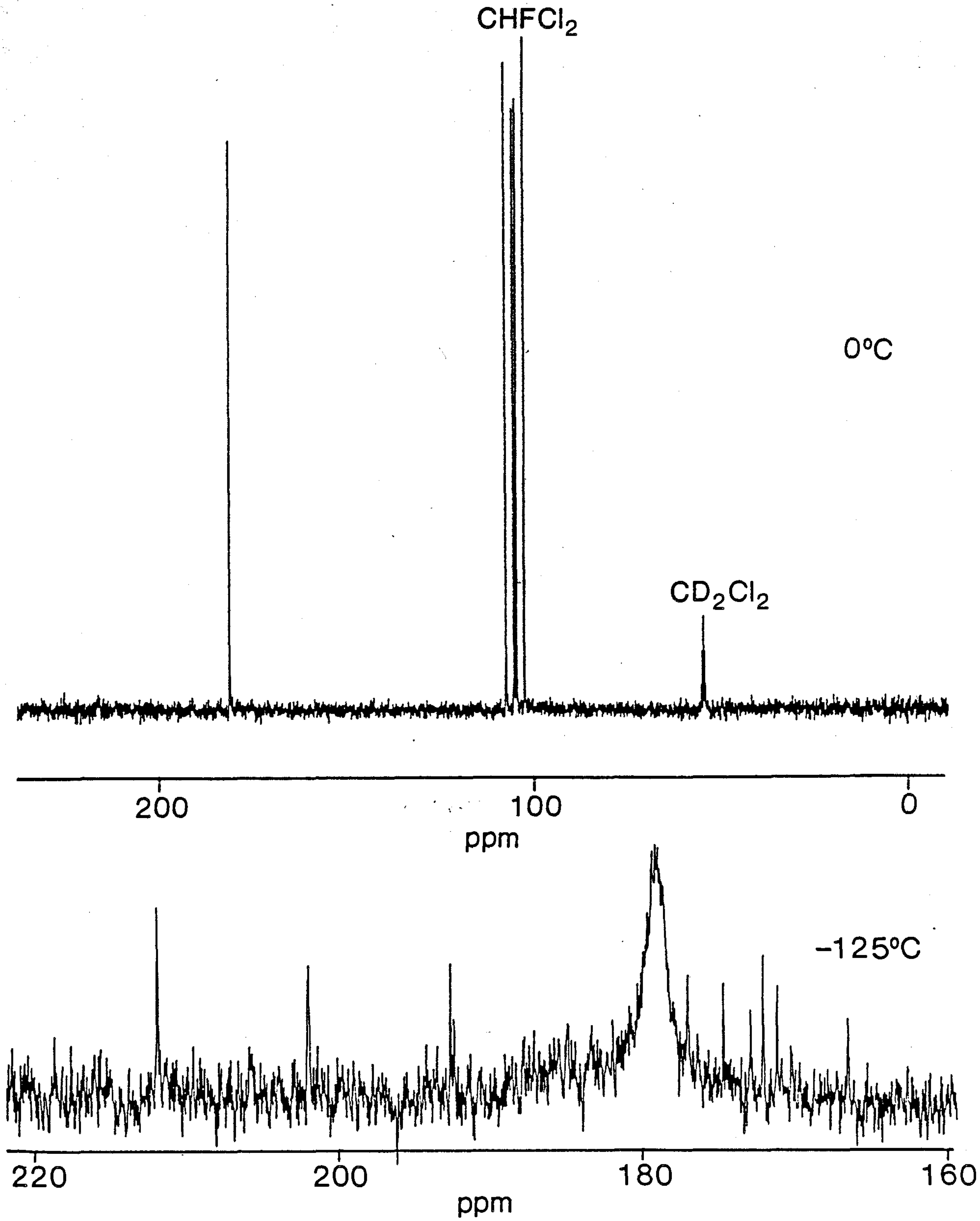


Figure B.2.18. ^{13}C NMR Spectra of $Os_4(CO)_{13}PMe_3$. (The scale is expanded on the lower spectrum.)

the broadening of the signal due to **4** was indeed due to slowed exchange and not to loss of field homogeneity of the spectrometer or solvent viscosity.

2.5 Summary and Conclusions

The $Os_4(CO)_nPMe_3$ (n=15,14,13) series constitutes the first fully characterized example where a 64 electron complex displays sequential ligand loss to 62 and then to a 60 electron species. The gross skeletal features of each of the three clusters conforms to that predicted by the current bonding theories. Nevertheless, many of the details of the structures are unexpected. The 64 electron species $Os_4(CO)_{15}PMe_3$ (1) has a dative covalent metal-metal bond, i.e., $Os(CO)_4PMe_3$ acts as a two electron donor ligand in the cluster. The bonding is best described in terms of a triangular cluster with twelve two electron donor ligands, one of which is unusual.

Unlike most 62 electron species, $Os_4(CO)_{14}PMe_3$ (2) is flat, and its perpheral framework is asymmetric. A novel bonding model involving Os-Os bond orders of 1.5 and 0.5 has been proposed to account for the unusual bond lengths. Similar non-integral bond orders may be applicable to other osmium clusters that have Os-Os bonds of unusual lengths.

The structure of **2** has been compared to that of $(\mu_2\text{-}H)_2Os_4(CO)_{13}PMe_3$ (3) which has the more common butterfly framework with a dihedral angle of 112.2°. A hydrogen ligand bridging the hinge has been proposed as the reason 3 is bent.

The 60 electron tetrahedral complex $Os_4(CO)_{13}PMe_3$ (4) is stable despite a forecast to the contrary. We believe it is the first reported closed cluster with two ML_4 vertices.

As was noted earlier 4 is the most stable of the series. The rapid decomposition of 1 in solution at room temperature shows it to be the least stable. A temperature of 90 °C is necessary to cause ligand loss from 2 at a reasonable rate. The mass spectra are consistent with this ranking in that 1 and 2 show as the peaks of highest mass, ions due to the parent ion of 4^+. It may be that increased metal-metal interactions inhibit decomposition; the 'spike' osmium in 1 takes part in only one metal-metal bond while each osmium in 4 is bonded to three others. Also, complex 4 may resist further ligand loss as there is no facile framework reorganization available that can make up for the loss of two more electrons. Further CO ligand loss from 4 was not studied although it did appear that it melted without decomposition at 183 °C.

The ^{13}C NMR spectra reveal that while 3 is nearly rigid at room temperature all members of the series $Os_4(CO)_nPMe_3$ (n=15, 14, 13) undergo rapid ligand exchange. Furthermore the barrier to non-rigidity is lowered as the complexes become more compact. The low temperature limiting spectra for 1 was reached at -67 °C, for 2 at -115 °C while 4 was still fluxional at the latter temperature, which is about the lowest accessible to us.

The well known bridge-terminal carbonyl exchange mechanism accounts for the observed spectra of 1 provided that exchange involving the carbonyls of the $Os(CO)_4PMe_3$ ligand is assumed to occur concurrently with carbonyl exchange on the osmium triangle at temperatures above -26 °C. We believe the remarkable fluxional behaviour of 2 involves not only ligand exchange but skeletal rearrangement as well. The 'windshield wiper' mechanism proposed here is unique. The extremely low barrier to the non-rigidity exhibited by the tetrahedral complex 4 may be a consequence of the weak semi-bridging C-Os interactions. The lack of a low temperature limiting spectra for 4 prohibited development of a definite proposal for the ligand exchange mechanism.

There are several reasons why the bonding theories discussed in the introduction cannot predict the fine detail of these structures. Neither Lauher nor Teo take into account any ligand influence on localized bonding. The values calculated for the orbital energy levels using the EHMO method are a qualitative guide at best. Wooley has pointed out that the fundamental assumption of the EHMO method, i.e., that the resonance integral is proportional to the overlap integral, is invalid.[208] As a result, models based on EHMO calculations greatly underestimate the d orbital contribution to cluster bonding.

If accurate bonding models for osmium clusters are to be developed, relativistic effects must be considered. Drs. Malli and Arratia-Perez of this department and others have shown that the d orbitals of third row transition metals are destabilized while the s orbitals are stabilized by relativity effects.[209,210,211] As a result, there is considerable s-d orbital mixing. It is unfortunate that full relativistic calculations are currently possible only on molecules of high symmetry, but such calculations are planned for the $Os(CO)_4$ and $Os(CO)_3$ fragments.[212]

CHAPTER 3

EXPERIMENTAL PROCEDURES

3.1 Materials and Instrumentation

Unless otherwise stated, manipulations of starting materials and products were carried out under a nitrogen atmosphere using standard Schlenk techniques. Hexane was refluxed over potassium and methylene chloride over phosphorus pentoxide; they were distilled and stored under nitrogen before use. The complexes $H_2Os_3(CO)_{10}$, $Os_3(CO)_{11}MeCN$ and $Os_3(CO)_{10}(MeCN)_2$ were prepared by literature methods,[213,214,215] and $Os(CO)_4PMe_3$ was prepared as in Part A. The reagent Me_3NO was sublimed, then dissolved in MeOH before use.

Infrared spectra were obtained with a Perkin-Elmer 983 spectrophotometer; NMR spectra with a Bruker 400-MHz instrument and mass spectra with a Kratos MS-50 using a direct insertion probe at 220-250 °C and electron impact with an ionization voltage of 70eV. Microanalyses were performed by M. K. Yang of the Microanalytical Laboratory of Simon Fraser University. Analytical and mass spectral data are given in Table B.3.1. The infrared stretching frequencies in the carbonyl region, melting points and ^1H NMR resonances are listed in Table B.3.2.

Table B.3.1. Analytical and Mass Spectral Data for Os_4 Compounds.

Compound	%Calcd.		%Found		Mass Spectrum[a]
	C	H	C	H	
$Os_4(CO)_{15}PMe_3$	17.20	0.72	17.09	0.76	1202 $(P-2CO)^+$
$Os_4(CO)_{14}PMe_3$	16.60	0.74	16.84	0.67	1202 $(P-CO)^+$
$(\mu-H)_2Os_4(CO)_{13}PMe_3$	15.98	0.92	16.12	0.82	1176 $(P-CO)^+$
$Os_4(CO)_{13}PMe_3$	16.00	0.76	16.11	0.79	1202 (P^+)

[a] Most intense peak of parent ion envelope; in all cases the parent ion agreed with that simulated by computer.

3.2 Synthetic Methods

3.2.1 Preparation of $Os_4(CO)_{15}PMe_3$

METHOD I. A solution of of $H_2Os_3(CO)_{10}$ in hexane (200 mg, .27 mmol in 25 mL) was stirred at room temperature with a large excess of $Os(CO)_4PMe_3$ (230 mg, .60 mmol) for approximately 2 h. Evolved gases were allowed to escape through an oil bubbler. During this time $Os_4(CO)_{15}PMe_3$ precipitated from solution as an orange powder. The supernatant liquid was decanted and the product washed with hexane (≃3x5 mL), dried on a vacuum line and then dissolved in a minimum of hot CH_2Cl_2 (≃10 mL). Hexane was added to precipitate the product. The yield was 194 mg (.15 mmol, 57%) yield. The analytical sample was recrystallized from CH_2Cl_2.

METHOD II. A hexane solution of $Os_3(CO)_{11}MeCN$ (130 mg) and excess $Os(CO)_4PMe_3$ (55 mg), was stirred at 60 °C for 2 h. The supernatant liquid was decanted and the orange precipitate, $Os_4(CO)_{15}PMe_3$, dried on a vacuum line. The yield was about 40% and was not improved by longer reaction times.

3.2.2 Preparation of $Os_4(CO)_{14}PMe_3$

METHOD I. To a solution of $Os_4(CO)_{15}PMe_3$ in CH_2Cl_2 (typically 100 mg, .079 mmol in 25 mL), Me_3NO in MeOH was added until the infrared band at 2086 cm^{-1} had just disappeared. During this time the colour of the solution changed from orange to deep red. The solution was filtered through a short silica column (≈10x2.5 cm) and evacuated to dryness. The product was then extracted into hot hexane (3x20 mL). Removal of solvent gave the dark red crystalline product $Os_4(CO)_{14}PMe_3$; the yield was 80 mg (0.065 mmol, 80%). The analytical sample was recrystallized from hot hexane.

METHOD II. A toluene solution of $Os_3(CO)_{10}(MeCN)_2$ (≈30 mg in 10 mL) and excess $Os(CO)_4PMe_3$ (150 mg) was degassed with two freeze-thaw cycles and stirred at room temperature overnight. The solvent was removed on the vacuum line and the excess $Os(CO)_4PMe_3$ sublimed at 40 °C onto a cold water probe to leave the crude product $Os_4(CO)_{14}PMe_3$, which was purified as in Method I.

Table B.3.2. CO Stretching Frequencies, ^{1}H NMR Resonances and Melting Point Data for Os_4 Compounds.

Compound	ν CO (cm^{-1})	δ ^{1}H NMR (ppm)[a]	m p (°C)
$Os_4(CO)_{15}PMe_3$	2115vw, 2086m, 2048s, 2033s, 2005m(asym), 1974w, 1961w, 1916w(br)	0.57, (10.4)	148
$Os_4(CO)_{14}PMe_3$	2116w, 2069s, 2046m, 2035vs, 2028 (sh), 2014m, 2004w, 1986vw, 1978m, 1951vw, 1927w	0.95, (10.2)	128
$(\mu\text{-}H)_2Os_4(CO)_{13}PMe_3$	2101w, 2069s, 2052s, 2030s, 2016s, 2003s, 1985m, 1976w	1.03, (10.2)	204
$Os_4(CO)_{13}PMe_3$	2091m, 2048vs, 2016s, 1992m	1.02, (10.6)	183

[a] J_{P-H} values are in parenthesis.
[b] Infrared spectrum in CH_2Cl_2 solution.
[c] Infrared spectrum in hexane solution.

3.2.3 Preparation of $(\mu\text{-}H)_2Os_4(CO)_{13}PMe_3$

A CH_2Cl_2 solution of $H_2Os_3(CO)_{10}$ (100 mg, .12mmol in 15 mL) was stirred with a slight excess of $Os(CO)_4PMe_3$ (25 mg, .13 mmol). A solution of Me_3NO in MeOH was added dropwise until the purple colour was discharged and the infrared bands at 2094, 2074 and 2060 cm^{-1} had disappeared. The resulting red solution was then filtered through a short silica gel column (10x2.5 cm) and evacuated to dryness. The product was extracted with cold hexane (4x5 mL) and chromatographed on a silica gel column (30x2.5 cm) with 1:2 CH_2Cl_2/hexane as the eluent. The first band, a faint yellow, was not indentified. The second band, which was orange, was the product and was followed by a broad dark brown band identified as $Os_4(CO)_{14}PMe_3$. Further bands were discarded without identification. The yield was 31 mg (.025 mmol, 26%) and the analytical sample was recrystallized from a 3:4 CH_2Cl_2/hexane mixture.

3.2.4 Preparation of $Os_4(CO)_{13}PMe_3$

A hexane solution of $Os_4(CO)_{14}PMe_3$ (85 mg, .071 mmol in 20 mL) was placed in a sealed tube and degassed with two freeze-thaw cycles. It was then stirred at 90 °C for approximately 24h with frequent degassing (every 2h, when possible). The reaction was followed by infrared spectroscopy and when it appeared no further changes in the relative intensities of the CO bands were taking place the sample was cooled and chromatographed on a silica gel column (30x2.5 cm) with 9:1 hexane/CH_2Cl_2 as the eluent. The first band, (light yellow) was identified by infrared spectroscopy as $Os_3(CO)_{11}PMe_3$[182]; the second, brown-purple band was the product, and was collected in fractions as it was not well separated from the third band, $Os_4(CO)_{14}PMe_3$. Two further bands, light orange and purple, were not identified. The yield was 29 mg (.024 mmol, 34%) and the analytical sample was recrystallized from hexane.

3.3 Crystal Structure Determinations

3.3.1 General

The following procedure was followed for each of the four compounds. Details for the individual complexes are given subsequently. A crystal of suitable size (see Table B.3.3) was mounted on an Enraf-Nonius CAD4-F diffractometer. Use of the diffractometer 'Search', 'Index' and 'Transformation' routines allowed approximate cell dimensions to be assigned on the basis of 25 high θ angle reflections. The NRC 'Creduc' routine was used to check for possible alternate Bravais lattices.[98] Subsequent examination of the systematic absences and Laue symmetry allowed these particular monoclinic space groups to be determined unambiguously. The triclinic space group was confirmed during structure refinement. Diffraction data were collected at 20±1 °C using graphite monochromated Mo-$K_{\alpha 1}$ (λ=0.7930Å) radiation. Background measurements were made by

Table B.3.3. Crystallographic Data for Os_4 Compounds.

	$Os_4(CO)_{15}PMe_3$	$Os_4(CO)_{14}PMe_3$	$(\mu\text{-}H)_2Os_4(CO)_{13}PMe_3$	$Os_4(CO)_{13}PMe_3$
Formula Wt.	1258	1230	1204	1202
Colour	orange	deep red	red	burgandy
Solvent	CH_2Cl_2	hexane	hexane/CH_2Cl_2	hexane
Space Group	$P\bar{1}$	$P2_1/a$	$P2_1/n$[c]	$P2_1/c$
Crystal System	triclinic	monoclinic	monoclinic	monclinic
a, Å	12.473(2)	13.525(5)	15.541(6)	15.470(2)
b, Å	13.325(2)	12.969(6)	11.013(3)	10.193(1)
c, Å	17.547(2)	14.825(5)	16.280(4)	16.527(2)
α, deg	109.05(1)	--	--	-
β, deg	90.44(1)	99.14(3)	114.10(3)	113.452(9)
γ, deg	94.60(1)	--	--	-
V, Å^3	2745	2567	2560	2390
Z	4	4	4	4
d_{cald}, g/cm^3	3.036	3.185	3.153	3.337
μ(Mo K_α) cm^{-1}	186	199[b]	199	213
Crystal Size, mm	0.11x0.29x0.28	0.34x0.16x0.11	0.11x0.18x0.27	0.24x0.19x0.08

[a] Alternate $P2_1/c$ no.14.

[b] An emperimentally based absorption correction was applied, see text.

[c] $P2_1/n$, non-standard setting for $P2_1/c$; equivalent positions are: x,y,z; 1/2-x,1/2+y,1/2-z; -x,-y,-z; 1/2+x,1/2-y,1/2+z.

extending the scan range by 25% at each side of the scan. Monitoring of two standard relections every one or two hours revealed no significant crystal decay. A Lorentz polarization correction was applied. Accurate cell dimensions were assigned on the basis of 25 [24 for $Os_4(CO)_{15}PMe_3$ and 19 for $(\mu\text{-}H)_2Os_4(CO)_{13}PMe_3$] carefully centered high angle ($2\theta>21°$) reflections widely scattered in reciprocal space. Psi scans were run for a number of reflections (typically about six) throughout the 2θ range of data collection and having chi near 90°. Crystal faces were measured and indexed using a locally modified optical telescope with a filar eyepiece and the diffractometer 'Micros' and 'Micror' routines.

The osmium atoms were located by electron density methods and other non-hydrogen atoms by alternating Fourier difference maps with least squares refinement. Since the linear absortion coefficients were so large, $\approx 200\ cm^{-1}$, great care was taken with the absorption correction. Analytical corrections were applied to those reflections for which psi scans had been obtained and the results were compared to those of the empirical method. Small adjustments in the values of the crystal dimensions were made when necessary, to ensure that the intensity variation as determined by the analytical method matched that of the empirical method. In general, the analytical correction was preferred to the empirical one; see the following individual structure determinations for details. The strong inner data showed evidence for extinction in all four structures as $|KF_o|$ values were less than $|F_c|$ values. Extinction was added as a refinable parameter if its size, significance and the improvement in the agreement so warranted, otherwise those reflections suffering most noticeably from extinction were removed from the refinement process (see Table B.3.3).[216] Unit weights were used during the initial stages of refinement for all four structures. After anisotropic refinement the weight, ω, for each reflection was set to be $\omega=[\sigma^2(F)+KF^2]^{-1}$ and the value of K was adjusted to remove trends in the average $\omega\Delta^2$ values as a function of $|F_o|$ and $\sin\theta/\lambda$ in the error analysis. There were no significant trends in the final error analyses. In each case the largest peaks in the final Fourier difference map were in the vicinity of the osmium atoms. Crystallographic data are given in Table B.3.3 and details of data collection in Table B.3.4. Atomic scattering factors which included anomalous dispersion were taken from reference 95. Diagrams of the molecules as computed by the SNOOPI program[217] are shown in Figures B.2.1, B.2.6, B.2.10 and B.2.16. Bond lengths and angles are given in Tables B.2.1 to B.2.4. Final atomic coordinates, anisotropic thermal parameters and structure factors are listed in the appendix. The computer programs used were from "The Vax 750/780 Crystal Structure System."[98]

Table B.3.4. Data Collection Parameters for Os_4 Compounds.

	$Os_4(CO)_{15}PMe_3$	$Os_4(CO)_{14}PMe_3$	$(\mu\text{-}H)_2Os_4(CO)_{13}PMe_3$	$Os_4(CO)_{13}PMe_3$
scan method	ω-2θ	ω-2θ	ω-2θ	ω-2θ
scan range, 2θ, deg	0.0-45.0	0.0-45.0	0.0-45.0	0.0-45.0
scan width, 2θ, deg	1.3	1.3	1.3	1.3
scan rate, 2θ, deg/min	1.4-6.6	1.4-6.6	1.4-6.6	1.4-6.6
collection range	±h,±k,+l	±h,+k,+l	±h,+k,+l	±h,+k,+l
transmission coeffecient range	0.120-1.00[a]	0.0555-0.146	0.0141-0.164	0.0249-0.422
unique relections	7167	3331	3544	3104
observed reflections[b]	5172	2424	2503	2060
variables in final model	386	325	308	163
R_1[c]	0.0367	0.0385	0.0325	0.0470
R_2[d]	0.0407	0.0479	0.0380	0.0601
K factor in wt. scheme	0.0004	0.0008	0.0004	0.0006
gof	1.3508	1.3112	1.4231	1.6416
largest shift[e]	0.03	0.00	0.00	0.02
map σ e/Å^3 [f]	0.25	0.27	0.23	0.39
largest peak e/Å^3 [g]	1.55	1.59	1.79	2.18
extinction parameter($\times 10^{-8}$)[h]	22(1.3)	--	6.7(1.3)	23(2.6)

[a] Empirical absorption correction, see text.

[b] $I>2.3\sigma(I)$ except for $(\mu\text{-}H)_2Os_4(CO)_{13}PMe_3$ for which $I>3.0\ \sigma(I)$.

[c] $R_1=\Sigma||F_o|-|F_c||/\Sigma|F_o$

[d] $R_2=|\Sigma\omega(|F_o|-|F_c)^2/\Sigma\omega|F_o|^2|^{1/2}$

[e] Largest shift/error in the final cycle of refinement.

[f] Standard deviation of the final Fourier difference map.

[g] Largest peak in the final Fourier difference map.

[h] Parameter is g in the formula $F_c'=k|F_c|(1+g|F_c|^2Lp_2/p_1)^{-1/2}$ where F_c' is the corrected, calculated structure factor, k is a scale factor, Lp is the Lorentz polarization factor and $P_n=1+\cos^{2n}2\theta$.

3.3.2 $Os_4(CO)_{15}PMe_3$

After all the atoms had been located, refinement proceeded quickly with only the osmium atoms having anisotropic thermal parameters (R_1=0.082). Since the crystal had been cut to appropriate size it was necessary to define some 16 crystal faces with indexes as high as 25 in order that an analytical absorption correction[97] could be applied. Extinction was added as a refinable parameter.[96] (It was noted, in particular, that the 1,0,2 and 2,0,0 reflections had much better agreement after this proceedure)[218] (R_1=0.041). Initial positions of hydrogen atoms on the methyl carbons in each of the two molecules in the asymmetric unit were located in a Fourier difference map using inner data only. These were used to calculate the positions of the second and third hydrogen atoms of the methyl groups. This procedure was applied to five of the six methyl groups; hydrogen atoms on the sixth methyl group could not be located. In view of the difficulty in defining crystal faces it was decided to try an empirical absorption correction,[94] which proved advantageous (R_1=0.038). At this point the phosphorus and methyl carbon atoms were allowed to vary anisotropically and the weighting scheme was adjusted (R_1=0.037). Finally the structure was refined to completion using block diagonal methods and the positions of the hydrogen atoms were recalculated.

3.3.3 $Os_4(CO)_{14}PMe_3$

Isotropic refinement of all non-hydrogen atoms proceeded quickly (R_1=0.088), however correction for absorption proved difficult. The variations of intensity as measured by the psi scans were not consistent for the different reflections, nor was there any match with the analytical correction. It was not surprising, therefore, that neither the empirical[94] nor the analytical[97] correction improved the value of the residual, even though the measurement of crystal dimensions was carefully checked. Since the transmission factors for the analytical correction appeared to be too small (0.00529-0.06219) it was decided to decrease the absorption coefficient from the calculated value of 199 cm^{-1} in a systematic way. It was found that a μ value of 100 cm^{-1} gave the best results (R_1=0.064). The reason for this difficulty was very probably that the crystal had re-entrant angles making it impossible for the computer program to handle the absorption correction properly. All non-hydrogen atoms were allowed to vary anisotropically (R_1=0.0393), and then the weighting scheme was adjusted (R_1=0.039). Hydrogen atoms were included at calculated positions[219] with a single isotropic temperature (R_1=0.039). Addition of extinction as a refinable parameter did not improve the agreement and gave an unreasonably small extinction coefficient ($2.4(.26)x10^{-8}$), but four reflections were removed from the refinement as they suffered from extinction.[220] The data were then refined to completion using full matrix least squares.

3.3.4 $(\mu\text{-}H)_2Os_4(CO)_{13}PMe_3$

Full-matrix least-squares refinement with only the osmium and phosphorus atoms located and with these atoms assigned isotropic thermal parameters gave a residual (R_1) value of 0.19. Application of an analytical absorption correction greatly improved the agreement (R_1=0.11) as did location of the other non-hydrogen atoms (R_1=0.052). Anisotropic temperature factors were then added and the weighting scheme was adjusted. Methyl hydrogen atom positions were generated from initial positions located on a Fourier difference map generated using inner data only (R_1=0.036). The -2,2,2 reflection was omitted from structure refinement as it had an anomalously large $\omega\Delta^2$ value i.e., 441. (The next highest $\omega\Delta^2$ value was 74.) Because the error analysis showed the weak data had a large average $\omega\Delta^2$ it was decided to flag unobserved those reflections for which $I \leq 3\sigma(I)$. This procedure reduced the number of observed reflections from 2597 to 2503 and the residual (R_1) value to 0.033. Attempts to locate the bridging hydrogens using difference Fourier synthesis on inner data only were not successful. Final convergence was achieved using full matrix least-squares refinement.

3.3.5 $Os_4(CO)_{13}PMe_3$

Initial phasing difficulties were overcome by application of an analytical absorption correction. This was necessary because the transmission coefficients ranged from 0.0249 to 0.422. The heavy and light atoms were then easily located, and refined with anisotropic thermal parameters assigned to the osmium atoms only (R_1=0.051). At this point the phosphorus and oxygen atoms were allowed anisotropic thermal parameters and attempts were made to locate the hydrogen atoms using Fourier difference synthesis on inner data only. This proved to be a non-trivial matter. Initially only one hydrogen atom could be located. The methyl carbon atoms were allowed anisotropic parameters and two hydrogen atoms were added at calculated positions. Full matrix refinement reduced the R_1 value to 0.047. The weighting scheme was then adjusted and the -5,3,8 reflection which had an anomalously high $\omega\Delta^2$ value of 401 was eliminated from the refinement process. (No other reflection had an $\omega\Delta^2$ value greater than 150.) At this point it was possible to locate two more hydrogen positions from the difference synthesis and consequently calculate the position of the remaining four (R_1=0.046). Analysis of low angle strong data revealed several reflections having large $\omega\Delta^2$ values for which the observed structure factors were smaller than the calculated values suggesting the data might suffer from extinction. This, combined with the fact that not all thermal parameters for the oxygen and carbon atoms were well behaved led to the decision to return to isotropic parameters for these atoms. Full matrix refinement produced an R_1 value of 0.047. Addition of extinction as a refinable parameter reduced the residual R_1 to 0.045. Further investigation of the weighting scheme led to a K value of 0.0006 being assigned. A second attempt at allowing the oxygen atoms anisotropic thermal parameters was made but the results were no better than those of the first trial. It was decided to leave all oxygen and carbon atoms isotropic. The hydrogen atom positions were then recalculated and the structure was refined to completion by full matrix least squares. One large peak ($2.2e/Å^3$, 5.6σ) in the final Fourier difference map was located inside the tetrahedron of osmium atoms at a distance of 1.319(1)Å from Os(4), but there was no evidence to suggest it had any chemical significance.

APPENDIX

Supplemental Tables

Table S.1. Fractional Coordinates for Ru(CO)$_4$AsPh$_3$

ATOM	X	Y	Z	BISO
RU	0.35373(4)	0.19970(4)	0.23603(5)	4.57(2)
AS	0.20818(5)	0.31855(5)	0.13740(5)	4.18(2)
C1	0.2193(5)	0.0705(5)	0.2070(6)	6.2(3)
O1	0.1387(4)	-0.0043(4)	0.1941(5)	9.0(3)
C2	0.3699(5)	0.3512(5)	0.4186(6)	5.5(3)
O2	0.3770(4)	0.4417(4)	0.5281(4)	7.0(2)
C3	0.4571(5)	0.1771(5)	0.0764(6)	6.1(3)
O3	0.5152(4)	0.1628(5)	-0.0202(5)	8.7(3)
C4	0.4686(5)	0.1122(5)	0.3134(6)	6.4(3)
O4	0.5392(4)	0.0582(4)	0.3591(5)	9.7(3)
C11	0.1925(4)	0.2555(5)	-0.0744(5)	4.6(3)
C12	0.1768(5)	0.1237(6)	-0.1561(6)	6.3(3)
C13	0.1618(6)	0.0733(6)	-0.3085(6)	7.7(4)
C14	0.1657(6)	0.1601(8)	-0.3739(6)	8.9(6)
C15	0.1809(6)	0.2903(7)	-0.2955(7)	9.3(5)
C16	0.1940(5)	0.3399(6)	-0.1438(6)	6.7(4)
C21	0.2510(4)	0.5048(5)	0.2005(5)	4.8(3)
C22	0.1593(5)	0.5956(5)	0.2319(5)	5.4(3)
C23	0.1908(6)	0.7290(5)	0.2790(6)	6.7(4)
C24	0.3150(7)	0.7693(6)	0.2932(7)	8.2(5)
C25	0.4056(6)	0.6821(7)	0.2627(8)	9.4(5)
C26	0.3747(5)	0.5474(6)	0.2164(7)	7.3(4)
C31	0.0355(4)	0.3147(4)	0.1864(5)	4.2(2)
C32	-0.0632(5)	0.2969(6)	0.0869(6)	6.2(4)
C33	-0.1869(5)	0.2937(7)	0.1231(7)	7.5(5)
C34	-0.2120(5)	0.3095(6)	0.2592(7)	6.8(4)
C35	-0.1163(6)	0.3277(7)	0.3604(6)	8.0(5)
C36	0.0083(5)	0.3305(6)	0.3245(6)	6.7(4)
H12	0.171(4)	0.066(4)	-0.118(5)	8.(0)
H13	0.158(5)	-0.018(5)	-0.365(5)	8.(0)
H14	0.152(4)	0.126(5)	-0.461(5)	8.(0)
H15	0.178(5)	0.359(5)	-0.335(5)	8.(0)
H16	0.207(4)	0.432(4)	-0.089(5)	8.(0)
H22	0.080(4)	0.570(4)	0.221(4)	8.(0)
H23	0.128(4)	0.791(4)	0.305(5)	8.(0)
H24	0.328(4)	0.857(5)	0.332(5)	8.(0)
H25	0.479(5)	0.681(5)	0.247(5)	8.(0)
H26	0.437(4)	0.486(4)	0.189(5)	8.(0)
H32	-0.051(4)	0.286(4)	-0.001(4)	8.(0)
H33	-0.251(4)	0.289(5)	0.060(5)	8.(0)
H34	-0.294(4)	0.308(4)	0.285(5)	8.(0)
H35	-0.128(4)	0.334(4)	0.437(5)	8.(0)
H36	0.067(4)	0.347(4)	0.387(5)	8.(0)

Table S.2. Thermal Parameters for $Ru(CO)_4AsPh_3$

Atom	U_{11}	U_{22}	U_{33}	U_{12}	U_{13}	U_{23}
Ru	5.53(2)	5.80(3)	6.03(3)	0.27(2)	-0.13(2)	2.77(2)
As	5.21(3)	5.55(3)	5.12(3)	-0.02(2)	0.00(2)	2.6(3)
C1	8.4(4)	6.6(4)	8.7(4)	-0.2(3)	-1.2(3)	4.2(3)
C2	5.9(3)	7.5(4)	7.5(4)	0.0(3)	-0.5(3)	3.2(3)
C3	6.1(3)	8.7(4)	8.6(4)	1.2(3)	0.4(3)	3.9(3)
C4	8.2(3)	7.6(3)	8.3(4)	0.4(3)	-1.4(3)	2.8(3)
O1	10.9(3)	8.3(3)	14.8(4)	-2.8(2)	-1.2(3)	6.0(3)
O2	10.2(3)	8.8(3)	7.9(3)	-0.4(2)	-0.1(2)	-1.0(2)
O3	8.5(3)	14.5(4)	10.0(3)	1.5(3)	3.3(2)	5.2(3)
O4	12.5(4)	11.6(4)	12.8(4)	3.3(3)	-3.2(3)	5.5(3)
C11	4.8(3)	6.7(3)	5.6(3)	0.3(2)	0.5(2)	2.6(3)
C12	9.5(4)	8.5(4)	5.9(4)	-0.4(3)	-0.3(3)	2.3(3)
C13	12.2(5)	10.2(5)	6.8(4)	0.7(4)	0.3(4)	0.7(4)
C14	11.4(5)	16.8(7)	5.6(4)	2.3(5)	1.6(4)	3.4(4)
C15	11.2(4)	16.9(3)	8.2(5)	1.0(5)	1.8(4)	7.5(5)
C16	7.7(4)	10.4(3)	7.2(4)	0.6(3)	1.0(3)	5.0(4)
C21	6.3(3)	6.3(3)	5.6(3)	-0.4(3)	-0.8(2)	3.4(3)
C22	8.0(4)	6.2(3)	6.3(3)	-0.5(3)	-.01(3)	3.2(3)
C23	11.0(5)	6.7(4)	7.5(4)	0.2(3)	-0.8(3)	3.4(3)
C24	14.2(6)	6.4(4)	10.5(5)	-2.5(4)	-4.2(4)	4.5(4)
C25	8.4(5)	10.4(5)	17.8(5)	-2.9(4)	-3.2(4)	8.3(5)
C26	7.4(4)	7.4(4)	13.0(4)	-1.1(3)	-1.5(4)	5.8(4)
C31	6.1(3)	5.4(3)	4.4(3)	0.4(2)	0.1(2)	1.9(2)
C32	6.0(3)	11.1(5)	6.3(3)	-0.8(3)	0.4(3)	3.3(3)
C33	6.1(4)	13.5(6)	8.7(4)	-0.6(4)	0.5(3)	3.6(4)
C34	5.5(4)	10.3(5)	10.2(5)	-0.4(3)	2.2(3)	2.9(4)
C35	9.9(5)	13.5(6)	7.1(4)	0.5(4)	3.4(3)	4.4(4)
C36	7.3(4)	12.2(5)	5.9(4)	0.4(3)	0.5(3)	3.6(4)

U_{ij} values have been multiplyed be 100.

Table S.3. Bond Lengths and Angles for the Phenyl Groups of $Ru(CO)_4AsPh_3$

a) **Bond Lengths (Å).**

C(11)–C(12)	1.357(7)
C(12)–C(13)	1.392(8)
C(13)–C(14)	1.361(10)
C(14)–C(15)	1.337(10)
C(15)–C(16)	1.386(8)
C(16)–C(11)	1.368(7)
C(21)–C(22)	1.374(7)
C(22)–C(23)	1.383(7)
C(23)–C(24)	1.362(9)
C(24)–C(25)	1.339(10)
C(25)–C(26)	1.397(8)
C(26)–C(21)	1.362(7)
C(31)–C(32)	1.356(7)
C(32)–C(33)	1.383(7)
C(33)–C(34)	1.341(9)
C(34)–C(35)	1.344(9)
C(35)–C(36)	1.391(8)
C(36)–C(31)	1.366(7)

b) **Bond Angles (°)**

C(11)–C(12)–C(13)	121.3(5)
C(12)–C(13)–C(14)	118.0(6)
C(13)–C(14)–C(15)	121.6(6)
C(14)–C(15)–C(16)	120.0(6)
C(15)–C(16)–C(11)	119.9(6)
C(16)–C(11)–C(12)	119.0(5)
C(21)–C(22)–C(23)	121.1(5)
C(22)–C(23)–C(24)	118.8(5)
C(23)–C(24)–C(25)	120.9(5)
C(24)–C(25)–C(26)	120.6(6)
C(26)–C(21)–C(22)	119.1(5)
C(31)–C(32)–C(33)	121.4(5)
C(32)–C(33)–C(34)	120.3(5)
C(33)–C(34)–C(35)	119.7(5)
C(34)–C(35)–C(36)	120.3(5)
C(35)–C(36)–C(31)	120.8(5)
C(36)–C(31)–C(32)	117.6(5)

Table S.4. Structure Factors for $Ru(CO)_4AsPh_3$

```
COLUMNS ARE 10FO,10FC,  10SIG

   H   KFO    FC   SIG        H   KFO    FC   SIG        H   KFO    FC   SIG
      H,  0,  0              -6   132   123     4        2   237   242     3
   1   201   192     1       -4   249   250     3        3   496   501     3
   2   892   917     2       -3   429   435     2        4    85    84     5
   3   579   557     2       -2  1082  1088     2        5   219   214     4
   4   341   346     3       -1   870   863     2        6    68    68     7
   5   793   779     3        0   492   480     2             H,  0,  7
   6   522   535     3        1   525   527     2       -6   147   136     5
   7   695   690     3        2   218   197     2       -5   374   367     4
   9   181   165     4        3   418   414     2       -4   161   169     4
      H,  0,  1               4   374   370     3       -3   310   308     4
 -10   105   104     5        5   874   877     3       -1    84    87     5
  -9   263   264     4        6   145   149     4        1   317   318     4
  -8   490   494     4        7   331   338     4        2   374   371     4
  -7   218   231     4        9   114   111     5        3   198   207     4
  -6   529   535     3             H,  0,  4             4   199   189     4
  -4   602   594     3       -9    64    59     8             H,  0,  8
  -3   322   314     2       -8   308   299     4       -4   167   162     4
  -2  1331  1333     2       -7    80    72     5       -2    69    49     6
  -1  1328  1333     1       -6    56    60     6       -1    78    73     5
   0   636   599     1       -5   119   120     4        0   243   234     4
   1   954   924     1       -4   431   431     3        1    67    57     6
   2   613   600     2       -3   754   755     3        2   290   290     4
   3   622   624     2       -1  1067  1051     2        3    74    57     6
   4   186   178     3        0    82   101     3             H,  1, -9
   5   555   556     3        1    68    77     3        0   210   203     4
   6   459   458     3        2   296   280     3        1   137   142     5
   7   283   282     4        3   666   669     3        2   139   136     5
   8   193   197     4        4   495   500     3             H,  1, -8
   9   116   116     5        5   308   314     3       -3    74    77     6
  10    46    35    10        6   390   392     3       -2   118   117     5
      H,  0,  2               8   134   139     5       -1   337   328     4
 -10   225   223     5             H,  0,  5             0   111   115     5
  -9   135   130     5       -8   117   129     5        1   265   261     4
  -8   287   289     4       -6    66    63     6        2    88   100     5
  -7   275   293     4       -5   518   525     3        4    87    93     5
  -6   122   126     4       -4    76    76     5        5   160   158     5
  -5   245   244     3       -3   617   607     3             H,  1, -7
  -3   422   417     2       -2   310   317     3       -3   231   216     4
  -2   813   810     2        1   269   266     3       -2   429   437     4
  -1   761   733     2        2   512   511     3       -1   257   264     4
   0  1577  1571     2        3   108   109     4        0   420   409     3
   1   613   594     2        4   408   406     3        1    79    75     5
   2   418   409     2        5   238   246     4        3    86    87     5
   3   167   174     2        6    95   108     5        4   253   249     4
   4   765   774     3             H,  0,  6             5   221   228     4
   5   310   302     3       -7   114   111     5        6   206   205     4
   6   501   502     3       -6   100   106     5        7   281   266     4
   7   244   246     4       -5   116   111     4             H,  1, -6
   8    99   113     5       -4   486   479     3       -7   101   104     5
   9    97   101     6       -3   130   125     4       -5    87    86     5
      H,  0,  3              -2   194   208     3       -4   363   367     3
  -9   284   280     4       -1   229   227     3       -3    90    94     5
  -8   119   120     5        0   106   101     4       -2   513   510     3
  -7   279   271     4        1   212   218     3       -1   269   269     3
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COLUMNS ARE 10FO,10FC,  10SIG

   H   KFO    FC   SIG        H   KFO    FC   SIG        H   KFO    FC   SIG
      H,  1, -6               6   106   101     4        8   420   411     4
   0    82    84     4        7    89    86     5        9    94    96     6
   2   152   151     4        8   280   278     4       10   117   123     5
   3   300   308     3        9    87    92     6             H,  1,  1
   4    76    83     5             H,  1, -2           -10   105   106     5
   5   469   471     4       -9   164   171     5       -9   258   263     4
   6    86    78     6       -7   291   302     4       -8   207   213     4
   7   121   114     5       -6   191   202     3       -7   590   597     3
   8    86    86     6       -5   694   699     3       -5   447   444     3
      H,  1, -5              -4    66    64     4       -4   155   134     3
  -8   218   218     4       -3   733   731     2       -3   558   541     2
  -7   184   179     4        0   504   492     2       -2   259   268     2
  -6   103   107     5        1   529   536     2       -1   377   375     2
  -5   243   244     4        2   862   850     2        0  1071  1051     1
  -4    80    79     4        4   771   760     2        1   208   197     2
  -3   617   613     3        6    59    59     6        2   279   274     2
  -2   131   132     3        7    67    70     6        3   126   133     3
  -1   481   472     3        8   341   341     4        4    54    43     4
   0   106   113     3        9   316   309     4        5   169   179     3
   1    95    91     3             H,  1, -1             6   254   271     3
   2   138   134     3       -8    94    99     6        7   489   478     4
   3   293   305     3       -7   407   406     4        8   210   211     4
   4   741   738     3       -6   422   433     3        9   223   226     5
   6   269   268     4       -5   371   374     3             H,  1,  2
      H,  1, -4              -4   810   803     2       -9   242   236     4
  -6   128   127     4       -3   355   364     2       -8   341   348     4
  -5   527   527     3       -2   452   445     2       -7   262   264     4
  -4   690   695     3       -1   109    85     2       -6   474   471     3
  -3   467   465     3        0  1039  1019     1       -5   104    80     4
  -2   493   498     3        1   957   935     1       -4    64    56     4
  -1    96    72     3        2   259   257     2       -2   856   857     2
   0   214   202     2        3  1156  1151     2       -1   434   436     2
   1   308   288     2        4   259   247     3        0   792   768     2
   2   761   769     2        5    67    64     4        1   433   427     2
   3   497   497     3        7   538   546     3        2   207   196     2
   4   491   501     3        8   232   238     4        4   363   363     3
   5   436   433     3        9   337   343     4        5   485   502     3
   7    91    87     5       10   186   184     5        6   245   258     4
   9   193   182     5             H,  1,  0             7   400   403     4
      H,  1, -3              -9   109   108     5        8   162   171     5
  -8   129   130     5       -8   337   335     4             H,  1,  3
  -7    57    60     6       -7   252   261     4       -8   411   411     4
  -6   463   463     3       -6   857   856     3       -7   330   333     4
  -5    76    77     4       -5   764   766     3       -6   150   154     4
  -4   609   623     3       -4   365   347     3       -5   132   136     3
  -3   664   661     2       -3   341   325     2       -3   557   552     3
  -2    58    63     3       -1   797   799     1       -1  1252  1247     2
  -1   366   347     2        0   117   121     1        0   480   483     2
   0   365   345     2        1  1431  1467     2        1   214   202     2
   1   574   563     2        2   642   648     2        2   122   119     3
   2    76    82     3        4   131   122     3        3   160   166     3
   3   818   818     2        5    63    69     4        4   320   330     3
   4   335   338     3        6   453   454     3        6   578   575     3
   5   315   308     3        7   115   111     4        7   137   138     4
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COLUMNS ARE 10FO,10FC,  10SIG

   H   KFO    FC   SIG       H   KFO    FC   SIG       H   KFO    FC   SIG
     H,  1,  3                 H,  1,  8               0   853   853     3
   8   172   171     4      -3   160   152     5       1    49    72     5
     H,  1,  4               1   182   190     4       3   426   430     3
  -9   285   281     5       2   142   140     5       4   210   215     3
  -7   355   360     4         H,  2, -9               5   801   806     3
  -6   101   100     5      -1   246   240     4       6    53    33     7
  -5    48    41     6       0   102   105     5       7   133   133     4
  -4   412   418     3       1   231   232     4         H,  2, -4
  -3   390   402     3       2   193   200     5      -8   322   327     4
  -2   902   908     3       3   104   107     5      -7    78    70     5
  -1   117   113     3         H,  2, -8              -6    83    75     4
   0   479   473     3      -4   151   151     5      -5   204   205     3
   1    97    87     3      -2   314   319     4      -4   211   217     3
   2   128   130     3      -1   153   151     4      -3   832   826     3
   3   233   230     3       0   458   473     4      -2   260   262     3
   4   509   512     3       1   126   132     4      -1   974   959     2
   5   397   401     3       2   207   208     4       0    91   108     3
   6   184   186     4       5   138   134     5       1    73    70     3
   7   269   264     4         H,  2, -7               2    82    70     3
     H,  1,  5              -6   291   283     4       3   477   484     3
  -8   184   189     5      -5    73    67     6       4   582   585     3
  -6   109   112     5      -3   146   149     4       5   287   297     3
  -5    64    61     6      -2   278   279     3       6   385   386     3
  -4   458   469     3      -1   505   508     3       7    58    68     7
  -3   362   364     3       0   233   238     4       8    61    58     7
  -2   351   360     3       1   456   463     3         H,  2, -3
  -1   524   525     3       4   160   166     4      -9   175   172     5
   0   115   117     4       5   276   278     4      -8   121   122     5
   2   117   114     4       6   188   179     4      -6    80    84     4
   3   506   510     3       7    64    74     8      -5   459   455     3
   4   153   151     4         H,  2, -6              -4   199   196     3
   5   360   356     4      -7   281   283     4      -3   575   575     2
   6   259   248     4      -6    78    74     5      -2   846   847     2
     H,  1,  6              -5   116   113     4      -1   114   110     2
  -5   257   257     4      -3   330   328     3       0   865   857     2
  -3   553   561     3      -2   368   377     3       1    59    65     3
  -2   316   315     3      -1   682   684     3       2   480   482     2
  -1   163   170     4       0   548   566     3       3   311   290     2
   1   105   100     4       1   255   258     3       4   949   953     3
   2   442   440     3       2   183   183     3       5   434   438     3
   3   149   160     4       4   409   413     3       6   155   163     4
   4   400   401     4       5   213   216     4       7   136   133     4
   5    97    86     5       6   328   333     4       8   132   133     5
   6   119   127     5       7   233   232     4       9   234   240     5
     H,  1,  7               8   114   119     5         H,  2, -2
  -6    81    83     6         H,  2, -5              -9   141   138     5
  -5    74    76     7      -8   170   178     5      -8   183   175     4
  -4   329   327     4      -7   223   224     4      -7    57    58     6
  -2   210   206     4      -6   190   198     4      -6   295   294     3
  -1    52    57     7      -5    83    93     4      -5   318   318     3
   0   126   122     4      -4   276   277     3      -4   785   791     3
   1   146   145     4      -3    91    81     4      -3   563   557     2
   2   270   271     4      -2   948   958     3      -2   461   458     2
   3   257   245     4      -1   522   524     3      -1   898  895.     2
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COLUMNS ARE 10FO,10FC,  10SIG

   H   KFO    FC   SIG       H   KFO    FC   SIG       H   KFO    FC   SIG
     H,  2, -2              -4   290   297     3      -4    71    80     5
   0   369   351     2      -3    74    84     4      -3   315   320     3
   1   236   241     2      -2   159   169     3      -2   301   323     3
   2   601   603     2      -1   285   285     2      -1   821   821     3
   3  1320  1326     2       0   605   597     2       1   198   198     3
   4   558   548     3       1  1330  1328     2       3   151   147     3
   5   415   402     3       2   431   443     2       4   200   202     4
   6   256   258     3       3   311   307     2       5   253   257     4
   7   124   134     5       4   171   177     3       6   499   501     4
   8   194   203     4       5   195   202     3         H,  2,  5
   9   192   201     5       6   230   233     4      -7   170   162     4
     H,  2, -1               7   383   375     4      -4    46    18     6
 -10   261   250     5       8   343   337     4      -3   471   481     3
  -9   121   124     5         H,  2,  2              -2   415   414     3
  -7   204   213     4      -8   188   189     4      -1   217   224     3
  -6   315   322     3      -7   431   432     4       0   361   356     3
  -5   681   699     3      -6   110   113     4       2   202   203     4
  -4   140   139     3      -5   644   632     3       3    73    79     5
  -3  1038  1036     2      -3   164   165     3       4   429   435     4
  -2   911   912     2      -1   798   797     2       5   263   260     4
  -1   427   411     2       0   694   685     2       6   245   249     4
   0   447   450     2       1   283   277     3       7   158   156     5
   1   986   974     2       2   709   708     3         H,  2,  6
   2  1389  1384     2       3   218   226     3      -4   299   308     4
   3   139   143     3       4   132   127     3      -3    64    52     6
   4   922   894     3       5    52    57     6      -2   388   383     4
   6   192   192     3       6   456   462     3      -1   219   218     4
   7    74    82     5       7   349   356     4       2    78    70     5
   8   378   382     4       8   290   299     4       3   322   325     4
   9   227   221     4       9   212   201     5       5   236   242     4
     H,  2,  0                 H,  2,  3                 H,  2,  7
 -10    77    75     7      -9   129   122     5      -5   145   152     5
  -8    91    97     5      -8   147   154     5      -3   297   289     4
  -7   466   469     4      -7   327   322     4      -1   187   180     4
  -6   453   456     3      -6   428   432     4       2   231   236     4
  -5   761   760     3      -5    62    60     5       3   178   179     4
  -4   311   327     3      -4    60    56     5         H,  3, -9
  -3   208   198     2      -3    90   102     3       0   243   244     4
  -2   249   253     2      -2   445   446     3       1   258   274     4
  -1   262   264     2      -1   292   282     3       2   215   209     4
   0  1360  1375     2       0   682   690     2       3   225   215     4
   1   289   277     2       1   459   471     3         H,  3, -8
   2   671   651     2       2   210   207     3      -5   187   185     5
   3   550   557     3       3    61    53     4      -4    85    82     6
   4   147   138     3       4   233   228     3      -3   142   142     4
   6   169   165     4       5   489   487     3      -1   331   333     4
   7   471   480     4       6    66    64     6       0   108   110     4
   8    87    90     6       7   453   456     4       1   368   367     4
   9   305   309     4       8    88    83     6       2   275   281     4
     H,  2,  1                 H,  2,  4               3   131   135     4
  -8   272   279     4      -8   294   287     5       4    65    67     6
  -7    75    76     6      -7   129   124     5       6   110   111     5
  -6   518   524     3      -6   350   348     4         H,  3, -7
  -5   169   170     3      -5    62    57     5      -5   278   280     4
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COLUMNS ARE 10FO,10FC,  10SIG

   H   KFO    FC   SIG
       H,  3, -7
  -4   197   198     4
  -2   312   318     3
  -1   146   139     4
   0   573   595     3
   1   124   122     4
   2   441   443     3
   5   253   255     4
   6   211   205     4
   7   308   305     4
       H,  3, -6
  -7   137   139     5
  -6   345   339     4
  -3    51    56     6
  -2   449   455     3
  -1   545   549     3
   0   341   341     3
   1   457   466     3
   2   102    98     4
   4    72    65     5
   5   395   405     4
   6   165   169     4
   7   169   161     4
   8   209   201     5
       H,  3, -5
  -8   311   315     4
  -7   296   290     4
  -6   187   192     4
  -5    96    98     4
  -3   542   546     3
  -2   152   151     3
  -1   712   718     3
   0   530   533     3
   1   110   108     3
   2    76    74     4
   4   341   344     3
   5    59    55     6
   6   483   482     4
   7   139   138     4
   8   157   154     5
       H,  3, -4
  -9   298   297     4
  -7   441   435     4
  -6   151   149     4
  -5   217   213     3
  -4   389   390     3
  -3   218   229     3
  -2   735   729     3
  -1   110   116     3
   0   583   582     2
   2   215   229     3
   3    53    55     4
   4   368   379     3
   5   515   518     3
```

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   H   KFO    FC   SIG
   7   309   304     4
       H,  3, -3
  -9   125   120     5
  -8   436   433     4
  -6   165   169     4
  -5    97    99     4
  -4   555   570     3
  -3   883   879     2
  -2   683   688     2
  -1   890   879     2
   0    91    85     3
   1   130   122     2
   2   212   225     2
   3   656   658     2
   4   555   551     3
   5   482   487     3
   6   479   475     3
       H,  3, -2
  -9   269   271     5
  -8   189   190     4
  -7   194   199     4
  -6   108   117     4
  -5   549   554     3
  -4    89    88     3
  -3  1375  1381     2
  -2  1089  1084     2
  -1   342   335     2
   0   485   477     2
   1   200   209     2
   2   716   710     2
   3   198   205     2
   4   975   973     3
   5   227   232     3
   6    54    42     6
   7    60    45     7
   8   106   109     5
   9   238   238     4
       H,  3, -1
  -9   233   234     5
  -8   281   285     4
  -7    75    74     6
  -6   344   358     3
  -5    88    91     4
  -4   885   893     3
  -3   185   185     2
  -2   845   842     2
  -1   327   343     2
   0   330   329     2
   1   342   343     2
   2   394   381     2
   3   701   682     2
   4    57    56     5
   5   352   362     3
   6    81    78     5
```

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   H   KFO    FC   SIG
   7    71    73     6
   8    94   103     5
   9   183   186     5
       H,  3,  0
  -8    79    73     6
  -6   342   344     4
  -5   636   635     3
  -4   362   362     3
  -3   811   831     3
  -1   824   835     2
   0   374   357     2
   1  1090  1087     2
   2   596   596     2
   3   676   659     3
   4   460   473     3
   5   234   238     3
   8   343   354     4
   9   135   134     5
       H,  3,  1
  -9   127   120     5
  -8    91    92     5
  -7   293   292     4
  -6    82    78     5
  -5   755   762     3
  -4   528   542     3
  -3   171   180     3
  -2   145   149     3
   0   617   607     2
   1   671   665     2
   2  1257  1258     2
   3   273   289     3
   4    97   100     4
   6   178   182     4
   7   307   306     4
   8   197   198     5
   9   269   259     5
       H,  3,  2
  -9    61    51     7
  -8   115   113     5
  -7   231   229     4
  -6   413   429     4
  -5   132   134     4
  -4   376   378     3
  -3   416   420     3
  -2   162   169     3
  -1   122   121     3
   0   461   458     2
   1   786   787     2
   2   175   171     3
   3   436   448     3
   4   177   180     3
   5   127   133     4
   6   116   118     5
   7   289   287     4
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COLUMNS ARE 10FO,10FC,  10SIG

   H   KFO    FC   SIG
       H,  3,  2
   8   236   228     5
       H,  3,  3
  -8   185   186     5
  -7   233   238     4
  -6   221   212     4
  -5   437   436     4
  -2   107   103     3
  -1   603   603     3
   0   370   361     3
   1   540   543     3
   2   469   472     3
   3   218   222     3
   5   122   126     4
   6   424   430     4
   7   150   142     5
   8   256   263     5
       H,  3,  4
  -7   296   286     4
  -6   227   219     4
  -5   132   139     4
  -4   105   103     4
  -3   213   212     3
  -2   250   257     3
   0   795   803     3
   1   340   339     3
   2   300   303     3
   4   151   144     4
   5   325   323     4
   6   138   145     5
   7   397   387     4
       H,  3,  5
  -6   260   245     4
  -4   136   131     4
  -3   194   200     4
  -2   338   339     3
  -1   584   574     3
   0   112   113     4
   1   285   287     4
   3   192   185     4
   4   134   139     4
   5   291   284     4
   6   241   232     4
       H,  3,  6
  -5    72    64     6
  -3   288   287     4
  -2    84    84     5
  -1   194   191     4
   0   216   212     4
   3    68    61     6
   4   206   199     4
       H,  3,  7
  -2   289   284     4
  -1   108   109     5
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   H   KFO    FC   SIG
   0   136   147     5
   1    92    88     5
       H,  4, -9
  -3   321   324     4
   0    90    81     6
   1   155   150     4
   2   274   280     4
   3   141   142     5
   4   193   184     4
       H,  4, -8
  -5   180   178     4
  -4   228   228     4
  -2    89    86     5
  -1   183   181     4
   0   160   157     4
   1   164   165     4
   2   178   187     4
   3   309   315     4
   4    89    91     5
   5   103    98     5
       H,  4, -7
  -6   304   293     4
  -5   157   160     5
  -4   232   228     4
  -3   292   289     4
  -1   247   246     3
   0    65    57     5
   1   567   563     3
   2   256   252     3
   3   306   308     3
   6   117   125     5
   7    85    75     6
       H,  4, -6
  -7   403   404     4
  -5   345   337     4
  -4    56    56     6
  -3    80    84     4
  -2   170   173     3
  -1   416   425     3
   0   485   479     3
   1   219   222     3
   2   429   436     3
   3    79    86     4
   5   168   172     4
   6   332   328     4
   7   182   189     4
   8   192   190     5
       H,  4, -5
  -8   232   238     4
  -7   252   256     4
  -6   329   324     4
  -5    74    77     5
  -4    47    46     7
  -3    58    51     5
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   H   KFO    FC   SIG
  -2   476   469     3
  -1   143   138     3
   0   722   723     3
   1   300   316     3
   2    87    93     4
   3   118   116     3
   4   135   142     4
   5   436   447     3
   7   316   313     4
   8   103   107     5
       H,  4, -4
  -8   322   328     4
  -7   120   112     5
  -6   367   371     4
  -5   193   200     3
  -4   212   213     3
  -3   492   495     3
  -2   334   343     3
  -1   681   684     2
   0   220   223     3
   1   395   403     3
   2   432   434     3
   3   135   144     3
   4   196   200     3
   5   304   312     3
   6   619   617     3
   7    77    78     6
   8   203   199     4
       H,  4, -3
  -9   242   246     5
  -7   410   420     4
  -6   164   167     4
  -5    58    56     5
  -4    72    73     4
  -3   468   481     3
  -2   972   967     2
  -1   160   161     3
   0   766   765     2
   1   175   176     2
   2   147   146     3
   3   120   106     3
   4   659   675     3
   5   586   591     3
   6   268   264     4
   7   365   354     4
       H,  4, -2
  -9   120   120     6
  -8   390   395     4
  -7    87    86     5
  -5    57    52     5
  -4   566   577     3
  -3   392   385     3
  -2   823   827     2
  -1   701   714     2
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COLUMNS ARE 10FO,10FC,  10SIG

   H    KFO     FC   SIG       H    KFO     FC   SIG       H    KFO     FC   SIG
     H,  4, -2                 4    397    405     3      -1    188    190     5
   0     77     82     3       5     64     68     6       0     88     91     6
   1    343    330     2       8    247    236     5       1    270    258     4
   2    125    130     3         H,  4,  2                   H,  5, -9
   3    545    551     3      -8     95     94     5      -2    250    240     4
   4    224    226     3      -7    210    214     4      -1     69     73     6
   5    661    654     3      -6     73     76     6       0    115    117     5
   6    265    268     4      -5    506    518     4       1    130    124     5
   7    174    172     4      -4    107    108     4       2    152    145     4
     H,  4, -1                -3    288    296     3       3    233    230     4
  -9    119    125     5      -2    126    126     4         H,  5, -8
  -8    207    197     5       0    394    388     3      -5    210    202     4
  -7    119    118     5       1    253    265     4      -4     85     78     6
  -6     80     90     5       2    856    865     3      -3    396    402     4
  -5    439    451     3       3     52     51     6       1    213    216     4
  -4     99    106     3       4    290    292     3       2    320    321     4
  -3    687    706     3       7    230    237     4       3    140    139     4
  -2    127    127     3       8    172    168     5       4    287    291     4
  -1    631    629     2         H,  4,  3                   H,  5, -7
   0    274    254     2      -7    206    198     4      -6    176    174     5
   1    557    548     2      -6    386    375     4      -5    305    302     4
   2    326    322     2      -5    145    144     4      -4    345    346     4
   3    315    323     3      -4    435    428     4      -3    277    282     4
   4    839    835     3      -2     62     51     5      -2    168    161     4
   6    365    358     4      -1    147    138     3       0    410    408     3
   9    136    149     5       0    556    562     3       1     63     63     6
     H,  4,  0                 1    597    590     3       2    524    536     3
  -9    218    217     5       2    223    226     3       3    220    218     4
  -8     96     92     6       3    375    377     3       4    184    182     4
  -6    123    117     4       6     86     93     6       5     87     89     5
  -5    355    361     4       7    261    258     4       6    105     96     5
  -4    567    584     3         H,  4,  4                 7    131    132     5
  -3    322    330     3      -7    118    107     6         H,  5, -6
  -2    593    606     3      -6    314    305     4      -6    364    364     4
   0    122    116     3      -5    296    288     4      -5     46     41     8
   1     41     31     6      -4     66     65     6      -4    423    417     3
   2    942    932     3      -1    420    426     3      -3    212    209     3
   3    766    765     3       0    221    220     4      -1    250    248     3
   4    295    286     3       1    498    502     4       0    239    243     3
   5    400    396     3       2    312    311     5       1    497    492     3
   7     98     96     5       3    139    138     4       3    383    378     3
   9    222    209     5       6    269    277     4       5     93     87     5
     H,  4,  1                   H,  4,  5                 6     93     94     5
  -8     74     45     6      -6     69     65     7       7    141    153     5
  -7     55     51     7      -5    204    192     4         H,  5, -5
  -6    358    361     4      -3    117    118     5      -8    175    171     5
  -5    271    279     4      -2    215    211     4      -7    251    253     4
  -4    703    711     3      -1    161    168     4      -6    208    215     4
  -3    422    445     3       0    380    383     4      -5    426    424     4
  -2    109    112     4       2     95     95     5      -4     79     80     5
  -1    127    109     3       4     75     83     6      -3    153    155     3
   0     47     44     5       5     50     65     9      -2     77     79     4
   1    884    863     3         H,  4,  6                -1    434    434     3
   3    653    659     3      -2    203    200     4       0    397    402     3
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COLUMNS ARE 10FO,10FC,  10SIG

   H    KFO     FC   SIG       H    KFO     FC   SIG       H    KFO     FC   SIG
     H,  5, -5                   H,  5, -1                -4    549    553     4
   1    595    597     3      -9    217    207     5      -3    250    252     4
   2    414    423     3      -8    207    204     5      -2    198    201     4
   5     89     93     5      -7    177    172     4      -1    115    114     4
   6    429    432     4      -6    119    109     4       0     84     84     4
   7    123    126     5      -5    190    192     4       1    241    235     3
   8    201    202     5      -4    356    370     3       2    118    121     6
     H,  5, -4                -3    183    182     3       3    647    651     3
  -8     66     51     6      -2    705    717     3       4    278    282     4
  -7    353    348     4      -1    691    700     3       5    272    278     4
  -6    283    280     4       0    505    509     3       6     90     90     6
  -5     73     76     5       1    147    169     3         H,  5,  3
  -4    431    428     3       2     97     86     3      -7    104    116     6
  -3    298    300     3       3    382    382     3      -6    180    180     5
  -2    362    365     3       4    104    105     4      -5    455    445     4
   0    791    789     3       5    814    801     3      -3    259    260     4
   1    446    446     3       6     92     88     5      -2    100    105     4
   2    158    162     3       7    249    245     4      -1    104    111     5
   3    167    157     3         H,  5,  0                 0    152    155     4
   4    108    109     4      -8    263    257     4       1    293    296     3
   5    357    360     3      -7    124    115     5       2    509    510     3
   6     91     88     5      -6     98    104     5       3     84     85     5
   7    430    433     4      -5    333    337     4       4    298    302     4
   8    135    130     5      -4    404    413     3         H,  5,  4
     H,  5, -3                -3    678    690     3      -6    242    235     5
  -8    342    342     4      -2    119    120     3      -5    249    250     4
  -6    391    393     3      -1    711    726     3      -4    272    260     4
  -5    355    345     3       0    134    116     3      -3     88     88     5
  -4    236    239     3       1    174    182     3      -1    112    116     5
  -3    322    328     3       2    260    249     3       0    414    406     4
  -2    264    277     3       3    505    501     3       1    168    182     4
  -1    886    881     3       4    683    672     4       2    298    312     4
   1    586    577     3       5    264    262     4       3    143    142     5
   2     97     93     3       6    341    345     4       4     52     57     7
   4    375    372     3       7     63     74     8         H,  5,  5
   5    489    486     3       8    115    114     5      -4    152    143     5
   6    414    416     4         H,  5,  1                -2     95    104     5
   7    147    145     5      -7     58     62     7      -1    200    193     4
   8    193    187     5      -5    480    485     4       0    113    125     5
     H,  5, -2                -4    235    235     4       1    312    311     4
  -9    194    192     5      -3    401    408     4       2     58     46     8
  -8    124    125     5      -2    301    306     4       3     77     78     6
  -7    294    303     4       0     89    102     5         H,  6, -9
  -5     93     88     4       1    167    168     3      -1    122    121     5
  -4    146    149     3       2    441    447     3       0     95     89     5
  -3    577    574     3       3    231    240     3       1    106    113     5
  -2    347    343     3       4    399    410     4       2    158    152     4
  -1    561    565     3       5    368    373     4       3    109     99     5
   0    363    379     3       6    140    139     5         H,  6, -8
   1    146    130     3       8     98     84     6      -4    272    267     4
   4    550    563     3         H,  5,  2                -2    358    356     4
   5    149    149     4      -8     82     84     6      -1    133    124     4
   6    436    427     4      -7    101    100     6       1     72     80     6
   7    232    221     4      -6    260    258     4       2    182    180     4
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COLUMNS ARE 10FO,10FC,  10SIG

   H   KFO    FC   SIG
       H,  6, -8
   3   354   352     4
   4   124   125     5
   5   222   216     4
       H,  6, -7
  -6   213   204     4
  -5   255   242     4
  -4   252   251     4
  -3   389   380     4
  -2   200   196     4
   1   405   399     4
   2   159   158     4
   3   416   416     4
   4   250   250     4
   5   174   177     4
       H,  6, -6
  -7   218   215     5
  -5   349   347     4
  -4   107   108     5
  -3   365   366     3
  -2   154   157     4
  -1   130   132     4
   0   397   394     3
   1   275   278     3
   2   610   610     3
   3    70    71     5
   4   320   325     4
   6   122   132     5
   7   124   120     5
       H,  6, -5
  -7   207   212     4
  -6   391   385     4
  -5    95    96     5
  -4   445   450     3
  -3    71    75     5
  -2   132   123     3
  -1   104   109     4
   0   615   611     3
   1   554   554     3
   2   208   208     3
   3   471   463     3
   4   110   107     4
   7   230   234     4
       H,  6, -4
  -8   221   214     5
  -7   185   178     4
  -6   299   298     4
  -5   400   397     3
  -4    66    60     5
  -3    71    69     4
  -1   494   504     3
   0   383   387     3
   1   709   707     3
   2   541   547     3

   H   KFO    FC   SIG
   3    94   100     4
   6   340   331     4
   7   113   122     5
   8   262   256     5
       H,  6, -3
  -8    80    84     6
  -7   351   341     4
  -6   129   130     4
  -5   347   348     4
  -4   266   269     3
  -3    70    76     4
  -2   542   551     3
   0   821   817     3
   1   136   138     3
   2   416   410     3
   3   146   149     3
   4    66    61     5
   5   264   262     4
   6   132   134     5
   7   424   413     4
       H,  6, -2
  -8   294   295     5
  -7    88   107     6
  -6   349   346     4
  -3    64    61     4
  -2   425   425     3
  -1   801   813     3
   0   340   353     3
   1   553   557     3
   3    34    25     7
   4    92    83     4
   5   485   472     3
   6   344   352     4
   7   163   164     5
   8   214   214     5
       H,  6, -1
  -8   215   205     5
  -7   283   276     4
  -6    66    72     6
  -5    82    67     5
  -4    94    96     4
  -3   388   387     3
  -2   141   140     3
  -1   737   744     3
   0   552   556     3
   1    75    77     4
   3   108   118     4
   4   416   425     3
   5    73    80     6
   6   375   367     4
   7   197   195     5
       H,  6,  0
  -8   100    91     6
  -7   224   217     5

   H   KFO    FC   SIG
  -6   151   146     5
  -5   114   119     5
  -4   320   332     4
  -3   152   150     4
  -2   556   559     3
  -1   174   183     3
   0   467   475     3
   1   120   119     3
   2   250   246     3
   3   253   251     3
   4   211   208     4
   5   429   421     4
   6    82    80     7
   7   131   129     5
       H,  6,  1
  -8   222   210     5
  -5    64    74     6
  -4   395   396     4
  -3   363   358     4
  -2   208   210     4
  -1   433   440     4
   2    63    68     5
   3   512   499     3
   4   352   358     4
   5   115   119     6
   6   212   210     5
       H,  6,  2
  -7    69    64     7
  -5   295   297     4
  -4   119   125     5
  -3   415   414     4
  -2   400   392     4
  -1    97    95     5
   1    76    74     5
   2   418   418     4
   4   351   343     4
   5   194   198     5
       H,  6,  3
  -6   171   173     5
  -4   412   397     4
  -3    92    88     6
  -2   239   241     4
   0    62    58     6
   1   252   252     4
   2   159   161     5
   3   374   375     4
   5   112   121     5
       H,  6,  4
  -5   219   216     5
  -4   153   157     5
  -3   219   206     4
   1   299   295     4
   2   178   187     4
   3   190   204     5
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COLUMNS ARE 10FO,10FC,  10SIG

   H   KFO    FC   SIG
       H,  6,  5
  -2    89    82     6
  -1    75    70     6
   0   190   170     5
       H,  7, -9
  -1   110   119     5
   0    89    80     6
       H,  7, -8
  -3   311   305     4
  -1   264   263     4
   0    94    79     5
   2   187   192     4
   3   115   109     5
   4   313   325     4
       H,  7, -7
  -5   242   228     4
  -4   204   202     4
  -3   246   256     4
  -2   346   345     4
  -1    73    89     6
   2   304   299     4
   3   273   283     4
   4   308   308     4
   5   189   187     4
       H,  7, -6
  -6   298   295     4
  -4   410   408     4
  -3   192   188     4
  -2   286   281     4
  -1   147   135     4
   1   370   359     3
   3   533   538     4
   4   203   206     4
   5   242   241     4
       H,  7, -5
  -7   168   163     5
  -6   199   201     4
  -5   426   421     4
  -3   358   353     3
  -2   134   132     4
  -1   133   137     4
   0   250   253     3
   1   253   253     3
   2   476   486     3
   4   355   358     4
   7   113   111     5
       H,  7, -4
  -7   250   241     4
  -6   300   286     4
  -5   245   247     4
  -4   429   431     3
  -2    85    78     4
  -1    62    71     5
   0   315   320     3

   H   KFO    FC   SIG
   1   292   293     3
   2   252   254     3
   3   436   430     3
   4   134   141     4
   5    94   102     5
   7   191   192     5
       H,  7, -3
  -7   105   111     5
  -6   368   378     4
  -5   172   172     4
  -4   271   269     4
  -3   154   143     4
  -2   139   140     4
  -1   451   456     3
   1   494   501     3
   2   247   254     3
   3   312   305     3
   4   131   134     4
   6   154   153     4
       H,  7, -2
  -7   370   370     4
  -5   397   396     4
  -4   118   110     4
  -3    91    98     4
  -2   259   265     3
  -1   351   353     3
   0   638   638     3
   2   319   327     3
   3    75    79     5
   6   224   210     4
   7   235   248     5
       H,  7, -1
  -7   181   181     5
  -6   347   346     4
  -5    67    62     6
  -3   100    91     4
  -2   435   432     3
  -1   411   426     3
   0   553   559     3
   1   296   288     3
   5   254   252     4
   6    76    74     7
   7   259   233     5
       H,  7,  0
  -7   186   177     5
  -6   177   171     5
  -5    91    78     6
  -4    82    82     6
  -3   368   367     4
  -1   556   569     3
   0   158   158     4
   1   164   165     4
   2   101   104     4
   3   172   165     4

   H   KFO    FC   SIG
   4   178   172     4
   5   112   108     6
   6   294   295     5
       H,  7,  1
  -6   140   138     5
  -4   165   167     5
  -3   170   161     5
  -2   513   500     4
   0   353   357     4
   2    89    82     5
   3    58    54     7
   4   242   243     5
   5   309   294     5
       H,  7,  2
  -4   238   234     5
  -3   265   268     5
  -2   179   177     5
  -1   316   313     4
   3   288   292     4
   4    96   103     6
   5   224   226     5
       H,  7,  3
  -3   251   244     5
  -2   164   161     5
  -1   145   149     5
   2   192   179     4
   3   131   121     5
       H,  7,  4
  -2   146   142     5
   0    64    52     7
       H,  8, -8
  -2   347   344     4
  -1    74    81     6
   0   248   247     4
   1   146   152     5
   3   144   147     5
       H,  8, -7
  -4   162   161     5
  -3   329   320     4
  -2   147   149     5
  -1   373   376     4
   0    71    68     6
   3   268   262     4
   4   326   324     4
       H,  8, -6
  -5   280   273     4
  -4   175   178     4
  -3   324   317     4
  -2   297   298     4
  -1    98   104     5
   1   136   127     4
   2   327   323     4
   3   101   104     5
   4   328   334     4
```

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COLUMNS ARE 10FO,10FC,  10SIG

   H   KFO    FC   SIG       H   KFO    FC   SIG       H   KFO    FC   SIG
      H, 8, -6               2   364   358     4      -3    76    76     6
   5   203   193     4       6   296   292     5      -2   332   330     4
      H, 8, -5                  H, 8, 0               -1   166   168     4
  -6   234   228     4      -6   214   208     5       1    98   102     5
  -4   354   348     4      -5    77    79     7       2   201   196     4
  -3    77    67     5      -4    73    74     7       3   335   331     4
  -2   265   265     4      -3    89    90     6       5   189   181     5
  -1   112   113     4      -2   210   208     4         H, 9, -3
   0    98   105     5      -1   116   122     5      -5   207   199     4
   1   256   258     4       0   441   440     4      -4   139   144     4
   2   168   170     4       1   282   289     4      -3   429   428     4
   3   440   434     4       2    86    93     6      -2    68    62     6
   5   173   166     4       3    55    62     7       1   336   328     4
   6    71    71     6       5   285   274     5       2   190   211     4
      H, 8, -4                  H, 8, 1                3   291   289     4
  -6   199   191     4      -5    95    82     6       4   199   192     4
  -5   265   264     4      -4   109   104     6       5    72    74     7
  -4   131   127     5      -3   146   134     5         H, 9, -2
  -3   381   378     4      -2    87    81     6      -5   275   270     4
   0    71    71     5      -1   324   325     5      -4   148   147     5
   1   374   374     3       0    77    71     7      -3   132   129     5
   2   305   313     4       1   206   209     5      -2   142   146     4
   3   212   203     4       4   142   148     5      -1   136   135     4
   4   298   300     4          H, 8, 2              0   348   353     4
      H, 8, -3              -3   196   181     5       1    78    82     6
  -6   133   133     5      -2   199   193     5       2   357   357     4
  -5   312   314     4      -1   141   143     5       3    49    82     9
  -4   324   320     4       0   204   191     5       4   132   135     5
  -3   170   166     4         H, 9, -7                H, 9, -1
  -2   151   160     4      -3    95    91     5      -4   161   159     5
   0   395   391     3      -2   420   408     4      -3   145   149     4
   1   152   160     4       0   279   272     4      -2   123   124     5
   2   516   525     4       1   102    90     5      -1    97    95     5
   3   324   323     4       3   115   117     5       0   298   303     4
   4   196   195     4         H, 9, -6               1   318   326     4
   6   100    96     6      -4   228   221     4       3   174   168     5
      H, 8, -2              -3   314   300     4         H, 9, 0
  -6   336   337     4      -2   240   240     4      -4    54    53     9
  -4   333   337     4      -1   315   319     4      -2    48    46     9
  -3   129   138     4       3   248   244     4      -1   243   251     4
  -2    44    46     7       4   132   142     5       0   177   182     5
  -1   339   347     3         H, 9, -5               1   233   223     4
   0   219   223     4      -5   221   214     4       2   189   191     5
   1   536   537     3      -4   129   130     5         H, 9, 1
   3   270   277     4      -3   339   346     4      -3    77    74     8
   5   158   162     5      -2   214   209     4      -2   211   202     5
   6   162   162     5      -1   208   205     4       0   295   300     5
      H, 8, -1               0    82    74     6         H, 10, -6
  -6   122   117     5       1   135   127     4      -2   220   214     4
  -5   270   273     4       2   216   217     4      -1    95    97     6
  -4    70    47     6       4   274   272     4       0   244   243     4
  -1   257   253     4         H, 9, -4                H, 10, -5
   0   372   363     4      -5   113   112     6      -3    95    99     6
   1   197   199     4      -4   328   333     4      -2   188   189     4
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COLUMNS ARE 10FO,10FC,  10SIG

   H   KFO    FC   SIG       H   KFO    FC   SIG       H   KFO    FC   SIG
      H, 10, -5              0   111   118     6      -3   127   119     5
  -1   171   169     4       3    56    41     8      -2    70    79     7
   1    98    85     5         H, 10, -3               0   124   122     5
   2    70    63     6      -3   141   140     5       1   231   219     5
   3   170   166     4      -2   250   258     4         H, 10, -1
      H, 10, -4              2   170   206     5      -2    68    69     7
  -3   256   236     4       3   168   193     5       0   156   159     5
  -2    65    73     7         H, 10, -2               1   143   146     5
  -1   175   174     4
```

Table S.5. Fractional Coordinates for Ru(CO)$_4$SbMe$_3$

atom	x	y	z
Ru	0.(-)	0.(-)	0.(-)
Sb	0.(-)	0.(-)	-0.27183(9)
C(1)	0.(-)	0.(-)	0.196(2)
C(2)	-0.206(1)	-0.052(1)	-0.0066(8)
C(3)	-0.176(1)	-0.194(1)	-0.3682(9)
O(1)	0.0(-)	0.0(-)	0.317(1)
O(2)	-0.326(8)	-0.080(1)	-0.0091(9)

Table S.6. Thermal Parameters for Ru(CO)$_4$SbMe$_3$

```
ATOM      U11         U22        U33         U12        U13         U23
RU     4.91( 4)    4.91( 0)   3.81( 9)    2.45( 0)   0.00( 0)    0.00( 0)
SB     5.34( 4)    5.34( 0)   3.48( 7)    2.67( 0)   0.00( 0)    0.00( 0)
C1     7.6( 5)     7.6( 0)    4.6( 6)     3.8( 0)    0.0( 0)     0.0( 0)
C2     6.3( 4)     8.8( 5)    4.8( 3)     4.0( 4)    0.1( 3)     0.6( 3)
C3     6.8( 4)     6.6( 4)    6.7( 5)     2.2( 3)   -0.9( 3)    -1.7( 3)
O1    11.3( 6)    11.3( 0)    3.9( 4)     5.6( 0)    0.0( 0)     0.0( 0)
O2     6.4( 4)    15.2( 6)   10.7( 5)     5.2( 4)    0.8( 3)     1.4( 5)

  TEMP=-2(PI)**2(U11*H*H*ASTAR*ASTAR+---+'2*U12*H*K*ASTAR*BSTAR+---)

        THE UIJ VALUES HAVE BEEN MULTIPLIED BY 100.
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Table S.7. Structure Factors for $Ru(CO)_4SbMe_3$

```
     COLUMNS ARE 10FO,10FC,  10SIG                                             COLUMNS ARE 10FO,10FC,  10SIG

  K   KFO    FC   SIG      K   KFO    FC   SIG      K   KFO    FC   SIG      K   KFO    FC   SIG      K   KFO    FC   SIG      K   KFO    FC   SIG
       1, K,  0           12   186   200     7      9   157   152     8          -2, K,  2            0    46    34   24*     11   129   142    10
  1  2300  2609    1*         -7, K,  1                  5, K,  1           8    94    88     9         -11, K,  3                  3, K,  3
  4  1565  1579     2     10   352   351     4      1   727   753     2     11     6    64  181*     13   143   145    10      0  1542  1508     2
  7   732   716     3     13   153   151     9      4   451   454     3          -1, K,  2                -10, K,  3            3   836   866     2
 10   308   316     5         -6, K,  1             7   196   190     6      3   242   255     2     11   233   230     6      6   478   484     4
       2, K,  0            8   498   485     3          6, K,  1            6   218   222     4         -9, K,  3            9   185   196     7
  2  1949  2007     2     11   295   294     5      2   573   576     3      9    70    76    13     12   218   226     7          4, K,  3
  5  1149  1141     2     14   104   120    13      5   279   274     5     12    58    38   20*         -8, K,  3            1  1196  1233     2
  8   553   538     4         -5, K,  1             8   126   124    11          0, K,  2           10   352   366     4      4   629   626     3
 11   180   195     8      6   850   837     2          7, K,  1            1   419   371     1     13   181   176     8      7   343   335     5
       3, K,  0            9   434   410     3      0   552   533     3      4   326   324     2         -7, K,  3                  5, K,  3
  0  2191  2247     2     12   233   228     6      3   361   356     4      7   204   207     5      8   511   491     3      2   834   842     3
  3  1385  1406     2         -4, K,  1             6   134   142    10     10    97    80    11     11   309   316     5      5   409   408     4
  6   695   696     3      7   818   815     3          8, K,  1                1, K,  2           14   128   131    11      8   172   174     8
  9   288   287     5     10   271   271     5      1   309   299     4      2   885   844     2         -6, K,  3                  6, K,  3
       4, K,  0           13   151   157     9      4   185   190     7      5   223   226     4      9   537   518     3      0   881   839     3
  1  1861  1854     2         -3, K,  1                  9, K,  1            8    52    49   17*     12   226   228     6      3   487   479     4
  4   861   843     3      5   831   846     2      2   259   252     6     11     6    32  183*         -5, K,  3            6   245   238     6
  7   473   467     4      8   573   564     3      5   113   115    12          2, K,  2            7   782   769     3          7, K,  3
 10   154   166     9     11   277   274     5         10, K,  1            0   775   780     2     10   445   445     4      1   554   565     3
       5, K,  0               -2, K,  1             0   243   250     6      3   425   422     2     13   193   184     7      4   318   310     5
  2  1327  1270     2      3   493   513     2      3   139   133     9      6   175   172     5         -4, K,  3            7   155   144     9
  5   628   612     3      6   797   780     2         11, K,  1            9     6    54  169*      5  1045  1010     2          8, K,  3
  8   233   237     6      9   358   340     4      1   142   149    10          3, K,  2            8   613   612     3      2   381   378     4
       6, K,  0           12   190   174     7        -10, K,  2            1   163   161     4     11   301   309     5      5   168   170     8
  0  1335  1280     2         -1, K,  1            12    18    33   63*      4   148   159     5         -3, K,  3                  9, K,  3
  3   674   642     3      4  1228  1242     2         -9, K,  2            7    57    76   17*      6  1076  1080     2      0   384   386     4
  6   323   325     5      7   667   650     3     10    61    38   16*     10    69    21   17*      9   484   472     3      3   227   223     6
       7, K,  0           10   288   280     5     13    54    30   22*          4, K,  2           12   242   241     6         10, K,  3
  1   768   745     3     13   122   115    11         -8, K,  2            2   154   165     5         -2, K,  3            1   234   233     6
  4   447   432     4          0, K,  1            11    59    33   16*      5   107   121     8      4  1180  1196     2         11, K,  3
  7   175   184     9      2  1433  1543     1     14    80    19    14      8     6    39  172*      7   863   854     3      2   117   147    12
       8, K,  0            5   929   965     2         -7, K,  2                5, K,  2           10   332   332     4         12, K,  3
  2   494   490     4      8   459   456     3      9   116   104     8      0   469   459     2     13   126   139    11      0   141   150    10
  5   249   238     6     11   152   155     8     12    64    47   15*      3   125   123     7         -1, K,  3               -11, K,  4
       9, K,  0                1, K,  1              -6, K,  2            6    51    88   21*      2  1709  1726     2     12   190   191     8
  0   535   528     4      0  1618  1616     1      7   143   141     6      9     7    16  194*      5  1139  1156     2        -10, K,  4
  3   326   323     5      3   997  1005     2     10   112   109     9          6, K,  2            8   497   510     3     13   179   181     8
      10, K,  0            6   518   515     3     13    48    19   25*      1   138   143     6     11   259   256     6         -9, K,  4
  1   355   346     5      9   292   286     5         -5, K,  2            4    74    81    13          0, K,  3           11   300   302     5
  4   168   165     9     12    98   113    14      8   187   188     5      7    58    29   19*      0  2716  2683     1         -8, K,  4
      11, K,  0                2, K,  1            11    52    69   19*          7, K,  2            3  1368  1403     2      9   490   489     4
  2   189   198     8      1  1507  1527     2     14    47    24   25*      2   145   144     7      6   829   845     3     12   245   253     6
      12, K,  0            4   733   739     2         -4, K,  2            5    49    59   21*      9   371   372     4         -7, K,  4
  0   205   212     7      7   459   468     3      6   188   186     4          8, K,  2           12   147   153     9     10   438   444     4
     -11, K,  1           10   149   155     9      9   157   153     6      0   135   126     7          1, K,  3           13   197   197     7
 12   148   154     9          3, K,  1            12     6    18  178*      3    77    51    13      1  1419  1453     2         -6, K,  4
     -10, K,  1            2  1069  1110     2         -3, K,  2            6    44    18   28*      4  1067  1096     2      8   649   637     3
 13   153   142     9      5   422   428     3      4   367   352     2          9, K,  2            7   560   557     3     11   324   342     5
      -9, K,  1            8   247   238     5      7   185   187     5      1    74    69    14     10   225   225     6         -5, K,  4
 11   240   241     6          4, K,  1            10    87    87    11      4    23    27   52*          2, K,  3            6  1004   965     3
 14    70   109   19*      0   979   969     2     13    56    25   21*         10, K,  2            2  1397  1451     2      9   531   535     4
      -8, K,  1            3   631   636     3         -2, K,  2            2     6    39  189*      5   792   803     3     12   265   269     6
  9   341   330     4      6   408   393     4      5   290   291     3         11, K,  2            8   401   402     4         -4, K,  4
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         COLUMNS ARE 10FO,10FC,  10SIG

   K   KFO    FC   SIG         K   KFO    FC   SIG         K   KFO    FC   SIG
       -4, K,  4               4   265   264     6         3   472   480     3
   7   939   935     3                9, K,  4             6   260   260     4
  10   407   422     4         2   304   301     5         9   126   126     9
  13   188   197     8               10, K,  4                    3, K,  5
       -3, K,  4               0   297   297     5         1   617   628     3
   5  1182  1172     2         3   164   178     9         4   386   394     4
   8   712   711     3               11, K,  4             7   176   183     7
  11   337   345     5         1   180   186     8                4, K,  5
       -2, K,  4                    -10, K,  5             2   465   483     3
   3  1487  1464     2        12    46    84   27*         5   239   241     5
   6  1045  1026     3               -9, K,  5             8   110   113    11
   9   480   479     4        10   152   165     8                5, K,  5
  12   207   216     7        13    78    77    15         0   395   367     3
       -1, K,  4                     -8, K,  5             3   314   312     4
   4  1540  1554     2        11   153   147     8         6   140   143     8
   7   817   803     3               -7, K,  5                    6, K,  5
  10   346   351     5         9   223   229     5         1   339   343     4
        0, K,  4              12    72   110   17*         4   193   199     6
   2  1592  1607     2               -6, K,  5             7    73    83   18*
   5   983   997     2         7   370   371     4                7, K,  5
   8   528   546     4        10   163   184     7         2   189   189     6
  11   210   208     7        13    85    90    15         5   113   112    11
        1, K,  4                     -5, K,  5                    8, K,  5
   0  1903  1875     2         8   304   298     4         0   215   214     5
   3  1285  1329     2        11   141   144     8         3   140   145     9
   6   744   749     3               -4, K,  5                    9, K,  5
   9   361   365     5         6   476   470     3         1   132   138     9
        2, K,  4               9   210   208     5         4    70    91   20*
   1  1661  1715     2        12   127   118    10               10, K,  5
   4  1026  1030     3               -3, K,  5             2     7    99  209*
   7   536   546     4         4   638   624     2               11, K,  5
  10   217   211     7         7   381   362     3         0    51    94   25*
        3, K,  4              10   173   175     7              -10, K,  6
   2  1217  1269     2               -2, K,  5            11    72    85   17*
   5   657   667     3         5   528   521     3               -9, K,  6
   8   322   322     5         8   317   316     4        12   101    90    12
        4, K,  4              11   112   125    11               -8, K,  6
   0  1327  1266     2               -1, K,  5            10   133   134     9
   3   863   882     3         3   729   731     2               -7, K,  6
   6   441   451     4         6   419   414     3         8   208   208     6
   9   194   197     8         9   228   232     5        11    71   101   16*
        5, K,  4              12    86    81    15               -6, K,  6
   1   934   944     3                0, K,  5             9   195   198     6
   4   560   548     3         1   826   832     2        12    84    80    14
   7   253   250     6         4   549   544     3               -5, K,  6
        6, K,  4               7   270   265     4         7   268   248     4
   2   690   710     3        10   109   112    11        10   148   163     8
   5   333   336     5                1, K,  5                   -4, K,  6
        7, K,  4               2   829   828     2         5   385   373     3
   0   675   651     3         5   410   408     3         8   230   238     5
   3   430   423     4         8   219   216     5        11   127   118     9
   6   199   201     8        11    45    85   28*               -3, K,  6
        8, K,  4                      2, K,  5             6   408   405     3
   1   451   453     4         0   565   563     2         9   197   212     6
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         COLUMNS ARE 10FO,10FC,  10SIG

   K   KFO    FC   SIG         K   KFO    FC   SIG         K   KFO    FC   SIG
       -3, K,  6               9   356   353     5                7, K,  7
  12    40    89   31*        12   173   178     8         0   462   464     4
       -2, K,  6                     -7, K,  7             3   266   272     6
   4   490   495     3        10   310   307     5                8, K,  7
   7   271   264     4               -6, K,  7             1   323   329     5
  10   123   127     9         8   428   434     4         4   189   194     8
       -1, K,  6              11   243   240     6                9, K,  7
   2   655   653     2               -5, K,  7             2   200   207     8
   5   341   347     3         6   632   608     3               10, K,  7
   8   190   199     6         9   373   376     4         0   203   206     7
  11    85    95    14        12   186   180     8               -9, K,  8
        0, K,  6                     -4, K,  7            10   192   190     7
   0   617   604     2         7   553   546     3               -8, K,  8
   3   469   466     3        10   336   325     5        11   174   178     8
   6   276   268     4               -3, K,  7                   -7, K,  8
   9   116   128    10         5   815   797     3         9   269   276     6
        1, K,  6               8   453   474     4               -6, K,  8
   1   441   455     3        11   248   233     6         7   376   386     4
   4   408   388     3               -2, K,  7            10   264   248     6
   7   222   230     5         3  1134  1095     3               -5, K,  8
  10    57    89   21*         6   707   690     3         8   322   322     5
        2, K,  6               9   338   350     5        11   199   188     7
   2   469   490     3               -1, K,  7                   -4, K,  8
   5   327   329     4         4   966   943     3         6   476   478     4
   8   145   142     8         7   534   541     4         9   285   278     5
        3, K,  6              10   232   240     6               -3, K,  8
   0   584   577     3                0, K,  7             4   618   594     3
   3   309   318     4         2   966   971     3         7   422   421     4
   6   174   176     6         5   672   671     3        10   222   214     6
   9    84    76    14         8   326   344     5               -2, K,  8
        4, K,  6                      1, K,  7             5   577   585     3
   1   365   379     4         0  1196  1173     2         8   349   349     5
   4   278   276     5         3   836   816     3        11   165   167     9
   7    97   113    12         6   523   541     4               -1, K,  8
        5, K,  6               9   235   247     6         3   705   693     3
   2   274   267     4                2, K,  7             6   511   515     4
   5   124   123     9         1   947   959     3         9   239   230     6
        6, K,  6               4   705   710     3                0, K,  8
   0   273   255     4         7   334   341     5         1   866   854     3
   3   191   187     6                3, K,  7             4   606   601     3
   6    90    94    14         2   749   771     3         7   328   338     5
        7, K,  6               5   470   489     4        10   159   166     9
   1   245   237     5         8   236   235     6                1, K,  8
   4   122   108    10                4, K,  7             2   622   632     3
        8, K,  6               0   884   853     3         5   480   484     4
   2   156   147     8         3   614   610     4         8   237   239     6
        9, K,  6               6   288   297     5                2, K,  8
   0   159   156     8                5, K,  7             0   734   702     3
   3    84    79    15         1   652   657     3         3   520   535     3
       10, K,  6               4   364   356     5         6   300   307     5
   1     7    74  196*         7   185   191     8         9   169   164     8
       -9, K,  7                      6, K,  7                    3, K,  8
  11   211   206     7         2   454   457     4         1   654   645     3
       -8, K,  7               5   235   238     7         4   416   428     4
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COLUMNS ARE 10FO,10FC,  10SIG

  K   KFO    FC    SIG     K   KFO    FC    SIG     K   KFO    FC    SIG
     3, K,  8              8     7    58   182*     3   240   238      6
  7   256   239      6          3, K,  9                 5, K, 10
     4, K,  8              0   125   131      8     1   270   273      6
  2   543   537      4     3   111   125      9     4   145   139      9
  5   278   279      5     6     6    70   184*          6, K, 10
     5, K,  8                   4, K,  9            2   181   176      8
  0   541   536      4     1   169   166      6          7, K, 10
  3   350   343      5     4    45    64    24*     0   215   199      7
  6   202   199      7          5, K,  9                -6, K, 11
     6, K,  8              2   106   110     10     7   260   246      6
  1   408   410      4     5    27    70    45*         -5, K, 11
  4   226   223      7          6, K,  9            8   236   227      7
     7, K,  8              0   117   126      9         -4, K, 11
  2   229   238      6     3    71    68    16*     6   326   310      5
     8, K,  8                   7, K,  9                -3, K, 11
  0   272   266      5     1    71    53    16*     4   394   392      4
  3   185   182      8          8, K,  9            7   286   288      6
     9, K,  8              2     7    46   190*         -2, K, 11
  1   189   186      8          9, K,  9            5   379   378      5
    -8, K,  9              0    49    37    23*     8   223   221      7
 10    27    46    45*         -6, K, 10                -1, K, 11
    -7, K,  9              8   182   173      7     3   411   428      4
  8    60    63    18*         -5, K, 10            6   339   335      5
    -6, K,  9              6   247   242      6          0, K, 11
  9     6    63   175*     9   175   162      8     1   513   521      4
    -5, K,  9                  -4, K, 10            4   382   390      5
  7   120   121      9     7   210   200      6     7   234   230      7
 10     7    47   182*         -3, K, 10                 1, K, 11
    -4, K,  9              5   322   314      5     2   395   412      4
  5   141   139      7     8   200   194      7     5   327   316      5
  8    80    86     13         -2, K, 10                 2, K, 11
    -3, K,  9              3   433   439      4     0   472   470      4
  6   122   119      8     6   276   273      5     3   363   363      5
  9    74    46     14     9   151   142      9     6   220   219      7
    -2, K,  9                  -1, K, 10                 3, K, 11
  4   127   125      7     4   344   349      4     1   410   417      5
  7   126   118      8     7   217   219      7     4   280   274      6
 10    34    45    34*          0, K, 10                 4, K, 11
    -1, K,  9              2   354   379      4     2   330   341      5
  2   167   163      6     5   285   292      5          5, K, 11
  5   165   166      6     8   124   129     10     0   366   357      5
  8    80    72     14          1, K, 10            3   216   226      8
     0, K,  9              0   462   459      4          6, K, 11
  0   308   303      4     3   300   308      5     1   269   267      6
  3   192   194      5     6   233   226      6         -4, K, 12
  6   109   114      9          2, K, 10            5   211   195      6
  9     7    60   191*     1   351   354      4         -3, K, 12
     1, K,  9              4   294   290      5     6   188   195      8
  1   234   237      5     7   143   132      9         -2, K, 12
  4   145   147      7          3, K, 10            4   224   215      6
  7    76    64     14     2   291   298      5         -1, K, 12
     2, K,  9              5   203   198      7     2   265   259      5
  2   190   187      6          4, K, 10            5   214   215      7
  5     6    63   171*     0   347   350      5          0, K, 12
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COLUMNS ARE 10FO,10FC,  10SIG

  K   KFO    FC    SIG     K   KFO    FC    SIG     K   KFO    FC    SIG
     0, K, 12              2   247   247      6     3     7    52   184*
  0   314   316      5          3, K, 12                 0, K, 13
  3   248   248      6     0   228   232      6     2    14    52    89*
     1, K, 12              3   179   182      8          1, K, 13
  1   272   279      5          4, K, 12            0     7    43   180*
  4   203   199      7     1   204   216      7          2, K, 13
     2, K, 12                  -2, K, 13            1    14    53    88*
```

Table S.8. Fractional Coordinates for Os(CO)$_4$SbPh$_3$

ATOM	X	Y	Z	BISO
OS	0.67903(2)	0.44175(3)	0.21107(2)	3.35(1)
SB	0.82775(3)	0.69625(4)	0.50892(3)	3.13(1)
C1	0.5342(6)	0.4872(8)	0.1543(7)	5.3(3)
C2	0.7344(8)	0.2647(8)	0.1069(7)	6.8(5)
C3	0.5592(7)	0.3104(9)	0.2312(8)	6.5(4)
C4	0.7885(6)	0.5495(7)	0.1677(6)	4.3(3)
O1	0.4473(5)	0.5078(7)	0.1140(6)	8.3(3)
O2	0.7634(7)	0.1558(7)	0.0360(6)	11.7(5)
O3	0.4920(6)	0.2333(9)	0.2420(8)	12.0(5)
O4	0.8507(5)	0.6056(6)	0.1364(5)	7.2(3)
C11	0.7652(5)	0.8940(6)	0.6142(5)	3.9(2)
C12	0.6238(6)	0.8461(8)	0.5595(6)	5.0(3)
C13	0.5798(6)	0.9708(9)	0.6204(7)	6.2(4)
C14	0.6749(7)	1.1420(9)	0.7331(8)	7.8(4)
C15	0.8158(6)	1.1920(7)	0.7904(7)	5.6(3)
C16	0.8601(5)	1.0679(7)	0.7306(6)	4.3(2)
C21	0.8263(5)	0.6416(6)	0.6418(5)	3.8(2)
C22	0.8276(7)	0.7558(7)	0.7808(6)	5.9(4)
C23	0.8282(8)	0.7170(9)	0.8642(8)	8.0(5)
C24	0.8277(8)	0.5698(9)	0.8124(8)	7.7(4)
C25	0.8271(8)	0.4556(9)	0.6753(8)	7.7(5)
C26	0.8266(7)	0.4895(7)	0.5878(7)	5.8(4)
C31	1.0440(5)	0.8531(6)	0.6123(5)	3.1(2)
C32	1.1363(5)	0.9006(7)	0.7390(6)	3.8(2)
C33	1.2762(5)	1.0091(8)	0.8101(6)	4.4(3)
C34	1.3246(5)	1.0726(7)	0.7557(6)	4.3(3)
C35	1.2343(6)	1.0236(8)	0.6285(7)	5.2(3)
C36	1.0945(5)	0.9146(7)	0.5565(6)	4.5(3)
H12	0.551(5)	0.717(6)	0.471(5)	5.(0)
H13	0.483(6)	0.929(7)	0.577(6)	6.(0)
H14	0.638(6)	1.225(8)	0.771(7)	8.(0)
H15	0.887(6)	1.312(7)	0.868(6)	6.(0)
H16	0.963(5)	1.108(6)	0.773(5)	5.(0)
H22	0.828(5)	0.852(7)	0.813(6)	6.(0)
H23	0.834(6)	0.798(8)	0.955(7)	8.(0)
H24	0.826(6)	0.547(8)	0.868(7)	8.(0)
H25	0.838(6)	0.357(8)	0.640(7)	8.(0)
H26	0.828(5)	0.406(7)	0.488(6)	6.(0)
H32	1.100(5)	0.851(6)	0.769(5)	4.(0)
H33	1.344(5)	1.041(6)	0.897(5)	5.(0)
H34	1.407(5)	1.143(6)	0.798(5)	5.(0)
H35	1.266(5)	1.067(6)	0.593(5)	5.(0)
H36	1.037(5)	0.885(6)	0.471(5)	4.(0)

Table S.9. Thermal Parameters for $Os(CO)_4SbPh_3$

Atom	U_{11}	U_{22}	U_{33}	U_{12}	U_{13}	U_{23}
Os	4.41(1)	4.59(1)	3.20(1)	1.10(1)	1.11(1)	2.78(1)
Sb	3.38(2)	4.35(2)	3.66(2)	1.65(1)	1.60(1)	2.77(2)
C1	6.2(3)	7.6(4)	6.4(4)	2.6(3)	3.1(3)	5.3(3)
C2	12.2(6)	7.2(4)	6.6(4)	4.9(4)	4.6(4)	5.4(4)
C3	5.9(4)	9.6(5)	9.2(5)	0.8(4)	1.5(4)	7.3(5)
C4	5.9(3)	5.4(3)	4.8(3)	1.9(3)	2.0(3)	3.2(3)
C4	5.9(3)	13.3(4)	11.0(4)	6.0(3)	4.1(3)	9.6(4)
O2	22.4(7)	11.6(4)	10.7(4)	11.8(5)	10.0(5)	8.7(4)
O3	9.1(4)	17.3	19.4(7)	0.6(4)	4.1(4)	15.8(6)
O4	9.5(3)	8.8(3)	8.8(3)	2.2(3)	5.1(3)	6.5(3)
C11	4.8(3)	5.4(3)	4.6(3)	2.9(2)	2.8(2)	3.9(2)
C12	5.2(3)	7.2(4)	6.6(4)	3.3(3)	3.2(3)	4.9(3)
C13	5.7(3)	9.3(5)	8.3(4)	4.7(3)	4.2(3)	6.4(3)
C14	9.3(5)	9.7(5)	10.7(5)	7.3(4)	7.2(4)	8.3(5)
C15	7.7(4)	5.5(3)	7.9(4)	3.6(3)	4.3(3)	4.7(3)
C16	5.3(3)	5.3(3)	5.8(3)	2.8(3)	2.8(3)	3.9(3)
C21	5.1(3)	4.8(3)	4.2(3)	2.5(2)	2.5(3)	3.3(2)
C22	10.9(5)	5.5(3)	6.0(3)	4.6(3)	5.1(4)	4.3(3)
C23	14.1(7)	8.8(5)	7.4(4)	7.0(5)	7.3(0)	6.4(4)
C24	11.4(5)	9.5(5)	8.1(4)	5.7(4)	6.1(4)	7.5(4)
C25	12.5(6)	7.5(4)	9.1(5)	5.8(4)	5.5(4)	6.7(4)
C26	9.9(5)	6.0(3)	6.2(4)	5.0(4)	4.7(3)	4.4(3)
C31	4.0(2)	4.1(2)	3.8(2)	1.9(2)	1.9(2)	2.5(2)
C32	4.4(3)	5.5(3)	4.6(3)	1.4(2)	1.5(2)	3.4(3)
C33	4.7(3)	7.4(4)	4.7(3)	1.9(3)	1.1(2)	4.0(3)
C34	4.1(3)	6.7(4)	5.7(3)	1.5(3)	2.1(3)	3.6(3)
C35	6.0(3)	7.0(4)	7.0(4)	2.6(3)	3.7(3)	5.2(3)
C36	4.9(3)	7.0(4)	5.3(3)	2.5(3)	2.2(3)	4.6(3)

U_{ij} values have been multiplyed be 100.

Table S.10. Bond Lengths and Angles for the Phenyl Groups of $Os(CO)_4SbPh_3$

a) Bond Lengths (Å).

C(11)-C(12)	1.392(7)
C(12)-C(13)	1.379(8)
C(13)-C(14)	1.367(10)
C(14)-C(15)	1.384(9)
C(15)-C(16)	1.375(8)
C(16)-C(11)	1.384(7)
C(21)-C(22)	1.371(7)
C(22)-C(23)	1.380(8)
C(23)-C(24)	1.343(9)
C(24)-C(25)	1.359(9)
C(25)-C(26)	1.385(8)
C(26)-C(21)	1.388(7)
C(31)-C(32)	1.379(7)
C(32)-C(33)	1.383(7)
C(33)-C(34)	1.378(8)
C(34)-C(35)	1.365(8)
C(35)-C(36)	1.388(7)

b) Bond Angles (°).

C(11)-C(12)-C(13)	120.1(5)
C(12)-C(13)-C(14)	120.0(5)
C(13)-C(14)-C(15)	120.6(5)
C(14)-C(15)-C(16)	119.5(5)
C(15)-C(16)-C(11)	120.6(5)
C(16)-C(11)-C(12)	119.1(5)
C(21)-C(22)-C(23)	119.4(5)
C(22)-C(23)-C(24)	121.4(6)
C(23)-C(24)-C(25)	119.9(5)
C(24)-C(25)-C(26)	120.6(6)
C(25)-C(26)-C(21)	119.1(5)
C(26)-C(21)-C(22)	119.6(5)
C(31)-C(32)-C(33)	120.5(5)
C(32)-C(33)-C(34)	120.3(5)
C(33)-C(34)-C(35)	119.6(5)
C(34)-C(35)-C(36)	120.5(5)
C(35)-C(36)-C(31)	120.4(5)
C(36)-C(31)-C(32)	118.7 4)

Table S.11. Structure Factors for $Os(CO)_4SbPh_3$

```
    COLUMNS ARE 10FO,10FC,  10SIG

  L    KFO     FC   SIG      L    KFO     FC   SIG      L    KFO     FC   SIG
      -13,  1,  L            -3    194    200     8      0    177    171     7
  5    253    251     8     -1    144    120     9      1    404    409     7
      -13,  2,  L             0    281    277     8      4    298    290     8
  5    188    172     9          -12,  8,  L             5    187    184    10
      -13,  3,  L            -1    124    136    11          -11,  6,  L
  3    246    250     9          -11,  0,  L            -3    404    405     6
  4    165    172    11      1    179    170     9     -2    164    150     7
  5     78     61    16      2    476    494     7     -1     98     91     9
      -13,  4,  L             3    109    116    10      0    274    280     7
  3    292    278     9      5    439    426     6      1    345    336     7
      -13,  5,  L             6    304    315     6      4    267    262     9
  1    101     91    10      8    117    129    11          -11,  7,  L
      -12,  0,  L             9    280    274     7     -5    151    159     8
  2    114    111    12          -11,  1,  L            -3    172    174     8
  3    362    349     7     -1    176    181     9     -1    187    179     8
  6    306    296     7      1    324    314     7      0    153    137     9
  7    236    252     8      2    369    373     6      1     98     87    12
      -12,  1,  L             3    128    114     9      2    190    181     9
  1    244    251     8      5    405    388     6          -11,  8,  L
  3    137    150    10      7     80     83    13     -5    304    309     7
  4    224    213     7      8    284    279     7     -4     97     91    10
  5    181    177     8      9    212    226     8     -2    273    269     7
  8    279    261     7          -11,  2,  L            -1    274    287     8
      -12,  2,  L            -2    275    268     7      1     97    102    14
  0    184    186     8     -1    129    132     9          -11,  9,  L
  1    405    414     6      0    306    316     6     -5    272    263     7
  4    357    373     8      1    151    140     6     -2    214    211     8
  5    215    222     8      3    350    359     7          -10,  0,  L
  7    198    185     9      4    111    109    10      1    314    327     7
      -12,  3,  L             5    218    228     7      2    229    234     8
  0    232    237     7      6    149    134    10      3    215    215     5
  1    282    285     6      7    280    285     8      4    444    436     5
  2    129    136     9          -11,  3,  L             6    308    305     6
  4    268    274     8     -3    106    124    11      7    198    192     7
  6    118    123    11     -1    380    373     6      8    254    251     7
  7    149    142    11      0    367    380     6      9    153    145     8
      -12,  4,  L             2    190    181     8          -10,  1,  L
 -2    141    127     9      3    489    483     7     -3    358    368     7
 -1    290    285     6      4    181    178     8     -1    131    131     9
  2    355    350     7      6    350    356     8      0    452    449     6
  3    108    135    15      7    267    275     8      1    544    552     6
  5    199    190     9          -11,  4,  L             2    105     96     7
  6    210    218     9     -4    336    318     7      3    166    157     7
      -12,  5,  L            -1    405    408     6      4    711    696     6
 -2    273    283     6      0    155    155     7      5    111    120     8
 -1    308    317     6      1    172    185     8      7    433    414     6
  1    142    135    10      2    187    177     8      8    355    346     7
  2    380    380     8      3    256    260     8     10    173    149    10
      -12,  6,  L             4    151    136     9          -10,  2,  L
 -2    174    168     8      6    197    198     9     -4    137    146    10
  0    208    194     8          -11,  5,  L            -3    472    451     6
  2    161    149    09     -4    110    109     9      0    494    493     5
  3    180    171    11     -3    292    290     6      1    317    316     5
      -12,  7,  L            -2    272    271     6      2    164    172     8
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    COLUMNS ARE 10FO,10FC,  10SIG

  L    KFO     FC   SIG      L    KFO     FC   SIG      L    KFO     FC   SIG
      -10,  2,  L             0    224    223     7      2    558    552     6
  3    207    201     8      2    208    207     8      3    788    816     6
  4    426    426     6      3    230    242     8      6    579    569     6
  5     88     80    11          -10,  8,  L             7    272    285     7
  7    401    395     7     -6    199    198     7      9    263    244     8
  8     99    128    13     -4    225    222     6           -9,  3,  L
  9    147    152    10     -3    237    238     6     -6    100     96    10
      -10,  3,  L            -2    168    169     7     -5    357    347     6
 -4     97     85    10     -1    185    187     8     -4    444    443     6
 -3    205    214     7      1    225    237     8     -1    579    585     5
 -2    343    345     6          -10,  9,  L             0    149    154     6
 -1    257    264     6     -7    163    163     8      1    276    271     6
  0    229    225     5     -6    311    313     7      2    354    354     6
  1    146    142     7     -3    389    394     7      3    308    324     6
  2    502    503     6     -2    218    211     7      4    185    194     8
  4    198    189     7      0    194    198     9      5    143    140     8
  5    347    348     7      1    225    223     9      6    378    389     6
  6    245    254     7          -10, 10,  L                  -9,  4,  L
  7    106     98    13     -6    214    207     7     -6    237    234     7
  8    193    186     9     -3    239    239     7     -5    204    212     7
      -10,  4,  L            -1    113     87    12     -4     64     78    11
 -5    441    434     6           -9,  0,  L            -3    542    541     5
 -3     72     88    12      1    618    636     6     -1    237    238     5
 -2    583    581     5      2    478    482     6      0    447    449     5
 -1    243    247     6      3    195    188     5      1    423    436     6
  0    117    106     9      4    333    328     5      2    277    286     6
  1    344    343     6      5    734    731     5      4    515    529     7
  2    485    491     6      6     98    104     9      6    110    107    10
  4     77     98    16      7     62     34    13      7    273    257     7
  5    462    458     7      8    462    446     6      8    209    223     9
  6    184    193     9      9    157    163     8           -9,  5,  L
      -10,  5,  L            10    100     95    11     -7    384    365     7
 -6    232    221     7     11    121    141    12     -6    390    378     6
 -5    284    275     6           -9,  1,  L            -5     91     91     9
 -4    171    184     7     -4    241    244     7     -4    218    220     6
 -2    348    359     5     -3    147    142     9     -3    539    545     5
  1    351    337     6     -2    375    380     6      0    497    503     5
  2    221    223     8     -1    214    210     6      1    478    479     6
  3    251    233     8      0    196    204     6      2    118    112     9
  5    194    195     9      1    460    467     5      3    245    258     8
  6    122    115    11      3    581    571     5      4    441    431     7
      -10,  6,  L             4    115    112     9           -9,  6,  L
 -4    471    459     5      5    198    206     6     -7    345    352     6
 -2    191    208     6      6    497    493     5     -6    131    125     8
 -1    356    343     6      7    202    214     7     -5    300    291     6
  0    383    379     6      8    203    202     7     -4    234    244     6
  2    166    160     8      9    157    152     9     -3    354    350     5
  3    468    466     7     10    260    271     8     -2    192    194     6
      -10,  7,  L                  -9,  2,  L             0    388    388     6
 -7    244    238     7     -5    223    225     8      2    251    244     7
 -5    149    154     8     -4    443    431     7      3     82     71    13
 -4    446    433     6     -1    699    706     5      4    112    111    11
 -3    106     94     8      0    427    432     5      5    221    200     8
 -1    406    408     6      1    143    149     6           -9,  7,  L
```

```
COLUMNS ARE 10FO,10FC,  10SIG

  L   KFO    FC   SIG
     -9,   7,  L
 -8   170   162    9
 -7   171   178    8
 -6   197   203    6
 -5   463   458    5
 -4   122   111    7
 -2   537   545    6
 -1   281   276    6
  1   274   262    7
  2   395   406    7
     -9,   8,  L
 -8   154   142    8
 -7   105    96    9
 -6   327   329    6
 -5   420   438    6
 -3   147   162    7
 -2   456   452    6
 -1    94    76   11
  1   248   245    8
  2   161   159    9
     -9,   9,  L
 -8    80    99   12
 -7   136   127    8
 -6   221   228    7
 -5    87    75   10
 -4   302   309    6
 -2   129   134    9
 -1   223   232    8
  0   172   181    9
     -9,  10,  L
 -8   250   243    7
 -7   238   235    7
 -5   147   148    8
 -4   399   388    6
 -1   257   251    8
     -9,  11,  L
 -7   126   111    9
 -5   101    87   14
 -4   186   175    9
     -8,   0,  L
  1   390   402    6
  2   280   277    5
  3   561   549    4
  4   848   842    4
  5    94    82    8
  7   852   836    5
  8   298   309    6
  9    75    82   11
 10   332   320    7
 11   314   327    7
     -8,   1,  L
 -5   110   112   11
 -4   368   372    6
 -3   588   592    6
```

```
  L   KFO    FC   SIG
 -2   102   110    8
 -1   117   117    7
  0  1004   998    5
  1   287   288    5
  2   198   205    6
  3   675   680    5
  4   645   645    5
  5   186   179    6
  6   182   175    7
  7   600   596    5
  9   155   168    8
 10   258   251    8
     -8,   2,  L
 -6   110   108   11
 -5   213   220    7
 -4   332   326    6
 -3   155   152    7
 -2   549   553    5
  0   572   582    4
  1   427   434    4
  2   436   446    6
  3   401   413    6
  4   112   104    8
  5   646   649    5
  7   168   163    7
  8   304   300    6
  9   237   251    8
     -8,   3,  L
 -6   433   413    6
 -5   452   432    6
 -3   205   183    5
 -2   746   754    4
 -1   196   194    5
  0    81    79    9
  1   877   886    5
  2   682   689    5
  3   129   135    9
  4   363   369    6
  5   615   624    6
  8   422   426    7
  9   213   219    9
     -8,   4,  L
 -6   540   531    6
 -5   216   223    6
 -4   253   252    5
 -3   364   369    5
 -2   718   731    4
  0   129   132    7
  1   609   604    5
  2   115   125    9
  3   349   350    6
  4   204   201    7
  5   333   346    6
  6   151   132    8
```

```
  L   KFO    FC   SIG
  8   214   221    9
     -8,   5,  L
 -8   274   271    7
 -7   134   135    8
 -6   310   310    6
 -5   180   182    6
 -4   484   478    5
 -3    93    78    8
 -1   662   662    5
  0   285   286    5
  1   224   229    6
  2   357   373    6
  3   576   575    6
  6   395   388    7
     -8,   6,  L
 -8   527   525    6
 -7   224   211    6
 -6   141   143    7
 -5   575   581    5
 -4   675   667    5
 -3   129   137    6
 -1   685   686    5
  0   232   234    6
  2   481   483    6
  3   434   428    6
  4   104    88   11
  5   113   114   12
  6   251   254    8
     -8,   7,  L
 -8   385   381    6
 -7    80    66    9
 -6   226   225    6
 -5   337   339    5
 -4   141   141    6
 -3   330   329    5
 -2   106   100    9
 -1   314   310    6
  0   167   167    7
  1   190   190    8
  2   242   252    8
  4   208   216    8
     -8,   8,  L
 -8   120   117    8
 -7   364   369    6
 -6   313   324    6
 -5   179   195    7
 -4   226   245    6
 -3   578   590    5
  0   427   442    6
  1   253   259    7
  2   101    76   10
  3   154   159   10
     -8,   9,  L
 -8    83    75   10
```

```
COLUMNS ARE 10FO,10FC,  10SIG

  L   KFO    FC   SIG
     -8,   9,  L
 -7   423   412    6
 -6   296   294    6
 -4   246   250    6
 -3   408   392    6
  0   286   286    7
     -8,  10,  L
 -9   177   164    7
 -7   213   215    7
 -6    94    91    9
 -5   256   261    6
 -4   127   123    9
 -2   306   298    7
     -8,  11,  L
 -9   348   351    7
 -8   169   171    8
 -6   263   254    7
 -5   306   298    7
 -3   120   113   11
 -2   269   268    8
     -8,  12,  L
 -6   178   162    9
     -7,   0,  L
  1   577   606    5
  2   325   310    4
  3   406   408    4
  4   603   590    4
  5   271   268    5
  6   595   587    5
  8   336   340    5
  9   285   274    6
 10   202   205    7
 11   179   154    8
     -7,   1,  L
 -6   143   148    9
 -5   425   428    6
 -4   516   514    6
 -3   259   251    6
 -2    91   127   10
 -1   881   879    4
  0   103    98    6
  1   200   216    4
  2   897   914    5
  3   779   775    5
  4   173   168    5
  5   413   402    5
  6   851   862    5
  9   481   480    6
 10   233   234    8
     -7,   2,  L
 -5   608   610    6
 -4   294   296    5
 -3   344   340    5
 -2   458   476    4
```

```
  L   KFO    FC   SIG
 -1  1013  1018    4
  1    89    77    7
  2  1134  1160    5
  3   485   502    5
  4   384   376    5
  5   419   422    5
  6   557   566    5
  7   103    91    9
  9   322   313    7
     -7,   3,  L
 -8   228   228    7
 -7   261   264    6
 -6   143   138    7
 -5   396   389    5
 -3   456   450    4
 -2   306   318    4
 -1   315   322    4
  0   650   662    4
  1   292   276    5
  2   363   354    6
  3   408   418    5
  4   585   599    5
  5   167   162    7
  7   430   430    7
  8   172   175   10
  9    84    78   13
     -7,   4,  L
 -7   569   573    6
 -6   221   220    6
 -5   203   205    6
 -4   618   623    4
 -3   894   907    4
 -2    90    93    6
 -1   332   334    4
  0  1245  1237    4
  1   357   361    5
  3   640   652    5
  4   498   502    6
  6   153   141    8
  7   458   450    7
     -7,   5,  L
 -9   146   149    8
 -8   137   146    8
 -7   594   583    5
 -6   113    98    7
 -5   145   145    6
 -4   618   628    4
 -3   535   527    4
 -2   362   365    4
 -1   151   146    6
  0   644   637    5
  1   152   154    7
  2   216   209    7
  3   254   246    7
```

```
  L   KFO    FC   SIG
  4   150   137    8
  5   235   229    7
  7   177   179    9
     -7,   6,  L
 -9   367   371    6
 -7   248   246    5
 -6   421   444    5
 -5   456   456    5
 -4   179   183    5
 -3   289   295    5
 -2   834   837    5
 -1   113    43    7
  0   130   146    8
  1   541   543    5
  2   361   353    6
  3   129   124    9
  4   234   211    7
  5   405   404    7
     -7,   7,  L
-10   225   220    7
 -9   494   492    6
 -6   735   746    5
 -5   424   424    5
 -4   185   187    5
 -3   320   326    5
 -2   608   619    5
  0    82    61   11
  1   527   522    6
  2   316   318    6
  4   244   235    9
     -7,   8,  L
-10   173   174    8
 -9   306   289    6
 -8   198   203    6
 -6   354   356    5
 -5   103   102    8
 -4   290   282    5
 -3   211   208    6
 -2   212   222    6
 -1   281   273    6
  1   280   294    7
  2   155   137    9
  3   248   254    8
     -7,   9,  L
 -8   478   478    5
 -6   136   135    7
 -5   389   391    5
 -4   393   392    5
 -2   131   129    8
 -1   474   490    6
  0   191   177    8
  2   230   237    9
     -7,  10,  L
 -8   404   388    6
```

```
      COLUMNS ARE 10FO,10FC,  10SIG

   L   KFO    FC  SIG        L   KFO    FC  SIG        L   KFO    FC  SIG
     -7, 10,  L              1  1366  1378    4        1   128   134    7
  -5   352   352    6        2   502   501    5        2   870   869    5
  -4   316   304    6        3   167   188    5        3   361   345    6
  -3    82    63   12        4   796   792    5        4   114   112    9
  -1   239   231    8        5   721   725    5        5   335   329    7
     -7, 11,  L              6    96   102    9        6   391   385    7
 -10   207   205    7        7   295   306    6          -6,  6,  L
  -8   114   121    9        8   584   580    6      -10   167   163    8
  -7   215   214    7        9   159   153    8       -9   295   298    6
  -6   170   173    8          -6,  3,  L             -8   461   457    5
  -5   148   140    9       -9   348   347    7       -7   143   143    6
  -3   277   263    8       -8   120   125    9       -5   765   772    4
     -7, 12,  L             -7   122   118    8       -4   169   162    5
  -7   313   322    7       -6   775   771    5       -3   599   599    4
  -6   215   201    8       -5   198   187    5       -2   502   499    4
  -4   166   165   10       -4   197   188    5       -1   599   586    5
     -6,  0,  L             -3   899   907    4        0   488   479    5
   1   159   163    6       -2   764   772    4        2   585   602    6
   2   200   189    4       -1   232   233    4        3    91    82   11
   3  1416  1407    4        0   385   392    4        4   340   334    7
   4   576   560    4        1   909   910    4        5   153   159   10
   5   296   288    4        2    63    69   12          -6,  7,  L
   6   592   591    4        3   238   248    6      -11   155   158    8
   7   721   724    5        4   713   730    5      -10   304   304    7
   8   112   119    8        5   365   367    5       -9   195   200    6
  10   487   488    6        6   241   251    6       -7   549   552    5
  11   150   166    9        7   156   159    8       -6   282   280    5
     -6,  1,  L              8   362   356    7       -5   140   132    6
  -7   362   361    7        9    90    79   13       -4   433   447    5
  -6   191   198    8          -6,  4,  L             -3   666   679    4
  -5   169   170    7       -9   132   118    9       -2   137   149    7
  -4   516   519    5       -8   389   389    6       -1   106   109    9
  -2   439   443    4       -6   552   554    5        0   597   608    6
  -1   542   564    4       -5   425   433    4        1   168   162    7
   0   706   719    4       -4   605   612    4        2    71    64   13
   1   535   544    4       -3   640   651    4        3   428   424    7
   2   129   120    6       -2    70    48    6        4   298   301    7
   3   739   743    4       -1   959   954    4          -6,  8,  L
   4   428   419    4        1   309   305    5      -11   343   338    7
   5   699   695    5        2   732   739    5      -10   375   373    6
   6   451   437    5        3   484   475    5       -8   265   270    6
   7   231   230    6        4   265   260    6       -7   702   700    5
   8   483   487    6        5   135   135    9       -6   168   170    6
   9   107   124   10        6   461   465    6       -5    79    91    9
  10   201   214    9          -6,  5,  L             -4   619   622    5
     -6,  2,  L            -10   149   144    9       -3   510   500    5
  -8   143   117    9       -9   244   241    6       -2   131   127    7
  -6   713   704    5       -8   588   589    5       -1   173   179    7
  -5   179   176    6       -6    79    78    9        0   550   559    6
  -4   410   410    5       -5   972   980    4        3   231   256    8
  -3   686   687    4       -4   711   708    4          -6,  9,  L
  -2   846   860    4       -3   345   344    4      -11   308   309    7
  -1   296   292    4       -2   598   609    4      -10   142   133    7
   0   264   260    4       -1  1164  1161    4       -9   366   350    5
```

```
      COLUMNS ARE 10FO,10FC,  10SIG

   L   KFO    FC  SIG        L   KFO    FC  SIG        L   KFO    FC  SIG
     -6,  9,  L              5   941   941    4        0   781   780    4
  -7   345   335    5        6   564   561    5        1   592   589    4
  -6   201   196    6        7   271   269    5        2   146   152    8
  -5   176   163    6        8   267   246    6        3   901   890    5
  -4   253   258    6        9   426   426    6        5   182   189    7
  -2   343   343    6          -5,  2,  L              6   344   345    6
   0   131   129    9       -9   378   376    7        7   250   254    7
   1   240   237    8       -8   287   288    7        8   181   178    9
   2   154   148   10       -7   405   400    6          -5,  5,  L
     -6, 10,  L             -6   204   206    6      -11   243   240    8
 -11   104    75    9       -5   749   747    5      -10   149   157    8
 -10   216   238    7       -4   450   451    4       -9   344   347    6
  -9   494   486    6       -3   450   450    4       -8   285   282    5
  -6   448   455    5       -2   585   591    3       -7   260   266    5
  -5   245   234    6       -1   234   240    3       -6   605   611    4
  -3   268   275    7        0   799   801    3       -5   247   241    4
  -2   428   433    7        1   204   201    5       -4   549   558    4
     -6, 11,  L              2   639   652    4       -3   565   572    4
 -11   156   144    9        3   774   784    4       -2   742   741    4
 -10   230   238    7        4   637   636    4       -1   485   487    4
  -9   328   332    6        5   501   502    5        0   171   177    5
  -8   128   136    8        6   108   116    8        1   791   804    5
  -6   371   372    6        7   519   530    5        2   199   196    7
  -3   225   219    8        9   137   130    9        3    75    74   11
  -2   149   153   10       10   245   241    8        4   434   420    6
     -6, 12,  L               -5,  3,  L              5   401   403    7
  -8   214   209    7       -9   183   200    8          -5,  6,  L
  -5   199   205    8       -8   226   222    7      -10   398   389    6
  -4   201   191    9       -7   804   789    5       -9   465   454    5
     -6, 13,  L             -5    89    80    8       -7   238   230    5
  -8   315   321    7       -4  1152  1158    4       -6   972   992    4
     -5,  0,  L             -3   647   649    3       -5   210   210    4
   1   366   357    4       -2   417   415    3       -4   152   159    5
   2  1627  1598    3       -1   783   784    3       -3   896   912    4
   3   388   372    3        0  1404  1407    3       -2   741   746    4
   4   483   470    4        1   160   151    5       -1   211   226    5
   5   752   746    4        2    91    69    7        0   492   483    5
   6   894   890    4        3   928   945    5        1   927   941    5
   8   179   167    6        4   452   447    5        2   225   229    6
   9   687   688    5        5   133   138    7        4   453   448    7
  10   166   167    7        6   403   408    6        5   245   230    8
     -5,  1,  L              7   504   510    6        6   111   118   12
  -8   384   375    7        8    96    89   12          -5,  7,  L
  -7   141   139    8        9    89    76   14      -10   476   468    5
  -6   188   189    7          -5,  4,  L             -9   307   311    5
  -5   886   883    5      -10   209   206    7       -8   268   267    5
  -4   196   197    6       -9   208   205    7       -7   248   240    5
  -2  1052  1048    4       -8   399   396    5       -6   656   663    4
  -1   966   956    3       -7   763   760    5       -5   154   146    5
   0   101    94    4       -6   190   182    5       -4   197   205    5
   1   457   450    4       -4  1259  1268    4       -3   633   644    4
   2  1484  1512    4       -3   254   263    4       -2   142   123    6
   3   204   193    4       -2   540   544    3       -1   427   427    5
   4   142   133    5       -1   992   977    4        0   119   117    8
```

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    COLUMNS ARE 10FO,10FC,  10SIG                                                  COLUMNS ARE 10FO,10FC,  10SIG

   L   KFO    FC  SIG       L   KFO    FC  SIG       L   KFO    FC  SIG       L   KFO    FC  SIG       L   KFO    FC  SIG       L   KFO    FC  SIG
       -5,  7,  L          -8   184   176    7       9   183   181    8           -4,  5,  L         -11   170   163    6      11    96    85   12
   1   343   342    6      -7   301   303    7           -4,  3,  L           4   102   108   10     -10   390   398    5          -3,  1,  L    
   2   237   224    7      -4   212   200    8     -10   413   417    7       5   409   402    7      -9   474   472    5      -9   470   479    7
   3   205   206    8          -5, 13,  L          -8   386   375    6       7   200   190   10      -8   245   243    5      -8    72    61   13
   4   221   213    8      -9   242   241    7      -7   500   514    5           -4,  6,  L          -6   752   753    5      -7   312   310    6
       -5,  8,  L              -4,  0,  L          -6   504   501    4     -12   214   207    7      -5   147   140    7      -6   612   618    5
 -12   282   281    7       1  1128  1108    3      -5   846   856    4     -11   275   273    6      -4   131   125    8      -5   726   730    4
 -11   202   207    7       2   235   246    3      -4   305   291    4     -10   234   231    6      -3   573   572    6      -4   740   735    4
 -10   209   206    7       3   962   950    3      -3   892   896    3      -9   338   339    5      -2   483   477    6      -2  1442  1439    3
  -9   189   196    6       4   555   544    3      -2   336   344    3      -8    91   106    8       0   138   136    9      -1    85    79    4
  -8   549   548    5       5   240   240    4      -1  1051  1050    3      -7   705   709    4       1   369   369    7       0   323   311    2
  -5   719   726    4       6   801   790    4       0   757   752    3      -6   233   236    5           -4, 10,  L           1   434   435    3
  -4   493   475    5       8   617   626    5       1   223   220    4      -5   321   311    4     -13   372   375    7       2   700   682    3
  -3   124   129    7       9   125   120    8       2   891   901    4      -4   955   955    4     -10   474   478    5       3   562   562    3
  -2   376   368    5      10   210   211    7       3   102   100    7      -3   611   603    4      -9   350   341    5       4   158   146    5
  -1   597   594    6      11   303   292    7       4   413   419    5      -2   482   477    4      -8   145   156    6       5   732   741    4
   2   407   399    7          -4,  1,  L           5   458   458    5      -1   297   316    5      -7   273   276    5       6   193   196    5
   3   172   170    9      -9   207   200    8       6   433   426    6       0   934   944    5      -6   569   555    5       7   512   515    5
       -5,  9,  L          -8   297   301    7       7   183   176    7       1   162   167    7      -3   428   430    6       8   278   274    6
 -12   462   452    6      -6   649   652    5       9   325   315    8       2   115   119    9      -2   142   152   10      10   336   338    7
 -11   200   208    7      -5    80    74   10           -4,  4,  L           3   621   615    6      -1   176   163    8          -3,  2,  L    
 -10   104   103    8      -4   249   243    4     -10   172   178    7       4   292   289    7       0   141   158   10      -9   326   317    6
  -9   417   423    5      -3  1120  1104    4      -9   424   430    6       5   127   123   10          -4, 11,  L          -8   398   395    5
  -8   474   468    5      -2   617   613    3      -8   619   618    5           -4,  7,  L         -12   178   184    7      -7   676   675    5
  -7    90   103    8      -1   350   367    3      -7   239   242    5     -11   543   543    6     -10   342   344    6      -6   364   359    5
  -6   152   155    7       0   935   930    3      -6   392   387    4     -10   292   290    6      -8   390   391    6      -5    93    74    6
  -5   690   690    5       1  1430  1454    4      -5  1296  1312    4      -9   183   171    5      -6   131   127    8      -4  1644  1647    3
  -4   192   184    6       2    73    56    6      -4   163   169    4      -8   498   514    4      -5   308   304    7      -3   202   206    3
  -3   106   105    9       3   146   140    5      -3   530   521    3      -7   931   933    4      -4   182   165    8      -2   665   651    3
  -2   345   351    6       4  1295  1294    4      -2  1346  1355    3      -6    63    53    9      -3   184   180    8      -1  1430  1442    3
  -1   370   369    6       5   709   716    4      -1  1365  1356    3      -5   157   166    5      -2   107   114   11       0  1172  1167    3
   0   111   117   10       6   255   246    5       0   409   411    4      -4  1008  1006    4          -4, 12,  L           1  1042  1044    3
   2   259   249    8       7   477   485    5       1   476   470    4      -3   363   358    4     -12   322   328    7       2   497   506    4
       -5, 10,  L           8   746   754    5       2  1481  1502    5      -2   186   180    5     -11   158   163    9       3  1641  1672    4
 -12   292   299    7       9    67    48   14       3   127   113    7      -1   578   578    5      -9   287   297    7       4   423   404    4
 -10   266   260    6          -4,  2,  L           4   121   130    8       0   494   502    5      -8   324   321    6       5   173   163    5
  -9   176   172    7      -9   269   261    7       5   584   575    6       2   162   165    8      -6    82    72   11       6   852   851    5
  -8   103   100    9      -8   209   199    7       6   380   363    6       3   490   477    6      -5   341   329    8       7   597   590    6
  -7   301   304    6      -7   571   570    5       8   168   160   11          -4,  8,  L          -4   116   106   12       8   141   131    7
  -5   257   259    6      -6  1073  1066    5          -4,  5,  L         -11   425   416    6          -4, 13,  L           9   148   146    9
  -3   284   283    6      -5   188   186    5     -10   115   118    9      -9   284   291    5     -10    76    89   13          -3,  3,  L    
   0   237   244    9      -4   138   130    5      -9   673   666    5      -8   406   415    5      -9   148   162   10     -11   438   423    7
       -5, 11,  L          -3  1632  1631    3      -8   441   435    5      -7   480   483    4      -8   154   156    9      -8   868   855    5
 -11   315   315    7      -2   413   412    3      -7   374   383    4      -6   383   391    4          -3,  0,  L          -7   673   671    4
 -10   308   297    6      -1   693   691    3      -6   398   401    4      -4   652   654    5       1  1318  1287    2      -6   246   257    4
  -9    90    99   10       0  1154  1144    3      -5  1044  1054    4      -3   223   226    6       2  1199  1171    3      -5   692   700    3
  -8   190   180    6       1  1246  1239    4      -4    64    58    7      -2   299   289    6       3   219   207    3      -4  1354  1361    3
  -7   442   444    6       2   203   221    4      -3    98   103    5      -1   312   318    6       4    62    38    6      -3    61    62    5
  -6   138   122    8       3   389   397    4      -2   971   967    4       0   121   118    8       5  1387  1383    4      -2   386   376    3
  -4   342   343    7       4   975   991    4      -1   582   571    4       1   342   331    7       6   467   452    4      -1  1844  1847    3
  -3   292   301    8       5   206   200    6       0   438   451    4       3   188   182    9       7   225   225    5       0  1049  1023    3
       -5, 12,  L           6   242   244    6       1   491   495    5           -4,  9,  L           8   649   651    5       1   251   246    4
 -11   298   295    7       7   471   480    6       2   597   596    5     -13   320   327    7       9   522   521    6       2   852   857    4
 -10   178   171    8       8   327   330    7       3   421   421    6     -12    93    71   10      10   169   155    7       3   939   953    4
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      COLUMNS ARE 10FO,10FC,  10SIG

   L   KFO    FC  SIG       L   KFO    FC  SIG       L   KFO    FC  SIG
      -3,  3,  L            1   338   330    6      -4   541   521    6
   4   175   181    6       2   263   252    6      -3   246   247    7
   6   502   503    6       4   336   335    7      -1   288   271    7
   7   121   112   10          -3,  7,  L            0   284   288    8
   8   157   161    9     -12   430   424    7          -3, 11,  L
      -3,  4,  L          -10   341   344    5     -12   124   120    9
 -11   346   340    7      -9   382   387    5     -11   483   469    6
 -10   238   225    6      -8   570   577    4     -10   162   165    7
  -9   137   140    7      -7   461   469    4      -9    96   105    9
  -8   681   676    4      -6   204   203    4      -8   338   335    6
  -6   650   661    4      -5  1070  1077    4      -7   308   314    6
  -5   312   310    4      -4    83    75    8      -6   115   119    9
  -4   606   602    3      -3   288   300    4      -4   379   361    7
  -3   762   754    3      -2   767   757    5          -3, 12,  L
  -2   325   332    3      -1   529   532    5     -13   209   199    7
  -1  1143  1118    3       0   282   297    6     -11   163   163    7
   0   685   672    4       2   514   501    6     -10   184   188    8
   1  1359  1368    4       3   119   127   11      -9   185   184    7
   2   189   187    5          -3,  8,  L           -8   184   180    7
   3   121   129    8     -13   173   184    8      -6   310   306    7
   4   762   770    5     -12   504   500    6          -3, 13,  L
   5   181   175    7     -10   122   115    7     -10   268   276    7
   6   271   283    7      -9   680   673    5      -9   208   190    8
   7   145   145   10      -8   538   538    5      -7   128   127   10
      -3,  5,  L           -7   196   195    5          -2,  0,  L
 -10   692   695    5      -6   493   500    4       1  1540  1506    2
  -9   384   382    5      -5   927   933    4       2   925   884    2
  -8   230   224    5      -4    74    74    8       4  1551  1547    3
  -7   624   624    4      -2   658   658    5       6   342   339    4
  -6   884   891    4      -1   313   315    6       7   891   899    5
  -5   106   105    5       1   262   256    7       8   604   605    5
  -4   327   312    3       2   377   387    7       9   197   190    6
  -3  1458  1450    3          -3,  9,  L           10   186   182    8
  -2   696   679    3     -13   184   189    8      11   421   413    7
  -1   100    95    6     -12   390   367    6          -2,  1,  L
   0   838   837    4     -11   171   175    6     -10   471   471    7
   1   972   983    5     -10   121   117    7      -8   112   106    8
   2   110   118    9      -9   521   520    5      -7   845   840    5
   3   121   115    8      -7   379   370    5      -6   864   855    4
   4   554   554    6      -6   346   351    5      -5   381   376    4
   5   154   163    9      -5   387   376    5      -4   429   431    4
      -3,  6,  L           -4   397   402    5      -3  1925  1942    3
 -11   103   108    9      -3   103    90    9      -2   444   439    2
 -10   708   702    5      -2   335   339    6      -1   444   421    2
  -9    95    92    8      -1    74    74   12       0  1859  1885    2
  -8   355   350    4       0   293   288    7       1  1428  1465    3
  -7   708   717    4       1   125   104   09       2   142   128    4
  -6   843   835    4          -3, 10,  L            3   886   887    3
  -5   357   369    4     -11   448   445    5       4  1389  1386    4
  -4   177   176    4     -10   254   253    6       5    75    51    9
  -3   732   733    4      -9    99    95    7       7   793   804    5
  -2    57    65    8      -8   380   377    5       8   268   263    6
  -1   413   409    5      -7   544   537    5       9   205   218    7
   0   515   523    5      -6   112   116    8      10   218   221    9
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      COLUMNS ARE 10FO,10FC,  10SIG

   L   KFO    FC  SIG       L   KFO    FC  SIG       L   KFO    FC  SIG
      -2,  2,  L            1   802   806    4      -2   236   229    5
 -10   415   416    6       2   789   779    5      -1   550   559    5
  -9   123   127    8       3   484   479    5       1   181   192    7
  -8    60    68   12       4    79    72   12       2   247   258    7
  -7   790   782    5       5   551   563    6       3   187   177    8
  -6   196   199    5       6    65    67   14       4   185   176    8
  -5   993   987    3       7   112   126   13          -2,  8,  L
  -4   865   854    3          -2,  5,  L          -13   353   352    6
  -3  1289  1273    3     -12   198   210    8     -12   127   111    7
  -2  1333  1318    2     -11   433   440    6     -11   185   181    6
  -1   157   143    3      -9   632   640    4     -10   465   462    5
   0  2038  2097    3      -8   477   473    4      -9   210   225    5
   2  1239  1256    4      -7   518   524    4      -8   381   377    4
   3   505   519    4      -6   662   660    3      -7   472   466    4
   4   436   446    4      -5   158   159    4      -6   805   806    4
   5   763   762    5      -4  1086  1092    3      -5    69    71    8
   6   255   250    6      -3    59    69    6      -4    82    82    9
   7   391   395    6      -2   597   595    3      -3   869   875    5
   8   204   199    7      -1   696   685    4      -2   166   147    7
   9   312   315    8       0   613   610    4      -1   251   257    6
      -2,  3,  L            1   346   358    5       0   375   377    6
 -11   136   132    8       2   215   213    6       1   419   409    7
 -10   178   164    7       3   747   754    6          -2,  9,  L
  -9   632   616    5       5   176   171    9     -14   270   266    7
  -8   396   400    5       6   313   302    8     -13   380   389    6
  -7   415   406    4          -2,  6,  L          -11   112   117    8
  -6   569   565    4     -13   119   120    9     -10   879   877    5
  -5  1230  1235    3     -12   146   158    8      -9   281   281    5
  -4   238   223    3     -11   724   718    5      -8   298   298    5
  -3   285   280    3     -10    77    81    9      -7   589   592    5
  -2  1672  1662    2      -9    63    81   10      -6   703   697    5
  -1   951   931    3      -8   929   920    4      -5   223   228    6
   0   164   158    4      -7   666   668    4      -4    95   109    9
   1  1211  1211    4      -6   350   344    4      -3   636   634    6
   2  1194  1218    4      -5   577   579    3      -2   131   133    8
   3   170   179    5      -4  1532  1522    4       0   311   319    7
   4   135   134    7      -3   122   114    5       1   222   211    8
   5   961   959    5      -2   116    90    5          -2, 10,  L
   6   174   180    7      -1  1094  1107    4     -14   259   244    7
   7   109   121   10       0   552   541    5     -13   203   217    7
   8   352   364    8       1   250   257    6     -12   180   183    7
      -2,  4,  L            2   396   404    6     -10   369   375    5
 -12   404   399    7       3   597   591    6      -9   286   280    5
 -10    90   101   10          -2,  7,  L           -8   372   371    5
  -9   866   865    5     -13   182   180    7      -7   367   375    5
  -8   234   243    5     -12   291   290    6      -5   340   334    6
  -7   240   239    4     -11   554   552    5      -4   171   172    8
  -6  1254  1258    3     -10   246   240    5      -3   247   245    7
  -5  1177  1164    3      -8   923   923    4      -2   231   237    8
  -4   245   245    3      -7   426   428    4      -1   201   191    8
  -3   201   207    3      -6   405   410    4          -2, 11,  L
  -2  1689  1669    3      -5   537   529    4     -13   105   113   10
  -1   421   389    3      -4   769   766    4     -12   412   435    6
   0   439   436    4      -3   454   451    4     -10    94    97    8
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COLUMNS ARE 10FO,10FC,  10SIG

   L   KFO    FC  SIG      L   KFO    FC  SIG      L   KFO    FC  SIG
      -2, 11,  L          -6   231   227    4      7   421   434    7
  -9   478   484    5     -5  1303  1277    3         -1,  5,  L
  -8   323   323    6     -4  1538  1518    3    -13   257   248    7
  -7   220   207    6     -3   435   424    2    -12   145   151    8
  -6   222   213    7     -2   330   326    2    -11   368   360    6
  -5   459   445    6     -1  2073  2110    2    -10   730   731    5
      -2, 12,  L           0   811   791    3     -9   156   154    5
 -13   162   175    8      1  1067  1075    3     -8    65    79    8
 -12   310   307    7      2  1420  1444    4     -7  1185  1195    4
  -9   355   356    6      3  1181  1195    4     -6   578   572    3
  -8   152   157    7      4   548   543    5     -5   436   440    3
  -6   179   185    9      5   284   292    5     -4   928   911    3
  -5   222   229    8      6   855   860    5     -3  1255  1250    3
      -2, 13,  L           8   121   113   10     -2   319   318    4
 -12    70    84   14      9   306   308    8     -1   191   182    5
 -11   197   201    7         -1,  3,  L           0   931   947    4
  -9   142   129    8    -12   341   336    7      1   373   361    5
      -1,  0,  L         -11   241   250    7      2   285   287    6
   1  1703  1778    2    -10   337   329    6      3   294   282    6
   2   119   103    3     -9   213   214    6      4   329   334    7
   3   973   936    3     -8   784   783    4      5   172   178    9
   4   635   633    3     -7   182   185    5         -1,  6,  L
   5   772   769    4     -6   401   404    3    -12   361   365    6
   6   539   544    4     -5   879   881    3    -11   275   278    6
   7   122   135    7     -4   248   227    3    -10   346   339    5
   8   526   523    5     -3   614   594    2     -9   579   576    4
  10   290   299    7     -2   161   156    3     -8   163   160    5
      -1,  1,  L          -1   495   485    3     -7   580   586    4
 -10   163   183    9      0   606   602    3     -6   234   232    4
  -9   219   217    7      1   705   696    4     -5   910   909    3
  -8   588   584    5      2   800   797    4     -4   396   400    4
  -7   264   269    5      3   115    99    7     -3    49    47    8
  -6   486   493    4      4   801   810    5     -2   918   927    4
  -5   514   502    4      5   109   112    9     -1   174   182    6
  -4  1196  1188    3      6   295   290    6      0   363   356    5
  -3   396   366    3      7   355   349    7      1   420   421    6
  -2   472   463    2      8   183   203   10      2   538   531    6
  -1  1782  1790    2         -1,  4,  L             -1,  7,  L
   0   833   818    2    -12   170   167    8    -14   151   161    9
   1   530   532    2    -11   208   187    7    -13   340   336    6
   2  1261  1279    3    -10   710   692    5    -12   561   558    5
   3  1712  1722    3     -8   336   339    4    -11   239   232    5
   4   378   386    4     -7  1090  1098    4    -10   156   158    6
   5    85    98    7     -6   890   881    3     -9  1020  1023    4
   6   938   950    5     -5   396   407    3     -8   368   369    4
   7   254   251    6     -4   718   703    3     -7   186   192    4
   8   118   131    8     -3  1364  1346    3     -6  1064  1047    4
   9   395   390    7     -2   118   114    4     -5  1046  1045    4
      -1,  2,  L           0  1247  1263    4     -4   204   219    5
 -11   415   399    7      1   860   849    4     -3   283   292    5
 -10   121   116    8      2   226   224    5     -2  1038  1047    5
  -9   197   195    6      3   449   459    5     -1   165   158    7
  -8  1047  1028    5      4   827   823    6      0   143   143    8
  -7   317   319    4      5    78    56   12      1   468   487    6
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COLUMNS ARE 10FO,10FC,  10SIG

   L   KFO    FC  SIG      L   KFO    FC  SIG      L   KFO    FC  SIG
      -1,  7,  L          -4    85    97   14      0   639   625    3
   2   370   364    7     -3   241   243    8      1  1407  1438    3
   3   113    83   10         -1, 12,  L           2   824   840    4
      -1,  8,  L         -13   282   282    7      3   629   638    4
 -14    82    86   11    -10   403   399    6      4   588   593    5
 -13   439   434    6     -8   112    88    9      5   960   965    5
 -12   337   336    6     -7   312   306    7      8   517   514    7
 -11   257   257    5     -6   305   307    7          0,  3,  L
 -10   236   239    5         -1, 13,  L         -12   275   274    7
  -9   708   713    4    -12   106   115   10    -11   201   201    7
  -8   123   122    6    -11    92    99   11    -10   358   349    5
  -7   194   192    6    -10   298   295    7     -9   947   932    5
  -6   681   679    4          0,  0,  L          -8    89    87    6
  -5   288   280    5      1   658   627    2     -7    95    80    5
  -4   473   465    5      2  1028   982    2     -6  1779  1765    3
  -3   131   116    7      3  1834  1856    3     -5   884   867    3
  -2   422   424    6      4  1046  1048    3     -4   723   708    3
  -1   232   255    7      5   518   511    4     -3   854   832    2
   0   215   211    7      6   260   277    5     -2  1303  1283    2
   1   248   243    7      7   946   943    5     -1   220   220    3
      -1,  9,  L           8   162   152    7      0   213   197    4
 -14   199   211    7      9   100    98   11      1  1288  1312    4
 -13   220   222    7     10   384   376    7      2   558   550    4
 -12    83    88   10          0,  1,  L           3   316   323    5
 -11   601   610    5    -11   400   395    7      4   580   572    5
  -9   167   159    6    -10   352   350    6      5   613   605    6
  -8   633   627    5     -9   244   251    6      6   201   191    7
  -7   343   340    5     -8   221   220    6          0,  4,  L
  -6   267   272    5     -7   894   891    4    -13   347   353    7
  -5   326   322    5     -5   132   134    5    -11   361   360    6
  -4   671   663    5     -4  1044  1017    3    -10   317   314    5
  -1   438   435    6     -3  1508  1498    2     -9   626   626    4
   0   202   197    8     -2   895   866    2     -8   513   509    4
      -1, 10,  L          -1   516   474    1     -7   198   210    4
 -14   178   177    7      0  1357  1391    2     -6  1146  1138    3
 -13    78    72   10      1  1261  1268    3     -5   446   426    3
 -12   318   325    6      2   676   637    3     -4   769   749    3
 -11   543   552    5      3  1110  1108    4     -3   529   522    3
  -8   599   595    5      5   688   676    4     -2   685   667    3
  -7   208   216    6      6   320   327    5     -1   822   811    4
  -6   229   232    6      7   443   434    6      0   251   251    5
  -5   333   327    6      8   336   340    7      1   695   703    5
  -4   457   455    6      9   227   229    8      2   346   353    5
  -1   299   296    8          0,  2,  L           3   691   697    5
      -1, 11,  L         -11   229   229    7      4   263   249    6
 -13   171   177    7     -9   590   595    5      6   430   421    8
 -12   173   168    7     -8   131   116    6          0,  5,  L
 -11   217   212    6     -7   309   319    4    -13   213   211    8
 -10   216   220    7     -6   960   949    3    -12   386   380    6
  -9   107   102    9     -5   976   952    3    -11   619   628    5
  -8   240   240    6     -4   241   235    3    -10   265   260    5
  -7    99   108   10     -3  1214  1187    2     -8  1343  1346    4
  -6   235   235    7     -2  2146  2142    2     -7    86    99    6
  -5   163   167    8     -1   247   219    2     -6   452   452    3
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        COLUMNS ARE 10FO,10FC,  10SIG

   L   KFO    FC   SIG       L   KFO    FC   SIG       L   KFO    FC   SIG
        0,    5,  L         -9    82    86     8            1,    0,  L
  -5  1331  1319     3      -7  1029  1013     4       0   124   109     2
  -4  1336  1343     3      -6   485   487     4       1   288   273     2
  -3   415   412     3      -5   209   202     5       2  1856  1885     3
  -2   172   182     4      -4   639   636     5       3   775   750     3
  -1  1349  1357     4      -3   769   757     5       4   615   602     4
   0   376   375     5      -2   129   117     8       5   377   383     4
   1    90    93     9       0   488   481     6       6   943   946     5
   2   785   785     5       1   129   128     9       9   505   501     7
   3   541   538     6            0,    9,  L               1,    1,  L
   4   119   127     9     -14   377   385     6     -11   304   287     7
   5   159   148    10     -13    84    85    10     -10   163   158     7
        0,    6,  L        -12   228   224     6      -9   406   396     6
 -13   110   106     9     -11   302   300     5      -8   864   871     5
 -12   540   531     5     -10   457   469     5      -6   235   225     4
 -11   550   560     5      -9   328   328     5      -5  1344  1339     3
 -10   240   239     5      -7   736   721     5      -4   650   643     3
  -9   420   418     4      -5   392   390     5      -3   354   329     2
  -8   988   989     4      -4   347   339     6      -2  1303  1266     2
  -7    54    49     8      -3   209   210     7      -1  2005  2086     2
  -6   180   179     4      -2   317   328     7       0   161   147     3
  -5   978   970     3       0   208   213     8       1   596   597     3
  -4   579   578     4            0,   10,  L          2  1759  1799     4
  -3   546   542     4     -14   175   177     7       3   611   609     4
  -2   381   372     5     -13   208   207     6       4   476   466     4
  -1   893   916     5     -12   345   346     6       5   671   669     5
   0   182   179     6     -11   141   133     7       6   784   785     5
   1   221   227     7      -9   631   622     5       7   110   111     9
   2   497   504     6      -8   168   174     7       9   410   406     8
   3   111   114    11      -7   154   163     7            1,    2,  L
   4   269   273     8      -6   440   437     6     -12   421   414     7
        0,    7,  L         -5   397   385     6     -11   102    93     9
 -14   134   156    10      -4   118   111     9     -10   280   285     6
 -13   223   228     7      -3   160   156     9      -9   566   559     5
 -12   417   422     5      -2   375   375     7      -8   777   765     4
 -10   708   700     5            0,   11,  L         -7   402   401     4
  -9   111   103     6     -13   371   369     6      -6    69    58     6
  -8   404   411     4     -12   326   342     6      -5  1376  1360     3
  -7   654   653     4     -11   102   115     8      -4   843   828     2
  -6   599   608     4     -10   245   242     7      -3  1098  1066     2
  -5   499   504     4      -9   542   550     5      -2   680   656     2
  -4   201   217     5      -7    81   102    12      -1   952   941     2
  -3   860   844     5      -6   389   378     6       0   708   708     3
  -1   116   112     9      -5   220   205     8       1   154   149     5
   0   563   565     6      -4   134   140    10       2   943   969     4
   1   240   226     7            0,   12,  L          3   194   192     5
   2   165   153     8     -13   235   233     7       4   588   583     5
   3   199   175     8     -12    65    64    13       5   445   439     6
        0,    8,  L        -11   271   265     7       6   210   208     7
 -14   414   427     6      -9   166   150     7       7   478   469     6
 -13   317   324     6      -8   209   200     7            1,    3,  L
 -12   106   116     9      -7   118   115    11     -12   252   239     7
 -11   438   428     5            0,   13,  L        -11   314   321     6
 -10   689   695     5     -11   312   322     7     -10   462   457     5
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        COLUMNS ARE 10FO,10FC,  10SIG

   L   KFO    FC   SIG       L   KFO    FC   SIG       L   KFO    FC   SIG
        1,    3,  L          3   227   229     7      -2   199   209     8
  -9   435   439     5       4   171   158     9      -1   369   364     7
  -7  1010   995     4       5   306   288     8            1,   10,  L
  -6   432   428     3            1,    6,  L        -14   116   109     8
  -5   329   332     3     -13   425   433     6     -12   400   399     6
  -4  1647  1611     3     -12   364   370     5     -11   153   170     6
  -3  1575  1560     2     -11   130   125     7     -10   214   219     6
  -2   402   386     3     -10   565   579     4      -9   142   153     7
  -1   382   379     3      -9  1069  1072     4      -8   306   301     5
   0  1457  1490     4      -8   175   176     5      -7   197   196     7
   1   196   204     5      -7    95    88     5      -6   156   157     8
   2   226   236     5      -6  1072  1068     4      -5   265   272     7
   3   794   809     5      -5   484   490     4      -3   263   252     7
   4   664   674     6      -4   267   262     4            1,   11,  L
   5   112   103     9      -3   684   679     4     -14   303   297     7
   6   149   164    10      -2  1033  1034     5     -13   148   164     8
   7   416   422     8       1   718   708     6     -12   180   181     7
        1,    4,  L          2   249   241     7     -11   205   209     7
 -13    81    66    11       3   121   116    11     -10   460   457     6
 -12    76    93    12            1,    7,  L         -7   439   426     6
 -11   593   592     5     -13   585   601     5      -6   176   195     9
 -10   496   493     5     -12   223   233     6      -5   106   104    11
  -9   169   168     5     -11   393   401     5      -4   147   148    10
  -8   607   607     4     -10   513   511     5            1,   12,  L
  -7  1590  1601     3      -9   735   739     4     -13   125   122    10
  -6   368   346     3      -8   375   376     4     -12    97    81    10
  -5   121   123     4      -6  1070  1075     4     -11   322   316     6
  -4  1371  1360     3      -5   136   146     6     -10   302   304     6
  -3   895   884     3      -4   349   339     5      -9   128   136     9
  -2   674   652     3      -3   521   529     5      -7   313   306     7
  -1   599   606     4      -2   446   442     5            2,    0,  L
   0  1411  1436     4      -1   363   379     6       0  1807  1907     2
   2   166   143     7       1   455   446     6       1  1082  1060     3
   3   643   646     6            1,    8,  L          2   105   115     5
   4   213   209     8     -13   248   248     6       3  1458  1453     4
   5   299   294     7     -12   320   322     5       4   112   108     6
   6   126   122    11     -11   386   395     5       5   554   544     5
        1,    5,  L        -10   324   325     5       6   655   643     5
 -13   131   119     8      -8   656   654     4       7   356   346     6
 -12   132   131     8      -6   370   365     5       8   392   388     6
 -11   587   589     5      -5   585   574     5            2,    1,  L
 -10   253   249     5      -4   565   562     5     -11   296   311     7
  -9   686   689     4      -3   166   168     7     -10   180   187     7
  -8   115   107     5      -2   106    94    10      -9   455   460     5
  -7   552   562     3      -1   512   516     7      -8   323   324     5
  -6   663   655     3       1   101   103    11      -7   218   228     5
  -5   532   517     3            1,    9,  L         -6  1160  1160     4
  -4   530   537     3     -12   498   510     5      -5   250   255     4
  -3    91    89     6     -11   389   399     5      -4   862   839     3
  -2   824   825     4      -9   295   283     5      -3   643   626     2
  -1   267   259     5      -8   692   694     5      -2   801   781     2
   0   320   336     5      -5   699   687     5      -1  1127  1077     2
   1   674   682     5      -4   414   398     6       0   281   272     4
   2   355   351     6      -3   161   154     8       1  1256  1255     3
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COLUMNS ARE 10FO,10FC, 10SIG

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   L   KFO    FC  SIG      L   KFO    FC  SIG      L   KFO    FC  SIG
        2,  1,  L        -10   335   332    5     -7  1030  1035    4
   2   337   335    4     -9   284   278    5     -6   130   142    6
   3   197   207    5     -8   860   864    4     -5   145   153    6
   4   765   769    5     -7    84    75    6     -4   945   942    5
   5   687   683    5     -6    75    60    5     -3   638   641    5
   6   226   210    6     -5  1600  1576    3     -2   222   224    7
   7   165   169    8     -4   721   714    3     -1   275   267    6
   8   529   525    7     -3   488   484    3      0   559   548    6
        2,  2,  L         -2   912   894    4           2,  8,  L
 -12    94    98   11     -1  1369  1408    4    -15   187   187    7
 -11    96   103   10      0   187   183    6    -14   444   454    6
 -10   532   521    5      2   936   932    6    -11   560   557    5
  -9   662   669    5      3   312   317    6    -10   242   241    5
  -8   147   145    6      4   223   210    7     -9   282   276    5
  -7   389   381    4      5   258   252    8     -8   328   316    5
  -6  1468  1460    3           2,  5,  L         -7   722   726    4
  -5   308   304    3    -12   761   775    5     -6   110    98    7
  -4   423   413    3    -11   325   337    5     -5    97   104    9
  -3  2269  2261    2    -10   282   294    5     -4   523   529    6
  -2  1128  1101    2     -9   817   820    4     -2   343   349    7
  -1   667   657    3     -8  1104  1109    4     -1   190   185    8
   0  1113  1120    4     -7   458   447    4      0   222   226    8
   1  1408  1451    4     -6   201   203    4           2,  9,  L
   2   187   185    5     -5  1410  1407    3    -14   161   152    7
   3    93    94    8     -4   388   386    4    -13   358   353    6
   4   845   850    5     -3   569   553    4    -12   177   195    6
   5   446   447    6     -2   770   768    4    -11   230   237    6
   6   251   259    7     -1   796   805    5    -10   174   180    7
   7   202   186    8      0   356   357    5     -9   531   537    5
        2,  3,  L          1   160   161    8     -8    92    86    9
 -13   358   366    7      2   612   608    6     -7   148   140    6
 -12   117   110    9      4   173   164    9     -6   573   566    5
 -11   182   181    7           2,  6,  L         -5   331   328    6
 -10   698   696    5    -14   190   194    7     -4   206   206    7
  -9   451   452    5    -12   447   464    5     -3   211   205    8
  -8   473   476    4    -11   148   147    7     -2   362   380    7
  -7   414   413    4    -10   536   542    5           2, 10,  L
  -6  1584  1579    3     -9   509   506    4    -13   463   476    6
  -5   476   461    3     -8   160   173    5    -12   189   198    6
  -4  1019   992    3     -7   815   817    4    -11   109   101    8
  -3  1625  1615    3     -5   582   583    4    -10   464   463    5
  -2   170   163    4     -4   429   422    4     -9   507   519    5
  -1   937   944    4     -3   694   698    5     -8   101   104    8
   0   326   323    5     -2   425   427    5     -7    97    83    9
   1   464   472    5      0   660   659    6     -6   444   437    6
   2   545   545    5      2   215   219    8     -4    79    76   12
   3   276   278    6      3   313   296    8     -3   267   276    8
   4   340   337    7           2,  7,  L               2, 11,  L
   5   111   102   10    -14   427   421    6    -13   361   361    6
   6   350   336    7    -13   132   145    8    -11   221   224    7
        2,  4,  L        -11   603   616    5    -10   310   303    6
 -13   149   157    9    -10   568   566    5     -9   127   131    9
 -12   432   421    6     -9   251   245    5     -8   325   332    6
 -11   352   351    5     -8   396   397    4     -6   241   238    8
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COLUMNS ARE 10FO,10FC, 10SIG

```
   L   KFO    FC  SIG      L   KFO    FC  SIG      L   KFO    FC  SIG
        2, 11,  L          5   282   282    6      1   754   768    6
  -5   129   105   10      6   262   258    8           3,  6,  L
        2, 12,  L          7   413   412    8    -14   233   226    7
 -13    87    90   12           3,  3,  L        -13   445   445    6
 -12   283   288    7    -11   763   758    5    -11    65    71   11
 -11   260   253    7    -10   312   312    5    -10   851   846    4
 -10   113   115   10     -9   213   223    5     -9   568   577    4
  -9   119   127   10     -8   848   852    4     -8   346   345    4
  -8   344   328    7     -7  1093  1085    3     -7   619   608    4
        3,  0,  L         -6   185   182    4     -6  1078  1076    4
   0   475   467    3     -5   151   149    4     -5   194   193    5
   1   596   569    3     -4  1792  1769    3     -4   138   127    6
   2  1559  1558    4     -3   352   347    3     -3   873   873    5
   3   166   157    5     -2   181   189    4     -2   251   254    6
   4   141   138    6     -1  1260  1270    4     -1   307   313    6
   5   976   974    5      0   822   838    5      0   306   302    7
   6   536   526    5      1   319   322    5      1   406   385    7
   7   235   237    7      2   204   201    6      2   139   150   11
   8   255   254    7      3   715   727    6           3,  7,  L
        3,  1,  L          5   129   120   10    -14   205   201    7
 -12   424   412    7      6   327   331    8    -13   289   309    6
  -9   782   789    5           3,  4,  L        -12   291   283    6
  -8   542   538    5    -13   147   145    8    -11   189   190    6
  -7   501   501    4    -11   491   479    5    -10   465   470    5
  -6   723   710    4    -10   218   223    5     -9   114   121    6
  -5  1347  1333    3     -9   363   371    4     -8   618   606    4
  -4   601   575    3     -8   695   705    4     -7   187   181    5
  -3   228   214    3     -7   711   707    3     -6   277   281    5
  -2  1219  1169    2     -6   625   632    3     -5   715   713    5
  -1   788   772    3     -5   195   186    4     -4   335   342    6
   0   322   329    4     -4  1065  1047    3     -3   370   368    6
   1   580   578    4     -3   512   504    4     -2   297   302    6
   2   843   851    4     -2   637   628    4     -1   503   504    7
   3   348   346    5     -1   593   605    5      0   150   143   10
   4   292   282    5      0   202   200    6           3,  8,  L
   5   508   512    6      1   634   639    6    -15   325   329    7
   7   310   324    8      3   329   328    7    -12   638   645    5
        3,  2,  L          4   246   257    8    -11   215   223    6
 -12   238   237    7           3,  5,  L         -9   529   529    5
 -11   318   332    6    -14    74    46   12     -8   532   534    5
 -10   201   198    6    -13   473   481    6     -6   211   204    6
  -9   474   480    5    -12   124   135    8     -5   703   704    5
  -8   266   262    4    -11   212   212    5     -4   198   202    7
  -7  1087  1089    4    -10   467   464    5     -3   144   147    8
  -6   158   152    4     -9   692   697    4     -2   366   369    7
  -5   239   244    3     -8   331   338    4     -1   325   320    7
  -4  1401  1396    3     -7    81    77    6           3,  9,  L
  -3   689   676    3     -6  1335  1343    4    -15   252   254    7
  -2  1026   999    3     -5   234   224    4    -14   182   180    7
  -1   740   746    4     -4   126   138    5    -13   134   137    8
   0  1295  1331    4     -3  1025  1022    4    -12   534   548    5
   1    91   107    8     -2   611   614    5    -10   194   206    6
   3   945   955    5     -1   300   290    6     -9   356   364    5
   4   381   388    6      0   371   374    6     -8   252   256    6
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COLUMNS ARE 10FO,10FC,  10SIG

   L   KFO    FC  SIG       L   KFO    FC  SIG       L   KFO    FC  SIG
       3,  9, L            -9   121   113    7     -10   179   183    6
  -7   253   245    6      -8   294   297    4      -9   757   762    4
  -5   388   385    6      -7   881   881    4      -8   118   111    6
  -3   172   172   10      -6   536   542    3      -7   795   803    4
  -2   210   213    9      -5   555   549    3      -6   720   717    4
       3, 10, L            -4   384   369    3      -5   647   643    4
 -14   323   334    6      -3  1213  1198    3      -4   871   856    4
 -12   145   152    8      -2   371   370    4      -3   210   207    6
 -11   364   357    6      -1   685   682    4      -2   608   622    5
 -10   297   310    6       0   864   888    5      -1   173   188    7
  -9   152   154    7       1   344   355    5       0   503   499    6
  -8   145   139    8       2   605   626    5       1   214   219    8
  -7   408   407    6       4   531   520    6       2   142   125    9
  -5    97   106   12       5   148   143    8       3   353   356    8
  -4   295   291    8       6   205   207    9           4,  6, L
       3, 11, L                4,  3, L           -14   351   339    6
 -14   329   332    7     -12   492   491    6     -13    96   109    9
 -11   428   415    6     -11   162   162    7     -11   565   578    5
 -10   246   251    7     -10   445   447    5     -10   326   328    5
  -8   213   201    7      -9   506   506    4      -9   191   202    5
  -7   347   334    7      -8   747   749    4      -8   590   589    4
       3, 12, L            -7   582   587    4      -7   885   888    4
 -11   241   234    7      -6   165   159    4      -6   111   120    6
       4,  0, L            -5  1377  1375    3      -5   253   244    5
   0   506   508    4      -4   143   138    4      -4   993   994    5
   1  1524  1516    4      -3   317   311    4      -3   186   186    7
   2   257   250    4      -2  1035  1028    4      -2   212   210    6
   3   125   131    6      -1   663   688    5      -1   506   511    6
   4   997   987    5       0   366   371    5       0   440   441    6
   5   337   335    5       1   278   269    6       1   118   108   10
   6   378   381    6       2   783   784    6           4,  7, L
   7   245   235    7       5   435   430    7     -14   308   309    6
   8   409   403    8           4,  4, L           -13    84    93   11
       4,  1, L           -13   233   236    7     -12   206   211    6
 -10   712   702    6     -12   605   605    5     -11   653   657    5
  -9   381   373    5     -10   185   193    6     -10   149   157    6
  -8   158   164    5      -9   888   888    4      -9    77    82    8
  -7   902   886    4      -8   660   669    4      -8   633   630    5
  -6  1304  1289    4      -7   410   410    4      -7   514   521    5
  -5   286   271    4      -6   805   781    4      -6   316   305    5
  -4   197   190    3      -5  1412  1416    4      -4   641   644    5
  -3  1685  1664    3      -4   160   155    5      -2   184   186    8
  -2   766   748    3      -3    54    57   11      -1   361   355    7
  -1   292   311    4      -2  1041  1047    5       0   165   170   10
   0  1286  1323    4      -1   504   513    5           4,  8, L
   1  1188  1211    4       0   253   245    6     -15   227   230    7
   2   171   173    6       1   413   415    6     -14   141   140    8
   3   211   223    6       2   598   594    6     -13   333   335    6
   4   707   712    5       3   119   110   10     -11   280   287    6
   6   127   120    9           4,  5, L           -10   360   372    5
   7   375   383    8     -14   170   174    8      -9   363   382    5
       4,  2, L           -13   203   208    7      -8   222   224    6
 -11   163   165    7     -12   411   412    5      -6   449   460    5
 -10   709   716    5     -11   278   279    5      -4   189   180    8
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COLUMNS ARE 10FO,10FC,  10SIG

   L   KFO    FC  SIG       L   KFO    FC  SIG       L   KFO    FC  SIG
       4,  8, L            -6   236   233    4      -5   326   337    5
  -3   381   382    7      -5   816   801    3      -4   268   262    5
  -2   261   252    7      -4  1354  1331    3      -3   803   798    5
       4,  9, L            -3   243   231    4      -1   148   155    8
 -14   169   176    8      -2   214   210    5       0   514   513    7
 -13   537   544    6      -1  1201  1221    5       1   313   316    7
 -10   551   559    5       0   668   678    5       2   160   158   10
  -9   324   324    6       1   339   337    6           5,  6, L
  -8   243   235    6       2   443   443    6     -14   282   288    6
  -7   229   226    6       3   707   697    6     -13   164   158    8
  -6   556   565    6           5,  3, L           -12   246   245    6
  -3   370   368    7     -13   170   163    8     -11   121   125    7
       4, 10, L           -12   260   272    7     -10   411   413    5
 -14   207   207    8     -11   491   498    5      -9   250   254    5
 -13   284   292    7     -10   246   250    5      -8   338   344    5
 -12   169   177    7      -8  1045  1047    4      -7   412   400    5
 -10   458   438    6      -7   246   233    4      -5   536   529    5
  -8   260   260    7      -6   367   366    4      -4   169   162    7
  -7   238   231    7      -5   611   602    4      -3   302   308    6
  -6   213   208    8      -4   705   696    4      -2   350   348    7
  -5   200   206    9      -3   495   493    4      -1   189   209    8
       4, 11, L            -2   106   107    7       0   244   249    8
 -12   276   286    7      -1   744   741    5           5,  7, L
 -11   101   107   10       0   131   121    8     -14   161   164    8
  -9   266   260    7       1   477   472    6     -13   165   169    8
  -8   312   310    7       2   336   342    7     -12   588   598    5
       5,  0, L             3   222   235    7     -10   122   125    7
   0   247   257    5       4   335   326    8      -9   676   681    5
   1   903   889    4           5,  4, L            -8   450   452    5
   2   596   579    4     -14   127   136   10      -7   235   228    5
   3   506   498    5     -13   314   306    6      -6   278   268    5
   5   572   568    6     -12   109   115    9      -5   636   631    5
   7   193   179    8     -10   611   616    5      -2   484   476    7
       5,  1, L            -9   147   155    6      -1   221   236    9
 -12   178   175    8      -8   425   421    4           5,  8, L
 -11   367   366    6      -7   631   619    4     -14   104    85    9
  -9   522   508    5      -6   953   955    4     -13   279   295    7
  -8   467   470    5      -5   219   218    4     -12   447   458    6
  -7   552   544    4      -4   176   178    5     -11   157   168    7
  -6   470   474    4      -3  1090  1091    5      -9   571   581    5
  -4   869   861    3      -2   242   244    6      -7   167   181    7
  -2   519   517    3      -1   264   275    6      -6   429   412    6
  -1   850   838    4       0   512   514    6      -5   381   386    6
   0   679   701    5       1   535   538    6      -4   158   156    9
   1   474   479    5       2   121   127   11           5,  9, L
   2   338   339    5           5,  5, L           -14   242   239    7
   3   780   783    6     -14   340   340    7     -13   167   165    7
   5   165   166    8     -13   391   388    6     -12   114   115    9
   6   403   397    7     -11   224   231    5     -11   405   407    6
       5,  2, L           -10   754   767    5     -10    99   115    9
 -12   175   193    8      -9   265   268    5      -9   260   263    6
 -11   606   604    6      -8   169   168    5      -8   231   223    6
  -8  1027  1028    4      -7   851   851    4      -7   336   341    6
  -7   515   510    4      -6   807   804    4      -6   140   145    9
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          COLUMNS ARE 10FO,10FC,  10SIG

   L   KFO    FC  SIG       L   KFO    FC  SIG       L   KFO    FC  SIG
          5,    9,  L     -11    68    68   12      -6   159   152    6
  -4   343   353    8     -10   134   130    6      -5   437   434    6
          5,   10,  L      -9   873   868    5      -4   489   483    6
 -14   278   264    7      -8   269   259    5      -3   122   120    9
 -12   144   151    8      -7   187   183    5      -1   405   417    7
 -11   429   430    6      -6  1057  1047    4             6,    7,  L
 -10    93   112   10      -5  1053  1052    4     -13   257   264    6
  -8   368   353    7      -4   255   265    4     -12   217   214    7
  -7   273   279    8      -3   351   340    5     -11   248   258    6
          5,   11,  L      -2  1167  1179    5     -10   411   417    5
 -11   219   218    8      -1   127   133    8      -9    84    74   10
          6,    0,  L       0   184   208    8      -8   446   439    5
   0  1306  1310    4       1   572   571    6      -7   172   161    7
   1   640   638    5       2   387   379    7      -6   333   334    6
   2   380   382    5       3   159   175    9      -5   185   189    7
   3   474   479    5              6,    4,  L      -4    77    76   13
   4   819   808    6     -13   374   386    6      -3   338   348    7
          6,    1,  L     -12   267   268    6             6,    8,  L
 -11   228   259    7     -11   279   284    6     -14   231   251    7
 -10   530   529    5     -10   185   184    6     -13   362   362    6
  -8   104   115    8      -9   654   653    4     -11    99    93    9
  -7   985   974    4      -8    80    80    8     -10   627   631    5
  -6   433   420    4      -7   145   142    6      -8   172   168    7
  -5   465   457    4      -6   658   656    4      -7   504   505    6
  -4   628   619    4      -5   212   203    5      -6   369   386    6
  -3   907   889    4      -4   622   614    5      -5   107   113   10
  -2   337   342    4      -3   172   176    7      -4   164   160    9
  -1   144   141    7      -2   447   457    6             6,    9,  L
   0  1057  1094    5      -1   333   351    6     -14   262   275    7
   1   169   164    7       0   183   194    8     -13   240   245    7
   2   331   329    6       1   362   361    7     -12   113   115    9
   3   412   414    6              6,    5,  L     -11   116   133    9
   4   281   284    7     -14   214   204    8     -10   368   383    7
   5   287   279    8     -13   192   209    7      -9   106    98    9
          6,    2,  L     -12   145   149    7      -7   368   364    7
 -12   240   239    7     -11   591   595    5      -6   123   129   11
 -11   244   258    6      -9    74    73   10             6,   10,  L
 -10   266   274    6      -8   734   726    4     -12   282   282    7
  -9   470   467    5      -7   463   454    5     -10    90   104   11
  -8   170   167    6      -6   257   259    5      -9   283   272    7
  -7   475   477    4      -5   371   358    5             7,    0,  L
  -6   409   403    4      -4   776   766    5       0   175   186    6
  -5   748   735    4      -3   101    74   10       1   466   464    5
  -4   361   344    4      -2    98   119   10       2   306   300    6
  -3   144   141    5      -1   545   551    7       3   484   481    6
  -2   895   901    5       0   265   270    8       4   204   203    7
  -1   228   220    7       1   138   127    9              7,    1,  L
   0   311   313    6              6,    6,  L     -12   210   206    7
   1   574   574    6     -14   220   225    7     -11   374   375    7
   2   574   590    6     -13   119   108    9     -10   107   120   10
   3   163   162    9     -12   382   393    6      -8   843   827    5
          6,    3,  L     -11   589   603    5      -7   296   292    5
 -13   248   265    7      -8   664   667    5      -6   147   139    6
 -12   440   435    6      -7   157   172    6      -5   914   909    4
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          COLUMNS ARE 10FO,10FC,  10SIG

   L   KFO    FC  SIG       L   KFO    FC  SIG       L   KFO    FC  SIG
          7,    1,  L     -11   306   314    6             8,    2,  L
  -4   770   762    4     -10   291   284    5     -12   195   180    7
  -3   273   257    5      -9   270   278    6     -10   276   282    6
  -2   317   308    5      -7   518   529    5      -9   596   591    5
  -1   949   983    5      -6   121   128    7      -8   126   128    7
   0   189   185    7      -5   274   288    6      -7   156   154    6
   1   108   118   11      -4   210   211    7      -6   852   841    4
   2   708   715    6      -3   182   172    8      -5   318   312    5
   3   465   456    7      -2   329   330    7      -4   235   237    6
   4   164   160    9       0   217   224    9      -3   544   536    5
          7,    2,  L              7,    6,  L      -2   621   624    6
 -12   344   353    6     -12   332   338    6      -1   142   151    9
 -11   315   290    6     -11   182   186    7       0   123   129   10
 -10   108   115    8     -10    90    96   11       1   637   643    7
  -9   358   369    5      -9   570   584    5              8,    3,  L
  -8   792   790    4      -7    90    89    8     -13   335   346    7
  -6   209   207    5      -6   564   563    5     -12   117   120    9
  -5   824   810    4      -5   451   451    6     -11   120   119    9
  -4   393   388    4      -3   140   141    9     -10   333   355    6
  -3   481   484    5              7,    7,  L      -9   434   439    5
  -2   288   279    6     -12   336   341    6      -8   210   223    6
  -1   731   734    6     -11   154   153    7      -6   651   651    5
   0   139   145    9     -10   257   257    6      -4   302   304    5
   1   163   173    9      -9   640   636    5      -3   469   471    6
   2   441   437    7      -6   469   454    6      -2   411   414    6
          7,    3,  L              7,    8,  L      -1   275   282    7
 -13    91   111   13     -13   236   240    7       1   344   327    8
 -12   256   269    7      -9   166   157    7              8,    4,  L
 -11    84    97   10              7,    9,  L     -13   171   176    8
 -10   410   409    5     -12   240   248    7     -12   249   255    6
  -8   222   207    5     -11   349   337    6     -11   351   360    6
  -7   599   593    4      -8   370   364    7     -10   157   160    6
  -6   488   483    4              8,    0,  L      -8   426   430    5
  -5   380   375    4       0   765   773    5      -6   228   218    6
  -4   223   222    6       1   140   138    8      -5   399   391    5
  -3   750   754    5       2   109   131   10      -4   418   413    6
  -2   131   135   10       3   509   491    6      -3   128   135   10
  -1   113   113    9       4   143   141    9      -2   116   146   13
   0   620   623    6              8,    1,  L      -1   483   490    7
   1   287   280    8     -11   245   250    7              8,    5,  L
   2   169   161    9     -10   111   110    9     -12   421   435    6
          7,    4,  L      -9   335   321    6     -11   338   338    6
 -11   426   443    5      -8   121   143    8     -10   180   179    6
 -10   461   468    5      -7   404   404    5      -9   241   234    6
  -8   184   185    6      -6   546   537    5      -8   631   628    5
  -7   683   671    4      -5   443   424    4      -5   596   593    6
  -6   300   299    5      -4   475   471    4      -4   370   362    7
  -5   137   136    7      -3   160   163    6      -3   129   144   10
  -4   613   615    5      -2   677   673    6      -2   166   170    9
  -3   703   700    6      -1   175   182    9              8,    6,  L
  -2   164   135    8       0   273   282    7     -13    86    62   12
   0   550   557    7       1   480   491    6     -12   358   365    6
          7,    5,  L       2   227   229    8     -10   286   280    6
 -12   209   209    6       3   209   211    9      -9   228   233    7
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     COLUMNS ARE 10FO,10FC,  10SIG

    L   KFO    FC   SIG         L   KFO    FC   SIG         L   KFO    FC   SIG
         8,  6,  L             -3   378   371     7        -3   433   434     7
   -8   368   367     6        -2   112   109    11        -1   160   175    10
   -7   273   275     6        -1   218   220     9         0   198   206    10
   -6   156   160     8         0   420   395     8             10,  3,  L
   -5   293   290     7              9,  4,  L            -12   156   153     9
   -3   297   294     8       -11   357   367     6       -11   124   117     9
         8,  7,  L            -10   121   117     8       -10   271   277     7
  -13   154   147     8        -9   192   184     6        -8   356   350     6
  -11   223   222     6        -8   313   320     6        -7    91    82    10
  -10   388   383     6        -7   404   408     5        -6    88    76     9
   -7   498   495     6        -6   157   179     7        -5   405   397     6
   -6   178   169     8        -5    95    72    11        -4   194   188     7
   -5   121   118    11        -4   373   378     7        -3   170   168     9
         8,  8,  L             -2   234   244     9        -2   166   175    11
  -11   278   291     7              9,  5,  L                 10,  4,  L
  -10   291   295     6       -13   242   231     7       -12   389   383     7
   -9   111   108    11       -12   162   164     8       -11   203   183     7
   -7   330   321     7       -11   138   134     8       -10    97    81    10
         9,  0,  L            -10   168   173     7        -9   363   376     6
    1   109   102    10        -9   429   436     6        -8   421   420     6
    2   562   554     6        -8    76    66    11        -6   126   131     9
    3   181   171     9        -6   444   437     6        -5   479   485     6
         9,  1,  L             -5   209   206     8        -4   106   104    11
  -11   176   156     8        -4   141   133    10        -3    83    84    16
   -9   440   442     6        -3   221   215     9             10,  5,  L
   -8   567   553     5              9,  6,  L            -10   125   140     9
   -7   135   120     6       -12   141   127     8        -9   281   280     6
   -6    94    88     9       -10   313   309     7        -8   167   162     7
   -5   704   696     5        -9   343   343     6        -7   260   246     6
   -4   119   107     7        -7   137   131     8        -6    88    82    13
   -3   255   254     6        -6   483   473     6        -5   298   291     8
   -2   511   515     6              9,  7,  L                 10,  6,  L
   -1   429   453     7       -10   234   231     7       -11   231   227     7
    0   201   207     8        -9   127   119     9       -10   208   214     8
    2   368   369     8        -8   241   246     7        -7   335   322     7
         9,  2,  L                  10,  0,  L                 11,  0,  L
  -12   210   205     8         1   370   375     8         0   135   132    10
  -11   101   106    10             10,  1,  L                 11,  1,  L
  -10   191   189     7       -10   250   255     7        -9   305   306     7
   -9   211   221     7        -9   274   266     7        -7   212   195     7
   -7   402   403     5        -8    97   102    10        -6   159   166     7
   -5   281   276     6        -7   128   144     7        -5   178   171     7
   -4   350   356     5        -6   574   557     5        -4   270   272     7
   -3   380   372     6        -5   124   122     7        -3   128   113    10
   -2   264   272     7        -3   551   552     6        -2   168   185    10
    0   464   477     7        -2   350   353     7             11,  2,  L
         9,  3,  L             -1   149   120     9        -9    65    66    14
  -11   389   394     6         0   240   236     9        -8   347   350     6
  -10   305   303     6         1   409   409     8        -7   409   389     6
   -9   121   123     7             10,  2,  L             -5   158   167     7
   -8   234   232     6       -10   392   392     6        -4   453   441     7
   -7   620   608     5        -9   221   214     7        -3   114    95    12
   -6   178   179     7        -7   386   386     6             11,  3,  L
   -4   533   519     6        -6   496   481     5        -8   354   355     6
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     COLUMNS ARE 10FO,10FC,  10SIG

    L   KFO    FC   SIG         L   KFO    FC   SIG         L   KFO    FC   SIG
        11,  3,  L             -8   150   155     8        -4   135   138     9
   -7   244   242     7        -7    98    75    10        -3   316   301     8
   -6   173   165     8        -6   324   321     7             12,  2,  L
   -4   319   306     7             12,  1,  L             -8   127   115     9
        11,  4,  L             -7   295   307     7        -7   209   217     7
  -10   193   195     8        -6   236   229     7        -5   271   262     7
   -9   191   186     7
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Table S.12. Fractional Coordinates for $Os_4(CO)_{15}PMe_3$, Molecule 1

ATOM	X	Y	Z	BISO
OS(11)	0.28363(5)	0.95360(6)	0.11918(4)	2.59(3)
OS(12)	0.27094(5)	1.18189(6)	0.20523(4)	2.55(3)
OS(13)	0.24664(6)	1.40409(6)	0.24823(4)	3.20(3)
OS(14)	0.20324(5)	1.27036(6)	0.08238(4)	2.93(4)
P(1)	0.2743(3)	0.7686(4)	0.0516(3)	3.12(22)
C(11)	0.1433(15)	0.7001(15)	0.0572(13)	4.7(12)
C(12)	0.2939(15)	0.7320(16)	-0.0548(12)	4.4(11)
C(13)	0.3712(15)	0.6975(16)	0.0888(13)	5.7(14)
C(14)	0.3459(13)	0.9913(15)	0.0316(11)	3.9(4)
C(15)	0.2309(13)	0.9367(15)	0.2169(11)	3.6(4)
C(16)	0.4266(13)	0.9688(15)	0.1648(10)	3.5(4)
C(17)	0.1412(12)	0.9574(14)	0.0796(10)	3.3(3)
C(18)	0.1233(13)	1.1504(15)	0.2239(10)	3.6(4)
C(19)	0.4172(14)	1.1952(16)	0.1804(12)	4.6(4)
C(110)	0.3111(13)	1.1818(15)	0.3048(11)	4.0(4)
C(111)	0.0978(14)	1.3757(16)	0.2698(12)	4.6(4)
C(112)	0.2815(15)	1.4373(17)	0.3570(12)	5.0(4)
C(113)	0.3951(15)	1.4207(18)	0.2224(12)	5.2(5)
C(114)	0.2219(16)	1.5342(18)	0.2395(13)	5.7(5)
C(115)	0.1827(14)	1.1508(16)	-0.0120(11)	4.1(4)
C(116)	0.1755(17)	1.3764(19)	0.0385(14)	6.0(5)
C(117)	0.3513(16)	1.2846(19)	0.0636(13)	5.8(5)
C(118)	0.0571(14)	1.2478(16)	0.1087(12)	4.5(4)
O(14)	0.3865(10)	1.0141(11)	-0.0197(8)	5.3(3)
O(15)	0.2024(11)	0.9256(12)	0.2767(9)	6.3(3)
O(16)	0.5126(10)	0.9853(12)	0.1930(8)	5.5(3)
O(17)	0.0560(9)	0.9634(10)	0.0577(8)	4.6(3)
O(18)	0.0351(11)	1.1262(12)	0.2355(9)	6.2(3)
O(19)	0.3100(11)	1.2016(13)	0.1711(9)	6.7(4)
O(110)	0.3378(11)	1.1869(13)	0.3704(9)	6.8(4)
O(111)	0.0114(11)	1.3645(13)	0.2857(9)	6.7(4)
O(112)	0.3004(13)	1.4580(14)	0.4263(10)	8.0(4)
O(113)	0.4845(12)	1.4352(13)	0.2115(10)	7.1(4)
O(114)	0.2055(11)	1.6207(13)	0.2382(9)	6.9(4)
O(115)	0.1722(11)	1.0781(12)	-0.0687(9)	6.0(3)
O(116)	0.1635(14)	1.4396(16)	0.0071(11)	9.3(5)
O(117)	0.4385(13)	1.2901(15)	0.0442(11)	8.5(5)
O(118)	-0.0333(11)	1.2290(12)	0.1170(9)	6.0(3)

BISO=8PI**2(U11+U22+U33)/3

Table S.13. Fractional Coordinates for $Os_4(CO)_{15}PMe_3$, Molecule 2

ATOM	X	Y	Z	BISO
OS(21)	0.77334(5)	0.03464(5)	0.37813(4)	2.40(3)
OS(22)	0.81459(5)	-0.18932(5)	0.30054(4)	2.28(3)
OS(23)	0.80617(5)	-0.41600(6)	0.25594(4)	2.79(3)
OS(24)	0.66744(5)	-0.30249(6)	0.38046(4)	2.65(3)
F(2)	0.7459(4)	0.2145(4)	0.4453(3)	3.23(23)
C(21)	0.8585(16)	0.3065(16)	0.4408(14)	5.3(14)
C(22)	0.6284(16)	0.2564(16)	0.4069(13)	5.3(12)
C(23)	0.7250(16)	0.2469(14)	0.5530(12)	4.4(11)
C(24)	0.7665(13)	0.0554(15)	0.2738(10)	3.5(4)
C(25)	0.7813(12)	0.0013(14)	0.4769(10)	3.1(3)
C(26)	0.9282(13)	0.0545(15)	0.3819(10)	3.6(4)
C(27)	0.6212(12)	-0.0130(14)	0.3627(10)	3.3(3)
C(28)	0.7083(13)	-0.1934(14)	0.2187(10)	3.4(3)
C(29)	0.9227(12)	-0.1695(13)	0.3825(10)	2.9(3)
C(210)	0.9167(14)	-0.1682(16)	0.2320(11)	4.3(4)
C(211)	0.9182(14)	-0.3966(17)	0.3358(12)	4.6(4)
C(212)	0.9092(14)	-0.4482(16)	0.1789(12)	4.6(4)
C(213)	0.7013(14)	-0.4227(16)	0.1737(11)	4.2(4)
C(214)	0.7612(14)	-0.5534(16)	0.2602(11)	4.3(4)
C(215)	0.5986(13)	-0.1955(14)	0.4531(10)	3.4(3)
C(216)	0.7814(12)	-0.2872(14)	0.4589(10)	3.2(3)
C(217)	0.5625(13)	-0.3083(15)	0.2990(11)	3.8(4)
C(218)	0.6005(14)	-0.4240(16)	0.3979(11)	4.3(4)
O(24)	0.7657(10)	0.0755(11)	0.2159(8)	5.2(3)
O(25)	0.7891(9)	-0.0126(10)	0.5375(8)	4.7(3)
O(26)	1.0214(9)	0.0687(10)	0.3826(7)	4.4(3)
O(27)	0.5330(9)	-0.0430(10)	0.3527(7)	4.2(3)
O(28)	0.6469(9)	-0.1910(11)	0.1716(8)	4.7(3)
O(29)	0.9958(9)	-0.1491(10)	0.4290(8)	4.6(3)
O(210)	0.9814(11)	-0.1600(12)	0.1863(9)	6.0(3)
O(211)	0.9921(11)	-0.3910(13)	0.3781(9)	6.5(4)
O(212)	0.9733(11)	-0.4719(13)	0.1283(9)	6.8(4)
O(213)	0.6366(10)	-0.4324(11)	0.1242(8)	5.5(3)
O(214)	0.7368(11)	-0.6369(12)	0.2622(9)	6.2(3)
O(215)	0.5510(10)	-0.1268(11)	0.4954(8)	4.9(3)
O(216)	0.8455(10)	-0.2780(11)	0.5101(8)	5.2(3)
O(217)	0.4940(10)	-0.3062(11)	0.2566(8)	5.3(3)
O(218)	0.5552(11)	-0.4990(13)	0.4082(9)	6.7(4)

BISO=8PI**2(U11+U22+U33)/3

Table S.14. Thermal Parameters for $Os_4(CO)_{15}PMe_3$, Molecule 1

ATOM	U11	U22	U33	U12	U13	U23
OS(11)	3.40(3)	3.30(4)	3.14(4)	0.45(3)	-0.10(3)	1.04(3)
OS(12)	3.67(4)	3.09(4)	2.94(4)	0.13(3)	-0.06(3)	0.95(3)
OS(13)	5.38(4)	2.88(4)	3.90(4)	-0.22(3)	0.00(3)	0.59(4)
OS(14)	4.02(4)	3.86(5)	3.24(4)	0.21(3)	-0.08(3)	1.40(4)
P(1)	4.7(3)	3.2(3)	4.0(3)	0.9(2)	0.1(2)	1.1(2)
C(11)	6.2(12)	3.8(13)	8.0(15)	-0.7(10)	0.8(10)	2.7(12)
C(12)	6.7(13)	4.6(14)	5.8(14)	1.5(11)	-0.1(10)	-1.3(11)
C(13)	6.2(13)	5.2(14)	10.3(18)	2.5(11)	-1.3(12)	4.5(14)
C(14)	4.9(5)					
C(15)	4.6(5)					
C(16)	4.5(4)					
C(17)	4.2(4)					
C(18)	4.5(5)					
C(19)	5.8(5)					
C(110)	5.1(5)					
C(111)	5.8(5)					
C(112)	6.3(6)					
C(113)	6.5(6)					
C(114)	7.2(6)					
C(115)	5.1(5)					
C(116)	7.7(7)					
C(117)	7.3(6)					
C(118)	5.6(5)					
O(14)	6.8(4)					
O(15)	8.0(4)					
O(16)	6.9(4)					
O(17)	5.8(3)					
O(18)	7.8(4)					
O(19)	8.4(5)					
O(110)	8.6(5)					
O(111)	8.5(5)					
O(112)	10.1(5)					
O(113)	9.0(5)					
O(114)	8.7(5)					
O(115)	7.5(4)					
O(116)	11.8(6)					
O(117)	10.7(6)					
O(118)	7.6(4)					

Table S.15. Thermal Parameters for $Os_4(CO)_{15}PMe_3$, Molecule 2

ATOM	U11	U22	U33	U12	U13	U23
OS(21)	3.80(4)	2.56(4)	2.75(4)	0.34(3)	0.05(3)	0.55(3)
OS(22)	3.28(3)	2.37(4)	3.01(4)	0.26(3)	0.11(3)	0.55(3)
OS(23)	3.72(4)	3.20(4)	3.16(4)	-0.09(3)	0.01(3)	1.05(3)
OS(24)	4.52(4)	2.48(4)	3.58(4)	0.47(3)	-0.25(3)	0.28(3)
P(2)	5.4(3)	2.7(3)	4.2(3)	0.5(2)	0.3(2)	0.6(2)
C(21)	6.9(14)	4.4(14)	9.1(17)	-0.8(11)	1.0(12)	1.8(13)
C(22)	7.6(14)	4.7(14)	7.9(16)	0.5(11)	0.4(11)	3.5(13)
C(23)	9.4(15)	2.4(11)	5.4(13)	2.0(10)	0.6(11)	0.3(10)
C(24)	4.5(4)					
C(25)	3.9(4)					
C(26)	4.5(5)					
C(27)	4.2(4)					
C(28)	4.3(4)					
C(29)	3.6(4)					
C(210)	5.5(5)					
C(211)	4.3(4)					
C(212)	4.1(4)					
C(213)	4.9(5)					
C(214)	5.4(5)					
C(215)	5.8(5)					
C(216)	5.8(5)					
C(217)	5.3(5)					
C(218)	5.4(5)					
O(24)	6.6(4)					
O(25)	5.9(4)					
O(26)	5.6(3)					
O(27)	5.3(3)					
O(28)	5.9(4)					
O(29)	5.8(3)					
O(210)	7.7(4)					
O(211)	6.2(4)					
O(212)	6.6(4)					
O(213)	6.7(4)					
O(214)	8.5(5)					
O(215)	8.2(4)					
O(216)	8.6(5)					
O(217)	6.9(4)					
O(218)	7.9(4)					

```
TEMP=-2(PI)**2(U11*H*H*ASTAR*ASTAR+---+2*U12*H*K*ASTAR*BSTAR+---)

      THE UIJ VALUES HAVE BEEN MULTIPLIED BY 100.
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Table S.16. Fractional Coordinates for Hydrogen Atoms of $Os_4(CO)_{15}PMe_3$

ATOM	X	Y	Z	B
H(111)	0.1433	0.6230	0.0367	5.
H(112)	0.1186	0.7221	0.1132	5.
H(113)	0.0976	0.7268	0.0238	5.
H(121)	0.2991	0.6551	-0.0810	5.
H(122)	0.2303	0.7563	-0.0738	5.
H(123)	0.3610	0.7693	-0.0660	5.
H(211)	0.8794	0.2964	0.3849	5.
H(212)	0.9228	0.3017	0.4710	5.
H(213)	0.8292	0.3769	0.4652	5.
H(221)	0.5631	0.2115	0.4110	5.
H(222)	0.6267	0.3306	0.4463	5.
H(223)	0.6353	0.2537	0.3528	5.
H(231)	0.6977	0.3189	0.5736	5.
H(232)	0.7951	0.2527	0.5805	5.
H(233)	0.6743	0.1892	0.5550	5.

Table S.17. Structure Factors for $Os_4(CO)_{15}PMe_3$

```
        COLUMNS ARE 10FO,10FC,  10SIG

   L   KFO    FC   SIG       L   KFO    FC   SIG       L   KFO    FC   SIG
      -13,  0,  L           -6   654   653    48       8  1365  1282    25
   1  1199  1114    29      -3   517   572    54            -11,  1,  L
   3   827   741    40      -2   387   514    74      -8  1680  1707    24
   4   833   849    41       1   580   661    51      -7  1063  1023    31
      -13,  1,  L            2  1035   990    31      -6  1498  1486    24
  -3   445   444    69       3   546   475    52      -5  1757  1764    21
  -2   507   464    60       4   951   902    32      -4   671   663    41
   0   787   713    41       6   435   390    67       1  1901  1922    19
   1  1649  1564    24       7   740   742    44       3  1214  1187    25
   3  1302  1230    28            -12,  3,  L           4  1154  1193    27
   4   907   925    38      -7  1052  1033    32       5   771   744    37
      -13,  2,  L           -5  1830  1788    22       6  1675  1646    21
  -3   816   805    40      -2   934   853    32       8   687   664    44
  -2   467   367    64       1  1475  1432    24       9  1489  1480    25
  -1   760   655    41       2  1252  1219    26      10   960   906    34
   0  1088  1079    32       3   855   873    36            -11,  2,  L
   1   921   798    35       4   596   575    50     -10  1322  1272    28
   4  1001   928    35       6   595   628    52      -7   387    65    71
      -13,  3,  L                 -12,  4,  L          -6   950   945    32
  -2   410    21    72      -7   744   732    43      -5  1158  1154    27
  -1   914   925    36      -6   689   598    43      -4   568   577    46
   0  1378  1348    27      -4   561   564    52      -3   629   577    42
   2  1225  1154    29      -2  1559  1567    23      -2   631   657    41
   3   795   749    42      -1  1754  1671    22       0   580   604    45
      -13,  4,  L            0  1553  1523    23       1   439   423    59
  -3   705   712    46       3   574   564    52       3   366   430    72
  -2   503   386    60       5  1230  1242    29       5  1067  1055    28
  -1   390    93    78            -12,  5,  L           6  1152  1129    27
   0   526   412    57      -7   713   661    45       7   675   636    43
   1   970   927    35      -6  1979  1931    22       8  1242  1265    28
      -12,  0,  L           -4   985   898    32            -11,  3,  L
   1   760   808    40      -1   637   626    46     -10   430   542    74
   3  1576  1634    24       1   683   592    42      -9   569   522    53
   6  1493  1401    24       3   882   822    36      -8   918   833    33
   8   494   461    61       4   404   317    73      -7  2063  2071    20
      -12,  1,  L                 -12,  6,  L          -5   448   453    58
  -7   968   877    36      -7   731   675    45      -3   936   935    30
  -6   820   839    39      -6   610   579    50      -2   442   434    58
  -5   430   354    67      -4   465   451    64      -1  1435  1446    22
  -4   771   764    40      -3  1784  1764    22       0  1837  1840    20
  -3   639   661    46       0   907   935    36       1  1442  1402    22
  -2   508   504    55       1   771   724    40       3   413   473    64
  -1  1221  1151    26       2   485   498    65       6   637   555    45
   0   566   485    50            -12,  7,  L           7   702   778    43
   1  1132  1075    28      -5   927   915    36       9   510   440    61
   2  1026  1049    31      -3   824   729    39            -11,  4,  L
   3  1208  1200    28      -1   710   702    45     -10   398   255    73
   4   709   730    43       0   792   812    41      -7   777   752    38
   6  1073  1038    31            -11,  0,  L          -6   550   520    50
   7  1170  1140    30       1   816   843    34      -5   380   319    68
   8  1376  1323    27       2   727   681    37      -4  1184  1151    26
      -12,  2,  L            3  1360  1308    24      -3  1227  1242    25
  -8  1840  1833    23       4  1196  1118    26      -2   672   696    40
  -7   408   523    75       5  1741  1711    21       0  1059  1081    28
```

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        COLUMNS ARE 10FO,10FC,  10SIG

   L   KFO    FC   SIG       L   KFO    FC   SIG       L   KFO    FC   SIG
      -11,  4,  L           -2  1018   978    34      -1   586   528    42
   1  1316  1344    25            -10,  0,  L           0   597   543    41
   2  1335  1307    24       3  1372  1312    22       1  1692  1712    19
   6   630   569    46       4  1001   915    27       2  1781  1789    19
   7  1071   989    31       6  1734  1774    20       3  2399  2400    16
   8  1738  1736    24       7  1377  1355    23       5   650   694    41
      -11,  5,  L            9   460   392    58       6   652   596    40
 -10   389   162    75      10   629   621    45       8   992  1074    33
  -9   616   570    49      11  1106  1071    29       9  1296  1263    26
  -8   472   464    62            -10,  1,  L          10   440   353    67
  -7   546   585    53     -10   907   945    36            -10,  4,  L
  -6   411   372    70      -7   659   764    44     -12   728   782    44
  -5   862   804    34      -6   390   383    66      -9  1244  1193    25
  -4  1266  1267    25      -5   911   903    31      -7  1351  1362    23
  -2  1284  1314    25      -4  1197  1170    24      -3   834   809    31
  -1   392   363    66      -3  1770  1788    19      -2  1628  1627    20
   0  1380  1391    24      -2  1886  1911    18      -1  2770  2768    16
   1   535   467    51       0   348    74    64       0  2106  2156    18
   2   511   464    54       3  1635  1615    20       1   998   963    28
   3   971   903    31       4  1285  1270    23       2   366    70    65
   5   665   656    46       5   461   408    56       4   569   572    46
   7   400   163    76       6  1088  1056    26       5  1448  1474    23
      -11,  6,  L            7  1195  1178    25       6   767   765    37
 -10  1078  1090    33       8  1528  1604    22       7   705   751    42
  -9  1472  1440    25      11   411   373    71            -10,  5,  L
  -8  1660  1598    23            -10,  2,  L         -12   797   793    41
  -7  1318  1263    26     -11   971   988    35     -11   716   689    43
  -6  1012   949    30     -10   963   950    33     -10   698   632    41
  -5  1026  1007    30      -9  1536  1529    23      -9   724   748    41
  -2   679   648    42      -8  1478  1444    23      -8  1303  1271    25
  -1  1993  1979    20      -6   705   712    38      -7  1500  1532    23
   2  1461  1475    24      -4   570   475    43      -6  1481  1399    22
   4   664   679    48      -3  1423  1436    21      -5   471   600    56
      -11,  7,  L           -1   557   580    44      -2   608   640    42
  -9   644   630    49       0  1107  1103    25      -1   439   346    57
  -6   576   535    50       2   536   492    46       0   680   655    39
  -5  1271  1243    26       3   494   477    50       1   878   847    31
  -3  1349  1337    25       4   552   617    47       2  1345  1318    23
   0   908   916    34       5   361   360    71       3   620   649    44
   2   748   845    44       6  1021   956    28       5   930   906    32
   3  1166  1151    32       7  1609  1648    21       6   594   578    49
   4  1897  1862    24       8   581   629    48       8   538   535    59
      -11,  8,  L           10   970   898    33       9  1107  1123    33
  -4   399   436    75      11   395   299    78            -10,  6,  L
  -3   700   649    44            -10,  3,  L         -11  1276  1234    28
  -2  1049  1021    32     -12   557   551    58     -10   848   837    36
  -1   490   523    63     -11  1059  1057    32      -9  1472  1398    24
   0   900   890    37     -10   486   364    58      -7  1412  1371    23
   1   472   484    68      -9  1346  1300    25      -6  1568  1601    21
   2   864   817    40      -8   648   580    43      -5   865   886    32
      -11,  9,  L           -7   936   956    31      -4   494   487    51
  -5  1040   965    34      -5  2369  2435    17      -3  1379  1363    23
  -4   854   788    39      -3   406   357    60       0  1581  1553    21
  -3   408   310    76      -2  1696  1673    19       1  1111  1129    27
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COLUMNS ARE 10FO,10FC, 10SIG

L	KFO	FC	SIG
	-10,	6, L	
2	387	428	71
3	390	310	68
4	1468	1485	24
5	853	894	38
6	606	627	52
7	976	933	35
	-10,	7, L	
-10	1331	1340	27
-9	1108	1101	29
-8	1119	1043	28
-7	370	60	71
-5	663	692	42
-4	597	646	45
-3	1081	1079	28
-2	527	534	51
-1	575	609	47
0	538	562	52
1	762	706	39
2	1860	1882	22
3	401	74	73
5	643	677	52
6	1061	1107	34
	-10,	8, L	
-9	782	794	40
-7	911	882	33
-6	870	865	34
-4	444	512	64
-1	577	551	51
0	532	379	54
1	1463	1480	25
2	883	916	39
3	795	837	43
4	1341	1335	30
	-10,	9, L	
-9	410	415	73
-7	716	631	42
-5	1204	1214	29
-4	2221	2266	21
-3	1710	1691	23
-2	1272	1280	28
-1	717	722	45
2	766	758	46
	-10,	10, L	
-7	1143	1112	32
-6	1449	1433	27
-5	669	702	50
-2	1053	1046	34
-1	681	687	50
	-9,	0, L	
1	352	218	59
3	1209	1208	21
4	925	925	27
5	2148	2073	16

L	KFO	FC	SIG
6	598	602	41
7	1015	959	27
8	1758	1749	19
9	1101	1072	26
11	767	829	38
13	1456	1522	25
	-9,	1, L	
-13	834	761	41
-11	1261	1270	28
-10	770	776	39
-9	584	573	47
-8	985	961	29
-7	1662	1673	20
-6	617	639	42
-5	2935	2887	15
-4	1496	1490	19
-3	595	556	38
-2	799	780	29
-1	454	345	47
0	1943	1880	16
1	1839	1846	16
3	374	272	58
4	971	948	25
5	908	923	28
6	1847	1913	18
7	378	320	64
8	514	479	49
9	1322	1351	23
10	635	695	44
11	1040	1117	31
12	400	86	73
13	922	900	36
	-9,	2, L	
-13	1378	1393	28
-12	640	576	48
-11	2144	2117	20
-9	389	165	67
-8	386	416	68
-7	576	650	46
-5	641	634	37
-4	1353	1361	20
-3	548	538	41
-2	2003	2023	16
0	323	153	64
1	859	870	26
2	831	807	28
3	1166	1130	22
5	2576	2603	16
6	635	545	39
7	533	535	48
8	1147	1151	26
9	385	627	73
11	1371	1440	26
12	394	342	77

L	KFO	FC	SIG
	-9,	3, L	
-13	816	799	41
-12	964	974	34
-11	2134	2134	20
-10	1107	1135	28
-8	552	529	46
-7	2108	2088	18
-4	925	885	26
-3	1228	1200	21
-2	731	778	33
-1	1373	1356	20
0	2685	2608	15
1	2284	2210	15
4	634	603	38
5	1323	1293	22
6	567	536	45
7	356	304	71
9	535	474	52
10	961	1054	34
11	1085	1089	32
12	771	747	44
	-9,	4, L	
-13	699	620	45
-10	566	469	47
-9	646	632	41
-8	1176	1204	25
-7	758	700	34
-4	558	504	41
-3	1332	1379	20
-2	1321	1354	21
-1	974	964	26
0	897	900	27
1	2659	2618	15
2	2243	2214	16
3	642	644	40
5	806	840	34
7	1654	1635	21
8	1133	1184	28
9	721	743	43
	-9,	5, L	
-13	1293	1315	28
-12	612	498	46
-11	563	579	51
-10	758	741	36
-9	524	521	51
-7	889	833	30
-6	1652	1585	19
-5	2026	2095	18
-4	747	736	33
-3	2531	2486	15
-2	834	869	30
-1	774	776	33
0	2041	1967	17
1	363	285	66

COLUMNS ARE 10FO,10FC, 10SIG

L	KFO	FC	SIG
	-9,	5, L	
3	2211	2225	17
4	768	758	36
5	958	939	31
7	1167	1143	28
8	870	800	36
9	390	80	76
10	590	528	57
	-9,	6, L	
-12	530	468	54
-11	538	431	51
-10	1058	1041	28
-9	2290	2265	18
-8	2056	2041	19
-7	2211	2297	18
-6	413	478	62
-4	1045	1114	27
-2	381	415	64
-1	1635	1652	20
1	1111	1108	26
2	1948	2013	19
4	691	736	42
6	608	644	50
7	1429	1408	26
9	2005	1944	23
	-9,	7, L	
-13	745	704	42
-11	1376	1329	25
-7	709	663	38
-6	1502	1551	21
-5	1270	1251	23
-4	355	111	67
-3	852	849	32
-1	497	434	52
0	956	1004	31
1	974	983	31
2	716	748	41
3	1835	1861	21
4	1840	1871	22
5	1024	1006	34
6	417	357	76
7	640	641	53
	-9,	8, L	
-12	756	735	41
-11	466	396	62
-9	974	991	32
-8	800	804	36
-5	384	252	67
-4	1365	1377	24
-3	800	872	36
-2	710	664	40
-1	1912	1920	21
0	520	468	55
1	856	833	36

L	KFO	FC	SIG
2	616	655	50
3	1088	1110	32
6	602	607	60
	-9,	9, L	
-11	566	479	53
-9	1132	1185	29
-7	487	498	60
-6	1641	1641	23
-5	1297	1307	26
-2	1579	1592	24
-1	1199	1155	29
0	635	603	50
1	903	882	37
4	1087	1101	35
	-9,	10, L	
-9	414	356	74
-7	648	619	49
-6	983	957	35
-5	1555	1519	25
-4	2051	2087	22
-3	713	612	45
-2	665	632	49
-1	394	233	78
1	1139	1111	33
2	490	590	74
	-9,	11, L	
-7	422	395	75
-3	1008	1012	36
-2	637	731	57
-1	1283	1248	31
	-8,	0, L	
1	1964	1936	15
2	869	774	24
3	629	526	32
4	684	672	31
5	477	448	44
6	1445	1459	19
7	1753	1725	17
9	1680	1676	20
10	885	856	30
11	1541	1610	22
13	1432	1481	24
14	417	346	70
	-8,	1, L	
-14	794	732	43
-13	530	481	60
-12	843	803	37
-8	495	615	52
-7	371	307	61
-6	468	500	49
-5	2687	2764	14
-4	709	744	31
-3	3274	3197	13
-2	2687	2723	14

L	KFO	FC	SIG
0	525	511	37
1	1263	1241	18
2	1076	1068	20
3	1969	1926	14
4	747	787	29
5	614	623	36
6	1062	1032	23
7	1050	1057	24
8	1414	1403	21
13	657	677	46
	-8,	2, L	
-13	405	521	75
-12	1000	999	32
-11	1950	2010	20
-10	1406	1434	24
-9	2713	2851	16
-7	1270	1217	21
-5	327	48	62
-4	1118	1083	21
-3	1169	1179	20
-2	1234	1249	19
-1	1714	1716	15
0	2478	2468	13
2	568	563	34
3	1860	1849	15
5	1080	1036	23
6	1225	1224	22
7	3495	3481	14
9	467	540	55
10	394	588	68
11	493	545	57
13	2420	2452	21
	-8,	3, L	
-14	636	526	49
-13	2733	2717	19
-12	519	445	55
-11	1747	1718	21
-9	1621	1586	20
-8	1149	1172	24
-7	384	392	58
-5	2563	2594	14
-2	2298	2304	14
0	708	733	29
1	1851	1865	15
2	1769	1757	16
3	4128	4177	13
4	453	417	48
5	2771	2718	15
8	487	504	53
9	1127	1159	27
11	2053	2083	21
12	602	501	53
	-8,	4, L	
-12	532	553	52

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        COLUMNS ARE 10FO,10FC,  10SIG

   L   KFO    FC   SIG       L   KFO    FC   SIG       L   KFO    FC   SIG
       -8,    4,  L          9   873   898    43      -7  1760  1792    23
 -10  1376  1377    22           -8,    7,  L         -6  1101  1096    30
  -9  1326  1287    22     -14  1007   953    33      -3   653   606    46
  -7  1056  1045    24     -13   584   568    50      -2  1323  1321    27
  -6  1219  1210    21     -12   561   553    50      -1   739   748    44
  -5   470   390    44     -11  1170  1192    26       3   763   755    48
  -4   734   679    29     -10   447   499    60       4   654   651    57
  -3  2585  2642    14      -9  1865  1907    19           -8,   11,  L
  -2   469   418    43      -8  1385  1445    23     -10   904   879    38
  -1  3367  3385    13      -4  1640  1620    19      -9   549   499    58
   0  1886  1951    16      -3  1734  1684    18      -8   680   713    48
   1   791   787    29      -2   358    45    64      -7  1233  1167    30
   3   537   521    41       1   872   837    32      -4  1103  1125    33
   4  1053  1093    25       2  1353  1382    24      -3   914   977    40
   5  1214  1204    24       3   918   879    33      -2   525   544    66
   7   373   295    71       5  1249  1218    27      -1   938  1027    41
   8   547   580    51       6   476   418    65       1   810   754    46
   9   674   686    44       7  1116  1084    34           -8,   12,  L
  10   865   847    38       9  1206  1215    35      -3   515   486    70
       -8,    5,  L              -8,    8,  L             -7,    0,  L
 -15  1316  1240    28     -14   503   513    62       1  1716  1652    14
 -13  1237  1275    28     -13   554   542    54       2   788   725    23
 -10   580   543    44     -12   613   617    47       3   345   373    50
  -9   621   587    42     -11   589   509    46       5   681   644    28
  -8  2105  2080    17      -9   358   216    72       6  1288  1223    18
  -7  2147  2093    16      -7  1214  1265    25       7  1411  1414    18
  -5  2220  2119    15      -6  1732  1791    20       8  1296  1308    20
  -4  1036  1043    23      -5   585   558    44       9  1403  1423    20
  -3   582   559    37      -3   862   833    32      10   364   301    65
  -2   886   915    26      -2   745   779    38      11  1587  1643    20
  -1  2017  2017    16      -1   989   977    30      12   528   533    50
   1   867   878    28       1  3461  3514    17      13  1703  1734    22
   2  2144  2140    16       2   676   556    45      15  1273  1277    28
   3   575   524    41       3  1713  1729    24           -7,    1,  L
   5  2397  2453    17       4   782   734    41     -15   469   472    72
   7   526   623    56       7  1904  1936    26     -14   863   818    40
   9  1997  2021    21           -8,    9,  L        -13   912   909    35
  11   646   674    56     -13   446   409    68     -11  1402  1482    24
       -8,    6,  L        -12   392   298    73     -10  1407  1423    23
 -13   982   967    31     -11  1669  1681    23      -9  1366  1369    22
 -11  1009  1032    29      -9   654   647    43      -8   486   560    48
 -10   898   880    31      -8   505   485    55      -7  2927  2887    14
  -9   973  1024    29      -5  1477  1517    24      -6  1101  1066    22
  -7  1951  1913    17      -4  1971  1999    20      -5  2798  2801    13
  -6  2337  2280    16      -3  2486  2503    18      -4  1572  1593    16
  -5  2367  2331    15      -2   857   841    35      -3  1060  1059    19
  -4   583   557    38      -1  1896  1905    22      -2   622   593    27
   0  1157  1105    23       0   393   387    75      -1   291   317    54
   1   959   971    28       5  1349  1387    32       0  2866  2793    12
   3   843   852    32       6   512   513    73       1  1046  1076    18
   4  1166  1212    27           -8,   10,  L          3  1548  1625    15
   5   927   884    32     -12  1369  1369    27       4   299   242    57
   6   727   727    42     -10   558   542    54       5  1126  1143    19
   7  1670  1729    24      -9  1209  1170    28       6   872   858    24
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        COLUMNS ARE 10FO,10FC,  10SIG

   L   KFO    FC   SIG       L   KFO    FC   SIG       L   KFO    FC   SIG
       -7,    1,  L        -12  1008   962    28       0   538   496    40
   7  1365  1357    19     -11   708   660    38       1   788   844    30
   9  1395  1415    20      -8  2479  2496    15       2  1433  1482    20
  10   362   334    69      -7   722   700    30       3   494   324    49
  11  1229  1264    25      -5   779   770    26       5   660   703    43
  12   397   190    66      -4   840   861    24       7  1802  1763    22
  13  1001   995    32      -3   726   732    26       9  2814  2866    20
  15   725   670    47      -2  1434  1411    16           -7,    7,  L
       -7,    2,  L         -1  2932  2992    12     -15   948   958    35
 -13  1353  1297    26       1  3102  3136    13     -13  1101  1090    28
 -12   924   929    33       2   932   908    22     -12   731   722    38
 -11  2042  2117    19       3  1158  1165    20     -11  1140  1169    26
 -10   926  1006    30       5  2205  2264    16      -9   928   956    29
  -8  1220  1258    22       6   497   434    48      -7  1062  1088    26
  -7  2091  2030    15       7  2261  2250    18      -6  2334  2312    16
  -6   861   896    25       8   487   522    57      -5  1404  1408    20
  -5  1318  1302    17       9   561   502    51      -4   875   881    28
  -4  1336  1325    16      10   631   581    48      -3   353   221    61
  -3   872   848    21           -7,    5,  L         -2   946   947    27
  -2  2310  2284    12     -16   676   669    49      -1   907   908    28
  -1   308   286    51     -15  1163  1122    29       0   498   434    48
   0   390   416    42     -13  1064  1093    29       1  2070  2084    18
   1  2183  2199    13     -11  1130  1173    26       3  2208  2294    19
   2  1403  1363    15     -10  1348  1373    22       4   463   450    64
   3  1268  1285    17      -7   680   690    33       5  1066  1032    31
   4   902   885    23      -6  2058  2068    15       7   691   687    48
   5  4184  4131    12      -5  3078  3137    13      10   467   520    82
   6   325   133    63      -4   746   681    27           -7,    8,  L
   7   468   412    47      -3  4921  5019    12     -14  1418  1397    26
   8   774   761    32      -2   346   359    55     -13  1389  1386    24
   9  1421  1435    21      -1  1140  1111    20     -11   702   659    38
  11  1237  1232    26       0  1171  1187    20     -10   455   404    57
       -7,    3,  L          1   536   543    38      -9   999   952    29
 -15   479   529    66       3  3011  3053    14      -8  1268  1259    24
 -12   397   412    69       4  1146  1138    23      -7  1041   993    26
 -11  2886  2920    16       5  1173  1245    25      -5   933   911    29
 -10  1261  1286    23       6   409   465    64      -4  1522  1565    21
  -9  1242  1257    22       7  2136  2232    20      -1  3073  3103    16
  -7  1115  1096    21       8   698   713    44       1   743   721    41
  -6  1012   980    21       9   539   499    56       3  2320  2274    20
  -4   545   607    33      11  1843  1843    25       7   522   486    68
  -1   545   530    31           -7,    6,  L             -7,    9,  L
   0  1986  1997    13     -15  2178  2133    20     -13   956   998    34
   1  2042  2025    13     -14   842   873    36     -12   992   959    31
   3   811   763    24     -13   811   826    35     -11   459   470    60
   5  2556  2467    14     -11   515   563    50      -9   510   532    54
   6   486   522    46      -9  3017  3039    15      -6   965   982    31
   7  2191  2207    16      -8  1629  1618    19      -5   562   430    49
   8   482   522    53      -7  2888  2882    14      -2  1138  1108    28
  11  1564  1582    24      -5   522   657    44      -1  2005  2102    21
  13  2090  2148    23      -4  1129  1155    21       1  2450  2414    19
       -7,    4,  L         -3   399   493    52       5   581   691    63
 -15   962   933    34      -2   518   500    39       7  1616  1674    31
 -13   750   728    38      -1   337   326    61           -7,   10,  L
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COLUMNS ARE 10FO,10FC, 10SIG

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    L   KFO    FC   SIG
       -7, 10,  L
  -13   813   845    41
  -10  1156  1152    28
   -7  2252  2333    20
   -5  2625  2637    19
   -4  1274  1304    27
   -3   690   701    45
   -1   591   684    56
    0   417   336    73
    1  1635  1643    26
    4   575   555    64
    5   669   586    58
       -7, 11,  L
  -12  1260  1276    31
  -11  1373  1423    28
  -10   856   777    39
   -9  2272  2343    21
   -8   497   449    64
   -7   796   814    42
   -5   953   941    36
   -3   882   931    40
   -2   826   841    43
   -1  1700  1693    26
    1   967  1010    41
    3   443   421    88
       -7, 12,  L
  -10  1080  1089    35
   -5   669   701    53
       -6,  0,  L
    1  3289  3196    10
    2  1061  1153    17
    3  2348  2415    11
    6   816   853    23
    7  1505  1498    16
    8  1096  1121    21
    9  2138  2153    15
   11  1609  1610    20
   12   386   238    68
   13  1557  1613    22
   14   796   716    37
   15   740   764    44
       -6,  1,  L
  -16   588   531    60
  -14   525   495    59
  -12  1887  1899    21
  -11   726   722    38
   -9   530   434    42
   -8  1817  1787    16
   -7  1465  1438    17
   -6  1981  1974    14
   -5  4635  4652    11
   -4  1597  1512    14
   -3  3445  3389    11
   -2  1639  1637    13
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    L   KFO    FC   SIG
   -1   466   425    30
    0   692   676    22
    1  2869  2859    10
    2  1873  1892    12
    3  1715  1733    13
    4   673   664    24
    5  1397  1449    15
    6   619   621    30
    7   828   895    25
    8   367   397    57
    9   434   387    51
   10  1251  1279    23
   11   614   633    43
   12  1587  1646    22
   13   896   892    35
   15   782   803    44
       -6,  2,  L
  -15  1096  1080    32
  -14   633   619    48
  -11  2000  2047    18
  -10  1132  1140    24
   -9  4268  4288    13
   -8  2210  2144    14
   -7  3262  3293    13
   -6  1126  1092    19
   -5   406   403    41
   -4  1555  1497    14
   -3   558   575    27
   -2  1879  1806    12
   -1  2680  2697    11
    0  2830  2883    11
    1   317   225    44
    3  2950  2941    11
    4   337   383    49
    5  1143  1164    18
    6  1164  1178    20
    7  5128  5291    12
    8  1234  1285    22
    9  1184  1181    23
   10   854   883    32
   11   488   527    59
   13  2227  2256    21
   15  1317  1321    33
       -6,  3,  L
  -15   645   676    48
  -14   681   709    44
  -13  2288  2257    18
  -11  1067  1118    26
   -9  1440  1433    19
   -8  2031  2032    15
   -6   681   664    27
   -5   841   869    21
   -3   547   574    28
   -2  1508  1440    13
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    L   KFO    FC   SIG
   -1  1468  1448    13
    1  1750  1756    13
    3  3844  3931    11
    4  1069  1061    20
    5  3679  3755    12
    8  1012  1038    27
    9   398   440    67
   10   844   785    36
   11  1499  1529    25
   13   752   802    47
       -6,  4,  L
  -16  1327  1348    27
  -15   382   300    76
  -13  1012  1038    29
  -12   547   445    47
  -10  2555  2582    15
   -9  1959  1942    16
   -7   497   506    39
   -6  2153  2151    13
   -4   749   756    23
   -3  4315  4369    11
   -2  1059  1094    18
   -1  3207  3221    11
    1   531   538    32
    2   457   487    38
    5   613   655    37
    6  1254  1244    21
    7  1540  1536    20
    8   391   442    71
    9  1431  1443    24
   10   808   826    41
   11   805   728    42
       -6,  5,  L
  -15   733   653    40
  -13  1449  1470    22
  -12   644   733    41
  -11   536   489    45
  -10   471   453    48
   -9   349   242    59
   -8  1694  1680    16
   -7  1492  1503    17
   -5  2811  2768    12
   -4  1196  1176    18
   -3  1194  1229    18
   -2  1083  1106    19
   -1  4646  4786    12
    2   796   816    26
    3   675   699    33
    5  3356  3300    15
    7  1028  1081    31
    8   721   763    44
    9  2180  2178    21
   10   426   379    79
   11  1080  1097    37
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COLUMNS ARE 10FO,10FC, 10SIG

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    L   KFO    FC   SIG
       -6,  5,  L
   12   542   583    70
       -6,  6,  L
  -16   857   936    38
  -15   466   394    61
  -14   374   452    73
  -13   785   837    35
  -12   589   649    44
  -10   591   520    41
   -9   530   458    42
   -7  2615  2653    14
   -6  1227  1256    20
   -5  2842  2933    13
   -3  1909  1950    15
   -1   541   564    37
    2   894   888    27
    3  1062  1112    26
    5   694   671    41
    6   406   303    69
    7  1619  1635    24
    8   765   676    45
    9  1037  1070    37
   11  1555  1498    30
       -6,  7,  L
  -15   601   561    49
  -14  1391  1445    24
  -13   858   882    33
  -11  2790  2717    15
  -10  1109  1078    25
   -9  2780  2799    15
   -8  1075  1071    24
   -7   574   672    40
   -5   529   472    40
   -4  1654  1663    17
   -3  2299  2410    15
   -2   835   776    27
   -1   901   929    26
    1   996   973    27
    2   547   515    47
    3  1480  1490    23
    5  1963  2014    21
    6  1065  1048    34
    7  1835  1889    24
    9  1310  1301    33
       -6,  8,  L
  -16   874   897    38
  -15  2023  1986    20
  -13  1179  1184    26
  -12   980  1096    31
  -11   509   557    53
   -9  1180  1216    24
   -7  1474  1495    20
   -6  1779  1830    19
   -5  1604  1582    19
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    L   KFO    FC   SIG
   -4   388   401    60
   -3   982  1038    27
   -1  1221  1235    24
    1  4896  4859    15
    2   408   159    71
    3  2364  2428    20
    4   594   611    55
    7  1471  1511    30
    9  1469  1530    33
       -6,  9,  L
  -15   926   954    36
  -14  1004  1005    32
  -12   745   741    39
  -11  1229  1243    26
   -9  1068  1029    28
   -7  1170  1196    26
   -5  1891  1936    20
   -4   620   657    45
   -3  2104  2159    19
   -1  2505  2560    18
    3   720   697    47
    4   921   969    40
    5   792   768    46
       -6, 10,  L
  -14   584   579    54
  -13   763   876    44
  -12  1389  1421    26
   -9  1952  1948    21
   -8   896   883    36
   -7  2121  2176    20
   -5  1044  1064    32
   -3  1368  1378    26
   -2   532   499    58
    0   645   713    52
    1   426   404    80
    2   864   907    42
    3  1283  1385    33
       -6, 11,  L
  -11   687   716    47
  -10  1016  1041    35
   -9   761   818    44
   -8   467   486    69
   -7  2823  2874    20
   -5   883   935    39
   -4   458   551    71
   -3  1109  1170    33
   -1  1145  1187    34
    1  1132  1108    35
    3  1659  1702    30
       -6, 12,  L
  -11  1039  1088    37
   -9   544   563    63
       -6, 13,  L
   -8   478   600    80
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    L   KFO    FC   SIG
   -5   807   802    49
   -3  1350  1393    35
       -5,  0,  L
    1  2189  2183    10
    2   516   513    25
    3   599   612    22
    4  1366  1362    13
    5   793   821    20
    6  1289  1329    15
    7   587   587    29
    8   543   509    34
    9  1335  1338    18
   11  1405  1393    21
   12  1202  1253    25
   13  1547  1576    23
   15  1182  1190    30
       -5,  1,  L
  -15   687   717    50
  -14  1963  1979    22
  -13  1377  1395    26
  -11   880   918    32
  -10  1610  1640    19
   -9  1580  1565    18
   -8  2186  2138    14
   -7  3854  3920    12
   -6  2997  3048    12
   -5  1467  1424    14
   -4  1410  1416    14
   -3  2723  2675    10
   -2   808   858    17
   -1   644   683    20
    0  1368  1362    12
    1   869   880    16
    2   904   887    16
    3  2642  2646    10
    4   419   426    34
    5  1419  1448    14
    6  1188  1214    17
    7  1712  1752    14
    8   865   888    25
    9  1742  1719    17
   10  2246  2279    16
   11  1172  1138    26
   12   454   513    64
   14   451   535    73
   15   514   437    69
   16  1157  1190    38
       -5,  2,  L
  -17  1326  1363    31
  -12   932   987    31
  -11   993   948    27
  -10  1328  1294    21
   -8  1589  1572    16
   -7  3455  3466    12
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COLUMNS ARE 10FO,10FC,  10SIG

  L   KFO    FC   SIG
      -5,   2,  L
 -6  2502  2488   12
 -5  3629  3672   10
 -3   861   802   16
 -2  1864  1820   11
 -1  1004  1004   14
  0   742   711   18
  1  3091  3094   10
  2  1044  1031   14
  3   756   721   20
  4  1010  1042   17
  5  4668  4690   11
  6   844   866   23
  8   630   656   36
  9  2282  2276   16
 10   641   702   42
 12   969   981   35
 15  1472  1437   31
      -5,   3,  L
-17  1034   994   35
-16   910   949   37
-13   924   994   32
-12   967   933   28
-11  2931  2917   14
 -9  1619  1554   16
 -7   452   351   37
 -6   662   668   25
 -5   408   282   34
 -4   645   662   23
 -3  1292  1289   13
 -2   261   275   48
 -1   692   694   19
  1   890   899   17
  3   686   720   24
  4  1904  1915   13
  5  3219  3214   12
  6   706   647   30
  7  3427  3530   14
  9   656   647   42
 10  1918  1883   21
 11  1735  1740   24
 12  1078  1071   34
 13  1716  1773   27
      -5,   4,  L
-17  1538  1484   26
-16   729   741   42
-15  1668  1656   22
-14  1518  1553   22
-13   739   687   37
-12  1332  1377   22
-11  1747  1732   17
-10   439   395   48
 -9   452   435   43
 -8  2802  2802   12

  L   KFO    FC   SIG
 -7  1634  1666   14
 -6   714   708   23
 -5  1775  1751   13
 -4   308   390   47
 -2  1006  1011   16
 -1  5170  5278   10
  0  2159  2141   12
  1  4190  4267   11
  2  2533  2606   12
  3  1288  1238   17
  5  2543  2553   14
  6   588   563   41
  7  2480  2532   17
  8  2079  2094   19
 10   851   875   41
 11   658   637   53
 12  1007   984   39
 13   849   881   49
 14   460   217   89
      -5,   5,  L
-17   442   429   68
-16   787   792   39
-15  1196  1203   27
-12   609   555   40
-11  1931  1844   17
-10  1959  1952   16
 -9  1702  1673   16
 -7   804   788   24
 -6   774   780   23
 -5  2915  3006   12
 -4  1726  1734   14
 -3  6406  6609   11
 -2  1632  1604   14
 -1  1438  1478   15
  0   333   348   50
  1  1908  1938   14
  2   578   630   34
  3  2139  2127   15
  4   628   594   36
  5  1246  1213   22
  6   707   712   39
  7  2244  2221   19
  8   889   888   37
  9   458   648   78
 10   434   356   81
 11  1424  1440   32
 12   511   570   79
 13  1232  1378   41
      -5,   6,  L
-17   566   541   54
-16   925   933   34
-15  1709  1804   22
-14   834   894   34
-13   866   883   32

  L   KFO    FC   SIG
-11  1502  1554   20
-10  1215  1174   21
 -9  2799  2779   14
 -8   378   312   54
 -7  1527  1566   16
 -6  1034  1036   20
 -5   701   700   28
 -3  1207  1228   18
 -2   809   804   25
 -1   954  1024   22
  0  1826  1845   15
  1   547   573   37
  6  1669  1669   23
  7  2008  2002   22
  8   668   604   54
  9  2161  2151   24
 12   538   658   81
      -5,   7,  L
-17   670   667   47
-16  1429  1415   25
-13  1396  1407   22
-12  1597  1611   20
-11   874   861   30
 -9  2861  2917   14
 -8  1122  1137   23
 -7  1633  1722   17
 -6   834   855   27
 -5  1556  1538   17
 -4  1128  1139   21
 -3   951   981   24
 -2   697   713   31
 -1  1304  1292   20
  0   630   564   36
  1  2271  2275   16
  2   378   191   66
  3  2428  2401   18
  4  1394  1423   25
  5   622   666   53
  8  1178  1248   36
      -5,   8,  L
-14   953   928   31
-13  1433  1537   23
-11  2071  2159   18
-10   668   697   39
 -9   518   572   49
 -8  1051  1078   25
 -7  2000  2028   17
 -5  1011   916   25
 -4   713   719   34
 -3   376   370   64
 -1  2775  2857   16
  0   511   443   52
  1   447   463   64
  3  3187  3171   18
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COLUMNS ARE 10FO,10FC,  10SIG

  L   KFO    FC   SIG
      -5,   8,  L
  5  1595  1645   27
  6   848   955   45
  9  1608  1605   30
      -5,   9,  L
-15   388   479   76
-14   412   422   71
-13   713   745   41
-12   607   604   46
-10   532   579   52
 -5   790   749   35
 -3  1155  1157   27
 -2   854   818   34
 -1  2349  2413   19
  0   759   732   43
  1  2991  3036   18
  2   518   451   65
  3   787   822   46
  4   819   810   46
  5  1076  1105   38
  6  1367  1409   33
  7  1252  1302   37
      -5,  10,  L
-14  1130  1188   31
-13  1708  1711   23
-12   699   716   43
-11   480   493   61
-10   886   933   36
 -7  3221  3321   17
 -6   683   700   48
 -5  3397  3472   17
 -4   704   781   46
 -3   692   646   46
 -1   431   509   76
  1  1358  1357   30
  2   936   965   41
  4  1100  1209   38
  5   956   963   44
  6   502   540   86
      -5,  11,  L
-13   618   703   56
-12   642   590   51
-11  1161  1213   31
 -9  2840  2853   19
 -8   582   643   57
 -7   992  1027   36
 -5  1735  1812   25
 -2   581   587   60
 -1  1570  1576   27
  1   929   936   42
  2   592   639   67
  5  1897  2009   30
      -5,  12,  L
-11   498   534   72

  L   KFO    FC   SIG
 -6   632   588   56
 -3   496   438   73
 -2   512   588   74
 -1   441   464   86
  0   460   609   87
  1  1408  1513   35
  2   578   555   73
  3  1425  1546   37
      -5,  13,  L
-10   502   553   74
 -9   772   796   53
 -7   460   774   89
 -6   487   416   76
 -5   992   950   42
 -3  1780  1869   30
      -4,   0,  L
  1  2909  2876    9
  2  3480  3470    8
  3  3796  3662    9
  4  1175  1180   14
  5   830   873   18
  6  3768  3791   10
  7   939   956   19
  8  1874  1944   14
  9  1166  1182   20
 10  1129  1142   22
 11  1418  1441   21
 13  1062  1023   32
 14  1050  1121   35
      -4,   1,  L
-17   582   640   65
-16  1365  1370   29
-15   797   743   43
-13   433   477   69
-12  2864  2814   16
-11  1303  1363   23
-10   469   441   49
 -9   334   204   60
 -8  1157  1236   19
 -7  2175  2180   13
 -6  2587  2604   11
 -5  6519  6441   10
 -4  5141  5000    9
 -3  3394  3346    9
 -2   337   255   35
 -1  1236  1158   12
  1  2979  2949    8
  2   771   779   17
  3  1315  1287   12
  4  2810  2767   10
  5  2324  2378   11
  6   851   872   20
  7  1059  1065   19
  8  1771  1739   15

  L   KFO    FC   SIG
 10  2022  2024   18
 11  1502  1522   23
 12  3165  3172   18
 13   975  1056   39
 16   670   649   66
      -4,   2,  L
-17  1307  1233   31
-16   508   521   64
-15  1412  1459   26
-14  1258  1270   27
-13  1428  1425   23
-12   373   273   68
-11  1629  1634   19
 -9  2929  2848   13
 -8  3331  3310   12
 -7  3607  3570   11
 -6  1954  1936   12
 -5   973   985   16
 -4  1204  1165   13
 -3  3112  3028    9
 -2  2496  2358    9
 -1  2773  2770    9
  0  1740  1709   10
  1   755   769   17
  2   845   854   16
  3  2920  2944   10
  4  1518  1502   13
  5  1410  1536   16
  6  1276  1248   17
  7  4579  4611   12
  8  2449  2455   15
  9  1381  1342   22
 10  2064  2039   19
 12   634   598   56
 13  1151  1108   35
 14   486   700   86
 15   732   840   62
 16   918   915   55
      -4,   3,  L
-17  1043   971   34
-15  1048  1085   31
-14  1572  1553   22
-13  1714  1716   20
-12   616   601   40
-11   460   455   49
-10   717   657   29
 -9  1003  1013   21
 -6  1165  1136   15
 -5   597   604   22
 -4   793   801   17
 -3   660   662   20
 -2  1542  1531   11
 -1  1851  1889   10
  0   291   185   41
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COLUMNS ARE 10FO,10FC,  10SIG

  L   KFO    FC   SIG
      -4,    3,  L
  1  1900  1911    11
  2  3489  3565    10
  3  2926  2854    11
  4  2070  2021    13
  5  3173  3222    12
  6  1098  1009    21
  8  1400  1400    22
 10  1242  1190    29
 11   529   457    67
 12  1163  1219    37
 13  1176  1219    39
 14   728   665    59
 15   827   781    58
      -4,    4,  L
-16  1618  1624    23
-14  1136  1176    27
-13  2225  2290    18
-12  1749  1737    18
-10  2402  2404    14
 -9  2436  2395    13
 -8  1076  1103    18
 -7   275   203    54
 -6  1177  1127    15
 -4   996   963    15
 -3  4146  4254     9
 -2  1513  1512    12
 -1  2762  2846    10
  0  1344  1319    13
  1  1465  1451    13
  2  1024   958    18
  3  1064  1046    19
  4  2360  2388    14
  6  1043  1030    25
  7  1376  1361    23
  9  1579  1622    25
 10  2411  2356    21
 11  1206  1230    36
 12   617   533    65
 13   606   798    75
 14  1383  1419    39
      -4,    5,  L
-17  1127  1104    30
-13  1282  1318    23
-12   980  1034    26
-11  1677  1643    17
 -9   606   625    32
 -8   630   645    29
 -6   966  1041    19
 -5  1950  1932    12
 -4   600   570    26
 -3  1436  1463    14
 -2  1940  1910    12
 -1  5461  5489    10
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```
  L   KFO    FC   SIG
  0   836   864    22
  1   667   742    27
  2  1138  1154    19
  4  1500  1526    19
  5  2444  2436    16
  7   911   867    35
  8   753   755    46
  9  1219  1199    34
 11  1128  1162    40
 12   862   843    52
      -4,    6,  L
-17  1076  1130    31
-16   730   811    41
-14  1009  1049    28
-12   745   658    33
-11   489   423    46
-10   541   512    41
 -9  2458  2423    14
 -8  1022  1031    21
 -7  2715  2737    13
 -6  1902  1955    14
 -5  2540  2585    12
 -4  1483  1479    15
 -3  2783  2791    12
 -2   729   748    26
 -1   493   550    38
  0  1691  1731    16
  2  2093  2088    16
  3   405   400    58
  4  1487  1559    22
  5   425   558    69
  7   422   523    83
  8  1584  1649    29
  9  1627  1655    29
 10  1058  1108    42
 11  1215  1216    40
      -4,    7,  L
-17  1663  1679    23
-16   703   766    43
-15   652   771    42
-14  1052  1101    28
-13   901   915    30
-12   881   877    31
-11  3787  3866    14
-10  2576  2517    15
 -9  2968  3047    14
 -7  1442  1494    19
 -6   680   700    31
 -4   467   521    43
 -3  2254  2276    15
 -2  1604  1593    17
 -1   749   693    30
  0   825   817    29
  1  1252  1244    23
```

```
  L   KFO    FC   SIG
  2   789   729    35
  3  2134  2139    19
  4   711   673    45
  5  2761  2782    20
  6  3121  3165    20
  7  2170  2279    25
  8   890   862    47
 11   871   911    55
 12  1465  1530    40
      -4,    8,  L
-17   941   930    34
-16   532   406    54
-15   961  1036    32
-14   597   596    46
-13  1412  1418    23
-12  1009  1013    29
-10   617   608    41
 -9  2107  2162    17
 -8   732   685    33
 -7   944   991    28
 -6  1157  1169    24
 -5  2209  2166    16
 -3   430   504    57
 -2  1068  1046    25
 -1   943   968    30
  0  1306  1338    25
  1  4141  4204    16
  2   972  1017    35
  3  2062  2083    21
  4  2040  2086    23
  6   643   689    60
  9   726   728    60
      -4,    9,  L
-15  1085  1084    30
-13   376   139    71
-12   926   930    32
-11   633   670    46
-10   717   718    41
 -9   465   456    58
 -7  1814  1796    19
 -5  2130  2220    19
 -4  1788  1810    21
 -3  1320  1313    25
 -2  1436  1438    25
 -1  1626  1586    23
  0   982  1031    34
  1   598   641    57
  3   896   892    43
  4  1163  1233    37
  6   698   661    57
  7  1040  1188    44
  8   802   925    58
  9   813   858    59
      -4,   10,  L
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COLUMNS ARE 10FO,10FC,  10SIG

  L   KFO    FC   SIG
      -4,   10,  L
-16   693   685    49
-15  1827  1874    23
-14   957   880    35
-13   995  1055    34
-12   809   940    40
-11   790   757    40
 -9  1847  1902    22
 -8   800   774    41
 -7  1800  1821    23
 -6   587   571    56
 -5  1984  1992    22
 -3  2222  2314    22
 -2  1246  1331    31
  1   470   401    75
  2   977   971    41
  3  1431  1476    31
  4   925   986    45
  5   737   825    58
  6   665   699    66
  7   979   917    48
      -4,   11,  L
-14   531   657    67
-13  1022  1068    37
-12   410   292    76
 -9   946   981    38
 -8   717   690    48
 -7  3248  3268    19
 -5  1612  1655    26
 -3  1073  1064    36
 -2   534   558    67
 -1   861   905    45
  1   879   906    47
  3  1098  1106    40
  4   473   422    89
  5   482   516    90
      -4,   12,  L
-13  1960  2020    26
-11   954   958    40
-10   453   290    76
 -9   435   518    84
 -4  1184  1211    35
  0   577   707    73
  2  1099  1064    42
  3  1843  1828    31
      -4,   13,  L
-11   952   889    45
 -9  1338  1389    35
 -8   675   517    57
 -7   698   693    58
 -6   746   689    55
 -5   448   456    88
 -3  1430  1486    35
 -1  2457  2421    25
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```
  L   KFO    FC   SIG
  0  1203  1139    40
      -3,    0,  L
  1  2143  2171     8
  2  1698  1687     9
  3  1388  1398    10
  4  2637  2655     9
  5  1940  1956    10
  6  1185  1132    14
  8  2899  2968    12
  9  1243  1281    20
 10  1212  1271    24
 11   575   507    49
 12  2151  2121    21
 13  1084  1136    38
 14   763   865    56
      -3,    1,  L
-17   451   461    81
-15   454   649    73
-14  2725  2773    19
-13  2144  2106    20
-12  1104  1051    27
-10   932   946    25
 -8  1637  1608    14
 -7  3399  3342    11
 -6  3335  3285    10
 -5   520   530    27
 -4  1017   984    14
 -3  4783  4671     8
 -2  2836  2773     8
 -1   921   873    11
  0   894   830    12
  1   592   587    17
  2   598   627    19
  3  3102  3128     8
  4   361   357    36
  5  1087  1093    15
  6  2952  2919    11
  7   490   511    38
  8  1076  1077    22
  9  1522  1551    20
 10  3675  3726    16
 11  1080  1150    34
 13   885   872    50
 14  1094  1114    45
 16   758   725    70
      -3,    2,  L
-17   938   939    39
-16   638   566    51
-15   825   767    39
-12  1057  1034    26
-11  1183  1155    22
-10   630   528    32
 -9   421   374    43
 -8  1460  1406    15
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```
  L   KFO    FC   SIG
 -7  2344  2302    11
 -6  3426  3385    10
 -5  5184  5125     9
 -4  1087   968    13
 -3   409   313    27
 -1  1534  1471     9
  0  1519  1496    10
  1  1759  1761     9
  2  1112  1127    13
  3   890   830    17
  4   771   769    20
  5  2448  2452    12
  8   483   471    50
  9  1384  1356    24
 10  1834  1888    23
 11  1174  1215    35
 12  1744  1773    29
 14   908   907    55
 15   513   538   100
 16  1277  1322    47
      -3,    3,  L
-18   963   978    39
-17   597   692    56
-15   418   515    69
-14  1033  1038    30
-13  2498  2538    17
-12  2321  2275    16
-11  2562  2528    14
-10  2280  2276    13
 -9   351   323    47
 -8   389   332    39
 -7   947   947    17
 -6   578   542    23
 -5   463   508    27
 -4  1741  1640    10
 -3  1432  1433    11
 -2   890   834    15
  0  1911  1806    10
  3  1530  1505    13
  4  5136  5066    11
  5  2973  2903    13
  6  2509  2494    15
  7  1769  1730    19
  8   433   416    66
  9   726   692    46
 10  3131  3197    20
 11  1770  1782    29
 12  2220  2265    27
 13   701   609    65
      -3,    4,  L
-18   830   806    42
-17   925   899    35
-16  1266  1277    27
-15  1912  1959    20
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   L   KFO    FC   SIG        L   KFO    FC   SIG        L   KFO    FC   SIG
       -3,  4,   L             13  1339  1406    42      -13   928   927    31
 -14  2205  2216    18       14  1509  1453    39      -12  1426  1502    23
 -13   876   829    30            -3,  6,   L          -11  2661  2769    16
 -12  1143  1140    23      -18   535   550    58       -9   375   298    65
 -11  2838  2815    13      -17  1185  1112    28       -8   901   892    31
 -10   961   955    22      -16  1542  1553    22       -7  2282  2295    17
  -9   368   316    46      -15  1192  1303    25       -6  1224  1120    24
  -8  2522  2533    12      -13   719   748    35       -5   742   803    36
  -7  2600  2540    11      -11  2896  2965    14       -3   410   439    61
  -6  1385  1414    13      -10  1222  1204    20       -2   774   800    37
  -5  1092  1083    14       -9  2058  2109    14       -1  1548  1542    22
  -4   729   710    19       -8  1774  1740    15        0  1044  1059    31
  -3   748   745    18       -6  1009  1021    20        2   635   708    53
  -2   488   501    27       -4  2532  2573    13        3  2967  2953    20
  -1  3441  3471     9       -3   863   854    22        4  1267  1266    33
   0  3328  3395    10       -1  1431  1391    17        5  1900  1991    26
   1  3615  3694    10        0  2450  2437    14        6  1761  1819    28
   2  5804  5798    11        1   391   420    55        7   860   829    50
   3   517   504    36        2  1686  1656    18        8   901   972    50
   4  1307  1353    19        3   944   908    29        9   736   804    62
   5   422   497    54        4  1140  1170    28       10   866   833    54
   7  1195  1209    27        6  2285  2344    21       11   960   963    54
   8  2668  2763    20        7  1749  1791    27            -3,  9,   L
   9  1152  1140    34        8  1663  1754    30      -17  1389  1456    27
  10   908   924    47        9  1031  1085    45      -16   449   502    69
  11   886   901    52            -3,  7,   L          -13   608   531    47
  12  1666  1690    33      -18   849   825    38      -10   842   844    36
  13  1320  1335    41      -17   727   612    42       -8  1882  1870    20
  15   935   980    60      -16  1125  1192    28       -5  1576  1661    23
       -3,  5,   L          -15   652   663    42       -3  1957  2058    22
 -14   456   487    57      -13   993  1021    28       -2  3000  2982    18
 -13   975   960    27      -12  1030  1008    27       -1  2767  2825    19
 -12  1214  1219    21      -11   511   470    46        0  2642  2763    21
 -11  1613  1630    17      -10   694   717    34        1  2305  2397    22
 -10  1946  1928    15       -9  3682  3740    13        3   462   426    81
  -9  2925  2995    12       -8  1862  1859    16        4  1150  1179    38
  -8   649   688    27       -7  2401  2451    15        5  1201  1242    37
  -7   608   563    27       -6  1220  1212    20        6  1998  2042    28
  -6  2433  2467    11       -5  1395  1437    18        7  1067  1061    42
  -5  1880  1892    12       -4   854   898    26        9   775   761    61
  -4  3581  3561    10       -3   491   496    43            -3, 10,   L
  -3  4369  4472    10       -1  1136  1169    23      -16   774   777    45
  -2  1402  1409    14        0   922   988    29      -14   790   927    45
  -1  1279  1295    16        1  1014   953    28      -13  2344  2479    21
   0   396    94    41        3  1999  2124    21      -12  1025  1088    34
   1  1856  1859    14        4  2837  2850    19      -11   864   880    40
   2  1239  1227    19        5   517   572    70       -7  3268  3442    18
   3   483   471    45        7  1406  1333    33       -6  1238  1235    31
   4   372   410    64        8  2166  2229    26       -5  3253  3342    19
   6   427   403    70        9  1195  1246    40       -4  2234  2326    22
   7  1144  1019    32       11   563   475    82       -3   597   676    59
   9   550   512    73            -3,  8,   L           -2  1156  1169    34
  11   564   614    79      -17   936  1022    36        0   988   942    40
  12  1260  1301    41      -15   803   773    36        2   897   891    46
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        COLUMNS ARE 10FO,10FC,  10SIG

   L   KFO    FC   SIG        L   KFO    FC   SIG        L   KFO    FC   SIG
       -3, 10,   L              7   800   810    23       -1  1082  1097     9
   3  1047  1114    40        8  2477  2467    14        0   428   467    20
   4  1359  1322    34       10  1512  1518    25        1   815   830    14
   5   505   606    83       11  1251  1217    34        3   934   894    18
   6   726   647    60       12   950   873    49        4  2841  2759    11
   7   881   883    53       13   764   543    66        6  2232  2174    15
       -3, 11,   L           14  1253  1191    47        7  1680  1623    20
 -15  1681  1777    27       16  1056  1025    58        8  3428  3363    17
 -13  1026  1038    37       17   593   550   101        9  1044  1138    37
 -11   676   551    51            -2,  1,   L           10  2160  2225    25
 -10  1310  1361    30      -16  1545  1538    28       14   912   792    59
  -9  2102  2176    24      -15  1356  1338    29            -2,  3,   L
  -7   727   772    52      -13   737   744    44      -17   456   369    71
  -6   532   468    69      -12  3142  3138    16      -15  1335  1423    26
  -5  1826  1881    26      -11  2374  2413    16      -14  1508  1442    23
  -1   878   874    47      -10  1768  1815    17      -13   604   601    43
   1   576   487    66       -9   473   462    41      -12   797   765    31
   2   717   634    57       -8  1444  1518    16      -11  1751  1686    16
   4   709   630    61       -7   855   814    20      -10  1216  1250    18
   5  1233  1140    40       -6  3887  3812    10       -9   422   384    39
   6   503   517    88       -5  5305  5183     9       -8  3036  3055    10
       -3, 12,   L           -4  6346  6124     8       -7   267   273    47
 -14   453   508    88       -3  2034  2022     8       -6   841   851    17
 -13   558   553    71       -2  3275  3166     6       -5  1811  1764    10
 -11   984  1102    43       -1  1353  1309     7       -4  2651  2621     9
 -10   935   988    44        1  1212  1202     8       -3   778   749    16
  -9   699   787    57        3   906   918    14       -2  1412  1358    10
  -8   738   790    53        4  3350  3301     9       -1  1431  1397    10
  -6  1420  1388    31        6   697   681    27        0   710   647    19
  -2  1102  1174    40        7  1087  1075    22        1  2152  2123    10
  -1   458   405    86        8  2862  2735    16        2  6903  6716    10
   0  1140  1152    40       10  2261  2265    22        3   731   765    27
   1  1693  1706    31       11  1966  1996    28        4  3307  3285    13
   2  1618  1614    33       12  4514  4410    22        6  2746  2744    16
   3   803   784    59       14   969   912    57        7  1204  1225    28
   4   473   203    94       15   978   983    60        9   847   845    48
       -3, 13,   L           16   924   917    66       10   990   987    46
 -11   956   950    46       17   731   569    82       12  1424  1448    40
  -9   961   938    45            -2,  2,   L           13  1509  1455    39
  -8   673   731    64      -18   445   462    83       14  1706  1650    38
  -7   486   657    88      -16  1192  1204    31       16   728   644    77
  -4   825   672    52      -15  1123  1195    32            -2,  4,   L
  -3  1145  1159    42      -14  1999  1992    21      -16   862   945    36
   1  1483  1509    37      -13  2777  2745    17      -14  1728  1706    20
       -3, 14,   L          -12  1341  1359    22      -13  2950  2967    15
  -8   493   365    88      -11  1241  1194    21      -12  2190  2212    15
  -5   510   680    96      -10  2035  2054    15      -11   608   603    33
  -4  1023   918    49       -9   883   928    22      -10  1311  1273    17
       -2,  0,   L           -8  3890  3886    11       -9  2892  2904    11
   1  1902  1842     6       -7  3638  3600    10       -8  1068  1079    17
   2  2547  2539     6       -6   721   678    19       -7   281   339    50
   3  1759  1801     8       -4   739   712    16       -6   428   414    31
   4  1005   982    13       -3  2866  2871     7       -5   780   752    19
   6  5083  4982    10       -2  2472  2497     7       -4   657   590    22
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      COLUMNS ARE 10FO,10FC,  10SIG                                                   COLUMNS ARE 10FO,10FC,  10SIG

   L   KFO    FC  SIG       L   KFO    FC  SIG       L   KFO    FC  SIG       L   KFO    FC  SIG       L   KFO    FC  SIG       L   KFO    FC  SIG
       -2,  4,  L          -9  3293  3402   13      -5  1819  1913   20           -2, 11,  L           9  1215  1292   35      10  2912  2824   23
  -3  3102  3065   10      -8  1543  1571   16      -4   519   511   53     -13  1454  1478   32      10  2333  2267   24      11   826   773   57
  -2   286   176   50      -7  2541  2570   13      -2  2161  2233   19     -12   468   519   83      11   936   878   51      12  1677  1641   35
  -1  2009  1974   11      -6  5833  6047   12      -1  1779  1814   22     -10  1194  1219   36      12  1324  1267   40      14  1643  1581   38
   0  2908  2910   11      -5  2004  2057   14       0  2690  2770   19      -9  1194  1217   37      13   768   760   68      16  2154  2078   34
   1  2086  2060   13      -4  3172  3250   13       1  2383  2507   21      -8  2200  2324   25      14  1808  1769   35           -1,  3,  L    
   2  2572  2587   13      -3  1568  1621   16       2  1799  1805   25      -7  2577  2707   23      15  1115  1075   52     -18  1769  1650   26
   3  2864  2883   14      -2  2093  2059   15       3  1133  1211   36      -6   505   433   79           -1,  1,  L         -16   745   716   44
   4  4509  4518   14       0  1978  2007   17       4  1488  1464   30      -5  1310  1250   34     -18  1424  1330   35     -15   625   469   49
   5   942   955   30       1   754   746   34       7   465   331   91      -4   487   326   82     -17   743   739   55     -14  1013   995   31
   7   477   489   70       2  3342  3432   16           -2,  9,  L          -2  1037  1056   41     -14  2503  2468   21     -13  2656  2616   16
   8   464   503   80       3   401   423   70     -17  1032  1034   34      -1   624   513   64     -13  2286  2217   20     -12  2796  2789   14
   9  1163  1114   38       4  1331  1384   28     -15  1203  1214   29           -2, 12,  L         -12  1329  1272   25     -11  1373  1307   18
  10  2767  2774   24       5  1230  1193   31     -14  1059  1101   33     -13  1795  1841   29     -10   339   276   63     -10  4341  4421   11
  11  1724  1750   34       6   967   978   41     -13   542   580   59     -12  1516  1581   33      -9   663   580   31      -9   778   701   22
  12   883   914   58       8  1730  1685   30     -12   431   425   73     -11   739   808   59      -8   692   700   27      -8   273   243   52
  13   861   852   60       9  1844  1768   30     -11   622   626   53     -10  1432  1443   34      -7  2867  2915   11      -7   976   944   16
  14  1240  1093   46      10  2470  2381   27     -10  2487  2502   19      -8  1200  1137   39      -6   303   157   48      -6  3457  3350    9
  15  1158  1134   52      12  1141  1194   47      -7  1197  1181   29      -6   609   630   71      -5   640   647   21      -5  1096  1060   14
       -2,  5,  L               -2,  7,  L          -6   908   944   37      -5   530   383   79      -4  1285  1219   10      -4  1883  1903   10
 -17   376   181   74     -18  1758  1729   23      -5  1586  1578   24      -4  1896  1918   28      -3  2769  2591    6      -3   715   648   18
 -16   974   900   30     -17  1963  1984   20      -4  2320  2429   21      -3   814   872   54      -2  5772  5680    5      -2  3524  3523    8
 -15   712   725   38     -16  1300  1269   25      -3  1711  1698   24      -1   496   486   83      -1   997  1001    6      -1   686   675   20
 -14   627   674   40     -15   797   832   35      -2  1782  1828   25       0   613   749   69       0  5738  5778    5       0  2265  2265   11
 -13   399   415   57     -12  1560  1547   20       0  2337  2405   22       1   539   573   80       1   366   294   18       1   621   609   30
 -12  1094  1097   23     -11  3382  3458   15       1  2031  2023   24       2  1598  1600   33       2   225    77   41       2  1802  1783   16
 -11  2400  2434   14     -10  2383  2353   16       2  1826  1836   26       3  2282  2288   28       5   603   544   44       3  1003  1003   27
 -10  1427  1444   17      -9  2314  2388   16       4   676   579   61       4  1987  2009   31       6  3286  3407   16       4  6730  6832   14
  -8   537   555   32      -8  1507  1552   19       6   741   740   60           -2, 13,  L           7  1111  1064   31       5  2427  2452   18
  -7  1807  1867   14      -7  1568  1628   19       7  1582  1521   33     -11  1010  1066   48       9  1468  1476   30       6  4884  4796   16
  -6   293   232   52      -6   500   416   45       8  1504  1528   35     -10   497   491   91      10  3397  3523   22       7   758   741   47
  -5   931   964   19      -4  1501  1526   19           -2, 10,  L          -9   977   931   49      11   808   754   60       8   586   378   65
  -4  3286  3328   11      -3  1944  1909   17     -16   516   531   68      -7  1081   994   43      13  1804  1748   35      10  2367  2310   26
  -3  2085  2155   12      -2  1023  1053   26     -15  1834  1909   25      -6  1440  1421   35      14  1661  1631   39      11  1816  1729   31
  -2  4036  4052   11       0  1998  2042   19     -14  1071  1137   36      -3  1096   935   43      17  1138  1098   56      12  2450  2431   28
  -1  4317  4384   11       1   731   813   41     -13   867   898   42      -2   671   502   66           -1,  2,  L          15   766   774   73
   0  2622  2584   13       2   939  1019   35     -11  1101  1081   34      -1  2043  1822   28     -18   937   819   44      16   706   739   81
   1  1209  1305   20       4   953   965   39      -9   727   803   51       0  1965  1988   30     -15  1171  1095   31           -1,  4,  L    
   2  2753  2740   15       5  2215  2235   23      -8   447   410   80       1  1745  1721   32     -14   912   929   36     -16  1365  1379   26
   3   427   328   58       6  3919  4020   20      -7   909   872   42           -2, 14,  L         -13   709   716   42     -15  1430  1432   24
   4  2312  2373   18       7  2264  2194   26      -5  1784  1795   25      -9   626   535   74     -12   980   937   28     -14  1818  1810   19
   5   820   891   40       8  1829  1775   31      -4   449   551   82      -8   651   484   70     -11  1934  1948   17     -13   706   685   34
   6   672   813   52      12  1270  1203   44      -3  2262  2302   23      -7   609   567   79      -8  4917  4987   10     -12  1002   988   23
   8   632   616   63           -2,  8,  L          -2  3093  3122   21      -6  1506  1421   37      -7  1119  1089   15     -11  2223  2251   14
  11   707   585   67     -17   857   870   38      -1  1446  1490   31      -5  1622  1511   35      -6  5838  5811    8     -10  1091  1086   18
  12   593   438   78     -16   414   490   73       0  1247  1234   35           -1,  0,  L          -5  2401  2365    8      -9   361   306   44
  14  1106  1097   51     -14   993  1031   32       2   885   915   47       1   187   178   23      -4   551   505   18      -8   556   599   29
       -2,  6,  L         -13   751   867   40       3   554   487   74       2  6629  6598    6      -2  1672  1672    7      -7  2439  2454   12
 -18  1172  1193   29     -11   382    19   69       4  1200  1312   39       3   925   887   11      -1   553   599   15      -6  2711  2674   11
 -17   632   634   46     -10  1776  1889   20       5  1351  1333   36       4   894   859   18       0  2873  2872    7      -5  2254  2217   11
 -15  1116  1098   26      -9  2231  2325   18       6   695   649   64       5   538   500   41       1   412   434   28      -4  3651  3704   10
 -14  1498  1523   21      -8  1297  1329   24       8  1062   970   47       6  1299  1278   23       2  1274  1230   15      -3  1345  1357   16
 -12  1245  1265   21      -7   694   645   39           -2, 11,  L           7   461   427   66       4   748   797   35      -2  1754  1736   14
 -10   558   555   39      -6  1319  1326   24     -14   741   766   55       8  3390  3491   18       8  1609  1583   27      -1  2843  2851   12
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COLUMNS ARE 10FO,10FC,  10SIG

   L   KFO    FC   SIG        L   KFO    FC   SIG        L   KFO    FC   SIG
      -1,  4,  L              6  1884  1937    28      -17  1188  1265    33
   0  6766  6620    12        7  1802  1676    28      -16  1316  1370    31
   1  3234  3212    14        8  2597  2424    24      -15   739   673    48
   2  8572  8510    14       11  1097  1030    46      -13   585   567    62
   3  1288  1388    24       12   826   805    63      -12  1961  1941    24
   6   851   858    41            -1,  7,  L           -11   534   470    68
   8  1946  1882    26      -18   733   822    44      -10   420   266    83
   9  1730  1639    30      -16   691   756    43       -9   676   712    55
  11   818   679    60      -15  1380  1421    24       -8  3304  3264    19
  12  1515  1392    38      -10  1317  1240    24       -4   445   151    80
  13  1347  1271    42       -9  3005  3058    16       -3  1845  1759    25
  15   932   843    61       -8  2410  2480    17       -2  5229  4938    18
      -1,  5,  L             -7  1677  1651    20       -1  3023  2922    20
 -16   755   787    37       -6  3111  3133    16        0  4852  4657    18
 -15   396   432    66       -2  1550  1587    23        1   852   851    49
 -14   828   853    31        0  1143  1147    29        3   507   481    80
 -13  1042  1058    24        1   854   921    39        5  1417  1411    35
 -12  2935  2852    13        2   739   619    45        6  1773  1688    30
 -11   631   633    33        3   692   638    52        7   919   828    50
 -10  1951  1946    14        4  2114  2063    24        9  1209  1114    42
  -9  2312  2356    14        5  1663  1584    28            -1, 10,  L
  -8   485   366    38        6   619   657    68      -17  1000  1019    41
  -7   592   546    32        7  1616  1515    32      -16   614   618    64
  -6  3985  3985    12        8  3189  3045    23      -15   444   370    85
  -5  1955  1993    14        9  1491  1481    36      -14   464   553    85
  -4  4214  4201    12       10  1190  1228    43      -13  1906  1964    27
  -3  2824  2851    13       11   802   800    62      -12  1194  1263    38
  -2   332   244    64       12  1154  1000    46      -11   957   919    45
   0  1192  1227    22            -1,  8,  L           -10  1478  1523    32
   1   830   817    31      -18   729   738    46       -8  1593  1595    31
   2   406   251    64      -17  1269  1350    29       -7  1690  1748    29
   4   627   553    49      -15  1061  1112    33       -6  1448  1434    32
   5   715   727    48      -14  1779  1824    23       -5  1902  1831    27
   6  1034   960    38      -12  2624  2639    19       -4  2609  2580    23
  12  2027  1900    31      -11  1745  1767    23       -3  1097  1104    40
  14   950   951    59       -9   413   121    76       -2  1061  1004    41
      -1,  6,  L             -8   918   962    37        0  1905  1851    27
 -17  1371  1369    24       -7  1007   991    34        1   898   925    48
 -16  1810  1870    20       -6  1744  1810    23        2   498   528    83
 -15   382   506    69       -5   971  1043    36        3  1172  1167    39
 -14  1701  1780    20       -4   467   470    67        4   854   812    50
 -11  1686  1687    18       -2   614   578    53        6   844   839    53
  -9  1354  1412    20       -1   412   249    76        7   970   957    49
  -8  2806  2832    14        0  2068  2118    22        8   610   416    76
  -7   816   848    29        1  1336  1350    30            -1, 11,  L
  -6   749   759    32        2  2925  2841    21      -16  1520  1495    33
  -5   754   723    32        3  1070   987    38      -15  1302  1313    37
  -4  5218  5373    13        4  3115  3043    21      -13   635   737    69
  -3  1343  1407    21        5  1201  1170    38      -12   743   865    61
  -2  2442  2411    16        6  2211  2164    26      -10  2143  2151    28
   0  2873  2964    16        7  1056  1060    45       -9   612   656    75
   2  1898  1940    21        8  1299  1259    39       -8   569   409    78
   3  1762  1787    22       10  1860  1808    32       -7   497   326    86
   4  2161  2132    22            -1,  9,  L            -6  1465  1369    34
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COLUMNS ARE 10FO,10FC,  10SIG

   L   KFO    FC   SIG        L   KFO    FC   SIG        L   KFO    FC   SIG
      -1, 11,  L            -11  1325  1331    25      -15  1005  1010    35
  -5   883   885    51      -10  2617  2515    16      -14   384   205    76
   0   487   470    84       -9   651   662    36      -12  1272  1270    22
   3   735   689    58       -8  3369  3377    13      -11  2063  2060    15
   4   673   705    66       -7   789   769    24      -10  1927  1879    14
   6  1449  1479    38       -6  4057  4001    10       -8  5223  5293    10
      -1, 12,  L             -5  1857  1820    11       -7   962   965    17
 -11  1063  1057    47       -4  4740  4866     7       -5   712   698    28
 -10  2195  2067    28       -3   382   365    17       -4  3985  3967    11
  -9  1051   942    47       -2  5132  5185     6       -2  1920  1932    14
  -8  1744  1711    32       -1   213    62    41       -1   603   597    35
  -7   486   221    83        0  1354  1445    10        0  1404  1421    19
  -6  1410  1367    35        1   281   319    44        2  6411  6616    14
  -5   690   728    65        2  1153  1183    15        3  2928  3110    16
  -4   558   521    78        3   443   487    41        4  2235  2238    18
  -3   633   619    70        4  2420  2420    14        5   527   394    54
  -2  1419  1368    35        5  1528  1479    19        6  3140  3184    18
   0  1093  1157    41        6   709   741    36        7  1197  1152    30
   1  1330  1423    38        7   699   639    39        8  2130  2125    22
   2  1629  1673    33        8  1717  1665    21        9  2179  2100    24
      -1, 13,  L              9  1553  1568    25       10   654   562    65
 -13  1200  1128    46       10  2244  2216    22       12  1180  1069    44
 -12   502   516    99       11   912   925    46       13   845   952    63
  -8  1130   959    42       12  3723  3531    20       14  2282  2188    30
  -3   466    26    89       14  1327  1217    38       16  1313  1279    47
   0   844   696    55       15  1684  1607    34             0,  4,  L
   1  1063  1120    48       16  1039   927    52      -18   560   428    62
      -1, 14,  L                   0,  2,  L           -15   448   236    62
  -9   732   687    69      -18   798   778    55      -14  1988  1951    18
  -5  1461  1304    38      -16  2228  2200    23      -13  1688  1679    18
  -4  2058  1894    30      -14  1590  1530    26      -12  2034  1961    15
  -3  1428  1337    39      -13  2003  1956    21      -11   332   292    58
       0,  0,  L            -10  3191  3150    14       -9  1192  1181    18
   1   311   184    18       -9  1117  1077    19       -8   803   803    25
   2  4001  4142     7       -8  3792  3819    11       -7   329   245    57
   3   878   855    15       -7   527   498    27       -6  1254  1286    21
   4   341   295    47       -6  3252  3143     9       -4  1857  1759    18
   5   651   646    32       -5   419   457    29       -3   377   131    71
   6  4262  4280    12       -4  2709  2740     9       -2  1727  1789    19
   7  1983  2008    16       -2  2639  2712    10        0  1738  1807    19
   8  2852  2786    15        0   826   823    20        1  1062  1177    29
   9  1066  1048    28        1   605   641    31        2  5096  5102    15
  10   896   945    36        2   742   726    30        3   748   776    39
  11  1197  1175    31        3   523   362    47        4  5659  5770    15
  12  1749  1669    26        4  1920  1908    18        5  1188  1197    29
  13  1198  1221    38        5  1770  1792    20        6  1478  1476    27
  14   902   872    50        6  2987  2987    16        7  1461  1488    29
  16  2245  2167    28        7  1797  1805    22        8  2013  1980    26
  17  1079  1018    49        8  3933  3863    17       10  2256  2378    28
       0,  1,  L             10   541   555    73       11  1446  1405    37
 -18   521   450    90       11   982   922    44       14   610   636    86
 -16  1302  1236    35       13   927   828    52             0,  5,  L
 -15  1152  1062    37       14   970   990    54      -18  1307  1259    28
 -12  2581  2499    19             0,  3,  L           -17   797   775    38
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  COLUMNS ARE 10FO,10FC,  10SIG

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        0,    5,  L          -17  1500  1561    25         1  2059  2004    25
 -16  1155  1199    27       -16  1425  1489    27         2  3276  3180    21
 -14  1642  1688    19       -15   588   596    55         3   604   474    68
 -13   432   493    55       -14  1441  1403    27         4   780   788    55
 -12  1234  1247    22       -12  2149  2138    22         6   868   872    53
 -11   585   588    41       -11  1282  1264    31         7  1452  1484    36
 -10  2687  2711    15       -10  1369  1403    30         8  1607  1516    34
  -7   805   800    33        -9   804   789    45         9   504   312    92
  -6  1210  1229    24        -8  1374  1355    29              0,   10,  L
  -4  4224  4202    15        -6   854   896    42       -17   557   631    83
  -3  1242  1305    27        -4  1687  1614    24       -15   942   965    52
  -2  7401  7047    14        -2  1280  1291    29       -14   627   611    74
  -1   396   425    71        -1  1371  1327    27       -13   499   492    94
   0  4097  3955    15         0  1911  1888    22       -12   503   368    91
   2  1900  1860    19         1   874  1033    40       -11   513   663    97
   3  1741  1715    22         2   845   828    41        -8   684   763    68
   4  2358  2316    20         3   986   990    38        -6   989   963    46
   6  1452  1424    30         4  2392  2423    23        -4  1952  1904    27
   7   983   936    41         5   753   706    54        -3   882   841    49
   9  1227  1121    38         6  3594  3519    21        -2  3975  3638    20
  10  1187  1150    43         7  1642  1628    33        -1  1932  1768    28
  12   525   483    92         8  1546  1456    35         0  1406  1359    35
  13   714   510    70         9   906   900    53         4  1514  1565    34
  14  2151  2071    32        11   547   584    92         5  1250  1245    39
        0,    6,  L           12   697   689    77         8   510   590    97
 -18  1087  1019    30              0,    8,  L                 0,   11,  L
 -16   732   771    40       -16   688   736    54       -16  1451  1426    40
 -15  1501  1491    23       -15   681   683    56       -14  1284  1291    43
 -14  1693  1717    21       -14  1257  1301    34       -13  1014   958    52
 -12  2990  3022    17       -12  1557  1532    30       -11   523   676    95
 -10   731   754    42       -10  2613  2587    22       -10  2154  2072    30
  -9  1544  1575    23        -9   657   593    60        -9  1224  1091    43
  -8  1337  1307    26        -8  1386  1323    32        -8  3673  3411    23
  -7  1243  1221    27        -6  1330  1285    31        -7  1123   955    43
  -6  6286  6398    16        -4  1203  1123    32        -6  1178  1148    42
  -5  1325  1242    27        -2  2336  2191    22        -4   483    37    87
  -4  3931  3837    16        -1  1080   983    35        -2   544   451    78
  -2  2842  2750    17         0  3456  3370    19         0   825   825    52
  -1   979   834    31         2  2254  2235    23         4   704   700    64
   0   791   715    38         5   879   869    51         5   890   834    52
   1  1970  1960    21         6  1316  1343    38         6  1000   916    49
   2  3022  3037    18              0,    9,  L                 0,   12,  L
   3   585   590    56       -17   846   892    49       -13   965  1016    58
   4   920   941    38       -15   784   855    55       -12  1819  1753    35
   5  1756  1847    26       -14  1798  1833    30       -11   628   554    81
   7   870   881    48       -13   484   396    86       -10  1654  1610    37
   8  1857  1788    29       -10  3314  3311    22        -8  1651  1490    34
   9  1300  1301    40        -8   612   527    72        -7   516   652    92
  10  3309  3186    24        -6  1622  1450    29        -6  1140  1033    43
  11   518   716    94        -4  2555  2370    22        -4  2005  1877    29
  12  2012  2007    32        -3   932   821    43        -3  1289  1216    38
  13   568   568    93        -2  1672  1526    28        -2   691   587    64
        0,    7,  L           -1   766   623    52        -1   785   734    57
 -18  1986  1997    22         0  3020  3012    21         2  1464  1498    35
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  COLUMNS ARE 10FO,10FC,  10SIG

   L   KFO    FC   SIG         L   KFO    FC   SIG         L   KFO    FC   SIG
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   3  1774  1682    32        16   948   882    49        12  1528  1480    33
   4  2233  2225    29        17  1241  1132    42        14  1157  1110    43
        0,   13,  L                 1,    2,  L           16   767   869    71
 -10   589   539    85       -18  1412  1358    42              1,    4,  L
  -7   593   636    82       -17  1112  1018    47       -17   674   679    56
  -6  1340  1194    40       -16   499   250    87       -16  1306  1290    30
  -5   715   724    67       -15   889   975    58       -13   542   530    42
  -2  1421  1253    37       -14  2560  2424    24       -12   852   863    29
   0  1896  1896    31       -12   795   850    52       -11   440   418    67
   1  1021  1009    50       -11  1345  1350    32       -10   515   511    70
        0,   14,  L           -8  5406  5405    16        -8   534   438    71
  -7   645   627    78        -7   629   646    22        -6  1647  1656    23
  -6  1611  1563    38        -6  5753  5794    10        -5   999   995    30
  -4   774   673    66        -4  1281  1284    14        -4  2820  2788    15
  -3   818   750    63        -2  1056  1045    12        -2  2345  2418    15
        1,    0,  L           -1  1312  1326    10        -1  3152  3006    13
   0   663   642     7         0  3109  3130     8         0  4566  4642    13
   1   395   428    14         1   306   329    41         1  1071  1138    25
   2  7904  7797     6         3  1576  1577    15         2  4892  5034    13
   3   568   614    17         5  1754  1712    16         3  1968  1975    17
   4  1254  1248    12         6   565   207    39         4   366    54    70
   5  3545  3596    10         8  3458  3491    16         5  1072  1039    29
   6   613   687    29         9  2801  2863    18         7   764   775    44
   8  2889  2928    13        10  4281  4333    18         8  1136  1087    34
   9  1192  1199    22        11   463   601    84         9  1729  1694    27
  10  2442  2452    16        12   756   821    54        10  1154  1169    39
  11  1253  1182    26        14  1453  1422    35        12  1174  1125    42
  14  1930  1951    25        15  1234  1178    41              1,    5,  L
  15  1394  1339    32        16  2643  2530    27       -18   540   473    60
        1,    1,  L                 1,    3,  L          -16  1807  1750    20
 -18  1305  1255    48       -18  2159  2097    29       -15  1011  1025    29
 -14  1733  1620    34       -17   539   566    82       -14  1130  1124    28
 -13   707   696    68       -16  2158  2145    26       -12  3296  3368    20
 -10   607   552    67       -14  1176  1123    35       -10  2021  2073    27
  -8  1063   918    35       -13  1511  1516    26        -8   512   685    76
  -6  1128  1029    20       -12  1959  1916    20        -6  2962  2945    18
  -4  2194  2128     8       -10  4872  4858    11        -4  3886  3939    15
  -3  1145  1121     9        -9   942   941    35        -3  1885  1846    19
  -2  6286  6249     6        -7   524   587    57        -2   802   855    35
  -1   860   889     9        -6  3872  3926    14        -1   913   882    30
   0  6413  6023     6        -4  1554  1568    18         0  2846  2930    15
   1  1048  1084     9        -3   977   967    22         1  1966  2000    18
   2   678   653    16        -2  4114  4218    11         2  1317  1399    24
   3  1596  1533    11        -1   429   454    41         5  1319  1322    28
   4  1019  1015    18         0   528   460    34         6  1584  1544    27
   5  1166  1133    18         1  1254  1182    17         7   982   944    40
   6  2192  2144    13         4  5827  5929    13         8  2110  2080    25
   7  2576  2589    14         5  1009  1070    27         9   804   852    56
   8   465   528    50         6  4863  4851    14        11  1222  1205    42
  10  1572  1634    23         7  2760  2721    17        12  2442  2447    28
  11  1359  1357    28         8  1462  1561    26        13   536   409    94
  12  1415  1358    29         9   608   667    59              1,    6,  L
  13   794   681    50        10   937   946    42       -18   533   578    58
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COLUMNS ARE 10FO,10FC,  10SIG

   L   KFO    FC   SIG
         1,    6,  L
 -17   849   894    38
 -16  1393  1335    27
 -14  2391  2507    24
 -10  1770  1694    30
  -8  1760  1734    27
  -4  6206  6043    16
  -3  1200  1165    28
  -2  3624  3665    16
  -1  1290  1235    26
   0  1396  1428    25
   1   854   823    36
   2  1085  1154    32
   3  1444  1498    27
   4  1431  1472    28
   6   721   706    54
   7  1027  1062    43
   8  1605  1574    32
   9   758   792    61
  11   731   692    67
  12  1951  1899    33
         1,    7,  L
 -16   920   892    48
 -15   909   876    51
 -12  2214  2230    30
 -10  2686  2566    25
  -8  2438  2305    24
  -7   454   166    84
  -6  3158  2880    19
  -5  1106  1067    35
  -2   532   304    59
  -1   942   808    37
   0   888   913    38
   1  1478  1489    26
   3  1080  1078    36
   4   631   607    60
   5  1292  1306    35
   6  2018  2028    27
   8  2808  2747    25
  10  1541  1539    36
  11   985  1008    53
  12  1696  1626    37
         1,    8,  L
 -18  1250  1236    39
 -17   886   925    55
 -15   741   745    68
 -14  2458  2434    29
 -12  3494  3225    25
 -11   561   364    90
 -10   990   835    51
  -8  1611  1524    32
  -7   559   508    75
  -6  1758  1534    27
  -5   637   576    60

   L   KFO    FC   SIG
  -4  1804  1759    25
  -3   756   705    49
  -2   446   388    78
  -1   903   845    42
   0  1307  1346    31
   1  1295  1359    33
   2  3065  3139    21
   3   867   855    47
   4  4352  4260    20
   6  1664  1628    31
  10  2313  2157    29
  11   553   192    93
         1,    9,  L
 -17   578   575    91
 -16  1143  1080    50
 -14   675   669    84
 -12  2241  2097    30
  -8  4031  3507    21
  -7  1192  1124    40
  -6   933   813    47
  -5   453   481    90
  -4   605   551    67
  -2  4642  4264    19
  -1  1664  1571    29
   0  3882  3820    20
   2   780   843    54
   3  1301  1246    36
   4   473   481    91
   5  1002  1022    47
   6   791   684    56
   7   784   768    59
   8   662   613    72
   9   522   572    94
         1,   10,  L
 -16   531    19   104
 -14   827   814    71
 -12  1418  1232    43
 -10  1802  1656    34
  -9   847   767    61
  -8  1820  1630    32
  -6  1883  1729    29
  -5   695   629    63
  -4  1985  1836    28
  -3  1216  1058    38
   0  1330  1354    36
   1   863   769    51
   3   894   921    50
   5   628   679    72
   6   898   853    53
   8   827   869    63
         1,   11,  L
 -14   889   726    65
 -10  1914  1783    33
  -8   611   620    81

   L   KFO    FC   SIG
  -7   919   835    54
  -6  2604  2367    25
  -4  1689  1498    32
  -3   748   646    62
  -2   481   360    92
  -1   839   785    55
   2  1014  1036    46
   6  1937  1863    32
         1,   12,  L
 -12   595   232    89
 -10  2722  2348    27
  -9   985   890    55
  -8  2277  2137    30
  -6  1043   962    48
  -5  1012   916    47
  -4   801   743    58
  -3   992   916    48
  -2  1022   967    47
  -1  1034   986    47
   1   862   796    53
   2   822   759    57
         1,   13,  L
  -8   884   683    55
  -7   569   438    83
  -6   726   635    68
  -5   913   732    54
  -4   670   598    71
  -3  1087   964    47
   0  1644  1614    34
         1,   14,  L
  -6   823   680    62
  -5  1399  1229    40
  -4  2456  2210    29
         2,    0,  L
   0  9519  9452     6
   1  1028   940     9
   2  3049  2925     7
   3  2947  2917     8
   4   396   414    34
   5   743   718    21
   6  1795  1765    13
   7  1808  1892    14
   8  1525  1557    16
  10   636   629    39
  11   394   430    69
  12  1404  1398    25
  13  1129  1096    32
  15   539   601    67
  16  2134  2135    25
  17  1115  1150    41
         2,    1,  L
 -17   825   849    77
 -16   795   779    75
 -14  1274  1138    47
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COLUMNS ARE 10FO,10FC,  10SIG

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 -12  1908  1847    26
 -10  2147  2148    17
  -8  3133  3057    11
  -7   260   288    52
  -6  2547  2531     9
  -5  2987  2913     8
  -4  2903  2817     8
  -3  1609  1608     9
  -2  2029  1986     7
  -1  2678  2614     7
   0  1710  1507     8
   3  1515  1452    12
   4   999  1030    18
   5  2788  2768    11
   6   974   985    20
   7  1207  1236    19
   8   531   531    41
   9  2069  2176    18
  10  2540  2511    17
  11   921   927    35
  12  1840  1810    23
  13   490   540    74
  14   472   532    77
  15   744   854    55
  16   923   887    47
         2,    2,  L
 -18   680   653   100
 -17   983   904    67
 -16  2843  2776    31
 -15  1086  1025    58
 -14  1340  1310    43
 -13   679   609    62
 -12   857   721    40
 -10  2475  2543    13
  -9   610   643    28
  -8  2633  2736    11
  -7   383   373    35
  -6  3202  3140    10
  -5   880   858    18
  -4  4027  3941     9
  -3  2042  2024    10
  -2  1402  1297    11
  -1   248    79    45
   1  1801  1798    10
   2   522   434    29
   3  1228  1216    16
   4   543   508    32
   5   408   504    44
   6  2821  2806    13
   7  3037  3059    14
   8  3613  3629    15
   9   580   608    50
  10  1321  1287    27

   L   KFO    FC   SIG
  11  1151  1131    32
  12  1511  1469    28
  14  1107  1106    39
         2,    3,  L
 -16   687   613    92
 -15   779   729    72
 -14  1891  1809    28
 -12   382   263    58
 -10  1375  1364    17
  -9  1241  1242    18
  -8  5294  5433    11
  -6   704   698    26
  -4  3730  3723    10
  -3   445   441    37
  -2   809   768    21
  -1  2076  2070    12
   0  1566  1535    14
   1  1036  1082    19
   2  2398  2411    12
   4   721   775    28
   5  1172  1209    22
   6  2223  2196    16
   8  3170  3224    17
   9  2405  2347    20
  10  1752  1670    25
  11  1108  1087    36
  12   470   396    85
  14  1626  1640    33
  15   850   715    56
         2,    4,  L
 -16  1640  1626    40
 -14  2134  2148    16
 -12   981  1024    31
  -9  1140  1144    24
  -6   563   577    37
  -5  1271  1255    18
  -4  1163  1216    20
  -3  3143  3105    12
  -2  2335  2325    13
  -1   316   334    63
   0   579   617    34
   1  2134  2177    14
   2  4668  4699    12
   3  1267  1346    20
   4  4299  4407    14
   5   593   578    43
   6  1095  1121    28
   7  1886  1873    21
   8  2501  2500    20
   9  1073  1101    38
  10  1851  1824    26
         2,    5,  L
 -18  1555  1476    35
 -17   821   833    46

   L   KFO    FC   SIG
 -16  1605  1509    36
 -14  2054  2011    28
 -13   883   841    48
 -12  1130  1084    37
 -10  3516  3548    18
  -8  1631  1571    21
  -7   834   818    33
  -5   665   696    36
  -4  4638  4715    13
  -3   327   205    65
  -2  5979  6084    13
  -1  2499  2511    14
   0  3684  3807    13
   1  1830  1807    17
   3  1615  1582    20
   4   690   688    41
   5   398   233    71
   6  2652  2590    19
   7   994  1057    38
   9  1009   993    42
  10  1774  1763    29
  11   498   564    90
  12   976   975    50
  14  2443  2400    30
         2,    6,  L
 -16   900   884    73
 -14  1555  1517    40
 -12  3982  4025    22
 -10  1468  1430    30
  -8  1056   993    34
  -7  1010   992    33
  -6  5272  5420    16
  -5   388   554    73
  -4  3275  3318    16
  -3   600   723    46
  -2  2028  2063    18
  -1  1257  1239    24
   1  2035  2077    19
   2  1881  1918    20
   3   953   983    34
   4   519   468    62
   5  1039   969    36
   8   466   475    90
  10  2735  2693    25
  11  1286  1227    41
  12  2020  2045    32
  13   759   788    70
         2,    7,  L
 -18  2045  1827    41
 -17   592   167   113
 -16  1008   876    69
 -14  1588  1592    43
 -12  2065  2057    31
 -10   557   509    79
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COLUMNS ARE 10FO,10FC,  10SIG

   L   KFO    FC   SIG
        2,    7,  L
  -7  1737  1827    25
  -6  1717  1693    24
  -5   759   836    44
  -4  1682  1686    23
  -3  1347  1483    27
  -2  1101  1148    31
   1   901   844    36
   2   422   279    73
   3  1622  1628    27
   4  2431  2518    23
   5  1390  1428    32
   6  2052  2041    27
   8   477   290    88
   9   545   588    84
        2,    8,  L
 -14  1093   949    58
 -12  2136  2067    33
 -10  3416  3348    23
  -9   677   708    69
  -8   631   603    67
  -6  1825  1882    27
  -5  1602  1643    28
  -2   429   284    81
  -1  1110  1055    34
   0  1801  1895    26
   1  1155  1029    35
   2  2091  2102    24
   3  1310  1335    34
   4  1175  1103    39
   5   774   867    60
   6  2927  2910    23
   7   652   588    68
        2,    9,  L
 -14  1816  1666    40
 -12   909   811    62
 -10  3108  2970    25
  -9   888   677    56
  -7   523   599    86
  -6  1725  1669    29
  -5  1317  1318    36
  -3  1198  1227    37
   0  2175  2219    25
   1  1101  1041    39
   2  3151  3180    22
   3  1041  1103    44
   4  1785  1863    30
   5  1158  1210    42
   8  1050  1020    48
        2,   10,  L
 -10  1165   974    46
  -8  1158  1045    44
  -7  1049  1083    48
  -6  1738  1627    32
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   L   KFO    FC   SIG
  -5   937   974    51
  -4  3450  3263    22
  -3  1206  1101    40
  -2  3493  3352    22
  -1  1039   988    45
   4  1633  1540    32
   5   646   660    72
   6   488   290    97
        2,   11,  L
 -14  2179  1967    36
 -10  1870  1745    34
  -9  1049   950    50
  -8  3513  3137    24
  -6  1831  1715    31
  -5   980  1022    51
  -3   916   902    51
  -2   800   697    56
  -1   914   962    52
   0  1281  1273    37
   2   910   866    50
   3   460    52    89
   4   943   850    51
        2,   12,  L
 -12  1422  1287    44
 -11   586   610    94
 -10  1384  1208    42
  -8  1536  1410    38
  -7   731   627    67
  -6  1327  1131    40
  -4  1311  1279    41
  -3  1208  1201    43
  -2   692   716    70
  -1   787   671    60
   1   570   484    80
   2  1186  1104    42
        2,   13,  L
 -12   708   571    80
 -11   714   639    79
 -10   607   517    88
  -9   627   532    82
  -8   922   935    60
  -6  1009   926    52
  -5   780   730    65
  -2  1626  1595    36
  -1   642   646    78
   0  1422  1421    38
        3,    0,  L
   0  1163  1129    10
   1  1565  1538     9
   2  4657  4428     8
   3  1054  1016    14
   4  4379  4171     9
   5  3322  3275    10
   6   862   855    20
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   L   KFO    FC   SIG
   7  1002  1005    20
   8   773   761    26
  10  1781  1794    18
  11   579   683    49
  12  1439  1407    24
  13   708   636    46
  14  1237  1286    31
  15   767   686    45
        3,    1,  L
 -16   798   714    58
 -15   771   808    56
 -14   641   692    59
 -13   773   791    44
 -12   631   582    44
 -11   342   344    67
  -9  1363  1376    16
  -8  1311  1289    15
  -6  2470  2464    10
  -5   816   806    17
  -4  3387  3421     8
  -3  4863  4828     8
  -2  5147  5036     8
  -1  3746  3680     8
   0  1979  1933     9
   1  1399  1368    11
   2   408   359    32
   3  2027  2045    11
   4  1698  1668    13
   5  1608  1589    14
   6  1752  1745    14
   7  1200  1240    19
   8  1045   989    22
   9  1239  1234    22
  11   641   549    45
  12  2009  2036    21
  13   800   875    44
  14   923   869    39
  15  1019  1063    39
  16   726   661    56
        3,    2,  L
 -18  1563  1448    39
 -17   886   931    55
 -15   821   854    46
 -14  3127  3262    18
 -13  1208  1233    26
 -12  1395  1438    20
 -11   681   708    31
  -9   976   978    19
  -8  4586  4616    10
  -7  1695  1731    13
  -6  5266  5295    10
  -5  3491  3448    10
  -4   440   344    32
  -3   900   884    17
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COLUMNS ARE 10FO,10FC,  10SIG

   L   KFO    FC   SIG
        3,    2,  L
  -2   581   415    24
  -1  3339  3231     9
   0  2429  2353    10
   1  1010   984    16
   2  2459  2389    11
   3  1600  1603    13
   4   534   564    31
   5  2017  1883    14
   6  1126  1115    21
   8  3070  3127    15
   9  3056  3105    16
  10  4058  4114    16
  11  2101  2059    21
  13   772   822    48
  15   902   841    46
  16  2120  2089    27
        3,    3,  L
 -18  1583  1537    35
 -17   872   900    47
 -16  2457  2471    21
 -14  1000  1020    29
 -11  1400  1398    18
 -10  3858  3914    12
  -9   908   934    23
  -8   475   478    38
  -7  1214  1218    17
  -6  3437  3386    11
  -5   721   791    23
  -4  1044  1069    18
  -3  1904  1884    12
  -2  1968  1906    12
  -1   405   371    40
   0   698   671    24
   1  2384  2417    12
   3  1856  1904    14
   4  2910  2990    13
   5  1635  1597    17
   6  3332  3373    14
   7  2586  2626    16
   8  1130  1165    28
   9   910   921    35
  10   668   720    51
  12   555   458    64
  14  1186  1125    39
  15   768   711    60
        3,    4,  L
 -18   637   638    57
 -16   896   936    33
 -14   776   726    34
 -13   354   307    70
 -12  1075  1071    26
 -11  2008  1984    17
 -10   812   835    31
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   L   KFO    FC   SIG
  -9   661   690    35
  -8   549   568    38
  -7  2655  2614    13
  -6  1701  1705    15
  -4  1781  1777    14
  -3  1166  1159    17
  -2  2411  2428    12
  -1  2584  2627    12
   0  3420  3437    12
   1  2804  2839    13
   2  2106  2207    14
   3  1240  1306    20
   4  1803  1915    18
   8   538   613    59
   9  1034   936    35
  10  1514  1513    29
  11   979   991    41
  12   830   827    50
        3,    5,  L
 -18   607   647    50
 -16  1830  1862    22
 -15   663   709    49
 -14  1419  1485    27
 -12  3138  3131    17
 -11   901   840    34
 -10  1918  1967    19
  -9   944   951    30
  -8   853   820    30
  -7   646   606    36
  -6  1092  1078    23
  -5  1168  1209    21
  -4  1670  1692    17
  -3  1222  1275    20
   0  3154  3195    14
   1  3264  3315    14
   2  3472  3490    14
   3  1633  1609    19
   4   904   932    31
   5   686   626    43
   7   844   839    41
   8  2771  2790    21
   9   564   590    69
  11   960   869    44
  12  2094  2015    28
  13   827   717    58
        3,    6,  L
 -18   677   594    58
 -15   783   805    49
 -14  1997  2020    25
 -12   632   516    57
 -11   429   145    75
 -10  2112  2022    21
  -9   958   953    33
  -7  1999  1991    19
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   L   KFO    FC   SIG
  -6  1178  1182    25
  -5  1395  1375    22
  -4  5132  5169    14
  -2  3018  3081    15
  -1  1937  1953    18
   1   799   821    34
   2   694   754    42
   3  1185  1217    28
   4   903   883    37
   5   504   557    66
   6   710   624    49
   9   596   506    68
  12  2032  1954    30
        3,    7,  L
 -17   490   118    90
 -16  1365  1288    37
 -15   668   682    67
 -14   802   805    55
 -12  2087  1987    25
 -11   541   654    73
 -10  2321  2320    22
  -9  1783  1780    25
  -8  3100  3176    19
  -7  1798  1825    23
  -6  1933  1973    21
  -5  1777  1812    22
  -4   802   805    38
  -3   607   649    49
  -2   788   789    39
  -1  1215  1228    27
   0  1906  2021    21
   1   742   761    43
   2   550   449    57
   3  1267  1291    31
   4   430   432    84
   5   783   846    50
   6  2614  2616    23
   7  1319  1299    35
   8  2270  2280    26
   9  1131  1037    42
  10   862   833    56
  11   934   898    54
        3,    8,  L
 -14  1766  1775    33
 -12  2846  2806    25
  -9   523   346    74
  -8  1808  1807    26
  -7  1943  1960    24
  -6  1104  1171    35
  -5  1301  1298    30
  -4  2421  2500    21
  -3  1709  1765    24
  -2   968   963    37
   0   453   420    76
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```
COLUMNS ARE 10FO,10FC,  10SIG

   L   KFO    FC   SIG       L   KFO    FC   SIG       L   KFO    FC   SIG
     3,  8, L               -3  1390  1317    37       5  1630  1636    14
   1   565   560    63      -1   600   547    75       6  1788  1870    15
   2  2660  2679    21       1   506   509    88       7  1205  1212    20
   3  2064  2107    25       2  1434  1482    38       9   886   858    29
   4  4474  4480    20         3, 12, L               10  1812  1778    20
   5  1529  1562    33     -12   710   608    80      11  1990  2003    20
   6   922   903    49     -10  2253  2075    31      13  1261  1293    29
   8   758   790    62      -8  1672  1573    36      14   448   502    77
  10  1868  1796    33      -5   769   686    62        4,  2, L
     3,  9, L               -3   849   745    56     -17  1048  1048    37
 -16   740   706    77      -1   879   810    56     -16  2373  2448    21
 -13  1146  1100    47       2   497   329    92     -15  1118  1156    29
 -12  1647  1653    35         3, 13, L              -14   575   580    49
  -8  2809  2886    24     -11   874   770    68     -13   540   479    46
  -7   806   802    51     -10   824   656    66     -12  1389  1479    20
  -6  1160  1124    38      -9  1258  1117    46     -10  1164   908    19
  -5  1400  1518    33      -6  1612  1414    36      -9   576   633    32
  -4  1555  1554    29      -3   714   648    70      -8  1392  1384    15
  -3  1259  1279    34         4,  0, L               -7   568   560    29
  -2  2687  2602    22       0  5106  4978     8      -6  3109  3122    11
   0  2082  2089    26       1  1939  1960    10      -5  1458  1455    13
   1   567   588    72       2  1767  1780    11      -4  3738  3622    10
   2   896   918    49       3   885   840    17      -3  4637  4536     9
   3   503   373    84       7  1065  1077    20      -2   726   686    21
   4   763   871    61       8   334   280    58      -1  1171  1169    15
   8   610   560    80       9   525   365    43       0  1413  1373    13
     3, 10, L               10  1414  1400    21       1  2736  2756    11
 -14   870   952    66      11   859   843    33       2   306   444    51
 -13  1106  1032    51      12   795   817    39       3  1493  1491    14
 -12  1311  1361    44      14   610   596    54       4  2685  2672    12
 -10  1008   931    51      15  1280  1261    31       6  1111  1136    21
  -9   683   895    74      16  1459  1434    30       7  2527  2520    15
  -8   789   699    60         4,  1, L                8  2533  2645    16
  -7   571   719    82     -17   790   795    52       9   831   903    35
  -6  1377  1452    37     -16   679   681    54      10  2018  2046    20
  -5  1420  1478    36     -14  1424  1413    25      11   972  1012    35
  -4   854   707    53     -13   922   972    32      12  1857  1929    24
  -3  1092  1162    44     -12  1305  1283    22      13  1027   943    36
  -2  1812  1801    30     -11  2455  2524    15      14   926   841    42
  -1  1119  1112    43     -10  1090  1041    21      15  1026   930    42
   0  1448  1431    34      -9   488   476    38        4,  3, L
   2   768   833    59      -8  2214  2198    12     -16   667   691    43
   3   547   412    80      -7   376   305    40     -15   605   651    46
   4   647   594    69      -6  1771  1824    12     -14  2119  2150    18
   6  1042  1058    48      -5  4127  4185     9     -11  1597  1593    18
     3, 11, L               -4  1233  1228    13     -10  1137  1102    21
 -14   926   806    67      -3  1808  1737    11      -9  2535  2511    14
 -11   815   796    67      -2  1953  1917    10      -8  4032  4025    12
 -10   766   716    69      -1  4737  4704     9      -6   446   416    38
  -9   534   237    91       0  2911  2806     9      -4   976   978    18
  -8   567   594    88       1  2379  2257    10      -3   636   651    25
  -6  2525  2403    26       2   689   701    21      -2  1206  1192    16
  -5  1242  1198    41       3  1431  1418    13      -1  1415  1450    14
  -4  2393  2345    27       4  1352  1337    14       0   288   380    53
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COLUMNS ARE 10FO,10FC,  10SIG

   L   KFO    FC   SIG       L   KFO    FC   SIG       L   KFO    FC   SIG
     4,  3, L               -2  3703  3674    13       4  2172  2171    23
   1   545   587    30      -1  3779  3846    13       5  1865  1854    26
   2   762   728    24       0  4101  4139    13       6  1033   897    40
   3   759   763    26       1  1781  1822    17       7  1031   988    42
   4   508   532    39       2   905   904    28       8  1055  1063    43
   5   605   639    36       3  1597  1621    20      11   861   815    56
   6  1156  1196    23       4   965   947    29        4,  8, L
   7  1988  2087    18       6  2788  2867    18     -16   586   560    75
   8  2759  2804    17       8   763   672    46     -15   507   620    86
   9  2189  2236    20      10  1571  1566    29     -13   644   747    66
  10  1405  1403    27         4,  6, L              -12  1348  1318    33
  11  1209  1155    32     -17   884   885    42     -10  2415  2398    23
  13  1370  1443    32     -16   603   596    58      -9  1397  1411    30
  14   866   888    49     -15   965   999    38      -8   432   509    81
  15   887   817    52     -14  1178  1181    32      -7   779   772    45
     4,  4, L              -13  1263  1291    30      -6  1500  1477    27
 -16  1342  1454    25     -12  2600  2614    19      -5  2119  2137    22
 -14  1923  1869    18     -10   989  1039    33      -3   784   691    43
 -13  1538  1609    21      -9  1540  1503    23      -2   924   862    38
 -12  1038   986    26      -8   893   988    34       1  1012  1096    38
 -11   763   793    34      -7  2552  2657    17       2  1649  1689    27
  -9  2740  2777    14      -6  2204  2144    17       4  1201  1216    38
  -7  1262  1248    19      -5   555   509    45       5  1299  1349    36
  -6  1748  1775    15      -4  1386  1423    21       6  3312  3340    23
  -5  2580  2650    13      -3   682   757    37       7  1314  1346    38
  -4  1984  1951    14      -2   955   949    27       9  1107  1144    47
  -1   918   903    21      -1   376   351    64        4,  9, L
   0  1065  1062    20       1  1396  1433    23     -15  1100  1101    45
   1  3890  3944    12       2   392   349    69     -14  1453  1442    36
   2  5157  5140    12       3   416   423    67     -13   510   604    87
   3  3983  4087    13       4   686   735    45     -11  1110  1113    42
   4  2664  2780    15       5   407   131    76     -10  1467  1425    33
   5  1070  1054    26       6   444   614    81      -7   776   717    52
   7   942  1029    33       9  1586  1546    30      -6  1201  1193    36
   8  2291  2303    20      10  1299  1344    37      -5   902   945    44
   9   972   982    38      11  1167  1148    42      -3   621   650    60
  10  1428  1402    29      12  1116  1127    45      -2  1517  1511    30
  11   747   704    50         4,  7, L               -1  1234  1252    35
     4,  5, L              -17  1242  1225    36       0  1723  1713    28
 -18  1026  1089    33     -14   518   513    73       1  1224  1268    37
 -17   480   383    62     -13   901   955    44       2  2365  2346    24
 -16  1597  1637    24     -12   847   962    46       3  1258  1339    37
 -14  1415  1454    25     -11   464   328    73       4  1782  1849    30
 -13   617   564    49      -9  1429  1419    27       5   547   579    81
 -12   742   788    40      -7  2618  2645    18       8   668   623    72
 -11   936   958    32      -6  2504  2520    18        4, 10, L
 -10  2896  2887    16      -5  2350  2405    19     -15  1151  1095    50
  -9   374   465    69      -4   393   456    73     -13   914   904    56
  -8  1912  1918    17      -3  1251  1189    25     -12   758   733    63
  -7  2997  3094    14      -2  1908  1905    20     -11  1308  1272    39
  -6  1094  1125    23       0  1363  1417    25     -10  1569  1565    34
  -5   892   907    26       1   660   668    47      -9   756   785    61
  -4  1899  1987    16       2   878   834    38      -8   884   880    51
  -3   588   534    36       3  1033  1047    35      -7   682   665    62
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COLUMNS ARE 10FO,10FC,  10SIG

   L   KFO    FC   SIG
       4, 10,  L
  -6  1143  1222    41
  -5  1576  1494    31
  -4  3305  3362    23
  -3  2163  2198    27
  -2  2441  2508    26
   2   592   659    74
   4  1810  1825    32
   5   496    82    92
       4, 11,  L
 -14  1991  1933    35
 -13  1074   937    51
 -12   619   644    83
 -11   766   859    68
 -10   879  1063    59
  -8  1813  1842    32
  -7   709   710    69
  -6  1610  1688    35
  -5   836   815    56
  -3  1084  1077    44
  -2  1391  1377    37
  -1   851   846    56
   0  1185  1242    42
   2  1331  1415    40
   4   766   820    66
       4, 12,  L
 -12   826   828    67
  -9   952  1040    58
  -8   952   973    56
   0   568   614    84
       4, 13,  L
  -9   627   556    87
  -8  1513  1327    39
  -7  1045   934    53
  -4   830   797    64
       5,  0,  L
   0  2284  2210    10
   1  3426  3330    10
   2  1690  1665    11
   3  3536  3503    10
   4  1500  1577    14
   5  2646  2642    12
   6  1723  1744    15
   7  1246  1267    19
   9  1435  1398    20
  10   773   782    35
  11   642   604    44
  12  1563  1604    23
  13  1478  1476    26
       5,  1,  L
 -17   610   638    59
 -15   625   610    47
 -13  1887  1936    19
 -12  1179  1188    24

   L   KFO    FC   SIG
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 -10   842   789    26
  -9  3182  3258    12
  -8  1190  1210    18
  -6  1276  1288    15
  -4  1547  1464    13
  -3  6199  6240    10
  -2  4597  4584    10
  -1  4551  4501    10
   1  1003  1013    16
   2   765   780    20
   3   544   518    29
   4  2953  2974    12
   5  1413  1461    16
   6  1721  1742    16
   8   709   640    34
   9  1178  1159    25
  10   569   423    48
  11   502   429    59
  12  1416  1434    26
  13  1895  1914    23
  14   427   500    81
  15  1923  1914    26
       5,  2,  L
 -15   884   882    33
 -14  2338  2411    18
 -13  1454  1538    22
 -12   769   770    33
 -11  2276  2210    15
  -9  1525  1547    17
  -8  1817  1715    15
  -7  1610  1694    15
  -6  2962  2922    11
  -5  3023  3051    11
  -4  1167  1214    16
  -3   441   408    35
  -2   746   666    21
  -1  2817  2799    11
   0   793   780    20
   1   449   340    34
   2  3144  3106    11
   3  1481  1480    16
   4  1178  1171    19
   5   716   692    29
   6  1651  1676    18
   7  1466  1538    20
   8  1848  1949    20
   9  2996  2997    17
  10  2735  2768    18
  11  1809  1889    23
  12   775   834    45
  13   985  1015    38
  14   526   466    69
       5,  3,  L

   L   KFO    FC   SIG
 -17  1274  1319    27
 -16  1736  1731    21
 -15   392   179    68
 -14   758   681    35
 -13   723   726    37
 -11  1690  1758    19
 -10  1687  1714    18
  -9  1387  1375    19
  -7  1926  1976    14
  -6  1201  1210    18
  -5   572   452    31
  -4  1311  1266    16
  -2   510   407    32
   0   418   401    41
   1  1892  1916    14
   2  1316  1270    17
   3  2040  2090    15
   5  3019  3149    14
   6  1041  1054    26
   7  1512  1507    21
   8   788   748    37
   9   520   564    60
  10   676   640    48
  14   605   695    67
       5,  4,  L
 -17   788   791    38
 -16   390   506    73
 -12   877   844    32
 -11  2707  2726    16
 -10   829   821    31
  -9  1320  1315    21
  -8  1182  1146    22
  -7  3436  3532    13
  -6  1298  1327    19
  -5  1041  1005    21
  -4   758   766    27
  -3   931   906    22
  -1  2594  2634    13
   0  2347  2399    14
   1  2884  2921    14
   3  1153  1194    23
   4  2496  2594    16
   5  2125  2138    18
   7  1526  1570    23
   8   930   969    36
  10  1058  1117    35
  11   879   837    43
  12   779   743    50
  13  1471  1425    32
       5,  5,  L
 -16  1235  1181    29
 -14  1318  1343    26
 -12  1324  1363    26
 -11   632   579    44
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COLUMNS ARE 10FO,10FC,  10SIG

   L   KFO    FC   SIG
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  -8   785   812    33
  -7   678   675    36
  -6  1102  1135    23
  -5  1176  1210    22
  -4   561   492    38
  -2  1225  1258    21
  -1  1059  1107    24
   0  2609  2681    15
   1  3939  4023    14
   2  3193  3310    15
   3  1676  1775    20
   4   667   613    41
   5   458   496    62
   7   739   715    45
   8  2380  2468    22
  10   697   748    54
  12  1003   963    44
       5,  6,  L
 -17   917   940    40
 -15  1473  1435    27
 -14   799   787    43
 -13   967   997    36
 -12   981   924    34
 -11   742   718    43
 -10  1277  1290    26
  -9   375   371    74
  -8  1036  1091    30
  -7  2339  2374    18
  -6  2027  1960    18
  -5  3068  3168    15
  -4  2396  2496    16
  -3  1642  1606    19
  -2  1559  1613    20
  -1  1089  1109    26
   0   846   840    32
   2  1160  1170    27
   4   397   401    75
   6  1367  1412    29
   7  1091  1138    36
   8   585   608    64
  11  1453  1485    35
       5,  7,  L
 -16  1376  1375    32
 -15  1949  1991    25
 -14  1016  1019    38
 -13  1038  1065    37
 -12  1169  1204    33
 -11   439   462    76
 -10  1394  1422    28
  -9  2396  2436    20
  -8  2878  2902    18

   L   KFO    FC   SIG
  -7  2735  2786    18
  -6  1150  1154    29
  -5  1449  1529    25
  -4  1411  1460    25
  -3  1368  1419    25
  -2  1530  1447    23
  -1   653   669    46
   0  2588  2645    19
   2   825   849    40
   3   435   258    76
   5   445   412    85
   6  2243  2225    24
   7  2081  2153    26
   8  1536  1520    32
   9  2320  2383    27
       5,  8,  L
 -15   491   553    81
 -14   920   920    45
 -12  1354  1411    32
  -8   605   781    60
  -7  1916  1881    23
  -5   572   614    58
  -4  1961  1936    22
  -3  1400  1424    27
  -2  1691  1641    24
   1   911   902    41
   2  1019  1040    39
   3  2093  2119    25
   4  3078  3074    22
   5  1308  1332    35
   6   461   404    88
   7   480   550    90
   8  1081  1164    45
       5,  9,  L
 -13  1630  1638    31
 -12   849   918    51
 -10   822   934    51
  -9   818   839    49
  -8  1305  1252    33
  -5   941   897    42
  -4  1342  1351    32
  -3  1192  1187    35
  -2  1106  1116    37
  -1  1231  1280    36
   3  1094  1065    40
       5, 10,  L
 -13  1456  1449    37
 -12  1378  1391    37
 -11  1370  1421    36
  -9   896   808    48
  -8   707   717    60
  -6  1093  1132    42
  -5  1052  1069    43
  -4   675   607    61

   L   KFO    FC   SIG
  -3  1083  1089    43
  -2  2143  2153    26
  -1  1905  1918    28
   0  1218  1225    38
   1  1269  1234    37
   2   818   928    55
       5, 11,  L
 -12   824   800    63
 -11  1063  1016    48
  -9   831   855    57
  -6  1266  1268    40
  -5  1654  1621    32
  -4  2443  2339    26
  -3   878   962    54
   0   881   863    52
   2  1395  1429    39
       5, 12,  L
 -11  1296  1346    45
 -10  1502  1526.   39
       6,  0,  L
   1  2201  2200    12
   3   848   881    21
   4  1400  1382    16
   5  1839  1794    14
  10  1325  1325    24
  11  2014  2035    20
  14   607   552    55
  15  1815  1740    25
       6,  1,  L
 -15  1125  1172    29
 -14   709   741    40
 -12   586   611    44
 -11  3347  3365    14
  -9   827   865    28
  -8   492   503    40
  -7  1290  1309    17
  -5  2386  2361    12
  -4  1887  1937    13
  -3  1152  1083    16
  -2   278    94    55
  -1  4440  4448    11
   0  2594  2586    11
   1  3148  3078    11
   2  1676  1724    14
   3   352   266    47
   4  1173  1159    19
   6  2050  2026    16
   7  1086  1106    23
   8   592   619    43
  10   522   477    54
  11  1552  1586    24
  12   413   125    73
  13  1637  1607    25
  14  1064   953    36
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COLUMNS ARE 10FO,10FC, 10SIG

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   L   KFO    FC   SIG
        6,   1,  L
  15  1025   904    39
        6,   2;  L
 -16  1093  1059    29
 -15   610   653    47
 -13   603   601    44
 -12   690   656    37
 -11   639   595    38
 -10   547   518    41
  -9  2106  2123    15
  -7   963   966    22
  -5  2198  2225    13
  -4  1690  1639    14
  -3  3934  4032    11
  -2  1634  1649    14
  -1   626   577    27
   0  1017  1016    19
   1  1019  1034    20
   3   969   979    22
   4  3096  3147    13
   6  1038   978    25
   7  1149  1154    25
   8  1479  1455    22
  10  1183  1239    30
  11   990  1073    35
  12  1220  1219    31
  13  1443  1478    30
  14   598   631    64
        6,   3,  L
 -15  1067  1117    29
 -14  1171  1124    26
 -11  2351  2323    16
 -10   974  1017    28
  -9  3518  3572    14
  -8  1760  1725    17
  -5   831   863    25
  -4   891   882    23
  -2  1688  1709    15
   2  1335  1328    18
   4   828   885    30
   5  1922  1889    18
   7  4233  4270    15
   8  1120  1141    30
   9  1719  1708    23
  11   482   504    68
  13  1827  1838    27
        6,   4,  L
 -16   603   655    50
 -14   979  1031    31
 -13  1598  1586    22
 -12  1143  1203    28
 -11  1261  1273    25
  -9  3162  3158    15
  -8   413   283    57
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  -4  2143  2159    15
  -3   847   895    27
  -2   562   654    38
   0   352   295    60
   1  2730  2812    15
   2  3476  3577    14
   3  3881  3951    14
   4   842   817    32
   5  2295  2328    18
   6  1132  1159    28
   8  1243  1276    29
  10  1263  1277    31
  11  1095  1114    36
        6,   5,  L
 -16  1051  1024    32
 -15   515   594    61
 -13   391   226    73
 -11   687   562    42
 -10  1268  1276    25
  -9  1075  1072    27
  -8  1523  1523    21
  -7  2995  2973    15
  -6  1591  1637    20
  -5  1017   927    26
  -3  1732  1761    18
  -2   788   796    31
  -1  3096  3205    15
   0  2784  2866    15
   1   574   656    45
   2   885   900    31
   3  1143  1155    26
   4  1196  1207    26
   6  2036  2066    21
   8  1009  1036    36
   9   492   419    70
  10   722   734    54
        6,   6,  L
 -16   430    88    75
 -15  1294  1331    30
 -14  1015   986    34
 -13  1813  1797    23
 -12   698   728    46
 -10   421    83    71
  -9  1213  1206    27
  -8   983   952    31
  -7  2038  2013    19
  -6   993  1010    30
  -3  1649  1675    21
  -1  1933  1919    19
   0   692   631    40
   1   711   708    40
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   L   KFO    FC   SIG
   5   971   969    37
   9  2087  2102    25
        6,   7,  L
 -15   685   746    55
 -13  1333  1356    30
 -10   541   613    62
  -9   722   694    45
  -7  2553  2605    19
  -6  2672  2668    18
  -5  2756  2795    18
  -4   412   379    71
  -2  1954  1920    20
  -1   848   849    37
   0  1610  1582    23
   2  1682  1689    24
   4   631   677    55
   5   991  1029    39
   7  1266  1260    34
   8   864   913    50
   9   802   723    54
        6,   8,  L
 -15   974   961    42
 -13  1018  1057    39
 -12   593   703    62
 -10   952  1001    39
  -9  1236  1265    32
  -8  1287  1332    31
  -5  1581  1572    26
  -4   427   545    80
  -2  1667  1718    25
   0  1376  1388    28
   1   534   515    65
   2   853   884    44
   3   954  1004    41
   4   731   673    53
   5  1676  1678    30
   6  2041  2084    27
   7  1350  1353    35
        6,   9,  L
 -14   854   905    50
 -11  1294  1326    34
  -9   462   180    79
  -8  1378  1441    31
  -6   642   650    58
  -5   600   504    61
  -3   467   571    80
  -2  1437  1511    31
  -1  1311  1372    33
   0   974   969    41
   1  2721  2864    23
   2  1122  1060    38
   3  1561  1611    31
   4   914   930    48
        6,  10,  L
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COLUMNS ARE 10FO,10FC, 10SIG

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 -12   746   809    60
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 -10  1947  2004    28
  -9  1657  1706    30
  -5  1347  1372    35
  -4  2456  2513    24
  -3  1964  1963    27
  -2  1573  1565    31
  -1   705   784    61
   0   499   767    88
   3   949   859    49
   4  1435  1521    37
        6,  11,  L
 -11  1083  1015    46
  -6  1248  1257    40
  -3  1059  1164    46
  -2  1206  1216    41
  -1   487   381    91
   0   823   810    55
        6,  12,  L
  -7   892   997    57
  -3   563   655    84
        7,   0,  L
   0  1349  1293    16
   1  3883  3841    11
   3  4322  4316    12
   5   738   703    29
   6  1145  1154    22
   8   358   359    67
   9  2145  2072    18
  10   668   621    43
  11   753   814    41
  12  1148  1170    30
  13  1597  1588    25
        7,   1,  L
 -13  1721  1801    21
 -12   668   750    41
 -11   423   606    60
 -10  1019  1097    27
  -9  4015  4034    13
  -8  1053  1069    24
  -7  1299  1240    19
  -6   736   717    28
  -5   688   614    29
  -3  5116  5108    12
  -2  2990  2984    12
  -1  4036  3974    12
   0  1127  1140    19
   2   811   814    25
   3   803   818    26
   4  2367  2412    15
   5   728   687    31
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   L   KFO    FC   SIG
   6  1632  1646    19
   7  1300  1270    23
   9   392   318    71
  11   786   751    40
  12   675   606    48
  13  2057  2022    23
        7,   2,  L
 -15   983   962    32
 -14   751   714    38
 -13  1302  1347    24
 -11  2280  2374    17
 -10   459   364    54
  -9  1301  1344    21
  -7  1467  1531    19
  -6   752   745    29
  -5  1927  1863    15
  -4  2293  2181    14
  -3  1237  1182    19
  -1  1823  1840    15
   1   928   975    23
   2  2065  2092    15
   4  1547  1579    18
   6  1810  1888    19
   7  1592  1597    21
   9  1865  1877    21
  10   599   709    54
  11  1149  1161    32
  12   887   906    41
  13   876   828    43
        7,   3,  L
 -15   611   565    47
 -13   414   397    64
 -12   560   478    48
 -11  1477  1482    22
 -10   571   487    45
  -9  1354  1302    21
  -8   347   446    68
  -7  2832  2753    14
  -6   510   494    44
  -5   677   653    33
  -4  1464  1424    18
  -3   842   848    26
  -2  1085  1062    22
  -1  1171  1152    21
   0   615   623    35
   2   688   670    34
   3  1277  1329    22
   4  1280  1308    22
   5  3421  3408    16
   6   379   289    73
   9  1777  1820    23
  12   457   543    78
        7,   4,  L
 -11  2557  2552    17
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   L   KFO    FC   SIG
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  -9  1407  1421    22
  -8   418   495    60
  -7  2836  2864    15
  -6  1170  1189    23
  -5  1092  1067    24
  -4  1893  1929    17
  -3   474   399    48
  -2  1634  1706    18
  -1   574   579    41
   0  1597  1644    19
   1  1214  1238    23
   3   589   614    44
   4  1842  1859    20
   5  2857  2915    17
   7  2431  2453    19
   8   968   992    36
        7,   5,  L
 -16   407   387    79
 -14   557   498    55
 -11   584   642    51
  -9  1182  1198    27
  -7   777   757    35
  -6  1209  1254    25
  -5  1090  1024    26
  -4  1225  1239    24
  -3   692   713    38
  -2  1416  1421    22
  -1  2634  2645    16
   0   720   736    38
   1  3501  3525    16
   2  1981  1976    19
   3  1270  1291    26
   4   418   536    73
   5   949   975    35
   7   955   951    36
   8  1378  1450    29
  10   847   863    46
        7,   6,  L
 -15  1510  1512    27
 -13   857   919    41
 -12  1392  1370    27
 -11  1614  1738    24
  -9   628   606    48
  -7  1167  1171    29
  -6  1721  1696    21
  -5  2832  2817    17
  -4  1061  1030    29
  -3  3115  3108    17
  -1   495   507    57
   0  1072  1080    29
   1  1208  1268    27
   2  1227  1277    29
   3   863   886    38
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         COLUMNS ARE 10FO,10FC,  10SIG                                                           COLUMNS ARE 10FO,10FC,  10SIG

   L   KFO    FC   SIG      L   KFO    FC   SIG      L   KFO    FC   SIG        L   KFO    FC   SIG      L   KFO    FC   SIG      L   KFO    FC   SIG
      7,  6,  L            -1  1714  1744    31     -2  1540  1487    18           8,  5,  L            -6   682   736    51      7  1121  1147    28
   4   649   625    49      0   770   734    55     -1   580   540    37      -14   678   627    49     -5   657   669    52      8   646   627    46
   5  1043  1095    35      1  1843  1849    29      1   341   287    63      -12   616   583    49     -3   806   829    43     11   437   663    78
   6   978  1028    38      2   520   606    86      3  1329  1312    21       -9  1366  1430    25     -2  1280  1301    30     12   795   758    46
   7  1257  1221    32         7, 11,  L             4  2214  2211    17       -7  1458  1432    23      0  1039  1135    36         9,  2,  L       
      7,  7,  L            -9   521   678    87      5   384   461    66       -6   746   780    39      3  1701  1773    28    -14   817   793    39
 -15  2055  2075    25     -7  1250  1241    39      6  1287  1242    24       -4  1083  1090    28      5  1815  1801    28    -13  1227  1214    28
 -14   922   922    41     -5  1677  1758    32      7   389   257    72       -3  2050  2067    19         8,  9,  L           -12   567   580    50
 -13  1391  1388    29     -4  1315  1410    39      8   543   456    54       -2  1038   974    28    -11  1134  1102    38    -11   999   953    30
  -9  1769  1767    23     -2   517   492    83      9  1163  1217    30       -1  1958  2004    19     -9   673   633    56    -10   559   568    49
  -8  2006  2077    22         8,  0,  L            11  1224  1284    31        0  1478  1418    23     -8  1410  1494    31     -8   696   702    40
  -7  1753  1777    23      0   970   948    23         8,  3,  L               1   986  1030    32     -7   902   879    42     -7  1142  1149    26
  -6  1259  1236    28      1  2220  2187    14    -15  1549  1520    25        3   882   907    36     -5  1355  1463    32     -6   702   601    37
  -5   798   912    42      2   605   588    34    -11  1358  1407    24        6  1115  1054    32     -2   704   666    53     -5   589   626    43
  -4  1248  1287    28      3  1857  1884    16    -10   904   900    32        7   690   703    50     -1   867   868    46     -4  1866  1903    18
  -3  1263  1249    28      4  1478  1472    19     -9  2744  2756    16        9   600   557    60      1  2842  2955    24     -3  1869  1890    18
  -2  1446  1462    26      5  3121  3110    14     -7   864   855    30           8,  6,  L             2   470   113    85     -2  1116  1124    24
   0  2265  2391    21      6  1091  1080    24     -6   565   589    44      -14   546   563    64      3  1325  1305    36     -1   759   755    33
   1   910   854    38      7   537   498    46     -5  1255  1259    22      -13  1969  2005    23         8, 10,  L             1  1327  1329    22
   3   810   826    43      8   363   337    73     -4  2134  2129    16      -12   561   590    59     -9  1179  1187    39      2   705   675    36
   5   436   205    80     11  2036  2011    21     -3   618   589    38      -10   980  1120    35     -7   791   736    52      3   565   580    46
   6   672   622    56     13   425   265    75     -2  1756  1726    18       -8   581   667    53     -6   683   718    60      6   709   669    41
   7  1607  1617    29         8,  1,  L            -1  1732  1677    18       -6   411   284    71     -5   927   928    46      7  1226  1252    28
      7,  8,  L           -13   418   376    65      1  1620  1602    19       -5   738   683    42     -4   795   798    52      8   807   819    39
 -10   794   872    45    -11  2496  2574    17      2   993   953    27       -4   524   592    58     -3  1042  1093    42      9   912   917    37
  -9   699   734    50     -8  1107  1090    25      3   843   775    32       -3  1469  1487    25     -2   536   610    79     10   946   890    37
  -7  1259  1352    31     -7  1702  1671    18      5  1613  1676    22       -2   589   611    52     -1   784   773    55         9,  3,  L       
  -6   546   485    61     -6  1024   968    24      6   554   618    54       -1  3061  3136    18         9,  0,  L           -13   627   552    49
  -5   573   568    57     -5   529   520    42      7  3871  4012    17        0   880   857    36      1  3034  2992    14    -12   790   820    38
  -4  1156  1176    32     -4  2093  1987    15      9  1132  1150    32        3  1068  1122    33      2  1681  1562    18    -11   696   646    41
  -3   987  1014    37     -1  3193  3144    13     10   875   840    39        5  1255  1307    32      3  4013  3913    14     -8   478   392    57
  -2  1178  1194    32      0  1101  1113    21         8,  4,  L               7   659   652    55      4  1163  1113    24     -7  1928  1957    20
   0   595   702    58      1  3154  3116    14    -15   448   423    69           8,  7,  L             6   499   492    52     -6   975   967    30
   1  1505  1586    28      2  1823  1826    16    -14   392    34    71      -14   502   462    71      7   643   668    42     -5  1312  1347    24
   3  1782  1833    27      3  1427  1469    19    -13  1117  1159    30      -13  1399  1436    30      9  2036  2069    21     -4   930   892    30
   4   930   948    44      4   959   954    26    -12  1190  1237    28      -12   871   838    41     10   669   722    47     -3  1393  1324    22
      7,  9,  L             5   347   450    69    -11   835   879    37      -11   618   609    55     11  1019   998    34     -2  1135  1104    25
 -13  1586  1635    31      6  1127  1127    25     -9  1750  1812    21      -10   797   751    42     12   639   679    53     -1  1401  1429    22
 -10   962   965    42      7   599   567    44     -8   558   556    49       -8   574   631    58         9,  1,  L             0   750   778    36
  -9  1126  1189    36      8   775   801    37     -7   518   525    52       -7  1690  1740    24    -13   855   943    38      1  1318  1289    23
  -7  1055  1021    36      9  1328  1339    26     -6  1496  1538    21       -6  1139  1232    31    -11   740   764    37      2   525   584    51
  -6   647   712    58     10   661   656    46     -5  1933  1888    18       -5  1745  1788    24     -9  2343  2335    17      3   364   146    70
  -1  1420  1515    32     11   710   751    46     -4  1706  1657    19       -2   956  1014    37     -8   366   484    71      4  1032  1071    30
   3  2256  2365    26     12   416   436    78     -3  1593  1586    20        0  1077  1101    33     -7   990   979    28      5  2289  2344    19
   5   883   920    51     13  1074  1063    36     -2  1168  1093    24        1   409   457    81     -6  1484  1476    21      9  2151  2188    23
      7, 10,  L                8,  2,  L            -1  1131  1038    25        2  1371  1461    28     -5   623   629    39         9,  4,  L       
 -12   990   976    46    -15   402   256    71      0   894   894    30        4   431   548    83     -4  1456  1450    20    -12   768   681    41
 -11  1348  1341    35    -11   869   937    32      1  1562  1588    21        7   570   638    70     -3  2287  2279    16    -11  1555  1537    23
 -10   778   762    55    -10   572   518    46      2  1084  1097    27           8,  8,  L            -2   858   930    30    -10   928   954    34
  -9   485   435    81     -9  1353  1352    22      3  2627  2687    18      -13   938   953    43     -1  2118  2064    16     -9   680   692    43
  -8  1457  1509    33     -7   998   902    25      5  2168  2199    20      -11  1057  1096    38      0   486   487    47     -8   371   330    73
  -6   661   657    59     -6   983   955    26      6   492   462    61       -9  1046  1023    36      3   643   562    38     -7   986  1064    31
  -3  1014  1037    42     -5  3041  3033    14     10   865   900    44       -8  1110  1128    34      4  1633  1582    20     -6   384   273    71
  -2  1346  1365    34     -3  3062  2963    14         8,  5,  L              -7   440   737    80      6   837   907    34     -5   541   490    50
```

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COLUMNS ARE 10FO,10FC,  10SIG

   L   KFO    FC    SIG      L   KFO    FC    SIG      L   KFO    FC    SIG
        9,    4,  L          2   439    26     73     -4  1168  1143     26
  -4  1499  1484     22      3   796   831     46     -3  1412  1490     23
  -2  1662  1678     21           9,    8,  L         -2   497   576     54
  -1   540   521     52    -10   972   911     40     -1   958   982     30
   1   570   609     50     -9  1326  1323     31      0   877   852     32
   2   495   428     57     -8   784   878     48      1   878   908     32
   3   491   466     59     -7   971   929     38      2   613   671     45
   5  1850  1964     23     -5  1225  1294     32      3  1585  1595     22
   6   582   564     55     -3   608   503     55      4   729   689     39
   7  1982  2050     23      1  1045  1071     38      6   593   576     50
   8   543   550     63      3  1071  1134     41      8   488   462     65
        9,    5,  L              9,    9,  L          9  1116  1068     33
 -12  1272  1209     29     -9   741   688     53         10,    3,  L
 -11   820   884     41     -7  1162  1238     38    -12   580   653     56
 -10  1100  1171     31     -6  1128  1150     38    -11   571   496     53
  -7  1546  1584     23     -3   693   698     55    -10   623   560     48
  -6   412   523     71     -1  1054   965     40     -9  1427  1387     24
  -5   614   593     47      0   496   207     76     -7  1410  1379     24
  -4   981   966     32         10,    0,  L         -5   607   612     46
  -3   482   425     60      0   810   814     32     -4  1439  1516     24
  -2   968   958     33      1  1435  1443     22     -3   873   847     33
  -1  2745  2817     18      3  1464  1488     22     -2  1202  1243     26
   0   903   875     35      4  1122  1166     27     -1  1914  1914     20
   1  2309  2405     20      5  2418  2446     18      1  1880  1936     20
   5   823   827     42      6   958   952     31      3   643   710     46
   6   514   554     66      7   393   471     73      4   697   712     42
   7  1081  1041     35      8   896   886     34      5   484   611     62
   8   583   526     62      9   647   590     48      6   739   690     44
        9,    6,  L         11  1577  1582     26      7  2720  2729     20
 -13   769   790     48         10,    1,  L          8   716   679     49
 -12 .1090  1099     35    -12   904   884     36      9   586   655     61
 -11  1730  1736     24    -11  1030  1005     31         10,    4,  L
 -10   664   583     49     -8   588   636     46    -12  1184  1111     31
  -9  1147  1152     31     -7  1129  1169     27    -10  1220  1202     29
  -8   547   543     57     -6   902   963     32     -9   846   838     37
  -5  1376  1472     27     -5   590   612     46     -5   764   827     40
  -3  2728  2770     19     -4  1227  1274     25     -3   898   966     35
   1  1592  1673     25     -3   854   850     32     -2   724   789     42
   2  1119  1165     32     -2   998  1017     28     -1  1056  1036     30
   3  1046  1055     34     -1  1319  1337     23      0  1170  1154     28
   4  1106  1110     34      0   465   496     55      2   940   972     34
   5  1295  1309     31      1  1624  1657     20      3   911   896     35
   6   445   548     80      2  1030   992     28      5  1151  1122     31
   7   641   729     60      3  1272  1304     25      7   448   635     79
        9,    7,  L          9  1594  1556     25         10,    5,  L
 -10   629   631     55     10  1437  1377     28    -12   787   775     45
  -9  1032  1025     35         10,    2,  L        -11   418   121     78
  -8   880   919     40    -12  1010   952     33    -10   713   724     47
  -7   637   669     53    -11  1346  1343     27     -9  1689  1671     24
  -6  1033  1112     35     -9   618   622     46     -8   871   866     37
  -3   491   565     66     -8   393   388     69     -5   636   658     48
  -2   718   710     46     -7   486   503     57     -4   731   771     42
   0  1193  1194     30     -6  1505  1516     23     -3  1161  1261     29
   1   912   959     39     -5  2677  2620     17     -2  1013   980     32
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COLUMNS ARE 10FO,10FC,  10SIG

   L   KFO    FC    SIG      L   KFO    FC    SIG      L   KFO    FC    SIG
       10,    5,  L          2   917   944     32     -4   519   494     63
  -1  1011  1019     33      4   621   612     46     -3  1954  1983     24
   1  1506  1529     25      7  1040   992     33      1  1210  1212     33
   2   492   474     63      8   891   895     39      2   631   629     58
   3   846   850     40         11,    2,  L             11,    7,  L
   4   997   964     36    -10   410   559     77     -6   811   787     47
   5   459   315     71     -9   491   543     62     -5   415   215     80
       10,    6,  L         -7  1169  1081     28     -4   849   863     43
 -11   426   439     81     -6   407   412     69     -2   600   631     61
 -10   963   963     38     -5   731   605     40         12,    0,  L
  -9   653   619     52     -4  1375  1368     25      1  1190  1112     27
  -8   608   541     55     -3  1907  1860     21      2   914   849     34
  -7   768   747     43     -2  1375  1392     25      3   581   650     53
  -4   397   251     78      0   760   768     38      4  1071  1062     31
  -3   645   657     51      1  1332  1353     25      5  1565  1537     25
  -2   695   736     47      5   965   925     34      6   949   860     34
  -1  2556  2611     20      6   392    53     74         12,    1,  L
   0   684   700     48      8   854   808     42     -4   643   649     48
   2   627   506     52         11,    3,  L         -3   864   821     36
   3  1034  1069     37    -10   736   694     44     -2  1170  1158     29
   5   928   918     41     -7   946   951     34     -1   637   600     47
       10,    7,  L         -6  1083   998     30      0  1823  1767     22
 -10   680   630     53     -5  1840  1775     22      1   727   760     43
  -9   901   812     41     -3   487   488     59      2   626   643     48
  -8   892   936     42     -2  1007   887     30      3   639   647     48
  -7  1297  1275     31     -1   982  1014     32      4   696   681     45
  -5  1043  1051     36      0   982   996     33      6   403   237     77
  -3   572   573     60      1  1650  1598     23         12,    2,  L
  -2   418   130     78      2   890   822     35     -7   422   155     71
   0   846   854     43      3  1072  1047     31     -6  1020   960     34
   2   776   798     48      4   661   624     48     -5  2176  2084     20
   3   776   786     49      5  1028  1038     34     -4  1046   949     31
       10,    8,  L             11,    4,  L         -3  1124  1071     30
  -8   766   845     51    -10   520   460     63     -1   818   859     39
  -7  1017   981     39     -8   664   693     48      0   898   924     37
  -6   953   974     41     -6   616   661     51      1   782   756     41
  -4   449   642     83     -4   706   732     45      2  1030  1088     34
  -3  1519  1534     30     -2   393   340     75      3  1520  1517     26
  -2   642   629     58     -1   813   862     40      5   694   631     48
       11,    0,  L          1   708   733     45         12,    3,  L
   0   995  1008     29      2   409   336     73     -7  1375  1282     27
   1  .951   977     31      4  1341  1404     29     -6   529   475     60
   2  1222  1222     25      5  1314  1272     30     -4  1144  1075     31
   3  2322  2315     18         11,    5,  L         -3   757   664     42
   4   618   573     46     -7  1989  2016     23     -1  1354  1384     27
   7   888   915     36     -6   566   466     55      1  1323  1349     29
   9  1308  1276     29     -2   822   809     41      3   671   619     50
       11,    1,  L         -1  1899  1918     23      4  1106  1108     34
  -9  1023   993     32      0   804   850     43         12,    4,  L
  -7   529   437     53      1  1733  1754     25     -7   748   634     45
  -6  1064  1028 [illegible]      2   977   940     36     -4   954   907     36
  -5   664   622 [illegible]         11,    6,  L         -2   479   544     66
  -4  1216  1197     26     -8   750   713     48      2  1390  1408     30
  -3   592   621     47     -7   416    35     75         12,    5,  L
```

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    COLUMNS ARE 10FO,10FC,  10SIG

  L   KFO     FC   SIG       L   KFO    FC   SIG       L   KFO    FC   SIG
      12,   5,  L            2  1176  1047    29           13,   2,  L
 -5  1156  1192     34       3  1211  1134    30      -3  1136  1085    31
 -1   736   690     49          13,    1,  L          -2  1021  1024    35
      13,   0,  L           -2   901   904    38       0   977   980    35
  0  1196  1137     30       2  1730  1656    24
```

Table S.18. Fractional Coordinates for $Os_4(CO)_{14}PMe_3$

ATOM	X	Y	Z
OS(1)	0.30601(5)	0.46157(6)	0.31561(5)
OS(2)	0.24561(6)	0.64841(6)	0.23286(5)
OS(3)	0.20186(5)	0.45139(7)	0.12628(5)
OS(4)	0.28547(6)	0.26800(6)	0.23360(6)
P(1)	0.2911(4)	0.7534(4)	0.3594(4)
C(1)	0.217(2)	0.738(2)	0.448(2)
C(2)	0.416(2)	0.740(2)	0.420(1)
C(3)	0.285(2)	0.889(2)	0.334(2)
C(11)	0.437(2)	0.475(2)	0.282(1)
C(12)	0.188(1)	0.459(2)	0.368(1)
C(13)	0.368(2)	0.465(2)	0.437(1)
C(21)	0.380(2)	0.661(2)	0.202(1)
C(22)	0.114(2)	0.630(2)	0.264(1)
C(23)	0.196(2)	0.755(2)	0.150(2)
C(31)	0.083(2)	0.432(2)	0.181(1)
C(32)	0.334(2)	0.480(2)	0.085(1)
C(33)	0.141(2)	0.557(2)	0.050(1)
C(34)	0.167(2)	0.342(2)	0.044(2)
C(41)	0.405(2)	0.293(2)	0.176(2)
C(42)	0.172(2)	0.256(2)	0.297(1)
C(43)	0.362(2)	0.201(2)	0.328(2)
C(44)	0.248(2)	0.147(2)	0.161(2)
O(11)	0.519(1)	0.482(1)	0.277(1)
O(12)	0.123(1)	0.458(1)	0.411(1)
O(13)	0.402(1)	0.463(2)	0.514(1)
O(21)	0.460(1)	0.676(1)	0.189(1)
O(22)	0.035(1)	0.629(1)	0.279(1)
O(23)	0.169(1)	0.823(2)	0.102(1)
O(31)	0.009(1)	0.420(1)	0.207(1)
O(32)	0.403(1)	0.496(1)	0.058(1)
O(33)	0.093(1)	0.612(2)	0.001(1)
O(34)	0.142(1)	0.278(2)	-0.011(1)
O(41)	0.474(1)	0.300(1)	0.142(1)
O(42)	0.104(1)	0.243(1)	0.333(1)
O(43)	0.408(1)	0.155(1)	0.391(1)
O(44)	0.224(2)	0.076(2)	0.121(2)
H(11)	0.229(0)	0.793(0)	0.493(0)
H(12)	0.145(0)	0.742(0)	0.424(0)
H(13)	0.228(0)	0.674(0)	0.479(0)
H(21)	0.431(0)	0.798(0)	0.463(0)
H(22)	0.464(0)	0.743(0)	0.379(0)
H(23)	0.424(0)	0.679(0)	0.454(0)
H(31)	0.304(0)	0.933(0)	0.387(0)
H(32)	0.327(0)	0.910(0)	0.290(0)
H(33)	0.217(0)	0.913(0)	0.307(0)

Table S.19. Thermal Parameters for $Os_4(CO)_{14}PMe_3$

ATOM	U11	U22	U33	U12	U13	U23
OS(1)	3.41(4)	3.34(5)	2.81(4)	-0.21(3)	0.10(3)	-0.06(4)
OS(2)	3.54(4)	3.78(5)	3.38(5)	0.44(3)	0.93(3)	0.53(4)
OS(3)	3.54(4)	5.43(6)	2.53(4)	-0.11(4)	0.23(3)	-0.27(4)
OS(4)	4.06(5)	3.79(5)	4.27(5)	-0.06(4)	0.83(3)	-0.89(4)
P(1)	4.7(3)	4.1(3)	4.7(3)	-0.2(3)	1.0(2)	-0.2(3)
C(1)	11.9(23)	8.8(21)	6.3(17)	-2.8(17)	4.8(16)	-3.1(16)
C(2)	6.4(14)	5.8(15)	4.3(12)	-0.9(11)	1.1(10)	-0.2(12)
C(3)	10.8(21)	5.2(17)	6.1(16)	0.1(14)	1.7(15)	-0.7(13)
C(11)	6.3(15)	3.6(13)	4.3(12)	0.2(11)	2.5(11)	1.3(10)
C(12)	4.2(11)	4.3(13)	3.5(11)	-0.3(10)	0.4(9)	1.1(10)
C(13)	6.7(14)	6.0(15)	2.8(12)	-2.8(12)	0.4(10)	0.9(11)
C(21)	6.9(16)	4.6(14)	3.0(11)	-0.7(11)	3.0(10)	1.5(10)
C(22)	5.0(14)	3.7(12)	4.2(12)	1.5(10)	1.4(10)	1.1(10)
C(23)	4.7(13)	6.5(16)	6.2(15)	1.2(11)	1.8(11)	1.6(14)
C(31)	3.9(12)	5.4(15)	4.3(12)	0.2(10)	0.4(10)	-2.2(11)
C(32)	6.2(15)	6.3(16)	2.5(11)	1.2(12)	0.8(11)	-0.2(11)
C(33)	5.4(14)	9.7(21)	4.4(13)	2.4(14)	1.6(11)	3.7(15)
C(34)	5.5(15)	12.1(24)	4.2(13)	-1.1(15)	0.7(11)	-4.0(16)
C(41)	6.2(15)	4.3(14)	5.5(14)	1.5(12)	-0.7(12)	-0.2(12)
C(42)	5.3(14)	8.2(19)	3.0(12)	1.5(13)	-1.7(10)	-1.3(12)
C(43)	4.6(13)	6.8(17)	5.8(15)	0.4(12)	2.0(11)	-1.7(13)
C(44)	5.8(15)	5.9(17)	9.4(20)	-1.8(12)	2.7(14)	-3.2(16)
O(11)	5.1(10)	8.6(13)	6.9(11)	-0.9(9)	1.6(8)	-0.1(9)
O(12)	5.9(10)	6.8(12)	6.5(10)	-0.3(8)	1.4(9)	-0.8(9)
O(13)	8.6(12)	13.8(18)	3.1(9)	-3.2(11)	-0.4(8)	2.9(11)
O(21)	5.7(9)	6.7(11)	7.7(11)	-1.3(8)	4.4(9)	0.6(9)
O(22)	4.3(9)	6.9(12)	12.0(15)	1.2(8)	4.2(10)	-0.3(10)
O(23)	9.6(14)	9.7(15)	7.6(13)	2.6(12)	0.3(10)	4.4(12)
O(31)	4.6(9)	6.9(11)	5.3(9)	-0.9(8)	1.1(7)	-1.2(8)
O(32)	5.1(9)	8.5(12)	5.1(10)	0.0(8)	3.1(8)	0.6(8)
O(33)	7.0(11)	11.5(16)	6.4(11)	2.4(11)	-1.8(9)	3.8(11)
O(34)	9.0(13)	11.4(16)	6.6(12)	-2.6(12)	1.7(10)	-3.4(12)
O(41)	6.5(11)	8.5(13)	6.7(11)	0.6(9)	3.7(9)	1.5(10)
O(42)	4.6(9)	6.4(11)	8.7(12)	0.5(8)	2.1(9)	0.0(10)
O(43)	7.8(12)	10.7(16)	7.8(12)	3.9(11)	2.6(10)	3.1(12)
O(44)	18.0(22)	7.6(14)	13.0(19)	-4.2(15)	3.4(16)	-8.1(15)

TEMP=-2(PI)**2(U11*H*H*ASTAR*ASTAR+---+2*U12*H*K*ASTAR*BSTAR+---)

THE UIJ VALUES HAVE BEEN MULTIPLIED BY 100.

Table S.20. Structure Factors for $Os_4(CO)_{14}PMe_3$

```
   COLUMNS ARE 10FO,10FC,  10SIG

   H   KFO    FC   SIG         H   KFO    FC   SIG         H   KFO    FC   SIG
     H  0,  0                 11   728   758    34         0  4090  4288    17
   4  3986  4388     8        12  1999  2094    20         1  2124  2108    20
   6  1074  1094    14             H  5,  0                2  3658  3633    17
   8  1302  1464    16         1  1808  1857    15         3  1321  1291    25
  10  2352  2543    16         3   917   891    17         4  2003  1884    19
  12  1297  1388    24         4  1077  1150    18         6   521   522    47
     H  1,  0                  5  1484  1448    18         7   654   661    41
   2  1022  1068     9         6   755   745    28         9  1038   996    33
   4  1468  1569    10         7  1264  1246    21        10   793   715    43
   6  1702  1856    12         9   738   776    32             H 11,  0
   7   313   286    40             H  6,  0                2   582   603    49
   8  1429  1529    15         0   530   522    34         3   682   632    43
   9   714   789    27         1  6328  6916    13         5   781   761    35
  10  1039  1088    23         2   647   645    29         7   600   567    45
  11   676   710    35         3  3540  3553    12             H 12,  0
  12   561   583    42         5  1220  1262    19         0  1130  1118    29
  13   395   451    61         6   873   918    28         2   795   774    37
     H  2,  0                  7   830   824    29         6   791   738    37
   0   502   445    20         8  1509  1451    20         7   818   760    37
   1   649   629    15         9  1930  1865    20             H  0,  1
   2   297   307    37        10  1787  1714    20       -14   913   836    35
   4  1262  1251    12        11  1648  1554    22       -12   443   453    58
   5  2336  2500    10        12  1381  1345    26       -10   332    68    58
   6  2262  2340    11             H  7,  0               -8  1163  1130    17
   7  3000  3297    12         3   348   314    48        -6  1870  1872    11
   8  2113  2330    14         5   507   524    37        -4  2761  2777     9
   9  2919  3212    14         6   699   726    32        -2  2819  2769     7
  10  1673  1773    18         7   930   888    29         2   443   415    17
  11  2067  2274    18         8   793   844    35         4  1014  1084    13
  12   430   482    54         9   733   692    39         6  1853  1950    12
  13  1277  1372    24        10  1048  1017    32         8  1172  1248    18
     H  3,  0                 11   721   622    42             H  1,  1
   1   747   725    20        12   634   568    48       -14  1611  1532    25
   2   287   281    39             H  8,  0              -13   851   830    36
   3   398   354    34         2   379   430    55       -12  1909  1855    20
   4  2088  2043    12         3  1167  1141    21       -11  1568  1513    20
   5   419   395    32         4   749   728    29       -10  2564  2548    15
   6  2157  2237    13         5  2229  2218    16        -9  1140  1122    19
   8  1498  1573    17         6  1381  1258    19        -8  2136  2201    14
  10  1193  1219    22         7  2455  2417    18        -7   431   473    32
  11   341   402    65         8  1157  1132    29        -6  1279  1343    13
  12   435   466    54         9  2257  2239    20        -5  3109  3244    10
     H  4,  0                 10   764   699    39        -3  4715  4978     8
   0  3581  3597    11        11  1306  1221    28        -2   884   877    12
   1  4678  4697    12             H  9,  0                0  1771  1694     7
   2  1961  1973    11         2   827   860    30         1  5634  5557     6
   3  1997  2062    11         3   904   856    28         2   744   617    15
   4   514   513    32         4  1239  1200    23         3  1067   990    12
   5   725   660    25         5  1185  1123    23         4  1019   976    13
   6  1962  1957    15         6  1269  1245    23         5   992  1008    14
   7   766   752    25         7  1290  1293    24         6  1471  1512    13
   8  2845  2912    15         8   720   734    41         7  2187  2401    13
   9  1351  1373    20         9  1122  1037    31         8  1757  1868    15
  10  2768  2944    16             H 10,  0                9  1754  1925    17
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   COLUMNS ARE 10FO,10FC,  10SIG

   H   KFO    FC   SIG         H   KFO    FC   SIG         H   KFO    FC   SIG
     H  1,  1                -13   781   749    40        -8   718   735    32
  10  2042  2197    17       -11  1049  1036    27        -7   800   805    27
  11   604   633    38       -10   903   881    28        -6   907   891    23
  12  1315  1468    24        -9  1470  1532    19        -5  1647  1676    16
  13   371   547    69        -8  1551  1611    17        -4  1102  1150    19
  14   964   981    33        -7  1128  1142    18        -3  1628  1666    16
     H  2,  1                 -6  2296  2402    13        -1  1354  1226    20
 -14   523   479    58        -4  2122  2168    12         1   422   309    45
 -12  1045  1025    28        -3   999   998    16         4   970   982    19
 -10  2176  2136    16        -2  1406  1404    14         5   716   709    27
  -8  1951  1973    14        -1   369   346    47         6  1168  1223    22
  -6  1436  1493    13         0   782   781    27         7   714   668    33
  -5   714   693    18         1   270   271    50         8  1193  1217    22
  -4   466   483    24         2  1862  1866    11         9   366   264    69
  -3   607   629    19         3   995   991    16        10  1232  1117    26
  -2   333   331    32         4  2179  2211    13        11   377   157    72
   0   498   480    23         5  1264  1246    19        12   881   840    36
   2  1432  1324    11         6  2683  2625    15             H  7,  1
   3   546   523    26         7   887   867    26       -12  1080  1027    33
   4  1191  1145    14         8  1823  1737    18       -11  1860  1829    23
   5  1109  1088    15         9   953   956    26       -10  1392  1421    25
   6  2161  2198    12        10   997   982    26        -9  1811  1846    20
   7  1234  1252    16        11   423   429    56        -8   915   913    29
   8  1300  1343    18        12   554   543    46        -7  1304  1376    21
   9   755   797    28             H  5,  1               -5   641   670    32
  10  1136  1188    23       -13   707   657    45        -4  1080  1088    22
  11   693   708    34       -12  1220  1195    28        -2  2000  1996    16
  12   406   507    58       -11   747   751    36        -1   558   549    39
  13   416   440    60       -10  1210  1274    24         0  1550  1570    19
     H  3,  1                 -9   993   968    24         2   517   548    37
 -13  1540  1495    25        -7   496   432    36         3   727   716    26
 -12   899   898    32        -6  2255  2332    14         4  1776  1808    16
 -11  1903  1880    19        -5   696   697    24         5  1101  1151    21
 -10  1346  1300    21        -4  4905  5279    12         6  2763  2867    16
  -9  2654  2713    15        -3  1436  1452    15         7  1908  1874    19
  -8   868   875    23        -2  6215  6699    12         8  2598  2731    18
  -7  1675  1710    15        -1  1777  1703    16         9  1840  1865    20
  -5  1221  1273    14         0  7855  8454    13        10  1334  1328    25
  -4   811   827    17         1  2395  2352    13        11  1421  1343    25
  -2  1074  1082    15         2  4773  4913    11             H  8,  1
  -1   906   849    20         3   997   975    17       -11   642   617    49
   0   421   340    40         4  1598  1704    15       -10   722   754    42
   1  1031  1036    14         6   618   642    35        -9   887   885    33
   2  1819  1783    10         7   486   486    43        -8  1267  1296    25
   3  2318  2282    11         8  1337  1323    23        -7   663   666    39
   4  2731  2601    12         9   845   809    31        -6  1101  1147    25
   5  4709  4488    12        10   953   990    30        -4   794   781    30
   6  3994  3898    12        11   578   582    46         0   674   675    33
   7  3786  3748    13             H  6,  1                1   432   415    49
   8  2959  3016    14       -13   669   629    50         2   727   772    32
   9  3182  3166    15       -12   387   402    75         4  1349  1342    19
  10  1289  1336    22       -11   602   631    47         6   783   831    32
  11  1386  1383    21       -10   606   604    43         7   457   412    55
     H  4,  1                 -9   351    64    65         8   646   640    45
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COLUMNS ARE 10FO,10FC,

  H   KFO    FC  SIG      H   KFO    FC  SIG      H   KFO    FC  SIG
     H 8, 1             2   384   261   72      2  4142  3974    9
  9   478   552   58      3  1318  1305   28      3  3084  2824   11
 11   560   503   52      4   553   527   59      4  4158  3983   11
     H 9, 1             5  1736  1624   25      5  3961  3769   12
-10  1679  1752   25         H 0, 2             6  4792  4607   12
 -8  1759  1798   23    -14  1071  1066   31      7  3054  3027   14
 -7   505   534   53    -12  1402  1345   23      8  2438  2437   15
 -6   961   966   30    -10   821   851   27      9  2199  2229   17
 -5  1150  1171   26     -8  1820  1866   15     11   907   895   30
 -3  1604  1612   22     -6  4697  4923   11     12  1165  1138   26
 -2   958   899   28      0  7479  7967    6         H 3, 2
 -1  1546  1505   22      2  3155  2775    8    -13   601   582   51
  0   754   814   34      4   768   748   16    -12   806   857   37
  1   784   780   31      6  1873  1943   12    -11   428   421   57
  4  1070  1074   24      8  1359  1476   17    -10  1218  1207   22
  5  1181  1092   23     12   616   663   42     -9   552   450   37
  6  1940  1793   18         H 1, 2            -8  1246  1275   19
  7  1073  1060   28    -13  1146  1110   28     -6   731   736   23
  8  2021  1919   20    -11   956   941   28     -5   767   839   20
  9   522   484   60     -9   391   368   47     -3   415   379   35
 10  1405  1399   26     -8  1204  1213   18     -2   616   559   30
     H 10, 1            -7  1062  1049   18     -1   775   721   26
 -9   921   937   37     -6  2277  2300   12      1   806   806   17
 -7  1456  1453   25     -5  2396  2389   11      2   738   729   18
 -5  1682  1693   23     -4  3545  3564   10      3   544   310   27
 -4   944   933   34     -3  1952  1785   11      4   364   321   45
 -3  1203  1195   28     -2  2193  2088   11      5  1376  1342   16
 -2   724   673   43     -1  1738  1592    9      6   555   469   34
 -1   637   707   46      0   955   851   10      7   436   396   46
  1  1050  1060   29      1   626   501   15      8   814   841   30
  3  1311  1294   25      2   795   762   17     10   617   628   41
  5  1505  1465   21      3  1096   966   14         H 4, 2
  7  1118  1134   27      4  1268  1190   13    -12  2184  2123   20
  9   582   559   53      5   735   689   19    -10  2420  2432   17
     H 11, 1             6  2213  2196   13     -9  1016  1048   25
 -8   413   347   76      7   378   353   40     -8  1998  2056   17
 -6   465   483   64      8  2087  2132   15     -7  2133  2177   15
 -5  1524  1555   26     10  1743  1769   18     -6   303   307   54
 -4   732   793   44     12  1105  1089   27     -5  3336  3464   13
 -3  2916  3007   20     13   494   391   54     -4  1095  1088   18
 -2   878   890   38         H 2, 2            -3  3289  3329   12
 -1  3572  3665   19    -14   590   536   52     -2  1175  1124   21
  0   985  1015   32    -13  1834  1792   22     -1  3410  3306   13
  1  2912  2906   19    -12   502   580   53      0   697   646   25
  2   727   709   39    -11  1975  1973   19      1   435   486   31
  3  1510  1454   24     -9  2191  2223   16      2   256   215   49
  4   399   388   64     -7   931   965   20      3  1406  1363   15
  7   766   774   37     -6  1039  1040   16      4  1551  1543   15
     H 12, 1            -5   258   272   49      5  2653  2518   14
 -2   380   266   76     -4  1947  1930   12      6  2644  2673   15
  7   693   699   46     -3   366   333   39      7  2230  2144   16
     H 13, 1            -1   634   608   24      8  2576  2449   17
 -2   397   186   73      0  2193  2099    9      9   504   477   49
  1   691   630   43      1  2177  2173    9     10  1702  1737   23
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COLUMNS ARE 10FO,10FC,  10SIG

  H   KFO    FC  SIG      H   KFO    FC  SIG      H   KFO    FC  SIG
     H 4, 2            -1   914   905   27      2  1150  1120   27
 11  1044  1027   29      0   929   957   26      3   680   637   38
 12   967   919   32      2   536   560   36      6   650   646   39
 13  1471  1485   26      3   837   864   25      7   630   659   43
     H 5, 2             4   390   327   47      8   488   504   58
-12   934   860   33      5  1060  1088   22      9   714   687   44
 -9   970  1010   26      7  1716  1667   21         H 11, 2
 -8  1131  1145   23      8   642   592   43     -7  1180  1191   33
 -7  1332  1325   20      9  1430  1455   24     -5  1616  1647   28
 -6  2737  2778   14     10   806   839   36     -3  1712  1707   26
 -5  2007  2013   15     11  1249  1223   28     -2   388   307   77
 -4  3492  3553   13     12   604   610   54     -1   815   828   38
 -3   361   356   52         H 8, 2             0   532   565   53
 -2  2715  2597   15    -11  1001   976   34      2   803   659   35
 -1   896   811   25     -9  1058  1061   29      3   597   599   46
  0  1662  1690   16     -7   559   522   47      5   898   853   32
  1   990  1034   18     -1  1087  1157   26      6   372   318   71
  3  1174  1073   16      0  1247  1259   23      7   581   601   50
  4   841   858   21      1  2737  2674   17      8   697   625   44
  5  1316  1293   19      2  2148  2187   17         H 12, 2
  6  1092  1091   24      3  3265  3349   15     -7   642   675   56
  7   774   781   30      4  2279  2318   16     -5   424   481   81
  8  1022  1069   27      5  3660  3785   15     -4   913   893   40
  9   510   428   49      6  1637  1680   20     -2   824   851   38
     H 6, 2             7  2876  2863   17      2   546   561   54
-13  1054  1012   36      8  1049  1023   30      4  1251  1253   28
-12  1256  1210   28      9  1492  1475   24      5   442   440   66
-11   997  1046   30         H 9, 2             6  1335  1260   27
-10  1323  1354   24    -11   674   706   51         H 13, 2
 -8  1054  1090   25     -9   889   853   36     -1   464   507   65
 -7  1753  1781   19     -8   919   918   34      1   636   641   49
 -6   536   551   40     -7   798   727   38      3   434   300   75
 -5  4050  4085   14     -6  1446  1523   25         H 0, 3
 -4   568   510   36     -4  1178  1216   27    -14  1485  1502   26
 -3  4980  5124   14     -2   602   662   47    -12   354   387   70
 -2   332   188   66      0   682   658   37    -10  1019  1000   24
 -1  4346  4352   15      2  1184  1125   24     -8  3254  3253   14
  1  2888  2859   14      4  1384  1355   21     -6  4894  4980   11
  3   540   508   29      5   680   667   36     -4  6565  6931   11
  4   706   744   26      6  1324  1333   24     -2  3185  2970    9
  5  1101  1105   21      7   622   665   43      0   591   535   16
  6  1244  1277   22      8   773   735   37      2  1688  1584   11
  7  1613  1704   20      9   677   609   45      4  2431  2257   11
  8  1151  1189   25         H 10, 2            6  1668  1619   14
  9   692   763   40     -9   848   897   42      8   827   803   24
 10  1297  1293   26     -8   995  1044   35         H 1, 3
 12   889   834   37     -6  2303  2338   22    -14  1799  1736   22
     H 7, 2            -5   846   783   39    -12  1839  1860   20
-12   671   688   50     -4  3165  3060   20    -10  2194  2234   17
-10   777   829   38     -3  1511  1523   27     -9  1597  1551   18
 -7   632   664   39     -2  3319  3388   19     -8  2221  2153   15
 -5  1115  1119   24     -1  1570  1593   23     -7  3355  3361   13
 -4   371   324   59      0  2439  2495   19     -6  1417  1419   16
 -3  1405  1452   21      1  1397  1366   24     -5  5155  5353   11
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COLUMNS ARE 10FO,10FC,  10SIG

         KFO    FC   SIG       H   KFO    FC   SIG       H   KFO    FC   SIG
       H  1,  3                3  4517  4451    11     -13   872   838    42
  -4  1076  1027    18         4  4962  4799    12      -9  1380  1319    24
  -3  3770  3684    11         5  4230  4237    13      -8   570   567    46
  -1  1644  1476    10         6  3611  3611    14      -7  2822  2824    17
   0   407   360    24         7  2990  2871    15      -6   938   898    27
   1   336   247    31         8  1393  1267    21      -5  3166  3159    16
   2   719   662    19         9  1225  1158    24      -4  1315  1310    23
   3  1578  1486    12        10   764   696    37      -3  2590  2491    17
   5  2181  2014    13        12  1682  1633    24      -2   825   878    29
   6  1079  1001    19        13   609   619    53      -1  1075  1039    25
   7   948   921    21             H  4,  3              1   336   343    49
   8  1153  1111    20       -13   968   955    35       2   653   636    26
   9   676   629    33       -11   426   395    62       3  1420  1457    16
  10  1009  1024    27       -10  1023   997    28       4  1056  1146    21
  11  1858  1806    20        -9   359   383    64       5  1273  1344    21
  12   825   788    36        -8  1721  1806    19       6  1631  1667    19
  13  1828  1784    24        -7  1231  1197    19       7   733   723    38
       H  2,  3               -6  2464  2501    15       8  1663  1725    22
 -14   988   971    34        -5  1510  1494    18      10  1384  1402    25
 -13   613   586    46        -4  1947  1834    16      12   772   762    43
 -12   815   778    33        -3   601   584    31           H  7,  3
 -10   607   679    40        -2   557   595    35     -11  1332  1336    29
  -7  1401  1346    17         0  1205  1194    16     -10   434   392    67
  -5  1293  1246    16         1   425   525    34      -9  1289  1257    27
  -4   842   800    22         2  2017  2071    13      -8  1290  1210    26
  -2   549   461    33         3   818   836    20      -7  1031   998    29
   0  1454  1390    11         4  2366  2364    14      -6  1840  1811    20
   1  1776  1731    10         6  2031  2042    16      -5   786   779    35
   2  1375  1263    13         8  1787  1682    19      -4  1800  1694    20
   3  3224  3079    11         9   836   782    34      -3   635   595    40
   4  1119  1069    17        10  1098  1068    30      -1   771   826    32
   5  1881  1857    14        11   915   831    34       0  2283  2367    17
   6   350   268    50        12   574   550    56       1  1044  1093    22
   7  1760  1596    17        13   822   757    42       2  3818  3891    14
   8  1000   950    25             H  5,  3              3  1061  1054    22
   9  1157  1126    24       -13   820   831    42       4  3740  3918    14
  10  1165  1085    25       -11   779   771    37       5  1163  1231    22
  11   739   688    38       -10   367   298    71       6  2739  2872    17
  12   723   753    43        -9   686   701    38       7  1096  1056    28
  13   386   299    76        -8  1960  1936    19       8  1050  1098    30
       H  3,  3               -6  3886  4004    15       9   673   767    43
 -13  1403  1354    26        -5   485   482    45      10   385   485    74
 -11   882   924    33        -4  5297  5174    14      11   440   399    66
 -10   962   931    28        -3  1370  1321    20           H  8,  3
  -9   737   765    31        -2  3721  3683    14     -10   565   539    57
  -8  1713  1750    18        -1   759   745    30      -3   667   619    41
  -6  1826  1732    15         0  3635  3728    13      -1  1183  1259    25
  -5   454   406    38         1  1057  1013    17       0   561   521    44
  -4  1059  1054    20         2  1368  1396    15       1  2023  1995    18
  -2  1170  1068    20         3   510   535    32       2   881   877    28
  -1  2325  2137    12         8   637   594    38       3  1149  1199    23
   0  4786  4866    10        10  1233  1286    27       4   455   360    49
   1  5980  6154     9        12  1475  1379    26       5   751   726    33
   2  6519  6874    10             H  6,  3              9   645   627    45
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COLUMNS ARE 10FO,10FC,  10SIG

   H   KFO    FC   SIG       H   KFO    FC   SIG       H   KFO    FC   SIG
       H  9,  3                  H 13,  3             -6  1670  1704    17
 -11   926   902    42        -2   450   397    67      -5  1106  1067    20
 -10  1354  1360    31        -1  1109  1120    32      -4   416   417    41
  -9  1411  1434    29         0   833   809    40      -3  1977  1821    15
  -8  1045  1006    34         1  1878  1787    23      -2  2249  2121    12
  -7  2058  1915    23         2   910   835    40      -1  2279  2154    11
  -5  1954  1897    24         3  2391  2290    23       0  4196  4193     9
  -4   406   419    73         4   933   815    39       1  4221  4264    10
  -3   999   987    33             H  0,  4              2  7016  7206    10
   1  1415  1431    24       -12   357   347    66       3  2734  2655    12
   2   924   922    30       -10  1383  1351    19       4  3988  3942    12
   3  2030  2022    18        -8  3257  3423    14       5  2060  2093    14
   4  1307  1276    23        -6  3806  4006    13       6  2128  2103    15
   5  1473  1472    22        -4  4408  4465    12       7  1000   954    23
   6  1378  1432    24        -2  1929  1874    11       9   470   261    53
   7   532   558    51         0  1362  1363    11      10  1600  1410    22
   8  1193  1171    28         6  1344  1345    17      12  1891  1782    24
   9   554   481    55         8  2193  2136    16           H  3,  4
  10   527   495    59        10  2606  2506    18     -11   353   306    70
       H 10,  3               12  1916  1901    23      -9   874   918    29
 -10   425   358    83             H  1,  4             -8   509   470    42
  -9  1190  1187    35       -14   776   671    38      -7   820   795    26
  -8  1100  1081    36       -13   491   499    55      -4  1256  1260    18
  -7  1499  1500    29       -11   526   587    46      -3   926   879    23
  -6  1713  1641    27       -10   866   861    29      -2  1728  1588    15
  -5  1360  1361    30        -9  2443  2489    16      -1  2333  2212    13
  -4  1650  1624    27        -8  2204  2332    16       0  1708  1678    13
  -3   471   542    68        -7  3278  3271    14       1  4215  4281    10
  -2  1174  1131    28        -6  2535  2587    14       2  2964  2965    11
   1  1019  1005    32        -5  2766  2712    14       3  2300  2255    13
   3  1063  1058    28        -4  2437  2456    13       4  1181  1146    19
   4   682   608    37        -3  1344  1271    17       5  1390  1375    18
   5   924   912    29        -2   991   995    17       6   465   421    40
   7   531   564    52        -1   732   690    18       8  1357  1319    22
       H 11,  3                0   630   633    20      10  1330  1278    26
  -7  1235  1234    36         1  2324  2228    10      12  1018   936    34
  -6   939   973    42         2  1863  1793    12           H  4,  4
  -5  2155  2037    24         3  2173  2061    12     -13   780   781    41
  -4  1197  1125    33         4  2156  2165    13     -12  1657  1621    22
  -3  2207  2191    23         5   702   701    25     -11  1319  1309    26
  -2   824   899    40         6  2823  2648    14     -10  1501  1468    23
  -1  1665  1699    24         8  2458  2342    16      -9  2422  2473    18
   0   620   584    46         9  1244  1200    25      -8  1071  1095    26
   1   953   891    33        10  1733  1580    21      -7  2678  2701    16
       H 12,  3               11  1193  1134    28      -6   520   505    41
  -6   728   765    52        12   996   896    34      -5  3014  2934    15
  -5   802   764    47        13   911   870    39      -3  1364  1318    19
  -4   553   497    61             H  2,  4             -1   680   639    27
  -3   811   829    41       -13  1207  1206    27       0  1260  1188    16
  -1   601   652    51       -11   861   876    31       1  2905  2954    12
   0   426   494    68       -10   909   907    28       2  1455  1508    15
   2   650   671    49        -9   847   840    28       3  2619  2674    13
   3   641   562    46        -8  2032  2089    17       4  1322  1299    18
   5  1043   967    32        -7   515   523    38       5  1366  1267    19
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COLUMNS ARE 10FO,10FC, 10SIG

H	KFO	FC	SIG
	H 4, 4		
6	1078	1031	23
7	374	438	58
8	478	457	50
9	1735	1665	21
11	2261	2092	20
	H 5, 4		
-11	382	354	74
-10	1779	1765	22
-9	1331	1274	25
-8	3813	3868	17
-7	1101	1138	27
-6	3988	3968	16
-5	978	925	26
-4	3430	3424	15
-2	2023	2016	18
0	453	460	38
1	739	734	24
2	2012	2063	14
3	704	725	26
4	1710	1767	16
5	436	526	49
6	1004	993	28
7	416	455	57
10	640	677	45
12	667	645	48
	H 6, 4		
-12	823	860	41
-10	906	957	36
-9	1198	1182	29
-8	1385	1428	25
-7	2437	2398	19
-6	1191	1163	26
-5	2636	2571	18
-4	1333	1315	21
-3	1817	1824	19
-2	1057	1055	26
-1	943	946	27
0	676	730	29
2	375	409	46
3	823	810	24
6	360	460	69
7	988	955	31
9	1456	1525	23
10	376	503	73
11	1658	1617	24
	H 7, 4		
-10	508	418	59
-9	565	516	52
-8	921	897	36
-7	1347	1354	27
-6	523	480	53
-5	1504	1488	23
-4	732	733	35

H	KFO	FC	SIG
-3	872	830	31
-2	1620	1677	22
0	2223	2262	17
2	1569	1637	19
3	1927	2007	17
4	1012	1048	24
5	1763	1833	18
6	627	644	41
7	1679	1675	23
8	1303	1352	27
9	1253	1346	27
10	1215	1277	29
11	833	877	39
	H 8, 4		
-10	412	434	79
-8	535	485	61
-7	547	533	58
-4	696	681	41
-3	1123	1152	29
-2	1458	1500	24
-1	2403	2566	19
0	2428	2552	19
1	3989	4077	16
2	2307	2326	17
3	3944	3983	15
4	1698	1717	19
5	2592	2664	17
6	695	703	38
7	1367	1357	25
10	543	617	56
	H 9, 4		
-10	1045	1034	39
-9	652	475	55
-8	1436	1391	30
-7	554	515	59
-6	1221	1236	32
-5	386	68	76
-1	672	759	43
0	1633	1655	23
1	1198	1224	27
2	1836	1820	20
3	731	779	36
4	1319	1320	23
5	352	254	67
6	855	837	32
7	638	706	45
9	1042	1013	35
	H 10, 4		
-9	602	542	62
-8	1756	1590	28
-6	2027	2000	25
-5	627	590	54
-4	1804	1798	26
-3	942	948	37

H	KFO	FC	SIG
-2	1010	947	31
-1	813	782	37
0	380	258	74
8	1006	976	33
	H 11, 4		
-7	2109	2077	26
-5	1965	1872	26
-4	610	523	54
-3	1167	1172	31
-2	424	476	70
1	560	577	53
3	834	896	36
4	620	584	44
5	712	710	40
6	1008	994	32
	H 12, 4		
-6	690	673	55
-5	958	1034	43
-3	750	764	44
0	884	888	38
2	1489	1385	27
4	1326	1307	28
	H 13, 4		
-3	917	989	39
-1	1352	1377	29
1	1326	1302	31
2	433	370	81
3	857	778	43
	H 0, 5		
-12	1208	1229	24
-10	2442	2535	16
-8	4451	4856	14
-6	4031	4155	13
-4	2256	2180	14
-2	334	269	39
0	1184	1126	14
2	2051	1871	13
4	964	879	19
6	1121	1059	21
8	1356	1257	22
10	1491	1356	23
12	893	860	38
	H 1, 5		
-14	1403	1423	26
-13	639	682	43
-12	1691	1727	20
-11	945	1045	29
-10	1781	1839	19
-9	2026	2137	17
-8	2536	2693	16
-7	2358	2456	16
-6	1890	1945	16
-5	1304	1329	17
-4	1127	1084	19

COLUMNS ARE 10FO,10FC, 10SIG

H	KFO	FC	SIG
	H 1, 5		
-3	395	366	40
-1	654	670	22
0	954	924	16
1	1766	1698	12
3	1084	1000	19
4	585	539	29
5	641	658	28
7	2204	2089	16
9	2559	2359	18
11	2219	2073	22
12	759	672	45
	H 2, 5		
-12	933	955	31
-11	671	622	37
-10	1282	1366	24
-9	1133	1212	24
-8	1155	1221	24
-7	848	857	27
-4	2489	2438	15
-3	914	858	21
-2	3857	3746	12
-1	2355	2297	12
0	4980	4980	10
1	3119	3217	11
2	3349	3176	11
3	2339	2310	13
4	935	900	22
5	1360	1394	18
6	876	877	24
7	749	760	30
8	2277	2185	18
10	2149	1984	21
12	1234	1126	30
	H 3, 5		
-14	491	453	63
-13	687	724	44
-12	857	893	34
-10	1356	1348	24
-8	1498	1452	20
-6	321	350	59
-5	1154	1134	20
-4	1808	1767	17
-3	3080	2933	15
-2	3688	3614	13
-1	3456	3352	12
0	4414	4470	11
1	4882	5038	11
2	4679	4755	11
3	3765	3698	12
4	2868	2813	14
5	2207	2147	16
6	762	736	28
7	550	566	40

H	KFO	FC	SIG
8	860	883	30
9	354	320	71
10	1435	1386	25
11	618	529	50
12	1324	1223	29
	H 4, 5		
-13	686	627	45
-11	1250	1273	27
-10	926	1033	34
-9	2060	2064	20
-8	1536	1500	22
-7	1527	1524	21
-6	1136	1071	22
-5	507	511	40
-4	440	404	47
-3	1615	1553	20
-2	698	224	32
-1	2181	2141	14
0	1882	1870	14
1	2465	2559	13
2	1970	1984	13
3	1228	1275	19
4	1368	1384	18
5	633	589	36
6	1094	1103	24
7	1619	1653	20
8	885	938	31
9	2127	2153	20
10	672	639	43
11	1659	1610	24
12	871	779	38
	H 5, 5		
-13	767	673	44
-11	507	469	59
-10	937	906	34
-9	658	592	46
-8	2019	1960	21
-6	1831	1893	19
-4	1957	1916	18
-3	611	646	40
-2	1561	1509	20
-1	524	516	38
0	1002	1002	21
1	400	367	43
2	829	835	23
4	1858	1926	17
6	2299	2350	19
7	532	516	49
8	2187	2295	19
10	2017	2003	21
11	393	228	73
	H 6, 5		
-11	1499	1504	28
-9	2613	2468	20

H	KFO	FC	SIG
-8	478	431	62
-7	3019	2982	18
-6	698	732	38
-5	1788	1801	20
-4	736	819	36
-3	431	492	57
-2	466	487	56
-1	956	1005	26
1	1361	1343	18
2	1035	1094	22
3	1112	1203	21
4	1164	1250	22
6	1634	1666	21
7	1159	1195	30
8	1407	1398	24
9	1156	1236	28
10	1051	1039	30
11	715	778	44
	H 7, 5		
-12	455	531	81
-11	1119	1103	35
-10	1006	1031	37
-9	1354	1325	27
-8	1243	1274	30
-7	1755	1726	23
-6	786	749	36
-5	1715	1729	21
-4	575	614	46
-3	1437	1539	24
-2	1959	1950	21
-1	1334	1365	23
0	3113	3254	16
1	980	1001	25
2	3744	3842	15
4	2286	2452	17
6	557	531	47
8	763	722	39
10	1217	1289	29
	H 8, 5		
-11	772	669	48
-10	556	567	61
-9	738	672	45
-5	1332	1317	25
-4	731	694	40
-3	2491	2536	20
-2	1724	1882	24
-1	2983	3188	20
0	1668	1685	21
1	3024	3144	17
2	1690	1721	19
3	1352	1315	22
4	858	850	31
7	839	843	34
8	408	438	75

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COLUMNS ARE 10FO,10FC,  10SIG

   H   KFO    FC   SIG       H   KFO    FC   SIG       H   KFO    FC   SIG
     H  8,  5                  H  0,  6                4  2565  2448    15
   9   950  1014    36     -12   525   628    50       6   677   629    30
  10   409   534    76     -10   442   525    54       8   796   787    33
     H  9,  5               -8   492   525    44      10   972   911    33
 -10   883   838    42      -6   374   373    48         H  3,  6
  -9  1592  1624    29      -4   662   589    26     -13   799   786    40
  -7  1435  1414    28       0  1059  1092    16     -12  1173  1209    29
  -5   560   590    57       2  3099  2920    12     -11   776   813    38
  -2   456   494    62       4  3461  3416    13     -10   961   906    30
  -1  1209  1278    28       6  3710  3594    14      -9   523   617    50
   0   888   901    35       8  3587  3342    16      -6  1744  1870    18
   1  1621  1571    22      10  2337  2096    20      -5  2090  2164    17
   2  1181  1240    26      12   476   494    71      -4  3870  3681    15
   3  1114  1129    26         H  1,  6               -3  4505  4395    14
   4  1047   992    27     -13  1494  1593    25      -2  5099  5030    13
   6   731   656    36     -11  2048  2139    20      -1  3931  3788    12
   7   547   599    53     -10   564   654    44       0  3555  3538    12
   9  1276  1209    32      -9  2380  2409    17       1  3322  3400    12
     H 10,  5               -8   939   957    27       2  1996  2040    14
  -9   978   991    41      -7  1577  1583    18       3  1223  1232    19
  -8  1717  1701    26      -6  1062  1136    21       4   432   444    46
  -7   856   863    42      -5   495   397    37       6  1528  1590    20
  -6  1511  1465    28      -4   685   609    27       7   907   942    28
  -5   735   644    46      -3  2248  2231    13       8  2067  2125    20
  -4   689   643    48      -1  2322  2364    14       9   825   749    34
   0   446   527    68       0   984  1002    17      10  1558  1468    24
   1   475   486    60       1  1485  1462    14      12   710   651    48
   2   575   570    47       2  1698  1683    14         H  4,  6
   6   432   481    65       4  1766  1779    15     -13  1003   974    35
   8   938   884    37       5  1810  1843    16     -12  1232  1258    30
     H 11,  5                6  1423  1410    19     -11  1143  1161    30
  -8   903   898    44       7  2707  2602    16     -10  1474  1411    24
  -7   842   745    46       8  1402  1264    22      -9  1598  1576    23
  -6  1158  1146    35       9  2478  2273    19      -8  1712  1704    21
  -5   786   818    48      10  1309  1215    26      -7  1378  1385    22
  -4   941   984    39      11  1275  1222    29      -6  1540  1525    19
  -3   657   657    48      12  1004   861    35      -5   676   665    33
  -2   595   611    51         H  2,  6               -4  1581  1577    21
  -1   489   475    59     -13   882   962    36      -3   528   489    43
   5   895   905    35     -12   684   779    42      -2  1358  1307    20
     H 12,  5              -11   930   965    32      -1  1080  1105    21
  -5   831   737    45     -10  1118  1195    27       0   801   828    25
  -3   573   579    57      -9  1118  1159    25       1   965  1051    21
  -2  1017  1065    35      -8  1319  1400    22       4   542   509    38
   0  1222  1290    32      -7  1686  1736    18       5   849   741    30
   2   712   693    48      -5  2095  2158    16       6   744   731    33
   3   909   874    38      -4  1049  1029    23       7  1462  1607    23
   5  1116  1135    33      -3  2734  2671    14       8   649   569    39
     H 13,  5               -2  2455  2358    13       9  1436  1485    24
  -3   838   798    44      -1  1736  1673    13      11  1044  1030    34
  -2   895   874    41       0  2835  2892    12         H  5,  6
  -1  1693  1654    27       1  2503  2464    12     -12  1877  1813    25
   0   968   921    40       2  3721  3687    12     -10  2514  2471    20
   1  2068  2089    26       3   739   698    26      -9   473   495    61
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COLUMNS ARE 10FO,10FC,  10SIG

   H   KFO    FC   SIG       H   KFO    FC   SIG       H   KFO    FC   SIG
     H  5,  6               -6   453   456    66      -8  1711  1843    19
  -8  2839  2861    19      -5   736   688    43      -6   448   476    45
  -7   444   376    57      -4  1093  1036    33      -4   732   726    26
  -6  1924  1958    20      -3  1563  1540    26      -2   342   377    45
  -5   431   332    52      -2   929  1056    41       0   372   441    42
  -4   673   650    38      -1  2245  2300    21       2  2821  2719    14
  -2  1087  1011    25       0  1573  1577    23       4  3418  3446    14
   0  1393  1359    19       1  2807  2849    18       6  3163  3095    15
   4   768   904    31       2  1145  1087    26       8  1976  1892    20
   6  1825  1853    22       3  2424  2496    18      10   696   659    43
   8  1821  1812    21       4   531   592    50         H  1,  7
  10  1133  1135    29       5  1280  1348    24     -12  1809  1895    22
     H  6,  6                9   450   296    69     -11   416   549    66
 -12  1192  1192    34         H  9,  6             -10  1793  1750    20
 -11   406   337    78     -10   802   850    46      -9   659   661    36
 -10  1265  1326    30      -9   906   878    40      -8  2039  2198    18
  -9   625   628    49      -5  1040  1060    35      -7   543   551    39
  -8  1846  1877    23      -4   998   936    35      -6  1486  1513    19
  -7   700   621    39      -3  1945  1948    25      -5   786   840    28
  -6  2099  2121    20      -2  1308  1343    29      -4  1358  1293    18
  -4  1760  1716    21      -1  1880  1953    24      -2   490   439    33
  -2   625   710    43       0  1542  1552    25      -1   283    99    54
   0   339   308    62       1   985   988    31       1   681   680    25
   1   532   518    38       2  1057  1112    29       2   586   594    31
   2   436   462    47       5  1064  1085    29       3  1875  1802    17
   3  1244  1400    22       7  1613  1588    25       4  1175  1205    21
   4  1069  1169    25         H 10,  6                5  1377  1406    19
   5  1522  1580    22      -8   739   737    50       6   532   495    40
   6   528   581    53      -6   633   587    53       7  1843  1888    19
   7  1966  1994    23       2   762   761    39       9  1200  1193    28
   9  1662  1815    23       4  1159  1187    28      10   480   376    59
  10   422   418    68       5   595   441    46         H  2,  7
     H  7,  6                6  1602  1559    24     -12  1914  1951    23
 -12  1290  1245    33       7   671   634    48     -11   419   469    64
 -10   863   867    40         H 11,  6             -10   807   825    34
  -7   533   466    54      -7  1170  1173    36      -8  1198  1257    23
  -6  1136  1147    29      -5   608   546    57      -7  1075  1126    24
  -5   365   208    73      -1   541   510    57      -6  3468  3564    15
  -4  2872  2929    19       0   400   235    80      -5  1860  1823    18
  -2  3176  3224    19       2   866   871    38      -4  5502  5441    14
  -1   850   894    34       4   893   900    36      -3  2939  2879    14
   0  2882  2913    17       5   730   668    44      -2  5437  5302    12
   1  1127  1252    27       6   971   984    36      -1  2262  2234    14
   2   731   780    33         H 12,  6                0  3139  3198    13
   3  1352  1340    22      -5  1224  1218    36       1  1484  1529    16
   4   710   753    36      -3   659   669    52       2   496   568    36
   5  1003  1043    29      -2   665   666    51       4  1816  1786    18
   6  1804  1795    21       0  1060  1026    36       6  2762  2817    16
   7   846   895    38       2  1029  1013    36       8  2479  2392    18
   8  1837  1826    23       3   674   652    51      10  1235  1198    28
   9   719   748    43       4   676   525    47      11   783   721    42
  10  1233  1290    29         H  0,  7                  H  3,  7
     H  8,  6              -12  1940  2041    21     -13   661   616    49
  -9   400   308    77     -10  1734  1783    20     -12   576   421    52
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COLUMNS ARE 10FO,10FC, 10SIG

H	KFO	FC	SIG
	H 3, 7		
-9	680	672	38
-7	931	984	27
-5	1278	1280	23
-4	1596	1532	20
-3	2244	2281	17
-2	1643	1621	17
-1	2028	2022	15
0	1679	1696	16
1	2095	2158	15
2	1509	1522	17
3	1525	1558	18
4	847	866	29
5	818	784	31
	H 4, 7		
-13	1856	1875	25
-11	1406	1421	26
-9	1026	1017	29
-7	642	647	37
-5	2350	2333	18
-4	883	826	32
-3	3380	3367	16
-2	712	704	33
-1	2275	2268	15
0	701	723	28
1	492	522	37
3	1484	1586	19
5	2974	3042	17
7	2465	2600	19
8	802	837	37
9	1744	1827	23
10	1325	1251	27
11	845	820	39
	H 5, 7		
-9	370	300	70
-8	603	584	46
-6	552	607	46
-4	1152	1122	28
-2	1329	1287	22
0	1827	1869	18
2	2804	2920	16
3	539	646	43
4	2552	2625	17
6	2133	2143	22
7	557	600	52
8	1608	1668	24
9	555	554	52
10	744	835	42
	H 6, 7		
-11	1668	1601	25
-9	1001	973	32
-6	374	315	70
-5	812	806	35
-4	611	589	47

H	KFO	FC	SIG
-3	1230	1224	29
-1	877	859	30
1	607	701	39
2	940	988	28
3	2327	2402	18
4	655	667	41
5	2373	2475	20
6	1088	1147	32
7	1990	1946	23
8	960	961	34
9	1009	984	30
10	885	887	36
	H 7, 7		
-11	1567	1493	27
-9	1796	1735	23
-8	385	376	76
-7	2066	2015	21
-5	1908	1852	22
-4	976	996	35
-3	1370	1317	28
-2	1835	1795	24
0	1580	1576	22
2	1488	1455	21
3	523	549	48
4	631	653	43
5	481	474	56
8	607	593	52
	H 8, 7		
-8	514	480	59
-7	1724	1713	24
-6	1618	1630	26
-5	3040	3051	21
-4	2425	2394	23
-3	3527	3562	20
-2	2637	2638	22
-1	2973	3015	20
0	1587	1593	24
1	1561	1576	23
4	474	457	55
5	983	992	31
6	830	876	38
7	1052	1041	32
8	912	856	39
	H 9, 7		
-9	836	804	42
-7	733	743	44
-6	443	484	73
-4	707	623	50
-2	772	860	47
-1	393	324	78
0	877	863	36
2	794	759	35
7	434	442	75
	H 10, 7		

H	KFO	FC	SIG
-8	791	739	44
-6	403	35	76
1	419	479	72
2	717	700	41
3	542	468	52
4	1498	1534	26
6	1528	1534	27
	H 11, 7		
-6	915	860	41
-1	490	531	68
1	877	934	40
3	1128	1098	32
5	1333	1320	29
	H 12, 7		
-4	1443	1439	31
-2	1329	1410	32
0	915	840	41
	H 0, 8		
-10	565	468	42
-4	873	882	24
-2	1909	1898	15
0	2392	2351	14
2	3441	3341	14
4	3599	3644	15
6	2528	2599	17
8	1330	1252	24
	H 1, 8		
-13	1590	1685	25
-11	1119	1133	27
-10	399	427	62
-8	476	465	47
-7	1756	1763	18
-6	527	479	43
-5	2284	2205	16
-4	973	960	23
-3	1858	1775	15
1	2239	2230	15
3	4293	4120	15
5	3494	3548	15
6	734	703	33
7	2291	2273	18
8	1142	1098	27
9	733	759	38
10	1372	1300	27
11	499	465	63
	H 2, 8		
-13	1126	1166	32
-11	1205	1200	26
-10	769	793	35
-9	1199	1209	25
-8	1015	1013	26
-7	1802	1837	19
-6	915	899	29
-5	1441	1362	21

COLUMNS ARE 10FO,10FC, 10SIG

H	KFO	FC	SIG
	H 2, 8		
-3	1365	1330	19
-2	1294	1245	19
-1	654	645	30
0	1760	1750	16
1	853	877	24
2	1579	1550	17
4	1323	1357	23
6	767	777	32
8	525	506	49
11	470	476	70
	H 3, 8		
-12	884	864	35
-9	991	974	29
-8	1679	1736	21
-7	2877	2982	17
-6	3687	3817	16
-5	3967	3942	17
-4	3910	3952	16
-3	3688	3667	15
-2	3226	3194	15
-1	2167	2183	16
0	1415	1456	18
1	774	779	26
2	468	470	42
3	904	871	26
4	2175	2193	18
5	1140	1124	26
6	1748	1739	20
8	916	920	32
9	416	454	65
	H 4, 8		
-12	1315	1369	29
-11	604	619	47
-10	1388	1402	24
-9	770	782	36
-8	1430	1538	24
-7	1254	1278	24
-6	1787	1845	20
-5	1015	960	29
-4	1269	1255	25
-3	613	656	40
-2	592	616	38
0	387	406	51
1	361	277	53
2	355	428	59
3	729	710	33
4	1261	1358	24
6	566	777	54
	H 5, 8		
-12	1364	1371	28
-10	703	674	41
-6	706	792	40
-4	928	911	33

H	KFO	FC	SIG
0	2019	2171	18
1	846	868	29
2	3543	3777	16
3	901	861	29
4	3581	3753	17
6	2577	2549	20
8	1085	1107	31
9	433	449	68
10	383	45	73
	H 6, 8		
-10	1563	1576	25
-8	1829	1913	23
-6	1623	1596	24
-4	912	897	37
-1	939	972	30
0	682	731	38
1	1144	1191	26
2	870	882	32
3	1367	1399	24
4	695	696	42
5	1498	1503	25
7	1215	1222	31
	H 7, 8		
-11	417	389	76
-8	1569	1582	25
-7	844	849	38
-6	2735	2738	20
-5	880	910	41
-4	2992	3090	21
-3	839	703	42
-2	2073	2098	23
0	877	888	33
1	484	451	54
2	1424	1478	24
4	2044	2092	20
6	1615	1645	24
7	701	624	45
8	958	903	36
	H 8, 8		
-5	426	297	80
-3	1123	1071	38
-1	1613	1594	26
0	559	532	53
1	1707	1766	23
2	451	459	61
3	1339	1400	24
4	510	483	54
5	695	795	44
6	514	501	59
7	474	491	69
	H 9, 8		
-8	647	696	52
-7	1022	1050	36
-6	1382	1377	30

H	KFO	FC	SIG
-5	1941	1823	25
-4	1453	1476	31
-3	1632	1648	29
-2	947	995	41
-1	784	722	42
3	1225	1290	28
4	405	327	68
5	1913	1887	22
7	1434	1445	29
	H 10, 8		
-4	683	702	53
-2	800	872	46
0	1198	1133	31
2	1326	1360	29
3	707	707	45
4	1258	1244	30
5	923	987	38
	H 11, 8		
0	562	469	61
1	1444	1506	30
2	877	912	42
3	1924	1999	25
	H 12, 8		
0	612	598	63
	H 0, 9		
-8	707	716	34
-6	627	625	38
-4	947	921	24
-2	3162	3118	14
0	4514	4621	14
2	5880	5797	15
4	4014	4059	15
6	1721	1770	20
10	1388	1271	27
	H 1, 9		
-12	1463	1431	24
-10	1320	1400	24
-9	975	966	27
-8	1543	1568	20
-7	1130	1140	25
-6	1644	1624	20
-5	1056	1031	25
-4	1298	1255	20
-3	722	740	29
-2	661	601	30
-1	445	526	44
3	1081	1053	26
4	931	910	29
5	567	605	42
6	583	590	43
	H 2, 9		
-12	403	387	69
-11	885	866	32
-10	960	961	29

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COLUMNS ARE 10FO,10FC,  10SIG                                                     COLUMNS ARE 10FO,10FC,  10SIG

   H   KFO    FC   SIG       H   KFO    FC   SIG       H   KFO    FC   SIG           H   KFO    FC   SIG       H   KFO    FC   SIG       H   KFO    FC   SIG
      H  2,  9                  H  5,  9             -2  1053  1013    36                 H  2, 10             -10   836   830    36       2   497   521    62
  -9  1313  1347    23     -11   372   140    73      -1  1009  1064    35         -12   955   926    34      -8   664   589    43       3  1082  1037    32
  -8  2652  2732    17      -8   516   569    53       2   526   508    54         -11   574   615    48      -4  1988  1906    22          H 10, 10        
  -7  2291  2364    18      -7   475   456    56       4   933   913    34         -10  1512  1498    22      -3   679   659    44      -5   793   746    50
  -6  4115  4075    16      -6   862   911    35       5   528   577    58          -9   388   503    68      -2  3912  3831    17      -4   638   751    62
  -5  2161  2150    19      -5   532   551    56       6   584   521    54          -8  1547  1536    22      -1   847   833    34      -3   692   690    57
  -4  3699  3639    15      -4  1148  1114    29          H  9,  9                 -7   671   698    41       0  4335  4471    17      -2   580   601    66
  -3  1472  1514    19      -3   446   471    60      -7  1066  1099    37          -6  1041  1033    29       1  1018   979    29       2   595   497    60
  -2  2022  2034    16      -2  1269  1178    24      -6   683   597    54          -5   534   550    49       2  3750  3973    17          H  0, 11        
   2  2014  2035    18      -1   348   222    68      -5  1063  1092    39          -3   975   951    26       3   630   643    46     -10   804   805    34
   3   755   715    33       0   998   968    28      -4  1033   938    39          -2  1093  1046    24       4  2338  2330    20      -6  1891  1731    19
   4  2621  2555    18       2  1371  1424    23      -2   921   906    41          -1   833   853    29       6   643   643    52      -4  3616  3526    16
   6  1364  1391    23       3   631   698    45       0   780   788    42           0  1802  1813    19       7   387   329    75      -2  4987  5082    15
   7   787   772    34       4  1542  1555    24       5   454   474    70           1   818   812    30       8   692   638    45       0  4738  4767    16
   9  1374  1275    25       5   918   930    36       6   434   535    80           2  1719  1771    21          H  6, 10                2  3410  3353    18
  10   618   617    51       6  1333  1346    30          H 10,  9                  3   622   592    41     -10  1089  1053    31       4  1034  1140    29
      H  3,  9                 7   696   730    45      -3   427   439    84           4  1675  1625    22      -9   711   692    43       6   610   664    44
 -10   666   708    40       8   626   680    51      -2   894   962    44           5   452   268    55      -8  1082  1114    31       8  1309  1345    28
  -8   735   759    36       9   427   502    71      -1   678   749    53           6   911   877    31      -7   495   518    59          H  1, 11        
  -6   995  1001    30          H  6,  9              0  1775  1743    26              H  3, 10             -6   639   695    50     -11  1333  1396    26
  -5   455   488    60     -10   589   542    51       1   997  1061    38         -11  1209  1241    28       3   628   615    47     -10   922   984    32
  -4   668   602    37      -9   679   735    44       2  2095  2121    23         -10  1124  1097    28       5   718   814    46      -9  1151  1230    27
  -3   967   997    28      -7  1221  1302    29       3   742   793    46          -9  1833  1733    20       7   611   575    57      -8   985  1026    31
  -2   318    91    63      -5   810   816    41       4  1751  1742    26          -8  1923  1883    20          H  7, 10               -7   806   833    35
  -1  1260  1253    21      -3   589   666    54          H 11,  9                 -7  2465  2469    18      -9  1121  1079    33      -6  1627  1518    21
   0   952   978    25      -1  2163  2254    21      -3   439   211    81          -6  2435  2392    19      -8  1771  1705    24      -4  1401  1438    23
   1  1609  1700    19       1  3054  3249    18       1   676   644    56          -5  2260  2219    19      -7  1102  1087    33      -3   861   843    30
   2   836   865    29       2   599   613    46          H  0, 10                 -3  1120  1114    25      -6  1907  1818    25      -2   925   942    28
   3   931   953    28       3  3362  3502    18      -4   838   824    28          -2   647   645    37      -4  1282  1223    34      -1   881   793    29
   4  1256  1278    25       4   653   643    46      -2   869   849    27           0   464   490    50       0   944  1027    35       4   636   659    44
   5   699   656    40       5  2006  2113    22       0   462   616    57           1   452   457    52       2  1331  1384    26       6   820   894    36
   6  1104  1197    29       6   882   855    40       2  1535  1472    22           2   857   839    31       4   829   881    39       7   813   844    37
   7   463   507    56       7   628   661    55       4  1449  1486    23           4   384   401    75       5   640   681    51       8   581   629    52
   8   699   779    41       8   906   950    39       6  1160  1206    26           5   706   586    41       7  1114  1083    37          H  2, 11        
  10   553   509    57          H  7,  9              8   827   807    36           7  1111  1160    29          H  8, 10             -11  1554  1572    24
      H  4,  9               -10   510   562    62          H  1, 10                  8   679   692    43      -9   578   573    61     -10  1224  1261    28
 -12   642   626    47      -9  1219  1276    31     -12  1217  1269    28           9  1481  1480    26      -8   471   576    73      -9  1322  1336    25
 -10   691   624    40      -8   799   828    42     -11   886   831    31              H  4, 10             -6   423   526    83      -8  1439  1451    23
  -9   708   734    39      -7  1372  1329    28     -10  1032  1046    29         -11  1167  1200    29      -3  1101   967    37      -7  1352  1378    26
  -8  1050  1044    29      -6   401   432    80      -9  1071  1088    27         -10  1058  1078    30      -1  1247  1305    31      -6  1264  1255    26
  -7  1882  1949    21      -5   859   835    43      -8  1143  1169    26          -9  1411  1466    25       0   735   790    44      -5   591   551    46
  -6  1040  1025    29      -2   776   692    42      -7  1177  1212    27          -8   967   982    31       1  1239  1305    30      -2   830   855    30
  -5  2276  2199    20       0   997   912    31      -6   667   643    38          -7  1660  1652    22       2   798   832    40      -1   632   699    39
  -4   382   487    70       2   792   809    37      -3  1504  1486    20          -6  1189  1084    28       3   927  1042    35       0   849   853    32
  -3   922   903    29       6   480   454    66      -2   892   864    26          -5  1385  1310    26       4   779   832    43       2   453   398    57
  -1   785   710    30       8   453   371    70      -1  3252  3328    15          -4  1155  1121    28       5   709   695    47       3   724   679    39
   0   679   714    35          H  8,  9              0  1114  1093    23          -3   673   625    39       6   653   667    54       4   483   462    61
   1  2451  2600    16      -9  1262  1296    32       1  3673  3770    16          -2   825   827    33          H  9, 10                5  1242  1266    27
   2   822   853    33      -8  1366  1351    30       2   462   482    54           1   517   568    48      -7   703   644    52       6   938  1030    33
   3  3037  3132    17      -7  2339  2349    23       3  3331  3202    17           4   834   779    37      -6  1084  1049    37       7  1595  1659    24
   5  2290  2265    21      -6  2095  2022    24       5  1346  1412    24           5   564   446    53      -5   646   618    59       8  1288  1280    28
   6   716   773    43      -5  2897  2828    23       6  1109  1130    26           6   835   863    38      -1   580   673    60          H  3, 11        
   7  1059  1063    30      -4  1854  1804    27       8  1364  1383    26              H  5, 10              0   585   580    56     -10  1560  1499    23
   8  1362  1372    26      -3  2317  2257    26       9  1248  1174    28         -11   448   430    65       1  1239  1200    30      -8  1273  1261    26
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COLUMNS ARE 10FO,10FC,  10SIG

  H   KFO    FC   SIG
      H  3, 11
 -6  1064  1067   31
 -5   723   631   39
 -3  1376  1389   24
 -2   772   757   34
 -1  1234  1243   25
  0  1477  1509   22
  1  1040  1101   28
  2  1406  1433   24
  3   688   648   41
  4  1304  1257   27
  6   717   709   42
      H  4, 11
-11   456   504   66
-10  1279  1300   28
 -9   683   644   42
 -8   812   916   37
 -6   534   456   56
 -5   645   598   48
 -3  1673  1707   23
 -2  1008   918   30
 -1  2192  2256   20
  0   928   925   32
  1  1851  1875   21
  3   876   842   35
  4   709   746   45
  6  1163  1164   31
  7   701   712   45
      H  5, 11
-10   825   851   40
 -9   414   444   70
 -8   703   668   42
 -7   631   662   48
 -5   818   858   43
 -4   726   690   45
 -3   651   677   48
 -2   602   677   54
  2   565   554   52
  3   624   632   48
  4  1038  1006   33
  5   919   946   38
  6  1201  1267   33
  7   603   699   55
      H  6, 11
 -9   711   695   43
 -8   396   277   73
 -5  1599  1440   28
 -3  2717  2717   21
 -1  3098  3128   20
  1  2535  2678   21
  3  1541  1674   26
  4   639   694   50
  6   953   999   42
      H  7, 11
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  H   KFO    FC   SIG
 -9   456   513   71
 -8   920   976   39
 -7   714   672   46
 -6   408   221   78
 -5   687   748   54
 -4   438   465   82
 -3   588   635   59
 -2  1006  1091   37
 -1   403   593   78
  0   954   964   36
  2   814   862   39
  4   698   706   48
      H  8, 11
 -7  1413  1394   30
 -6   713   727   53
 -5  1220  1204   35
 -3   546   497   68
  3   673   696   48
      H  9, 11
 -6   958   907   43
 -5   737   735   55
 -4  1180  1163   39
 -2   786   803   51
  1   556   621   63
      H 10, 11
 -3   788   824   57
 -2  1998  1948   29
 -1   998   991   42
      H  0, 12
-10   810   835   35
 -6   890   823   32
 -4  1745  1707   20
 -2  1293  1242   24
  2   718   692   43
  4  1376  1312   24
  6  1851  1920   23
      H  1, 12
-11   385   556   76
-10  1066  1079   31
 -8   728   702   39
 -7   754   736   38
 -5  2208  2137   20
 -4   700   690   40
 -3  2927  2948   17
 -2   929   887   30
 -1  2528  2562   18
  0   762   790   37
  1  1592  1523   22
  2   377   219   72
  4   907   923   35
  5  1034  1053   31
  6  1235  1305   28
  7  1131  1215   31
      H  2, 12
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  H   KFO    FC   SIG
-10  1327  1372   26
 -8   672   738   43
 -7   649   619   45
 -5  1296  1281   26
 -4   964  1000   32
 -3  1392  1360   24
 -2  1435  1337   22
 -1  1093  1096   29
  0  1360  1339   25
  1   592   599   47
  2   620   645   47
  7   525   530   59
      H  3, 12
 -9  1118  1115   30
 -7   936   915   34
 -5   420   351   67
  0   695   733   40
  1   723   775   40
  2  1025  1104   31
  3  1570  1596   25
  4  1330  1330   29
  5  1721  1796   25
  6  1347  1372   28
  7  1627  1658   25
      H  4, 12
-10   506   628   61
 -9  1233  1249   28
 -8   972   985   34
 -7   599   575   49
 -6  1562  1508   26
 -5   384   249   75
 -4  1546  1571   26
 -3   945   943   34
 -2   895   899   35
 -1   685   781   44
  1   434   477   65
  2   413   382   67
  4   813   885   42
  6   997   972   36
      H  5, 12
 -8   583   684   55
 -6  2323  2190   23
 -4  3586  3451   20
 -3   865   799   39
 -2  3667  3652   19
 -1   804   826   42
  0  2713  2748   20
  1   666   727   45
  2  1749  1757   23
  6   971   988   40
      H  6, 12
 -8   601   561   54
 -6   446   443   76
 -5  1309  1306   33
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COLUMNS ARE 10FO,10FC,  10SIG

  H   KFO    FC   SIG
      H  6, 12
 -3  1367  1359   30
 -1   791   828   43
  3   562   628   57
  5  1072  1118   37
      H  7, 12
 -4   431   387   81
  3   717   706   47
  4   993   967   39
      H  8, 12
 -5   840   799   49
 -4   519   469   77
 -3  1126  1120   39
 -2   649   711   58
 -1   824   810   46
  0   839   812   43
  1   612   562   56
  2   637   623   56
      H  9, 12
 -3   776   708   59
 -2   497   559   83
      H  0, 13
 -8  1098  1067   30
 -6  2576  2555   19
 -4  3503  3526   17
 -2  3169  3170   18
  0  1939  1957   22
  2   881   957   39
  6   818   766   39
      H  1, 13
-10   867   924   38
 -8  1371  1314   26
 -7   969   908   32
 -6  1570  1489   23
 -5  1642  1636   23
 -4  1413  1358   24
 -3  1413  1461   25
 -2   771   809   38
 -1   761   805   38
  2   851   794   39
  3  1326  1310   29
  4   968   955   35
  5  1303  1374   29
  6  1151  1107   30
      H  2, 13
 -9   644   564   46
 -7   629   508   45
 -6   545   465   53
 -1   678   641   43
  0  1078  1039   29
  1  1098  1091   30
  2  1440  1461   28
  3  1468  1434   28
  4  2007  1951   23
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  H   KFO    FC   SIG
  5  1420  1579   30
  6  1506  1531   26
      H  3, 13
 -8   425   373   70
 -7   942   908   36
 -5  1220  1181   29
 -4   925   918   34
 -3  1046  1089   31
 -2   946   910   33
 -1   438   553   66
  0   640   695   47
  3   661   661   50
  5   518   507   66
      H  4, 13
 -9   610   605   51
 -8   751   751   43
 -7  1176  1116   31
 -5  1729  1592   25
 -4   463   430   67
 -3  1348  1364   28
 -2   408   502   78
 -1   644   573   48
  3   611   670   55
  4  1024  1038   37
  5  1145  1166   35
      H  5, 13
 -8   943   876   37
 -7   693   739   50
 -6  1578  1576   28
 -5   627   657   60
 -4  1748  1645   25
 -2   796   803   43
  2  1228  1257   31
  3   860   831   40
  4  1648  1668   29
      H  6, 13
 -7  1089  1001   35
 -5  1961  1871   26
 -3  2105  2086   24
 -1  1594  1562   27
  1   878   902   38
  2   451   540   72
      H  7, 13
 -6   702   743   55
 -5   980   963   43
 -4  1192  1115   36
 -3   931   937   43
 -2   934   890   41
 -1   667   640   53
  0   459   457   72
      H  8, 13
 -3   460   328   89
 -1   736   749   52
      H  0, 14
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  H   KFO    FC   SIG
 -8  1750  1666   24
 -6  2098  2078   21
 -4  1972  1936   21
 -2   618   629   48
  0   745   727   44
  2  2130  2016   24
  4  1930  1917   25
      H  1, 14
 -7  1088  1112   31
 -5  1457  1501   27
 -3  1202  1188   28
  2   415   542   81
  4   799   737   42
      H  2, 14
 -8   515   480   60
 -7  1090  1126   33
 -6   906   823   36
 -5  1275  1220   28
 -4   583   594   51
 -3   751   793   41
  0   606   585   51
  1   587   643   57
  2  1134  1123   35
  3   811   885   47
  4   737   741   48
      H  3, 14
 -7   470   459   68
 -4   675   580   45
 -3   711   729   44
 -2  1143  1129   30
 -1  1096  1116   32
  0  1462  1424   26
  1  1401  1402   28
  2  1463  1437   29
  3  1737  1731   28
  4  1373  1391   32
      H  4, 14
 -7   930   856   38
 -6  1404  1390   30
 -5   854   812   42
 -4  1127  1121   32
 -3   400   380   78
  1   856   910   40
  2   986   987   38
  3  1071  1107   38
      H  5, 14
 -6  1978  1799   26
 -4  2073  1967   25
 -2  1652  1627   26
  0   911   893   39
  1   427   455   78
      H  6, 14
 -5  1567  1525   31
 -3   991   978   39
```

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   COLUMNS ARE 10FO,10FC,  10SIG

 H   KFO    FC   SIG      H   KFO    FC   SIG      H   KFO    FC   SIG
     H  6, 14            -5   885   941   38      -1   991   942   35
-2   553   545    65     -4   799   760   39       0  1522  1520   28
 1   977  1012    40     -1  1129  1132   33       1   991   923   38
     H  0, 15             0   537   576   61       2  1593  1536   29
-6  1228  1195    29      1  1705  1700   27           H  3, 15
-4  1406  1377    27      2   839   808   47      -5   467   429   70
-2  1434  1395    26          H  2, 15            -2   641   661   52
 0   924   866    39     -5   833   867   41      -1   972   957   37
 2   644   765    60     -4   756   688   43       0   907   950   41
     H  1, 15            -3  1012   996   34       1  1101  1130   36
-6  1071   982    32     -2  1126  1130   32
```

Table S.21. Fractional Coordinates for $(\mu\text{-H})_2Os_4(CO)_{13}PMe_3$

ATOM	X	Y	Z
OS(1)	0.33486(4)	0.10071(5)	0.05491(4)
OS(2)	0.30382(4)	-0.14812(5)	0.08784(4)
OS(3)	0.26492(4)	-0.05045(5)	-0.10381(4)
OS(4)	0.14666(4)	0.13670(5)	-0.08784(4)
P(1)	0.2452(4)	-0.3469(4)	0.0686(4)
C(1)	0.320(2)	-0.452(2)	0.154(2)
C(2)	0.136(2)	-0.363(2)	0.080(2)
C(3)	0.227(2)	-0.419(2)	-0.036(2)
C(11)	0.291(1)	0.161(2)	0.137(1)
O(11)	0.269(1)	0.206(1)	0.191(1)
C(12)	0.454(1)	0.065(1)	0.144(1)
O(12)	0.526(1)	0.046(1)	0.201(1)
C(13)	0.374(1)	0.256(2)	0.031(1)
O(13)	0.403(1)	0.346(1)	0.022(1)
C(21)	0.204(1)	-0.081(2)	0.115(1)
O(21)	0.150(1)	-0.047(1)	0.141(1)
C(22)	0.376(1)	-0.157(2)	0.216(2)
O(22)	0.418(1)	-0.160(2)	0.292(1)
C(23)	0.416(2)	-0.189(2)	0.075(1)
O(23)	0.488(1)	-0.217(1)	0.076(1)
C(32)	0.344(1)	-0.176(1)	-0.117(1)
O(32)	0.386(1)	-0.249(1)	-0.132(1)
C(31)	0.153(1)	-0.119(2)	-0.190(1)
O(31)	0.085(1)	-0.160(1)	-0.243(1)
C(33)	0.279(1)	0.046(2)	-0.194(1)
O(33)	0.289(1)	0.101(1)	-0.248(1)
C(41)	0.086(1)	-0.001(2)	-0.063(1)
O(41)	0.042(1)	-0.082(1)	-0.055(1)
C(42)	0.116(1)	0.252(2)	-0.018(1)
O(42)	0.097(1)	0.320(1)	0.025(1)
C(43)	0.042(1)	0.151(1)	-0.201(1)
O(43)	-0.024(1)	0.161(1)	-0.264(1)
C(44)	0.211(1)	0.254(2)	-0.131(1)
O(44)	0.246(1)	0.324(1)	-0.161(1)
H(11)	0.305(0)	-0.529(0)	0.121(0)
H(12)	0.308(0)	-0.459(0)	0.208(0)
H(13)	0.388(0)	-0.437(0)	0.175(0)
H(21)	0.093(0)	-0.322(0)	0.036(0)
H(22)	0.151(0)	-0.340(0)	0.146(0)
H(23)	0.127(0)	-0.457(0)	0.083(0)
H(31)	0.282(0)	-0.437(0)	-0.034(0)
H(32)	0.188(0)	-0.357(0)	-0.087(0)
H(33)	0.179(0)	-0.486(0)	-0.048(0)

Table S.22. Thermal Parameters for $(\mu\text{-H})_2Os_4(CO)_{13}PMe_3$

ATOM	U11	U22	U33	U12	U13	U23
OS(1)	3.33(4)	3.97(4)	3.18(4)	-0.03(3)	1.34(3)	-0.24(3)
OS(2)	4.20(4)	4.03(4)	3.52(4)	0.68(3)	2.00(3)	0.42(3)
OS(3)	3.81(4)	3.62(3)	2.99(4)	0.39(3)	1.54(3)	-0.03(3)
OS(4)	3.45(4)	3.71(4)	3.73(4)	0.41(3)	1.36(3)	0.03(3)
P(1)	7.3(3)	3.5(2)	5.9(3)	0.4(2)	3.6(3)	0.8(2)
C(1)	13.5(22)	6.9(14)	9.2(19)	3.4(14)	5.2(17)	3.6(13)
C(2)	9.5(18)	5.2(12)	15.0(26)	-0.6(11)	5.1(19)	-1.4(14)
C(3)	22.0(34)	5.4(13)	10.2(21)	-2.5(16)	8.4(23)	-1.8(14)
C(11)	4.6(11)	6.8(12)	5.9(13)	1.1(9)	1.9(10)	1.1(11)
O(11)	9.1(11)	11.1(11)	5.6(9)	0.3(9)	4.1(9)	-3.1(9)
C(12)	1.7(9)	5.6(10)	4.7(11)	0.7(7)	-0.5(8)	1.4(9)
O(12)	4.8(8)	8.3(9)	7.8(10)	0.0(7)	0.5(8)	1.0(8)
C(13)	4.1(9)	5.3(10)	3.6(9)	0.5(8)	1.8(8)	-0.2(8)
O(13)	7.2(9)	5.1(8)	8.1(11)	-2.2(7)	2.3(8)	0.0(7)
C(21)	3.2(9)	5.5(10)	4.9(11)	-0.9(8)	0.8(9)	-0.9(9)
O(21)	6.6(9)	8.3(9)	5.8(9)	2.3(7)	3.1(8)	0.3(7)
C(22)	5.0(11)	6.9(12)	8.3(16)	0.0(9)	5.6(12)	0.4(12)
O(22)	10.1(13)	17.0(17)	2.9(8)	-0.1(11)	1.7(8)	1.4(10)
C(23)	8.2(15)	6.5(12)	4.2(11)	0.2(10)	4.4(11)	-1.2(9)
O(23)	6.6(9)	13.3(13)	7.2(10)	4.0(9)	4.3(8)	0.8(9)
C(32)	4.4(9)	4.4(9)	4.3(10)	0.3(8)	2.3(9)	0.4(8)
O(32)	7.2(8)	5.6(7)	7.2(9)	2.5(7)	4.4(8)	-0.2(7)
C(31)	4.9(11)	5.9(11)	4.7(11)	0.6(9)	1.6(10)	-0.9(10)
O(31)	6.8(10)	10.8(11)	6.5(10)	-2.2(8)	1.0(8)	-4.3(9)
C(33)	5.3(12)	5.4(11)	5.4(13)	1.2(9)	1.6(10)	-0.4(10)
O(33)	10.7(12)	7.8(9)	6.2(10)	1.8(8)	5.1(9)	3.0(8)
C(41)	5.2(11)	6.3(11)	2.8(9)	2.3(9)	1.6(9)	0.4(9)
O(41)	6.3(8)	5.6(8)	7.9(10)	-0.5(6)	4.6(8)	0.9(7)
C(42)	5.4(11)	3.8(10)	5.8(12)	0.5(8)	-0.1(10)	0.6(9)
O(42)	9.5(11)	7.5(9)	10.1(13)	-0.1(8)	6.1(10)	-2.5(9)
C(43)	2.7(9)	5.7(10)	4.8(11)	1.0(8)	-0.9(9)	1.0(9)
O(43)	5.8(10)	13.7(13)	7.4(11)	-1.3(9)	-2.1(9)	4.0(10)
C(44)	4.3(10)	5.7(10)	1.7(8)	1.1(8)	-0.5(8)	-0.2(8)
O(44)	7.9(10)	7.0(8)	5.5(9)	-0.8(7)	2.8(8)	2.5(7)

TEMP=-2(PI)**2(U11*H*H*ASTAR*ASTAR+---+'2*U12*H*K*ASTAR*BSTAR+---)

THE UIJ VALUES HAVE BEEN MULTIPLIED BY 100.

Table S.23. Structure Factors for $(\mu\text{-H})_2Os_4(CO)_{13}PMe_3$

```
COLUMNS ARE 10FO,10FC,  10SIG

  L   KFO    FC   SIG
      -16,   0,  L
  2  1564  1559    30
  4  1022   956    40
  6  1430  1531    22
  8  2540  2687    28
 10  1156  1124    39
      -16,   1,  L
  2   862   887    38
  3  1112  1069    27
  6   695   674    38
  7  2068  1989    24
  8   831   865    43
  9  1650  1682    28
      -16,   2,  L
  3   752   704    29
  6   614   559    36
  7  1064   990    32
  8   742   636    47
  9   826   801    43
      -16,   3,  L
  4   705   767    30
  7   562   515    44
  8   726   753    45
  9  1096  1040    35
      -15,   0,  L
  1   605   556    52
  3   745   762    52
  5  1027   980    33
  9   986   982    44
 13  1665  1858    30
      -15,   1,  L
  3  1121  1121    24
  4   796   789    25
  5  1669  1650    15
  7   444   576    71
  9   776   870    46
 11   907   927    46
 12   868   903    50
      -15,   2,  L
  1   986   996    26
  2   751   715    29
  4  2154  2105    15
  5   818   801    25
  6  1669  1606    19
  7   879   760    36
 10  1186  1214    33
 11   610   498    52
 12   800   832    47
      -15,   3,  L
  2   802   799    27
  3  1251  1210    19
  5  1477  1479    17
  6  1118  1036    22
  7   547   546    45
```

```
  L   KFO    FC   SIG
  8   596   608    51
 10   695   730    51
 11   615   540    55
 12  1110  1091    36
      -15,   4,  L
  2   560   612    36
  4   359   362    50
  7   630   612    38
 11   819   826    48
      -15,   5,  L
  5  1131  1082    22
  7  1268  1190    23
      -14,   0,  L
  2   794   840    46
  4   573   567    52
  6  2230  2260    21
  8  1598  1748    32
 10   941  1076    39
 12  2612  2786    23
 14  1710  1798    26
      -14,   1,  L
  1   641   585    41
  4   740   740    24
  5  1208  1194    19
  7  1905  1881    23
  9   452   505    72
 11  1635  1765    30
 13  2040  2096    27
      -14,   2,  L
  3   910   909    21
  5   738   724    26
  6   475   438    47
  7   641   604    47
  8   560   531    56
 12   758   766    47
      -14,   3,  L
  1   539   543    36
  3   390   342    44
  5   900   917    23
  7   707   662    38
  8   981   851    33
 10  1039  1023    35
 13   645   669    56
      -14,   4,  L
  1   546   543    35
  3   589   563    31
  4   969   988    21
  5   919   949    23
  6  1174  1133    21
  8   422   408    62
  9  1701  1667    24
 10   630   561    53
 11  1424  1379    30
 12  1034  1057    39
```

```
  L   KFO    FC   SIG
      -14,   5,  L
  1   482   456    40
  3   854   845    24
  4  1442  1420    17
  5   806   821    26
  6  1206  1261    21
  8   596   599    46
 10  1702  1638    25
 11   808   813    44
      -14,   6,  L
  3   686   706    30
  4   471   422    42
  5  1587  1524    18
  7   570   516    40
  9   830   788    35
      -13,   0,  L
  5   644   715    33
 13   945   972    38
      -13,   1,  L
  1  1145  1117    25
  3  2501  2609    14
  4   737   748    22
  5  1448  1369    18
  6   798   723    37
  7  1260  1283    28
  9  2256  2307    24
 11   846   936    48
 13   618   694    58
 15   762   795    43
      -13,   2,  L
  1  1181  1189    20
  2  3004  3073    13
  4  3003  3040    12
  5  1571  1584    16
  7  1151  1099    30
  8  3056  3145    21
  9   579   572    53
 10  2350  2363    22
 11   974  1013    38
 14  1390  1413    34
      -13,   3,  L
  1  1319  1331    18
  2  1073  1102    19
  3  2759  2805    13
  4  1024  1025    19
  5  1311  1304    17
  6  1988  1967    17
  7  1450  1312    23
  9  2112  2082    23
 10  1688  1709    27
 11  1053  1042    34
 12  1540  1535    28
      -13,   4,  L
  1  1462  1407    16
```

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COLUMNS ARE 10FO,10FC,  10SIG

  L   KFO    FC   SIG
      -13,   4,  L
  2   698   639    25
  3   486   491    34
  4   763   748    23
  5   639   658    29
  7   720   657    33
  9   901   885    36
 11  1693  1640    27
 13   487   486    72
      -13,   5,  L
  1   426   445    41
  2   328   357    52
  3   756   725    24
  4   686   649    26
  5   689   718    28
  6   651   665    32
  8   461   488    53
  9   793   783    36
 11   787   834    45
      -13,   6,  L
  1  1151  1118    20
  2   694   683    28
  4   972   935    22
  5  1749  1688    16
  6   576   577    36
  7  1602  1564    19
  8   617   584    41
 10  1380  1359    26
 11  1220  1157    30
      -13,   7,  L
  2  1057  1027    22
  4  1100  1091    22
  5   678   570    32
  6  2276  2204    17
  7   594   588    41
  8   788   706    34
  9   400   344    64
      -12,   0,  L
 10  1403  1511    30
 12  1779  1822    24
 14   571   601    53
 16  1336  1445    29
      -12,   1,  L
  1   440   517    51
  2  1032  1083    22
  4   641   681    23
 11  1567  1605    31
 13  1317  1404    31
      -12,   2,  L
  1  1701  1666    15
  2   327   284    48
  3  1582  1635    14
  4   698   664    22
  5   414   403    43
```

```
  L   KFO    FC   SIG
  8   551   531    56
 12   905   938    40
 15  1070  1021    38
      -12,   3,  L
  2  1573  1634    15
  3  1171  1162    16
  4   580   548    27
  5   799   767    23
  9  1090  1092    32
 10   802   777    42
 11   470   506    66
 14  1231  1184    34
      -12,   4,  L
  1   855   863    22
  2  1204  1232    17
  3   360   316    43
  4  1079  1088    18
  5   613   609    29
  8  1318  1259    25
  9  1183  1107    29
 10  1429  1441    29
 11   980   905    38
 13   607   655    59
      -12,   5,  L
  1  1101  1122    19
  3  1077  1035    18
  4   803   769    23
  6   995   960    22
  7   915   887    26
  8   482   497    50
  9  1338  1243    24
 10  1112  1075    31
 11   787   771    43
 14  1057  1042    40
      -12,   6,  L
  2   570   580    31
  3   621   631    30
  5  1325  1291    19
  6   646   610    32
  7   407   427    52
  8   710   612    35
  9   783   764    34
 11   844   851    37
      -12,   7,  L
  3   603   621    32
  4   943   926    23
  5   815   749    27
  6  1065  1061    24
 10   599   601    47
      -12,   8,  L
  4   939   920    25
  5   957   893    25
  7   929   864    28
  8  1326  1195    24
```

```
  L   KFO    FC   SIG
      -11,   0,  L
  3   887   844    24
  7  1336  1340    23
  9   779   815    42
 11   516   498    59
 13  1368  1388    26
 15  1277  1297    28
      -11,   1,  L
  1  2651  2717    15
  2   514   475    31
  3  1742  1775     8
  4   243   105    37
  5  1384  1260    16
  6  1171  1154    18
  7  3267  3329    13
  8   945   968    36
  9  1959  2028    25
 11   796   898    52
 12   968  1029    40
 13  1967  2090    23
 14   840   772    37
 15   841   883    38
      -11,   2,  L
  1   675   703    25
  2  3584  3718    11
  3   736   722    19
  4   738   697    14
  5  2140  2070    11
  6  4107  3874    17
  7   886   880    34
  8  4371  4494    18
  9  1181  1273    30
 10   900   879    36
 11  1720  1722    26
 12  2342  2430    24
 14  2415  2474    26
 15   794   900    48
      -11,   3,  L
  1  1987  2018    13
  3  2049  2054    12
  4  2325  2395    12
  5   852   838    21
  6  1740  1646    18
  7  3514  3287    17
  8  1286  1295    28
  9  2383  2399    21
 10  2552  2608    21
 12   758   732    45
 13  1838  1778    26
 14  1681  1639    29
 15  1116  1042    37
 16  1810  1921    31
      -11,   4,  L
  1  1473  1467    15
```

```
COLUMNS ARE 10FO,10FC,  10SIG

  L   KFO    FC   SIG       L   KFO    FC   SIG       L   KFO    FC   SIG
     -11,    4,  L          2  1086  1123    23      15  1244  1262    36
  3   515   540    28       4  2950  3048    11          -10,    5,  L   
  4   797   760    21       6  1168  1160    24       1   842   839    20
  5  1146  1176    18      12   454   560    67       2  1249  1261    15
  8  1017   912    28      16  1351  1357    26       3   503   477    29
  9  1426  1380    26          -10,    1,  L          4   574   565    27
 10   871   815    39       1   302   328    37       5  1577  1554    15
 11   858   854    40       2  1194  1211    10       6  1275  1236    20
 13  1215  1128    32       3  1859  1881     7       7  1768  1714    18
 14   560   423    63       4   511   512    21       9   904   868    31
 15  2012  2023    28       5  1978  1909    13      10  1145  1151    29
     -11,    5,  L          6   333   391    50      13   954   948    39
  1  1803  1806    14       8   607   638    34      14   596   517    58
  2   932   914    19       9   538   587    42      15   806   809    47
  4   683   679    25      10   565   531    61          -10,    6,  L   
  5  1179  1218    19      13   733   719    43       1   519   477    30
  6   438   352    43      15   536   549    52       4   676   701    27
  7  1152  1142    23      17  1212  1196    29       5  1265  1220    17
 11   731   671    45          -10,    2,  L          6  1139  1072    20
 12   914   858    39       1  2374  2433     8       7   711   713    32
 13   633   593    56       2   774   792    12       8   487   508    47
 14   929   917    41       3  1807  1869     8       9   768   741    33
     -11,    6,  L          4  1470  1468     9      11  1454  1452    25
  2  1131  1128    18       5   310   371    43      13   570   586    56
  3  1697  1693    14       6   716   686    25          -10,    7,  L   
  4   844   837    23       7  1052  1036    20       3   663   624    27
  5  1938  1884    15       8   929   923    22       4   520   527    34
  6  1628  1585    17       9   713   724    41       5   721   695    27
  8   935   952    28      11   609   695    54       6  1066  1010    21
  9  1297  1270    24      12   622   675    59      10  1079  1139    28
 11  1830  1734    22      15   567   654    60      12  1247  1172    27
 12   474   398    63          -10,    3,  L              -10,    8,  L   
     -11,    7,  L          2  1955  2024     8       1   325   226    53
  1   459   516    39       3   866   843    11       2   587   623    32
  2   636   645    29       4   389   399    24       5   558   559    35
  3   461   448    38       5   404   336    27       6   777   773    28
  4  2327  2303    14       6  1022   935    16       8  1259  1219    23
  5   783   803    27       7   775   737    24      11   958   892    31
  6  1606  1621    18       8   759   740    38          -10,    9,  L   
  8  1012   933    26       9   858   887    36       1   575   566    35
 10  2554  2461    19      14  1182  1190    34       2   594   616    35
 11   763   732    39      16   774   751    52       3   544   476    36
 12  1118  1108    31          -10,    4,  L          4   719   686    29
     -11,    8,  L          1  1841  1892    12       5   611   607    35
  1  1250  1188    19       2   380   428    34       7  1734  1657    20
  2  1039  1022    22       3   468   504    29       8   558   485    46
  4   645   645    32       4   934   944    18           -9,    0,  L   
  5  1366  1376    19       5  1095  1093    18       1  2427  2493    15
  6   804   752    29       6  1561  1529    17       3  2641  2486    11
  7   618   580    38       7   994   945    25       5  1040  1086    23
  8   731   692    36       8  1745  1698    20       7  2657  2858    15
  9  1263  1213    25      11   701   721    47      11  3059  3200    19
 10   643   734    43      13   708   621    46      13  2597  2661    20
     -10,    0,  L         14   928   943    42      17  1820  1788    23
```

```
COLUMNS ARE 10FO,10FC,  10SIG

  L   KFO    FC   SIG       L   KFO    FC   SIG       L   KFO    FC   SIG
      -9,    1,  L          8  1582  1588    21       5   909   849    24
  1  1171  1211    15       9  1052  1043    30       6  1195  1204    22
  2  2147  2237    10      10  1352  1338    27       7   662   620    38
  3  1128  1184    12      11   790   764    40       8  1219  1190    25
  4   755   700    27      12   492   518    64       9   717   683    36
  5  3456  3427    16      13  1981  1945    23           -9,   10,  L   
  6  1909  1870    18      14  1356  1361    31       4   657   611    34
  7  2062  2098    20      15  1220  1176    34           -8,    0,  L   
  8  1490  1589    25           -9,    5,  L          2  3489  3498    17
  9   804   707    40       1  1537  1542    13       4  3889  4013    17
 10  1268  1342    33       2   388   367    33       6   487   547    62
 11  2615  2764    23       3  2469  2450    12       8  2405  2588    21
 12  2326  2430    23       5  3364  3377    12      10  1974  1980    21
 13  1627  1698    24       7   454   398    43      16   710   727    41
 14   576   639    50       8   574   599    41           -8,    1,  L   
 15   482   485    56       9  2310  2204    18       1  1681  1692    11
 16   986  1008    32      10   795   824    38       2  1233  1237    11
 17  1088  1113    31      11  1730  1693    24       3  3977  3998     9
      -9,    2,  L         12  1025   959    34       5  2106  2079    16
  1   424   360    27      15  1292  1232    33       6  1098  1088    23
  2   418   409    24           -9,    6,  L          7  1261  1301    24
  3   525   480    21       1  1534  1570    14       8  1424  1544    25
  4  3139  3091    11       2   556   554    28       9  2552  2624    22
  5   994   916    22       3  1598  1613    14      10   767   832    48
  6  4667  4640    15       4  3400  3435    12      11   677   676    48
  8  1748  1773    22       6  2472  2476    15      13   876   917    36
  9  1410  1410    25       7  1489  1376    18      14   665   701    42
 10  2396  2359    21       8   693   639    33      16   501   523    53
 11  1384  1453    30       9  1865  1835    19      17   816   808    37
 12  3533  3624    22      10  1971  1941    20           -8,    2,  L   
 14  1283  1403    32      11   727   800    41       1  1945  2017    10
 15  1262  1289    30      12   937   904    34       2  1273  1313    11
 16  1035  1029    33      13   813   793    41       3  1976  1995    10
      -9,    3,  L              -9,    7,  L          4  2162  2069    12
  1   388   159    29       2  1724  1753    14       5   901   844    23
  2  1668  1729    11       3  1485  1491    15       6   687   639    31
  3   386   437    29       4  1519  1477    15       7  2286  2277    17
  4  2300  2322    11       5  1672  1625    16       8  1362  1340    23
  5  2250  2158    13       6   369   359    50       9  2556  2631    19
  7  2574  2452    17       8  1992  2003    18      10  1320  1369    28
  8  2342  2337    19       9   824   752    30      11   632   630    50
  9   806   776    36      10  1733  1716    20      13   705   646    54
 10  1745  1725    23      11   449   443    59      14   595   526    54
 11  1720  1811    25           -9,    8,  L         15   832   801    38
 12   786   748    45       2  1150  1128    18      17   898   821    36
 13  2344  2348    24       3   401   397    42           -8,    3,  L   
 14  2115  2091    26       4   492   436    35       1  1606  1610    10
 16   895   923    44       5   672   678    29       2  1616  1670    10
      -9,    4,  L          6   724   747    30       4   548   504    23
  3  1843  1839    11       9   879   871    30       5  1010   985    19
  4  1609  1603    13      10   587   648    44       6  2258  2121    15
  5   775   800    22           -9,    9,  L          8  2310  2285    18
  6   555   490    34       1  1181  1124    20      15   475   379    73
  7   920   885    25       2  1719  1611    16           -8,    4,  L   
```

COLUMNS ARE 10FO,10FC, 10SIG

```
   L    KFO     FC    SIG
        -8,    4,  L
   1   1884   1908     11
   2   1971   2041     10
   3    276    199     40
   4   1222   1160     14
   5   1939   1911     13
   6    612    539     30
   7   1874   1841     17
   8    452    325     51
  10    649    684     44
  11   1085   1058     31
  12    733    782     44
  14    716    758     47
  15    788    796     47
        -8,    5,  L
   1   1366   1433     13
   2   1404   1424     13
   3   2136   2167     11
   4   1386   1358     14
   5   1945   1915     14
   6   1882   1854     15
   8    362    364     58
   9    977    950     29
  10   1645   1631     23
  11   1370   1365     27
  12    815    806     40
  13    839    912     40
  14    874    843     40
        -8,    6,  L
   1   1132   1132     15
   2    945    966     16
   4   1884   1888     14
   5   1633   1574     15
   6   1096   1093     20
   7    554    495     36
   8    424    387     50
   9   1479   1437     21
  10   1341   1358     24
  11   1873   1894     22
  12   1082   1090     30
        -8,    7,  L
   1    760    707     21
   2    794    787     21
   3    540    516     29
   5   1271   1237     18
   6    557    573     34
   7    459    494     46
  10   1212   1258     24
  11    825    739     32
  12   1222   1205     27
        -8,    8,  L
   2    479    439     33
   3   1036   1031     19
   5    439    446     41
```

```
   L    KFO     FC    SIG
  11    416    532     62
  12    550    525     50
        -8,    9,  L
   1    438    472     40
   3    441    317     39
   4    395    368     46
   5    639    649     31
   6    479    534     45
   7    851    803     29
   8    597    527     39
        -8,   10,  L
   1    576    552     35
   6    784    727     32
   7    623    569     41
        -7,    0,  L
   1   4603   4715     17
   3   2322   2425     15
   5   3044   3141     20
   7   2993   3158     18
   9   1552   1611     23
  11   3566   3754     18
  13   1540   1542     23
  15   1942   2106     21
  17   2879   2881     20
        -7,    1,  L
   1   1818   1863     10
   2   3112   3293      8
   3   3019   2961     10
   4    605    647     29
   5   1861   1845     16
   6   2408   2373     16
   7   1443   1446     23
   9   2277   2349     22
  10   2281   2327     24
  11   2063   2130     22
  12   1951   2111     22
  14    563    676     50
  15   1306   1301     25
  16   2186   2237     21
  17    905    919     34
        -7,    2,  L
   1    762    815     13
   2   3483   3585      8
   3    742    765     14
   4   3982   3833     11
   6    784    829     26
   8   1982   1942     18
   9    852    841     33
  10   3302   3283     19
  11    676    646     47
  12   1724   1741     27
  15   1082   1050     31
  16   1248   1240     28
  17    549    497     52
```

```
   L    KFO     FC    SIG
        -7,    3,  L
   1   2726   2859      9
   2   1079   1134     11
   3   1865   1878     10
   4    276    310     41
   5    706    710     23
   6    928    920     23
   7    461    477     45
   8    887    886     28
   9   1245   1228     24
  11   1840   1803     22
  12   1205   1206     30
  13   1267   1232     30
  14    937    854     38
        -7,    4,  L
   1   1564   1640     10
   2    338    320     29
   3    622    624     18
   4   2728   2768     11
   5    856    825     19
   6    533    519     32
   7    720    667     28
   8   1770   1743     19
  10   1017   1043     29
  11   1400   1352     25
  12   1074   1115     32
  13    982    942     34
  14   1887   1836     25
  15    767    661     45
        -7,    5,  L
   1    409    404     27
   2    498    513     23
   3   3941   4099     10
   4    704    706     20
   5   3077   3008     12
   6    599    584     29
   7   2532   2524     15
   8    929    914     26
   9   3820   3852     16
  10    601    611     47
  11   1161   1151     30
  13   2104   2021     23
  14    782    788     43
  15   1941   1876     26
        -7,    6,  L
   1   1218   1263     14
   2   2598   2643     11
   3    535    548     25
   4   4010   4068     11
   5   1942   1994     14
   6    440    473     41
   7   1865   1826     16
   8   3002   2995     15
   9    758    781     33
```

COLUMNS ARE 10FO,10FC, 10SIG

```
   L    KFO     FC    SIG
        -7,    6,  L
  10   2612   2592     18
  11    494    454     53
  13   1307   1286     29
  14   1609   1588     28
  15    827    780     44
        -7,    7,  L
   1    993    990     17
   2    900    886     18
   3   1881   1892     13
   4    652    671     26
   5   1257   1302     17
   6   1468   1492     18
   7    732    719     30
   8   1047   1025     23
   9   1679   1636     19
  11    897    869     31
  12   1130   1093     28
  14    902    883     37
        -7,    8,  L
   2    346    343     43
        -7,    9,  L
   2   1146   1203     18
   3    718    708     26
   4    545    544     34
   5    547    450     35
   6   1954   1903     17
   7    457    407     49
   8   1340   1330     22
   9    822    794     31
        -7,   10,  L
   1   2133   2097     15
   2    617    546     31
   4    544    579     39
   5   2383   2309     16
   7   2527   2464     18
   8    585    512     43
        -6,    0,  L
   2   2293   2136     12
   6   2097   2168     19
   8   3430   3591     17
  10   1013   1036     26
  12   1472   1524     23
  14   1051   1089     29
        -6,    1,  L
   1   2922   3007      8
   2   1998   2034      8
   3   2067   1928     12
   6   2262   2288     17
   7   2937   3039     17
   8   2670   2727     19
   9   2689   2742     21
  12   1980   2047     21
  13   1445   1484     25
```

```
   L    KFO     FC    SIG
  14   1587   1665     23
  15    534    533     50
  17    565    543     48
        -6,    2,  L
   1   1919   2009      8
   2   1353   1327      9
   3   1654   1688     10
   4   2198   2100     12
   5   2028   1971     14
   6    651    665     30
   7   4465   4480     14
   8   2247   2249     17
   9   1859   1867     20
  10   1902   1941     22
  11   1298   1327     29
  13   2673   2674     22
  14   1068   1044     31
  15   1312   1294     26
  16    590    466     45
        -6,    3,  L
   1   3006   3118      8
   2   1146   1188     10
   3   1303   1285     10
   4    985    949     15
   5   2932   2850     12
   6   3265   3118     14
   7   1324   1327     19
   8   2078   2096     18
   9   1362   1334     22
  10   1027   1040     28
  11   1094   1116     29
  12   2193   2164     21
  14   1490   1485     28
  15    865    846     41
        -6,    4,  L
   2   1787   1821      9
   3    645    623     16
   4   1719   1740     12
   5   2005   1892     13
   6   2797   2714     13
   7   1327   1281     18
   8   1089   1128     24
   9   1014   1051     28
  10    579    500     44
  11   1794   1739     22
  13    515    392     57
  14    606    488     51
  15    514    509     65
        -6,    5,  L
   1   2263   2318     10
   3   1238   1237     13
   4   1025   1053     16
   6   1190   1134     18
   7   1990   1994     16
```

```
   L    KFO     FC    SIG
   8   1093   1119     23
   9   1764   1703     19
  10   1432   1420     23
  11    721    723     42
  14   1362   1309     29
  15    545    469     61
        -6,    6,  L
   1   1016    997     14
   2   1254   1271     13
   4   1943   1955     12
   5    943    913     19
   6    475    415     37
   8   1963   1939     17
   9   1441   1525     22
  10   2187   2171     19
  11    981    993     31
  12    576    501     49
  13    745    741     43
  14    965    880     37
  15   1810   1762     28
        -6,    7,  L
   1   1315   1309     14
   2   1756   1775     13
   3   1226   1219     15
   4    679    639     23
   5   2102   2080     14
   6    371    372     48
   9   1578   1511     19
  10    833    878     31
  11   1518   1432     22
  12    472    410     55
  14    950    922     36
        -6,    8,  L
   1   1959   1955     13
   2    768    765     22
   3   2255   2266     13
   4    991   1008     20
   5    612    590     30
   6   1114   1121     21
   7    960    928     24
   9    496    534     44
  10    736    728     33
        -6,    9,  L
   1   1174   1198     18
   2   1613   1660     16
   4   1334   1280     17
   5    486    495     40
   7    481    457     45
   8    891    875     28
  10    477    460     50
  11    607    668     44
        -6,   10,  L
   2    532    526     34
   3    507    479     36
```

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   COLUMNS ARE 10FO,10FC,  10SIG                                               COLUMNS ARE 10FO,10FC,  10SIG

  L   KFO    FC   SIG     L   KFO    FC   SIG     L   KFO    FC   SIG     L   KFO    FC   SIG     L   KFO    FC   SIG     L   KFO    FC   SIG
      -6,   10,  L       10   808   786    33     8  1105  1095    23         -4,    1,  L        4  1061  1082    14     8  1351  1362    21
  5   593   472    36    14   798   794    42     9  1611  1547    19    13  1369  1319    23     5  2087  2093    12         -4,   10,  L   
      -6,   11,  L       16   577   532    50    10  1055  1047    26    14   911   869    29     6  1454  1427    15     1   523   582    34
  2   879   861    26         -5,    4,  L       13   880   856    36    15   672   617    36     7  1774  1775    16     2   738   757    26
      -5,    0,  L        1  1034  1104    11         -5,    8,  L       16  1081  1140    27     8   477   462    42     3   435   480    41
  1  5483  5395    14     2   988  1000    11     1   653   690    24         -4,    2,  L        9   416   207    52     4   493   475    39
  3  1040  1125    28     3   996   973    12     2   503   447    30     1  2705  2863     6    11   615   545    44     6  1318  1319    22
  5  1969  2039    19     4  2909  2852    10     3  1076  1098    18     2   999   984     9    12   795   756    37     7   694   667    34
  7  2263  2257    18     5   822   817    19     4   421   306    37     3  1287  1259    11    13   702   659    43     8  1142  1075    24
  9  1685  1731    19     6  1137  1108    18     7   968   932    23     4  1616  1538    13    15   625   552    53         -4,   11,  L   
 11  2211  2264    18     7   748   752    27     8   615   570    34     5  4286  4287    11         -4,    6,  L        1   486   521    40
 13   477   434    50     8  1022  1023    24     9   770   710    30     6   320   301    49     1   293   346    34     2   784   749    27
 15  2724  2670    18     9  1307  1312    22    10   685   675    35     7  3340  3343    14     2  1138  1189    12     6   713   662    34
 17  1800  1834    22    10  1024  1021    28         -5,    9,  L        8  2400  2479    17     3  1087  1080    14         -3,    0,  L   
      -5,    1,  L       12  1166  1126    28     1  1065  1052    18     9   822   812    31     4   807   826    17     1  3279  3099     7
  1  3142  3247     6    13   977  1007    34     2   614   610    28    10  1740  1731    22     5   829   767    20     3   879   873    36
  2  3495  3588     7    14  1330  1293    29     3   773   792    24    11  4009  4106    19     6   940   916    20     5  1722  1650    18
  3  3431  3292    11    15  1257  1248    33     4   912   898    22    12   882   867    38     8  2391  2500    16     7  2043  2046    17
  4   373   402    39         -5,    5,  L        5   358   372    52    13  2821  2767    19    10  1706  1625    21    11   625   634    35
  5  2381  2390    14     1  1064  1093    11     6  1638  1601    18    14  1589  1650    25    11   683   655    40    15   856   884    29
  6  1879  1830    17     2  1160  1231    12     7   554   553    39    16   727   750    37    12   763   712    38         -3,    1,  L   
  7  3549  3507    16     3  3122  3209    10     8   826   818    29         -4,    3,  L       13   924   935    37     1  1840  1844     5
  8   827   820    36     4  1374  1379    13    10  1058  1095    26     2  2130  2168     8    14  1894  1819    25     2  2847  2607     8
  9  1804  1825    24     5   400   344    35    11   799   759    34     3  5197  5232     8         -4,    7,  L        3  2128  2090    10
 10  1390  1402    25     6   787   806    22         -5,   10,  L        4  1071  1030    14     2  2116  2214    11     4   530   549    30
 12   638   665    42     7  2598  2562    14     1   624   635    29     5  3785  3657    11     3  2887  2917    11     5  3099  3084    12
 13  1481  1510    23     8   548   507    37     2   441   497    41     6  3190  3147    13     4   620   547    24     6  3412  3377    14
 14  1685  1671    21     9  3030  3074    16     3  1063  1049    21     8  1000   969    23     5  2056  2058    14     7  1985  2043    18
 15   907   859    30    10   654   654    42     5  2281  2267    17     9  2830  2882    16     6  1213  1200    18     8  1961  1929    21
 16  1873  1802    20    12  1039  1084    32     6   728   678    33    10  2569  2601    18     7   857   820    24     9   777   769    34
      -5,    2,  L       13  2580  2528    21     7  1334  1306    22    11  1468  1470    24     8   877   895    26    11  1708  1741    20
  1  2323  2414     7    14  1188  1170    31     9   955   966    30    12  2928  3010    20     9  2401  2422    17    13  1006  1038    27
  2  3379  3455     7    15  1328  1299    31         -5,   11,  L       13  1082  1057    33    11  1086  1043    27    14   569   551    41
  3  2272  2230     9         -5,    6,  L        3   451   421    45    14   930   882    37    13  1207  1223    29    16   527   532    46
  4  1062  1025    16     1   506   506    21     4  1347  1389    22    15  1392  1449    27    14   679   740    49         -3,    2,  L   
  5   304   321    49     2  2309  2365    10         -4,    0,  L       16  1300  1270    27         -4,    8,  L        1  2451  2505     6
  6  4189  4172    13     3  2733  2803    10     2  1720  1788    17         -4,    4,  L        1  3207  3349    11     2  1070  1094     9
  7   982   952    23     4  1236  1213    14     4  2160  2234    19     1   893   887    11     2   789   777    21     3  2856  2677     9
  8  3180  3218    16     5  2635  2607    12     6  1706  1724    18     2  2303  2360     8     3  1989  1984    13     4  6621  6625    10
  9   734   699    34     6  1642  1565    15    10   654   620    36     3   441   438    21     4  2579  2590    13     5   966   962    18
 10   736   787    39     8  3124  3128    15    12   797   784    33     4  4745  4713    10     5  1138  1120    19     6  3371  3502    13
 12  1061  1119    35     9  1240  1258    24    14   660   657    37     5   395   381    34     6  1192  1171    20     7  2566  2641    15
 14  1130  1155    29    10  1390  1381    23         -4,    1,  L        6  2489  2454    13     7  2154  2152    16     9  1268  1266    23
 15   548   536    49    11  1171  1236    28     1   313   297    17     7   776   753    26     8   991   966    25    10  2337  2386    20
 16   721   617    36    12  1335  1292    27     2  1170  1111     9     8   984  1001    24     9   679   684    33    11   718   695    44
      -5,    3,  L       13   766   779    42     3  1326  1300    13     9   497   511    45    10  1521  1483    21    12  1971  2065    23
  1  3425  3506     7    14  1800  1839    27     4  2238  2150    12    10  2427  2448    18    11   594   617    43    13   803   797    37
  2  1265  1235     9         -5,    7,  L        5  1641  1664    16    11  1147  1160    28         -4,    9,  L       16   388   234    62
  3   483   461    18     1   930   963    16     6  3489  3531    14    12   433   401    64     1  1082  1085    18         -3,    3,  L   
  4  1960  1864    11     2  1217  1302    14     7  1559  1566    20    13   501   494    60     2  2069  2152    14     1  1888  1875     7
  5  3315  3141    12     3   571   613    25     8  1047  1094    30    14   899   875    38     3   670   667    26     2  3340  3326     7
  7  2662  2600    14     4  2302  2287    13     9   685   763    43         -4,    5,  L        5  1548  1515    17     3  4451  4371     8
  8  1246  1276    21     6   512   456    35    10  1918  1987    20     1   772   787    13     6  1810  1874    18     4   877   874    16
  9   521   589    44     7  1476  1491    18    12  3023  3110    18     3  1424  1437    11     7   996   965    24     5  5044  4981    11
```

```
COLUMNS ARE 10FO,10FC,  10SIG

 L   KFO    FC   SIG
     -3,   3,  L
 6  1002   947    19
 7  1076  1099    20
 8  1505  1490    18
 9  1849  1840    18
10   604   586    41
11  1881  1930    21
12  1686  1673    25
13   453   488    68
14   713   775    45
     -3,   4,  L
 2  1352  1363     9
 3  1434  1375    10
 4  3032  2961    10
 6  1395  1383    16
 7   791   732    26
 8  1179  1187    22
10  1389  1429    23
11  1245  1184    25
13  1098  1104    31
14   664   604    47
     -3,   5,  L
 1   738   758    13
 2  1225  1231    10
 3  1039  1054    12
 4   317   351    37
 5   343   375    40
 7  1687  1690    16
 8   990   946    24
 9  1218  1195    23
10  1529  1483    22
11   625   586    45
12   988   972    32
13  1462  1405    25
15   780   706    44
     -3,   6,  L
 1  1875  1942    10
 2   350   345    29
 3  2379  2430    10
 4   486   462    27
 5   546   561    27
 6  1015   987    18
 7  1894  1865    15
 8  1234  1296    21
 9  2158  2153    17
11   978   976    31
12  1259  1242    27
14  1269  1219    30
     -3,   7,  L
 1  1652  1697    11
 2  2402  2530    11
 3  1201  1215    15
 4  1224  1238    16
 5   417   411    39
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 L   KFO    FC   SIG
 6  1278  1334    18
 7   726   756    28
 8  1980  1949    17
 9   615   579    37
10   507   477    46
12   810   811    36
13  1083  1061    31
     -3,   8,  L
 1  1357  1439    14
 2  1324  1349    15
 3  1383  1358    15
 5   641   624    30
 7  1394  1424    19
10   496   404    46
11  1227  1216    26
     -3,   9,  L
 1  1160  1153    17
 2   490   557    33
 5   622   569    33
 6   980  1021    23
 9   428   379    51
10  1365  1374    23
     -3,  10,  L
 1   375   388    43
 3   553   544    33
 5   689   725    33
 9  1238  1241    24
     -3,  11,  L
 1   956   939    23
 3   709   694    30
     -2,   0,  L
 2  8617  8290    14
 4  1059   972    26
 6  1823  1913    17
 8  2276  2287    15
10   572   511    36
16   388   432    60
     -2,   1,  L
 1  5862  5847     5
 2   731   684    13
 3  3244  3178     9
 4  3377  3308    10
 5   533   512    34
 6  1838  1798    16
 7  1492  1522    21
 8  1417  1451    26
10  3308  3458    16
12  1643  1787    20
13   665   712    37
14   934   924    27
15   792   775    31
16  2013  1982    20
     -2,   2,  L
 1  2087  2151     5
```

```
 L   KFO    FC   SIG
 3   952   885    14
 4   979   936    16
 5  3649  3658    11
 6   517   495    31
 7   378   271    46
 8  1795  1914    18
 9  3398  3407    16
10   914   912    32
11  3729  3835    20
12  1111  1090    28
14  1729  1694    21
15  2451  2417    18
16   412   413    60
     -2,   3,  L
 1  4047  4164     6
 3  4393  4312     8
 5  1530  1527    14
 6  1329  1251    16
 7  2684  2770    14
 8   765   765    28
 9  2816  2834    16
10  2996  3073    18
12  1894  1880    23
13  1762  1770    24
14   826   835    36
15  1118  1083    28
16  2248  2165    20
     -2,   4,  L
 1  1616  1575     8
 2  5672  5888     7
 3  2802  2848     9
 4  3068  3028    10
 5  1665  1690    13
 6  1424  1472    16
 7   852   844    24
 8  3375  3390    15
 9   450   374    49
10  1837  1825    20
11   564   589    47
12   812   754    37
13   647   612    45
14  1090  1077    33
     -2,   5,  L
 1  2138  2155     8
 2  2394  2458     9
 3  2639  2668    10
 4  4485  4517    10
 5   965  1001    17
 6  1075  1087    17
 7   365   341    46
 8  1949  2008    18
 9  1174  1127    24
10  2090  2088    20
11   893   863    33
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COLUMNS ARE 10FO,10FC,  10SIG

 L   KFO    FC   SIG
     -2,   5,  L
14   988   936    35
     -2,   6,  L
 1   449   448    21
 2   886   905    14
 3  2910  2927    10
 4   777   780    19
 5  1286  1258    15
 6  1773  1809    14
 7  1790  1869    16
 8  1933  1998    17
 9  2249  2262    17
11   814   784    34
12  1786  1726    23
13   735   687    43
14  1850  1694    25
     -2,   7,  L
 1  1776  1836    11
 2  1463  1419    12
 3  2200  2248    11
 6  2072  2151    15
 7  2194  2250    16
 8  1972  2010    18
 9  1842  1845    18
11   567   522    45
12   661   600    41
13  2068  1976    22
     -2,   8,  L
 1  2269  2366    12
 2  2018  1999    12
 4  2251  2228    13
 5  2353  2404    14
 7  2064  2119    17
 8  1737  1704    18
10  1186  1199    24
11  1106  1118    27
12   625   585    44
     -2,   9,  L
 1   412   413    36
 3  1414  1392    16
 4  2091  2065    15
 5  1938  1924    16
 6  2119  2123    16
 7   545   480    37
 9  1115  1186    25
10  1256  1227    24
11  1107  1081    27
     -2,  10,  L
 1   498   516    33
 2   843   833    22
 4  1472  1502    18
 5   755   739    29
 6  2000  2032    18
 8   503   565    47
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 L   KFO    FC   SIG
     -2,  11,  L
 1  1188  1168    19
 4   720   720    31
 5  1330  1302    21
 6   921   832    27
     -1,   0,  L
 1  1804  1500    14
 3   601   665    35
 5  2685  2720    14
 7  3539  3633    14
 9   969   992    22
11  1173  1188    21
13  1672  1713    19
     -1,   1,  L
 1   876   861     6
 2  2037  1957     7
 3  2367  2397     9
 5  2167  2198    14
 6  2383  2391    15
 8  2776  2860    18
 9  1318  1354    21
11  1222  1246    21
12  1464  1505    20
14   884   900    28
     -1,   2,  L
 1  1320  1245     6
 2  3186  3091     7
 3  1480  1436    11
 4  2998  2996    10
 5   834   819    19
 7  1856  1885    15
 8  2390  2394    16
 9  1205  1214    24
10  2792  2877    19
11  1072  1046    28
12   907   943    30
13  1067  1102    26
16   850   801    31
     -1,   3,  L
 1   482   502    13
 2  1553  1517     8
 3  3533  3495     9
 4  1039  1021    15
 5  2214  2247    12
 6   811   823    22
 7  1128  1072    19
 8   491   560    40
 9  2935  3028    16
11  1882  1898    22
12   928   962    36
15   842   861    33
     -1,   4,  L
 1  1059  1029     9
 2  1333  1346     9
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 L   KFO    FC   SIG
 3  1765  1767    10
 4  2607  2636    10
 5   883   878    18
 6   807   790    22
 8  1580  1572    18
 9   462   476    48
10  1891  1936    20
11   725   665    38
14   832   816    39
15   695   763    45
     -1,   5,  L
 1  1007  1050    11
 3   524   513    21
 4  1061  1008    14
 5   987   965    17
 6  1350  1314    16
 7   495   429    35
 8  1305  1321    21
 9  1042  1001    26
10   998  1018    29
13   669   655    44
14  1022   962    34
     -1,   6,  L
 1  1201  1256    11
 2  2028  2085    10
 3   528   533    22
 4   360   348    35
 5   624   632    24
 6  1448  1437    16
 7  1927  1901    15
 9  1170  1164    24
12   428   386    64
13   929   869    36
14   671   652    49
     -1,   7,  L
 1  3046  3234    10
 2   854   840    16
 3  1205  1238    15
 5  1193  1174    17
 6  1560  1594    17
 7  1060  1073    22
 8  1087  1087    23
12  1067  1035    30
     -1,   8,  L
 1   805   833    18
 2  1232  1283    15
 3   660   668    23
 6   754   751    27
 7   703   716    30
11  1015  1058    30
     -1,   9,  L
 1   528   576    29
 2   905   906    20
 4   606   567    31
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    COLUMNS ARE 10FO,10FC,  10SIG                                                   COLUMNS ARE 10FO,10FC,  10SIG

  L   KFO    FC   SIG     L   KFO    FC   SIG     L   KFO    FC   SIG         L   KFO    FC   SIG     L   KFO    FC   SIG     L   KFO    FC   SIG
      -1,    9,  L        6  1116  1191    18     6  1892  1993    15              1,    1,  L        7   469   432    44     4   894   963    28
  5   453   432    43     7  2577  2717    14     7  1166  1241    21         6  2202  2142    17     8   428   350    52     5  1094  1104    25
 10   849   839    33     8   699   792    30     8  1357  1424    21         8  1588  1542    19     9  1606  1576    22            2,    0,  L
      -1,   10,  L        9   466   453    45    10   782   772    32         9  1359  1356    20    10   787   777    36     0  8221  7792    13
  2   540   581    33    10   587   616    41    11  1494  1479    23        10   937   995    27    12  1225  1208    28     2  2026  1965    15
  3   837   835    24    11  1425  1430    25    12  1458  1506    26        11   921   950    25    13   797   757    40     4  8891  9161    12
  6   447   424    47    12   444   350    63           0,    8,  L          12  2360  2402    16    14   854   870    39     6  5608  5646    13
      -1,   11,  L       13  1321  1295    26     0   866   883    16        14   834   868    28           1,    6,  L        8  1140  1108    20
  1  1208  1246    20    14  1469  1427    23     1   877   883    17        15   602   591    38     0  2952  3082     6    10  3554  3679    14
  2   964   966    23           0,    4,  L        2   888   911    18              1,    2,  L        2  1008   956    14    12  1341  1349    20
  3   472   397    42     0  5481  5980     6     3  1935  1971    13         0   444   442     7     4  2487  2417    13    14  1347  1286    21
  4  1088  1087    24     1  2465  2637     7     5  1753  1775    15         1  1300  1259     8     5   473   418    34           2,    1,  L
  5   533   510    42     2  2643  2721     8     6   866   905    24         2   435   348    26     6  2222  2227    15     0  2238  2278     3
       0,    0,  L        3  4518  4713     9     8  1028  1024    24         3  1606  1598    12     7   880   888    25     1  2024  1896     9
  2  5485  5290     8     4   795   844    16     9  1086  1109    24         4   679   665    22    10   859   845    32     2  1564  1553    12
  4  4456  4731     9     5  1908  1966    13    10   365   250    60         6   573   526    32    11   828   841    35     3  4354  4305    11
  6  6789  7297     9     6  3898  4022    13    11   916   938    30         7  1561  1525    18    13   933   938    39     4  1898  1799    15
  8  1983  2132    11     7  1772  1717    16           0,    9,  L           8  2020  1916    18           1,    7,  L        5  6171  6169    14
 10  1941  2042    11     8  2271  2385    16     1   292   231    47         9  1149  1140    26     0   922   925    10     6  2276  2214    17
 12  1451  1485    13     9  1839  1868    18     2  2086  2145    13        10  1876  1897    21     1  2538  2565    11     7  1514  1553    21
 14   525   463    28    12  1320  1359    27     3  1076  1068    19        11  1031  1038    27     3   739   693    21     8   730   701    31
       0,    1,  L       13   872   804    36     4  2167  2180    15        13  1169  1245    23     5  2678  2823    13     9  2937  2825    16
  1  7382  7611     5    14   538   510    55     5  1179  1243    20        14  1009  1009    26     6   474   504    38    10  1411  1494    19
  2  2153  2226     7           0,    5,  L        6   486   492    39              1,    3,  L        7  1635  1683    18    11  2110  2207    17
  3  1178  1246    12     1  2630  2779     8     8  1195  1171    22         1  1255  1154     8     8   513   557    43    12  1510  1483    19
  4  1820  1888    12     2  5127  5581     8     9  1561  1596    21         2  3007  2815     9    11   579   510    45    14  1070  1035    24
  5  5064  5352    12     3   953   938    14    10  1138  1145    26         4   951   968    17    12   544   591    54           2,    2,  L
  6  1496  1566    18     4  3966  4154    10           0,   10,  L           6   477   346    37           1,    8,  L        0  1764  1771     4
  7  3412  3559    16     5   993   987    16     0  2043  2105    13         7  1291  1211    20     0  2248  2339     8     1  1358  1283    10
  8  2659  2873    17     6  1471  1532    16     1   482   493    33         8  1301  1243    21     2   856   904    19     2  1203  1175    14
  9   625   743    33     7  1450  1480    18     3   874   859    23         9  1888  1821    20     3  1213  1203    17     3  1234  1138    15
 10  1948  2024    17     8  4026  4106    15     4  1910  1930    17        11   967   931    30     4  1049  1080    20     4   753   720    22
 11  1618  1585    19     9  1139  1138    25     6  1554  1551    19        13   766   787    36     5   671   639    29     5  3233  3195    14
 12   649   623    34    10  1649  1620    22     7   595   589    37        15  1099  1074    27     6  1711  1748    17     6  1624  1568    18
 14  2022  2033    13    12  1578  1532    25     8   715   720    33              1,    4,  L        8   705   706    32     7  2001  1960    18
 15   833   826    22    14  1812  1732    25           0,   11,  L           1  1065  1091    10     9   371   314    58     9  1246  1199    25
       0,    2,  L              0,    6,  L        1  1104  1121    20         2   578   542    17           1,    9,  L       10   632   649    39
  0   790   724     6     0   495   504    17     2   628   610    31         3  3364  3332    10     1   932   976    19    11  2377  2363    18
  1   806   796     8     1  2211  2293     9     3   759   798    29         4  1390  1352    14     2  1310  1311    16    13  1860  1811    18
  2   339   259    24     2   378   349    26     4   855   806    28         5  1883  1829    15     3   351   326    48           2,    3,  L
  3   691   685    18     3  2785  2904    10     5  1670  1662    20         8  1431  1462    21     4  1299  1257    18     0  1008   982     6
  4  1133  1155    14     4   740   743    19           1,    0,  L           9   858   900    29     7   721   743    31     1  1939  1924     8
  6   549   599    28     5   447   465    31     3   998   945    23        10  1580  1559    22     9   454   485    53     2  1971  1879    10
  7  2605  2754    14     6  1042  1051    18     5  2500  2536    14        11   954   992    31           1,   10,  L        3  3360  3213    11
  9  2371  2551    18     7  3228  3414    14     7  2879  2880    14        13   723   710    41     0   599   609    20     4  2499  2401    13
 12   725   672    34     9  2167  2256    18    11  2604  2689    15        14  1012   993    32     1  1012  1018    20     5  1872  1863    15
 13  2180  2162    18    10  1376  1427    24    13  2070  2110    17              1,    5,  L        3  1364  1370    18     6   454   381    41
 14   836   833    31    11   980   996    31           1,    1,  L           0   205   253    25     4   605   615    34     8  1095   988    25
 15  2537  2451    17    12  1554  1502    24     0   764   750     4         1  1365  1375    10     6   499   449    41     9  1602  1644    22
       0,    3,  L       13  2222  2169    23     1   617   576    13         2   950   927    13     7   499   556    44    10  1483  1491    23
  1  2506  2611     6           0,    7,  L        2   920   894    14         3  1411  1310    13           1,   11,  L       11   770   761    36
  2  1351  1356     9     1   934   994    14     3   583   479    26         4  2062  1939    12     0   546   554    24    12   835   859    34
  4  1836  1819    11     4   723   755    22     4   646   585    28         5  1740  1648    15     1   968  1049    23           2,    4,  L
  5  2481  2567    12     5  1349  1394    16     5  1396  1332    19         6  1244  1204    19     2  1585  1663    18     0  2470  2509     5
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COLUMNS ARE 10FO,10FC,  10SIG

  L   KFO    FC   SIG        L   KFO    FC   SIG        L   KFO    FC   SIG
       2,  4,  L                   2,  9,  L                   3,  3,  L
  1  3200  3166     8        0  2274  2376     9        0  1317  1338     6
  2  2326  2223    10        1   976  1061    19        1  3271  3115     9
  3  3413  3341    11        2  1941  2013    14        2  3163  3131    10
  4  3924  3898    12        5   704   703    29        3  1869  1781    14
  5   639   620    30        6  1329  1318    20        4  1521  1487    16
  6  2299  2244    16        8  1090  1097    25        5   480   451    40
  7  3275  3113    16        9  1121  1154    27        6   965   941    24
  8   503   429    47             2, 10,  L             8  2194  2082    19
  9  1861  1868    20        0  1478  1566    11        9   746   755    35
 10  1289  1280    25        1   866   848    22       10   862   853    33
 12   768   719    37        4  1533  1494    18       12   687   693    38
 13  1252  1198    27        5   652   676    33       13   794   755    32
       2,  5,  L             6   578   605    38             3,  4,  L
  0  2405  2473     6        7   638   639    37        0  1756  1766     6
  2  4584  4600    10             2, 11,  L             1  2292  2315     9
  3  2002  1962    12        0   822   844    18        2  1992  1939    11
  4  1449  1418    15        1   506   506    38        3  3138  3160    12
  5  2097  2055    14        2   867   852    26        4   801   736    23
  6  3271  3236    15        3   995   961    25        5   762   708    28
  7  1157  1108    24             3,  0,  L             7  2006  1972    19
  8  3372  3365    17        1  2195  2085    17        8   695   694    37
 12  2440  2300    20        3  1328  1297    18        9  2308  2304    19
       2,  6,  L             5   465   345    37       11   956   925    31
  1  2427  2399    10        7   718   726    26       12   636   524    42
  2   577   515    22        9  2099  2101    16       13   479   430    61
  3  1686  1598    14       11  2071  2086    16             3,  5,  L
  4   652   597    25       13   753   706    29        0  1290  1326     7
  5  1694  1640    16             3,  1,  L             1   267   159    37
  6   770   774    28        0  2564  2555     5        2  1487  1418    13
  7  2761  2844    16        1  3300  3206    10        4  1153  1131    17
  8  1211  1216    23        2  1091  1062    18        5   349   326    50
 10   813   859    35        3  3478  3267    12        6   604   574    36
 11  2098  2048    22        4   458   338    40        8  1402  1400    24
       2,  7,  L             5   692   615    32        9   794   814    36
  0  1394  1411     8        7   750   693    30       10  1464  1431    24
  1  1120  1081    15        8   444   502    47       12   543   577    53
  2   486   539    30        9   737   724    31             3,  6,  L
  3  1893  1887    14       10  1400  1445    20        0   410   388    17
  4   462   430    36       11   660   711    33        2   503   460    27
  5   729   714    26       12  1199  1258    22        3   674   665    24
  6   845   848    25             3,  2,  L             4  1687  1610    15
  7  1003  1011    23        0  1983  1913     5        5   459   425    40
  9  1430  1396    22        1   676   651    19        6  1084  1076    22
 10  1180  1160    25        2  3738  3528    11        8   561   567    42
 11   476   510    57        3  1360  1315    15       10   705   726    40
       2,  8,  L             6   939   898    25       11   619   601    48
  1  2504  2648    12        7  1211  1176    23             3,  7,  L
  2  1440  1493    15        8   478   361    49        0   545   555    16
  3  1089  1064    19        9   472   500    53        1   292   342    44
  4   970   956    21       10  1096  1177    26        2  1410  1359    15
  5   660   603    29       11   813   803    30        3  1833  1766    15
  7  1212  1210    21       13   846   918    29        4  1229  1240    18
  9   882   930    30       14  1119  1065    24        5  2563  2638    15
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COLUMNS ARE 10FO,10FC,  10SIG

  L   KFO    FC   SIG        L   KFO    FC   SIG        L   KFO    FC   SIG
       3,  7,  L             3  2996  2943    13        8   694   631    36
  7   924   911    27        4   672   673    30        9   776   744    36
  8  1035  1023    26        5  2209  2105    16       10   555   413    46
  9   828   890    33        6  1807  1700    18       11  1622  1596    25
 11  1064  1059    31        7  1025  1015    27             4,  7,  L
       3,  8,  L             9  2952  2916    18        0  1793  1798     8
  0  1244  1305    10       10  1206  1156    23        1  2665  2633    12
  1   795   762    20       11  1583  1608    20        3  1499  1575    16
  3  1948  1963    15       12   564   563    39        4   763   767    26
  4  2167  2231    16             4,  3,  L             5  1121  1124    21
  5   733   718    29        1  4316  4206    10        6   702   741    32
  6  2072  2076    17        2  2426  2352    12        7  1935  1959    19
  7   876   867    28        3  3321  3202    13        8   465   407    51
  9  1128  1115    27        4  2086  1960    16        9   554   506    47
 10  1230  1216    26        5   755   780    29       10   697   681    40
       3,  9,  L             6  1195  1220    23             4,  8,  L
  1  1047  1063    18        7  2427  2357    18        0  2281  2326     8
  2  1227  1211    18        8  2598  2588    18        1  1390  1447    15
  4  1079  1048    21        9   980  1051    30        2  2269  2359    14
  5  1293  1299    21       10  1415  1413    24        3  1274  1265    20
  7  1064  1086    25       13   759   701    34        5  2165  2236    16
  8  1088  1058    26             4,  4,  L             6  1413  1442    20
       3, 10,  L             0  2487  2547     6        7  1100  1079    25
  0   363   334    32        1  2090  2097    11        8   760   768    34
  1   595   655    31        2  4386  4318    11             4,  9,  L
  2   640   603    29        3  1184  1143    17        0  2048  2090     9
  3   680   634    30        4  2301  2225    15        1  1646  1692    16
       3, 11,  L             5  1415  1341    20        3   351   349    52
  0   739   742    19        6  1070   990    26        4  1634  1665    19
  2   813   814    28        7  2789  2846    18        5   663   677    33
  3   691   676    33        8  1987  1966    20        6  1348  1316    21
       4,  0,  L             9   957   903    30             4, 10,  L
  2  5129  4920    13       10   678   694    40        0   988  1044    14
  4  4662  4567    13       11  1002   930    29        3   566   576    37
  6  1248  1223    19             4,  5,  L             4   564   527    37
  8  2536  2410    15        0  1916  1960     7        5   574   606    39
 10  2731  2755    15        1  2247  2180    11             4, 11,  L
 12   436   380    46        2  1896  1847    13        0  1099  1058    15
       4,  1,  L             3  2309  2294    13             5,  0,  L
  0  1455  1422     6        4   533   558    34        1  3062  2985    16
  1   706   690    24        5   905   932    25        3  1578  1522    18
  3  3561  3493    13        6  2161  2227    17        5  3074  3071    15
  4  2016  1916    17        8   865   856    33        7  2772  2714    15
  5  2555  2509    17        9   786   819    36        9   476   458    41
  6   815   793    32       10  1212  1172    26       11   563   564    36
  7   560   453    40       11   451   485    62       13   927   886    26
  8  1954  1845    18       12  1820  1702    23             5,  1,  L
  9  2534  2678    16             4,  6,  L             0  3616  3690     6
 10  1726  1685    18        1   969   984    16        1  2926  2807    13
 11  1478  1516    19        2   560   517    28        2   481   365    36
 12   602   601    36        4   369   280    46        4  2670  2521    16
       4,  2,  L             5   998   990    21        5  2192  2175    18
  0  1825  1870     5        6  1268  1351    22        6  2458  2411    18
  2  1734  1704    13        7   684   634    35        7   886   868    28
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    COLUMNS ARE 10FO,10FC,  10SIG

  L   KFO     FC    SIG        L   KFO     FC    SIG        L   KFO     FC    SIG
       5,    1,   L            6   455    370     48        3  1637   1587     18
  9   539    613     40       10   507    470     54        4   948    916     25
 11   480    509     43              5,    7,   L           6  1523   1497     23
 13   561    560     39        0   984    961     11        7  2185   2298     20
       5,    2,   L            1   531    503     29        9  1666   1675     21
  0  4765   4809      6        2  2312   2318     14       10  1033   1045     26
  1  1436   1296     15        3  1107   1077     20       12   681    668     36
  2  1943   1856     15        4   864    874     25              6,    3,   L
  3  2661   2545     15        5   962    959     25        0   516    511     14
  4  1827   1777     17        6  1209   1238     23        1  4312   4192     12
  5   846    834     28        8  1276   1251     25        2   888    862     24
  6  2263   2174     18        9  1222   1204     26        3   988    948     25
  7  1046   1028     28              5,    8,   L           5  2384   2275     17
  9   695    706     38        1  1141   1201     18        6  1919   1972     19
 10  1015    976     25        2  1324   1315     18        7  1893   1898     21
 11   477    519     46        3  1581   1548     17        8  1901   1803     20
       5,    3,   L            4  1833   1843     17       11  1136   1123     27
  0  1743   1818      6        6   727    710     32              6,    4,   L
  1  4160   3932     11        7  1470   1514     22        0  3643   3700      7
  2  3211   3177     13        8  1064   1130     29        1   380    344     40
  3  1170   1121     20              5,    9,   L           2  2156   2114     14
  5  1886   1779     19        0   446    473     26        4  1053    949     26
  6  2641   2553     17        2   506    542     39        5  1003   1005     27
  7  1326   1376     23        3  1305   1307     20        6  2006   2033     20
  8  2029   2014     19        5  1327   1302     22        7  1302   1304     25
 12  1573   1597     23              5,   10,   L           8  1295   1238     25
       5,    4,   L            0   553    583     23       11   895    979     37
  0  2148   2187      6        1   605    625     33              6,    5,   L
  1  2577   2501     12              5,   11,   L           0   478    454     17
  2  3216   3101     12        0   701    662     21        1  1643   1588     15
  3  1049    995     20        1   384    302     51        5   783    741     31
  4   773    752     29              6,    0,   L           7  1041   1035     30
  5  1929   1880     19        0  2160   2133     19        9   650    612     42
  6  1172   1249     25        2  1664   1662     18       10   510    453     52
  7  2706   2704     18        6  1385   1354     20              6,    6,   L
  8  1103   1155     27        8  1543   1517     18        1   460    412     35
  9  1300   1292     25       10  1165   1128     21        3   546    572     34
 11   685    667     42              6,    1,   L           4   450    514     46
       5,    5,   L            0   363    389     23        5   784    810     30
  0   896    948     10        1  1031   1036     21        6   408    436     58
  1  1146   1108     15        2   818    817     26        7   429    424     59
  3  1931   1922     16        3   657    625     34              6,    7,   L
  4   812    763     26        4   812    816     31        0  1116   1123     11
  5   415    382     50        6   881    878     30        1  1912   1926     14
  6  1467   1475     22        7   747    740     31        2   952    962     22
  7   907    899     32        8  1462   1471     20        4  1843   1930     17
  8  1107   1141     28        9  1316   1285     20        5  1567   1520     19
  9   422    432     62       10   493    538     42        6  1177   1140     24
       5,    6,   L           11   815    805     29        7  1016   1009     29
  0   693    677     13       12   791    849     30        9   473    534     60
  1  1524   1491     14              6,    2,   L                  6,    8,   L
  2   582    545     30        0   658    685     12        0  2129   2156      9
  3  1669   1599     16        1   805    746     24        1   466    511     38
  5   507    514     41        2  1618   1581     18        2  1030    984     22
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    COLUMNS ARE 10FO,10FC,  10SIG

  L   KFO     FC    SIG        L   KFO     FC    SIG        L   KFO     FC    SIG
       6,    8,   L            8   747    671     36              8,    0,   L
  3  2263   2347     16       10  1142   1135     29        2  2386   2414     18
  4  1047   1059     25              7,    4,   L           4  1721   1722     19
  5  1732   1800     19        0  2254   2279      8        6   516    534     41
  6  1514   1525     21        1   941    887     21       10   398    310     55
       6,    9,   L            2  2465   2469     15              8,    1,   L
  0   335    355     34        3  1479   1351     20        0   664    682     19
  1  1114   1080     20        5  2545   2475     18        1  1169   1133     22
  2  1345   1397     20        6  2335   2402     20        3  1904   1798     20
  4  1492   1452     20        7  1105   1103     28        6   591    575     40
  5   842    843     31        8  1452   1355     23       10   600    578     38
       6,   10,   L            9   708    708     40              8,    2,   L
  0   825    860     18              7,    5,   L           0   567    589     18
  1   546    531     38        0   285    195     30        1   628    600     35
  2   584    559     39        1  3241   3097     14        2  1271   1207     22
  3   496    505     45        2  1324   1265     19        6   851    907     34
       7,    0,   L            3  2294   2351     16        7   719    712     38
  1   403    478     58        4  1314   1340     22       10   672    786     37
  3  4534   4495     15        5   936    916     29              8,    3,   L
  5  4155   4005     15        6   812    806     35        0  1586   1607      9
  9  1967   1966     17        7  2038   1993     21        1  1692   1602     19
 11  2173   2193     18        9   648    622     44        2   718    663     35
       7,    1,   L                  7,    6,   L           3   674    623     38
  0  2446   2496      9        0   768    792     14        5  1538   1534     22
  1   983    971     23        1  1913   1920     15        7  1052   1026     28
  2  2390   2357     17        2  2353   2435     15        9   502    452     53
  3  2164   2071     18        3  1101   1045     22       10   635    683     44
  4  4361   4269     17        4   826    834     29              8,    4,   L
  5  1742   1623     22        5   419    394     56        0  1368   1338     10
  6  1429   1421     22        6  1018    988     29        1  1607   1543     17
  8  1097   1176     24        7   542    456     48        2   587    610     39
  9   640    712     35        8   721    658     39        4  1492   1480     23
 10  1798   1778     19              7,    7,   L           6  1467   1399     23
       7,    2,   L            0  1608   1646     10              8,    5,   L
  0  1427   1440      9        2   994   1029     23        0  1676   1699     10
  1   764    705     28        3   421    512     50        1   490    570     39
  2  1709   1637     18        4   769    765     31        3  1204   1165     23
  3  2011   1849     17        6  1420   1393     23        4  1207   1235     24
  4  2592   2566     18        8   530    550     51        5  1142   1123     26
  6   744    646     34              7,    8,   L           7   598    534     46
  7   881    872     32        0   871    878     15        8   567    538     49
  8   721    717     37        1   512    540     38              8,    6,   L
  9   763    755     33        2  1166   1159     22        0   395    400     27
 10   674    641     36        4   470    420     48        1   366    126     51
 11   407    282     55        5   792    779     32        2   813    893     28
       7,    3,   L            6   784    753     35        3  1265   1334     22
  0  1788   1812      8              7,    9,   L           5  1330   1338     24
  1  1367   1254     17        0  1188   1195     13        8   521    417     52
  2   391    430     54        1   997   1042     24              8,    7,   L
  3   638    649     37        3  1070   1096     25        1   949    892     23
  4  1796   1779     20        4   437    472     54        2  1317   1332     21
  5  1914   1975     19              7,   10,   L           4  1700   1680     19
  6  2053   2067     20        1  1316   1321     22        5   647    668     40
  7  1024   1023     29        2   386    415     59              8,    8,   L
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    COLUMNS ARE 10FO,10FC,  10SIG

L   KFO    FC    SIG      L   KFO    FC    SIG      L   KFO    FC    SIG
    8,  8,  L             1  3159  3251     15      1   858   885     30
0   568   615     22      2  1463  1462     20      2   807   768     34
1  1252  1200     20      3   770   787     33      3   611   623     45
3  1668  1620     19      4   557   474     45      4   693   691     38
4   831   804     31      5  1945  1957     22      5   922   947     33
5   681   685     40      7  2006  1966     22         10,  5,  L
    8,  9,  L                 9,  6,  L             0  1023  1045     15
0   722   749     20      0  2533  2609      9      1  1271  1358     22
2   918   944     28      1   560   520     38      2   495   550     49
    8, 10,  L             2  2351  2328     17      3   902   875     30
0   591   597     26      3   437   486     55      4  1079  1097     28
    9,  0,  L             5   494   441     50         10,  6,  L
1  1911  1866     20      6  1461  1440     25      0   933   946     16
3  4373  4586     15          9,  7,  L             2  1045  1084     26
5  1376  1449     22      0   334   376     35      3   897   975     30
7  1743  1881     20      1  1137  1146     23         10,  7,  L
9  3176  3227     17      2   949   962     26      0   334   234     37
    9,  1,  L             3  1016  1050     26      1   723   733     33
0   590   618     24      4   925   986     30      2   769   746     32
1  1908  1868     19          9,  8,  L                11,  0,  L
2  3012  2980     18      0   947   932     16      1  1871  2026     21
3   881   832     32      1   697   648     32      3  1651  1664     19
4  2671  2707     20      3   494   409     47      5   784   876     32
7   664   711     35      4   931   919     30      7  2454  2590     18
8  2301  2422     18          9,  9,  L                11,  1,  L
    9,  2,  L             0  1413  1363     14      1   622   586     45
0  2486  2507     10      1   810   793     31      2  1389  1444     24
2  2470  2371     18         10,  0,  L             3   858   905     36
3   453   468     52      0  1929  1902     22      4   614   588     43
4   592   540     43      2  2446  2518     18      5   980   975     28
7   648   591     40      4   721   808     34      6  1301  1377     24
8   577   513     43      6   439   604     52         11,  2,  L
9   571   580     43      8   719   759     35      0  2491  2588     11
    9,  3,  L                10,  1,  L             1   808   912     35
0   321   270     33      0   940   979     19      4  1088  1083     29
1   685   648     37      1  2412  2498     18      6   680   584     42
2  1874  1912     19      3  1410  1401     25         11,  3,  L
3   796   762     33      4   704   618     41      0  2126  2150     11
4  1512  1483     22      7   618   674     40      1   530   468     50
5   758   744     36         10,  2,  L             2  1736  1719     21
7   605   601     44      0  1296  1243     13      4   412   430     63
8   961   939     32      1   769   834     32      6  1408  1414     26.
    9,  4,  L             2  1566  1590     22         11,  4,  L
0  2088  2159      9      3   799   804     34      0   677   738     21
1  1802  1807     18      5  1037  1050     30      1  2202  2299     19
2  1343  1355     23      7   900   864     32      4   967   881     31
3  2211  2253     19         10,  3,  L             5  1457  1491     25
4   918   892     32      0  1754  1803     11      6  1224  1221     28
5   469   436     56      1   552   471     45         11,  5,  L
6  2076  2081     20      4   925   951     31      0   978   945     16
7  1081  1061     30      5   773   783     36      1  1354  1351     22
8   962   947     33      6   961   942     31      3   555   506     44
    9,  5,  L                10,  4,  L             4   738   797     40
0  1262  1280     12      0   903   894     15      5  1783  1766     23
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    COLUMNS ARE 10FO,10FC,  10SIG

L   KFO    FC    SIG      L   KFO    FC    SIG      L   KFO    FC    SIG
   11,  6,  L                12,  3,  L                13,  3,  L
0  1961  1971     12      0   856   870     19      0  1603  1626     14
1   983  1048     27      1   808   859     35      1   435   578     65
2   967   950     28      2   764   730     37      3  1119  1135     30
3   799   809     34      3   429   350     60         13,  4,  L
4   822   843     34      4  1603  1683     24      3  1117  1105     29
   11,  7,  L                12,  4,  L                13,  5,  L
0  1327  1303     14      0   506   448     27      2   804   857     36
1  1293  1275     23      3   839   781     35         14,  0,  L
2  1166  1226     26         12,  5,  L             2   626   643     42
   12,  0,  L             0   471   454     29         14,  1,  L
0   977  1012     32      1   565   598     44      0   608   679     34
2  1243  1342     25         12,  6,  L             2  1072  1063     33
6   838   862     32      0   888   883     18         14,  2,  L
   12,  1,  L                12,  7,  L             1  1201  1255     29
1  1127  1131     28      0   399   376     38      2   472   462     61
2   655   785     46         13,  0,  L                14,  3,  L
3   797   853     39      3   699   784     38      1   723   742     42
4  1084  1063     28         13,  1,  L                14,  4,  L
6   593   641     43      1   724   742     40      0   434   416     36
   12,  2,  L             3  1269  1327     26         15,  1,  L
0   829   852     21         13,  2,  L             0  1115  1159     23
2  1032  1068     29      1   823   858     36         15,  2,  L
3  1603  1565     23      2  1469  1544     25      0   975  1011     22
5  1673  1706     25      4  1286  1348     29
```

Table S.24. Fractional Coordinates for $Os_4(CO)_{13}PMe_4$

ATOM	X	Y	Z	BISO
OS(1)	0.72624(6)	0.06807(9)	0.16526(7)	2.11(5)
OS(2)	0.81211(7)	0.08846(10)	0.35340(7)	2.91(5)
OS(3)	0.84245(7)	0.28599(10)	0.24489(7)	2.76(6)
OS(4)	0.66698(7)	0.26834(10)	0.25142(8)	2.92(6)
P	0.7071(4)	-0.1526(6)	0.1181(5)	2.8(4)
C(1)	0.726(2)	-0.272(2)	0.197(2)	3.3(5)
C(2)	0.591(2)	-0.187(3)	0.032(3)	6.1(8)
C(3)	0.783(2)	-0.207(3)	0.062(2)	3.6(6)
C(11)	0.851(2)	0.051(2)	0.169(2)	2.8(5)
O(11)	0.921(1)	0.019(2)	0.162(1)	3.2(3)
C(12)	0.605(2)	0.040(2)	0.167(2)	2.8(5)
O(12)	0.534(1)	-0.003(2)	0.164(1)	4.2(4)
C(13)	0.676(1)	0.141(2)	0.052(2)	2.1(4)
O(13)	0.642(1)	0.193(2)	-0.019(1)	4.6(4)
C(21)	0.849(2)	0.188(3)	0.459(2)	3.9(6)
O(21)	0.875(1)	0.254(2)	0.522(2)	5.9(5)
C(22)	0.697(2)	0.049(3)	0.361(3)	5.6(8)
O(22)	0.637(2)	-0.006(3)	0.374(2)	7.9(7)
C(23)	0.857(2)	-0.083(3)	0.400(2)	4.8(7)
O(23)	0.885(2)	-0.183(3)	0.425(2)	8.4(7)
C(24)	0.936(2)	0.104(3)	0.351(2)	4.3(6)
O(24)	1.014(1)	0.079(2)	0.365(2)	5.6(5)
C(31)	0.958(2)	0.282(2)	0.232(2)	3.3(5)
O(31)	1.026(1)	0.276(2)	0.219(1)	4.4(4)
C(32)	0.792(2)	0.398(2)	0.150(2)	3.3(5)
O(32)	0.757(1)	0.462(2)	0.086(2)	5.8(5)
C(33)	0.879(2)	0.425(3)	0.328(2)	4.2(6)
O(33)	0.905(2)	0.508(2)	0.377(2)	6.0(5)
C(41)	0.690(2)	0.411(3)	0.332(2)	4.1(6)
O(41)	0.707(1)	0.500(2)	0.369(2)	5.1(5)
C(42)	0.556(2)	0.233(3)	0.268(2)	4.8(7)
O(42)	0.487(2)	0.207(2)	0.278(2)	7.2(6)
C(43)	0.606(2)	0.370(3)	0.148(2)	4.3(6)
O(43)	0.561(2)	0.441(2)	0.093(2)	6.2(5)
H(11)	0.673(0)	-0.366(0)	0.155(0)	5.(0)
H(12)	0.705(0)	-0.238(0)	0.248(0)	4.(0)
H(13)	0.798(0)	-0.302(0)	0.226(0)	4.(0)
H(21)	0.566(0)	-0.098(0)	-0.008(0)	7.(0)
H(22)	0.591(0)	-0.269(0)	-0.013(0)	5.(0)
H(23)	0.542(0)	-0.209(0)	0.062(0)	7.(0)
H(31)	0.789(0)	-0.128(0)	0.025(0)	5.(0)
H(32)	0.745(0)	-0.287(0)	0.020(0)	5.(0)
H(33)	0.854(0)	-0.245(0)	0.103(0)	5.(0)

Table S.25. Thermal Parameters for $Os_4(CO)_{13}PMe_4$

ATOM	U11	U22	U33	U12	U13	U23
OS(1)	2.58(5)	2.76(5)	2.66(6)	0.01(4)	1.08(5)	-0.30(5)
OS(2)	3.83(6)	4.58(7)	2.66(7)	-0.40(5)	1.44(5)	-0.08(5)
OS(3)	3.28(6)	3.55(6)	3.65(7)	-0.83(4)	1.94(5)	-0.67(5)
OS(4)	3.28(6)	3.72(6)	4.10(7)	-0.04(5)	2.12(5)	-0.82(5)
P	3.3(3)	3.3(4)	3.9(5)	0.1(3)	1.3(3)	-0.5(3)
C(1)	4.2(7)					
C(2)	7.8(10)					
C(3)	4.6(7)					
C(11)	3.5(6)					
O(11)	4.1(4)					
C(12)	3.6(6)					
O(12)	5.3(5)					
C(13)	2.7(6)					
O(13)	5.8(5)					
C(21)	5.0(8)					
O(21)	7.5(6)					
C(22)	7.1(10)					
O(22)	10.1(9)					
C(23)	6.1(9)					
O(23)	10.6(9)					
C(24)	5.5(8)					
O(24)	7.1(6)					
C(31)	4.2(7)					
O(31)	5.6(5)					
C(32)	4.2(7)					
O(32)	7.3(6)					
C(33)	5.4(8)					
O(33)	7.6(7)					
C(41)	5.3(8)					
O(41)	6.5(6)					
C(42)	6.1(9)					
O(42)	9.1(8)					
C(43)	5.5(8)					
O(43)	7.8(7)					

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TEMP=-2(PI)**2(U11*H*H*ASTAR*ASTAR+---+'2*U12*H*K*ASTAR*BSTAR+---)

        THE UIJ VALUES HAVE BEEN MULTIPLIED BY 100.
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Table S.26. Structure Factors for $Os_4(CO)_{13}PMe_4$

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COLUMNS ARE 10FO,10FC,  10SIG

  L   KFO    FC   SIG      L   KFO    FC   SIG      L   KFO    FC   SIG
    -16,  0,  L            5   793   817    44     13   633   646    75
  4   951   921    34      6  1221  1217    35     14   842   751    66
  6  1299  1233    30      7  1800  1600    43        -13,  2,  L
  8  1630  1695    46      8   955   961    55      1  1875  1861    41
 10  1911  1865    45        -14,  0,  L            2  1011  1077    28
    -16,  1,  L            4   630   620    39      3   446   477    53
  3  1274  1217    31      6   831   838    32      5  1051  1085    27
  4  1077  1061    31     12  1070  1087    36      6   473   534    55
  7  1838  1835    43        -14,  1,  L            7   786   833    38
  9   999  1022    36      1  1820  1841    42      9   657   739    54
 10  1129  1058    34      2   571   556    45     10  1069  1028    41
 11   649   754    64      3   850   879    31     11  1640  1597    43
    -16,  2,  L            5  1101  1139    26     12  1261  1137    47
  4  1728  1680    40      6  1066  1030    28     13  1041   975    64
  6  1515  1495    37      7  1667  1632    39        -13,  3,  L
  7   620   654    52      8   392   386    70      1   734   728    39
  8  1248  1215    33     11  1527  1515    38      2  1131  1130    29
  9   775   760    47     12   763   803    55      3   850   850    32
 10  1180  1080    36     13  1209  1099    43      4   531   539    49
    -15,  0,  L              -14,  2,  L            5   526   517    53
  2  2250  2272    43      7   692   702    44      7   609   617    58
  4  1030   890    29     11   821   795    54      8   686   691    59
  6  1490  1508    40     13   760   672    75     10  1854  1816    56
  8  1229  1215    27        -14,  3,  L           12  2116  1899    47
 10  1283  1221    31      2  1629  1569    38        -13,  4,  L
 12  2541  2505    50      6  1936  1996    47      1  1129  1172    36
    -15,  1,  L            8  1278  1292    34      2   656   673    42
  3   514   446    50      9   644   646    67      5  1969  2016    47
  4   882   926    33     10   684   638    73      6   854   800    56
  5   555   581    47     12  1295  1186    59      7  2146  2048    51
  6   880   861    35        -14,  4,  L           10  1129   880    88
  7   538   568    53      3   484   370    55     11   974   744   113
  8   842   832    35      4   459   387    61        -13,  5,  L
 10  1025  1033    37      5   450   512    74      2   973   935    33
 11   551   516    64     11  1204  1047    79      4  1468  1373    60
 12  1558  1505    37        -14,  5,  L            5  1084   984    96
    -15,  2,  L            2  1423  1347    33      6  1146  1036   113
  1  1485  1404    33      5  1135  1200    61      7  1513  1221   108
  2   703   605    41      7  1495  1439    71        -13,  6,  L
  3   988   930    31        -13,  0,  L            1   893   880    49
  5   636   651    44      2  1020  1056    26      2  1162  1124    30
  6  1460  1471    32      4  1213  1217    29      3   818   827    47
  7  1496  1485    34      6  2690  2899    36      6  1228  1183    84
  8  1672  1677    43      8  1181  1210    26        -12,  0,  L
 11   970   913    47     10   706   720    41      2  1878  1993    35
    -15,  3,  L           12   922   843    40      4  3187  3301    31
  2   766   810    41        -13,  1,  L            6  3227  3415    32
  4   721   799    42      2  1099  1164    34      8  1879  2056    41
  6   946   977    35      4  1078  1062    25     10   526   556    55
  8   947  1004    44      5   442   486    52     14  2097  2011    45
  9   806   743    54      6  1694  1747    41     16  2763  2712    70
 11   861   919    64      8  1381  1379    34        -12,  1,  L
    -15,  4,  L           10   504   653    67      1  1925  2012    37
  3  1017   930    33     11  1165  1173    36      2   581   605    39
```

```
COLUMNS ARE 10FO,10FC,  10SIG

  L   KFO    FC   SIG      L   KFO    FC   SIG      L   KFO    FC   SIG
    -12,  1,  L            4  1053  1098    44     10  4167  3862    75
  4  1588  1620    39      5  1001   931    56     11   899   785   103
  5  1647  1819    39      6  1673  1520    47     12  3096  2881    87
  6  1746  1818    39      7  1733  1594    52     13  1158  1046    73
  7  1005  1057    28      8   976   932    90     14   606   463   107
  8   910   993    32      9  1742  1738    64     15  1026  1080    62
  9   980  1089    35     11  1168  1133    92        -11,  4,  L
 11  1692  1742    39        -12,  7,  L            1  1377  1389    37
 14  1046   903    57      1  1772  1766    44      2   941   968    28
 16  1363  1243    64      3   645   602    47      3  1158  1057    34
    -12,  2,  L            4   542   454    59      5  2921  2765    78
  1   677   727    39      9  1020   925    67      7  1894  1719    74
  2  1889  1939    36        -11,  0,  L            8  1582  1420    93
  3   836   907    30      4  3416  3499    29     10  1589  1527    61
  4  1627  1634    39      6  3491  3614    30     15  1156  1250    51
  6  1367  1431    32      8   746   853    32        -11,  5,  L
  8  2075  2081    49     10   759   767    41      1  1140  1051    34
  9  1165  1112    37     12   574   392    68      2  1910  1949    41
 10  2652  2673    57     14  1667  1745    45      3  1497  1509    39
 11  1894  1850    53     16  1659  1558    51      4  2404  2292    63
 12  2289  2145    59        -11,  1,  L            5  2551  2331    56
 13   809   932    88      1   637   689    34      6  1886  1700    67
    -12,  3,  L            2  2427  2431    31      7  2236  2188    70
  2  1640  1672    40      4  3189  3231    30      9  1042   890    91
  3   611   559    41      5   662   599    32     12   923  1045    69
  4   513   599    52      6  3689  3748    31     13  1020  1054    60
  6  1269  1221    31      8  2773  2690    37     14  1421  1545    46
  7   905   945    47      9  1557  1496    36        -11,  6,  L
  9   995   991    63     10  1361  1435    35      1  1044  1108    30
 10  2013  1998    50     11  1869  1872    49      3   761   810    40
 11   750   603    99     12  1621  1553    44      4  1765  1811    47
 12  1970  1773    54     14  2416  2427    61      6  1860  1715    43
    -12,  4,  L           15  1368  1226    61     11  1323  1281    73
  1   796   873    44     16  2714  2534    64     13  1238  1235    64
  2  1795  1830    41        -11,  2,  L              -11,  7,  L
  3  1776  1790    40      1  1612  1659    39      1  1362  1384    35
  4  1372  1349    34      2  1142  1161    33      3  1090  1079    30
  5  2014  1946    53      3   565   592    35      4   506   487    58
  6  1155  1087    61      5  1608  1651    35      5   854   837    43
  7  1558  1377    57      8  1276  1225    35      6  1010  1038    42
  8  1306  1198    78      9  1479  1458    44      7  1326  1277    38
 10  1905  1604    74     10  2142  2067    51      8  1090   951    47
 12  1780  1744    58     11  1675  1581    42      9  2343  2256    54
 13   690   749    99     12  1732  1680    47     11  2222  2240    53
 14   920  1011    74     14   796   809   108        -11,  8,  L
    -12,  5,  L              -11,  3,  L            2   720   723    44
  2   508   398    52      1  1525  1625    37      6   665   728    55
  5  3035  2119   107      2  2386  2347    33      7   487   529    78
  6  1820  1579   144      3  1566  1615    37        -10,  0,  L
  7  1667  1647   103      4  1146  1155    31      2  2428  2569    28
    -12,  6,  L            5  1221  1291    32      4  5341  5405    26
  1   983   917    35      6   977   934    41      6  4229  4219    28
  2   812   827    36      7  1299  1212    42      8  1306  1303    28
  3   668   640    49      8  2534  2527    65     12  1646  1657    48
```

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COLUMNS ARE 10FO,10FC,  10SIG

  L   KFO     FC    SIG
     -10,   0,   L
 14  3899   3700    59
 16  3569   3298    74
     -10,   1,   L
  1  1885   1924    32
  2  1218   1159    28
  3  1367   1329    34
  4  2182   2169    29
  5  3013   3020    28
  6  1488   1488    36
  7   382    393    60
  8   759    781    38
  9  1796   1758    47
 11  1384   1356    38
 12   696    776    77
 14  1258   1299    63
 16  1247   1130    65
     -10,   2,   L
  1  1203   1283    33
  2  1810   1809    32
  4  1208   1301    33
  5   570    651    40
  6  1463   1450    39
  8  3752   3612    46
  9  2418   2246    55
 10  3982   3758    59
 11  2434   2354    65
 12  2330   2171    60
 15  1157   1223    61
     -10,   3,   L
  1   583    588    39
  2   674    618    30
  4  1237   1213    36
  5   524    369    67
  6   663    621    69
  7   905    967    67
  8  1940   1780    57
 10  2721   2470    74
 12  1355   1391    59
     -10,   4,   L
  1   902    964   103
  2  2021   1974    51
  3  3063   2742    74
  4  1555   1287   106
  5  3223   2630    72
  8  1548   1602    65
 10  1876   2104    49
 12  1697   1883    41
 13  1607   1689    41
 15  2157   2426    49
     -10,   5,   L
  1   687    630    38
  3  1233   1341    34
  4  2031   2029    57
```

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  L   KFO     FC    SIG
  5  1391   1422    47
  6  2151   2113    54
  8   798    771   106
     -10,   6,   L
  1   803    754    33
  2   699    765    37
  4  1623   1699    37
  5  1217   1224    33
  6  1891   1928    47
  7  2064   2061    50
  9  2030   2023    50
 11  1356   1289    61
 13  1039    855    75
     -10,   7,   L
  1  1002   1010    30
  2  1060   1011    28
  3   594    534    43
  4  1227   1243    31
  5   952    972    35
  6   428    480    77
  9  1125   1091    47
 11  1465   1373    47
 12   962    948    76
     -10,   8,   L
  1  1589   1572    44
  2   499    462    55
  3  1104   1122    30
  4   451    547    62
  5   531    585    57
  7   924    922    42
  8   862    896    49
  9  1623   1619    43
      -9,   0,   L
  2   716    724    23
  4  3476   3514    25
  6  1658   1725    34
  8  1078   1024    27
 10  1060   1060    32
 14  1143   1055    55
      -9,   1,   L
  2   554    586    28
  3  1545   1622    30
  4  2521   2547    27
  5  1234   1229    29
  6  1720   1776    35
  7   818    721    30
  8   631    608    44
  9  2598   2525    46
 11  1834   1673    51
 12  1305   1204    48
 13   776    944    99
 14  2617   2418    68
 15  1869   1770    48
 16  1774   1789    45
```

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  L   KFO     FC    SIG
      -9,   2,   L
  3  2246   2262    29
  4   813    811    26
  5  1762   1759    41
  6   387    354    70
  8   994    996    48
  9   792    777    68
 10  1627   1467    45
 12  1104    950    82
      -9,   3,   L
  1  1229   1190    28
  3   725    715    37
  4  1857   1586    49
  7   804    538    97
  8  3280   2980    76
 10  3439   3546    73
 12  1046   1198    56
 14   978   1100    51
 15   867    869    53
 16   499    645    91
      -9,   4,   L
  1  1497   1515    35
  3  1306   1294    54
  5  1973   1715    60
  6   803    763   139
  8  1685   1707    54
  9  1420   1537    55
 10   850   1001    71
 11   841    940    66
 16   572    668    80
      -9,   5,   L
  2  1446   1441    37
  3  1456   1468    37
  4  1813   1863    45
  5  2206   2218    51
  7   746    777    78
 12   704    827    93
 13  1402   1499    47
 14  1253   1478    51
 15  1620   1806    41
      -9,   6,   L
  1   546    541    42
  2  1422   1464    40
  4  2202   2332    42
  5  1026   1035    34
  6  1384   1426    37
  7  1026    972    41
      -9,   7,   L
  1   371    410    65
  6   711    678    45
  7  1150   1134    34
  9  2386   2345    57
 11  1482   1459    44
      -9,   8,   L
```

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COLUMNS ARE 10FO,10FC,  10SIG

  L   KFO     FC    SIG
      -9,   8,   L
  2   969    948    31
  3   887    953    34
  5   534    587    55
  7   520    518    61
  8   787    641    47
  9   858    877    50
 10  1523   1474    36
      -9,   9,   L
  1  1096   1046    32
  3  1298   1271    27
  4   901    923    35
      -8,   0,   L
  2   512    451    26
  4  2431   2378    24
  6   597    557    29
  8  3357   3322    33
 10  2899   2767    44
 14  2571   2343    69
 16  1249   1197    57
      -8,   1,   L
  2   855    833    23
  3  2434   2441    25
  4   530    809    38
  5  1977   2018    31
  6   434    432    48
  8   650    629    48
  9  1251   1094    33
 10   834    683    53
      -8,   2,   L
  2  1978   1929    26
  3  2412   2439    31
  4  2054   2047    35
  5  2029   1880    41
  6  1110   1089    34
  8  1045    909    53
  9  2831   2560    71
 10  1041    963    73
 11  1212   1169    64
 13  1541   1701    44
 14  1239   1341    44
 15  1610   1727    41
 16   645    703    70
      -8,   3,   L
  1   702    727    30
  2  1207   1237    35
  3   784    670    67
  4  2325   2130    59
  8  1302   1313    56
  9   564    384    98
 10  1088   1006    48
 11  1019   1198    50
      -8,   4,   L
  2  1070   1105    27
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  L   KFO     FC    SIG
  3  1614   1690    43
  4  1762   1651    46
  5  1106   1063    51
  6   789    865    80
  7  1756   1636    48
  9  2562   2450    67
 11   678    653    78
 13  1359   1513    41
 14   836    831    54
 15  1649   1783    37
      -8,   5,   L
  1   657    377    31
  2   716    684    30
  3  1193   1075    31
  4  1889   1955    42
  5   682    113    46
  6  1605   1650    34
  7  1490   1454    35
  9  1398   1374    49
      -8,   6,   L
  1  1253   1324    31
  3  1229   1264    29
  4  1350   1412    33
  8  1977   2027    48
 10  1976   2014    53
 14  1661   1577    53
      -8,   7,   L
  2  1433   1467    36
  3  1706   1712    40
  4   912    953    31
  5  1576   1621    40
  7   576    542    54
 10   987   1039    49
 12  1334   1343    48
      -8,   8,   L
  2  1170   1186    29
  3  1108   1113    33
  4  1009   1069    31
  5  1014   1061    31
  8  1042   1059    37
  9   629    680    60
 10   546    567    74
      -8,   9,   L
  1   892    937    35
  5   811    818    37
  6   727    760    45
  8  1391   1337    34
      -7,   0,   L
  2  1285   1271    26
  4  1955   1981    24
  6   721    778    25
  8  2386   2432    37
 10  1025    992    37
 16   654    722    81
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  L   KFO     FC    SIG
      -7,   1,   L
  1  1377   1206    27
  2  1929   1972    24
  3  4222   3933    22
  4  1683   1673    30
  5  1991   1938    31
  6  2658   2490    33
  7  1914   1883    45
  8  3858   3644    43
  9  2651   2524    55
 10  3469   3180    57
 12  1028    900    72
 13  2631   2351    62
 15  1468   1708    45
      -7,   2,   L
  1  1382   1417    29
  2  1358   1406    30
  3  2436   2467    31
  4  1839   1782    40
  5  1049   1017    42
  6   772    757    62
      -7,   3,   L
  1   826    771    24
  2  4526   4386    60
  3  1392   1268    74
  4  5405   4806    86
  5  1401   1175    76
  6  1950   1874    48
  7  1215   1315    54
  8   798    930    69
  9  1138   1217    46
 11   698    781    64
 12  2362   2548    58
 14  3033   3386    53
 16  1278   1364    38
      -7,   4,   L
  1   647    643    25
  2  1074   1148    29
  3  1155   1138    29
  4   970    978    33
  5   784    782    47
  6   997    928    46
  7  1672   1620    45
  8   651    716    95
  9  2134   2002    55
 11  1002   1083    61
      -7,   5,   L
  1  1330   1261    32
  6  2019   1974    45
  7  2373   2459    51
  8  2937   2962    53
  9  3159   3270    58
 10  1804   1763    56
 11  1245   1215    57
```

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COLUMNS ARE 10FO,10FC,  10SIG

  L   KFO    FC   SIG      L   KFO    FC   SIG      L   KFO    FC   SIG
      -7,  5, L            1  2479  2558    21      6  1863  1888    42
 13   843   782    74      2  5692  5538    26      7  1621  1546    36
      -7,  6, L            3  5210  4912    38      8  3538  3594    43
  2  1566  1622    36      4  5408  5047    46      9  1617  1597    35
  3  1242  1267    27      5  2408  2177    60     10  2011  2049    51
  4  1492  1492    37      6  3220  3020    68     11  1546  1559    43
  5  1838  1869    41      7  1286  1134    63     13  1582  1511    47
  7  1394  1384    30      8  1425  1361    42     14   831   765    88
      -7,  7, L            9  1709  1980    52         -6,  7, L
  1  2029  2069    38     10  1541  1680    36      1   988  1000    28
  2   603   706    40     11  1102  1194    40      2   555   471    39
  3  2908  2928    34     12  3316  3679    51      3  1685  1713    38
  5  2195  2235    39     13  2969  3317    53      5  1208  1278    32
  6   497   371    53     14  3011  3269    52      6   891   882    32
  8  1010   962    36     15  1509  1606    34     10   974   989    42
  9   785   757    49     16  1465  1553    35         -6,  8, L
 10   807   815    53     17   686   571    62      1  2380  2338    35
 11   827   765    55         -6,  3, L            2  1536  1490    36
 13  2260  2218    65      1   277   299    48      3  3212  3222    34
      -7,  8, L            2  2777  2842    31      4  1159  1123    28
  1   955   930    28      3   637   546    53      5  2198  2246    39
  3  1284  1343    31      4  2253  2273    54      7   732   711    41
  4   636   623    41      9   932   851    51      8   930   914    36
  5   542   475    47     11  1245  1460    41     11  1530  1531    41
  8   818   842    41     12   545   565    77     12  1120  1084    50
 10  1462  1480    33         -6,  4, L                -6,  9, L
 11  1088  1037    45      1   530   524    28      1   970  1001    30
      -7,  9, L            2  3610  3698    25      2   582   584    45
  2   979   970    31      3   728   682    27      5   628   669    46
  4  1148  1124    28      4  3507  3731    33      8   618   742    54
  5  1240  1214    34      5  1441  1421    36      9  1040  1062    39
  7  1477  1540    45      6  1973  2024    46         -6, 10, L
  8  1002   922    36      7  4782  4816    46      1   654   631    44
  9  1249  1258    35      8  1548  1481    38      2   566   490    49
      -6,  0, L            9  3873  3842    60      5  1035  1062    35
  2  1193  1280    25     10  1760  1723    46         -5,  0, L
  4  1817  1817    24     11   934   944    69      2  2441  2417    18
  6  5429  5361    26     12  2345  2421    57      4   442   370    30
  8  7670  7453    35     14  1719  1883    48      6  1625  1615    35
 10  4415  4304    45     16   847  1024    55      8  1729  1578    38
 16  1587  1584    38         -6,  5, L           10  1047   894    46
      -6,  1, L            2   635   666    26     12  1237  1088    52
  1  1256  1258    25      3   558   438    30     14  1256  1281    44
  2   567   585    20      4  1094  1152    26         -5,  1, L
  3  2829  2739    22      5   999   922    26      1  4070  4002    17
  4   889   899    28      7  1870  1857    45      2  2576  2476    20
  5   720   802    31      8  1054  1010    38      3  6065  6008    22
  6  1648  1552    42      9   793   862    56      4  4991  4703    28
  7   977   929    38     10  1050   967    52      6  4925  4452    40
  8  1329  1222    36     15  1076  1075    54      7  4243  3918    48
 10  1082   953    56         -6,  6, L            8  6029  5782    52
 12   794   754    62      1  2982  3062    29      9  1496  1424    48
 16   717   701    57      3  2684  2785    31     10  3649  3681    54
      -6,  2, L            5  1671  1774    38     11  2041  2069    53
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```
COLUMNS ARE 10FO,10FC,  10SIG

  L   KFO    FC   SIG      L   KFO    FC   SIG      L   KFO    FC   SIG
      -5,  1, L                -5,  6, L           12   882   945    43
 12  1148  1249    40      1   581   569    31     13   742   644    51
 13  2755  2880    52      2   642   659    28     17   810   846    50
 14  1223  1272    41      3   936  1107    25         -4,  2, L
 15   951   989    45      4   480   512    39      1  4557  4691    19
 16  2065  2145    53      5  1442  1493    36      2  3354  3313    33
      -5,  2, L            6   843   852    29      3  3854  3717    43
  1  1061   973    25     12   619   506    80      4  3415  3386    54
  2  2496  2220    67     13   620   391    95      6  1250  1277    45
  3  1180  1136   106         -5,  7, L            7  2242  2338    48
  4  2185  2072    58      1  3285  3342    30      8  1179   672    38
  6   832   851    60      3  3768  3909    30      9   676   840    54
 14   598   711    66      5  2225  2277    37     10  2131  2341    51
 16   791   873    52      6  1175  1171    26     11  2381  2505    51
      -5,  3, L            8  1109  1160    30     12  3237  3540    49
  1  1166  1244    27     11  2168  2196    54     13  2666  2879    50
  2  5915  6349    23     13  2916  2903    67     14  2382  2520    51
  3  1516  1433    35         -5,  8, L           16   722   769    54
  4  5290  5589    35      1   979  1012    27     17   752   889    56
  5  2040  1977    50      2  1038   998    26         -4,  3, L
  6  1567  1338    39      3   673   667    36      1   296   309    36
  7  2531  2427    55      4  1168  1171    33      2  1637  1709    25
  9  2021  1992    53      6   887   847    31      4   566   605    35
 10  2108  2072    49      9   701   770    50      5   971   993    28
 11   967  1137    50     10   634   605    59      6   750   766    43
 12  4191  4592    50     11  1066  1007    42     16   650   699    63
 13   804   730    56         -5,  9, L                -4,  4, L
 14  3151  3480    52      1   901   927    32      1  1286  1348    28
 16   652   831    64      2  1519  1449    40      2  3356  3457    22
 17   759   845    55      3  1299  1290    25      3  1276  1243    30
      -5,  4, L            4   644   655    41      4  1843  1960    30
  1  1000   921    25      5  1883  1913    44      5  3154  3152    31
  2  1308  1327    29      6   868   882    35      7  4547  4675    37
  3  1357  1321    33      7  1959  1910    46      8  1017  1113    40
  5   471   409    45      8  1197  1181    31      9  2476  2454    55
  6   567   551    48      9  1558  1583    42     10  2014  2032    58
  7  1424  1396    39         -5, 10, L           12  2257  2171    46
  8   938   892    44      4   602   551    48     13   919   825    60
  9  1006   882    49         -4,  0, L           14  1297  1319    43
 10  1594  1562    41      2  1846  1716    17         -4,  5, L
 11   694   625    90      4  2259  2191    23      1  1236  1335    31
 13   716   773    70      6  6099  5831    30      3   640   606    25
 15   537   539    82      8  6492  6102    42      4   453   476    36
      -5,  5, L           10  2089  2030    52      6   412   401    51
  1   843   887    21     14   620   707    68      8  1001  1038    33
  4  1395  1474    33     16  1930  2180    52     10  1294  1281    38
  5  2043  2187    34         -4,  1, L           12   849   792    66
  6  3321  3340    34      1  1149  1107    23         -4,  6, L
  7  3898  4086    38      3  1199  1078    26      1  2385  2451    28
  8  3605  3541    43      4  1159  1054    32      2  1781  1621    30
  9  3560  3572    48      5   695   587    60      3  1919  1953    31
 10  1676  1672    39      6   825   637    61      4   306   122    54
 11   808   881    67      9   696   162    59      5  1263  1292    34
 15   681   771    82     10   485   563    75      6  2712  2923    36
```

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COLUMNS ARE 10FO,10FC,  10SIG

 L   KFO    FC   SIG
     -4,   6,  L
 7  1144  1149   33
 8  2925  3013   41
 9  1398  1301   29
11  1254  1196   40
12  1182  1126   47
13  1559  1427   43
     -4,   7,  L
 1   496   482   38
 2   651   609   30
 3   442   428   44
 4  1427  1419   35
 6  1483  1621   40
     -4,   8,  L
 1  2654  2623   33
 2  1648  1593   37
 3  2483  2507   35
 4   430   466   54
 5   786   797   34
 6   969  1023   31
 8   908   961   36
 9   822   818   39
11  1796  1795   49
12  1049  1112   49
     -4,   9,  L
 1   389   484   62
 2  1445  1428   34
 3   823   782   33
 4   891   864   32
 5   796   816   35
 9   894   903   41
     -4,  10,  L
 5  1266  1328   33
 7  2089  2077   48
     -3,   0,  L
 2  1388  1342   13
12   808   854   49
14   895   787   45
16   671   506   55
     -3,   1,  L
 1  4460  4244   13
 2  1132   982   24
 3  2329  2173   55
 4   708   597  100
 5  2133  2119   56
 6  1980  2001   51
 7  2695  2825   49
 8  2095  2194   52
11  2076  2120   46
12  1085   898   36
13  1700  1832   41
14   450   494   82
16  1099  1306   40
17  1069  1092   41
```

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 L   KFO    FC   SIG
     -3,   2,  L
 1   488   473   22
 2   843   795   20
11   919   913   41
13   614   826   66
16   593   630   66
     -3,   3,  L
 1  1057  1021   25
 2  3654  3739   19
 4   785   711   23
 6  2605  2699   40
 7   694   652   46
 8  2139  2067   52
 9   875   839   54
10  2035  1758   47
12  3129  3025   55
14  1255  1264   38
16   505   664   86
     -3,   4,  L
 1  1175  1150   27
 2  1097  1167   26
 3  1286  1357   29
 5   592   601   30
 8   755   844   44
10   988   883   48
13   715   388   79
     -3,   5,  L
 1  2378  2408   24
 2  1604  1633   27
 3  1337  1334   31
 4   599   613   27
 5  1974  2050   32
 6  2195  2236   34
 7  2836  2954   36
 8  1370  1302   33
 9  1019   969   35
11  1043  1042   48
12   978   803   56
13   858   760   70
15   944   840   67
     -3,   6,  L
 1   645   651   25
 2   543   549   29
 3   754   694   23
 4   722   749   26
 5   615   735   32
 6   685   697   33
 7   577   618   43
 9   863   893   39
10   983  1021   40
11   846   794   48
12  1130  1101   46
     -3,   7,  L
 1  2448  2504   30
```

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 L   KFO    FC   SIG
 2   579   699   36
 3  1581  1617   35
 5   830   805   27
 6   905   847   28
 7  1788  1864   43
11  1875  1849   47
13  1846  1781   41
     -3,   8,  L
 1   482   455   44
 2  1746  1792   37
 4  1842  1904   40
 5   613   596   39
 6  1392  1436   31
     -3,   9,  L
 1   734   722   33
 2  1489  1468   36
 5   820   826   34
 6  1563  1570   39
 7   802   788   38
 8   923   892   36
     -2,   0,  L
 2  6295  6574   11
 4   741   656   27
 6  3490  3189   45
10  2484  2654   52
12  2837  2980   49
14   558   535   65
16   941   878   43
     -2,   1,  L
 1   669   673   21
11  1009   983   36
12   633   504   55
13   877   928   43
16   445   561   84
     -2,   2,  L
 1  2651  2707   11
 2   349   404   34
 3   738   697   23
 4  2077  2085   33
 6  3326  3176   42
 7  4176  3756   46
 8  2363  1986   59
11  2264  2330   53
12   602   715   64
13   985  1124   44
15   900   891   44
16   878   933   49
     -2,   3,  L
 2  1405  1384   23
 3  1344  1337   26
 5  1406  1450   32
 6   701   625   35
 7   652   479   43
 8   496   473   69
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COLUMNS ARE 10FO,10FC,  10SIG

 L   KFO    FC   SIG
     -2,   3,  L
12   906   910   58
15   666   715   66
16   980   998   48
     -2,   4,  L
 1  4514  4621   19
 2   854   877   23
 3  2224  2305   24
 4  1662  1737   28
 5  1925  1959   29
 6  2560  2570   32
 7  2007  2070   39
 8  1385  1302   30
 9   650   621   52
11  2555  2444   60
12   706   346   83
13  1839  1492   43
14   691   437   75
     -2,   5,  L
 1  1415  1483   27
 2   408   300   31
 3   410   401   33
 6   762   825   27
 7  1346  1306   29
 8  1135  1127   28
 9   892   857   38
10  1103  1083   39
12  1083   830   49
     -2,   6,  L
 1   420   366   35
 2  3063  3147   26
 3   921   949   26
 5  1352  1472   35
 6  2403  2493   34
 7  1297  1322   30
 8   965   933   30
 9   644   650   48
10  1716  1657   36
12  2334  2148   52
     -2,   7,  L
 2  1485  1474   34
 4  1906  1925   34
 6  1154  1194   28
 9  1017  1038   35
11  1341  1287   35
12   899   774   51
13   606   402   79
     -2,   8,  L
 1   694   688   31
 2  1066  1070   23
 4   672   647   35
 5  1836  1886   40
 6  1655  1695   39
 7  1678  1670   36
```

```
 L   KFO    FC   SIG
 8  1022  1078   33
     -2,   9,  L
 2  1225  1232   31
 3  1430  1366   35
 4   927   982   31
 5   943   910   30
 6   825   831   35
 8  1006   941   34
 9   809   792   44
     -2,  10,  L
 1  1925  1923   41
 3   935   967   32
 7   619   690   53
     -1,   0,  L
 2   979   965   17
 4   577   320   58
 6  1858  1744   52
 8   785   744   44
10   919   951   39
12  1036  1090   36
16  1543  1725   41
     -1,   1,  L
 1  3962  4317    9
 2  5356  5797   14
 3   778   753   25
 4  3584  3072   38
 5  5119  4312   43
 7  3723  3503   45
 8  2151  2062   52
 9   656   537   50
10  3201  3431   44
11  2041  2166   44
12  2635  2891   51
14   818   916   49
15   947   955   42
     -1,   2,  L
 1   360   382   16
 3  1551  1542   26
 4   415   351   43
 7   644   612   56
 9   584   631   86
10  1580  1459   39
11  2005  1935   48
12   669   883   68
13   858   891   48
     -1,   3,  L
 1  1462  1484   20
 2   488   519   22
 3  3019  3025   20
 4  5537  5712   22
 5  1267  1179   32
 6  6558  6637   30
 7   495   536   52
 8  3753  3416   41
```

```
 L   KFO    FC   SIG
 9   903   818   46
10   895   860   57
11  1327  1198   47
12   834   742   69
13  1474  1247   39
14  1268  1330   42
16  1906  2035   50
     -1,   4,  L
 1  1577  1569   23
 3  1618  1624   24
 4   643   834   28
 5  1408  1454   34
 7  1238  1234   29
 8   963   899   31
10  1095   515   41
11   543   502   90
15  1391  1392   45
     -1,   5,  L
 1  4754  4966   21
 2  3373  3574   23
 3  2688  2777   25
 5   475   487   36
 6   497   667   39
 8   983   956   30
 9  2381  2322   45
10  1999  1998   50
11  2728  2588   53
12  2236  2051   53
13  1327  1168   50
14  1048   985   69
     -1,   6,  L
 2   599   596   25
 3   743   730   23
 4   520   561   32
 7  1470  1549   41
 9  1329  1416   36
10  1162  1102   35
11  1021   945   43
12  1335  1240   40
     -1,   7,  L
 2  1437  1392   35
 3  1737  1754   34
 5  3775  3870   32
 7  3322  3391   36
 8   807   877   37
 9   859   857   39
10  1248  1226   34
     -1,   8,  L
 2  1472  1472   36
 3   913   948   27
 4  1464  1553   36
 5   612   615   39
 6   754   795   36
11   758   755   54
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COLUMNS ARE 10FO,10FC,  10SIG

  L   KFO    FC   SIG      L   KFO    FC   SIG      L   KFO    FC   SIG
     -1,   9,  L          10  2081  1935    55      3  2662  2729    33
  1  2450  2391    35     12  1431  1319    50      4  1237  1228    33
  2  1108  1063    30     13   865   902    62      5  3198  3372    35
  3  1488  1498    41     15   750   692    67      6  1776  1710    42
  4   927   931    30          0,   4,  L           7  1903  1919    45
  5   673   724    41      0  2718  2747    19      8   837   834    38
  6  1591  1648    45      1  6074  6400    19      9   805   700    41
  7   548   633    58      2  3223  3251    20     11   897   773    45
  9  1015   943    37      3  1581  1726    28          0,   9,  L
     -1,  10,  L           4  4591  4631    23      1   723   682    34
  3   577   528    47      5  1343  1225    33      3  1423  1386    35
  5   525   493    53      6  3886  3767    29      5   558   622    48
  6   906   885    36      8  2070  1940    42      6   696   540    38
      0,   0,  L           9  3384  3251    44      7   478   481    60
  2  8312  8143    28     10   951   916    46      9   614   533    56
  8  3924  4230    41     11  3469  3218    57          0,  10,  L
 10  5390  5971    42     12  1554  1427    45      1  2661  2621    38
 12  3381  3810    49     13  1634  1437    46      3  1279  1269    40
 14  1108  1198    37     14  1903  1699    47          1,   0,  L
      0,   1,  L               0,   5,  L           4  1763  1694    48
  2   775   737    14      1   944   916    24      6  1805  1947    46
  3   686   667    20      2  1367  1324    28     10  1951  2084    44
  5  2064  1896    46      3   558   584    25     12   777   740    46
  6  1174  1078    39      4   872   861    24     14  1252  1360    35
  8   695   656    63      5  1186  1200    33          1,   1,  L
  9  1461  1561    38      7  1964  1932    38      0  7399  7485     7
 10   658   695    57      8   731   700    37      1  2385  2329     9
 11  1702  1832    45     10  1033   991    40      2  4989  5045    11
 15  1088  1227    42     11   697   646    65      3  2823  2761    23
 16   893   942    49          0,   6,  L           4  2892  2807    29
      0,   2,  L           0  4594  4686    24      5  4896  4645    34
  0  1908  1832    10      1  1872  1953    29      6  2578  2484    46
  1  1399  1392    12      2  3138  3121    26      7  1741  1615    47
  2  3446  3395    11      3  2236  2434    30      8  4350  4013    56
  3  1827  1795    22      5  3476  3509    30      9  1540  1489    49
  4  8625  8794    24      6   951   940    25     10  4119  4392    51
  5  5373  5175    28      7  2836  2868    38     11  1095  1162    41
  6  7068  6803    33      8  1184  1160    29     12  2419  2611    54
  7  3499  3247    41      9  1830  1890    41     14  1216  1276    38
  8  3739  3396    47     10  2790  2669    48     15   913  1009    49
  9   797   600    61     11  1104  1108    41          1,   2,  L
 10  1315  1187    50     12  2111  1942    54      1   904   886    15
 11  1285  1264    43     13   715   620    74      2   295   255    34
 12   849   893    57          0,   7,  L           3   755   784    18
 13   651   639    66      2  1276  1288    30      4  1018   910    22
 14  1721  1761    41      4   985  1027    23      5  2557  2559    29
 15  1518  1480    34      5   685   732    33      6   907   902    29
 16  1780  1858    47      6   388   360    60      7   974   962    33
      0,   3,  L           9  1526  1487    46      8   990   964    39
  1   425   410    22     11  1477  1416    33      9  1801  1736    55
  3  2193  2217    21     12   935   771    49     10  1870  1695    48
  4   323   277    41          0,   8,  L          11  1905  1699    47
  5  1201  1219    26      0  1201  1162    29     14   681   731    66
  6  1316  1331    35      1  1112  1090    28     15  1163  1224    44
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COLUMNS ARE 10FO,10FC,  10SIG

  L   KFO    FC   SIG      L   KFO    FC   SIG      L   KFO    FC   SIG
      1,   3,  L           5  4010  4059    32      5  3569  3513    28
  0  1925  1893    13      6   677   697    37      6  3120  3049    33
  1  3118  3050    17      7  2496  2505    39      7   713   852    47
  2  3298  3200    18      8  1415  1480    42      8  1158  1128    36
  3  2775  2770    21      9   579   617    55      9  1338  1236    39
  4  7344  7498    23     10  1158  1033    35     12   675   777    78
  5   833   836    22          1,   8,  L          13   816   908    64
  6  6125  6160    29      0   469   482    31     14  1426  1476    41
  7   675   700    37      2   369   413    57     15  1008  1017    50
  8  2265  2176    45      3   402    92    53          2,   3,  L
  9  1525  1346    34      4   725   755    33      0   972   968    17
 11  1909  1653    47      5   427   453    57      1   356   314    28
 12  1056   901    62      7   654   630    41      4  1736  1726    27
 13  1303  1267    51      8   903   860    36      6  1243  1228    26
 14  2201  2239    61     10   995   914    39      7  1061   979    27
      1,   4,  L               1,   9,  L           8  1217  1264    31
  0   617   626    13      0  1615  1590    27      9   548   663    68
  1   936   978    25      1  2360  2328    35     10  2102  2156    60
  2  1018   986    24      3  1466  1548    43     11   565   152    93
  3   921   851    24      4  1406  1464    38     14  1299  1262    50
  5  1298  1225    32      5   785   767    35          2,   4,  L
  6   429   260    42      6  1038   978    30      1  3008  3001    20
  9  1391  1368    31      7   687   734    46      2  2206  2260    23
 11  1282  1236    43          1,  10,  L           3  1003  1018    26
 12   701   681    79      0   870   834    23      4  2616  2644    27
      1,   5,  L           2  1525  1564    41      5  1456  1391    34
  0  5060  5097    15      3   554   544    51      6  1622  1562    35
  1  4039  4077    22      4   565   565    49      7   984   935    26
  2  2464  2600    25          2,   0,  L           9  2455  2434    48
  3   805   808    22      0  7317  7429     8     10   535   527    77
  6   347   350    54      2   353   236    38     11  1988  1808    49
  7  2001  1945    38      4  2043  1989    50     12  1292  1183    48
  8  1711  1689    37      8  3032  3180    50     14  1192  1123    68
  9  3009  3003    44     10  3443  3733    47          2,   5,  L
 10  2435  2375    52     12  1494  1609    32      0   614   624    15
 11  2131  2127    56     14   536   514    71      1  1581  1546    26
 12  2094  1978    46          2,   1,  L           2  1947  1909    25
 13   865   747    68      0   840   788    16      4  1286  1310    31
 14  1034   911    68      2   599   612    20      5   967  1021    25
      1,   6,  L           3  1634  1598    26      8   484   528    56
  0   260   344    48      4   790   811    26      9  1486  1492    42
  1  1509  1514    30      5  1736  1657    40     10   835   744    48
  3  1907  1961    30      6   961  1050    36     11  1310  1261    40
  4  1103  1178    27      8   894   709    55          2,   6,  L
  5   671   473    30      9  1588  1452    43      0  3044  3073    18
  6  1393  1438    39     10  1236  1113    43      1   553   491    27
  7   853   859    31     11  1201  1238    42      2   568   515    28
  9   755   747    43     15  1533  1531    40      3  1160  1142    30
 10  1194  1234    37          2,   2,  L           4  1689  1706    34
      1,   7,  L           0   412   388    15      5  2050  1990    34
  0  1531  1500    23      1   614   553    18      6   721   717    32
  1   628   658    28      2  1753  1784    21      7  1680  1628    39
  2   519   525    34      3  2573  2566    21      8  1212  1228    35
  3  3043  3033    30      4  3737  3716    24      9  1006  1038    36
```

```
COLUMNS ARE 10FO,10FC,  10SIG
```

```
 L   KFO    FC   SIG
      2,   6,  L
10  1869  1951   54
12   808   793   60
      2,   7,  L
 3  1744  1762   35
 4   639   638   34
 5  1344  1348   37
 6  1198  1217   29
 8   694   718   44
 9  1185  1173   32
      2,   8,  L
 0  1255  1264   20
 1   545   571   39
 3  2187  2206   37
 4  1193  1266   30
 5  1907  1874   41
 6  1311  1311   31
10   827   703   47
      2,   9,  L
 0  1191  1203   22
 1   929   921   28
 2   684   706   37
 3   896   920   31
 7   811   884   42
 8   847   780   41
      2,  10,  L
 1  1310  1302   34
 5   428   512   69
      3,   0,  L
 0   780   790   12
 2  1613  1596   29
 4  1845  1626   39
 8  1115  1078   45
10  1855  1998   50
14  1345  1444   42
      3,   1,  L
 0   343   313   22
 1   269   192   35
 2   913   946   21
 3  2565  2552   24
 4  1936  1946   31
 5  2089  2048   37
 6   683   651   43
 8   939   770   51
 9  1716  1534   45
10  1148  1017   54
      3,   2,  L
 0   386   382   18
 1   357   425   27
 3  1439  1408   26
 4   658   679   24
 5  2363  2319   30
 8  1147  1052   35
 9  1791  1771   56
```

```
 L   KFO    FC   SIG
10   921   861   61
11   577   523  112
13  1087  1057   53
14   968   887   54
      3,   3,  L
 0  3426  3436   13
 1   499   480   21
 2   864   850   21
 4  2777  2711   25
 6  1188  1080   31
 7   493   469   50
 8  1576  1552   43
10  1270  1247   42
      3,   4,  L
 0  1321  1316   17
 2   927   911   23
 3   847   788   25
 5   447   505   38
 7  1107  1032   27
 8   837   819   36
 9  2012  1939   46
10   891   926   48
11  1247  1209   44
      3,   5,  L
 0  1472  1479   19
 2   489   572   30
 3  2339  2344   27
 4  2079  2131   30
 5  1438  1341   33
 6   747   732   31
 7   567   527   43
 8   552   512   51
 9  1337  1323   32
10   906   806   44
      3,   6,  L
 1  1405  1378   29
 2  1521  1552   33
 3  1051  1057   27
 4  2667  2735   32
 6  1281  1299   31
 8   944   882   33
10   897   948   44
11   526   435   76
      3,   7,  L
 1   799   872   24
 2   708   681   27
 3  1179  1284   29
 4   575   605   38
 5  1615  1585   38
 8   581   595   51
 9  1030   951   36
      3,   8,  L
 0   886   862   19
 5   815   825   33
```

```
 L   KFO    FC   SIG
 6  1161  1144   30
 8  1747  1675   47
      3,   9,  L
 0  1161  1148   20
 2   578   556   42
 4  1273  1296   37
 5   860   848   34
      3,  10,  L
 0  1728  1678   28
 2  1648  1603   40
 3   860   888   35
 4   612   654   49
      4,   0,  L
 0  1142  1161   17
 2  3531  3452   23
 4  5237  5085   33
 6  1676  1640   36
12   873   944   52
14   774   899   58
      4,   1,  L
 0   436   497   18
 1   454   455   23
 3  2089  2112   26
 4  1802  1817   33
 5  1377  1395   33
 7   853   882   46
 8  1310  1245   40
 9  1893  1873   51
13  1235  1301   44
14   849   779   55
      4,   2,  L
 0  3741  3727   14
 1   249   200   40
 2  1025  1005   25
 3  1696  1695   26
 4   487   530   34
 5   935   946   24
 6   747   741   32
 7  1278  1257   30
 8  2001  1929   48
 9  1972  1883   54
10  1751  1687   44
12   787   752   88
      4,   3,  L
 0  1600  1544   16
 2  1003  1029   26
 4  1919  1967   28
 7  1145  1096   29
 8  2368  2322   46
10  1698  1771   47
      4,   4,  L
 0  2084  2053   16
 1  1565  1460   26
 3  3818  3957   25
```

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COLUMNS ARE 10FO,10FC,  10SIG
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```
 L   KFO    FC   SIG
      4,   4,  L
 4   624   628   27
 5  2327  2444   33
 6  1651  1604   36
 8  1673  1729   42
      4,   5,  L
 0  1179  1149   21
 1   608   595   25
 2  2201  2174   27
 3   584   562   29
 4  1284  1321   31
 5  1009   963   23
 7   891   892   33
 8   476   465   62
 9  1492  1508   37
11   937   799   50
12   855   744   65
      4,   6,  L
 0   283   396   50
 1  1743  1769   31
 2  2127  2080   30
 3  1063  1099   29
 4  2449  2475   32
 6   806   787   33
 9   873   862   41
11  1133  1024   43
      4,   7,  L
 1   489   453   37
 3  1487  1517   38
 4  1346  1391   35
 5   775   733   32
 6  1258  1276   32
 7   597   592   47
 9  1187  1164   37
      4,   8,  L
 0  1104  1148   20
 1   805   822   30
 4  1006  1032   28
 5   706   656   37
 7  1556  1528   39
      4,   9,  L
 0  1046  1081   21
 1  1175  1161   28
      4,  10,  L
 0   464   482   52
 3  1688  1618   44
      5,   0,  L
 0   923  1015   18
 2  3971  3932   24
 4  2096  2065   39
 6   651   511   62
 8  2524  2280   55
10  1282  1348   47
12   897   886   53
```

```
 L   KFO    FC   SIG
      5,   1,  L
 0  4467  4548   13
 1   861  1176   24
 2  4426  4442   22
 3  2247  2288   28
 4  3980  3966   29
 6  2455  2435   42
 7  1485  1430   38
 8  1257  1278   44
 9  1334  1370   51
10  1570  1387   51
12  1397  1399   46
      5,   2,  L
 0   295   287   35
 2  1422  1478   28
 3  2450  2483   26
 4   741   699   25
 5  1437  1526   33
 6  1115  1106   26
 7  1478  1468   38
 8  1526  1509   41
 9  1727  1569   41
10   630   629   85
13  1482  1397   50
      5,   3,  L
 0  4539  4500   15
 1  1781  1790   25
 2   671   671   22
 3  1514  1593   31
 4   546   565   31
 5  1806  1940   35
 6  2468  2397   36
 7  1559  1619   42
 8  2824  2777   46
 9   631   561   62
10  1705  1712   54
12   985   779   67
      5,   4,  L
 0  1664  1690   19
 1   939   886   26
 2   516   537   29
 3  1462  1561   34
 4   490   482   36
 7  1664  1696   42
 8  1027   964   34
 9  1813  1866   44
10   640   749   69
      5,   5,  L
 0   888   943   19
 1  3313  3313   26
 2  3035  2965   27
 3  3482  3536   29
 4  2954  2935   31
 5  1996  2031   36
```

```
 L   KFO    FC   SIG
 6  1239  1250   30
 7   502   556   53
 9   620   504   52
11  1204  1128   44
      5,   6,  L
 1  1036  1019   23
 2  1920  1891   33
 3   481   521   41
 4  2363  2378   34
 8  1187  1224   36
      5,   7,  L
 0  1191  1161   21
 1  1833  1872   35
 2  1473  1442   33
 3   532   557   44
 4   528   541   45
 5   700   759   38
 7  1709  1620   40
 9  1998  1872   46
      5,   8,  L
 2   807   799   31
 3   681   682   37
 6  1043  1102   35
      5,   9,  L
 1  1172  1155   29
 2   986   991   30
 3  1697  1652   42
 4   603   710   49
 5  2010  1880   45
      5,  10,  L
 0  1230  1199   21
 1   746   729   39
 2   688   624   43
      6,   0,  L
 0  4237  4309   14
 2  6429  6458   25
 4  5076  5112   34
 6  2246  2329   53
 8  1585  1507   48
10  1785  1804   47
12  1296  1314   46
      6,   1,  L
 0   432   412   20
 1  1671  1657   25
 2  1841  1898   27
 3  2529  2566   28
 4  1776  1753   37
 6   403   339   72
 7  2178  2157   54
 8  1267  1217   44
 9  1557  1473   45
12   808   737   76
      6,   2,  L
 0  4341  4393   18
```

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COLUMNS ARE 10FO,10FC,  10SIG

  L   KFO   FC   SIG
       6,   2,  L
  2  2446  2540   25
  4  2156  2191   32
  5   605   595   37
  6  2551  2588   40
  7  1778  1709   44
  8  2705  2611   51
  9  1464  1403   38
 10  2182  2188   52
 12  1475  1307   63
       6,   3,  L
  0   515   496   22
  1   735   725   20
  2  2330  2407   26
  3  1247   996   28
  4  1343  1413   33
  6  1539  1539   38
  7   763   768   43
  8  2453  2540   51
 10   730   799   69
       6,   4,  L
  0  1906  1846   19
  1  3233  3219   25
  2  1472  1492   34
  3  3657  3797   29
  4  2270  2353   38
  5  2055  2172   37
  6  2607  2688   37
  7   712   727   43
  8  1707  1780   43
  9   600   514   60
 10   797   779   59
 11   663   654   81
       6,   5,  L
  0  1638  1647   22
  1   950  1015   27
  2  1910  2011   33
  3  1681  1679   36
  4   547   574   39
  5   495   411   47
  6   658   676   41
  7  1108  1074   30
  8   870   816   39
  9   978  1060   42
       6,   6,  L
  0  1606  1525   23
  1  2484  2598   31
  2  2534  2616   32
  3  1764  1641   39
  4  1708  1773   41
  5  1010  1028   32
  6   656   684   41
  7  1125  1085   30
  9  1705  1616   39
```

```
  L   KFO   FC   SIG
       6,   7,  L
  0   630   513   25
  1   684   748   33
  3  1270  1215   30
  4   910   862   30
  7  1437  1389   29
       6,   8,  L
  0   815   791   21
  1   737   777   34
  3   841   806   32
  4   588   629   47
  5  1957  1933   45
       6,   9,  L
  1  1163  1217   29
  2   937   900   31
       6,  10,  L
  0   756   731   28
       7,   0,  L
  0  2147  2245   17
  2  3400  3476   27
  4  1491  1519   39
  6  1310  1283   36
  8  2124  1958   52
       7,   1,  L
  0  3342  3417   16
  1  1239  1231   29
  2  3323  3430   26
  3  1135  1149   31
  4  2673  2661   35
  6  1943  1992   48
  7  1187  1105   39
  8  1224  1380   48
  9   756   605   77
 10  1620  1448   49
       7,   2,  L
  1  1161  1239   28
  2  1128  1147   29
  3  1934  2007   34
  5   409   403   57
  6  1422  1377   31
  7  2344  2351   49
  8  1436  1379   34
  9  1225  1067   43
       7,   3,  L
  0  1769  1707   24
  1  1052  1109   24
  2   434   483   38
  3  1266  1264   31
  4  1160  1167   31
  5  1731  1714   41
  6  2254  2196   41
  7  1095  1106   33
  8  1857  1889   49
 10  1499  1299   39
```

```
  L   KFO   FC   SIG
       7,   4,  L
  1  2577  2662   28
  2   648   597   28
  3  2271  2380   33
  6   436   531   63
  7  1570  1602   41
  8   725   789   51
       7,   5,  L
  0  1102  1089   20
  1  2851  2873   30
  2  2448  2503   32
  3  2190  2211   35
  4  1778  1845   39
  5  1088  1133   32
  6  1085  1091   30
  7   434   535   69
  9   920   831   44
       7,   6,  L
  0   560   514   25
  2  1817  1919   38
  4   746   827   36
  5   723   716   36
  6  1170  1233   33
  7   753   728   43
  8  1519  1512   43
       7,   7,  L
  0  1336  1363   25
  1  1051  1023   29
  2  1060  1061   27
  5   686   695   42
  7  1487  1362   30
       7,   8,  L
  0  1384  1393   25
  2  1478  1455   34
       7,   9,  L
  1   936   856   32
  2   837   814   37
  3  1639  1546   40
       8,   0,  L
  0  2074  2148   19
  2  2965  2985   30
  4  1229  1229   30
 10   983   825   88
       8,   1,  L
  0   543   622   21
  1  1980  2123   30
  2  1746  1771   32
  3  1390  1372   34
  4   631   561   39
  5   989   992   32
  6   963   901   39
  7  2164  2128   55
  8   923   821   55
       8,   2,  L
```

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COLUMNS ARE 10FO,10FC,  10SIG

  L   KFO   FC   SIG
       8,   2,  L
  0   469   491   31
  1   763   830   24
  3   414   448   51
  5   578   476   46
  6  1048   989   34
  7   835   739   46
  8  1009  1037   47
 10  1073   934   59
       8,   3,  L
  0  1522  1536   26
  1   836   834   22
  2  2667  2791   31
  3   592   593   35
  4   605   618   39
  6  2103  2148   45
  8  1724  1705   39
       8,   4,  L
  1  1969  2027   32
  3  1525  1570   31
  4  1017  1052   27
  6  1256  1180   27
       8,   5,  L
  0   880   995   21
  1  2126  2213   33
  2   903   880   27
  3  1803  1868   40
  6  1212  1210   29
  7  1000  1024   36
  8   986   957   40
       8,   6,  L
  0   946   941   20
  2  1195  1298   40
  4   725   693   36
       8,   7,  L
  0   933   949   20
  1  1377  1379   34
  3   714   711   37
  5  1114  1107   31
       8,   8,  L
  0   392   434   57
  1   465   407   54
  2   595   521   45
  4   641   695   48
       8,   9,  L
  0  1353  1340   24
  1   937   911   34
       9,   0,  L
  0  2059  2102   21
  2  2480  2563   34
  6  2494  2396   56
  8  1148  1186   62
       9,   1,  L
  0   309   281   47
```

```
  L   KFO   FC   SIG
  1  1271  1340   30
       9,   2,  L
  0  1555  1624   25
  1  2279  2336   31
  2  1594  1682   38
  3  1059  1073   30
  5  1569  1567   40
  6  1203  1215   32
  7  2191  2131   53
  8   774   705   58
       9,   3,  L
  0  1885  1802   26
  1   434   449   43
  2  1205  1321   33
  3   354   325   64
       9,   4,  L
  0  1039  1061   25
  1  2599  2715   33
  2  1088  1029   27
  3  1218  1269   29
  5  1069  1114   31
  7  1330  1314   32
       9,   5,  L
  0   454    55   48
  2   652   670   36
  5   652   642   45
       9,   6,  L
  0   544   535   31
  2  1039  1068   27
  3   527   519   49
  4   682   661   40
  5   586   584   51
  6  1873  1898   48
       9,   7,  L
  0   684   670   27
  1  1051  1001   27
  3   984   949   32
  4   892   816   35
       9,   8,  L
  0  1870  1824   29
  1   866   845   34
  2  1541  1480   34
      10,   0,  L
  0   901   935   17
  2  1028   995   27
  4  1468  1418   40
  6  1268  1282   42
      10,   1,  L
  0   475   420   36
  1  2318  2370   34
  4   722   736   43
  5  1826  1760   46
  6  1359  1350   35
  7  1533  1575   38
```

```
  L   KFO   FC   SIG
      10,   2,  L
  0  2312  2253   23
  1  1095  1080   29
  2  2187  2141   36
  3   636   644   41
  4  1634  1652   44
  6  1035  1038   38
  8   496   491   96
      10,   3,  L
  0  2919  2986   25
  1   570   519   40
  2  2419  2501   36
  6  1724  1655   40
      10,   4,  L
  0  2086  2037   31
  2   992  1014   28
  3   700   665   36
  5   728   690   42
  7   513   584   76
      10,   5,  L
  0   644   683   36
  1  1670  1725   40
  3   579   530   45
  4  1170  1141   29
  5   956   920   36
  6  1383  1394   42
      10,   6,  L
  1  1664  1648   42
  3  1626  1645   44
  5   990  1117   38
      10,   7,  L
  0   496   557   48
  1  1525  1590   44
      10,   8,  L
  1  1144  1261   31
      11,   0,  L
  0  1660  1694   25
  2   417   520   64
  4  1845  1867   49
  6  2145  2153   48
      11,   1,  L
  0  2436  2476   24
  1   846   871   33
  2  2076  2162   40
  3   604   571   47
  4  1848  1816   40
  6  1575  1531   45
      11,   2,  L
  0  2373  2385   25
  1  2050  2134   38
  2  1360  1464   34
  5  1687  1652   42
  7   987  1011   48
      11,   3,  L
```

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COLUMNS ARE 10FO,10FC,  10SIG

L   KFO    FC    SIG        L   KFO    FC    SIG        L   KFO    FC    SIG
     11,   3,  L            6  1285  1153     45        1  1568  1581     40
0  2479  2538     27              12,   1,  L                 13,   0,  L
1   904   941     29        1  1412  1476     40        0  1298  1331     21
2  1987  2088     41        4  1169  1212     34        4  1697  1674     40
3   497   384     54        5  1382  1361     36              13,   1,  L
4  1785  1720     43        6  1133  1100     44        0  1187  1229     20
5   615   529     54              12,   2,  L           2   995  1024     34
6  1276  1341     35        0  1928  1950     29        4   780   731     47
     11,   4,  L            1   552   606     50              13,   2,  L
0  1287  1291     29        2  1952  2004     44        0  1205  1246     20
1  1356  1417     35        3   775   777     41        1  1342  1359     33
2   839   804     32        4  1658  1671     41        4   526   461     66
5  1465  1473     37        5   771   799     50              13,   3,  L
     11,   5,  L                  12,   3,  L           0   972   985     24
0   889   916     29        0  2492  2630     28        2  1006  1060     34
1  1382  1347     35        2  1089  1153     29              13,   4,  L
2   420   530     63        4   913   850     38        0   794   755     30
3  1366  1384     39              12,   4,  L                 13,   5,  L
4   518   564     60        0  1455  1481     27        1   767   748     41
5  1024  1024     37        1   883   834     32              14,   1,  L
     11,   6,  L            2   962   968     31        0   696   685     30
0  1015   994     23        3   644   665     49        1   627   637     47
1   487   584     56        4   805   759     42              14,   2,  L
     11,   7,  L                  12,   5,  L           2   623   611     50
1  1507  1554     38        0   730   749     36              14,   3,  L
     12,   0,  L            1   573   615     47        0  1389  1367     25
0  1490  1472     25        3   698   729     47              15,   0,  L
2  1600  1735     35              12,   6,  L           0  1268  1299     22
4  1566  1516     35        0   564   537     47
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218. Without Extinction

	kF_o	F_c	$\omega\Delta^2$
1,0,2	656	779	88
2,0,0	766	944	135

With Extinction

	kF_o	F_c	$\omega\Delta^2$
1,0,2	790	779	0.48
2,0,0	952	944	0.16

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220. These four reflections were:

	kF_o	F_c
2,0,0	710	987
-1,1,1	702	757
-2,0,2	818	835
-4,0,2	867	1015