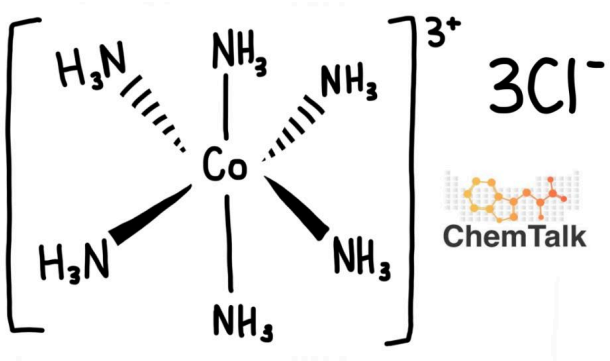
Unit 16: Coordination Chemistry

Introduction to Coordination Chemistry and Definitions

This worksheet will cover coordination compounds/complexes, structures with a central metal atom with covalent bonds to one or more ligands. It will discuss the classification of ligands, coordination numbers, and coordination spheres. As you progress through the worksheet, you will develop the skills necessary to determine inner-sphere ligands, identify counter-ions, and write the chemical formula of given coordination complexes.

Practice Problems:

1. Answer the following questions using the diagram presented.



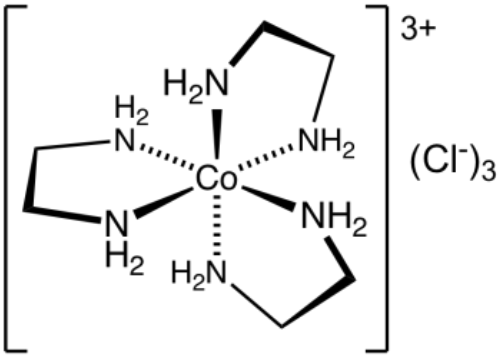
a. What is the coordination number of the metal ion compound?

b. Identify the inner-sphere ligands. Identify the counter-ion, if any.

c. Are the inner-sphere ligands mono-, bi-, or polydentates? Why?

d. Write the chemical formula for the complex in the form of $[MX_m]Y_n$.

2. Answer the following questions using the diagram presented.



$[Co(en)_3]Cl_3$ ("en" is the abbreviation for ethylenediamine)

a. What is the coordination number of the metal ion compound?

b. Identify the inner-sphere ligands. Identify the counter-ion, if any.

c. Are the inner-sphere ligands mono-, bi-, or polydentates? Why?

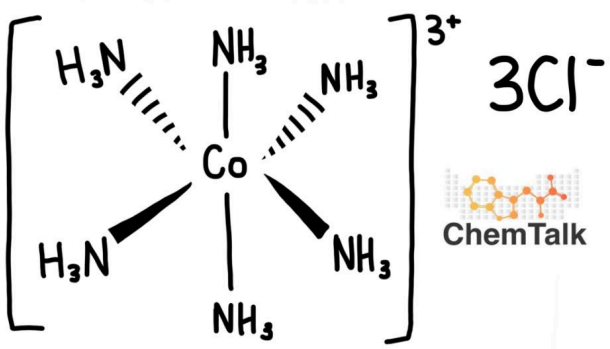
3. What is a coordination number and how does the denticity of a ligand influence this number? Justify with your own example.

ANSWER KEY

Introduction to Coordination Chemistry and Definitions

Practice Problems:

1. Answer the following questions using the diagram presented.



a. What is the coordination number of the metal ion compound?

The metal atom, Co, has six covalent bonds to six NH_3 ligands, resulting in a coordination number of 6.

b. Identify the inner-sphere ligands. Identify the counter-ion, if any.

The inner-sphere ligands are included inside the brackets, as they are directly bonded to the metal atom Co. Thus, the inner-sphere ligands are ammonia (NH_3).
The counter-ions are indicated outside of the brackets and are chloride ions (Cl^-).

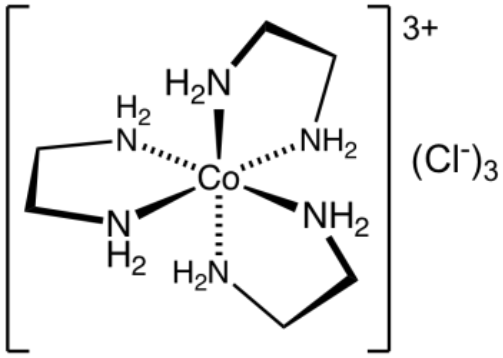
c. Are the inner-sphere ligands mono-, bi-, or polydentates? Why?

The inner-sphere ligands, NH_3 each have one bond to the center atom, meaning each is donating only one electron pair. This means that the inner-sphere ligands are monodentates.

d. Write the chemical formula for the complex in the form of $[MX_m]Y_n$.

"M" refers to the cation metal, which will be Co. We know that the directly bonded ligands are included in the brackets, and there are six NH_3 molecules, so "X_m" is $(NH_3)_6$. Finally, "Y_n" will refer to the counter ions, since the complex within the brackets has a positive charge. "Y_n" will be the three chloride ions, or Cl_3.
Putting this all together, the formula for this complex is $[Co(NH_3)_6]Cl_3$.

2. Answer the following questions using the diagram presented.



$[Co(en)_3]Cl_3$ ("en" is the abbreviation for ethylenediamine)

a. What is the coordination number of the metal ion compound?

The metal atom, Co, has six covalent bonds, so its coordination number will be 6.

b. Identify the inner-sphere ligands. Identify the counter-ion, if any.

We are told the chemical formula for the compound, so we can identify the directly bonded ligands by looking at the atoms inside the brackets. There are three “en” molecules, or three ethylenediamine molecules bonded to the Co atom, so those are the inner-sphere ligands.
The counter-ions are indicated outside of the brackets and are three chloride ions (Cl_3).

c. Are the inner-sphere ligands mono-, bi-, or polydentates? Why?

There are six covalent bonds on the Co atom, but three ethylenediamine molecules, so each ethylenediamine molecule is donating two electron pairs. Since there are two covalent bonds made per ligand molecule, the inner-sphere ligands are bidentate.

3. What is a coordination number and how does the denticity of a ligand influence this number? Justify with your own example.

The coordination number is defined as the total number of coordinate bonds formed between the central metal and its surrounding ligands. In monodentate ligands, the number of covalent bonds formed and the number of ligands are equal, as each ligand donates one electron pair each. However, in bidentate and polydentate ligands, the number of covalent bonds formed and the number of ligand molecules will differ, as the ligand molecules will donate more than one electron pair. Thus, the coordination number will not always match the number of inner-sphere ligands.
For example, the coordination number of the metal atom in $[Co(en)_3]^{+3}$ is 3, because the

bidentate ligand, ethylenediamine (en), influences the coordination number by donating two electron pairs per ligand molecule.