Unit 18: Coordination Chemistry

Nomenclature

This worksheet will cover the nomenclature of coordination complexes and ions. It will discuss the steps of naming coordination compounds and writing their chemical formulas. As you progress through the worksheet, you will develop the skills necessary to determine the oxidation states of central metal atoms, differentiate ligand prefixes, assign IUPAC names to complexes, and derive the chemical formula of complexes from their names.

1. Determine the oxidation state of the metal for the following.

a. $[Cr(NH_3)_6]^{+3}$

b. $[Ni(CN)_4]^{-2}$

c. $[Ga(OH)Cl_3]^{-}$

d. $(NH_4)_2[CoCl_4]$

2. Fill in the blanks to describe the nomenclature of anionic ligands and provide examples of each type of ligand and the name change they would undergo.

Anionic ligands which end in “-ide” are replaced with the ending “___”. Those which end in “-ite” are replaced with the ending “___”, and anionic ligands which end in “-ate” are replaced with the ending “___”.

Examples:

3. Explain the difference between the use of "bis," "tris," and "tetrakis" versus "di," "tri," and "tetra" in naming coordination complexes. Additionally, discuss why this distinction is important in the nomenclature of coordination compounds.

3. Name the following coordination complexes.

a. $Pt(NH_3)_2Cl_2$

b. $Cr(NH_3)_4Cl_2$

c. $[CrCl_2(OH_2)_4]^+$

d. $[CuCl_4]^{-2}$

5. Provide the chemical formula of the following coordination complexes.

a. Amminesulfatochromium (II)

b. Potassium hexacyanoferrate (III)

c. Triamminedicarbonylchloroiron (III) ion

d. Trichlorohydroxogallate (III) ion

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ANSWER KEY

1. Determine the oxidation state of the metal for the following.

a. $[Cr(NH_3)_6]^{+3}$

Cr is the central metal atom; *x* will represent its oxidation number. The charge of the entire complex is +3, so we can set this equation equal to +3. NH_2 is a neutral ligand; thus, its oxidation number is 0.

$$x + 6(NH_3) = 3$$
$$x + 6(0) = 3$$
$$x = 3$$

The oxidation number of Cr is +3.

b. $[Ni(CN)_4]^{-2}$

Ni is the central metal atom; *x* will represent its oxidation number. The charge of the entire complex is -2, so we can set this equation equal to -2. CN^- has a charge of -1; thus, its oxidation number is -1.

$$x + 4(CN^-) = -2$$
$$x + 4(-1) = -2$$
$$x = 2$$

The oxidation number of Ni is +2.

c. $[Ga(OH)Cl_3]^-$

Ga is the central metal atom; *x* will represent its oxidation number. The charge of the entire complex is -1, so we can set this equation equal to -1. OH^- has a charge of -1; thus, its oxidation number is -1. The chloride ion ligands have an individual charge of -1.

$$x + (OH^-) + 3(Cl^-) = -1$$
$$x + -1 + 3(-1) = -1$$
$$x = 3$$

The oxidation number of Ga is +3.

d. $(NH_4)_2[CoCl_4]$

Co is the central metal atom; *x* will represent its oxidation number. The charge of the entire complex is -2, so we can set this equation equal to -2. This is determined by the charge of the counter ion, NH_4^+. Since the counter cations' combined charge is +2, the coordination complex charge must be -2. Cl^- has a charge of -1; thus, its oxidation number is -1.

$$x + 4(Cl^-) = -2$$
$$x + 4(-1) = -2$$
$$x = 2$$

The oxidation number of Co is +2.

2. Fill in the blanks to describe the nomenclature of anionic ligands. Then provide examples of each type of ligand and the name change they would undergo.

Anionic ligands which end in "-ide" are replaced with the ending "-o". Those which end in "-ite" are replaced with the ending "-ito", and anionic ligands which end in "-ate" are replaced with the ending "-ato".

Examples:

An example of the -ide → -o name change is OH^- (hydroxide → hydroxo).
An example of the -ite → -ito name change is NO_2^- (nitrite → nitrito).
An example of the -ate → -ato name change is SO_4^{-2} (sulfate → sulfato).

3. Explain the difference between the use of "bis," "tris," and "tetrakis" versus "di," "tri," and "tetra" in naming coordination complexes. Additionally, discuss why this distinction is important in the nomenclature of coordination compounds.

The number of ligands present in a coordination complex is usually indicated using the prefixes "di," "tri," and "tetra." However, the prefixes "bis," "tris," and "tetrakis" are used when the ligand has a complex structure and specific name – these include polydentates that already have a prefix (like "di," "tri," or "tetra") in their name. Examples of these are "bis(ethylenediamine)" and "tris(1,2-diaminoethane)." This compares to simple ligands, like "tetraaqua" and "dichloro." This distinction helps scientists avoid confusion with coordination complex nomenclature and offers a systematic approach to naming compounds and ligands.

3. Name the following coordination complexes.

a. $Pt(NH_3)_2Cl_2$

We can begin by identifying the ligands, NH_3 and Cl^-. There are two ammonia → diammine. There are two chloride ions → dichloro. The metal is Pt (platinum), and since this is a neutral complex, its overall charge is 0. We can now find the oxidation number of platinum.

Pt is the central metal atom; *x* will represent its oxidation number. The charge of the entire complex is 0, so we can set this equation equal to 0. NH_3 has a charge of 0; thus, its oxidation number is 0. Cl^- has a charge of -1.

$$x + 2(NH_3) + 2(Cl^-) = 0$$
$$x + 2(0) + 2(-1) = 0$$
$$x = +2$$

Now, we can write the entire name of the compound. This complex is called diamminedichloroplatinum (II).

b. $[Cr(NH_3)_4Cl_2]^+$

We can begin by identifying the ligands, NH_3 and Cl^-. There are four ammonia → tetraammine. There are two chloride ions → dichloro. The metal is Cr (chromium), and the overall charge of the complex is +1. We can now find the oxidation number of Cr.

Cr is the central metal atom; *x* will represent its oxidation number. The charge of the entire complex is +1, so we can set this equation equal to +1. NH_3 has a charge of 0; thus, its oxidation number is 0. Cl^- has a charge of -1.

$$x + 4(NH_3) + 2(Cl^-) = +1$$
$$x + 4(0) + 2(-1) = +1$$
$$x = +3$$

Now, we can write the entire name of the compound. This complex is called tetraamminedichlorochromium (III).

c. $[CrCl_2(OH_2)_4]^+$

We can begin by identifying the ligands, Cl^- and OH_2. There are four aqua → tetraaqua. There are two chloride ions → dichloro. The metal is Cr (chromium), and the charge of the complex is +1. We can now find the oxidation number of Cr.

Cr is the central metal atom; *x* will represent its oxidation number. The charge of the entire complex is +1, so we can set this equation equal to +1. OH_2 has a charge of 0; thus, its oxidation number is 0. Cl^- has a charge of -1.

$$x + 4(OH_2) + 2(Cl^-) = +1$$
$$x + 4(0) + 2(-1) = +1$$
$$x = +3$$

Now, we can write the entire name of the compound. This complex is called tetraaquadichlorochromium (III).

d. $[CuCl_4]^{-2}$

We can begin by identifying the ligands, Cl^-. There are four chloride ions → tetrachloro. The metal is Cu (copper), and the charge of the complex is -2. We can now find the oxidation number of Cu.

Cu is the central metal atom; *x* will represent its oxidation number. The charge of the entire complex is -2, so we can set this equation equal to -2. Cl^- has a charge of -1.

$$x + 4(Cl^-) = -2$$
$$x + 4(-1) = -2$$
$$x = +2$$

Now, we can write the entire name of the compound. We must add an "-ate" to the end of the metal atom because this complex is an anion. Copper has a special nomenclature; it uses its Latin name (cuprate). This complex is called tetrachlorocuprate (II).

5. Provide the chemical formula of the following coordination complexes.

a. Amminesulfatochromium (II)

The metal of this complex is chromium, Cr, in its +2 oxidation state. There are two ligands, ammine (which is ammonia, NH_3) and sulfato (sulfate, SO_4^{-2}), and since there are no prefixes, there are only one ligand of each per molecule. There is no charge indicated in this name, so we can write the chemical formula as $[Cr(NH_3)(SO_4)]$.

b. Potassium hexacyanoferrate (III)

The metal is iron (ferrate), Fe, in its +3 oxidation state. There are six (hexa) cyanide (cyano) ligands. We can find the charge of the complex and the number of potassium ions using oxidation states.

$$Fe + 6(CN^-) = x$$
$$+3 + 6(-1) = x$$
$$x = -3$$

The charge of the complex is -3, and there are 3 K^+ counter ions. Thus, the chemical formula is $K_3[Fe(CN)_6]$.

c. Triamminedicarbonylchloroiron(III) ion

The metal is iron, Fe, in its +3 oxidation state. There are three NH_3 (ammine) ligands, two CO (carbonyl) ligands, and one chloride (chloro) ligand. We can find the charge of the anionic complex using oxidation states.

$$Fe + 3(NH_3) + 2(CO) + (Cl^-) = x$$
$$+3 + 3(0) + 2(0) + (-1) = x$$
$$x = +2$$

The charge of the complex is +2. Thus, the chemical formula is $[Fe(NH_3)(CO)_2Cl]^{+2}$.

d. Trichlorohydroxogallate (III) ion

The metal is gallium, Ga, in its +3 oxidation state. There are three chloride (chloro) ligands, and one hydroxide (hydroxo) ligand. We can find the charge of the complex using oxidation states.

$$Ga + 3(Cl^-) + (OH^-) = x$$
$$+3 + 3(-1) + -1 = x$$
$$x = -1$$

The charge of the complex is -1. Thus, the chemical formula is $[GaCl_3(OH)]^-$.