10.1.2: Ligand Nomenclature and Classification

The nomenclature of coordination compounds was described in an earlier section (Section 9.2). Organometallic compounds are named using this same system, so it may be helpful to review before proceeding. Here, we will point out some of the symbols and terminology that are used heavily in naming organometallic complexes.

Hapticity

The eta (η) symbol is used to indicate the variable **hapticity** of ligands with conjugated π systems. For example, the cyclopentadiene anion (Cp, C_5H_5) ligand has the capability to coordinate a metal ion in several ways due to its cyclic conjugated π system. The hapticity (the number of atoms involved in the metal bonding interaction) must be indicated in the formula with the η^n notation, and in the name with the appropriate prefix. Figure 10.1.2.1illustrates three different hapticities, and the relevant formula symbols and names.

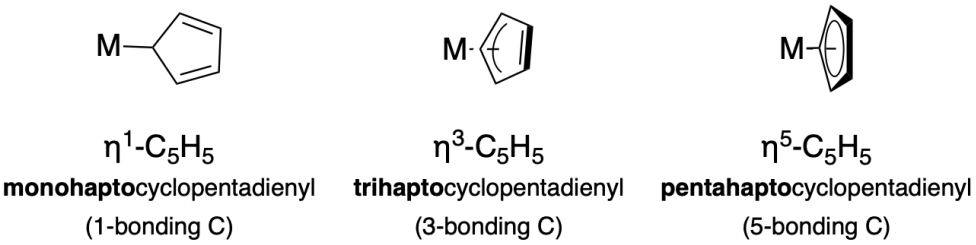


Figure 10.1.2.1: The cyclopentadiene anion is shown coordinating to a metal ion (M) using three different coordination modes: On the left, Cp as a monohapto ligand. In the center, Cp is shown bonding to a metal in a trihapto fashion where the metal interacts with three carbons. On the right, Cp is shown bonding in a pentahapto fashion, where the five ligand carbons interact equally through the π system . (CC-BY-SA 4.0; Kathryn Haas)

Another common ligand is the π-allyl anion (C_3H_3), which can coordinate in either an η^1 or η^3 fashion, as illustrated below (Figure 10.1.2.2).

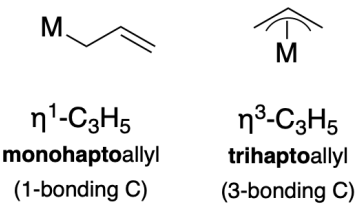


Figure 10.1.2.2: The allyl anion is shown coordinating in a η^1 and eta^3 modes. (CC-BY-SA 4.0; Kathryn Haas)

Bridging ligands

Ligands that bridge two or more metal ions are indicated using the symbol, mu (μ). For a ligand that bridges n metal ions, the symbol is written as μ_n. However the subscript is often ommitted when $n = 2$. Some examples of the carbonyl ligand are given below. More specific rules for naming are found in Section 9.2.

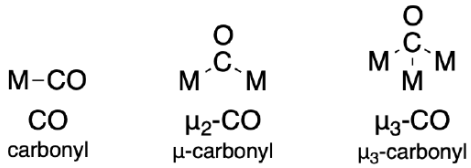
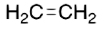
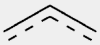
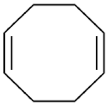


Figure 10.1.2.3: The carbonyl ligand is shown as a terminal ligand (with no μ necessary), bridging two metals (μ_2), and bridging three metals μ_3). (CC-BY-SA 4.0; Kathryn Haas)

Common Ligands and Classifications

Some common organic ligands found in organometallic compounds are listed below with their names and structures.

Name	Structure	CBC description
Alkyl		X
Carbonyl		L
Carbene (alkylidene)		X_2
Carbyne (alkylidyne)		X_3
Ethylene		L
Acteylene		L
Acyl		X
π-allyl ($C_3H_5^-$)		X for η^1 LX for η^3
Cyclopropenyl (cyclo-C_3H_3)		X for η^1 LX for η^3
Cyclobutadiene (cyclo-C_4H_4)		L_2 for η^4
Cyclopentadienyl (cyclo-C_5H_5, Cp)		X for η^1 LX for η^3 L_2X for η^5
Benzene		L_3 for η^6
1,5-cyclooctadiene (1,5-COD)		L_2 for η^4

Covalent Bond Classification Method (CBC)

Later in this chapter, you will learn to count electrons. The way in which you count depends on what counting scheme you choose to use. But in any case, the way in which we "count" the electrons from ligands depends on the ligand type. The covalent bond classification method (CBC) has been in use since the late 1990's to classify ligands in organometallic complexes. This method classifies ligands into three main types as follows. (see Application of the Covalent Bond Classification Method for the Teaching of Inorganic Chemistry. Malcolm L. H. Green and Gerard Parkin, Journal of Chemical Education 2014 91 (6), 807-816, DOI: 10.1021/ed400504f.)

CBC Ligand Class/Type	Examples	Use in neutral Ligand Method of Electron Counting	Use in Donor Pair Method of Electron Counting
X-type	$H-, Cl-, H_3C^-$	Considered neutral Donates 1 electron to the metal	Considered anionic Donates 2 electrons to the metal
L-type	CO, NH_3, H_2O	Considered neutral Donates 2 electrons to the metal	Considered neutral Donates 2 electrons to the metal

CBC Ligand Class/Type	Examples	Use in neutral Ligand Method of Electron Counting	Use in Donor Pair Method of Electron Counting
Z-type (rarely used)	BR_3, Lewis acids	Considered neutral Accepts 2 electrons	Considered cationic Donates 0 electrons