

Naming Coordination Compounds



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A **coordination complex** is a substance in which a metal atom or ion accepts electrons from (and thus associates with) a group of neutral molecules or anions called **ligands**. A complex can be an anion, a cation ion, or a neutral molecule. **Coordination compounds** are neutral substances (i.e. uncharged) in which **at least** one ion is present as a complex. You will learn more about coordination compounds in the lab lectures for experiment 5 in this course.

The coordination compounds are named in the following way. (At the end of this tutorial, there are additional examples that demonstrate how coordination compounds are named.)

- A. When naming coordination compounds, **always name the cation before the anion**. This rule holds regardless of whether the complex ion is the cation or the anion. (This is just like naming an ionic compound.)
- B. In naming the complex ion:
 1. **Name the ligands first, in alphabetical order, and then name the metal atom or ion**. **Note:** The **metal atom or ion** is written **before** the **ligands** in the **chemical formula**.
 2. The names of some common ligands are listed in Table 1.
 - *Anionic ligands end in “-o.”* For anions that end in “-ide”(e.g. chloride, hydroxide), “-ate” (e.g. sulfate, nitrate), and “-ite” (e.g. nitrite), change the endings as follows:
 - ide → -o; e.g., chloride → chloro and hydroxide → hydroxo
 - ate → -ato; e.g., sulfate → sulfato and nitrate → nitrato
 - ite → -ito; e.g., nitrite → nitrito
 - For neutral ligands, the common name of the molecule is used (e.g. $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$ (ethylenediamine)). **Important exceptions:** water is called ‘aqua’, ammonia is called ‘ammine’, carbon monoxide is called ‘carbonyl’, and the N_2 and O_2 molecules are called ‘dinitrogen’ and ‘dioxygen’.

Table 1. Names of Some Common Ligands

Anionic Ligands	Names
Br^-	bromo
F^-	fluoro
O^{2-}	oxo
OH^-	hydroxo
CN^-	cyano
$\text{C}_2\text{O}_4^{2-}$	oxalato
CO_3^{2-}	carbonato
CH_3COO^-	acetato

Neutral Ligands	Names
NH_3	ammine
H_2O	aqua
NO	Nitrosyl
CO	Carbonyl
O_2	dioxygen
N_2	dinitrogen
$\text{C}_5\text{H}_5\text{N}$	pyridine
$\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$	ethylenediamine

3. The Greek prefixes di-, tri-, tetra-, etc. are used to designate the number of each type of ligand in the complex ion. If the ligand already contains a Greek prefix (e.g. ethylene**d**iamine) or if it is a polydentate ligand (i.e. it can attach at more than one coordination site), the prefixes bis-, tris-, tetrakis-, and pentakis- are used instead (See examples 3 and 4). The numerical prefixes are listed in Table 2.

Table 2. Numerical Prefixes

Number	Prefix	Number	Prefix	Number	Prefix
1	mono	5	penta (pentakis)	9	nona (ennea)
2	di (bis)	6	hexa (hexakis)	10	deca
3	tri (tris)	7	hepta	11	undeca
4	tetra (tetrakis)	8	octa	12	dodeca

4. After naming the ligands, name the central metal. If the complex ion is a cation, the metal is named same as the element. For example, Co in a complex cation is called cobalt and Pt is called platinum. (See examples 1-4.) If the complex ion is an anion, the name of the metal ends with the suffix -ate. (See examples 5 and 6.) For example, Co in a complex anion is called cobaltate and Pt is called platinate. For some metals, the Latin names are used in the complex anions (e.g. Fe is called ferrate and not ironate).

Table 3: Name of Metals in Anionic Complexes

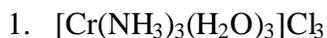
Name of Metal	Name in an Anionic Complex
Iron	Ferrate
Copper	Cuprate
Lead	Plumbate
Silver	Argentate
Gold	Aurate
Tin	Stannate

5. Following the name of the metal, the oxidation state of the metal in the complex is given as a Roman numeral in parentheses.

- C. To name a neutral complex molecule, follow the rules of naming a complex cation.
Remember: Name the (possibly complex) cation **BEFORE** the (possibly complex) anion. See examples 7 and 8.

For historic reasons, some coordination compounds are called by their common names. For example, $\text{Fe}(\text{CN})_6^{3-}$ and $\text{Fe}(\text{CN})_6^{4-}$ are named ferricyanide and ferrocyanide respectively, and $\text{Fe}(\text{CO})_5$ is called iron carbonyl.

Examples Give the systematic names for the following coordination compounds:



Answer: triamminetriaquachromium(III) chloride

Solution:

- *The complex ion is found inside the parentheses. In this case, the complex ion is a cation.*
- *The ammine ligands are named first because alphabetically, “ammine” comes before “aqua.”*

- *The compound is electrically neutral and thus has an overall charge of zero. Since there are three chlorides associated with one complex ion and each chloride has a -1 charge, the charge on the complex ion must be $+3$.*
- *From the charge on the complex ion and the charge on the ligands, we can calculate the oxidation number of the metal. In this example, all the ligands are neutral molecules. Therefore, the oxidation number of chromium must be the same as the charge of the complex ion, $+3$.*



Answer: pentaamminechloroplatinum(IV) bromide

Solution:

- *The complex ion is a cation, and the counter anions are the 3 bromides.*
- *The charge of the complex ion must be $+3$ since it is associated with 3 bromides.*
- *The NH_3 molecules are neutral while the chloride carries a -1 charge.*
- *Therefore, the oxidation number of platinum must be $+4$.*



Answer: dichlorobis(ethylenediamine)platinum(IV) chloride

Solution:

- *Since Ethylenediamine is a bidentate ligand, the prefix bis- is used instead of the prefix di-.*



Answer: tris(ethylenediamine)cobalt(III) sulfate

Solution:

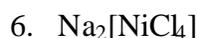
- *The sulfate has a charge of -2 and is the counter anion in this molecule.*
- *Since it takes 3 sulfates to bond with two complex cations, the charge on each complex cation must be $+3$.*
- *Since ethylenediamine is a neutral molecule, the oxidation number of cobalt in the complex ion must be $+3$.*
- *Again, remember that you never have to indicate the number of cations and anions in the name of an ionic compound.*



Answer: potassium hexacyanoferrate(II)

Solution:

- *Potassium is the cation, and the complex ion is the anion.*
- *Since there are 4 K^+ associated with the complex ion (each K^+ having a $+1$ charge), the charge on the complex ion must be -4 .*
- *Since each ligand carries -1 charge, the oxidation number of Fe must be $+2$.*
- *The common name of this compound is potassium ferrocyanide.*



Answer: sodium tetrachloronickelate(II)

Solution:

- *The complex ion is the anion so we have to add the suffix -ate to the name of the metal.*



Answer: diamminetetrachloroplatinum(IV)

Solution:

- *This is a neutral molecule because the charge on Pt^{+4} equals the negative charges on the four chloro ligands.*
- *If the compound is $[Pt(NH_3)_2Cl_2]Cl_2$, even though the number of ions and atoms in the molecule are identical to the example, it should be named: diamminedichloroplatinum(IV) chloride because the platinum in the latter compound is only four coordinated instead of six coordinated.*

8. $Fe(CO)_5$

Answer: pentacarbonyliron(0)

Solution:

- *Since it is a neutral complex, it is named in the same way as a complex cation. The common name of this compound, iron carbonyl, is used more often.*

9. $(NH_4)_2[Ni(C_2O_4)_2(H_2O)_2]$

Answer: ammonium diaquabis(oxalato)nickelate(II)

Solution: The oxalate ion is a bidentate ligand.

10. $[Ag(NH_3)_2][Ag(CN)_2]$

Answer: diamminesilver(I) dicyanoargentate(I)

You can have a compound where both the cation and the anion are complex ions. Notice how the name of the metal differs even though they are the same metal ions.

Can you give the molecular formulas of the following coordination compounds ?

1. hexaammineiron(III) nitrate
2. ammonium tetrachlorocuprate(II)
3. sodium monochloropentacyanoferrate(III)
4. potassium hexafluorocobaltate(III)

Can you give the name of the following coordination compounds?

5. $[CoBr(NH_3)_5]SO_4$
6. $[Fe(NH_3)_6][Cr(CN)_6]$
7. $[Co(SO_4)(NH_3)_5]^+$
8. $[Fe(OH)(H_2O)_5]^{2+}$

Answers:

1. $[Fe(NH_3)_6](NO_3)_3$
2. $(NH_4)_2[CuCl_4]$
3. $Na_3[FeCl(CN)_5]$
4. $K_3[CoF_6]$
5. pentaamminebromocobalt(III) sulfate
6. hexaammineiron(III) hexacyanochromate (III)
7. pentaamminesulfatocobalt(III) ion
8. pentaquahydroxoiron(III) ion