IR-10 Organometallic Compounds

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IR-10.1 INTRODUCTION

The enormous growth in organometallic chemistry over the last fifty years and the discovery of new classes of compounds with unprecedented bonding modes has resulted in the need for additional nomenclature rules for organometallic compounds. This Chapter is therefore considerably expanded over Section I-10.9 of Ref. 1 and is largely based on the IUPAC recommendations published in 1999 for organometallic compounds of the transition elements.2
An organometallic compound is defined as any compound containing at least one bond between a metal atom and a carbon atom. The names of organometallic compounds should therefore accord with the rules of both organic and coordination chemistry nomenclature (even though these have tended to evolve separately).

The major part of this Chapter presents a system of nomenclature for transition element organometallic compounds, based on the additive nomenclature system introduced in Chapter IR-7 and applied to coordination compounds in Chapter IR-9 but incorporating, as far as possible, the rules for naming organic ligands. Most importantly, further rules are formulated which unambiguously designate the special modes of bonding often found in organometallic compounds.

The later part of this Chapter briefly describes aspects of the naming of main group organometallic compounds, where the substitutive system of nomenclature (introduced in Chapter IR-6) is applied by substituting the appropriate parent hydrides of the elements of groups 13–16. The names of organometallic compounds of group 1 and 2 elements are, on the other hand, based on the additive nomenclature system.

It should be emphasized that the nomenclature described in this Chapter is confined to the precise description of the composition of a compound and the connectivity of atoms within a molecule or ion; it is often also important to specify the spatial relationships between the structural components of the molecule or ion (see Section IR-9.3). It is particularly true of organometallic chemistry that nomenclature should not attempt to convey details about the polarity of bonds, patterns of reactivity or methods of synthesis.

IR-10.2 Nomenclature of Organometallic Compounds of the Transition Elements

IR-10.2.1 Concepts and conventions

The (additive) nomenclature of coordination complexes, the general definitions and rules of which are given in Sections IR-9.1 and IR-9.2, provides the basis for the system presented here for naming organometallic compounds of the transition elements. The general concepts of coordination chemistry can be applied to organometallic compounds but need to be expanded to deal with the additional modes of connectivity afforded by the interaction of metals with, for example, organic ligands containing unsaturated groupings, such as alkenes, alkynes and aromatic compounds. This section examines relevant concepts and conventions from coordination chemistry as they are applied to organometallic compounds, and indicates what new conventions need to be introduced in order to designate unambiguously the special bonding modes of organometallic compounds.

IR-10.2.1.1 Coordination number

The definition of coordination number as being equal to the number of σ-bonds between the ligands and the central atom (Section IR-9.1.2.6) also applies to ligands such as CN⁻, CO, N₂ and PPh₃, where the bonding of a single ligating atom to a metal may involve a combination of σ- and π-components. The π-bond components are not considered in determining the coordination number, and so [Ir(CO)Cl(PPh₃)₂], [Rh₂(Ph)(PPh₃)₂] and [W(CO)₆] have coordination numbers of four, five and six, respectively.
However, this definition cannot be applied to the many organometallic compounds in which two or more adjacent atoms of a ligand interact with the central metal atom through what is often a combination of $\sigma$, $\pi$ and $\delta$ bonding (the labels $\sigma$, $\pi$ or $\delta$ referring to the symmetry of the orbital interactions between ligand and central atom).

For example, a ligand such as ethene, consisting of two ligating carbon atoms, nevertheless brings only one pair of electrons to the central atom. Likewise, ethyne, coordinating via both carbon atoms, can be thought to bring either one or two pairs of electrons to a single metal atom, depending on the type of coordination involved. Both ligands are normally regarded as monodentate. This changes when ethene or ethyne is considered to add oxidatively to a central metal atom; they are then considered to be bidentate chelating ligands which, on electron counting and dissection of the coordination entity to determine oxidation numbers, are assumed to take two pairs of electrons with them. This different view can be expressed by referring to compounds of such ligands as metallacyclopropanes or metallacyclopropenes rather than ethene or ethyne complexes.

**IR-10.2.1.2 Chelation**

The concept of chelation (Section IR-9.1.2.7) can again be applied strictly only to those organometallic complexes in which the donor atoms of a ligand are attached to the central metal atom through $\sigma$-bonds alone. Otherwise, ambiguities will result, as outlined above, even with a simple ligand such as ethene. Butadiene and benzene supply two and three pairs of electrons upon coordination and are therefore regarded as bi- and tridentate ligands, respectively.

In stereochemistry, however, such ligands are often treated as if they were monodentate.

**IR-10.2.1.3 Specifying connectivity**

In the event of a ligand containing several different donor atoms, particularly when not all are used, the point or points of attachment to the metal are specified using the kappa ($\kappa$) convention (see Sections IR-9.2.4.1 and IR-9.2.4.2). In organometallic nomenclature the ligating carbon atoms are often sufficiently specified within the ligand name. However, use of the kappa notation becomes necessary to indicate the attachment of heteroatoms, and also to specify the particular points of attachment of a single ligand when bridging different metal centres in a polynuclear complex. The strength of the kappa convention is that its use completely avoids any ambiguities in describing the connectivities between a ligand and one or more metal centres. Its use in organometallic nomenclature is discussed further in Section IR-10.2.3.3.

A complementary notation, the eta ($\eta$) convention, is used to specify the number (‘hapticity’) of contiguous ligating atoms that are involved in bonding to one or more metals. The need for this convention arises from the special nature of the bonding of unsaturated hydrocarbons to metals via their $\pi$-electrons, and it is used only when there are several contiguous atoms involved in the bond to the metal. The contiguous atoms of the $\pi$-coordinated ligand are often the same element, but they need not be, and they may also be atoms other than carbon. The eta convention is defined in Section IR-10.2.5.1, where its use is extensively illustrated. Even though all connectivity can be expressed by the kappa convention alone, the practice in organometallic nomenclature is that the eta convention should be used wherever there are contiguous ligating atoms. Complicated structures may require the use of both conventions (see Section IR-9.2.4.3).
Organic ligands with the ability to form more than one bond to a metal centre may be chelating (if bonding to a single metal), bridging (if bonding to more than one metal), or sometimes even both chelating and bridging. The bridging bonding mode is indicated by the Greek letter \( \mu \) (mu) prefixing the ligand name (Section IR-9.2.5.2). This convention is further exemplified for organometallic compounds in Sections IR-10.2.3.1 and IR-10.2.3.4.

IR-10.2.1.4  *Oxidation number and net charge*

The concept of oxidation number or state (see also Sections IR-4.6.1, IR-5.4.2.2 and IR-9.1.2.8) is sometimes difficult to apply to organometallic compounds. This is especially true when it cannot be determined whether complexation by a ligand is better regarded as a Lewis-acid or Lewis-base association or as an oxidative addition. Thus, for nomenclature purposes it is only the net charge on the coordination entity that is important, and formal oxidation numbers will not be assigned to the central atoms of the organometallic complexes in the following sections. The reader is referred to standard textbooks on organometallic chemistry for discussion of the assignment of oxidation number in such compounds.

IR-10.2.2  *Compounds with one metal–carbon single bond*

In naming organometallic compounds the usual rules for naming ligands in coordination entities are applied if the ligand coordinates via an atom other than carbon (Section IR-9.2.2.3). Thus, the ligand MeCOO\(^-\) is named acetato, Me\(_2\)As\(^-\) is named dimethyldarsanido, and PPh\(_3\) is named triphenylphosphane.

If an organic ligand coordinating via one carbon atom is regarded as an anion formed by the removal of one hydron from that atom, the ligand name is formed by replacing the ending ‘ide’ of the anion name by ‘ido’.

*Examples:*

1. \( \text{CH}_3^- \) methanido
2. \( \text{CH}_3\text{CH}_2^- \) ethanido
3. \( \text{(CH}_2=\text{CHCH}_2^- \) prop-2-en-1-ido
4. \( \text{C}_6\text{H}_5^- \) benzenido
5. \( \text{(C}_2\text{H}_3\text{)}^- \) cyclopentadienido

Although strictly speaking ambiguous, the anion name cyclopentadienide is acceptable as a short form of cyclopenta-2,4-dien-1-ide (and consequently the ligand name cyclopentadienido).

The compound \([\text{TiCl}_3\text{Me}]\) would be called trichlorido(methanido)titanium using the above type of ligand name.

The alternative for naming an organic ligand attached via a single carbon atom is to regard it as a substituent group, its name being derived from a parent hydride from which one hydrogen atom has been removed. This designation is somewhat arbitrary as such ligands in organometallic chemistry are generally treated as anions when deducing oxidation states, although the bonding in reality may be highly covalent. However, it has a long
tradition in organic and organometallic chemistry, and its major advantage is that names used in common practice for organic groups can be applied unchanged.

There are two methods for constructing substituent group names from parent hydride names:

(a) The suffix ‘yl’ replaces the ending ‘ane’ of the parent hydride name. If the parent hydride is a chain, the atom with the free valence is understood to terminate the chain. In all cases that atom has the locant ‘1’ (which is omitted from the name). This method is employed for saturated acyclic and monocyclic hydrocarbon substituent groups and for the mononuclear parent hydrides of silicon, germanium, tin and lead.

*Examples:*

6. CH$_3$– methyl
7. CH$_3$CH$_2$– ethyl
8. C$_6$H$_{11}$– cyclohexyl
9. CH$_3$CH$_2$CH$_2$CH$_2$– butyl
10. CH$_3$CH$_2$CH$_2$C(Me)H– 1-methylbutyl
11. Me$_3$Si– trimethylsilyl

The compound [TiCl$_3$Me] would be called trichlorido(methyl)titanium by this method.

(b) In a more general method, the suffix ‘yl’ is added to the name of the parent hydride with elision of the terminal ‘e’, if present. The atom with the free valence is given a number as low as is consistent with the established numbering of the parent hydride. The locant number, including ‘1’, must always be cited. (See Section P-29 of Ref. 3 for a more complete discussion of substituent group names.)

*Examples:*

12. CH$_3$CH$_2$CH$_2$C(Me)H– pentan-2-yl (cf. Example 10 above)
13. CH$_2$=CHCH$_2$– prop-2-en-1-yl

In fused polycyclic hydrocarbons as well as in heterocyclic systems, special numbering schemes are adopted (see Section P-25 of Ref. 3).

*Examples:*

14. ![Naphthalen-2-yl structure](image)

15. ![1H-Inden-1-yl structure](image)
Table IR-10.1 gives the names used for ligands forming a single bond to a metal, and this is followed by examples illustrating the naming of compounds containing one metal–carbon single bond. In this Table (as well as in Tables IR-10.2 and IR-10.4) the organic ligands are listed both as anions and as neutral species. Acceptable alternative names are given in the final column.

<table>
<thead>
<tr>
<th>Ligand formula</th>
<th>Systematic name as anionic ligand</th>
<th>Systematic name as neutral ligand</th>
<th>Acceptable alternative name</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₃⁻</td>
<td>methanido</td>
<td>methyl</td>
<td></td>
</tr>
<tr>
<td>CH₂CH₂⁻</td>
<td>ethanido</td>
<td>ethyl</td>
<td></td>
</tr>
<tr>
<td>CH₃CH₂CH₂⁻</td>
<td>propan-1-ido</td>
<td>propyl</td>
<td>isopropyl</td>
</tr>
<tr>
<td>(CH₃)₂CH⁻</td>
<td>propan-2-ido</td>
<td>propan-2-yl or 1-methylethyl</td>
<td>allyl</td>
</tr>
<tr>
<td>CH₂=CHCH₂⁻</td>
<td>prop-2-en-1-ido</td>
<td>prop-2-en-1-yl</td>
<td></td>
</tr>
<tr>
<td>CH₃CH₂CH₂CH₂⁻</td>
<td>butan-1-ido</td>
<td>butyl</td>
<td></td>
</tr>
<tr>
<td>CH₃CH₂−[C—]&lt;H</td>
<td>butan-2-ido</td>
<td>butan-2-yl or 1-methylpropyl</td>
<td>sec-butyl</td>
</tr>
<tr>
<td>H₃C—CH—CH₂⁻</td>
<td>2-methylpropan-1-ido</td>
<td>2-methylpropyl</td>
<td>isobutyl</td>
</tr>
<tr>
<td>H₃C—CH₃—C—</td>
<td>2-methylpropan-2-ido</td>
<td>2-methylpropan-2-yl or 1,1-dimethylethyl</td>
<td>tert-butyl</td>
</tr>
<tr>
<td>H₃C—CH₃—CH₂⁻—CH₃</td>
<td>2,2-dimethylpropan-1-ido</td>
<td>2,2-dimethylpropyl</td>
<td></td>
</tr>
<tr>
<td>H₂C—CH—</td>
<td>cyclopropanido</td>
<td>cyclopropyl</td>
<td></td>
</tr>
<tr>
<td>H₂C—C—</td>
<td>cyclobutanoide</td>
<td>cyclobutyl</td>
<td></td>
</tr>
</tbody>
</table>

16.

morpholin-2-yl
### Table IR-10.1 Continued

<table>
<thead>
<tr>
<th>Ligand formula</th>
<th>Systematic name as anionic ligand</th>
<th>Systematic name as neutral ligand</th>
<th>Acceptable alternative name</th>
</tr>
</thead>
<tbody>
<tr>
<td>C₅H₅⁻</td>
<td>cyclopenta-2,4-dien-1-ido</td>
<td>cyclopenta-2,4-dien-1-yl</td>
<td>cyclopentadienyl</td>
</tr>
<tr>
<td>C₆H₅⁻</td>
<td>benzenido</td>
<td>phenyl</td>
<td></td>
</tr>
<tr>
<td>C₆H₅CH₂⁻</td>
<td>phenylmethyl</td>
<td>phenylmethyl</td>
<td>benzil</td>
</tr>
<tr>
<td>H₂C⁻C₇O</td>
<td>1-oxoethan-1-ido</td>
<td>ethanoyl⁹</td>
<td>acetyl⁹</td>
</tr>
<tr>
<td>C₂H₅⁻C₇O</td>
<td>1-oxopropan-1-ido</td>
<td>propanoyl⁹</td>
<td>propionyl⁹</td>
</tr>
<tr>
<td>C₃H₅⁻C₇O</td>
<td>1-oxobutan-1-ido</td>
<td>butanoyl⁹</td>
<td>butyryl⁹</td>
</tr>
<tr>
<td>O=C-C₇O</td>
<td>oxo(phenyl)methanido</td>
<td>benzenecarbonyl⁹</td>
<td>benzoyle⁹</td>
</tr>
<tr>
<td>H₂C≡CH⁻</td>
<td>ethenido</td>
<td>ethenyl</td>
<td>vinyl</td>
</tr>
<tr>
<td>H⁻C</td>
<td>ethynido</td>
<td>ethynyl</td>
<td></td>
</tr>
<tr>
<td>H₃Si⁻</td>
<td>silanido</td>
<td>silyl</td>
<td></td>
</tr>
<tr>
<td>H₃Ge⁻</td>
<td>germanido</td>
<td>germyl</td>
<td></td>
</tr>
<tr>
<td>H₃Sn⁻</td>
<td>stannanido</td>
<td>stannyl</td>
<td></td>
</tr>
<tr>
<td>H₃Pb⁻</td>
<td>plumbanido</td>
<td>plumbyl</td>
<td></td>
</tr>
</tbody>
</table>

⁹ These acyl names are preferred to 1-oxoethyl, *etc.*

**Examples:**

17. [OsEt(NH₃)₃]Cl pentaamine(ethyl)osmium(1+), chloride

18. Li[CuMe₂] lithium dimethylcuprate(1−)

19. \[
\text{tetraakis(bicyclo[2.2.1]heptan-1-yl)chromium}
\]

20. [Pt(C(O)Me)Me(PEt₃)₂] acetyl(methyl)bis(triethylphosphane)platinum
21. carbonyl(η⁵-cyclopentadienyl)((E)-3-phenylbut-2-en-2-yl)(triphenylphosphane)iron

(The η term used here is explained in Section IR-10.2.5.1.)

22. (phenylethynyl)(pyridine)bis(triphenylphosphane)rhodium

23. bis[ethane-1,2-diylbis(dimethylphosphane-κP)]hydrido(naphthalen-2-yl)ruthenium

IR-10.2.3 Compounds with several metal–carbon single bonds from one ligand

When an organic ligand forms more than one metal–carbon single bond (to one or more metal atoms), the ligand name may be derived from the name of the parent hydrocarbon from which the appropriate number of hydrogen atoms have been removed. In the systematic substitutive name, the suffix ‘diyl’ or ‘triyl’ is attached to the name of the parent hydrocarbon if two or three hydrogen atoms, respectively, are replaced by one or more metal atoms. There is no removal of the terminal ‘e’. The locant ‘1’ is assigned so as to create the longest chain of carbon atoms, and the direction of numbering is chosen to give the lowest possible locants to side chains or substituents. The locant number(s) must always be cited, except for ligands derived from methane.

Alternatively, when considering these ligands as anions, the endings ‘diido’ and ‘triido’ should be used. This nomenclature also applies to hypervalent coordination modes, e.g. for bridging methyl groups. Typical ligands forming two or three metal–carbon single bonds are listed in Table IR-10.2.
Table IR-10.2 Names for ligands forming several metal–carbon single bonds

<table>
<thead>
<tr>
<th>Ligand formula</th>
<th>Systematic name as anionic ligand</th>
<th>Systematic name as neutral ligand</th>
<th>Acceptable alternative name</th>
</tr>
</thead>
<tbody>
<tr>
<td>−CH₂−</td>
<td>methanediido</td>
<td>methanediyl</td>
<td>methylene</td>
</tr>
<tr>
<td>−CH₂CH₂−</td>
<td>ethane-1,2-diido</td>
<td>ethane-1,2-diyl</td>
<td>ethylene</td>
</tr>
<tr>
<td>−CH₃CH₂CH₃−</td>
<td>propane-1,3-diido</td>
<td>propane-1,3-diyl</td>
<td></td>
</tr>
<tr>
<td>−CH₃CH₂CH₃−CH₃</td>
<td>butane-1,4-diido</td>
<td>butane-1,4-diyl</td>
<td></td>
</tr>
<tr>
<td>H₃C−</td>
<td>methanetriido</td>
<td>methanetriyl</td>
<td></td>
</tr>
<tr>
<td>CH₃CH₂&lt;</td>
<td>ethane-1,1-diido</td>
<td>ethane-1,1-diyl</td>
<td></td>
</tr>
<tr>
<td>CH₃C−</td>
<td>ethane-1,1,1-triido</td>
<td>ethane-1,1,1-triyl</td>
<td></td>
</tr>
<tr>
<td>−CH=CH−</td>
<td>ethene-1,2-diido</td>
<td>ethene-1,2-diyl</td>
<td></td>
</tr>
<tr>
<td>H₂C≡C−</td>
<td>ethene-1,1-diido</td>
<td>ethene-1,1-diyl</td>
<td></td>
</tr>
<tr>
<td>−C≡C−</td>
<td>ethyne-1,2-diido</td>
<td>ethyne-1,2-diyl</td>
<td></td>
</tr>
<tr>
<td>−C₆H₆−</td>
<td>benzenediido</td>
<td>benzenediyl</td>
<td>phenylene</td>
</tr>
<tr>
<td>(-1,2-diido, etc.)</td>
<td>(-1,2-diido, etc.)</td>
<td>(1,2-, etc.)</td>
<td></td>
</tr>
</tbody>
</table>

IR-10.2.3.1 The μ (mu) convention

Organic ligands forming more than one metal–carbon bond can be either chelating, if coordinating to one metal atom, or bridging, if coordinating to two or more metal atoms. A bridging bonding mode is indicated by the Greek letter μ (Sections IR-9.2.5.2 and IR-10.2.3.4).

![Diagram of μ-propane-1,3-diyl (bridging) and propane-1,3-diyl (chelating)]

The number of metal atoms connected by a bridging ligand is indicated by a right subscript, μₙ, where n ≥ 2, though the bridging index 2 is not normally indicated.

![Diagram of μ-methyl and μ₃-methyl]

The name methylene for CH₂ can only be used in connection with a bridging bonding mode (μ-methylene), whereas a CH₂ ligand bonding to one metal only has a metal–carbon double bond and should be named as methylidene (see Section IR-10.2.4).
Likewise, the ligand HC will have at least three different bonding modes: bridging three metals (μ₃-methanetriyl), bridging two metals (μ-methylene) and coordinating to one metal (methylidyne, see Section IR-10.2.4).

In a bridging mode the ligand CH₂CH₂ should be called μ-ethane-1,2-diyl, while the same ligand coordinating through both carbon atoms to a single metal centre should be called η²-ethene (see Section IR-10.2.5).

A similar situation arises with CHCH which, when bridging with the carbon atoms individually bonded to each of two metals, should be called μ-ethene-1,2-diyl or, when the metal-carbon bonds are double, μ-ethanediyldiene (see Section IR-10.2.4). The same ligand coordinating through both carbon atoms to both metal centres should be called μ-ethyne; when coordinated through both carbons to one metal it is named η²-ethyne (see Section IR-10.2.5).

IR-10.2.3.2 Chelating ligands

Where a chelating ligand is formed by removing two or more hydrogen atoms from a parent compound, the atoms with free valencies, understood to form the bonds to the central atoms, are indicated by using the appropriate ligand name (such as propane-1,3-diyl), cf. Section IR-10.2.3. This is demonstrated in Examples 1–3 below. Note that an alternative nomenclature for such metallacycles is currently being developed.
Examples:

1. 

\[
\begin{align*}
\text{(butane-1,4-diyl)bis(triphenylphosphane)platinum}
\end{align*}
\]

2. 

\[
\begin{align*}
(2,4\text{-dimethylpenta-1,3-diene-1,5-diyl)tris(triethylphosphane)iridium(1+)}
\end{align*}
\]

3. 

\[
\begin{align*}
(1\text{-oxo-2,3-diphenylpropane-1,3-diyl)bis(triphenylphosphane)platinum}
\end{align*}
\]

IR-10.2.3.3 The kappa (κ) convention

Chelate rings that contain a coordinate (dative) bond from a heteroatom in addition to a carbon attachment should be named using the κ convention. In this convention (see Section IR-9.2.4.2) the coordinating atoms of a polydentate ligand bonding to a metal centre are indicated by the Greek letter kappa, κ, preceding the italicized element symbol of each ligating atom. A right superscript numeral may be added to the symbol κ to indicate the number of identical bonds from a type of ligating atom to the central atom(s); non-equivalent ligating atoms should each be indicated by an italicized element symbol preceded by κ.

In simple cases one or more superscript primes on the element symbol may be used to differentiate between donor atoms of the same element. Otherwise a right superscript numeral corresponding to the conventional numbering of the atoms in the ligand is used to define unambiguously the identity of the ligating atom. These symbols are placed after that portion of the ligand name which represents the particular functionality, substituent group, ring or chain in which the ligating atom is found.

Often it is only necessary for the coordinating heteroatom to be specified using the κ convention, the ligating carbon atom being adequately specified by the appropriate substitutive suffix. For illustrative purposes only, an arrow is used in the examples that
follow to indicate a coordinate bond in the chelate ring. In Example 1 the \( \kappa C^1 \) specification is included for clarity but is not strictly necessary as the bonding from carbon atom number 1 is implied by the name ‘phenyl’.

**Examples:**

1. 

   ![Tetra(carbonyl)[2-(2-phenyldiazen-1-yl-\( \kappa C^3 \)]phenyl-\( \kappa C^1 \)]manganese](image)

   tetracarbonyl[2-(2-phenyldiazen-1-yl-\( \kappa N^2 \))phenyl-\( \kappa C^1 \)]manganese

2. 

   ![Chlorido(2-methyl-3-oxo-\( \kappa O \)-but-1-en-1-yl)bis(triisopropylphosphane)rhodium](image)

   chlorido(2-methyl-3-oxo-\( \kappa O \)-but-1-en-1-yl)bis(triisopropylphosphane)rhodium

**IR-10.2.3.4 Bridging ligands**

A bridging ligand is indicated by the Greek letter \( \mu \) (mu) prefixing the ligand name (see Sections IR-9.2.5.2 and IR-10.2.3.1). Bridging ligands are listed in alphabetical order along with the other ligands, but in names a bridging ligand is cited before a corresponding non-bridging ligand, and multiple bridging is listed in decreasing order of complexity, e.g. \( \mu_3 \) bridging before \( \mu_2 \) bridging.

**Example:**

1. 

   ![\( \mu \)-ethane-1,1-diyl]bis(pentacarbonylrhenium)](image)

   \( \mu \)-ethane-1,1-diyl]bis(pentacarbonylrhenium)

The metal centres in heterodinuclear coordination entities are numbered and listed according to the element sequence given in Table VI*, the central atom arrived at last when traversing this table being numbered ‘1’ and listed in the name first (see Section IR-9.2.5).

The numerical locants of the central atoms are used in conjunction with the \( \kappa \) notation to indicate the distribution of the ligating atoms. Such locants are placed before the \( \kappa \) symbol which, as before, may be followed by a right superscript numeral to denote the number of equivalent bonds to the central atom specified by the locant (see Section IR-9.2.5.5). Thus, decacarbonyl-1\( \kappa^5 C^5 \cdot 2 \kappa^5 C^1 \) indicates that the carbon atoms of five carbonyl ligands are bonded to central atom number 1 and another five to central atom number 2. In the names of bridging ligands, the \( \kappa \) terms indicating the bonding to each of the central atoms are separated by a colon, e.g. \( \mu \)-propane-1,2-diyl-1\( \kappa C^1 \cdot 2 \kappa C^2 \).

* Tables numbered with a Roman numeral are collected together at the end of this book.
Example:

2. 

\[
\begin{array}{c}
\text{(OC)}_3\text{Re} \\
\text{H}_2 \\
\text{CH}_3 \\
\end{array}
\]

\[
\begin{array}{c}
(\text{OC})_5\text{Mn} \\
\end{array}
\]

decacarbonyl-1κ^5\text{C}_2,2κ^5\text{C}-(\mu\text{-propane-1,2-diyl}-1κ^1\text{C}^{\text{4}};2κ^2\text{C}^2)\text{rheniummanganese}

IR-10.2.3.5 Metal–metal bonding

Metal–metal bonding is indicated by the italicized element symbols of the appropriate metal atoms, separated by an ‘em’ dash and enclosed in parentheses, placed after the list of central atom names and before the ionic charge. The element symbols are placed in the same order as the central atoms appear in the name, i.e. with the element met last in the sequence of Table VI given first. The number of such metal–metal bonds is indicated by an arabic numeral placed before the first element symbol and separated from it by a space. For the purpose of nomenclature, no distinction is made between different metal–metal bond orders.

Examples:

1. 

\[
\begin{array}{c}
\text{H}_2\text{C—CH}_2 \\
\text{(OC)}_4\text{Os} \\
\text{Os(CO)}_4 \\
\end{array}
\]

(\mu\text{-ethane-1,2-diyl})\text{bis(tetracarbonylosmium)}(\text{Os—Os})

2. 

\[
\begin{array}{c}
\text{Me} \\
\text{(OC)}_3\text{Co} \\
\text{Co(CO)}_3 \\
\text{Co(CO)}_3 \\
\end{array}
\]

(\mu_3\text{-ethane-1,1,1-triyl})\text{-triangulo-tris(tricarbonylcobalt)}(3 \text{ Co—Co})

3. 

\[
\begin{array}{c}
\text{W} \\
\text{Fe} \\
\text{O} \\
\text{O} \\
\text{O} \\
\text{O} \\
\end{array}
\]

di-\mu\text{-carbonyl-carbonyl-2κC-bis(1\eta^5\text{-cyclopentadienyl})(2\eta^4\text{-cyclopentadienyl})tungstenrhenium}(W—Re)

The \eta terms involved here are explained in Section IR-10.2.5.1. For a more detailed discussion of dinuclear compounds and larger polynuclear clusters, with further examples, see Section IR-9.2.5.
IR-10.2.4 **Compounds with metal–carbon multiple bonds**

Ligands regarded as forming metal–carbon double or triple bonds may also be given substituent prefix names derived from the parent hydrides, the ligand names ending with ‘ylidene’ for a double bond and with ‘ylidyne’ for a triple bond. These suffixes are used according to two methods (see Section P-29 of Ref. 3).

(a) The suffix ‘ylidene’ or ‘ylidyne’ replaces the ending ‘ane’ of the parent hydride name. If the parent hydride is a chain, the atom with the free valencies is understood to terminate the chain. This atom has, in all cases, the locant ‘1’ (which is omitted from the name). This method is used only for saturated acyclic and monocyclic hydrocarbon substituent groups and for the mononuclear parent hydrides of silicon, germanium, tin and lead. Note that the suffix ‘ylene’ should only be used in conjunction with μ to designate bridging –CH2– (methylene) or –C6H4– (phenylene) (see Section IR-10.2.3.1).

(b) In a more general method, the suffix ‘ylidene’ or ‘ylidyne’ is added to the name of the parent hydride with elision of the terminal ‘e’, if present. The atom with the free valence is given a number as low as is consistent with the established numbering of the parent hydride. For ligand names with the suffix ‘ylidene’, this locant must always be cited, except if it is the only locant in the name and there is no ambiguity.

*Example:*

1. EtCH= propylidene [method (a)]
2. Me3C= propan-2-ylidene [method (b)]

Note that in numbering a ligand that has several points of attachment, the longest chain of carbon atoms is chosen as the parent chain before assigning the lowest possible locant to the atom with the free valence. In a metallacycle, the direction of numbering is chosen so as to give the lowest possible locants to side chains or substituents. Once again, special numbering schemes apply to heterocyclic and polycyclic systems (see Sections P-25 and P-29 of Ref. 3).

If a ligand forms one or more metal–carbon single bonds as well as metal–carbon multiple bonds, the order of endings is ‘yl’, ‘ylidene’, ‘ylidyne’. Method (b) should then be used to give the lowest possible set of locants for the free valencies. If a choice remains, lower numbers are selected for the ‘yl’ positions before the ‘ylidene’ positions and then for any side chains or substituents.

*Example:*

2. \[
\text{CH}_2-\text{CH}=\text{C} \quad \text{propan-1-yl-1-ylidene}
\]

Typical ligands forming a metal–carbon double or triple bond are listed in Table IR-10.3, and this is followed by examples illustrating the naming of compounds containing one or more metal–carbon multiple bonds. The η term in Example 5 is explained in Section IR-10.2.5.1.

Note that the anion names given in Table IR-10.2 (methanediido, ethane-1,1-diido, etc.) may also be used for these ligands, but it is then not possible to communicate the concept of the carbon–metal bond as being a double or triple bond.
### Table IR-10.3 Names for ligands forming metal–carbon multiple bonds

<table>
<thead>
<tr>
<th>Ligand formula</th>
<th>Systematic name</th>
<th>Acceptable alternative name</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂C≡</td>
<td>methylidene</td>
<td></td>
</tr>
<tr>
<td>MeCH≡</td>
<td>ethylidene</td>
<td></td>
</tr>
<tr>
<td>H₂C≡C≡</td>
<td>ethenylidene</td>
<td>vinylidene</td>
</tr>
<tr>
<td>H₂C≡HC≡H⁻C≡</td>
<td>prop-2-en-1-ylidene</td>
<td>allylidene</td>
</tr>
<tr>
<td>H₂C≡C≡C≡</td>
<td>propa-1,2-dien-1-ylidene</td>
<td>allenyldiene</td>
</tr>
<tr>
<td>H₂C≡</td>
<td>propan-2-ylidene</td>
<td>isopropylidene</td>
</tr>
<tr>
<td>H₃C—C—C≡</td>
<td>2,2-dimethylpropylidene</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><img src="C%E2%89%A1" alt="Image" /></td>
<td>cyclopropylidene</td>
<td></td>
</tr>
<tr>
<td><img src="C%E2%89%A1" alt="Image" /></td>
<td>cyclobutylidene</td>
<td></td>
</tr>
<tr>
<td><img src="C%E2%89%A1" alt="Image" /></td>
<td>cyclopenta-2,4-dien-1-ylidene</td>
<td></td>
</tr>
<tr>
<td>PhHC≡</td>
<td>phenylmethylidene</td>
<td>benzyldiene</td>
</tr>
<tr>
<td>HC≡</td>
<td>methanylylidene</td>
<td></td>
</tr>
<tr>
<td>HC≡</td>
<td>methylidyne</td>
<td></td>
</tr>
<tr>
<td>MeC≡</td>
<td>ethylidyne</td>
<td></td>
</tr>
<tr>
<td>EtC≡</td>
<td>propylidyne</td>
<td></td>
</tr>
<tr>
<td>H₃C—C—C≡</td>
<td>2,2-dimethylpropylidyne</td>
<td></td>
</tr>
<tr>
<td>PhC≡</td>
<td>phenylmethylidyne</td>
<td>benzyldidyne</td>
</tr>
</tbody>
</table>
Examples:

3. 
\[
\text{(acetonitrile)tetracarbonyl(2-methoxyphenyl)methyldiene|tungsten}
\]

4. 
\[
\text{(2,4-dimethylpenta-1,3-dien-1-yl-5-yldiene)tris(triethylphosphane)|iridium}
\]

5. 
\[
\text{dicarbonyl(\(\eta^5\)-cyclopentadienyl)(3-methylbuta-1,2-dien-1-yldiene)manganese}
\]

6. 
\[
\text{tetracarbonyl[(diethylamino)methyldyne]iodidochromium}
\]

7. 
\[
\text{(2,2-dimethylpropyl)(2,2-dimethylpropylidyne)(2,2-dimethylpropylidyne)\(\subset\) [ethane-1,2-diylbis(dimethylphosphane-\(\kappa P\))|tungsten*}
\]
\[
\text{\(p \underset{\text{P}}{\overset{\text{P}}{\longrightarrow}} \text{Me}_2\text{PCH}_2\text{CH}_2\text{PMe}_2 = \text{ethane-1,2-diylbis(dimethylphosphane)\(\subset\)}}
\]

IR-10.2.5 Compounds with bonds to unsaturated molecules or groups

Since the discovery of Zeise’s salt, \(K[\text{Pt(\(\eta^2\)-C\(_2\)H\(_4\))}\text{Cl}_3]\), the first organometallic complex of a transition element, and particularly since the first reported synthesis of ferrocene, \([\text{Fe(\(\eta^5\)-C\(_5\)H\(_5\))}_2]\), the number and variety of organometallic compounds with unsaturated organic ligands has increased enormously.

Complexes containing ligands which coordinate to a central atom with at least two adjacent atoms in a ‘side-on’ fashion require a special nomenclature. These ligands normally contain

*The symbol ‘\(\subset\)’ is used to divide the name, necessitated by the line break. In the absence of the line break this symbol is omitted. Note that all hyphens are true parts of the name.
groups that coordinate via the π-electrons of their multiple bonds, such as alkenes, alkynes and aromatic compounds, but they may also be carbon-free entities containing bonds between heteroelements; the complexes are then generally referred to as ‘π-complexes’. However, the exact nature of the bonding (σ, π, δ) is often uncertain. The atoms bonded to the metal atom are therefore indicated in a manner independent of theoretical implications. Thus, the use of the prefixes σ and π is not recommended in nomenclature; these symbols refer to the symmetry of orbitals and their interactions, which are irrelevant for nomenclature purposes.

Ligands such as alkenes, alkynes, nitriles and diazenes, and others such as allyl (C₃H₅), butadiene (C₄H₆), cyclopentadienyl (C₅H₅), cycloheptatrienyl (C₇H₇) and cyclooctatetraene (C₈H₈), may be formally regarded as anionic, neutral (or sometimes cationic). The structures of, and bonding in, their complexes may also be complicated or ill-defined. Names for such ligands are therefore chosen that indicate stoichiometric composition and are derived in a similar way to those for the ligands discussed in preceding Sections.

Ligands considered as neutral molecules are given a name according to the rules of Ref. 3, including the special nomenclature and numbering applied to fused polycyclic or unsaturated heterocyclic ligands (see Section P-25 of Ref. 3).

Ligands regarded as substituent groups derived by removing hydrogen atoms from (substituted) parent hydrides are given the substituent names ending in ‘yl’, ‘diyl’, ‘yldiene’, etc., depending on the number of hydrogen atoms removed, again following Ref. 3 (in particular Section P-29). Ligands regarded as anions obtained by removing hydrons from (substituted) parent hydrides are given the endings ‘ido’, ‘diido’, etc., depending on the number of hydrons removed.

IR-10.2.5.1 The eta (η) convention

The special nature of the bonding of unsaturated hydrocarbons to metals via their π-electrons has led to the development of the ‘hapto’ nomenclature to designate unambiguously the unique bonding modes of the compounds so formed. (See also Section IR-9.2.4.3.) The Greek symbol η (eta) provides a topological description by indicating the connectivity between the ligand and the central atom. The number of contiguous atoms in the ligand coordinated to the metal is indicated by a right superscript numeral, e.g. η³ (‘eta three’ or ‘trihapto’), η⁴ (‘eta four’ or ‘tetrahapto’), η⁵ (‘eta five’ or ‘pentahapto’), etc. The symbol η is added as a prefix to the ligand name, or to that portion of the ligand name most appropriate to indicate the connectivity, as in cyclopenta-2,4-dien-1-yl-η²-ethene versus vinyl-η⁵-cyclopentadienyl:

\[
\text{cyclopenta-2,4-dien-1-yl-η²-ethene} \quad \text{vinyl-η⁵-cyclopentadienyl}
\]

The ligand name η⁵-cyclopentadienyl, although strictly speaking ambiguous, is acceptable as a short form of η⁵-cyclopentadienyl-2,4-dien-1-yl, due to common usage.

These ligand names are enclosed in parentheses in the full name of a complex. Note the importance of making rigorous use of enclosing marks, etc. to distinguish the above bonding modes from the other four cases below. Note also that when cyclopenta-2,4-dien-1-yl coordinates at the carbon with the free valence, a κ term is added for explicit indication of that bonding. In general, this is necessary with names of unsaturated ligands which may participate
in several types of bonding (see Example 17 below, where the ligand name ends in ‘yl’, but the bonding is described using an \( \eta \) term placed elsewhere in the name, and Example 24, where the C\(^1\) atoms in the cyclopentadienyl ligands are involved in binding to both central atoms).

![Diagrams of compounds](image)

(cyclopenta-2,4-dien-1-yl-kC\(^1\))(\( \eta^2 \)-ethene) (\( \eta^5 \)-cyclopentadienyl)(\( \eta^2 \)-ethene)

(cyclopenta-2,4-dien-1-yl-kC\(^1\))(vinyl) (\( \eta^5 \)-cyclopentadienyl)(vinyl)

Complexes of unsaturated systems incorporating heteroatoms may be designated in the same manner if both the carbon atoms and adjacent heteroatoms are coordinated. Names for typical unsaturated molecules and groups acting as ligands are listed in Table IR-10.4, and this is followed by examples illustrating the naming of compounds containing such ligands. Note that when using the \( \eta \) prefixes, shorthand forms of anion and substituent group names are acceptable, e.g. \( \eta^5 \)-cyclohexadienido instead of \( \eta^5 \)-cyclohexa-2,4-dien-1-ido and \( \eta^5 \)-cyclohexadienyl instead of \( \eta^5 \)-cyclohexa-2,4-dien-1-yl.

<table>
<thead>
<tr>
<th>Ligand</th>
<th>Systematic name as anionic ligand</th>
<th>Systematic name as neutral ligand</th>
<th>Acceptable alternative name</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \eta^1 )-prop Idaho</td>
<td>( \eta^1 )-propenyl</td>
<td>( \eta^1 )-allyl</td>
<td></td>
</tr>
<tr>
<td>( \eta^1 )-(Z)-butenilo</td>
<td>( \eta^1 )-(Z)-butenyl</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \eta^1 )-2-methylprop Idaho</td>
<td>( \eta^1 )-2-methylpropenyl</td>
<td>( \eta^1 )-2-methylallyl</td>
<td></td>
</tr>
<tr>
<td>( \eta^2 )-2-methylidene-propane-1,3-diido</td>
<td>( \eta^2 )-2-methylidene-propane-1,3-diyi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \eta^3 )-2,3-dimethylidene-butane-1,4-diido</td>
<td>( \eta^3 )-2,3-dimethylidene-butane-1,4-diyi</td>
<td>( \eta^3 )-2,3'-biallyl</td>
<td></td>
</tr>
<tr>
<td>( \eta^2 )-(Z,Z)-pentadienido</td>
<td>( \eta^2 )-(Z,Z)-pentadienyl</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \eta^5 )-cyclopentadienido</td>
<td>( \eta^5 )-cyclopentadienyl</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ligand a</td>
<td>Systematic name as anionic ligand</td>
<td>Systematic name as neutral ligand</td>
<td>Acceptable alternative name</td>
</tr>
<tr>
<td>---------</td>
<td>---------------------------------</td>
<td>---------------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td><img src="image1" alt="Structure" /></td>
<td>pentamethyl-η⁵- cyclopentadienido</td>
<td>pentamethyl-η⁵- cyclopentadienyl</td>
<td></td>
</tr>
<tr>
<td><img src="image2" alt="Structure" /></td>
<td>η⁵-cyclohexadienido</td>
<td>η⁵-cyclohexadienyl</td>
<td></td>
</tr>
<tr>
<td><img src="image3" alt="Structure" /></td>
<td>η⁷-cycloheptatrienido</td>
<td>η⁷-cycloheptatrienyl b</td>
<td></td>
</tr>
<tr>
<td><img src="image4" alt="Structure" /></td>
<td>η⁷-cyclooctatrienido</td>
<td>η⁷-cyclooctatrienyl c</td>
<td></td>
</tr>
<tr>
<td><img src="image5" alt="Structure" /></td>
<td>1-methyl-η⁵-1H-borole</td>
<td></td>
<td></td>
</tr>
<tr>
<td><img src="image6" alt="Structure" /></td>
<td>η⁵-azacyclopentadienido</td>
<td>η⁵-azacyclopentadienyl</td>
<td>η⁵-1H-pyrrolyl</td>
</tr>
<tr>
<td><img src="image7" alt="Structure" /></td>
<td>η⁵-phosphacyclopentadienido</td>
<td>η⁵-phosphacyclopentadienyl</td>
<td>η⁵-1H-phospholyl</td>
</tr>
<tr>
<td><img src="image8" alt="Structure" /></td>
<td>η⁵-arsacyclopentadienido</td>
<td>η⁵-arsacyclopentadienyl</td>
<td>η⁵-1H-arsolyl</td>
</tr>
<tr>
<td><img src="image9" alt="Structure" /></td>
<td>η⁵-borin-1-uido</td>
<td>η⁵-boranuidabenzene d</td>
<td></td>
</tr>
<tr>
<td><img src="image10" alt="Structure" /></td>
<td>η⁶-1,4-diborin-1,4-diuido</td>
<td>η⁶-1,4- diboranuidabenzene e</td>
<td></td>
</tr>
</tbody>
</table>

a The ligands are drawn as if complexed to a metal, i.e. these are depictions of bonded entities, not free ligands. The arcs used in these and later examples indicate delocalization (by analogy with the circle in benzene).
b The name η⁷-tropylium has been used previously but is no longer acceptable.
c The name η⁷-homotropylium has been used previously but is no longer acceptable.
d The name η⁶-boratabenzene has been used previously but is no longer acceptable.
e The name η⁶-1,4-diboratabenzene has been used previously but is no longer acceptable.
Examples:

1. 

\[
\begin{array}{c}
\text{Cr} \\
\circ\
\end{array}
\]

\text{bis(\(\eta^6\)-benzene)chromium}

2. 

\[
\begin{array}{c}
\text{V} \\
\circ\
\end{array}
\]

\text{(\(\eta^7\)-cycloheptatrienyl)(\(\eta^5\)-cyclopentadienyl)vanadium}

3. 

\[
\begin{array}{c}
\text{U} \\
\circ\
\end{array}
\]

\text{bis(\(\eta^8\)-cyclooctatetraene)uranium (cf. Section IR-10.2.6)}

4. 

\[
\begin{array}{c}
\text{Cr} \\
\circ\
\end{array}
\]

\text{tris(\(\eta^3\)-allyl)chromium}

5. 

\[
\begin{array}{c}
\text{Fe} \\
\text{MeB} \\
\text{BMe} \\
\circ\
\end{array}
\]

\text{bis(\(\eta^6\)-1-methyl-1-boranidabenzene)iron}

6. 

\[
\begin{array}{c}
\text{Os} \\
\text{PPh}_3 \\
\text{CO} \\
\text{H} \\
\text{CO} \\
\text{H} \\
\text{PPh}_3
\end{array}
\]

\text{dicarbonyl(\(\eta^2\)-formaldehyde)bis(triphenylphosphane)osmium}
7. (η²-carbon dioxide)bis(triethylphosphane)nickel

8. tricarbonyl[N, N-dimethyl-1-{2-(diphenylphosphanyl)}-
η⁰-phenyl]ethane-1-amine]chromium

9. tribromido[1,1'-dimethylsilanediyl]bis(2-methyl-η⁵-cyclopentadienyl]niobium

If not all unsaturated atoms of a ligand are involved in bonding, if a ligand can adopt several
bonding modes, or if a ligand bridges several metal atoms, the locants of the ligating atoms
appear in a numerical sequence before the symbol η, which is preceded by a hyphen.
Extended coordination over more than two contiguous carbon atoms should be indicated by,
for example, (1–4–η) rather than by (1,2,3,4–η). The locants and the symbol η are enclosed
in parentheses. No superscript on the symbol η is then necessary.

Examples:

10. dichlorido[(1–3,3a,8a:4a,5–7,7a-η)-4,4,8,8-tetramethyl-1,4,5,8-tetrahydro-
4,8-disila-s-indacene-1,5-diy]zirconium

11. dichlorido[1,1'-(ethane-1,2-diy)bis(1–3,3a,7a-η-1H-inden-1-yl)]zirconium
12. dicarbonyl[(1–3–κ)-cyclohepta-2,4,6-trien-1-yl](η⁵-
cyclopentadienyl)molybdenum

13. [(1,2,5,6–κ)-cyclooctatetraene](η⁵-
cyclopentadienyl)cobalt

14. tricarbonyl[(2–5–κ)-(E,E,E)-octa-2,4,6-trienal]iron

15. (η⁴-buta-1,3-dien-1-yl-κC⁴)carbonyl(η⁵-
cyclopentadienyl)chromium

16. [(1–3–κ)-but-2-en-1-yl-4-ylidene-κC⁴]carbonyl(η⁵-
cyclopentadienyl)chromium

17. tricarbonyl[6-oxo-κO-(2–4–κ)-hept-3-en-2-yl]iron(1+)

As indicated in the previous example, the κ symbol can, if necessary, be combined with the
κ symbol (see Section IR-10.2.3.3). The symbol η then precedes the ligand name while the
κ symbol is either placed at the end of the ligand name or, for more complicated structures,
after that portion of the ligand name which denotes the particular function in which the ligating atom is found.

*Examples:*

18.  
![Chemical Structure 1](image1)

\([\text{N-tert-butyl}(\eta^5\text{-cyclopentadienyl})\text{dimethylsilanaminido-}\kappa N]\text{dichlorodotitanium}\)

19.  
![Chemical Structure 2](image2)

\([\text{(E-}\eta^2\text{-but-2-enal-}\kappa O]\text{chloridobis(triethylphosphane)rhodium}\)

The symbol \(\eta^1\) is not used. For a cyclopentadienyl ligand bonded by only one \(\sigma\)-bond one uses cyclopenta-2,4-dien-1-yl or cyclopenta-2,4-dien-1-yl-\(\kappa C^1\).

*Example:*

20.  
![Chemical Structure 3](image3)

\(\text{dicarbonyl}(\eta^5\text{-cyclopentadienyl})(\text{cyclopenta-2,4-dien-1-yl-}\kappa C^1)\text{iron}\)

If an unsaturated hydrocarbon serves as a bridging ligand, the prefix \(\mu\) (see Sections IR-10.2.3.1 and IR-10.2.3.4) is combined with both \(\eta\) and \(\kappa\), where necessary. The colon is used to separate the locants of the bridging ligand which indicate binding to different metal atoms. The metal atoms are numbered according to the rules given in Section IR-9.2.5.6, and their numbers are placed before the \(\eta\) and \(\kappa\) symbols with no hyphens. If ligand locants are also specified, these are separated from the \(\eta\) symbol by a hyphen and the whole expression is enclosed in parentheses, as in \(1(2\text{-}4-\eta)\).

*Examples:*

21.  
![Chemical Structure 4](image4)

\(\mu-\eta^2\text{-but-2-ynel} \text{bis}[\eta^5\text{-cyclopentadienyl} ]\text{nickel]}(\text{Ni—Ni})\)
22. 
\[ \text{(CO)}_3\text{Fe} \begin{array}{c} \text{Fe} \text{(CO)}_3 \\
\end{array} \]

*trans*-\([\mu-(1-4-\eta;5-8-\eta)]\)-cyclooctatetraene\)bis\((\text{tricarbonyliron})

23. 
\[ \begin{array}{c} 6 \\
7 \\
8 \\
1 \\
5 \\
4 \\
3 \\
2 \\
\end{array} \]

\[ \begin{array}{c} \text{OC} \\
\text{Fe} \\
\text{Fe} \\
\text{CO} \\
\text{CO} \\
\end{array} \]

\([\mu-[2(1-3,3a,8a-\eta;1(4-6-\eta)]\text{azulene}\}(\text{pentacarbonyl-} \\
1\kappa^3\text{C},2\kappa^2\text{C})\text{diiron}(\text{Fe—Fe})

24. 
\[ \begin{array}{c} \text{H} \\
\text{W} \\
\end{array} \]

\[ \begin{array}{c} 1 \\
2 \\
\end{array} \]

\[(\mu-1\eta^5\text{-cyclopenta-}2,4\text{-diene-}1,1\text{-diyli}2\alpha\text{C})(\mu-2\eta^5\text{-cyclopenta-}2,4\text{-diene-}1,1\text{-diyli}1\kappa\text{C})\text{bis}[(\eta^5\text{-cyclopentadienyl})\text{hydridotungsten}]\]

25. 
\[ \begin{array}{c} \text{Nb} \\
\text{CO} \\
\text{CO} \\
\end{array} \]

\[ \begin{array}{c} 3 \\
4 \\
\text{Nb} \\
\text{Nb} \\
\end{array} \]

\[ \begin{array}{c} \text{CO} \\
\text{CO} \\
\end{array} \]

\[ \text{\mu}_3\text{-}1\eta^2\cdot2\eta^2\text{-carbonyl-}3\kappa\text{C-triangulo-} \\
\text{tris}[(\text{dicarbonyl(}1\eta^5\text{-cyclopentadienyl})\text{niobium})](\text{3Nb—Nb})\]

26. 
\[ \begin{array}{c} 1 \\
\text{Cr} \\
\end{array} \]

\[ \begin{array}{c} 2 \\
\text{Cr} \\
\end{array} \]

\[ (\mu-2\eta^4\text{-buta}-1,3\text{-diene-1,4-diyli}1\kappa^2\text{C}^4,\text{C}^4\text{carbonyl-}1\kappa\text{C-bis}[(\eta^5\text{-} \\
\text{cyclopentadienyl})\text{chromium}](\text{Cr—Cr})\]

The eta convention can also be extended to \(\pi\)-coordinated ligands containing no carbon atoms, such as cyclotriborazane and pentaphosphole ligands.
Examples:

27.

\[
\begin{align*}
\text{Me} & \quad \text{Me} \\
B & \quad N \\
\text{Me} & \quad \text{Me} \\
B & \quad N \\
\text{Me} & \quad \text{Me} \\
\text{Me} & \quad \text{Me} \\
\text{OC} & \quad \text{CO} \\
\text{CO} & \quad \text{CO}
\end{align*}
\]

tricarbonyl(\(\eta^6\)-hexamethyl-1,3,5,2,4,6-triazatriborinane)chromium, or tricarbonyl(\(\eta^6\)-hexamethyleneclotriborazane)chromium

28.

\[
\begin{align*}
\text{P} & \quad \text{P} \\
\text{Fe} & \quad \text{Me} \\
\text{Me} & \quad \text{Me} \\
\text{Me} & \quad \text{Me} \\
\text{Me} & \quad \text{Me}
\end{align*}
\]

(pentamethyl-\(\eta^5\)-cyclopentadienyl)(\(\eta^5\)-pentaphosphoryl)iron

This convention may also be used for ligands in which \(\sigma\)-bonds are coordinated in a side-on fashion, such as the H-H bond in complexes of dihydrogen (i.e. \(\eta^2\)-H\(_2\))^5 or the saturated C-H bonds in ‘agostic’ interactions.\(^6\) The \(\eta\) symbol and locants for agostic interactions are placed separately from other locants at the end of the ligand name. In Example 30 the agostic bond is denoted by a half arrow.

Examples:

29.

\[
\begin{align*}
\text{OC} & \quad \text{CO} \\
\text{H} & \quad \text{H} \\
\text{H} & \quad \text{PPH}_3 \\
\text{CO} & \quad \text{PPH}_3
\end{align*}
\]

tricarbonyl(\(\eta^2\)-dihydrogen)bis(triisopropylphosphane)tungsten

30.

\[
\begin{align*}
[(1-3-\eta)-\text{but-2-en-1yl}-\eta^2-C^4,H^4](\eta^5\text{-cyclopentadienyl})\text{cobalt}(1+)
\end{align*}
\]
31.  

\[
\begin{array}{c}
\text{BPh}_3 \\
\text{Rh}_3
\end{array}
\]

\((\eta^3,\eta^2\text{-cycloocta-1,5-diene})(\eta^6\text{-phenyltriphenylborato})\text{rhodium, or} \]

\[
[(1,2,5,6-\eta)\text{-cycloocta-1,5-diene})[(\eta^6\text{-phenyltriphenylboranuido})\text{rhodium}}
\]

**IR-10.2.6 Metalocene nomenclature**

The first transition element compound containing only carbocyclic rings as ligands was bis(\(\eta^5\)-cyclopentadienyl)iron, [Fe(\(\eta^5\)-C\(_5\)H\(_5\))\(_2\)], which has a ‘sandwich’ structure with two parallel \(\eta^5\)- or \(\pi\)-bonded rings. The recognition that this compound was amenable to electrophilic substitution, similar to the aromatic behaviour of benzene, led to the suggestion of the non-systematic name ‘ferrocene’ and to similar names for other ‘metalocenes’.

**Examples:**

1. \([V(\eta^5\text{-C}_5\text{H}_5)]_2\) vanadocene
2. \([\text{Cr}(\eta^5\text{-C}_5\text{H}_5)]_2\) chromocene
3. \([\text{Co}(\eta^5\text{-C}_5\text{H}_5)]_2\) cobaltocene
4. \([\text{Ni}(\eta^5\text{-C}_5\text{H}_5)]_2\) nickelocene
5. \([\text{Ru}(\eta^5\text{-C}_5\text{H}_5)]_2\) ruthenocene
6. \([\text{Os}(\eta^5\text{-C}_5\text{H}_5)]_2\) osmocene

Metalocene derivatives may be named either by the standard organic suffix (functional) nomenclature or by prefix nomenclature. The organic functional suffix system is described in Section P-33 of Ref. 3. Metalocene substituent group names have endings ‘ocenyl’, ‘ocenediyl’, ‘ocenetriyl’, etc.

**Examples:**

7.  

\[
\begin{array}{c}
\text{COMe} \\
\text{Fe}
\end{array}
\]

acetylferrocene, or 1-ferrocenylethyl-1-one

8.  

\[
\begin{array}{c}
\text{H} \\
\text{NMe}_2 \\
\text{Me} \\
\text{Fe}
\end{array}
\]

1-[1-(dimethylamino)ethyl]ferrocene, or 1-ferrocenyl-N,N-dimethylethan-1-amine
Substituents on the equivalent cyclopentadienyl rings of the metallocene entity are given the lowest possible numerical locants in the usual manner. The first ring is numbered 1–5 and the second ring 1′–5′ (see Examples 9 and 10).

Examples:

9. 

![Structure 9](image)

1,1′-diacetylsomocene, or 1,1′-(osmocene-1,1′-diyl)bis(ethan-1-one)

10. 

![Structure 10](image)

1,1′-(4-carboxybutane-1,3-diyl)ferrocene, or 3,5-(ferrocene-1,1′-diyl)pentanoic acid

11. [Ru(η⁵-C₅Me₅)₂]
   decamethylruthenocene, or bis(pentamethyl-η⁵-cyclopentadienyl)ruthenium

12. [Cr(η⁵-C₅Me₂Et)₂]
   1,1′-diethyloctamethylchromocene, or bis(1-ethyl-2,3,4,5-tetramethyl-η⁵-cyclopentadienyl)chromium

13. [Co(η⁵-C₅H₄PPh₂)₂]
   1,1′-bis(diphenylphosphanyl)cobaltocene, or (cobaltocene-1,1′-diyl)bis(diphenylphosphane)

Metalocene nomenclature does not, however, apply to all transition elements. For example, there are at least two isomers with the empirical formula C₁₀H₁₀Ti but neither has the regular sandwich structure analogous to that of ferrocene, and so neither should be named ‘titanocene’. Similarly, ‘manganocene’ is a misnomer for [Mn(η⁵-C₅H₅)₂] since it has a chain structure in the solid state, with no individual sandwich entities. However, decamethylvanogenocene, [Mn(η⁵-C₅Me₅)₂], has a normal sandwich structure, as does decamethylrhencocene, [Re(η⁵-C₅Me₅)₂]. With increasing atomic number, the occurrence of the classic ferrocene-type bis(η⁵-cyclopentadienyl) sandwich structure becomes rare.

The name-ending ‘ocene’ should therefore be confined to discrete molecules of the form bis(η⁵-cyclopentadienyl)metal (and ring-substituted analogues), where the cyclopentadienyl rings are essentially parallel, and the metal is in the d-block [i.e. the terminology does not apply to compounds of the s- or p-block elements such as Ba(C₅H₅)₂ or Sn(C₅H₅)₂].

The oxidized species have been referred to as metallocenium(n⁺) salts, although it should be noted that in this case the ending ‘ium’ does not carry the usual meaning it has in substitutive nomenclature, i.e. the addition of a hydron to a neutral parent compound.
To avoid this ambiguity, the name bis(η^5^-cyclopentadienyl)iron(1+), for example, is strongly preferred to ferrocenium(1+) for [Fe(η^5^-C_5H_5)_2]^+. The same comment applies to substituted derivatives.

**Examples:**

14. [Co(η^5^-C_5H_5)_2][PF_6]  
   bis(η^5^-cyclopentadienyl)cobalt(1+) hexafluoridophosphate

15. [Co(η^5^-C_5H_5)(η^5^-C_5H_4COMe)][BF_4]  
   (acetyl-η^5^-cyclopentadienyl)(η^5^-cyclopentadienyl)cobalt(1+)  
   tetrafluoridoborate

The oxidized form of osmocene is dinuclear in the solid state, with a long Os–Os bond, so should not in any case be named using the ‘ocmenium’ nomenclature. However, [Os(η^5^-C_5Me_5)_2]^+ has a mononuclear sandwich structure and may be described as the decamethylosmocenium(1+) ion, although bis(pentamethyl-η^5^-cyclopentadienyl)osmium(1+) is strongly preferred.

In strong protic acid media, ferrocene is hydronated to [Fe(η^5^-C_5H_5)_2H]^+. To avoid ambiguities, this should be named by the additive procedure, *i.e.* bis(η^5^-cyclopentadienyl)hydridoiron(1+).

Transition element complexes derived from ligands with additional rings fused to the cyclopentadienyl rings are also known. The names of these complexes are derived from the retained common or semisystematic names of the hydrocarbon ligands, *e.g.* 1H-inden-1-yl (C_9H_8), fluoren-9-yl (C_{13}H_{18}), and azulene (C_{10}H_{18}). Thus, [Fe(η^5^-C_9H_8)_2] is named bis(η^5^-indenyl)iron or, more specifically, bis[(1–3,a,7a-η)-1H-inden-1-yl]iron. To avoid possible ambiguities, the use of fusion nomenclature, such as ‘benzoferrocene’, is strongly discouraged.

Many compounds have ligands in addition to two η^5^-cyclopentadienyl rings. They are often referred to as metalocene di(ligand) species, *e.g.* [Ti(η^5^-C_5H_5)_2Cl] is frequently named ‘titanocene dichloride’. This practice is discouraged since metalocene nomenclature applies only to compounds in which the two rings are parallel. Thus, [Ti(η^5^-C_5H_5)_2Cl] is named dichloridobis(η^5^-cyclopentadienyl)titanium, and [W(η^5^-C_5H_5)_2]Cl_2, [Ti(CO)_5(η^5^-C_5H_5)_2] and [Zr(η^5^-C_5H_5)_2Me_2] should be named bis(η^5^-cyclopentadienyl)dihydridotungsten, dicarbonylbis(η^5^-cyclopentadienyl)titanium and bis(η^5^-cyclopentadienyl)dimethylzirconium, respectively.

The bis(cyclooctatetraene) compound [U(η^8^-C_8H_8)_2] has sometimes been described as ‘uranocene’. Related species are obtained from zirconium, [Zr(η^8^-C_8H_8)_2], and the lanthanoids, *e.g.* [Ce(η^8^-C_8H_8)_2]. In such complexes, the carbocyclic rings are parallel and there are certain similarities to ferrocene in the molecular orbital descriptions of their bonding. However, some lanthanoids also form metal(II) cyclopentadienyl complexes, such as [Sm(η^5^-C_5Me_5)_2]. Extension of the ‘ocene’ nomenclature to [U(η^8^-C_8H_8)_2] and similar compounds can therefore lead to confusion and is strongly discouraged.

Furthermore, the cyclooctatetraene ring can also function as an η^4^-ligand, as in [Ti(η^4^-C_8H_8)(η^8^-C_8H_8)]. Compounds of cyclooctatetraene should therefore be named using standard organometallic nomenclature, *e.g.* bis(η^5^-cyclooctatetraene)uranium and [([1–4-η)-cyclooctatetraene](η^8^-cyclooctatetraene)uranium. The ligand C_8H_8^2– is occasionally
referred to as ‘cyclooctatetraenyl’. This name is incorrect as it can only be used for the (as yet hypothetical) ligand C₈H₇.

IR-10.3 NOMENCLATURE OF ORGANOMETALLIC COMPOUNDS OF THE MAIN GROUP ELEMENTS

IR-10.3.1 Introduction

The nomenclature of organometallic compounds of the main group elements is an area of current and ongoing development. This section briefly describes key aspects of the naming of such compounds, leaving a full treatment of the subject to a future IUPAC project. Detailed information on the nomenclature of organic compounds containing the elements of groups 13–16 may be found in Sections P-68 and P-69 of Ref. 3.

In principle, all organometallic compounds, whether of the transition or main group elements, can be given names based on the additive system of nomenclature that is applied to coordination compounds, provided the constitution of the compound is known. Examples of such names were given in Sections IR-7.2 and IR-7.3. In addition, compounds of elements such as boron, silicon, arsenic and selenium are often considered to be organometallic, and are commonly named by notionally substituting the hydrogen atoms of the parent hydride with the appropriate substituent groups.

If a choice must be made, it is recommended here that organometallic compounds derived from the elements of groups 13–16 be named by a substitutive process, while those derived from the elements of groups 1 and 2 be named using the additive system of nomenclature or in some cases just compositional nomenclature if less structural information is to be conveyed. Where an organometallic compound contains two or more central atoms (which may be associated with different nomenclature systems according to the above recommendation), a choice must again be made to provide the basis of the name. A general rule is recommended in Section IR-10.4.

IR-10.3.2 Organometallic compounds of groups 1 and 2

Organometallic compounds of the elements of groups 1 and 2 with a defined coordination structure are named according to the additive system of nomenclature, the general definitions and rules of which are given in Chapter IR-7 and Sections IR-9.1 and IR-9.2. Thus, prefixes denoting the organic groups and any other ligands are placed in alphabetical order before the name of the metal. These prefixes may adopt either the additive ‘ido’, ‘diido’, etc. endings or, in the case of hydrocarbaryl groups, the substitutive ‘yl’, ‘diyl’, etc. endings (see Sections IR-10.2.2 and IR-10.2.3). The latter practice allows names in common usage for organic groups to be applied unchanged. The presence of a hydrogen atom attached to the metal centre must always be indicated (by the prefix ‘hydrido’) and the name of a cyclic compound with the central atom in the ring may be formed using appropriate locants of a divalent ‘diido’ or ‘diyl’ group to indicate chelate-type bonding to the metal, as in Example 5 below.
Many organometallic compounds of groups 1 and 2 exist in associated molecular form (as aggregates) or contain structural solvent, or both. However, their names are often based solely on the stoichiometric compositions of the compounds, unless it is specifically desired to draw attention to the extent of aggregation or the nature of any structural solvent, or both (see Example 3 below). In the examples below, note how the different types of name reflect the different structural content implied by the formulae shown. As usual, the formulae enclosed in square brackets designate coordination entities.

Note that metallocene terminology (Section IR-10.2.6) is not recommended for bis(cyclopentadienyl) compounds of the main group metals (see Examples 6 and 7).

Examples:

1. [BeEtH]
   ethylhydridoberryllium, or ethanidohydridoberryllium

2. Na(CHCH₂)
   sodium ethenide (compositional name)
   Na–CH=CH₂, or [Na(CH=CH₂)]
   ethenidosodium, ethenylsodium, or vinylsodium

3. [[Li(OEt₂)](μ₂-Ph)]₄
   tetrakis[(ethoxyethane)(μ₂-phenyl)]lithium, or
   tetrakis[(μ₂-benzeno)(ethoxyethane)]lithium

4. 2Na⁺(Ph₂CCPh₂)²⁻
   disodium 1,1,2,2-tetraphenylethene-1,2-diide (compositional name)

   Ph₂C(Na)─C(Na)Ph₂
   (μ-1,1,2,2-tetraphenylethene-1,2-diyl)disodium, or
   (μ-1,1,2,2-tetraphenylethene-1,2-diido-κ²C¹,C²)disodium

5. 

   

   [2-(4-methylpent-3-en-1-yl)but-2-ene-1,4-diyl]magnesium, or
   [2-(4-methylpent-3-en-1-yl)but-2-ene-1,4-diido-κ²C¹,C⁴]magnesium

6. [Mg(η⁵-C₅H₅)₂]
   bis(η⁵-cyclopentadienyl)magnesium, or
   bis(η⁵-cyclopentadienido)magnesium

7. [PP₄][Li(η⁵-C₅H₅)₂]
   tetraphenylphosphanium bis(η⁵-cyclopentadienyl)lithate(1–), or
   tetraphenylphosphanium bis(η⁵-cyclopentadienido)lithate(1–)

8. LiMe
   lithium methane (compositional name)
   [LiMe] methyllithium
   [(LiMe)₄] tetra-μ₃-methyl-tetralithium
   (LiMe)₄ poly(methyllithium)
ORGANOMETALLIC COMPOUNDS

9. MgI\textsubscript{Me}  
magnesium iodide methanide (compositional name)  
[\text{MgI(Me)}]  
iiodido(methanido)magnesium (additive name of coordination type)  
[\text{MgMe}]\textsubscript{I}  
methylmagnesium iodide (compositional name with formally electropositive component named using additive nomenclature)  
[\text{MgI(Me)}]_{n}  
poly[iodido(methanido)magnesium], or poly[iodido(methyl)magnesium]

IR-10.3.3 Organometallic compounds of groups 13–16

Organometallic compounds of the elements of groups 13–16 are named according to the substitutive system of nomenclature, dealt with in Chapter IR-6. Thus, the name of the parent hydride (formed in accordance with the rules of Section IR-6.2) is modified by a prefix for each substituent replacing a hydrogen atom of the parent hydride. The prefix should be in appropriate substituent form (chloro, methyl, sulfanylidene, etc.) and not in ligand form (chlorido, methanido, sulfido, etc.).

Where there is more than one kind of substituent, the prefixes are cited in alphabetical order before the name of the parent hydride, parentheses being used to avoid ambiguity, and multiplicative prefixes being used as necessary. Non-standard bonding numbers are indicated using the \( \lambda \)-convention (see Section IR-6.2.2.2). An overview of the rules for naming substituted derivatives of parent hydrides is given in Section IR-6.3, while a detailed exposition may be found in Ref. 3.

Examples:

1. AlH\textsubscript{2}Me  
methylalumane
2. AlEt\textsubscript{3}  
triethylalumane
3. Me\textsubscript{2}CHCH\textsubscript{2}CH\textsubscript{2}In(H)CH\textsubscript{2}CH\textsubscript{2}CHMe\textsubscript{2}  
bis(3-methylbutyl)indigane
4. Sb(CH=CH\textsubscript{2})\textsubscript{3}  
triethenylstibane, or trivinylstibane
5. SbMe\textsubscript{5}  
pentamethyl-\( \lambda^{5} \)-stibane
6. PhSb=SbPh  
diphenyldistibene
7. GeCl\textsubscript{2}Me\textsubscript{2}  
dichlorodimethylgermane
8. GeMe(SMe)\textsubscript{3}  
methyltris(methylsulfanyl)germane
9. BiI\textsubscript{3}Ph  
diodo(phenyl)bismuthane
10. Et\textsubscript{3}PbPbEt\textsubscript{3}  
hexaethylplumbane
11. SnMe\textsubscript{2}  
dimethyl-\( \lambda^{2} \)-stannane
12. BrSnH\textsubscript{2}SnCl\textsubscript{2}SnH\textsubscript{2}(CH\textsubscript{2}CH\textsubscript{2}CH\textsubscript{3})  
1-bromo-2,2-dichloro-3-propyltristannane
13. Me\textsubscript{3}SnCH\textsubscript{2}CH\textsubscript{2}C≡CSnMe\textsubscript{3}  
but-1-yn-1,4-diylbis(trimethylstannane)
In the presence of one or more characteristic groups that may be expressed using one or more suffixes (–NH₂, –OH, –COOH, etc.), the name of the parent hydride carrying the highest-ranking such group is modified by the suffix, and other substituents are then denoted by prefixes as described in Section IR-6.3.1. If acting as a substituent, the group 13–16 parent hydride name in question is modified by changing the ending ‘ane’ to ‘anyl’ (or ‘yl’ for the group 14 elements), ‘anediyl’, etc.

Examples:

14. (EtO)₃GeCH₂CH₂COOMe
methyl 3-(triethoxygermyl)propanoate
15. H₂As(CH₂)₄SO₂Cl
4-arsanylbutane-1-sulfonyl chloride
16. OCH₂CH₂GeMe₂GeMe₂CH₂CH₂CHO
3,3′-(1,1,2,2-tetramethyldigermane-1,2-diyl)dipropanal
17. SiMe₃NH₂
trimethylsilanamine

Sometimes it may be necessary or preferable to consider a parent hydride in which several (four or more) skeletal carbon atoms of a hydrocarbon have been replaced by main group elements. In this method of skeletal replacement the heteroatoms are designated by the ‘a’ terms of replacement nomenclature (Table X) cited in the order given by Table VI and preceded by the appropriate locant(s). The rules for locant numbering are specified in Section IR-6.2.4.1 and this nomenclature is fully described in Sections P-21.2 and P-22.2 of Ref. 3.

Examples:

18. MeSiH₂CH₂CH₂SiH₂CH₂CH₂SiH₂CH₂CH₂SiMe
2,5,8,11-tetrasiladodecane
19. MeSiH₂OP(H)OCH₂Me
3,5-dioxo-4-phospha-2-silaheptane
20. HSCH=NOCH₂SeCH₂ONHMe
3,7-dioxo-5-selena-2,8-diazanon-1-ene-1-thiol
21. 2,5,7-triselena-1,4-diphasphabicyclo[2.2.1]heptane

When elements from groups 13–16 replace carbon atoms in monocyclic systems, the resulting structures may be named using the extended Hantzsche–Widman procedures. This
nomenclature is fully described in Section IR-6.2.4.3 and in Section P-22.2 of Ref. 3 and will not be elaborated further here.

Sections P-68 and P-69 of Ref. 3 offer a more comprehensive treatment of the nomenclature of organic compounds containing the elements of groups 13–16.

**IR-10.4 ORDERING OF CENTRAL ATOMS IN POLYNUCLEAR ORGANOMETALLIC COMPOUNDS**

When an organometallic compound contains two or more different metal atoms, a choice must be made to provide the basis of the name. It is thus convenient to classify the possible central atoms as belonging to either (i) the elements of groups 1–12 (whose compounds are named according to the additive system of nomenclature) or (ii) the elements of groups 13–16 (whose compounds are named according to the substitutive system).

**IR-10.4.1 Central atoms from groups 1–12 only**

If both or all potential central atoms belong to class (i), then the compound is named additively using the methodology described in Section IR-9.2.5, including the rules given there for ordering the central atoms. Ferrocenyllithium (ferrocenyl, see Section IR-10.2.6) could thus be systematically named:

\[(2\eta^5\text{-cyclopentadienyl})(2\eta^5\text{-cyclopenta-2,4-dien-1-yl-1kC}^1)\text{lithiumiron},\]

a name which also illustrates the use of the \(\kappa\) and \(\eta\) conventions. Further examples in which both or all central atoms belong to class (i) are given in Sections IR-10.2.3.4, IR-10.2.3.5 and IR-10.2.5.1.

**IR-10.4.2 Central atoms from both groups 1–12 and groups 13–16**

If at least one possible central atom belongs to class (i) and one or more others to class (ii), then the compound is named additively using the metal atom(s) of class (i) as central atom(s). The remaining atoms of the complex are named as ligands by rules already presented (Sections IR-9.1, IR-9.2 and IR-10.2.1 to IR-10.2.5).

*Examples:*

1. \([\text{Li}(\text{GePh}_3)]\) (triphenylgermyl)lithium
2. \((\text{Me}_3\text{Si})_3\text{CMgC(SiMe}_3)_3\)
   \(\text{bis[tris(trimethylsilyl)methyl]}\text{magnesium}\)
3. \([\text{Mo(CO})_5(=\text{Sn}[\text{CH(SiMe}_3)_2]_2)]\)
   \(\{\text{bis[tris(trimethylsilyl)]methyl}\}^{\lambda^2}\text{-stannylidene}}\text{pentacarbyl}\text{molybdenum}\)
4.

![Ph₂Sb\[4\]
\[\text{[4-(diphenylstibanyl)phenyl]phenyl}\text{mercury}\]

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5. (phenylstibenediy)bis[dicarbonyl(η^5^-cyclopentadieny) manganese]

IR-10.4.3 Central atoms from groups 13–16 only

If the possible central atoms are both or all from class (ii), then the compound is named substitutively as described in Section IR-10.3.3 (and in more detail in Section IR-6.3). The parent hydride is chosen on the basis of the following element order (‘.’ > ‘.’ meaning ‘chosen before’, cf. Section P-41 of Ref. 3):

\[
\begin{align*}
\text{N} & > \text{P} > \text{As} > \text{Sb} > \text{Bi} > \text{Si} > \text{Ge} > \text{Sn} > \text{Pb} > \\
\text{B} & > \text{Al} > \text{Ga} > \text{In} > \text{Tl} > \text{S} > \text{Se} > \text{Te} > \text{C}
\end{align*}
\]

Thus, for a compound containing both arsenic and lead, the parent hydride would be selected as AsH₃, rather than PbH₄, the lead atom then appearing in the name as a prefixed substituent, often with its own substituent groups.

Examples:

1. As(PbEt₃)₃ tris(tributylplumbyl)arsane

2. \[
\text{H}_2\text{Sb} - \begin{array}{c}
\text{4} \\
\text{1}
\end{array} \text{AsH}_2
\]
   (4-stibanylphenyl)arsane

3. methoxydimethyl[2-(trimethylgermyl)phenyl]silane

4. \(\text{Et}_3\text{PbCH}_3\text{CH}_2\text{CH}_3\text{BiPh}_2\)
   diphenyl[3-(tributylplumbyl)propyl]bismuthane

5. \(\text{SiCl}_2\text{Sn(Me)} = \text{Sn(Me)SiCl}_2\)
   \(\text{Si},\text{Si}^\prime\)-[1,2-dimethyldistannene-1,2-diyl]bis(chlorosilane)

IR-10.5 REFERENCES

2. Nomenclature of Organometallic Compounds of the Transition Elements, A. Salzer, 