Lesson 12: Ligands

*Read through the lesson notes. You can write them out, print them or save them.

*Once you have tried to understand the lesson answer the questions that follow at the end.

*The answers to the question sheet(s) will be posted later and this will allow you to self-evaluate your learning.

Learning Intentions

-Learn about ligands and how to classify them.

-Learn about the term coordination number.

-Learn about the names and charges of common ligands.

Background

In this lesson we build on the concept that certain substances have non-bonding pairs of electrons. These non-bonding electrons/lone pairs are important because they can be donated into the orbitals of transition metals which leads to a huge variety of important compounds.

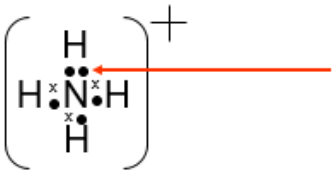
By definition, ligands may be negative ions or molecules with non-bonding pairs of electrons that they can donate to a central metal atom, forming dative covalent bonds. This regularly occurs with transition metals and forms a group of chemicals known as TRANSITION METAL COMPLEXES.

Until now, our understanding of a covalent bond has been the share of electrons, i.e. one electron from one atom and another electron from a separate atom. Although this is true in most cases, a dative covalent bond differs because both electrons forming the bond come from the one atom.

Example (ammonium ion)

$NH_3(g) + H^+(aq) \rightarrow NH_4^+(aq)$

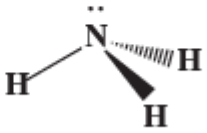
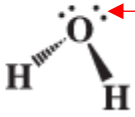
Ammonium ion



This bond is known as a dative covalent bond as it is the one atom (nitrogen) that provides both the electrons on the bonding pair.

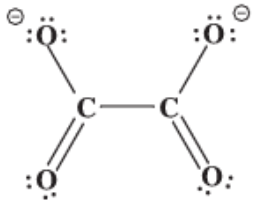
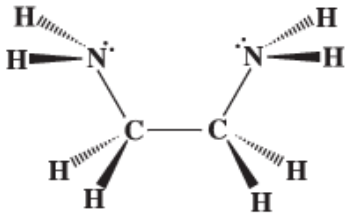
Classification of ligands

Ligands which donate one pair of electrons to the central metal ion are known as MONODENTATE.

Chloride ion	Cyanide ion	Ammonia molecule	Water molecule
			

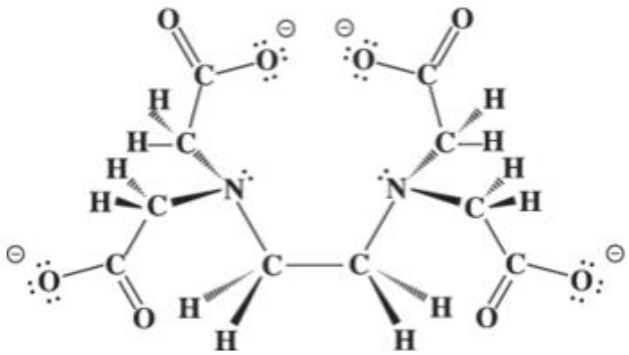
Although the oxygen atom on water has two lone pairs, water is classed as monodentate as it donates only one of them. Moreover, the lone pairs are on one atom of the molecule.

Ligands which donate two pairs of electrons to the central metal ion are known as BIDENTATE i.e. they donate lone pairs from two different atoms within the molecule.

Oxalate	Ethylenediamine (abbreviated to `en')
	

During the Advanced Higher course you will become familiar with EDTA (ethylenediaminetetraacetic acid). It is a useful chemical when carrying out certain types of titrations. It is classed as a HEXADENTATE ligand as it donates six pairs of electrons to the central metal ion. The term POLYDENTATE is also often used to describe EDTA.

EDTA



Names of ligands and their charge

The name that a ligand adopts when it bonds to a metal appears slightly different to what we have been used to, e.g. when chlorine acts as a ligand, we DO NOT say chloride, however we use the term chlorido.

The table below has some common ligands and the charge that they have. This table will help in particular for the next lesson as we use the ligand name and charge to give an overall name of TRANSITION METAL COMPLEXES.

Ligand Name	Ligand Formula	Charge
aqua	OH_2	0
*ammine	NH_3	0
cyanido	CN^-	-1
chlorido	Cl^-	-1
fluorido	F^-	-1
Bromido	Br^-	-1
Iodido	I^-	-1
Hydroxido	OH^-	-1
oxalato	$O_2C_2O_2$ / $C_2O_4^{2-}$	-2

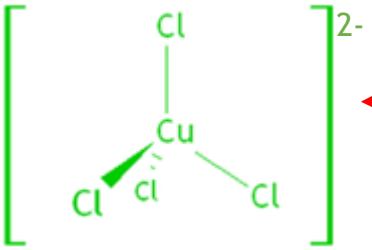
Notice NH_3 as a ligand is spelt with TWO "m's" i.e. ammine.

SQA has recently updated the names of ligands to fall in line with the International Union of Pure and Applied Chemistry (IUPAC). However, if you look at slightly older textbooks and past papers you will see subtle differences in the names of ligands, e.g chloro was used but it has now been updated to CHLORIDO.

Coordination numbers

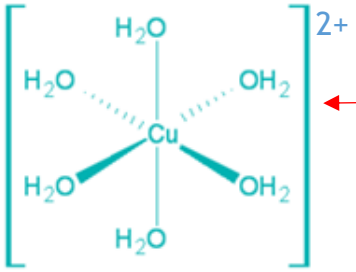
When ligands donate electron pairs to transition metals, they form TRANSITION METAL COMPLEXES. The coordination number is the number of bonds from the ligands to the central transition metal.

Coordination number 4



The four chlorido ligands each donate a lone pair of electrons to the central copper ion. The coordination number of copper is 4.

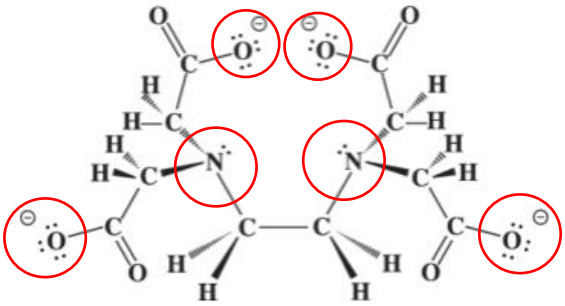
Coordination number 6



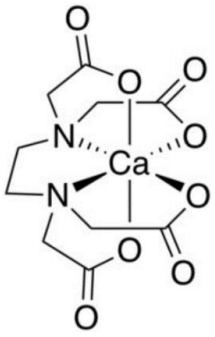
Each of the six aqua ligands donate a lone pair of electrons to copper. The coordination number of copper is 6.

*Notice that it is the oxygen atom that is shown to be bonded to copper. This is because the oxygen atom donates the lone pair of electrons which form the dative covalent bond.

If we look closely at EDTA, the hexadentate ligand we can see how it can bond with metal ions.



The red circles show the atoms on EDTA which donate electrons to a central metal ion.



This structure shows how the EDTA ligand wraps around to bond with the metal ion. Notice that the coordination number is 6.

Additional Resources

-Watch the clip on Youtube.

https://www.youtube.com/watch?v=C2T4MX466-o

-Read Scholar Section 3.3 and 3.3.1

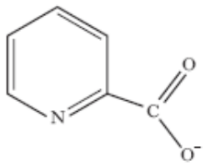
-Read BrightRed textbook page 22.

-Answer the questions from Sheet 1.15 and check the answers when you have completed them.

-If there are any questions regarding this lesson or the questions from sheet 1.15 then please leave a post on Microsoft Teams.

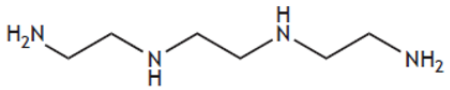
1.15 Ligands

1. A common dietary supplement taken by athletes is called chromium picolinate, the formula of which can be written as $Cr(pic)_3$.
   The structure of the picolinate ion shown below.



   a) What feature of the picolinate ion makes it suitable for use as a ligand?
   b) In the formula above, what is the oxidation number of chromium?
   c) In terms of s, p and d, write the spectroscopic notation for chromium in the above formula.

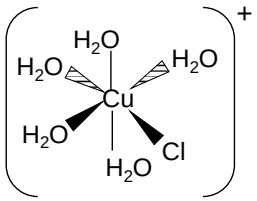
2. Trientine is a ligand which reacts with copper in a 1:1 ratio to form a complex.



trientine

   a) What features of trientine make it suitable for use as a ligand?
   b) Show a possible structure of the complex that forms when trientine bonds with copper.
   c) What is the coordination number of copper in the complex that forms?
   d) To which classification of ligands does trientine belong?

3. The transition metal complex below has been incorrectly drawn.



   a) Explain why the structure is incorrect and redraw it correctly.
   b) What is the coordination number of the complex?
   c) What is the oxidation number of copper in the above complex?
   d) In terms of s, p and d, write the spectroscopic notation for copper in the above complex.

4. Give the coordination number of copper and the classification of the ligand in the following example.